DEPARTMENT OF ENVIRONMENTAL PROTECTION
Bureau of Environmental Cleanup and Brownfields

DOCUMENT NUMBER:	253-0300-###
TITLE:	Land Recycling Program Technical Guidance for Vapor Intrusion into Buildings from Groundwater and Soil under Act 2
EFFECTIVE DATE:	Upon publication of notice as final in the *Pennsylvania Bulletin*
AUTHORITY:	The Land Recycling and Environmental Remediation Standards Act (Act 2 of 1995) (35 P.S. §§6026.101 et seq.) and the regulations issued pursuant to that legislation at 25 Pa. Code Chapter 250.
POLICY:	It is the policy of the Department of Environmental Protection (DEP) to implement Act 2 in accordance with the regulations contained in Chapter 250 of the Pa. Code and as described in this guidance manual.
PURPOSE:	The Department has developed a Technical Guidance Manual (TGM) to assist remediators in satisfying the requirements of Act 2 and the regulations published in Chapter 250 of the Pa. Code. This specific document provides guidance for how to address vapor intrusion (VI) from contaminated soil and groundwater into buildings.
APPLICABILITY:	The guidance is applicable to any person or persons conducting a site remediation under Act 2.
DISCLAIMER:	The policies and procedures outlined in this guidance document are intended to supplement existing requirements. Nothing in the policies or procedures will affect regulatory requirements. The policies and procedures herein are not an adjudication or a regulation. There is no intent on the part of the Department to give these rules that weight or deference. This document establishes the framework within which DEP will exercise its administrative discretion in the future. DEP reserves the discretion to deviate from this policy statement if circumstances warrant.
PAGE LENGTH:	## pages
DEFINITIONS:	Definitions of key terms are provided in the guidance. See 25 Pa. Code Chapter 250 for additional definitions.

Pennsylvania's Land Recycling Program

Vapor Intrusion Technical Guidance

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Introduction

Releases of volatile and some semi-volatile regulated substances to soil or groundwater can result in intrusion of these regulated substances into indoor air. The resulting impacts to indoor air may pose a threat to human health in existing or future inhabited buildings. For this exposure pathway to exist there must be a source of volatile substances in vadose zone soil or groundwater at the water table, current or future presence of inhabited buildings and a vapor transport pathway along which vapors may migrate from the source into the inhabited building(s). Inhabited buildings are buildings with enclosed air space that are designed for human occupancy. In order to properly address this pathway the remediator first develops a Conceptual Site Model (CSM) based on the site characterization to guide further assessment and, if necessary, remediation.

This document provides guidance for addressing potential vapor intrusion (VI) of volatile organic compounds (VOCs) and certain semi-volatile organic compounds (SVOCs) from soil and/or groundwater sources including those impacted by separate phase liquid (SPL) into inhabited buildings at sites using the Statewide health standard and the site-specific standard. As such, this guidance establishes screening values and assessment options that can be used under the Statewide health standard to address VI for existing or potential future inhabited buildings. (The potential VI impacts from volatile inorganic substances (e.g., mercury and cyanide), can only be addressed using the site-specific standard.) **The VI screening value tables in this guidance are not meant to be used to evaluate VI under the site-specific standard.** Guidance on VI evaluations under the site-specific standard, including the use of a human health inhalation risk assessment, is provided in Section K.

Section 250.312 states that a Statewide health standard final report must include an assessment of the VI exposure pathway. A site-specific standard exposure pathway assessment inclusive of VI is required by Section 250.404, and risk assessments are performed pursuant to Section 250.405. VI must be addressed for existing inhabited buildings and undeveloped areas of the property where inhabited buildings could be constructed in the future. VI must also be addressed at undeveloped properties where no current buildings exist but future inhabited buildings could be constructed. A VI evaluation is not required for the background standard.

It is important to note that, at any time in the VI evaluation process, mitigation measures may be used for existing inhabited buildings to eliminate unacceptable risks associated with VI under the Statewide health and site-specific standards. In addition, an environmental covenant may be established to address VI concerns with respect to potentially affected future inhabited buildings. As needed and appropriate, the covenant would be designed to ensure: (1) that potential risks associated with VI will be evaluated and addressed if necessary if or when an inhabited building is constructed in the future or (2) that appropriate mitigation measures will be taken in those buildings when they are constructed on currently undeveloped portions of a site's property or currently undeveloped land.

Furthermore, if the site is a petroleum release to surface or subsurface soil where full site

characterization has not been performed in association with an excavation, then the remediator may attain the Statewide health standard by following the sampling and statistical test requirements for excavations described in Section 250.707(b)(1)(iii). Further VI analysis may not be required for soil if the following conditions are also satisfied: (1) soil is sampled in a biased fashion on the bottom and sidewalls of the excavation based on field screening measurements; (2) at least one soil sample is collected on the sidewall nearest the inhabited building unless there are substantially higher field instrument readings elsewhere; and (3) contamination has not contacted or penetrated the building foundation based on visual and olfactory observations and the use of field instruments. (See Section X of TGM for additional detail.) Evaluation of groundwater for VI potential may still be necessary.

This guidance should be used to evaluate VI for sites where the report is expected to be submitted following the effective date of this guidance.

Beyond these actions, this guidance provides multiple options for addressing VI including soil and groundwater screening values, alternative assessment options, mitigation with an environmental covenant, and remediation. The alternative assessment options consist of screening values for indoor air, sub-slab soil gas, and near-source soil gas in addition to VI modeling. Use of the screening values and other options as well as important terms is described below.

A. Definition and Use of Important Terms

Several of the terms used in this guidance may have multiple meanings within the context of the Land Recycling Program (LRP) or other DEP programs. Therefore, it is important that their intended use in this guidance be well defined. The following definitions and uses are provided only for application under this VI guidance. They are presented in the order that allows the reader to make the best sense of each definition as opposed to alphabetical order.

- **Hydrogeologic Zones:**
  - ***Definition***- When used in this guidance, the "saturated zone," "capillary zone" and "vadose zone" are related to one another as shown on Figure 1 and do not overlap. The saturated zone is defined as the zone of groundwater saturation that occurs below the water table as measured in appropriately constructed monitoring wells. The capillary zone is the zone of tension saturation and its thickness is dependent on the soil type in which it occurs as provided in Table 10 in U.S. EPA (2004). The vadose zone is defined as unsaturated solid media that occurs between the top of the capillary zone and ground surface or a building foundation.
  - ***Use***- These three terms are used in this guidance principally to define points of application for various screening values as shown on Figure 1 and related sampling intervals for soil, groundwater and near-source soil gas.
- **Acceptable Soil or Soil-like Material:**
  - ***Definition***- Any unconsolidated material containing some amount of organic material that occurs in the vadose zone above the capillary fringe above a potential vapor intrusion source (soil and/or groundwater) that does not exceed the saturated hydraulic conductivity of sand or the net air-filled porosity of silt at

residual water content, both as derived from Tables 5 & 3 in U.S. EPA (2004). Natural soils coarser than sand or with air-filled porosity greater than silt may not constitute acceptable soil (e.g., gravel). Conversely, fill material that is otherwise soil-like and does not exceed the characteristics described above may constitute acceptable soil-like material (e.g., mixtures of granular material comprised predominantly of sand, silt and clay with brick, block and concrete fragments where the granular material occupies virtually all of the interstitial space between the fragments).

- ***Use-*** A minimum of five feet of acceptable soil or soil-like material needs to be present between a potential VI source and foundation level to permit the use of groundwater, soil or near-source soil gas screening values. Additionally, acceptable soil or soil-like material should NOT exhibit any of the following conditions for the purpose of applying screening criteria to soil, groundwater, and near-source soil gas data:
    - Visual or olfactory indications of contamination
    - Readings from an appropriate field screening instrument in the jar head space above soil samples that are greater than 100 ppmv
    - Evidence of separate phase liquids (SPL)
    - Meet the definition of contamination as defined in this guidance.

  Soil does not need to be sampled in areas beyond where soil has been directly impacted by a release of regulated substances to demonstrate an acceptable soil or soil-like material.

  For the purposes of the petroleum substance vertical proximity distances described below, the Department further defines acceptable soil or soil-like material as exhibiting greater than 2% oxygen in soil gas near the building slab.

- **Preferential Pathway:**
    - ***Definition-*** A natural or man-made feature that acts as a conduit for vapor transport by enhancing vapor migration from contaminated environmental media through soil or soil-like material to an existing or future inhabited building.

      Use- Preferential pathways act as VI sources because they do not allow for vapor attenuation through soil. If an underground feature is separated from the contaminated media or the building with enough acceptable soil or soil-like material, attenuation can take place and the feature does not act as a vapor source. Additional information regarding how to identify and evaluate preferential pathways is provided in Section C.
- **Contamination:**
    - ***Definition-*** A regulated VOC or SVOC released into the environment resulting in a VI concern. A soil or groundwater sample with a detected concentration or a detection limit greater than the Practical Quantitation Limit (PQL) is considered contamination. Additionally, visual or olfactory detections of a regulated VOC or SVOC, field instrument readings in the head space above soil samples greater than 100 ppmv and the presence of SPL in soil or groundwater are all considered evidence of contamination.
    - ***Use-*** This definition is used in this guidance to help guide the remediator in identifying areas of potential VI concern. Delineating to the PQL is not required by the remediator. Soil and groundwater should be sampled in areas directly

impacted by a release of regulated substances to delineate the area of contamination.

- **Proximity Distance:**
  - ***Definition*** **–** The acceptable distance between an existing or future inhabited building and contaminated groundwater or soil that poses a VI risk.
  - ***Use*** **–** For petroleum substances, the horizontal proximity distance is 30 feet. The vertical proximity distance for petroleum hydrocarbons is six feet for dissolved phase contamination or 15 feet for SPL. The use of the vertical proximity distances requires the presence of acceptable soil or soil-like material. The horizontal proximity distance for non-petroleum contamination is 100 feet. There is no vertical proximity distance for non-petroleum contamination. See figure 2B for an example of the application of proximity distance.
- **Vapor Intrusion Area of Potential Concern (VI AOPC):**
  - ***Definition-*** An area of groundwater contamination at the water table or soil contamination in the vadose or capillary zones that either lies within a proximity distance from an existing or potential future inhabited structure or within 30 horizontal or five vertical feet from a preferential pathway (see Figure 2A).
  - ***Use-*** VI AOPCs are delineated in order to locate the areas of contamination within which the remediator must address VI at a minimum by additional screening. As such, a VI AOPC is an area within which the remediator must first identify potential conditions that may limit the use of soil and groundwater screening values (i.e., SPL and contamination at less than five feet below foundation level). If none of these conditions is present, then contamination in the VI AOPC may be evaluated based on these screening values. If concentrations in a portion of the VI AOPC are determined to exceed screening values, then that area of groundwater or volume of soil is designated a "Potential VI Source" (see Figure 2C and the definition below). If one or more of the limiting conditions is present in the VI AOPC, precluding the use of soil and groundwater screening values, that portion of a VI AOPC affected by the limiting condition would become a Potential VI Source that must be addressed (see Figure 2D and the definition below). For further information refer to Section D.
- **Separate Phase Liquid:**
  - ***Definition-*** That component of a regulated substance present in some portion of the void space in a contaminated environmental medium (i.e., soil or bedrock) that is comprised of non-aqueous phase liquid (NAPL). As such, SPL is distinct from the mass of a regulated substance in the contaminated environmental medium that is adsorbed onto or diffused into the soil or rock matrix, or dissolved in water or diffused into air that may also occupy a portion of that void space.
  - ***Use-*** The presence of SPL provides one basis for limiting the applicability of screening values and the modeling assessment option. As shown in Figure 3, the presence of a SPL layer on the water table or SPL within a smear zone associated with such a layer precludes the use of the groundwater screening values or the modeling assessment option to evaluate groundwater contamination. This is the case whether the water table occurs in the soil or bedrock beneath a site. These options are available, however, beyond the limits of the SPL. In the vadose zone, soil contamination that includes interstitial residual SPL precludes the use of soil

screening values and the modeling assessment option to evaluate soil contamination since the model assumes partitioning from adsorbed mass on the soil to pore water and then to soil gas, as opposed to direct evaporation from SPL to soil gas. The same is true for screening values based on the generic soil-to-groundwater MSCs since they are also based on this partitioning equation. However, near-source soil gas screening values may be used provided the sampling is performed above the SPL-impacted soil or groundwater (Figure 3). The soil gas version of the J&E model may also be used to evaluate near-source soil gas sampling results under the modeling assessment option.

- **Potential Vapor Intrusion Source:**
  - ***Definition***- That portion of a VI AOPC in which groundwater contamination at the water table or vadose zone soil contamination exhibits concentrations of regulated substances of VI concern that exceed one or more of the corresponding screening values established by this guidance (see Figure 2D), and/or that portion of a VI AOPC that is affected by a condition that limits the use of soil and groundwater screening values (see Figure 2C).
  - ***Use***- Identifies areas of a site where VI must be addressed through further VI assessment, remediation, or mitigation. Refer to Section E.

B. Overview of the VI Evaluation Process

This guidance offers a flexible VI evaluation process for the Statewide health standard that provides multiple alternatives to the remediator. Figure 4 presents a flowchart outlining the process, which is described in detail in the following sections. It is important to note that the purpose of Figure 4 is to illustrate how all of the steps in the VI evaluation process under the Statewide health standard fit together. Figure 4 should not be used as your sole guide for performing a VI evaluation; rather, it should be used in conjunction with the text of this guidance. The principal steps of a VI evaluation under the Statewide health standard are:

- Conceptual site model development and preferential pathway evaluation;
- Identify VI Areas of Potential Concern (VI AOPCs) using proximity distances;
- Identify Potential VI Sources from conditions that limit screening and/or exceedences of soil and groundwater screening values;
- Utilize alternative assessment options including screening near-source soil gas, sub-slab soil gas, or indoor air data, or conducting VI modeling;
- Mitigate buildings and ensure future protection with an environmental covenant;
- Remediate the soil and/or groundwater contamination and reassess the pathway;
- Address the Chapter 250 Statewide health standard requirements;

In most cases all of the above steps will not be necessary, and the remediator is not required to follow the process sequentially. For instance, buildings with a potentially complete VI pathway may be mitigated without the collection of soil gas or indoor air data.

If conditions are identified that pose an immediate threat to human health or safety at any time in the VI evaluation process, prompt interim actions should be taken to protect human health.

B.1 VI Conceptual Site Model

The vapor intrusion conceptual site model (VI CSM) is central to the VI evaluation. The VI CSM is a representation of contaminant sources, migration pathways, exposure mechanisms, and potential receptors. The VI CSM is key to preparing a sampling plan (Appendix Z), and as the VI CSM is revised data gaps may be identified that will guide further sampling. The VI CSM is also a prerequisite for VI modeling (Appendix Y). The source description and contaminants of concern are components of the VI CSM supported by soil, groundwater, and possibly near-source soil gas data. The VI CSM development may also rely on sampling the vapor migration pathway (sub-slab soil gas) or receptor exposures (indoor air).

The goal of the VI CSM is to describe how site characteristics, such as subsurface and building conditions, might influence both the distribution of VOCs in soil gas and the potential indoor air quality of structures in the vicinity of a soil or groundwater VOC source. VOC concentrations in soil gas attenuate, or decrease, as the VOCs move from the source through the soil and enter indoor air. The extent of attenuation is related to site conditions, building properties and chemical properties. The soil vapor attenuation is quantified in terms of an attenuation factor defined as the ratio of indoor air concentration to source vapor concentration (Appendix X).

The level of the detail of the VI CSM should be tailored to the complexity of the site, the available data and the selected Act 2 remedial standard. For the VI pathway, complex relationships exist among the many factors that influence vapor intrusion. Hence, multiple lines of evidence are often used to evaluate risks associated with the vapor pathway. Finally, it should be remembered that the VI CSM is a dynamic tool to be updated as new information becomes available during site characterization.

Some important elements of the VI CSM include the following (California EPA, 2011; Massachusetts DEP, 2011; EPA, 2012; Hawaii DoH, 2014):

- Sources of contamination—origins, locations, substances, and concentrations; presence of separate phase liquid
- Transport mechanisms—route from source to indoor air, potential preferential pathways
- Subsurface and surface characteristics—soil type, depth to bedrock, heterogeneities; ground cover
- Groundwater and soil moisture—depth to water, water level changes, capillary zone thickness
- Fate and transport—biodegradation of petroleum hydrocarbons
- Weather—precipitation, barometric pressure changes, wind, frozen ground
- Building construction—basement, slab on grade, or crawl space; foundation condition (cracks, openings), sumps and French drains
- Building heating and ventilation

- Background sources—indoor air contaminants, ambient air pollution
- Receptor types—residential, nonresidential, sensitive receptors; potential future development.

B.2 Screening Values and Points of Application (POA)

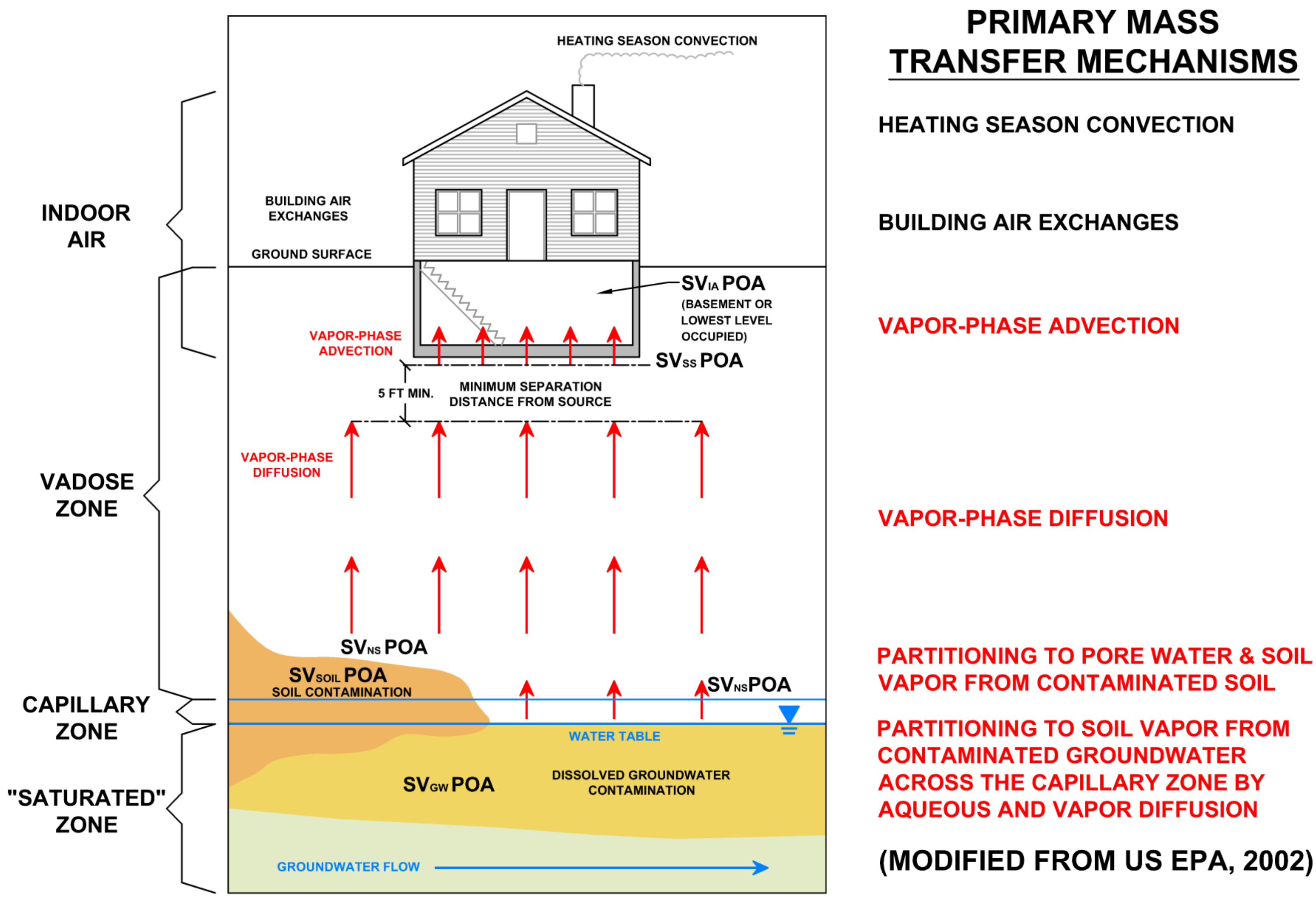
Screening values are published in Tables 1–5 for soil, groundwater, near-source soil gas, sub-slab soil gas and indoor air. Separate screening values are provided in these tables for residential and nonresidential uses of potentially affected inhabited buildings. In addition, there are two distinct nonresidential building categories: “nonresidential” and “converted residential.” The first category refers to buildings constructed for nonresidential use, and the second category refers to buildings that presently have a purely nonresidential use although they were originally constructed for residential use. An example is a dentist’s office in a converted home. The converted residential screening values are based on vapor flow and air exchange rates representative of residential structures but using exposure factors for nonresidential settings. Residential screening values apply if a building has both residential and nonresidential uses (e.g., apartments over a retail store).

The Point of Application (POA) for each of these screening values is shown in Figure 1. As shown on Figure 1, groundwater screening values (SV_{GW}) apply within the zone of groundwater saturation that will exhibit concentrations of regulated substances representative of concentrations at the water table. This is an interval within ten feet or less of the water table. Soil screening values (SV_{SOIL}) apply throughout the volume of contaminated soil in the vadose zone. Near-source soil gas screening values (SV_{NS}) apply just above a soil VI source and/or just above the capillary zone for a groundwater VI source. Near-source soil gas screening is also applicable to a preferential pathway when it is treated as a source. Sub-slab soil gas screening values (SV_{SS}) apply immediately below the slab of a building potentially impacted by VI, whether the building has a basement or is slab-on-grade construction. Finally, indoor air screening values (SV_{IA}) apply in the lowest occupied space of a potentially impacted building.

Screening values cannot be calculated for substances that have no inhalation toxicity data (Appendix X). Therefore, Statewide health standard VI evaluations are not required for substances without screening values. The remediator may choose to evaluate VI using the site-specific standard for these chemicals.

Table 6 summarizes data collection conditions for VI screening and how to apply the POAs. Methods for VI screening are described in Sections F and G and in Table 7. Appendix X describes the methodology for developing the screening values.

FIGURE 1: VI SCREENING VALUE POINTS OF APPLICATION



POA = Point of Application
SV_{IA} = Indoor air screening value
SV_{SS} = Sub-slab soil gas screening value
SV_{NS} = Near-source soil gas screening value
SV_{SOIL} = Soil screening value
SV_{GW} = Groundwater screening value

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B.3 Guidelines for Evaluating VI Using a Combination of Standards

When using a combination of standards (e.g., the Statewide health standard and the site-specific standard) the VI pathway must be evaluated along with all of the other requirements of each standard being used. The screening values presented in Tables 1 through 5 were designed to be used only when attaining the Statewide health standard. However, under specific circumstances, adjusted Statewide health standard VI screening values can be used when evaluating VI under the site-specific standard. See Section K.4 for additional detail on using screening values under the site-specific standard.

The VI pathway must be assessed to satisfactorily attain the Statewide health standard for soil and groundwater. Under the Statewide health standard a remediator cannot evaluate the VI pathway without also evaluating soil and groundwater because Act 2 does not define indoor air as an environmental medium. However, when using a combination of standards, a remediator can evaluate soil and groundwater under either the Statewide health standard or the site-specific standard then evaluate VI separately under the site-specific standard. This is permissible because the site-specific standard evaluates individual exposure pathways and Act 2 considers VI to be an exposure pathway, not an environmental medium.

When using VI modeling under the Statewide health standard, the desired output is a predicted indoor air concentration. This modeled concentration should be used in the evaluation of VI by comparing it to the associated indoor air screening value or, under appropriate circumstances, occupational limits acceptable in conjunction with an OSHA-compliant worker protection program (see Section G.2). The J&E model can calculate risk values which should not be used for Statewide health standard evaluations. Use of risk calculations to evaluate VI is considered to be a risk assessment, which is a tool to be used under the site-specific standard and is subject to additional reporting requirements and fees. If calculated risk values are used in the VI analysis, it will be assumed that the site is being remediated under a combination of standards and all associated fees and requirements of both standards will apply.

If the remediator intends to use the site-specific standard as the sole means of evaluating VI or under a combination of standards, the site-specific standard VI process described in Section K should be used.

C. Preferential Pathway Evaluation

Preferential pathways can act as conduits for contaminated vapors to flow from areas of contamination into inhabited buildings (see definition in Section A and Figure 2A). The presence and significance of preferential pathways are assessed in the conceptual site model development. Some examples of preferential pathways include sewer lines with faulty traps, utility line trenches backfilled with gravel, basement sumps, and bedrock fractures. Sumps and French drains should be evaluated for both wet and dry conditions. Wet sumps may introduce contaminated groundwater into the building. Dry sumps may convey contaminant vapors directly through the foundation.

Utility lines and their foundation penetrations in buildings the size of a typical single-family home are usually not considered to be preferential pathways. The backfill material around utility lines is what acts as the conduit for vapor transport, not the utility line itself. Since most structures the size of a typical single-family home are backfilled with native soil, these features do not act as preferential pathways. Underground features associated with larger buildings are typically backfilled with non-native soil (e.g. gravel or stone) which can act as a conduit for vapors and should therefore be considered preferential pathways.

The presence of a preferential pathway makes the affected portion of the VI AOPC a "Potential VI Source" (see Figure 2A) and acts as an extension of that source. If preferential pathways are identified, the proximity distances described in Section D do not apply to the contaminant source area because these distances are based on the movement of vapors, and associated attenuation, through soil. Proximity distances may be used for the preferential pathway itself, as it also acts as a source.

If an underground feature is within five vertical or 30 horizontal feet of contaminated media AND within five horizontal or five vertical feet of the building foundation, it is considered to be a preferential pathway. If an underground feature is separated from the contamination by at least five vertical or 30 horizontal feet of acceptable soil or soil-like material OR is separated from the building foundation by five horizontal or five vertical feet of acceptable soil or soil-like material, the feature is NOT considered to be a preferential pathway. For example, if petroleum vapors are present in a high-permeability backfilled trench that is 6 feet below the foundation, and 6 feet of acceptable soil or soil-like material is present between the trench and the foundation, then no further VI analysis would be necessary.

If preferential pathways are identified, the remediator should not use soil or groundwater screening values because these values are based on the attenuation of vapors through acceptable soil-like material which does not occur in the presence of a preferential pathway. Similarly, the default model for predicting indoor air concentrations (see Appendix Y) using soil or groundwater data should not be used when preferential pathways are present because this model is also based on the attenuation of soil vapors through soil. Near-source soil gas and sub-slab soil gas screening should not be performed if the preferential pathway penetrates the building foundation. The remediator may model appropriately collected near-source soil gas data.

As described later in this guidance, a preferential pathway may be eliminated by appropriate actions conducted during site remediation.

D. Identify VI Areas of Potential Concern Using Proximity Distances

If there are no preferential pathways, then the remediator identifies VI Areas of Potential Concern (VI AOPCs) where soil and/or groundwater contamination is present within applicable proximity distances from existing or potential future inhabited buildings. To accomplish this step, existing and/or future inhabited buildings are located and proximity distances from each of these buildings are delineated. Then, relying on the results of site characterization and/or post-remediation sampling, all areas of contaminated groundwater at the water table and volumes of contaminated vadose zone soil that are present within an applicable proximity distance from an existing or potential future inhabited building are identified. Predicted areas of contamination from the fate-and-transport analysis should be included. If no soil or groundwater contamination is present within these proximity distances, then additional VI analysis is unnecessary. However, if such an area of contamination is present, it is a VI AOPC (see Figure 2B).

A VI AOPC can also exist beyond the applicable proximity distances when a preferential pathway is present as shown in Figure 2C. In this situation the remediator should evaluate VI for both the potential VI source and the VI AOPC separately. The Department defines the VI AOPC as the contaminated area within 30 feet horizontally or 5 feet vertically of the preferential pathway.

A proximity distance is the acceptable distance between an existing or future inhabited building and contaminated groundwater or soil that poses a VI risk. Proximity distances are a function of the mobility and persistence of the chemical, as well as, in the case of petroleum substances, the depth of the source and the characteristics of the subsurface materials. The proximity distances that are applied in this guidance are for:

- Sites with contamination associated with non-petroleum regulated substances present in soil and/or groundwater, a horizontal proximity distance of 100 feet applies; and
- Sites with soil and/or groundwater contamination from only petroleum substances and related hydrocarbons, a horizontal proximity distance of 30 feet and a vertical proximity distance of six feet apply. For petroleum SPL, a further vertical proximity distance of 15 feet applies between the SPL and foundation level.

Note: The petroleum proximity distances apply to any petroleum substance, not just the substances listed on the Petroleum Short List from the Land Recycling Program Technical Guidance Manual.

Petroleum substances are treated differently than non-petroleum substances in setting proximity distances because their high rates of biodegradation play a key role in diminishing the effects of VI. Petroleum hydrocarbons typically biodegrade under both anaerobic and aerobic conditions, with aerobic degradation occurring much more rapidly. Since soil oxygen content is generally higher in surface and shallow sub-surface soils, vapors from petroleum hydrocarbons biodegrade rapidly as they migrate upward through the soil column reducing their concentrations prior to migrating into inhabited buildings. The Department defines an acceptable soil or soil-like material as having greater than 2% oxygen for purposes of applying proximity distances for petroleum substances. Measurement of soil oxygen content is described in Appendix Z.

If only petroleum substances have been detected, the remediator determines the horizontal and vertical distance of the building foundation to the groundwater plume or soil contamination. If a current or future inhabited building is greater than or equal to 30 horizontal feet from an area of petroleum substance contamination, then there is adequate distance for aerobic biodegradation to occur to reduce the vapor concentrations to acceptable levels. Likewise, if there is greater than or equal to six feet of acceptable soil or soil-like material vertically between the bottom of a current and/or future inhabited building foundation and the top of the dissolved phase petroleum groundwater contamination or vadose zone soil contamination, then there is adequate distance for biodegradation to occur to reduce the vapor concentration to acceptable levels. The minimum vertical distance is 15 feet for petroleum SPL. Vertical distances are calculated using the maximum groundwater elevation and the top of the measured or inferred SPL (smear zone or residual LNAPL). If neither the horizontal nor vertical proximity condition is met the remediator must evaluate VI.

E. Identify Potential VI Sources

If VI AOPCs are identified, the next step is to identify Potential VI Sources as part of the conceptual site model development. First, the remediator examines the VI AOPC(s) for the presence of conditions that might preclude the use of soil and groundwater screening values. These limiting conditions include:

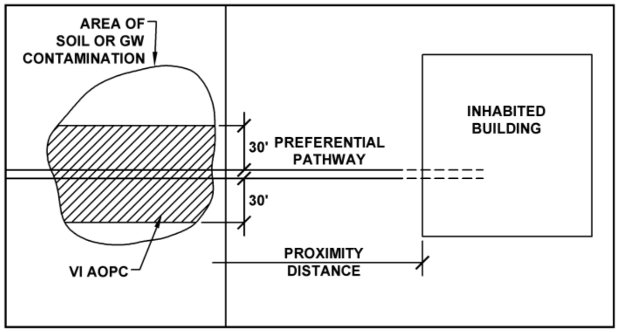
- The presence of preferential pathways (Section C);
- The presence of SPL within a proximity distance (see Figure 3);
- The presence of soil or groundwater contamination at <5 feet below foundation level within a proximity distance.

If one or more of these conditions is present, then the affected portion of a VI AOPC becomes a Potential VI Source (Figure 2C). Potential VI Sources are addressed through alternative assessment options, remediation, mitigation, or other restrictions established in an environmental covenant.

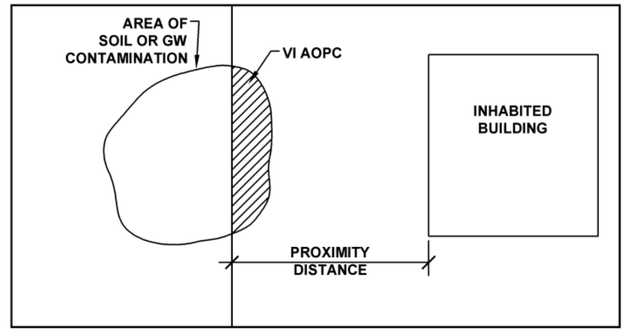
If there are no preferential pathways and there is no SPL or shallow source within a VI AOPC as described above, then the following step is screening soil and groundwater concentrations against their respective screening levels. As shown on Figure 4, if there are no exceedences of soil and groundwater screening values, then no further VI analysis is necessary. However, if there are concentrations that exceed screening values, then the area of groundwater or volume of soil where the exceedences occur constitutes a Potential VI Source (Figure 2D).

There can be situations in which a Potential VI Source exists because of a limiting condition, such as a preferential pathway, but a portion of the VI AOPC remains outside its boundaries (e.g., Figure 2C). If there are no other limiting conditions, then soil and groundwater screening may be applied to the VI AOPC beyond the Potential VI Source boundaries. Alternative assessment options or other remedies can be used for the Potential VI Source (Figure 4).

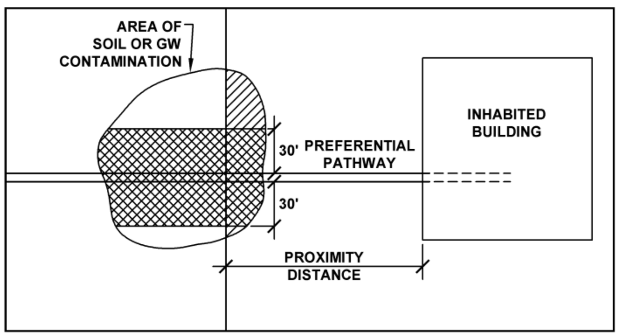
FIGURE 2:
DELINEATION OF VI AREAS OF POTENTIAL CONCERN AND POTENTIAL VI SOURCES, INCLUDING THE EFFECT OF PREFERENTIAL PATHWAYS



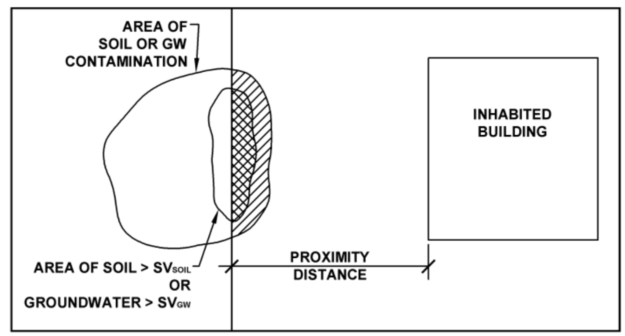
2A. VI AOPC IS PRESENT ALONG PREFERENTIAL PATHWAY BEYOND PROXIMITY DISTANCE



2B. VI AREA OF POTENTIAL CONCERN (AOPC) BASED ON PROXIMITY DISTANCE



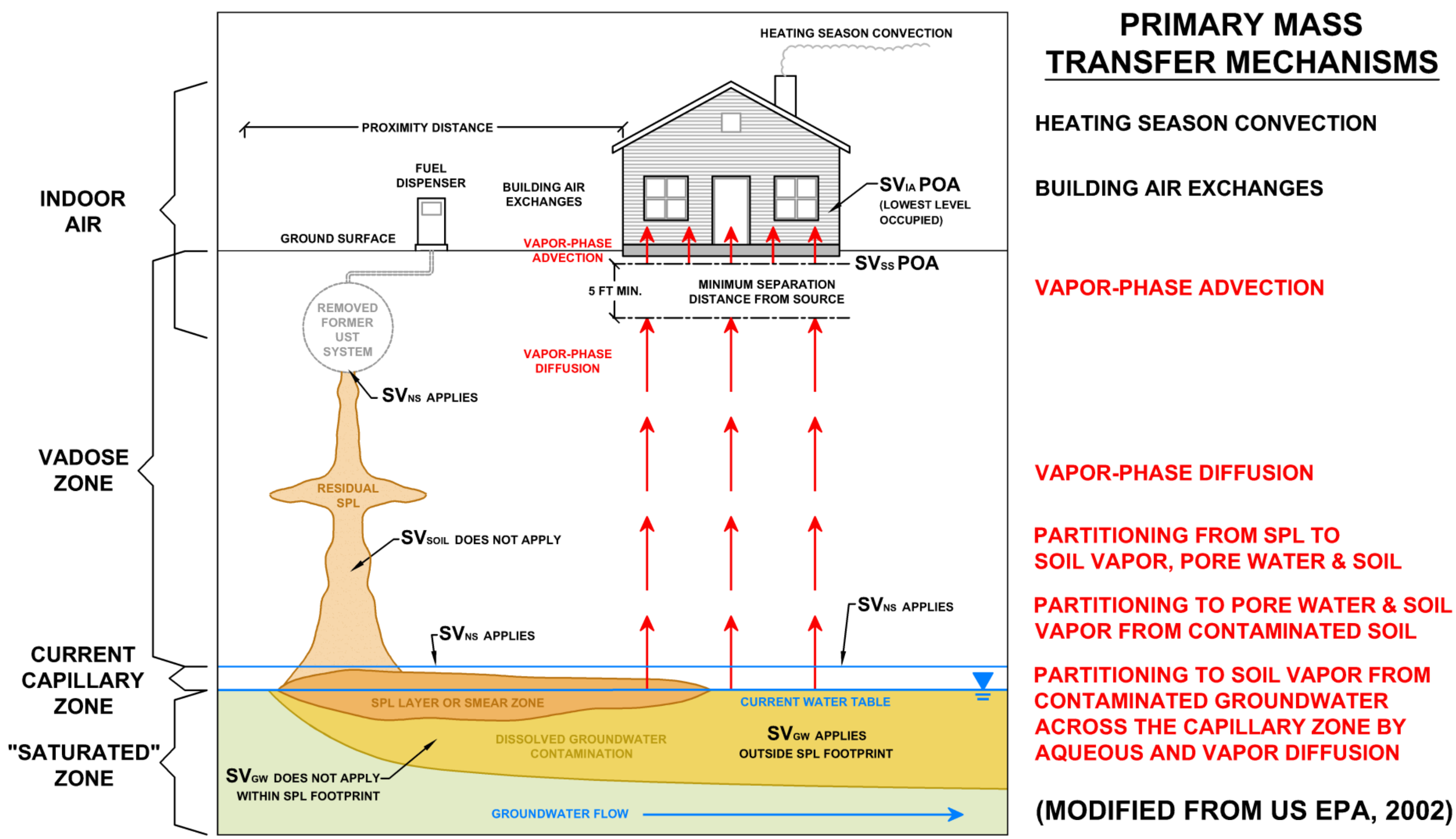
2C. POTENTIAL VI SOURCE IS PRESENT ALONG PREFERENTIAL PATHWAY WITHIN & BEYOND PROXIMITY DISTANCE



2D. POTENTIAL VI SOURCE BASED ON SOIL OR GROUNDWATER SCREENING VALUES WITHIN PROXIMITY DISTANCE

- VI AREA OF POTENTIAL CONCERN   - POTENTIAL VI SOURCE

FIGURE 3: EFFECT OF SEPARATE PHASE LIQUID ON THE APPLICABILITY OF SCREENING VALUES



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F. Soil and Groundwater VI Screening

F.1 Soil and Groundwater Screening Values

The groundwater VI screening values are provided in Table 1 and the soil VI screening values are provided in Table 2. The derivation of these values is explained in Appendix X. Table 6 describes important conditions for collecting soil and groundwater data to be used for VI screening.

The soil VI screening values (SV_{SOIL}) are the higher of the generic soil-to-groundwater numeric values (Chapter 250, Appendix A, Table 3B) and calculated soil screening values. The calculated soil screening values are based on the acceptable indoor air concentrations and model-derived attenuation factors. The generic soil-to-groundwater numeric values are considered appropriate for VI screening because soil contamination that is unable to impact aquifers in excess of groundwater MSCs is also unlikely to pose an excess inhalation risk. Furthermore, VI sources associated with contaminated soil are typically not directly beneath buildings and do not have an infinite lateral extent, making the assumptions of the model for calculating soil screening values conservative.

The groundwater VI screening values (SV_{GW}) are the higher of the groundwater MSCs (Chapter 250, Appendix A, Table 1) and the calculated groundwater screening values based on EPA's empirical attenuation factors. The groundwater MSCs are considered suitable VI screening values because groundwater with concentrations at or below the MSCs is acceptable for use inside buildings (e.g. cooking, showering, cleaning, etc.).

F.2 Soil and Groundwater Screening Methods

As shown on Figure 4, screening values for soil and groundwater may be used to address VI provided there are no conditions present that exclude their use (i.e., preferential pathways, presence of SPL or shallow sources within the appropriate proximity distance). The remainder of this subsection assumes none of these conditions is present to limit the use of soil and groundwater screening values.

Vapor intrusion can be addressed by screening either characterization data or post-remediation data from soil and groundwater. The volume of soil and the area of groundwater contamination (i.e., Potential VI Sources) will be determined from these sampling results and applicable proximity distances (see Figure 2C). Important conditions for screening are listed in Table 6. Among these are that there must be at least 5 ft of acceptable soil or soil-like material between the vapor source and the foundation, and groundwater must be sampled at the water table because it will be the source of vapors that can migrate to buildings.

Proper characterization of soil and groundwater contamination is required at all Act 2 sites and this data alone may be sufficient for the VI assessment. If the site attains the Statewide health standard on the basis of soil and groundwater characterization data in the Area of Potential VI

Concern, then those data may be used for VI screening (Table 7). No further VI evaluation is necessary if the applicable characterization data does not exceed soil and groundwater VI screening values (SV_{SOIL}, SV_{GW}). If the characterization data exceed MSCs but the remediator intends to pursue the Statewide health standard, then the characterization data should be used to identify Potential VI Sources.

When a VI AOPC or a Potential VI Source is remediated, VI screening may be performed with the soil or groundwater attainment data in accordance with the sampling methodologies and related statistical tests of Chapter 250, Subchapter G (Table 7). For example, when at least eight consecutive quarters of groundwater attainment data have been collected the remediator may apply the 75%/10x rule to monitoring wells on the property or the 75%/2x rule for off-site monitoring wells for VI screening (Section 250.707(b)(2)(i)). Fewer than eight rounds of data may be screened with Department approval pursuant to Section 250.704(d).

For soil remediated *in situ*, the POA is throughout the volume of soil originally determined to exceed the soil screening value(s) (i.e., a Potential VI Source). For soil excavated and removed from the site, the POA is the margins of the excavation.

The number and locations of groundwater monitoring wells is selected on the basis of their representativeness with respect to water quality in the relevant portion of the plume. For groundwater on developed properties, the POA is throughout the area of a plume that has been identified as a Potential VI Source prior to VI assessment or remediation. For groundwater on undeveloped properties or in undeveloped portions of properties where future inhabited buildings may be constructed, the POA is throughout the area of a plume that has been identified as a Potential VI Source prior to VI assessment or remediation and is not within an area subject to an environmental covenant restricting construction of future inhabited buildings.

G. Alternative VI Assessment Options

The purpose of the VI assessment options is to gather and evaluate enough information to adequately address the VI pathway for groundwater and/or soil under the Statewide health standard. These options may be applied to VI AOPCs and Potential VI Sources. There are several assessment options the remediator may choose:

1. **Near-source soil gas concentrations < SV_{NS}**
   (Not available if a preferential pathway penetrates the building foundation or a Potential VI Source is less than five feet below foundation level.)
2. **Sub-slab soil gas concentrations < SV_{SS} for existing buildings**
   (Not available if a preferential pathway penetrates the building foundation.)
3. **Indoor air concentrations < SV_{IA} at existing buildings**
4. **Vapor intrusion modeling using acceptable input parameters**
   (Not available for soil or groundwater where a preferential pathway or SPL is present. Not available for near-source soil gas if a preferential pathway penetrates the foundation.)

G.1 Soil Gas and Indoor Air Screening Values

The near-source soil gas screening values (SV_{NS}) are provided in Table 3, the sub-slab soil gas VI screening values (SV_{SS}) in Table 4, and the indoor air screening values (SV_{IA}) in Table 5. The derivation of these values is explained in Appendix X. Table 6 describes important conditions for collecting soil gas and indoor air data to be used for VI screening. Detailed information on sampling methodologies is provided in Appendix Z.

The near-source soil gas screening values are based on attenuation factors derived from modeling and endpoint concentrations equal to the acceptable indoor air screening values. Near-source soil gas is measured within or directly above the soil source in the vadose zone or directly above the capillary zone for a groundwater source. Near-source soil gas may also be sampled immediately above a preferential pathway that does not penetrate the building foundation. Vapor concentrations measured in near-source soil gas are theoretically the highest possible concentrations because they are directly adjacent to the source.

The sub-slab soil gas screening values are based on EPA's empirical attenuation factors and endpoint concentrations equal to the acceptable indoor air screening values. Sub-slab samples are collected immediately below the foundation, and their proximity to the receptor makes them a reliable indicator of potential exposures. Sub-slab sampling may also be done beneath intact paved areas large enough to be representative of future inhabited buildings.

The indoor air screening values (SV_{IA}) are calculated using the inhalation risk equations in the EPA's risk assessment guidance. Indoor air data represent conditions that are as close to the receptor as possible and, therefore, provide the most accurate representation of concentrations at the point of exposure. Indoor air can be influenced by background vapor sources inside or outside of the structure. This background vapor can cause false positive detections of indoor air contamination. However, the possibility of false negatives (not detecting vapor concentrations that are present in indoor air) is very low, which is why indoor air sampling is an acceptable single line of evidence. If the remediator suspects that background vapor contamination could be a problem at their site, indoor air sampling is not recommended.

G.2 Using an OSHA Program to Address VI

The indoor air screening values are based on the same target risk (i.e., hazard quotient (HQ) = 1.0 and excess cancer risk level = 10^{-5}) used for the soil and groundwater medium-specific concentrations (MSCs) published in Chapter 250 for attainment of the Statewide health standard. However, a special case exists when VI from soil or groundwater into industrial (or commercial) facilities that use the same chemical(s) in their industrial processes makes VI from environmental sources difficult to evaluate. The Department does not regulate indoor air. Rather, worker exposure to chemical vapors associated with an onsite industrial process is regulated by the Occupational Safety and Health Administration (OSHA). It is nearly impossible to accurately isolate and measure the VI component of the indoor air that can be attributed to soil and groundwater contamination using indoor air sampling. As a result, workers who are not properly trained to work in areas that contain these vapors can still be exposed to soil or groundwater related vapors due to VI.

Therefore, an OSHA program can be used to address VI if the remediator can demonstrate that the chemicals they are screening for are currently being used in a regulated industrial process inside the inhabited building(s) and that OSHA regulations are fully implemented and documented in all areas of the building(s). This means that workers and others who might be exposed to all chemicals of concern have full knowledge of the chemicals' presence, have received appropriate health and safety training, and have been provided with the appropriate protective equipment (when needed) to minimize exposure. It is the expectation that MSDS sheets are posted, a hazard communications plan is in place and employees have been properly trained in the handling of chemicals and the use personal protective equipment. If OSHA implementation cannot be documented then an OSHA program cannot be used as a means of addressing VI. Facilities that use an OSHA program to evaluate VI will have an environmental covenant to ensure that future owners know that the previous owner relied on the OSHA program to protect its workers. If the future owner does not use the same chemical(s) in their industrial process and/or does not fully implement an OSHA program for the same chemical(s) then VI would need to be reevaluated.

G.3 Soil Gas and Indoor Air Screening Methods

Near-source soil gas, sub-slab soil gas, and indoor air data may be acquired during the characterization phase or following soil or groundwater remediation. VI sampling requirements and statistical tests are not specified in Chapter 250. Therefore, the number of sample points for addressing VI is determined based on the CSM, professional judgment, and the guidance in this document. The Department recommends a minimum of two sample locations per building for near-source soil gas, sub-slab, and indoor air sampling.

The characterization data and CSM are used to determine the size and location of the area of Potential VI Sources. For most sites, sampling should be biased toward the most contaminated areas or the most appropriate locations for the sample type. In certain circumstances (large areas or buildings where a large number of samples is necessary) the locations of the samples should be determined by an appropriate randomization method (e.g., systematic random sampling, stratified random sampling, etc.) as described in the RCRA SW-846 manual (U.S. EPA, 2007, Chapter 9). These decisions are made on a case-by-case basis. Other important conditions for collecting data for the VI evaluation are listed in Table 6 and Appendix Z.

For near-source soil gas above a groundwater source, the number and locations of soil gas vapor probes are selected on the basis of their representativeness with respect to water quality in the relevant portion of the plume. When the water table occurs in soil, the POA for near-source soil gas is nominally within 1 foot of the top of the capillary zone, or as close to this interval as sampling can reasonably be performed given typical fluctuations in groundwater levels. When the water table occurs within bedrock, the POA for near-source soil gas is within 1 foot of the soil-bedrock interface, provided there is a minimum of 5 feet of Acceptable Soil or Soil-like Material between the top of bedrock and foundation level.

Sub-slab and indoor air samples should be biased toward areas of the building with the greatest expected VI impact. Indoor air samples should be collected in the basement, if present, or the lowest occupied floor. The Department recommends obtaining a concurrent ambient air sample (in addition to the two indoor samples) to account for potential background contamination from outside the building.

The indoor air data collected for screening purposes should be collected when the daily average outdoor temperature is at least 15°F below the minimum indoor temperature in the occupied space and the heating system is operating normally. Indoor air sampling can be performed during warmer seasons, but that data should be used for informational purposes only and should not be used to conclude the VI pathway is incomplete through screening. For instance, if an indoor air result collected in the summer exceeds the screening value, and indoor or ambient sources are not believed to be the cause, then the remediator might conclude that the VI pathway is complete and mitigation is needed.

The remediator may initially characterize VI with a minimum of two rounds of near-source soil gas, sub-slab soil gas, or indoor air sampling (Table 7). This data will normally be collected during the site characterization, but it can also be obtained following soil or groundwater remediation. The two sampling events should occur at least 45 days apart for statistical independence.

When preparing a sampling plan, many factors should be considered (Appendix Z). Two sample locations and two sampling rounds will not be sufficient at all sites and for all buildings. Spatial and temporal variability of VI data is significant, and small data sets have the potential of under-representing true mean concentrations and inhalation risks. Larger buildings will likely require more samples as source concentrations, vapor entry rates, and indoor ventilation rates will vary across the structure. If an undeveloped area is being evaluated, then there will need to be enough near-source soil gas points to encompass future building construction. Because petroleum hydrocarbons tend to pose a relatively low risk for VI owing to bioattenuation, the Department regards chlorinated VOCs as a greater concern for potential under-sampling.

No further vapor intrusion evaluation is necessary if none of the near-source soil gas, sub-slab soil gas, or indoor air characterization data exceed screening values (SV_{NS}, SV_{SS}, SV_{IA}).
If there are screening value exceedences, then the remediator has two options to continue evaluating the VI pathway. One option is to collect sufficient near-source soil gas, sub-slab soil gas, or indoor air data to apply statistical screening tests (Table 7). The other option is to select another assessment or remedial alternative (Figure 4). For example, if sub-slab sample results exceed screening values, then indoor air samples could be collected and screened, a mitigation system could be installed, or a risk assessment could be performed under the site-specific standard.

To screen near-source soil gas, sub-slab soil gas, and indoor air data using statistical tests, at least eight data points must be obtained at the existing or potential future building. This data can be a combination of sample locations and sampling rounds as long as there are at least two rounds collected at all of the same points. Sample locations should be biased toward areas of the greatest expected VI impact. The following soil and groundwater statistical tests of Section

250.707(b) may be applied to the collective data from the near-source soil gas, sub-slab soil gas, or indoor air sampling at each building:

- Seventy-five percent of all samples shall be equal to or less than the applicable VI screening value with no individual sample exceeding ten times the screening value (75%/10x rule).

- As applied in accordance with EPA approved methods on statistical analysis of environmental data, as identified in Section 250.707(e), the 95% upper confidence limit of the arithmetic mean shall be at or below the applicable VI screening value (95% UCL rule). The minimum number of samples is specified by the method documentation.

As an example, if there are two sub-slab sampling points in a building that have been sampled four times, the 75%/10x rule may be applied to those eight sets of analytical results. These tests should not be used for combinations of near-source and sub-slab data or soil gas and indoor air data. Data should be collected concurrently at all sample locations at the building.

Near-source soil gas, sub-slab soil gas, and indoor air sampling rounds should be performed in subsequent quarters or twice per quarter. Samples should be collected at least 45 days apart. The Department may allow alternative sampling frequencies with prior written approval.

G.4 Vapor Intrusion Modeling

VI modeling can be used to predict indoor air concentrations in current buildings. Modeling of any kind has an inherent amount of uncertainty involved but if acceptable input parameters are used with measured data, it can be a useful tool. The Johnson & Ettinger (J&E) model is currently the most widely used and accepted VI model available. The J&E model does have its limitations, namely it does not account for bioattenuation of petroleum hydrocarbons in its predictions. As a result, other models, such as BioVapor, can be used to predict indoor air concentrations at petroleum VI sites. Each model has its own set of conservative default input parameters that should be used when applicable. However, some parameters such as soil type, permeability and depth to the source can be adjusted to site-specific conditions.

Soil and groundwater data cannot be used for modeling if a preferential pathway or SPL is present. In this situation, near-source soil gas data can be modeled to evaluate VI provided that samples are collected directly above a preferential pathway, and that feature does not penetrate the building foundation. Likewise, near-source data may be collected above SPL and used in the model.

For sites that are completely or partially undeveloped, many of the modeling input parameters will have to be estimated. This can be done using either EPA's default input parameters (U.S. EPA, 2004), or, if building plans for future buildings are available, the remediator can use information from the plans for allowable parameter adjustments. A list of input parameters that can be adjusted based on site conditions is provided in the Modeling Guidance presented in Appendix Y.

Pennsylvania versions of EPA's J&E model spreadsheets are available on DEP's website and should be used for Statewide health standard J&E modeling. These versions have DEP default parameter inputs as well as physical/chemical properties and toxicological values from Chapter 250, Appendix A, Table 5A.

It is important to remember that when using VI modeling under the Statewide health standard, the desired output is a predicted indoor air concentration. This modeled concentration should be used in the evaluation of VI by comparing it to the associated indoor air screening value or, under appropriate circumstances, occupational limits acceptable in conjunction with an OSHA-compliant worker protection program. The J&E model can calculate risk values, but these should not be used for Statewide health standard evaluations. Use of risk calculations to evaluate VI is considered to be a risk assessment which is a tool to be used under the site-specific standard and is subject to additional reporting requirements and fees. If calculated risk values are used in the VI analysis, then the site is being remediated under a combination of standards and all associated fees and requirements of both standards will apply.

H. Environmental Covenants Requiring Mitigation or VI Evaluation

Properly installed and maintained mitigation measures eliminate or greatly reduce the VI pathway and therefore remain protective regardless of changes in subsurface concentrations or toxicity levels. Many areas of Pennsylvania have high levels of naturally occurring radon gas, which can pose a significant public health threat. VI mitigation systems not only address potential VI concerns associated with the release of regulated substances at remediation sites but also provide additional public health benefits associated with reducing the significant threat caused by naturally occurring radon gas. However, mitigation systems may not be feasible in all cases. The feasibility of using a mitigation system to address VI impacts for existing buildings will depend on the specific details of the site, the building, and the design of the system. Mitigation most commonly involves the installation of an active sub-slab depressurization system (similar to a fan-driven radon abatement system) (U.S. EPA, 2008).

For residential buildings, standard radon-type mitigation systems may be installed by individuals or firms certified by the Department for radon mitigation pursuant to Title 25 Pa. Code Chapter 240 (Pennsylvania DEP, 1997). Standard residential systems do not need to be designed or approved by a Licensed Professional Engineer. Active sub-slab depressurization systems can be tested using pressure differential testing or indoor air sampling. Performance and testing requirements for these systems are provided in Appendix Z. The remediator must demonstrate depressurization throughout the sub-slab. The remediator is not required to perform indoor air confirmation sampling when active sub-slab depressurization systems are tested using pressure differential testing.

An environmental covenant must be placed on the deed to ensure maintenance of the mitigation system. The environmental covenant must include language that requires the property owner to maintain the VI mitigation system, but the environmental covenant does not need to include language requiring periodic monitoring or reporting to the Department. The Department should be notified in the event of a property transfer, if there is a problem with the system or upon request by the Department.

Other engineering controls to mitigate vapor intrusion, such as the installation of a vapor barrier engineered to prevent VI, also require an environmental covenant for current and/or future buildings. Vapor barriers should be certified by the manufacturer for use in VOC mitigation. The material should be chemically resistant and have a demonstrated low permeability for the VOCs present. Moisture barriers typically do not meet these criteria. Vapor barriers should be installed and tested pursuant to the manufacturer's recommendations.

Environmental covenants are available to remediators for the following situations:

- When using mitigation as a means of eliminating or greatly reducing the VI pathway at existing structures.
- When committing to mitigation (as described below) of future inhabited building on the property.
- When committing to evaluate VI potential at the time a future inhabited building is constructed. The results of the evaluation should be submitted to the Department for review.
- When prohibiting construction of basements or residential and/or nonresidential inhabited buildings in a specified area of the property where the VI pathway may be complete.
- When using an OSHA program to address VI.

Natural attenuation resulting in decreasing concentrations of soil and groundwater contamination over time typically occurs at sites with releases of petroleum substances. Therefore, at sites for which an environmental covenant was used to address the VI pathway from Potential VI Source(s) of petroleum substances only, the environmental covenant may include a provision that allows for termination of the covenant or the AULs related to VI if the remediator can demonstrate to the Department that the AUL(s) is/are no longer necessary under current site conditions to comply with the selected standard.

The following language is provided as a guide for ECs with only one AUL related to VI:

> *This Environmental Covenant may be terminated if: (1) an evaluation is performed that demonstrates that mitigation to address a complete or potentially complete vapor intrusion pathway is no longer necessary and appropriate, and (2) the Department reviews and approves the demonstration.*

Alternatively, the following language is provided as a guide for ECs with multiple AULs, including AULs unrelated to VI:

> *This Environmental Covenant may be modified with respect to the VI AUL if: (1) an evaluation is performed that demonstrates that mitigation to address a complete or potentially complete vapor intrusion pathway is no longer necessary and appropriate, and (2) the Department reviews and approves the demonstration.*

I. Remediating and Re-Assessing the VI Pathway

Under some circumstances mitigation may not be practical or cost effective. The remediator may choose to perform further soil and/or groundwater remediation to address the VI pathway. Following the remediation, additional data must be collected for VI screening. This can include new soil or groundwater attainment data, or it can consist of soil gas or indoor air sampling data. The post-remediation data is evaluated following the process illustrated in Figure 4 (p. 35) and described in Sections F and G.

The timing of the remediation is an important consideration. If there is a complete VI pathway but remediation is a long-term action (such as a pump-and-treat system), then excess inhalation risks may exist for an unacceptably long time. In such cases the remediator is responsible for implementing interim measures to protect human health.

J. Addressing Chapter 250 Requirements

The final step in the process flowchart on Figure 4 is to address the requirements of Chapter 250 with respect to VI. This step is necessary to demonstrate compliance with the Statewide health standard in order to receive liability protection under Act 2 of 1995. The submitted report should include a description of the conceptual site model for VI. The flowchart endpoint can be reached in three ways, and compliance is documented in either the final report (Chapter 250) or the site characterization and remedial action completion reports (Chapter 245) as follows:

- **Use of Proximity Distances.** If no VI AOPCs are found to be present based on the presence of soil and groundwater contamination within applicable proximity distances, then no further analysis is necessary. Documenting this conclusion will only require the production of maps and cross sections that show the spatial relationship between soil and groundwater contamination, any preferential pathways, and existing or potential future inhabited structures. Applicable proximity distances should be shown on these exhibits.
- **Screening Values.** If screening values or modeling are used to assess the VI pathway, the remediator must demonstrate that there are no limitations to the use of screening values (e.g., SPL or a shallow source). If the site data satisfy the screening criteria, then no further analysis is necessary. Documenting this conclusion requires the same maps and cross sections described above to identify VI AOPCs, submittal of model results if applicable, and the tabulation of data used in the screening process to conclude that soil, groundwater, near-source soil gas, sub-slab soil gas, or indoor air screening values are satisfied within any VI AOPC pursuant to the tests described in Table 7.
- **Mitigation, Remediation, or Site-Specific Standard.** If screening values are not applicable or they are exceeded, then the remaining alternatives are mitigation, remediation, or selection of the site-specific standard. Mitigation requires testing to confirm the system's effectiveness and an environmental covenant to ensure future protectiveness. Remediation is followed by further evaluation with sampling and screening or modeling. When these options are successfully implemented, no further analysis is necessary. Site-specific standard VI evaluation procedures are described in Section K and Figure 5.

K. Evaluating the VI Pathway under the Site-Specific Standard

K.1 Overview

A site-specific standard VI evaluation may be required for one of two reasons:

- Substances of potential VI concern in soil and/or groundwater do not attain the Statewide health standard in those media;
- Soil and groundwater attain the Statewide health standard in themselves, but the site does not satisfy the Statewide health standard VI assessment process described previously in this guidance.

The site-specific VI evaluation process shares many elements with the Statewide health standard process, but the screening values are not the same, and a human health risk assessment is an option. The site-specific standard VI process is outlined in Figure 5. It is important to note that the purpose of Figure 5 is to illustrate how all of the steps in the VI evaluation process under the site-specific standard fit together. Figure 5 should not be used as your sole guide for performing a VI evaluation; rather, it should be used in conjunction with the text of this guidance. The principal steps of a VI evaluation under the site-specific standard are:

- Conceptual site model development and preferential pathway evaluation;
- Identify VI AOPCs using proximity distances;
- Identify Potential VI Sources from conditions that limit screening and/or exceedences of site-specific standard soil and groundwater screening values;
- Screen near-source soil gas, sub-slab soil gas, or indoor air data;
- Perform a cumulative human health risk assessment, which may include modeling;
- Mitigate buildings and ensure future protection with an environmental covenant;
- Remediate the soil and/or groundwater contamination and reassess the pathway;
- Address the Chapter 250 site-specific standard requirements.

In most cases all of the above steps will not be necessary, and the remediator is not required to follow the process sequentially. For instance, buildings with a potentially complete VI pathway may be mitigated without the collection of soil gas or indoor air data.

The Statewide health standard vapor intrusion screening values presented earlier in this guidance are based on either a carcinogenic target risk level of 10^{-5} and a non-carcinogenic hazard quotient of 1.0 or soil and groundwater MSCs. These screening values are not appropriate for use in risk assessments being performed under the site-specific standard because the Statewide health standard target risk levels and MSCs may not be sufficiently conservative to account for cumulative risks to receptors from multiple contaminants via multiple pathways.

K.2 Preferential Pathway Evaluation

The remediator must assess potential preferential pathways as part of the site-specific standard conceptual site model development (Section C). Preferential pathways may act as an extension of the source, which precludes the use of proximity distances for the soil or groundwater contaminant source area. Soil and groundwater screening values may not be used if preferential pathways are present, and they limit the use of other assessment options.

K.3 Use of Proximity Distances

The remediator may utilize proximity distances to identify VI AOPCs, as described in Section D. For non-petroleum substances the horizontal proximity distance is 100 feet, and for petroleum hydrocarbons it is 30 feet. When dissolved or adsorbed petroleum hydrocarbons are at least 6 feet deep and petroleum SPL are at least 15 feet deep, further VI evaluation is not required. These vertical separations must encompass acceptable soil or soil-like material with greater than 2% oxygen near the building slab (see Appendix Z).

K.4 Site-Specific Standard VI Screening

Screening of soil, groundwater, near-source soil gas, sub-slab soil gas, and indoor air data is available under the site-specific standard, as explained below. Samples are collected pursuant to the guidance in Table 6 and Appendix Z. Screening must be preceded by the evaluation of potential limiting conditions such as preferential pathways, SPL, or shallow sources (less than 5 feet below the foundation). The presence of these conditions, or the exceedence of the site-specific standard soil or groundwater screening values, defines Potential VI Sources.

If no limiting conditions exist, then soil and groundwater data may be screened using site-specific standard screening values. If limiting conditions are present, near-source soil gas, sub-slab soil gas, and indoor air may be screened with the following exceptions:

- Near-source soil gas screening cannot be performed when there is shallow contamination or a preferential pathway penetrates the building foundation.
- Sub-slab soil gas screening may not be performed when a preferential pathway penetrates the building foundation.

The Statewide health standard vapor intrusion screening values listed in Tables 1–5 may *not* be used for site-specific standard screening. The Statewide health standard criteria are based on a 10^{-5} target cancer risk and a 1.0 target hazard quotient (Appendix X). Attainment for the site-specific standard is demonstrated for cumulative risks for all substances, media, and pathways. VI screening with a combination of standards is discussed in Section B.2.

The Department permits the use of substance-by-substance site-specific standard VI screening values using either of the following methods:

- Select the appropriate values for soil, groundwater, near-source soil gas, sub-slab soil gas, or indoor air from Tables 1–5 and reduce them by a factor of 10.
- Use the current EPA residential or industrial indoor air Regional Screening Level (RSL) values (based on a target cancer risk of 10^{-6} and a target hazard quotient of 0.1) (U.S. EPA, 2015). RSLs based on a 10^{-5} cancer risk may be used for screening when it can be demonstrated that VI is the only complete exposure pathway for a receptor. RSLs may be used for screening indoor air data or for screening near-source or sub-slab soil gas data by using the following attenuation factors (refer to Appendix X):

Environmental Medium	**Attenuation Factor**		
	Residential	**Non-Residential**	**Converted Residential**
Sub-slab soil gas	0.026	0.0078	0.026
Near-source soil gas	0.005	0.001	0.005

The methodology for soil and groundwater screening is described in Section F.2, and the methods for near-source soil gas, sub-slab soil gas, and indoor air are provided in Section G.3. Screening may be applied to characterization and post-remediation data. A sufficient number of sample locations and rounds must be collected to satisfactorily evaluate the pathway. The Department recommends a minimum of two sample locations and two sampling rounds for screening.

For the site-specific standard the only acceptable screening criterion is no exceedences of the applicable screening values. Substances that screen out using either one-tenth of the Statewide health standard VI screening values or the EPA RSLs are not required to be included in a VI risk assessment.

K.5 Performing a VI Risk Assessment and Modeling

In a risk assessment, the VI pathway should be considered when developing the conceptual site model. The conceptual site model should use a qualitative fate and transport analysis to identify all current and future potential complete and incomplete exposure pathways, including source media, transport mechanisms, and all potential receptors (Section 250.404). The risks associated with all complete exposure pathways must be combined for individual receptors in order to evaluate the total cumulative risk to each receptor. For example, if ingestion of contaminated soil, dermal contact with contaminated groundwater, and inhalation of vapor-phase contamination via VI are all complete exposure pathways for the same receptor, the calculated risk values for each of these pathways must be combined to evaluate the total risk to the receptor.

Current toxicity values should be used in a site-specific standard risk assessment (Section 250.605). Therefore, if a toxicity value has been updated since the last revision of the Statewide health standard screening values, that substance must be included in a cumulative risk assessment. This provision is in keeping with the Department's discretion in allowing screening to substitute for a risk assessment.

VI modeling is one option for site-specific standard risk assessments. The Department's modeling guidance is provided in Appendix Y. For site-specific standard modeling, the user inputs soil, groundwater, or near-source soil gas concentrations into the Pennsylvania versions of EPA's Johnson & Ettinger models. The desired output is the incremental risks for each substance, *not* the predicted indoor air concentrations. The model risk results are then incorporated into the cumulative risk assessment.

The second option is to use indoor air, sub-slab soil gas, or near-source soil gas data for the risk assessment. Soil gas data must be converted to estimated indoor air concentrations using conservative attenuation factors provided in Section K.4. Inhalation risks are calculated using standard equations. (See Appendices X and Y.)

The VI risk assessment must be submitted in a risk assessment report meeting the procedural and substantive requirements of Act 2. For regulated storage tank sites the risk assessment is provided in the site characterization and remedial action completion reports. Human health risk assessment guidance is found in Section IV.G of the Technical Guidance Manual (TGM). Screening of chemicals of concern may follow the methodology described above.

K.6 Mitigation and Remediation

If a VI AOPC does not screen out using the site-specific standard criteria or the cumulative risks are excessive, then the remediator may choose to take an active approach to addressing VI. These options include mitigation and remediation.

Buildings may be mitigated to eliminate the VI pathway (Section H). Mitigation measures are considered to be engineering controls because they prevent the migration of vapor. The standard mitigation approach is an active sub-slab depressurization system (U.S. EPA, 2008). Performance and testing requirements are provided in Appendix Z. Mitigation systems installed on current buildings or planned for future construction must be implemented with an environmental covenant placed on the property deed.

Remediation of soil and/or groundwater is also an alternative to address the VI pathway (Section I). Post-remediation data must be collected and evaluated through screening or a risk assessment. If remedial action is not completed promptly, then the remediator may be responsible for employing interim measures to protect human health.

K.7 Addressing Chapter 250 Requirements

The final step in the process flowchart on Figure 5 (p. 36) is to address the requirements of Chapter 250 with respect to VI. This step is necessary to demonstrate compliance with the site-specific standard in order to receive liability protection under Act 2 of 1995. The submitted report should include a description of the conceptual site model for VI. The flowchart endpoint can be reached in four ways and compliance documented, as follows:

- **Use of Proximity Distances.** If no VI AOPCs are found to be present based on screening of soil and groundwater data within applicable proximity distances, then no further analysis is necessary. Documenting this conclusion will only require the production of maps and cross sections that show the spatial relationship between soil and groundwater contamination, any preferential pathways, and existing or potential future inhabited structures. Applicable proximity distances need to be shown on these exhibits. This information should be submitted in the remedial investigation and final reports or the site characterization and remedial action completion reports, as appropriate.
- **Screening Values.** If screening values are used to assess the VI pathway, the remediator must demonstrate that there are no limitations to their use (e.g., SPL or a shallow source). If the site data satisfy the screening criteria, then no further analysis is necessary. Documenting this conclusion requires the same maps and cross sections described above to identify VI AOPCs, together with tabulation of data used in the screening process to conclude that no soil, groundwater, soil gas, or indoor air screening values are exceeded within any VI AOPC. This information should be submitted in the remedial investigation and final reports or the site characterization and remedial action completion reports, as appropriate.
- **Risk Assessment.** If VI screening values are not applicable or they are exceeded, then a human health risk assessment may be performed. If the site-specific risk thresholds (cumulative 10^{-4} cancer risk and hazard index of 1.0) are satisfied, no further analysis is required. Documentation is supplied in a risk assessment report. The risk evaluation may include modeling.
- **Mitigation or Remediation.** If the vapor intrusion pathway is complete as determined from screening or a risk assessment, the source must be remediated or the pathway eliminated by mitigation. Remediation is followed by further evaluation with sampling, screening, modeling, and/or a risk assessment. Mitigation requires testing to confirm the system's effectiveness and an environmental covenant to ensure future protectiveness. When these options are successfully implemented, no further analysis is necessary. Documentation of this conclusion is provided in a risk assessment report, a final report, or a remedial action completion report, as appropriate.

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Figure 4. Statewide Health Standard Vapor Intrusion Assessment Process

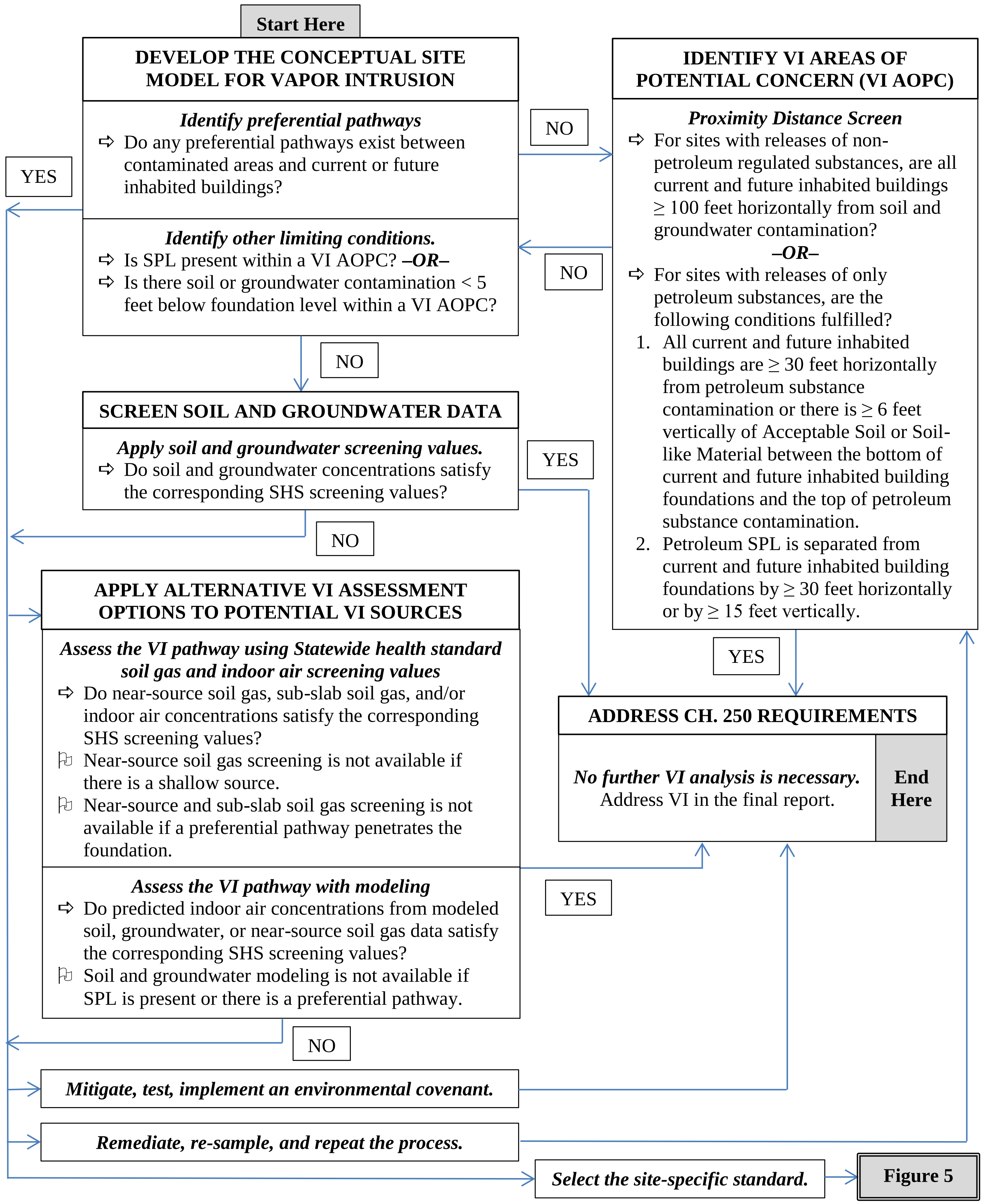

Figure 5. Site-Specific Standard Vapor Intrusion Assessment Process