INVESTIGATION PROTOCOL

Sewers And Utility Tunnels As Preferential Pathways For Volatile Organic Compound Migration Into Buildings: Risk Factors And Investigation Protocol

ESTCP Project ER-201505

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14. ABSTRACT
There is growing recognition that preferential pathways can play an important role at sites affected by vapor intrusion (VI). Although this pathway is often mentioned in regulatory guidance documents, there is little information detailing the conceptual model or prevalence of this pathway. There is also limited guidance on how to assess sites for preferential pathways. As a result, preferential pathways are not currently being investigated in a consistent manner. The goal of this ESTCP project was to obtain a better understanding of sewers and utility tunnels as preferential pathways for VI. Specifically, the project involved developing a conceptual model for this pathway, identifying risk factors, and developing and validating an investigation protocol.

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LIST OF ACRONYMS

AFB	Air Force Base
ASU	Arizona State University
COC	Chemical of concern
DoD	Department of Defense
ESTCP	Environmental Security Technology Certification Program
GC/MS	Gas Chromatograph/Mass Spectrometer
NAPL	Nonaqueous phase liquid
OU	Operable unit
PCE	Tetrachloroethylene
QA	Quality assurance
QC	Quality control
USEPA	United States Environmental Protection Agency
VI	Vapor intrusion
VOC	Volatile organic compound

KEY TERMS USED IN THIS DOCUMENT

Vapor intrusion	Migration of VOCs from any subsurface source into an overlying building.
Conventional vapor intrusion	Migration of VOCs from a subsurface source into an overlying building by advection and/or diffusion through soil (i.e., not through a preferential pathway). These mechanisms for vapor entry into buildings can also be viewed as “soil gas intrusion.” The term “conventional vapor intrusion” used in this document refers to the standard conceptual model that has historically and most commonly been utilized to describe VOC flux from the subsurface into buildings.
Preferential pathway	A migration pathway from a subsurface source that supports higher VOC flux/discharge into a building compared to transport through bulk soil. This general term typically includes features such as elevator shafts and dry wells that can enhance vertical transport from a VOC source below the building into the building and features such as sewers and utility tunnels that can enhance both lateral and vertical transport of VOCs. The term “sewer/utility tunnel vapor intrusion” or “sewer/utility tunnel VI” used in this document refers to VOC flux from the subsurface into buildings though this specific preferential pathway.
Sewer/utility tunnel vapor intrusion (sewer/utility tunnel VI)	A sewer or utility tunnel that supports higher VOC flux/discharge into a building compared to transport through bulk soil. The VOC flux is through the interior of the sewer line or tunnel. Sewer/utility tunnel vapor intrusion has also been referred to as “pipe VI” (Guo et al. 2015). Sewers or utility tunnels can enhance VOC transport into a building from a VOC source that is laterally separated from the building (i.e., not located directly below the building).

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EXECUTIVE SUMMARY

The potential for sewers and utility tunnels to act as preferential pathways for vapor intrusion (VI) should be evaluated in conjunction with standard VI investigations. The goal of this document is to provide a step-wise procedure for this evaluation. This sewer/utility tunnel VI investigation protocol is based on research findings from ESTCP Project ER-201505 (McHugh and Beckley 2018b). It includes i) initial screening, ii) field investigation of sewers/utility tunnels, and iii) building testing (see Figure ES.1).

The protocol is intended to supplement work plans for standard VI investigations. Users are expected to be familiar with basic sampling techniques (e.g., collecting air samples in Summa-type canisters) prior to use of this protocol. Guidance on basic techniques is provided elsewhere in a variety of documents (ITRC 2014; USEPA 2015) and state-specific VI guides.

No investigation protocol can fully account for all possible site conditions and factors. The user of this protocol should rely on professional judgement when applying it to ensure adequate evaluation of sewer/utility tunnel vapor intrusion.

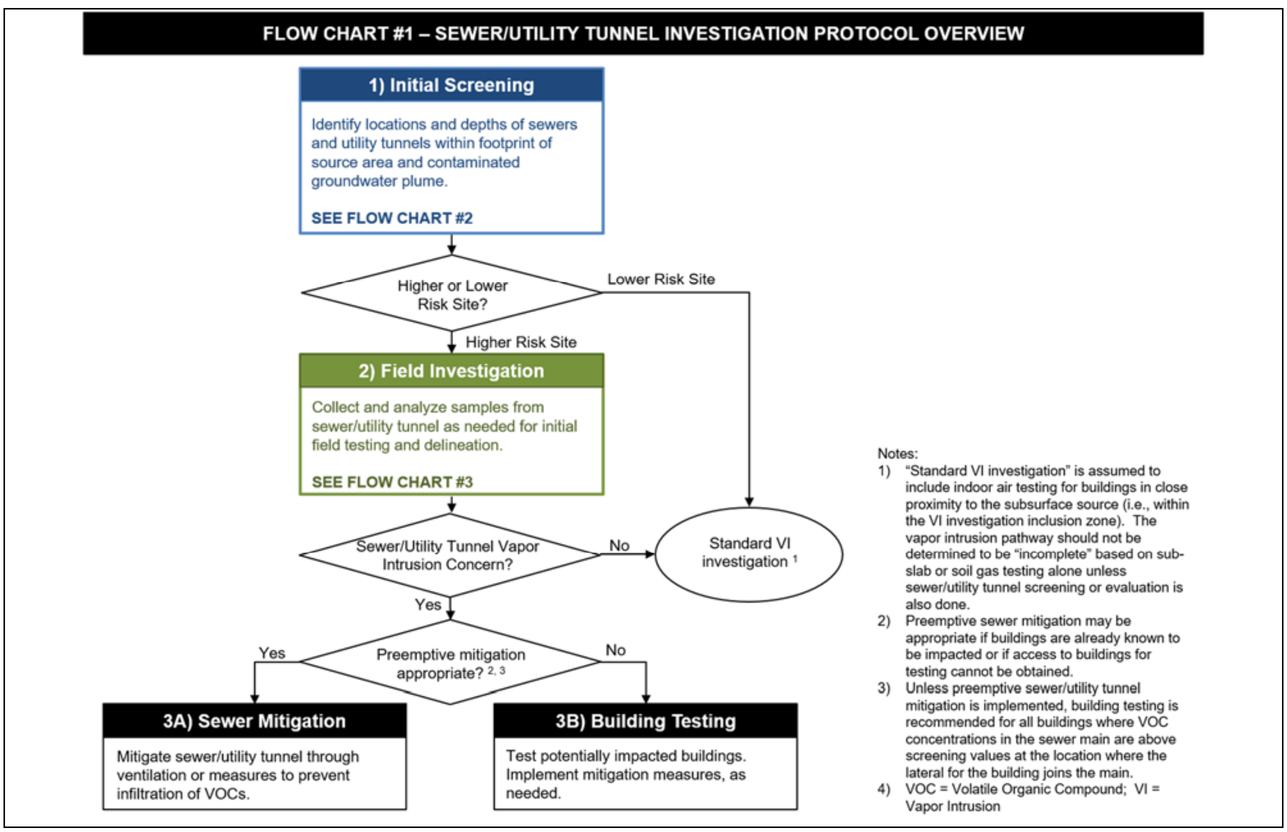


Figure ES.1 Sewer/Utility Tunnel VI Investigation Protocol

INITIAL SCREENING

Initial screening is a desktop exercise to categorize sites as higher risk or lower risk with respect to sewer/utility tunnel VI. Higher risk sites include sites where i) higher VOC concentrations may occur within the sewer or tunnel based on its proximity to the source and ii) VOCs may migrate through the sewer or tunnel (e.g., due to the entry of contaminated groundwater (see Figure ES.2)) resulting in possible VI risks for buildings located away from the subsurface source (i.e., outside of standard VI screening distances).

Higher risk sites merit sampling of the sewer/utility tunnel during the initial field investigation phase of the VI investigation. For lower risk sites, a conventional VI investigation (including testing of indoor air) is recommended without initial sampling of the sewer or utility tunnel. Further consideration of the sewer or utility tunnel may be warranted if conventional investigation results suggest that preferential pathways are a concern.

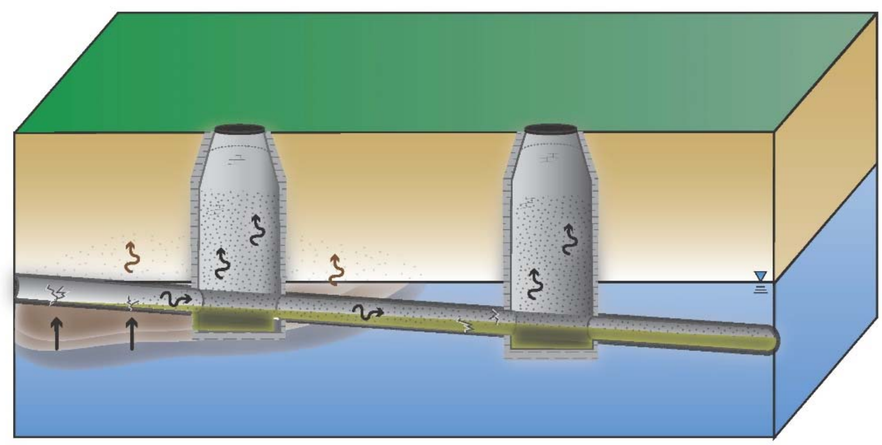


Figure ES.2 Example Higher Risk Scenario for Sewer/Utility Tunnel Vapor Intrusion

FIELD INVESTIGATION

Sewer/utility tunnel sampling is recommended for higher risk sites. The initial field testing consists of collecting vapor samples from the three highest risk locations identified. The highest risk locations are access points located within or immediately downstream of the area where the sewer or utility tunnel interacts with the contaminated groundwater or NAPL area (see Figure ES.3). Access points are typically manholes or other locations where a sample line (tubing) can be run for sample collection. The protocol emphasizes sampling vapor within sewers or utility tunnels. Sampling procedures are provided in Section 3.2.

Initial field test results should be compared against conservative screening values. Our field demonstration results suggest that worst-case sewer to indoor air attenuation factors are similar to sub-slab to indoor air attenuation factors. These results indicate that use of screening values equal to sub-slab screening values would be conservative and protective for evaluation of sewer vapor testing results. If COC concentrations are above conservative screening values, then further action is warranted to delineate and address the sewer/utility tunnel impacts. Although not addressed in detail in this protocol, an overview of options for building testing and preemptive sewer mitigation is provided in the ESTCP Project ER-201505 Final Report, Section 6.3.6.

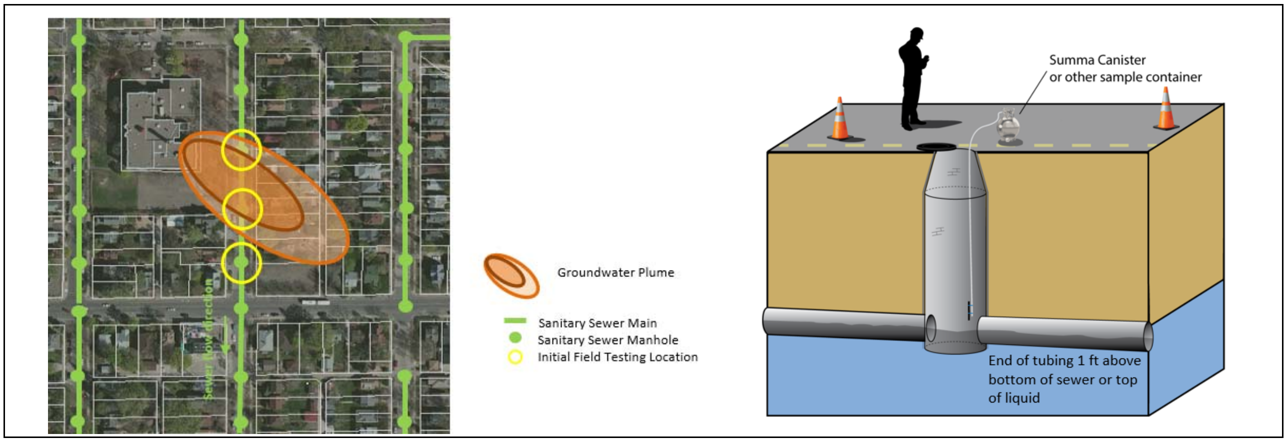


Figure ES.3 Example Initial Field Investigation Sample Locations

1.0 APPLICABILITY

Storm sewers, sanitary sewers, and utility tunnels have been identified as important preferential transport pathways for volatile organic compound (VOC) vapor intrusion (VI) at a small but growing number of sites. Examples include: vinyl chloride VI at a former dry cleaner site (Nielsen et al. 2014), several houses near a tetrachloroethene (PCE) plume in Denmark (Riis et al. 2010), the Arizona State University (ASU) VI Research House at Hill Air Force Base (AFB) Operable Unit (OU) 8 (Johnson 2013), a house at Hill AFB OU 2 (McHugh et al. 2011), and many others. At most of these sites, the importance of sewer/utility tunnel VI was not recognized until late in the investigation process resulting in wasted investigation efforts and delayed response actions. At some of these sites (e.g., Moffett Field Building 107, (McHugh et al. 2012)), vapor concentrations of site VOCs were higher in indoor air than in sub-slab samples, creating a misleading suggestion of an indoor source.

These examples highlight the need to evaluate sewer and utility tunnel VI in conjunction with standard VI investigations. The goal of this document is to provide a step-wise procedure for this evaluation. Users of this document may also wish to use the companion document, Conceptual Model for Sewer/Utility Tunnel Vapor Intrusion (McHugh and Beckley 2018a). The conceptual model document provides additional detail concerning our current understanding of VOC migration through sewers and utility tunnels into buildings. Validation of this investigation protocol and the conceptual model are described in the ESTCP Project ER-201505 Final Report (McHugh and Beckley 2018b).

The screening and investigation procedures recommended in this document were based on field testing conducted under ESTCP Project ER-201505 and other published information on sewer/utility tunnel investigations. The recommended procedures in this protocol may not be appropriate for all sites and are not intended to supersede the use of professional judgement by site environmental practitioners.

1.1 SITE-SPECIFIC CONSIDERATIONS

This investigation protocol is applicable to all sites where a site-specific evaluation of vapor intrusion is necessary. It is expected that most sites have a lower risk for sewer/utility tunnel VI and can be screened out during the initial site screening process. At most sites where sewer/utility VI has been identified to date, the sewer or utility line directly intersects contaminated groundwater. We do not expect this to be a common situation because, at many sites, sewer lines run through the vadose zone above the water table.

1.2 COST

The investigation protocol is a step-wise process. Cost estimates are given below to give the reader an idea of the level of effort and costs for implementation. These estimates assume implementation by experienced personnel. As for any procedure or field program, the time required by inexperienced personnel would be significantly higher.

1.2.1 *Initial Screening*

The protocol begins with an initial desktop screening step. This step focuses on gathering and evaluating existing site information. These costs are not expected to vary significantly between sites. Estimated costs for completing the initial screening are summarized in Table 1.1.

Table 1.1 Estimated Costs for Initial Screening

Cost Element	Labor Hours	Rate ($/hour)	Estimated Cost
1. **Data Collection and Evaluation:** Gather data and identify locations and depths of sewers and utility tunnels within footprint of source area and/or groundwater plume.	8	$100	$ 800
2. **Documentation:** Summarize findings.	2	$100	$ 200
		Total:	**$1,000**

1.2.2 *Field Investigation*

Based on the initial screening, follow-up field testing is recommended for some sites. The first step of field testing consists of collecting at least 3 vapor samples. Estimated costs are summarized in Table 1.2.

Table 1.2 Estimated Cost of Initial Field Testing

Cost Element	Category	Description	Quantity	Rate ($)	Estimated Cost
Project Planning and Preparation[1]					
	Labor	Senior Project Scientist/Engineer	2	150/hr	$ 300
	Labor	Project Scientist/Engineer	8	100/hr	$ 800
				Subtotal	***$1,100***
Field Program Implementation[2]					
	Labor	Project Scientist/Engineer	6	100/hr	$ 600
	Labor	Project Scientist/Engineer	6	100/hr	$ 600
	Laboratory	Summa canister rental (assume $90) and TO-15 analysis (assume $150) [1]	3	240/sample	$ 720
				Subtotal	***$1,920***
Data Evaluation and Reporting[3]					
	Labor	Senior Project Scientist/Engineer	4	150/hr	$ 600
	Labor	Project Scientist / Engineer	12	100/hr	$1,200
				Subtotal	***$1,800***
				TOTAL	***$4,820***

Notes: 1) Planning tasks include selection of sampling locations based on data compiled in the screening step, obtaining site access, and obtaining sampling supplies; 2) Does not include travel time, travel or shipping expenses. Collection of 3 sewer vapor samples is assumed, and is based on access to test manholes near the core of the plume or access to test manholes in areas where groundwater intersects sewer lines (i.e., test "worst-case" locations). Additional samples may be needed for plumes with complex geometries, or sites with multiple, independent sets of sewer lines or utility tunnels; 3) Includes review of laboratory results and preparation of data summary tables; and 4) Rates given in $/hour (labor) or $/item (non-labor categories).

These estimates consider implementation of the protocol itself (e.g., selecting sample locations, obtaining site access, collecting vapor samples from manholes, etc.). They do not include travel time, expenses, or other general costs unrelated to the protocol itself.

Depending on the results of initial field testing, follow-up delineation testing and other fieldwork may be needed. Costs will vary based on site-specific factors such as the size of the area of concern and number of potential sewers/utility tunnels and buildings to test. Costs will likely vary more, however, by the manner in which the protocol is implemented. The protocol is written to allow flexibility in sample analysis. If users choose to have samples analyzed by an off-site laboratory, multiple mobilizations may be needed. The most cost-efficient manner in which to implement these steps of the protocol would be to utilize an on-site laboratory or instrument so that field decisions can be made and follow-up sampling done in the same mobilization.

2.0 CONCEPTUAL MODEL

Sewers and utility tunnels are more likely to act as preferential pathways primarily in cases where they directly intersect contaminated groundwater or nonaqueous phase liquid (NAPL) or otherwise interact with high strength source material (e.g., discharge of VOC-impacted water into the sewer) (see Figure 2.1). Sewers and utility tunnels present exclusively in the vadose zone above the contaminated groundwater or NAPL are less likely to act as a preferential pathway (see Figure 2.1, right panel).

What is a Utility Tunnel?

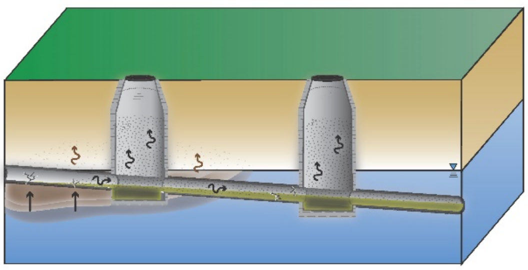
*A **utility tunnel** or **utility corridor** is a passage built underground or aboveground to carry utility lines such as electricity, water, and sewer pipes. Communication utilities like fiber optics, cable television, and telephone cables are also sometimes carried. They may also be referred to as a **services tunnel, services trench, services vault,** or **cable vault.** Utility tunnels are often installed in large military facilities as well as industrial plants, large institutions, such as universities, hospitals, research labs, and other facilities managed in common. They are not commonly installed in residential areas.*

*A directly buried utility line is **not** a utility tunnel.*

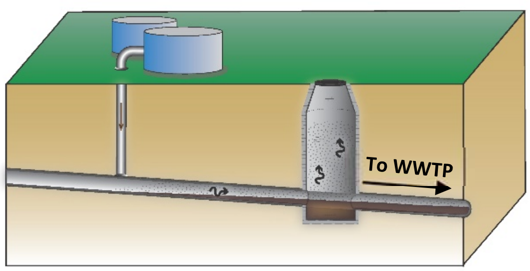
Some VI guidance documents suggest that vapors may migrate through the fill material around a sewer line as an alternative to transport through the sewer/utility line. However, for the available examples of sites with sewer/utility tunnel VI, the VOCs have been documented within the sewer pipe itself, rather than the backfill. Although methane from landfills (or other pressurized sources) may migrate through backfill in some cases, this may not be a concern at contaminated sites where no pressure gradient is present to drive flow through the backfill. Backfill material is commonly higher permeability than surrounding native material such that advective flow may occur preferentially within the backfill material. However, for diffusive transport, the VOC concentration gradient and the porosity of the material are more important than the permeability of the material. As a result, diffusive transport through the vadose zone (which is the most common transport mechanism at contaminated sites) is less likely to be influenced by a permeability contrast between backfill and the native material. In addition, in contrast to sewers and utility tunnels, backfill does not typically provide a direct conduit into a building. Although some practitioners have anecdotally mentioned local migration through backfill (e.g., contaminated backfill next to a building), to date, we have not been able to identify published examples of sites with appreciable VOC migration in the fill material but not inside the sewer/utility line itself. As a result, we do not recommend a specific focus on testing of backfill as part of a sewer/utility tunnel vapor intrusion investigation.

Higher Risk Scenarios

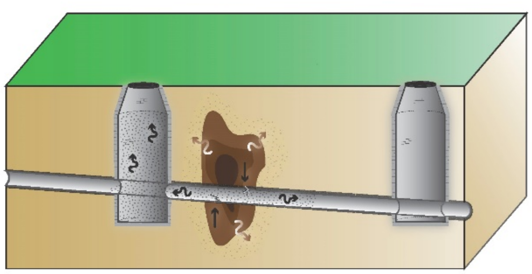
A: Sewer Intersects Contaminated Groundwater



B: Discharge of Groundwater to Sewer Line



C: Sewer Intersects NAPL/Vadose Zone Source



Lower Risk Scenario

Sewer in Vadose Zone above Plume

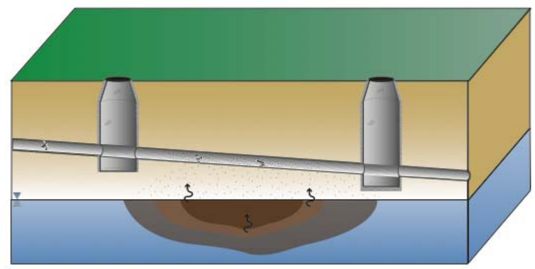


Figure 2.1 Higher and Lower Risk Sites for Sewers/Utility Tunnel Vapor Intrusion

3.0 INVESTIGATION PROTOCOL

The investigation protocol for evaluation of sewer/utility tunnel vapor intrusion is illustrated in Figure 3.1.

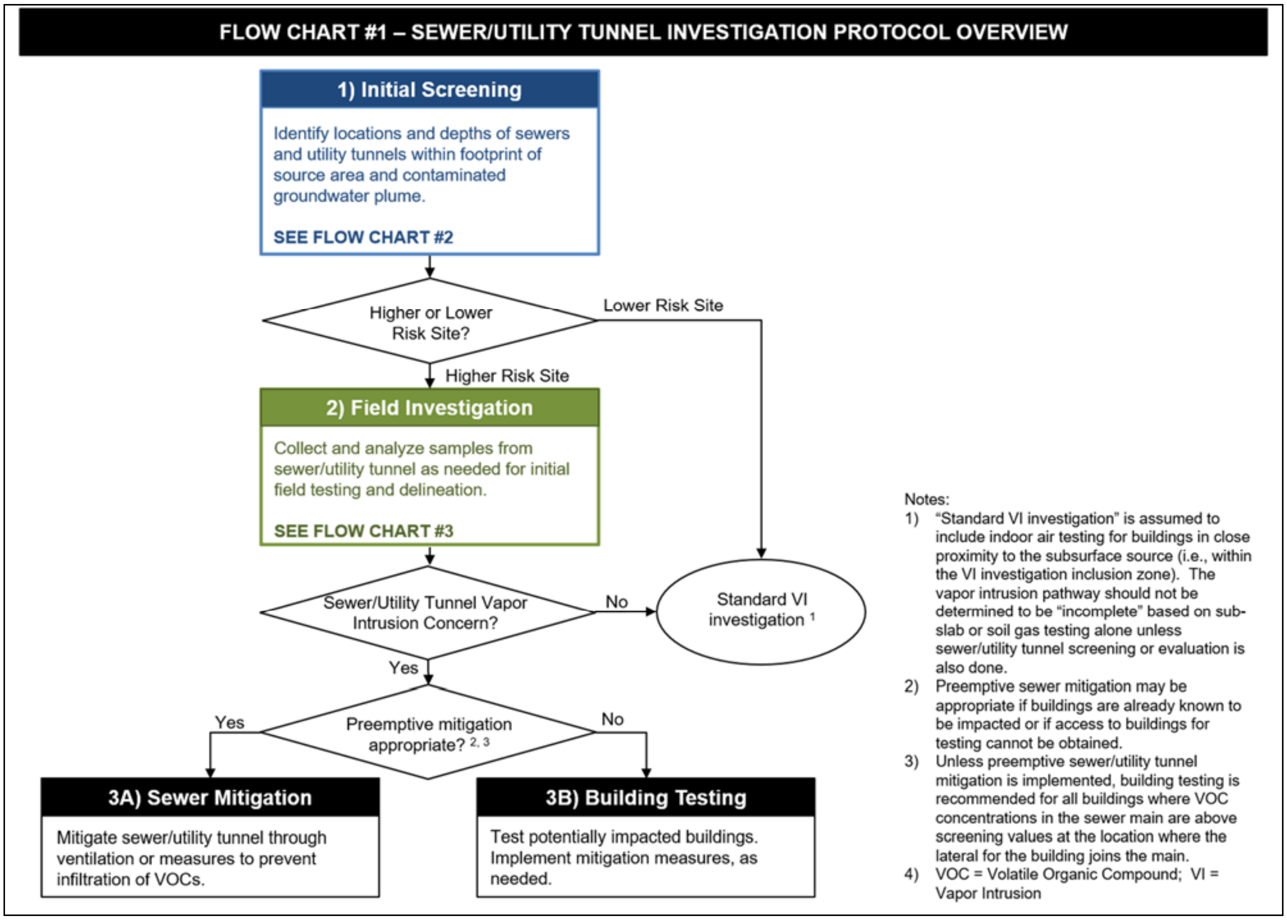


Figure 3.1 Overview of Investigation Protocol

3.1 INITIAL SCREENING

Initial screening is Step 1 from Figure 3.1. The goal of initial screening is to classify sites as higher risk or lower risk for sewer/utility tunnel vapor intrusion. The initial screening has 2 steps:

1. Gather Information (Table 3.1); and
2. Review Information (Figure 3.2).

Table 3.1 Initial Screening Step 1: Gather Required Information

Information	Example Source(s)
1) VOC Source Areas and Plumes: Identify the locations of all VOC source areas (NAPL or other high concentration materials in the vadose zone or in the saturated zone). Identify the extent of VOC plumes in groundwater using applicable groundwater screening values for VI.	Site investigation reports, plume maps.
2) Sewer Lines and Utility Tunnels: Identify the locations of sewer lines and utility tunnels present.	Sewer and/or utility tunnel plat maps. For DoD facilities, contact the base Facilities Manager. For municipal utilities, contact the municipal utility or public works office. If maps are not available, identify lines and tunnels in the area of concern through visual identification of manholes, storm drains, and utility tunnel access points. Use a depth gauge to determine depths of lines and tunnels if necessary.

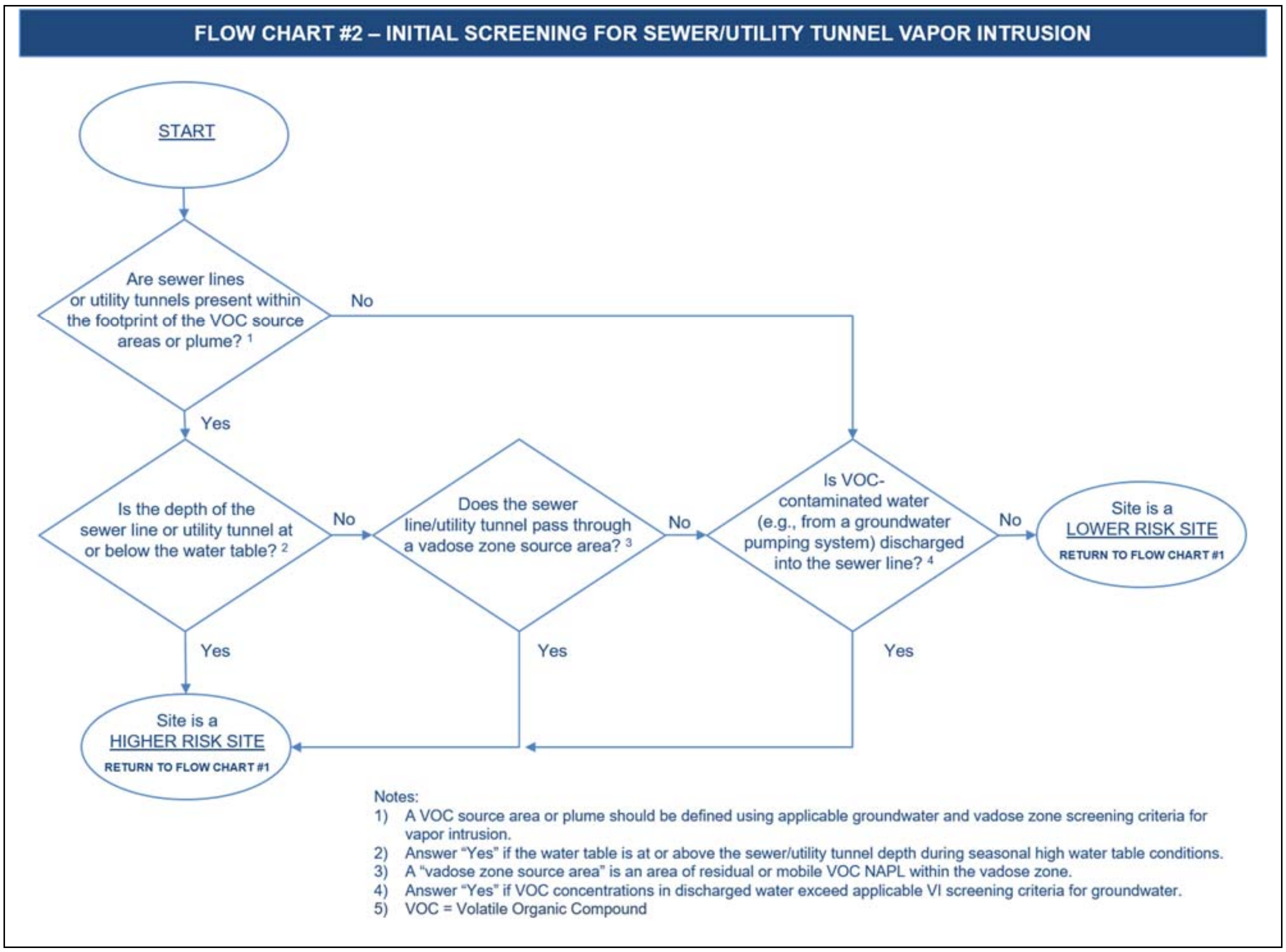


Figure 3.2 Initial Screening Step 2: Review Information using Screening Flow Chart

When sewer/utility tunnel vapor intrusion occurs at lower risk sites, the impacted buildings are typically limited to those within the inclusion area defined for a conventional VI investigation. This is because, at lower risk sites, VOC-containing liquids are not likely to enter the sewer or utility tunnel. As a result, the highest area of VOC vapors will be confined to the immediate vicinity of the subsurface source (i.e., within the VI inclusion area). Therefore, a conventional VI investigation that includes indoor air testing should be sufficient to identify buildings impacted by either conventional or sewer/utility tunnel VI. At lower risk sites, field investigation of sewers/utility tunnels is not recommended unless results from conventional testing suggest VOC entry though a sewer or utility tunnel.

3.2 FIELD INVESTIGATION FOR HIGHER RISK SITES

For higher risk sites, testing of the sewer/utility tunnel is recommended to determine the presence or absence of VOCs within the sewer/tunnel (i.e., Step 2 from Figure 3.1). The field investigation program consists of i) initial testing to determine the presence or absence of VOCs, ii) delineation of sewer/utility impacts, and iii) testing of buildings connected to affected sewers/tunnels (see Figure 3.3). If more than one separate sewer system or utility tunnel is potentially impacted, then the initial field testing program should be conducted in each system (i.e., test three locations from each system).

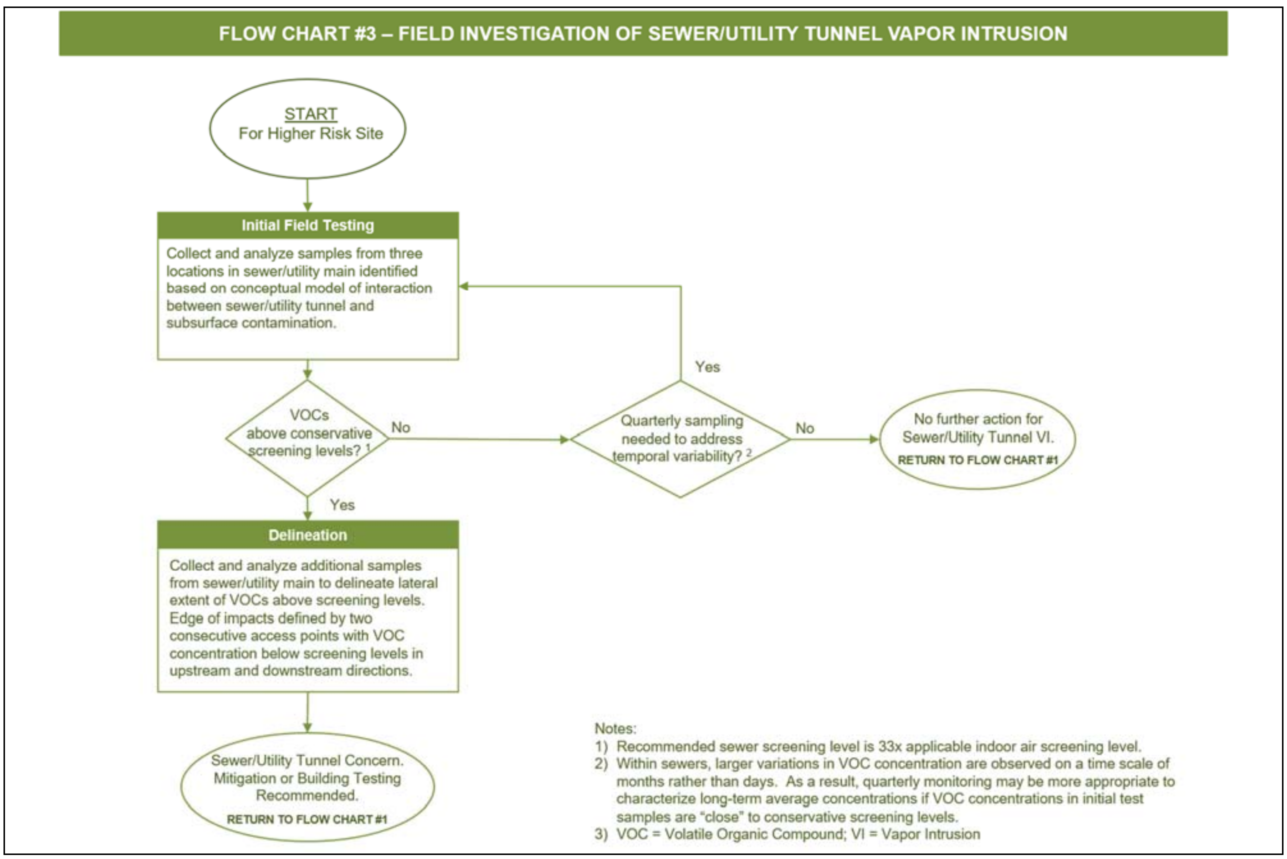


Figure 3.3 Sewer/Utility Investigation Program (i.e., Step 2 from Figure 3.1)

Initial Field Testing: For sites retained after the initial screening step, the initial field testing consists of collecting vapor samples from the three highest risk locations identified. The highest risk locations are access points located within or immediately downstream of the area where the sewer or utility tunnel interacts with the contaminated groundwater or NAPL area (see Figure 3.4). Access points are typically manholes or other locations where a sample line can be run for sample collection. If more than three access points are available, the three points within or downstream of the highest concentration groundwater/NAPL area should be selected. The site conceptual model, groundwater investigation results, and plume maps should be used to identify the area of highest groundwater concentration/NAPL.

Figure 3.4 Example Initial Field Testing Locations

For each sample location, samples are collected as follows:

- If the groundwater elevation varies seasonally such that the water table is below the sewer/utility tunnel at some times and at or above the sewer/utility tunnel at other times, then sampling should be conducted during the period with the higher water table.
- For sanitary sewers, samples should be collected between 9 am and 3 pm, when baseline flow is relatively low. For all sewers, samples should not be collected within 48 hours of a rainfall event of more than 0.1 inches.
- Minimize opening manhole covers prior to sampling by threading measurement or sampling equipment through vent holes, or opening covers just enough to insert the equipment into the manhole.
- Using a water level meter or weighted string, measure the distance from the access point to the bottom of the sewer/utility tunnel or the depth to any liquid (whichever is shallower).
- Collect a grab vapor sample from a depth of one foot above the bottom or liquid level using nylon or Teflon tubing extended through the access point (see Figure 3.5). The sample can be collected using any appropriate vapor sampling device but will typically be collected using a Summa-type canister. Typical air sampling quality assurance steps should be taken. For example, leak testing can be conducted using a shut-in test for the entire sampling train prior to extending the sample tubing into the sewer/utility tunnel. In addition, the sample

tubing can be purged of ambient air prior to sampling. When using a Summa-type canister for sample collection, a flow controller is not required.

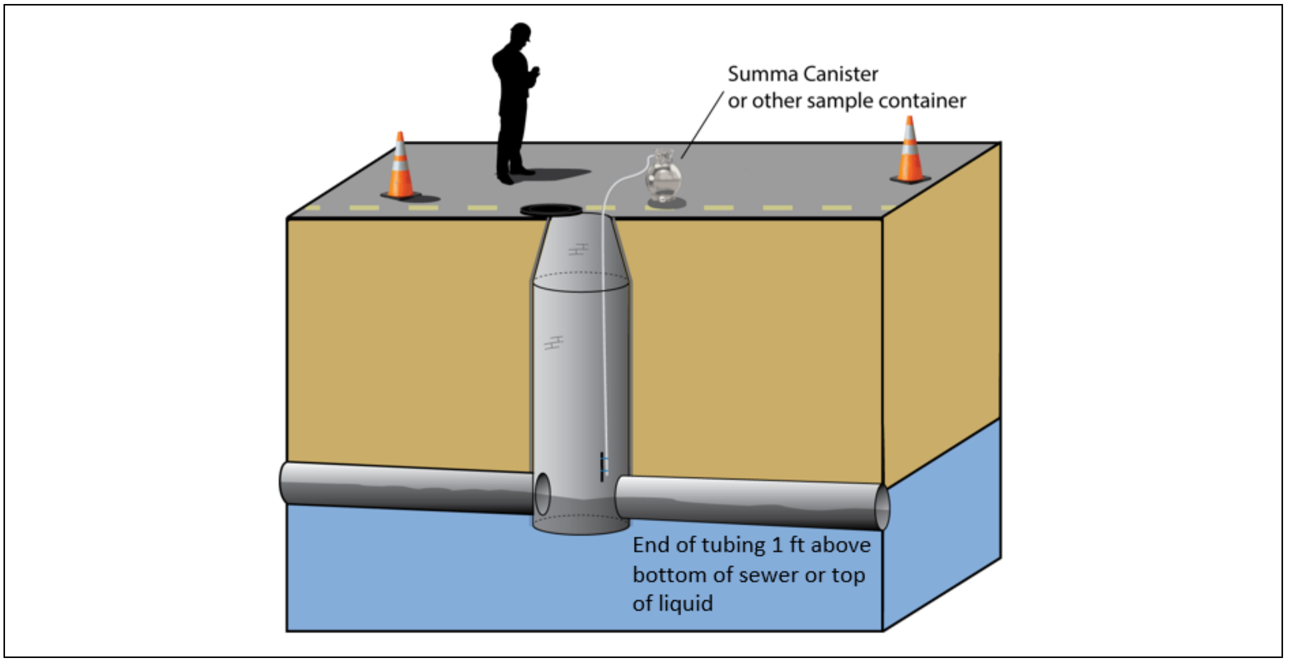


Figure 3.5 Vapor Sample Collection from Sewer

Evaluation of Initial Test Results: Tracer testing conducted for ESTCP Project ER-201505 indicated that an attenuation factor of 0.03 (33x attenuation) is a reasonable upper-bound attenuation factor for evaluation of VOC concentrations in sewers. As a result, sub-slab screening concentrations that have been developed based on an attenuation factor of 0.03 can also be applied to sewer test results.

When three sewer locations are included in the initial testing, the maximum VOC concentration across the three locations should be compared to screening values. Use of the maximum concentration from three locations serves to off-set some of the uncertainty associated with both spatial and temporal variability in VOC concentration. If the VOC concentrations exceed the sewer screening concentrations, then further testing is recommended to delineate the extent of vapors within the sewer and to evaluate potential impacts to buildings.

Consideration of Temporal Variability in Sewer Vapor VOC Concentrations: Results from ESTCP Project ER-201505 served to characterize temporal variability in VOC concentrations over two timescales: i) 1 to 3 days and ii) 12 to 18 months (McHugh and Beckley 2018b). These data showed much higher variations in VOC concentration over a timescale of months compared to a timescale of days. Among other implications, these results indicate that short-term time-integrated samples (e.g., 24-hour Summa canisters or 1-week passive sorbent samples) provide little value over grab samples.

- Uncertainty Associated with a Single Grab Sample: A single grab sample provides a good estimate of the short-term (1 to 3 days) average VOC concentration. 80% of individual grab samples have VOC concentrations within a factor of 2 of the short-term average concentration. However, a single sample provides a less certain estimate of the long-term (12 to 18 months) average VOC concentration. Only 33% of individual samples have VOC concentrations within a factor of 2 of the long-term average concentration but 84% of individual samples have VOC concentrations within a factor of 10 of the long-term average.

- Uncertainty Associated with Multiple Samples: A more accurate estimate of the long-term average VOC concentration in a sewer can be obtained through quarterly sampling. When four quarterly samples are collected from a sewer, the average of these four samples will be within a factor of 3 of the average long-term concentration 80% of the time.

If VOC concentrations measured during the initial testing step are close to screening values, quarterly sampling may be appropriate to obtain a better understanding of long-term average VOC concentrations in the sewer. Resampling within a few days of the initial testing is unlikely to provide a significantly more accurate understanding of the long-term average VOC concentration in the sewer line.

Delineation: The purpose of delineation is to determine the extent of vapors in the sewer/utility tunnel at concentrations exceeding the sewer screening concentrations. The delineation step focuses on main sewer lines and utility tunnels. Laterals (i.e., the connections between the main lines and individual buildings) are evaluated as part of building testing.

Delineation should be completed by collecting samples at access points both upstream and downstream of the exceedance locations. Delineation should proceed within the main sewer/utility tunnel(s) until all exceedance locations are bounded by two consecutive locations where VOC concentrations are less than the sewer screening values (see Figure 3.6, left panel). The sample collection procedures are the same as for initial field testing. The use of on-site analysis may make delineation more efficient by supporting real-time evaluation of whether delineation has been completed. On-site analysis can be conducted using a field-portable GC/MS instrument (e.g., Inficon HAPSITE, Syracuse, NY) or a mobile laboratory.

Evaluation of Delineation Results: Delineation results are used to identify areas where there may be a concern for sewer/utility tunnel VI and where additional characterization or mitigation efforts may be needed (see Figure 3.6, right panel).

3.3 SEWER MITIGATION

If potential sewer/utility tunnel VI is a concern based on sewer vapor sample results exceeding conservative screening criteria, preemptive sewer mitigation (Protocol Step 3A) may be a viable next step, depending on site-specific circumstances. Sewer mitigation can involve ventilation or taking measures to prevent VOCs from infiltrating the sewers. Examples of sewer mitigation are provided in the ESTCP Project ER-201505 Final Report, Section 6.3.6.

3.4 BUILDING TESTING

The field investigation and delineation process may identify buildings for which testing for vapor intrusion is appropriate (Protocol Step 3B). In the absence of sewer mitigation, testing should be done in all buildings where VOC concentrations in the main are greater than the sewer screening values at the location where the lateral for the building joins the main (see Figure 3.6, right panel).

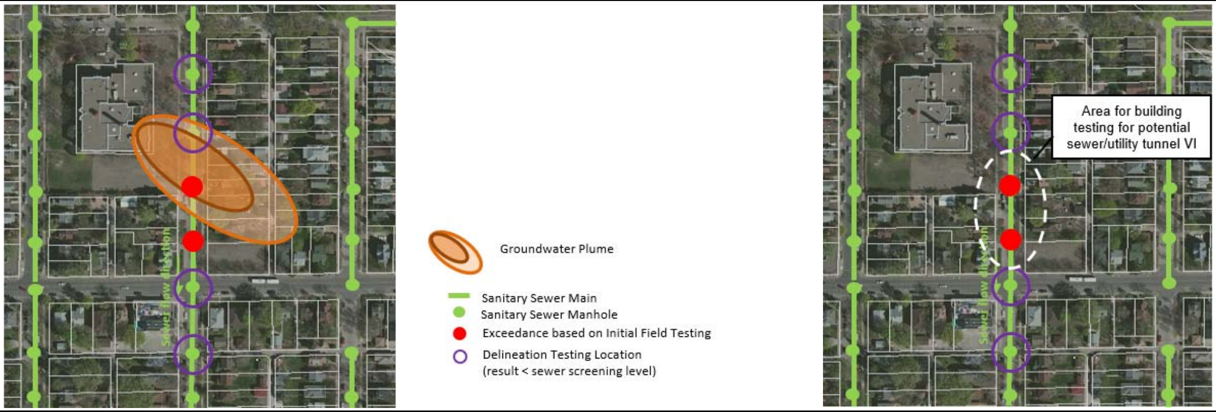
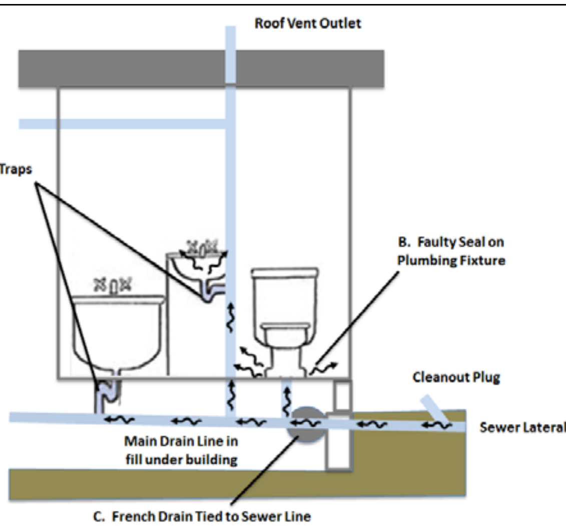


Figure 3.6 Example Delineation Results and Identification of Buildings to Test

Testing Program: VOCs from a sewer line or utility tunnel can enter a building through a variety of mechanisms and/or entry points that can be difficult to identify based on visual inspection of the building (Figure 3.7).



Notes: VOCs can move from sewers and utility tunnels into buildings through a variety of mechanisms, for example: A. Dry p-trap; B. Faulty seal on plumbing fixture (e.g., Pennell et al. 2013); and C. French drain tied to sewer line (Guo et al. 2015). Utility tunnels can vent directly into buildings.

Figure 3.7 Potential Entry Points into Buildings

The goals of building testing are i) to determine whether VOC concentrations in indoor air are above applicable indoor air screening values, and, if so, ii) verify that the source is vapor intrusion (i.e., indoor sources vs. vapor intrusion). Multiple approaches have been developed for testing buildings for vapor intrusion (Table 3.2). Any of these approaches may be appropriate. Selection of the specific approach depends on a number of factors including the complexity of the building, the availability of equipment (i.e., field portable GC/MS), and the experience of the project team.

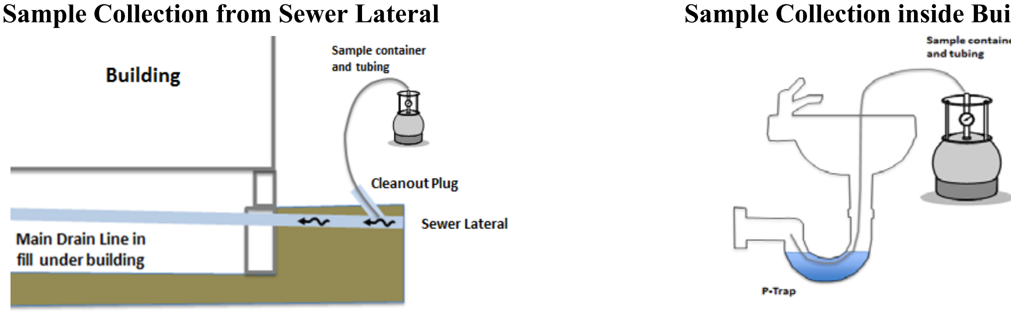
Table 3.2 General Building Testing Approaches

Approach	References
Typical Multiple Lines of Evidence	ITRC (2014) USEPA (2015) NJDEP (2013)
On-Site GC/MS Analysis	Beckley et al. (2014a) Beckley et al. (2014b) Gorder and Dettenmaier (2011)
Building Pressure Cycling	McHugh et al. (2012) Holton et al. (2015)

Although the approaches for building testing listed in Table 3.2 were originally developed for testing of buildings potentially impacted by conventional vapor intrusion (i.e., migration of VOCs through the vadose zone), these approaches are also appropriate for investigation of buildings potentially impacted by sewer/utility tunnel VI. For example, building pressure cycling can be used to "turn on" (negative building pressure) and "turn off" (positive building pressure) sewer/utility tunnel VI in the same way the approach is applied to conventional VI.

Although existing building testing protocols can be used for testing buildings potentially impacted by sewer/utility tunnel VI, **in buildings potentially impacted by sewer/utility tunnel VI, the sewer/utility lateral should be tested in addition to other samples collected for a given approach.** In other words, when an investigation approach specifies the collection of sub-slab samples, then both sub-slab and sewer/utility lateral samples should be collected. The collection of sewer/utility lateral samples is illustrated in Figure 3.8 (left panel). If access to the lateral is not available, then samples may be collected inside the building, for example, at p-traps (Figure 3.8 (right panel)).

Sample Collection from Sewer Lateral **Sample Collection inside Building**



Notes: 1) Samples can be collected in Summa-type canister or other containers for off-site laboratory analysis. Samples can also be collected for on-site analysis using portable instruments or an on-site laboratory. 2) Water typically fills p-traps to prevent sewer gas/odor migration into the building. The sample tubing must extend past the liquid barrier in the p-trap to collect gas from within the sewer line.

Figure 3.8 Sample Collection from Sewer Lateral Connected to Building

4.0 DOCUMENTATION

4.1 INITIAL SCREENING (APPLICABLE TO ALL SITES EVALUATED BY THIS PROTOCOL)

The following topics should be addressed in project documentation:

- Locations and depths of VOC source areas, including the extent of groundwater impacts above applicable groundwater screening values for conventional vapor intrusion;
- Locations, depths, and types of sewers and utility tunnels relative to the source area or groundwater plume;
- Descriptions of the sewers and utility tunnels (age, materials(s), diameter of lines, direction of flow, etc.)
- Description of whether the sewers/utility tunnels intersect the source area/plume; and
- Results from the initial screening (higher or lower risk scenario; no further action vs. field investigation needed).

In addition, maps of the plume and sewer/utility tunnel plans should be included and produced at the same scale, if possible. Cross-sections should also be included illustrating the relationship of the sewers/utility tunnels and buildings to the source area/plume.

4.2 FIELD INVESTIGATION

The results of the field evaluation should be documented through field notes and a report that presents the sampling methods, analytical results, interpretation, and overall conclusions.

4.2.1 Field Notes

Much of the information to record in field notes is typical of any investigation program (i.e., dates, times, activities, locations, and personnel). Additional information relevant to the sewer/utility tunnel VI investigation includes, but is not limited to:

- Weather conditions, including barometric pressure, wind, and recent rainfall/runoff (and observations of surface water flow (e.g., note if runoff drains into the sewers being assessed));
- Sampling equipment specifications (field instrument types, manufacturer, model, calibration, QA/QC measures);
- Sampling container specifications and sample collection methods (including how manholes are accessed (e.g., via vent holes in manhole covers));
- Detailed sample location descriptions (sketch, description of location type (e.g., main, lateral), depth to the bottom of the sewer/tunnel or depth to liquid, sampling depth); and
- Observations of conditions of the area or structure being sampled (e.g., construction, presence of liquid in manholes, flow direction, condition of line or plumbing seals).

4.2.2 Report

The field investigation report should include the following:

- Introduction: Identify the purpose and context of the investigation program. Provide a description of the sewers/utility tunnels and relationship to the plume. Discuss the scope of the investigation.
- Methods: Describe the sampling methods, sampling locations and rationale for location selection. Describe the investigation process. Instrument calibration and QA procedures should be documented in an appendix or by reference to an existing document.
- Results: Tabulate results and summarize them on maps and figures. Include applicable screening levels.
- Data Interpretation: Discuss the results from each step in the investigation process and identify and describe any field decisions. Discuss the overall conclusion regarding the presence or absence of current or potential preferential pathways for vapor intrusion (mechanisms for vapor migration, etc.). Discuss next steps (additional characterization of the sewer or buildings, mitigation, etc.).
- Appendices: Field notes, laboratory analytical reports, and investigation details should be provided in appendices, as appropriate.

4.3 OTHER DOCUMENTATION

The protocol focuses on initial screening and field investigation to determine whether sewer/utility tunnel vapor intrusion is a concern. Possible steps after the field investigation include proposals of no further evaluation of sewer/utility tunnel VI, mitigation, or building testing. Reporting should be tailored to site-specific needs and follow guidelines of regulatory oversight agencies, as appropriate.

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