DRAFT – FOR DISCUSSION PURPOSES ONLY

DRAFT 06-18-14

Land Recycling Program Technical Guidance Manual
Statewide Health Standards
Proposed Vapor Intrusion Guidance Discussion Document

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Explanation for general framework:

The focus of this draft document is to create a workable procedure for addressing vapor intrusion (VI) issues under the Statewide health standard (SHS). The General Assembly intended the SHS to be a streamlined procedure to facilitate the remediation process. If the VI requirements under the SHS become overly complicated the SHS will become dysfunctional. This SHS VI guidance uses screening values along with several other options which allows for a robust evaluation while keeping the process quick and not overly complicated.

EPA, NJ and some other states have expressed concerns regarding the use of soil screening values based on fate and transport modeling from volatile organic analysis of soil data. The main reason for this is that modeling using soil data has a high degree of uncertainty. The Department considered eliminating soil VI screening values for similar reasons but after careful consideration it was determined that soil screening values have a place in this guidance. Soil screening values are necessary in order to maintain the streamlined nature of the SHS and to avoid requiring remediators to perform site-specific investigations under the SHS solely to evaluate VI. The soil VI screening values have been determined by comparing calculated soil VI screening values to the *generic* soil-to-groundwater numeric values and the higher of the two becomes the soil VI screening value. The logic behind considering both the calculated values and the generic soil-to-groundwater numeric values is twofold:

- 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.
- The calculated soil screening values are based on a variation of the equilibrium partitioning equation currently used to calculate the *generic* soil-to-groundwater numeric values. The Department has enough confidence in that equation to use it to calculate the soil-to-groundwater values so it is therefore sufficient to use a variation of this equation to calculate soil VI screening values.

These policy decisions are expected to result in an acceptable level of protection of human health. Additional information regarding the methodology used to calculate all of the VI screening values is presented in Appendix X of this guidance.

Inhabited buildings located beyond the groundwater point of compliance, where SHS used aquifer standards are attained, do not need to address potential VI impacts from the groundwater under inhabited buildings since this groundwater is acceptable for use inside the inhabited buildings. This policy decision is also expected to result in an acceptable level of protection of human health.

Shallow soil gas sampling in open areas poses technical concerns regarding data quality, reproducibility, and validity. These technical limitations associated with accurately measuring soil gas concentrations in open areas force the SHS VI guidance to limit soil gas sampling to sub-slab soil gas sampling under

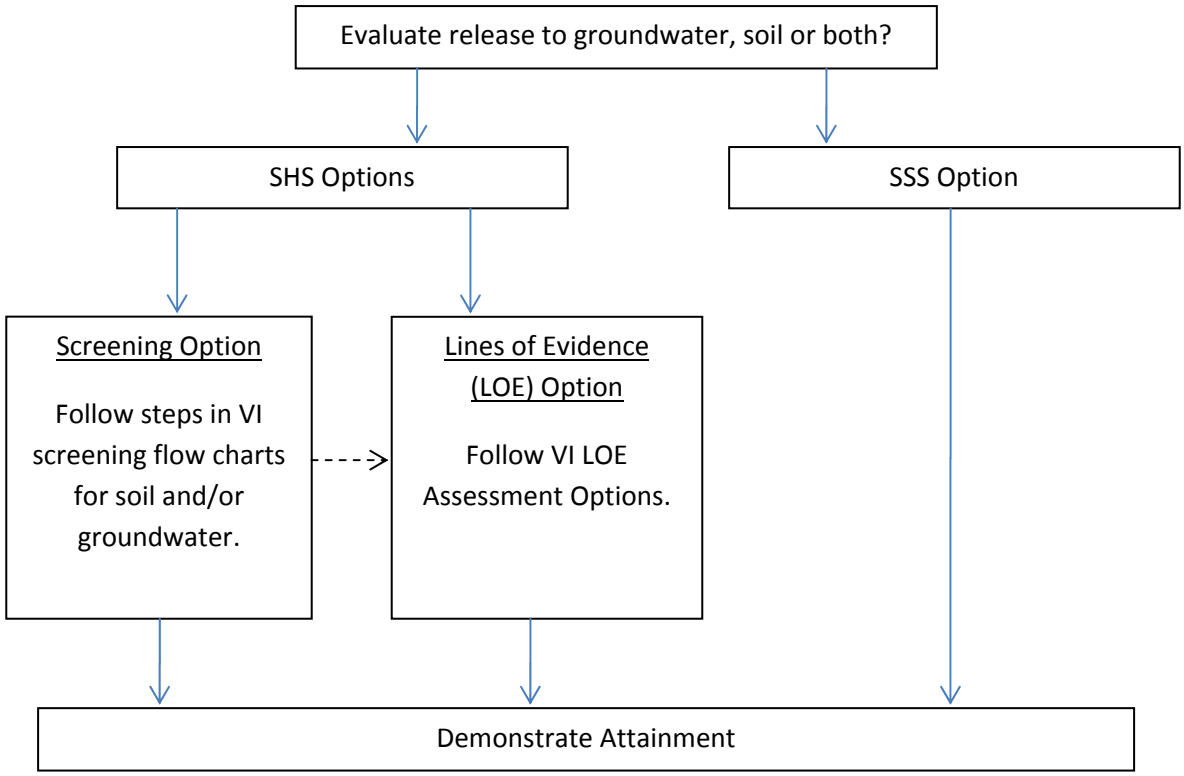
inhabited buildings and near-source soil gas sampling immediately above a groundwater or vadose zone soil source.

NOTES on Land Recycling Program Technical Guidance Manual (TGM):

As part of the overall project currently underway to revise the TGM, the existing SHS VI language included in the TGM under the Fate and Transport Analysis section (Section IV.A) will be deleted. The proposed SHS VI language (below) will be inserted under the SHS section (Section II.B) to emphasize that the SHS vapor screening process is only applicable under the SHS standard. This SHS VI language would be inserted as the new Section II.B.6. VI language relating to the site-specific standard will be added to the Site-Specific Standard section (Section II.C). VI guidance relating to the development of the screening values, VI modeling, and guidance on sampling and analysis will be added in separate appendices to the TGM.

A figure similar to the one below illustrating the different VI evaluation process options based on the standard selected will be provided in the TGM in a section yet to be determined.

VI Evaluation Process Options:



NOTES on Tables:

The following six tables are used in the VI guidance:

1. Groundwater SHS Vapor Intrusion Screening Values (SV_{GW})
2. Soil SHS Vapor Intrusion Screening Values (SV_{SOIL})
3. Sub-Slab Soil Gas SHS Screening Values (SV_{SS})
4. Indoor Air SHS Screening Values (SV_{IA})
5. Near-Source Soil Gas SHS Screening Values (SS_{NS})
6. Application of Statewide Health Standard Vapor Intrusion Screening

The following figures are used in the VI guidance:

1. Vapor Intrusion Evaluation Process
2. Vapor Intrusion Screening Process – Groundwater
3. Vapor Intrusion Screening Process – Soil
4. Vapor Intrusion Screening Value Points of Application

The following appendices are used in the VI guidance:

Appendix X – Methodology for Vapor Intrusion Screening Criteria
Appendix Y – Modeling Guidance
Appendix Z – Sampling Guidance

The numbering of the tables, figures and appendices is temporary. Final TGM table, figure and appendices numbers will be designated when this section is inserted into the TGM.

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PROPOSED SHS VAPOR INTRUSION SECTION TO BE ADDED TO TGM
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Land Recycling Program Technical Guidance Manual
Section II. Remediation Standards
B. Statewide Health Standards
6. Vapor Intrusion

Releases of volatile and some semi-volatile regulated substances to soil or groundwater can result in intrusion of the regulated substances into indoor air. The resulting impacts to indoor air may pose a threat to human health in inhabited buildings. Inhabited buildings are buildings with enclosed air space that are designed for human occupancy.

There are two conditions that must be met for the vapor intrusion pathway (VI) to be of potential concern. First, inhabited buildings must be close to a volatile/semivolatile source and, second, the source concentration must be above a threshold or screening concentration. The distance at which concentrations are negligible is a function of the mobility, toxicity and persistence of the chemical, as well as the geometry of the source, subsurface materials, and characteristics of the building of concern.

Many areas of Pennsylvania have high levels of naturally occurring radon gas, which can pose a significant public health threat. This guidance is intended to facilitate the installation of VI mitigation systems that will not only address potential VI concerns associated with the release of regulated substances at remediation sites but will also provide additional public health benefits associated with reducing the significant threat caused by naturally occurring radon gas.

This section provides guidance for addressing potential VI of volatile and certain semivolatile organic substances into inhabited buildings using the SHS. Use of risk calculations to evaluate VI is considered to be a risk assessment which is a tool to be used under the SSS 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. The potential VI impacts from volatile inorganic substances (e.g., mercury and cyanide), must be addressed under the site-specific standard.

Compliance with this guidance will address VI impacts under the SHS for existing and future inhabited buildings located in or near the source areas as required by Act 2 Section 303(c). 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 future inhabited buildings could be constructed.

Overview of the SHS VI Evaluation Process

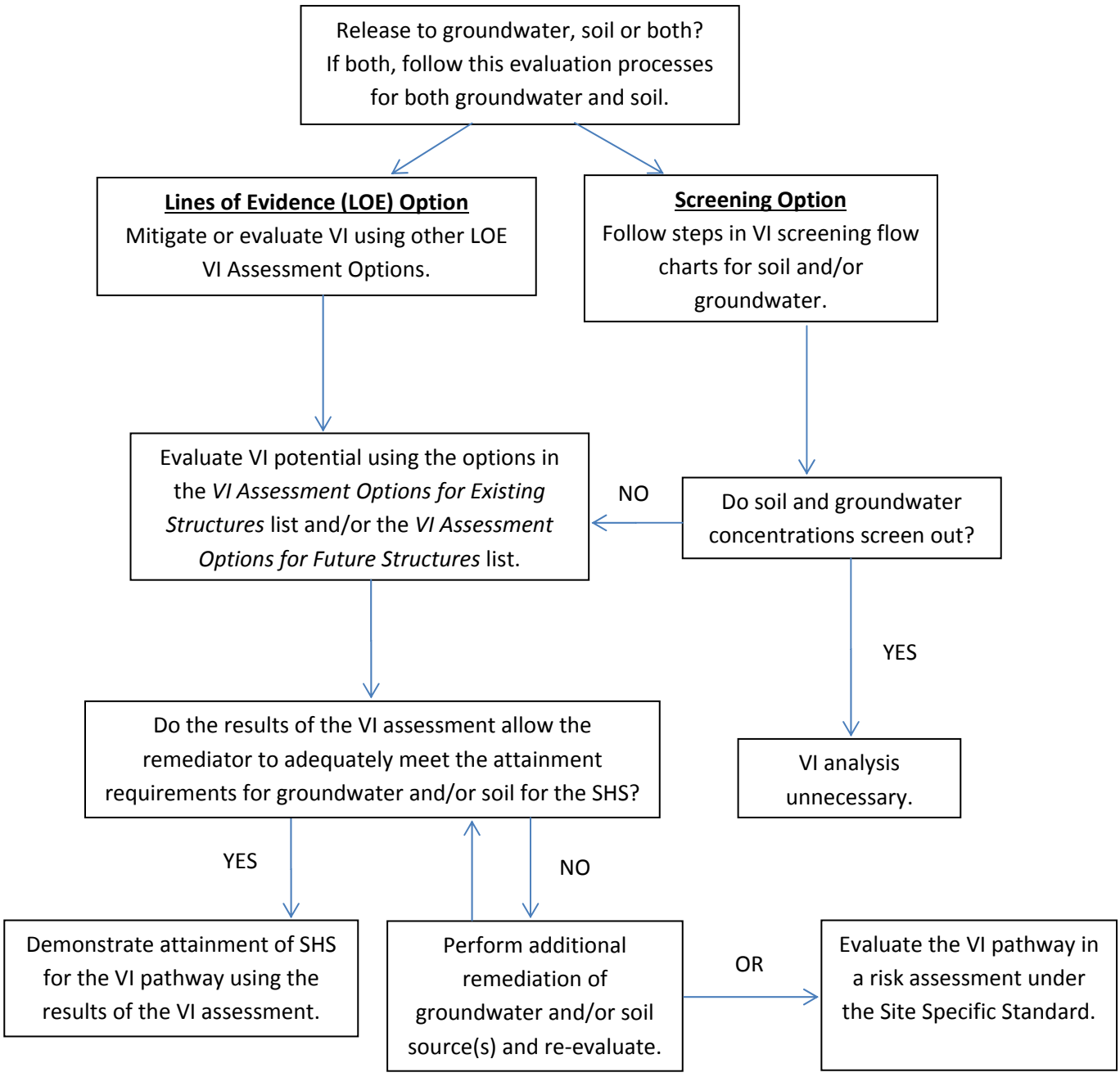
Remediators can choose to screen soil and/or groundwater data or they may instead choose to use a Line of Evidence (LOE) assessment approach to evaluate potential VI at a site. If soil and groundwater concentrations are below the screening values then additional VI analysis is unnecessary. If soil data screen out but groundwater data do not (or vice versa), the concentrations that screen out are considered to contribute a negligible risk for the VI pathway. Data that do not pass screening during the screening

process indicates a potential VI impact and needs to be evaluated further using the VI assessment options provided in Sections X.X (existing buildings) and X.Y (future buildings). The purpose of the VI Assessment Options is to gather enough information to adequately meet the attainment requirements for the VI pathway for groundwater and/or soil under the SHS. If attainment of the SHS cannot be demonstrated using results obtained from the VI assessment options, then the pathway will need to be addressed. This can be achieved by remediation, further evaluation using the SSS option or by pathway elimination using mitigation.

The Department allows the screening of groundwater, soil, sub-slab soil gas, near-source soil gas, and indoor air as described in the following sections. Tables 1–5 include residential and nonresidential screening values. In addition, for groundwater, soil, sub-slab, and near-source soil gas screening there are distinct "converted residential" values. This 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 exposure factors for nonresidential settings. Residential screening values must be used if a building has both residential and nonresidential uses (e.g., apartments over a retail store). See Table 6 for a summary of how to apply each of the VI screening values.

The VI evaluation process is illustrated in Figure 1 below:

FIGURE 1
STATEWIDE HEALTH STANDARD
VAPOR INTRUSION EVALUATION PROCESS



Screening Option

Groundwater VI Screening Process

To address VI for groundwater sources, remediators may choose to screen using the process described in this section or opt for going directly to the VI assessment options under SHS or a site-specific evaluation under SSS. Under the screening process, remediators have several options for addressing VI from releases that have impacted groundwater. First, the site must be evaluated for preferential pathways, groundwater contamination within five feet of the building foundation or separate phase liquids (i.e. non-aqueous phase liquids or NAPL). If any of these three conditions are present, the remediator can use either the non-petroleum proximity distance (100 feet), the VI assessment options or the SSS to further evaluate VI (see Figure 2). Proximity distances and the VI assessment options are explained in detail later in this guidance.

Preferential pathways can be natural or man-made features that acts as a conduit by facilitating vapor migration from a source, through soil or soil-like material to a receptor. Preferential pathways make the use of the default model for predicting indoor air concentrations unacceptable. If such a feature does not pass through the source, it must occur within 30 feet of the source in order to constitute a potential preferential pathway. Fill material (i.e. non-native soil) is considered a preferential pathway. A separate phase liquid is that component of contaminated environmental media comprised of interstitial non-aqueous phase liquid (NAPL) which is not adsorbed onto or diffused into the soil matrix or dissolved in groundwater.

If none of the above conditions are present, the remediator may screen groundwater data against the groundwater VI screening values provided in Table 1. The points of application for the groundwater VI screening values are illustrated in Figure 4. Groundwater data must not exceed the screening values throughout the portion of a plume at the water table that exceeds the screening value(s) and is within an applicable separation distance from an existing and/or future inhabited building, not just at the point of compliance. The groundwater VI screening values are the higher of the groundwater MSCs (Chapter 250, Appendix A, Table 1) and the calculated groundwater screening values. Groundwater MSCs are 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.). For additional information on how the screening values were calculated see the Methodology for Vapor Intrusion Screening Criteria presented in Appendix X.

If groundwater concentrations are below groundwater VI screening values throughout the plume then additional VI analysis is unnecessary. If groundwater concentrations exceed the groundwater VI screening values, the remediator should then evaluate the proximity of the foundation of the future or existing structure to the groundwater plume for either petroleum or non-petroleum products.

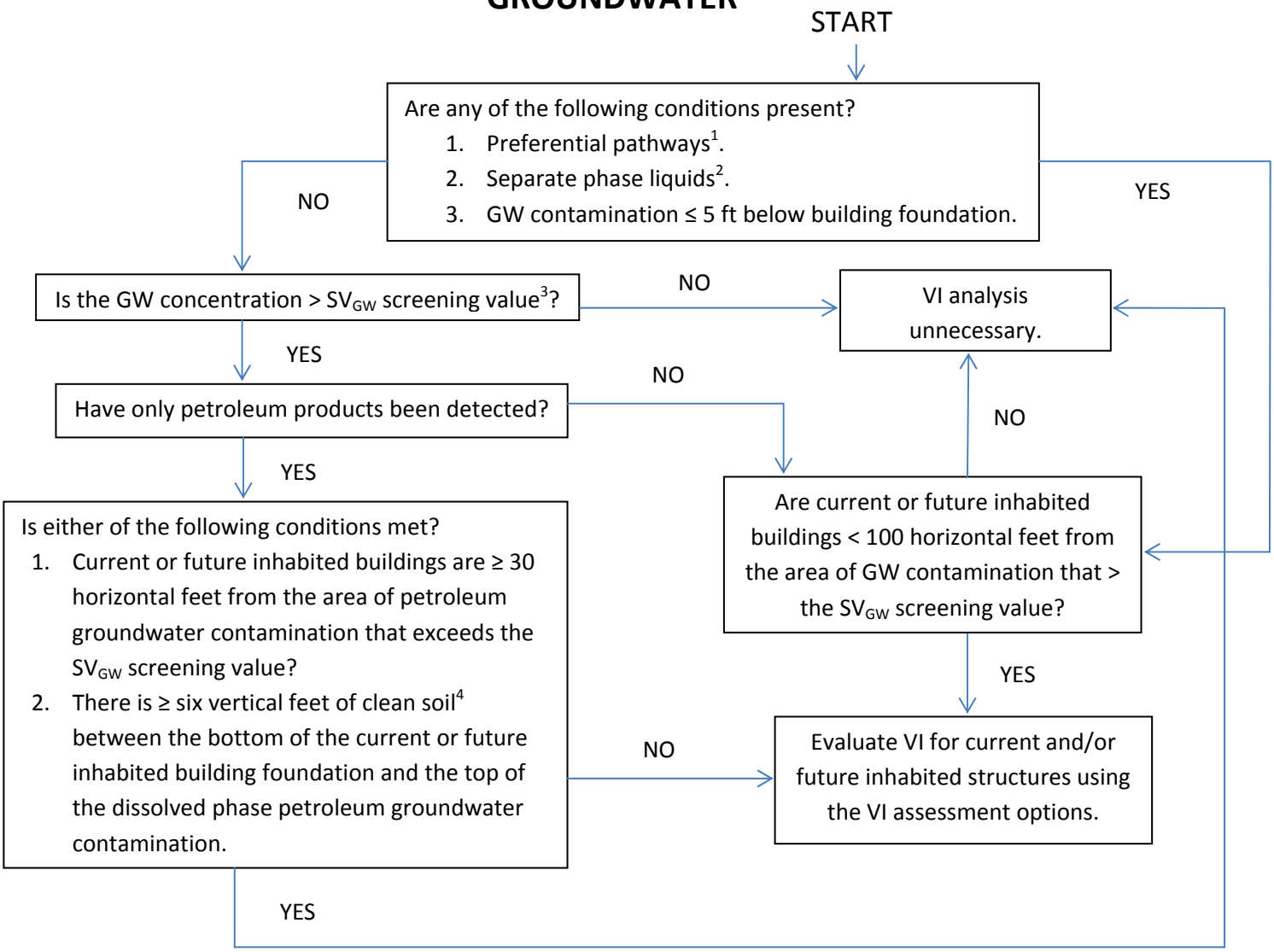
Petroleum products (products listed on the petroleum short list) are treated differently than non-petroleum compounds because biodegradation rate can play a key role in diminishing the effects of VI. Non-petroleum compounds, such as chlorinated compounds, usually biodegrade under anaerobic conditions while petroleum products biodegrade under aerobic conditions. Since soil oxygen content is generally higher in surface soils than in sub-surface soils, vapors from petroleum hydrocarbons biodegrade as they migrate upward through the soil column reducing their concentrations prior to migrating into inhabited buildings.

If only petroleum products have been detected the remediator determines the horizontal and vertical distance of the building foundation to the plume. If the current or future inhabited structure is greater than or equal to 30 horizontal feet from the area of petroleum contamination that exceeds the groundwater VI screening values 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 *clean soil* between the bottom of the current and/or future inhabited building foundation(s) and the top of the dissolve phase petroleum groundwater contamination then there is adequate distance for biodegradation to occur to reduce the vapor concentration to acceptable levels. If either of these proximity conditions is not met the remediator must evaluate VI using either the VI assessment options or the SSS. The Department defines *clean soil* as soil with greater than 2% oxygen in soil gas near the building slab and either cumulative petroleum short list detections less than 100 mg/kg or a measured total petroleum hydrocarbons (TPH) concentration less than 100 mg/kg using method 418.1. Additional VI analysis is not necessary for sites with petroleum SPL greater than or equal to 15 vertical feet between the SPL and the current or future building foundation.

If contaminants other than petroleum products are present in groundwater, the remediator must determine if current or future inhabited buildings are greater than or equal to 100 horizontal feet from the area of groundwater contamination that exceeds the groundwater VI screening values. If this distance is less than 100 feet then the remediator must evaluate VI using the VI assessment options within that portion of a plume at the water table that exceeds the screening value(s) and is within this separation distance from an existing and/or future inhabited building. If this distance is greater than 100 feet then additional VI analysis is unnecessary. There is no minimum vertical separation distance for non-petroleum contaminants.

The VI screening process for groundwater is illustrated in Figure 2 below.

FIGURE 2
STATEWIDE HEALTH STANDARD
VAPOR INTRUSION SCREENING PROCESS
GROUNDWATER



Note: At any point the remediator may bypass the screening process and proceed directly to the VI Assessment Option process.

[1] A preferential pathway is a natural or man-made feature that acts as a conduit by facilitating vapor migration from a source, through soil or soil-like material to a receptor. Preferential pathways make the use of the default model for predicting indoor air concentrations unacceptable. If such a feature does not pass through the source, it must occur within 30 feet of the source in order to constitute a potential preferential pathway.

[2] A separate phase liquid is that component of contaminated environmental media comprised of interstitial non-aqueous phase liquid (NAPL) which is not adsorbed onto or diffused into the soil matrix or dissolved in groundwater. VI analysis is unnecessary for sites with petroleum separate phase liquids having ≥ 15 feet vertical separation between the bottom of the slab/basement and the top of the separate phase liquid.

[3] Information on the derivation of the SV_{GW} screening values is provided in Appendix X.

[4] For petroleum-only sites, clean soil is defined as soil with cumulative petroleum short list detections less than 100 mg/kg or TPH less than 100 mg/kg.

Soil VI Screening Process

At petroleum sites where soil attainment requirements are being met using statistical tests, there may be circumstances where VI analyses are not necessary. If the site is a petroleum release to surface or subsurface soil where full site characterization has not been done in association with an excavation, then the remediator may follow the sampling and statistical test requirements for excavations described in Section 250.707(b)(1)(iii). The Department will not require further VI analysis if both of the following conditions are satisfied: (1) soil is sampled in a biased fashion on the excavation sidewall nearest an inhabited building; (2) contamination has not contacted or penetrated the building foundation based on visual and olfactory observations and the use of field instruments.

If the site is not an excavation being performed in accordance with Chapter 250.707(b)(1)(iii), it must be determined if preferential pathways, SPL or soil contamination within five feet of the building foundation exists. If any of these three conditions are present, the remediator can use either the non-petroleum proximity distance (100 feet), the VI assessment options or the SSS to further evaluate VI (see Figure 3). For the purposes of this guidance, soil is defined as unconsolidated, porous media created at land surface by weathering pressures derived from geologic, biologic, and/or hydrologic processes.

If none of the above conditions are present, the remediator may screen soil data against the soil VI screening values provided in Table 2. The points of application for the soil VI screening values are illustrated in Figure 4. The soil VI screening values are the higher of the generic soil-to-groundwater numeric values (Chapter 250, Appendix A, Table 3B) and the calculated soil screening values. The Department's position is that the generic soil-to-groundwater numeric values are 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. For additional information on how the soil VI screening values were calculated see the Methodology for Vapor Intrusion Screening Criteria presented in Appendix X.

If soil concentrations are below the soil VI screening values then additional VI analysis is unnecessary. If soil concentrations exceed the soil VI screening values then the remediator evaluates the proximity of the foundation of the future or existing structure to the soil contamination for either petroleum or non-petroleum products.

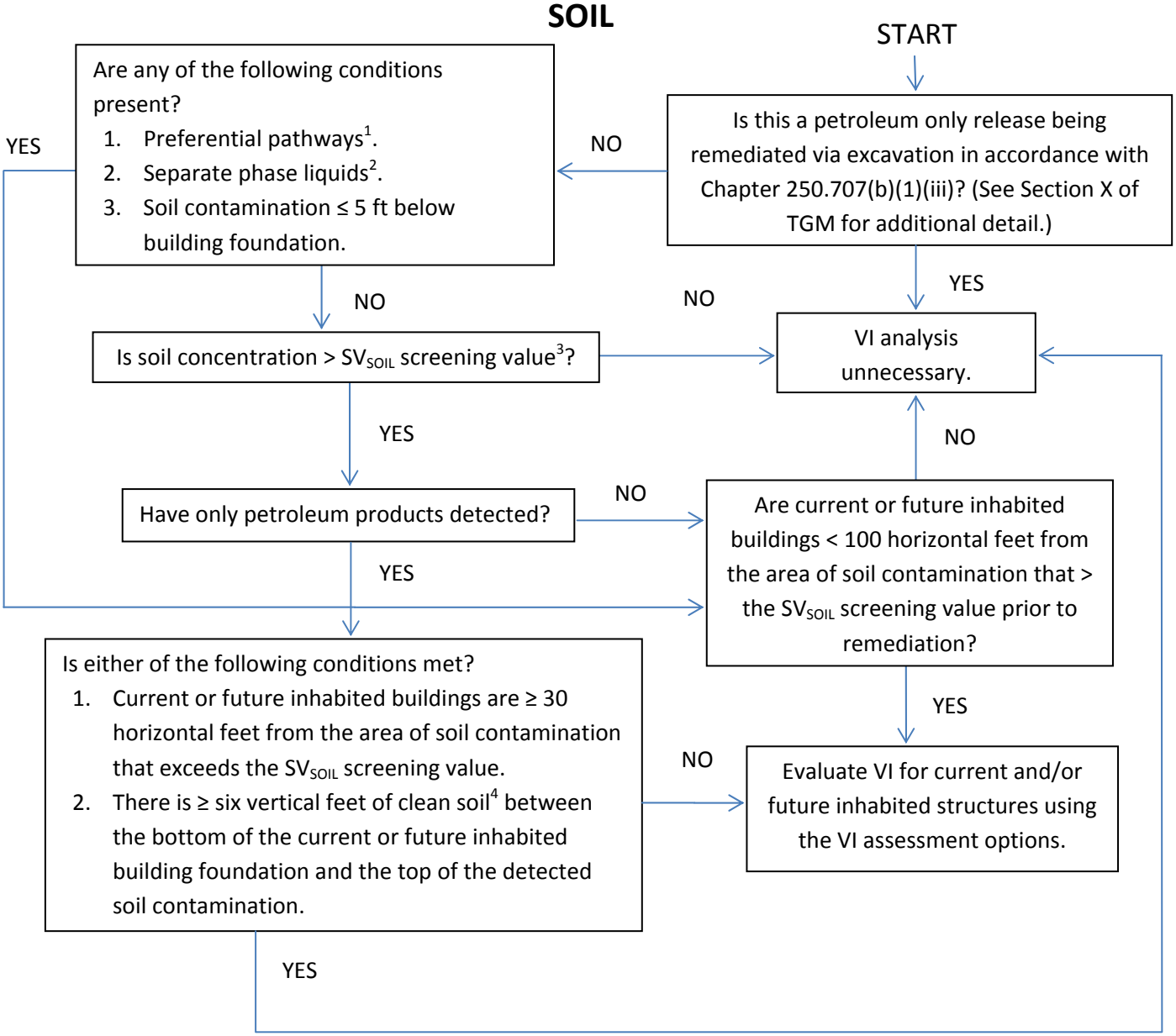
If only petroleum products have been detected the remediator determines the horizontal and vertical distance of the foundation of the structure to the plume. If the current or future inhabited structure is greater than or equal to 30 horizontal feet from the area of petroleum contamination that exceeds soil VI screening value then there is adequate distance for biodegradation to occur to reduce the vapor concentrations to acceptable levels. Likewise, if there is greater than or equal to six feet of clean soil between the bottom of the current or future building foundation and the top of the dissolved phase petroleum groundwater contamination then there is adequate distance for biodegradation to occur to reduce the vapor concentration to an acceptable risk level. If neither of these proximity conditions is met then the remediator must evaluate VI using the VI assessment options for existing and/or future buildings. Additional VI analysis is not necessary for sites with petroleum SPL greater than or equal to 15 vertical feet between the SPL and the current or future building foundation.

If contaminants other than petroleum products are present in soil then the remediator must determine if current or future inhabited buildings are greater than or equal to 100 horizontal feet from the area of soil contamination that exceeds the soil VI screening values. If this distance is less than 100 feet then the remediator must evaluate VI using the VI assessment options. If this distance is greater than 100 feet then

additional VI analysis is unnecessary. There is no minimum vertical separation distance for non-petroleum contaminants.

The VI screening process for soil is illustrated in Figure 2 below.

FIGURE 3
STATEWIDE HEALTH STANDARD
VAPOR INTRUSION SCREENING PROCESS
SOIL



Note: At any point the remediator can bypass the screening process and proceed directly to the VI Assessment Option process.

[1] A preferential pathway is a natural or man-made feature that acts as a conduit by facilitating vapor migration from a source, through soil or soil-like material to a receptor. Preferential pathways make the use of the default model for predicting indoor air concentrations unacceptable. If such a feature does not pass through the source, it must occur within 30 feet of the source in order to constitute a potential preferential pathway.

[2] A separate phase liquid is that component of contaminated environmental media comprised of interstitial non-aqueous phase liquid (NAPL) which is not adsorbed onto or diffused into the soil matrix or dissolved in groundwater. VI analysis is unnecessary for sites with petroleum separate phase liquids having ≥ 15 feet vertical separation between the bottom of the slab/basement and the top of the separate phase liquid.

[3] Information on the derivation of the SV_{SOIL} screening values is provided in Appendix X.

[4] When applying the six-foot vertical separation distance at petroleum-only sites, clean soil is defined as soil with cumulative petroleum short list detections less than 100 mg/kg or TPH concentrations less than 100 mg/kg.

When OSHA Permissible Exposure Levels (PELs) Can Be Applied as Screening Values

Chemical VI from soil or groundwater into commercial or industrial facilities that use that same chemical(s) in their industrial processes can be difficult to evaluate. The Department does not regulate indoor air so commercial worker exposure to chemical vapors associated with an onsite industrial process is regulated by 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. OSHA PELs can be used as screening values if the remediator can demonstrate that the chemicals they are screening for are currently being used in a regulated industrial process inside the inhabited structure(s) and that OSHA regulations are fully implemented and documented in all areas of the structure(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 to minimize exposure. MSDS sheets must be posted and a hazard communications plan must be in place. If OSHA implementation cannot be documented then the PEL values cannot be used. Facilities that use PELs to evaluate VI must use 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 do not fully implemented the OSHA program for that same chemical(s) then the PELs are no longer applicable and this may constitute as a reopener.

Lines of Evidence (LOE) Option

Vapor Intrusion Assessment Options for Existing Buildings

If the remediator proceeds through the soil and/or groundwater VI screening process and additional assessment is necessary or if the remediator chooses to bypass the screening process, the next step is to evaluate VI using the VI assessment options. This section discusses the various lines of evidence available as VI assessment options for sites with existing buildings. Remediators may also bypass the VI assessment options at any time and proceed directly to evaluating the VI pathway under the SSS.

There are several VI assessments options the remediator may choose. Single lines of evidence options provide adequate information or protection to be used individually as a means of fully assessing VI. The multiple lines of evidence options provide adequate information or protection for the VI pathway if used in conjunction with one another.

The following options are available to remediators as single lines of evidence for addressing the VI pathway for existing inhabited buildings. These options used individually achieve the highest level of confidence for the protection of human health.

1. **Mitigation with an environmental covenant**

2. **Near-source soil gas concentrations < sub-slab soil gas screening values (SV_{SS})**

3. **Sub-slab soil gas concentrations < sub-slab soil gas screening values (SV_{SS})**

4. **Indoor air concentrations < indoor air screening values (SV_{IA})**

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. However, mitigation systems may not be feasible in all cases. The feasibility of using a mitigation system to address VI impacts 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).

For residential buildings used as single family homes, standard radon-type mitigation systems may be installed by anyone certified by the Department to install radon systems. 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. 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 testing 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 must be notified in the event of a property transfer, if there is a problem with the system or upon request by the Department.

Sub-slab soil gas and indoor air data represent breathing air conditions that are as close to the receptor as possible and provide the most accurate representation of inhaled air concentrations. 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.

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. Vapor concentrations measured in near-source soil gas is theoretically the highest possible concentrations because they are directly adjacent to the source. Comparing near-source soil gas concentrations to sub-slab screening values is overly conservative (EPA citation) so near-source soil gas screening values were developed.

Sub-slab screening values are provided in Table 3, indoor air screening values are provided in Table 4 and near-source screening values are provided in Table 5. For additional information on how the sub-slab, near-source, and indoor air screening values were calculated see the Methodology for Vapor Intrusion Screening Criteria presented in Appendix X. The points of application for the sub-slab, near source and indoor air screening values are illustrated in Figure 4. Sub-slab, near-source and/or indoor air sampling may be performed prior to mitigation to determine if mitigation is necessary. At any point in the VI assessment process, the remediator may bypass the VI assessment options and proceed directly to evaluating the VI pathway under the SSS. Guidance on sub-slab, near-source and indoor air sampling is provided in Appendix Z.

The single lines of evidence options may not always be the best approach for your site. For example, proceeding directly to mitigation may be the most cost-effective solution for site closure for smaller buildings or new construction but for larger existing facilities, mitigation may be cost-prohibitive. In

these situations, a multiple lines of evidence approach may be the best solution. The multiple lines of evidence options are meant to be used in conjunction with one another in order to provide adequate information to fully evaluate the VI pathway. Some degree of professional judgment is necessary when evaluating multiple lines of evidence. The conceptual site model (CSM) developed in the site characterization should be used to determine which lines of evidence will provide the most useful information for the specific conditions at each site.

The following options are available to remediators as multiple lines of evidence for addressing the VI pathway for existing buildings. These options can only be used with at least two other lines of evidence (minimum of three) to evaluate VI. These options used in conjunction with one another achieve the highest level of confidence for the protection of human health.

1. **Near-source soil gas concentrations < near-source soil gas screening values (SV_{NS})**

2. **Evaluation of soil type and permeability with respect to vapor intrusion**

3. **Evaluation of depth to source with respect to vapor intrusion**

4. **Vapor intrusion modeling using acceptable input parameters**

Near-source soil gas concentrations that exceed the near-source soil gas screening values do not necessarily mean that the remediator cannot adequately meet the SHS attainment requirements for VI. This is information that needs to be used in conjunction with other lines of evidence to form a conclusion about the potential for VI. As previously stated, some degree of professional judgment is required when using multiple lines of evidence.

An evaluation of soil type, permeability and depth to the source should have been performed during site characterization. Reevaluating this information with respect to VI will provide insight into how these site-specific characteristics will impact vapor movement through the soil column and potentially into current or future buildings. Sandy soils and soils with high permeability will allow for higher vapor transport rates which may have an impact on soil vapor concentrations at the building foundation. Likewise, geologic features that prohibit soil vapor movement (e.g. clay lens) may result in lower concentrations at the building foundation. These evaluations will be highly site-specific and some degree of professional judgment will be necessary. Site-derived data should be used with this option to provide the most accurate VI analysis.

VI modeling can be used to predict indoor air concentrations in current buildings. Modeling of any kind has an inherent amount of uncertainty involved which is why this is an option to be used only in the multiple lines of evidence approach. 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 products 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. A list of input parameters that can be adjusted based on site-specific 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 SHS 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 SHS, the desired output is a predicted indoor air concentration. This modeled concentration should be used in the evaluation of VI by comparing to the associated indoor air screening value. Screening modeled indoor air concentrations cannot be used as a single line of evidence due to the elevated level of uncertainty with modeled data. The J&E model can be used to calculate risk values which should not be used for SHS evaluations. Use of risk calculations to evaluate VI is considered to be a risk assessment which is a tool to be used under the SSS 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.

Vapor Intrusion Assessment Options for Future Buildings

The overall concept of single lines of evidence and multiple lines of evidence used in the VI assessment options for existing buildings also applies to future buildings. However, some of the options are different. As always, remediators may bypass the VI assessment options at any time and proceed directly to evaluating the VI pathway under the SSS.

The following options are available to remediators as single lines of evidence for addressing the VI pathway for future buildings. These options used individually achieve the highest level of confidence for the protection of human health.

1. **Environmental covenant requiring mitigation or VI evaluation for future buildings**

2. **Near-source soil gas concentrations < sub-slab screening values (SV_{SS})**

For undeveloped sites or undeveloped portions of properties with existing inhabited buildings, VI mitigation cannot be performed until a structure is built. In order to ensure that future owners and occupants are protected from VI, a description of the VI mitigation measures proposed for future buildings must be provided in an environmental covenant.

As stated previously, near-source soil gas is measured directly above the soil source in the vadose zone or directly above the capillary zone for a groundwater source. Near-source soil gas concentrations are the highest possible concentrations in soil vapor. EPA determined that comparing near-source soil gas concentrations to sub-slab screening values is overly conservative so if near-source soil gas concentrations are lower than sub-slab screening values there is a high level of confidence that additional VI analysis is unnecessary.

The following options are available to remediators as multiple lines of evidence for addressing the VI pathway for future buildings. Any combination of at least three of these options is required when using the multiple lines of evidence approach. These options used in conjunction with one another achieve the highest level of confidence for the protection of human health.

1. **Near-source soil gas sampling < near-source soil gas screening values (SV_{NS})**

2. **Evaluation of soil type and permeability with respect to vapor intrusion**

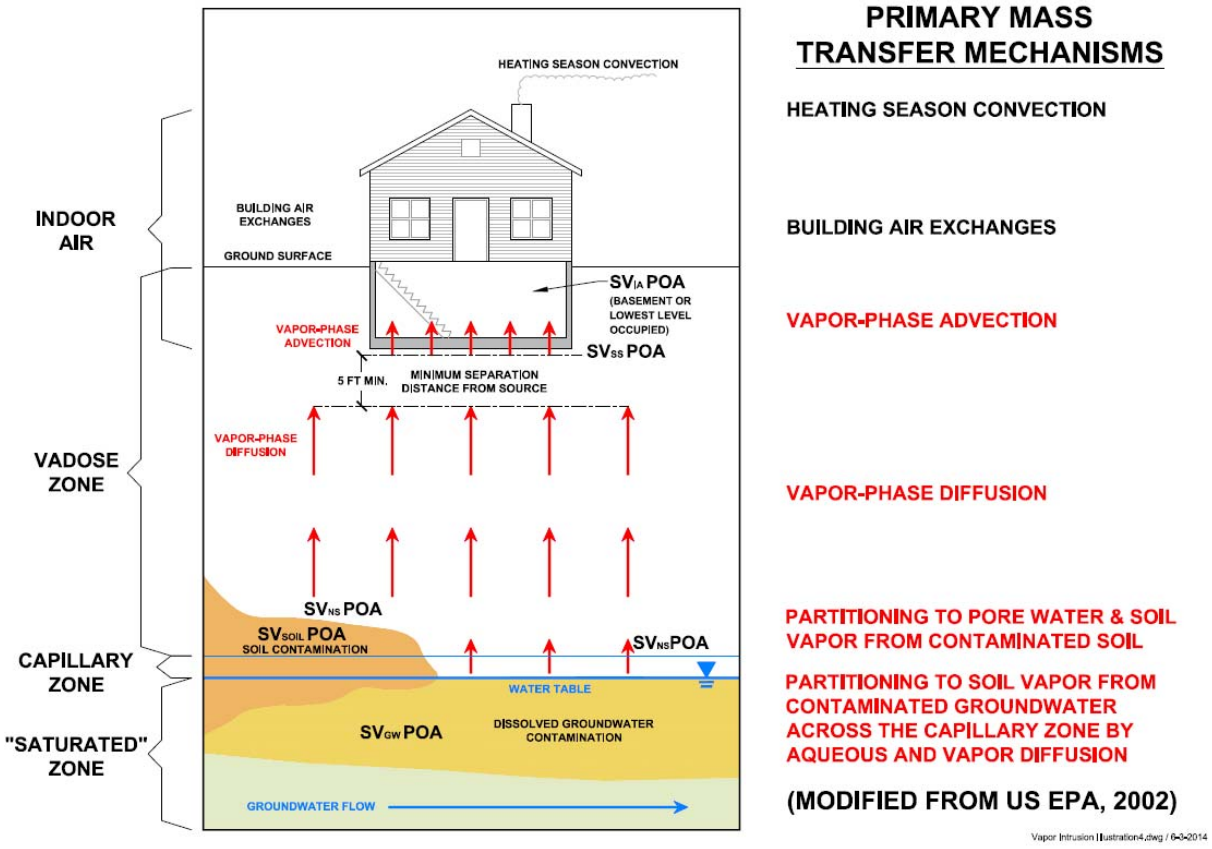
3. **Evaluation of depth to source with respect to vapor intrusion**

4. **Vapor intrusion modeling using existing building plans or the most conservative default input parameters if building plans are not available**

These multiple lines of evidence options should be used in the same way as described for sites with existing buildings. The only difference is regarding VI modeling. Since undeveloped sites and undeveloped portions of developed sites do not have buildings, many of the modeling input parameters will have to be estimated. This can be done using either the most conservative default input parameters available. If building plans for future buildings are available, the remediator can use site-specific information from the plans for allowable parameter adjustments. A list of input parameters that can be adjusted based on site-specific conditions is provided in the Modeling Guidance presented in Appendix Y.

For a summary of how to apply each of the VI screening values, see Table 6. See Figure 4 for an illustration of the points of application of each of the screening values.

FIGURE 4
STATEWIDE HEALTH STANDARD
VAPOR INTRUSION 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

Access to Inhabited Buildings on Neighboring Properties

If the remediator needs access to an inhabited building on a neighboring property to conduct sub-slab or indoor air sampling but access is denied by the neighboring property owner, the remediator should provide the Department with information documenting that a good faith effort was made to gain access and that access was denied.

After verifying that the neighboring property owner is unwilling to grant access, the Department can request the neighboring property owner either provide access to the inhabited building or have the property owner conduct the necessary sampling in the inhabited building.

Demonstration of Attainment of SHS for VI

Previous sections of this guidance dealt with the overall VI process, the use of screening values (Appendix X), and other assessment options to determine the need to address VI at a site. This section discusses demonstrating attainment of the SHS for VI at a site. The remediator does not demonstrate attainment for VI separately from other media because Act 2 does not define indoor air as an environmental medium. Demonstrating attainment of the SHS for VI, including the use of generic screening values, is only possible when the standard is attained for other all applicable environmental media (soil and/or groundwater).

Proper characterization of soil and groundwater sources is required for the SHS, and this characterization data may be sufficient for VI screening. If the soil and groundwater data do not adequately demonstrate an incomplete VI pathway, then near-source soil gas, sub-slab soil gas, and/or indoor air sampling are alternatives. Soil gas and indoor air integrate the impacts of soil and groundwater contamination. Therefore, it is recommended that the first step in assessing VI be review of the Conceptual Site Model (CSM) to devise the most appropriate sampling plan necessary to attain the SHS for VI.

Screening values can be used to demonstrate attainment of the SHS for VI using either characterization data or post-remediation attainment data from soil, groundwater, sub-slab soil gas, near-source soil gas and/or indoor air sampling under the conditions listed in Table 6. The attainment methodologies and related statistical tests discussed below can be used for each data set when demonstrating attainment.

General Attainment Approach

For demonstrating attainment of the SHS for VI, the points of application (POA) of the screening values are shown on Figure 4. Attainment sampling and statistical tests apply on and off the property on which the release occurred:

- To indoor air only for existing inhabited buildings.
- To sub-slab soil gas beneath existing inhabited buildings or intact paved areas large enough to be representative of future inhabited buildings.
- To groundwater, soil and near-source soil gas everywhere on a site where VI must be addressed, including undeveloped properties or portions of properties where no inhabited buildings are currently present. In all cases, use of the default screening values requires a minimum vertical separation of five feet between the water table and/or the top of a vadose zone soil source and foundation level (see Figure 4).

SHS Attainment for VI Using Soil and Groundwater Screening Values

The volume of soil and area of groundwater contamination for which VI must be addressed will be determined from characterization results or the results of post-remediation sampling. Once this volume/area has been identified, the demonstration of attainment for soil or groundwater is performed in accordance with attainment methodologies and related statistical tests presented in Title 25 Pa. Code Chapter 250, Subchapter G. DEMONSTRATION OF ATTAINMENT, as further explained in the Technical Guidance Manual (TGM). As noted above, the screening process can be applied on the basis of either characterization or post-remediation data.

For soil remediated in situ, the POA is throughout the volume of soil originally determined to exceed the soil screening value(s). 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 exceeds the screening value(s) at the water table and is within the VI horizontal setbacks for existing buildings. 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 exceeds the screening value(s) at the water table.

SHS Attainment for VI Using Soil Gas and Indoor Air Screening Values

Sampling requirements and statistical tests for near-source soil gas, sub-slab soil gas and indoor air are not specified in Chapter 250. Therefore, the number of sample points and sampling rounds to be evaluated for attainment is determined based on professional judgment and the VI sampling guidance provided in Appendix Z. The characterization data and CSM are used to determine the size and location of the area of potential VI impact. 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 Manual (SW-826). For most sites, sampling should be biased toward the most contaminated areas or the most appropriate locations for the sample type. These decisions are made on a case-by-case basis.

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. Sampling at these probes may be necessary during multiple seasons if it is determined that groundwater is likely to exhibit seasonal variation in concentrations. When the water table occurs in soil, the POA for near-source soil gas is within one foot of the top of the capillary zone. When the water table occurs within the bedrock, the POA for near-source soil gas is within one foot of the soil-bedrock interface, provided there is a minimum of five feet of soil between the top of bedrock and foundation level.

Two or more sampling rounds are required for VI screening. The Department recommends that multiple rounds of soil gas and/or indoor air data be collected in consecutive quarters to assess temporal variability. If only two characterization rounds are obtained, then they must be collected at least 45 days apart for statistical independence.

For any set of attainment data for near-source soil gas, sub-slab soil gas and indoor air when fewer than eight sample rounds are collected, the attainment criterion is a non-exceedance rule. For any dataset comprised of eight or more sample rounds, the 75%/10x rule and other acceptable statistical tests from Chapter 250, Subchapter G apply, provided a sufficient number of sample results are available to support the use of the method.

If the initial data indicate an exceedance of VI screening value(s), but subsequent samples do not, then eight consecutive quarters are generally required to demonstrate attainment of the SHS. The Department may accept fewer sampling events when the following conditions are satisfied:

- There is adequate characterization and monitoring of the vapor source in soil and/or groundwater.
- If the source is in groundwater, monitoring data for the contaminants of concern indicate a stable or decreasing trend.
- Concentrations of the contaminants of concern at all POA locations are all less than or equal to the VI screening values in the samples collected during the quarters of monitoring.
- Either the age of the source is sufficiently well known to permit a judgment to be made regarding its stability or the remediation has included source removal which would reduce the vapor flux.

Role of Environmental Covenants, Institutional Controls and Engineering Controls in Attaining the SHS for VI

Institutional controls in environmental covenants can be used, in combination with characterization and/or post-remediation sampling, to demonstrate attainment of the SHS for VI when existing or future inhabited buildings fall within an applicable setback from a vadose zone soil or groundwater source.

The following institutional controls are available to remediators for undeveloped properties or portions of properties where no inhabited buildings are currently present:

- To commit to mitigation (as described below) of future inhabited building on the property.
- To commit to evaluate VI potential at the time a future inhabited building is constructed. The results of the evaluation must be submitted to the Department for review. If the VI pathway is found to be complete, the site will reenter the Act 2 or Corrective Action program.
- To prohibit construction of inhabited buildings in a specified area of the property where the VI pathway may be complete.

Engineering controls in environmental covenants in the form of various mitigation measures may be used to attain the SHS for VI. Examples of such controls include, but are not limited to, the following:

- Installation of an active sub-slab depressurization system. The Department must be notified in the event of a property transfer, if there is a problem with the system or upon request by the Department.
- Installation of a vapor barrier in newly constructed buildings.

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