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DEPARTMENT OF ENVIRONMENTAL PROTECTION

Bureau of Environmental Cleanup & Brownfields



Vapor Intrusion Overview

Mike Maddigan (DEP)

Vapor Intrusion Guidance Training

January 10, 2017

Malvern, PA

Vapor Intrusion Overview

VI Guidance Training

- Overview: (Mike Maddigan, DEP)
 - ✓ New key terms
 - ✓ New evaluation options
- Evaluating the VI Pathway (Mike Maddigan, DEP)
- VI Screening (Colleen Costello, GHD)
- Mitigation, remediation, & modeling (Carolyn Fair, DEP)
- VI sampling techniques (Chuck Campbell, Leidos)
- Case Study (David Brown, DEP)

Vapor Intrusion Overview

What to Expect from this Training

- Introduction to new terms and concepts
- A general understanding of the process for addressing the VI pathway under Act 2
- Questions will arise as you apply the guidance to your sites
 - Learning through experience
 - Communication is key



Vapor Intrusion Overview

Why do we care about VI?

- Volatile substances in soil or groundwater can result in vapor phase intrusion of these substances into inhabited buildings, posing a threat to human health.
- This guidance details how to evaluate the threat under the Statewide Health Standard (SHS) and the Site-Specific Standard (SSS).

Vapor Intrusion Overview

What is Vapor Intrusion?

- Vapor Intrusion (VI) is not a medium like soil and groundwater.
- VI is a pathway between contamination of a volatile substance and a receptor in a building.
- VI is primarily associated with volatile organic compounds (VOCs) and some semi-volatile organic compounds (SVOCs)

Vapor Intrusion Overview

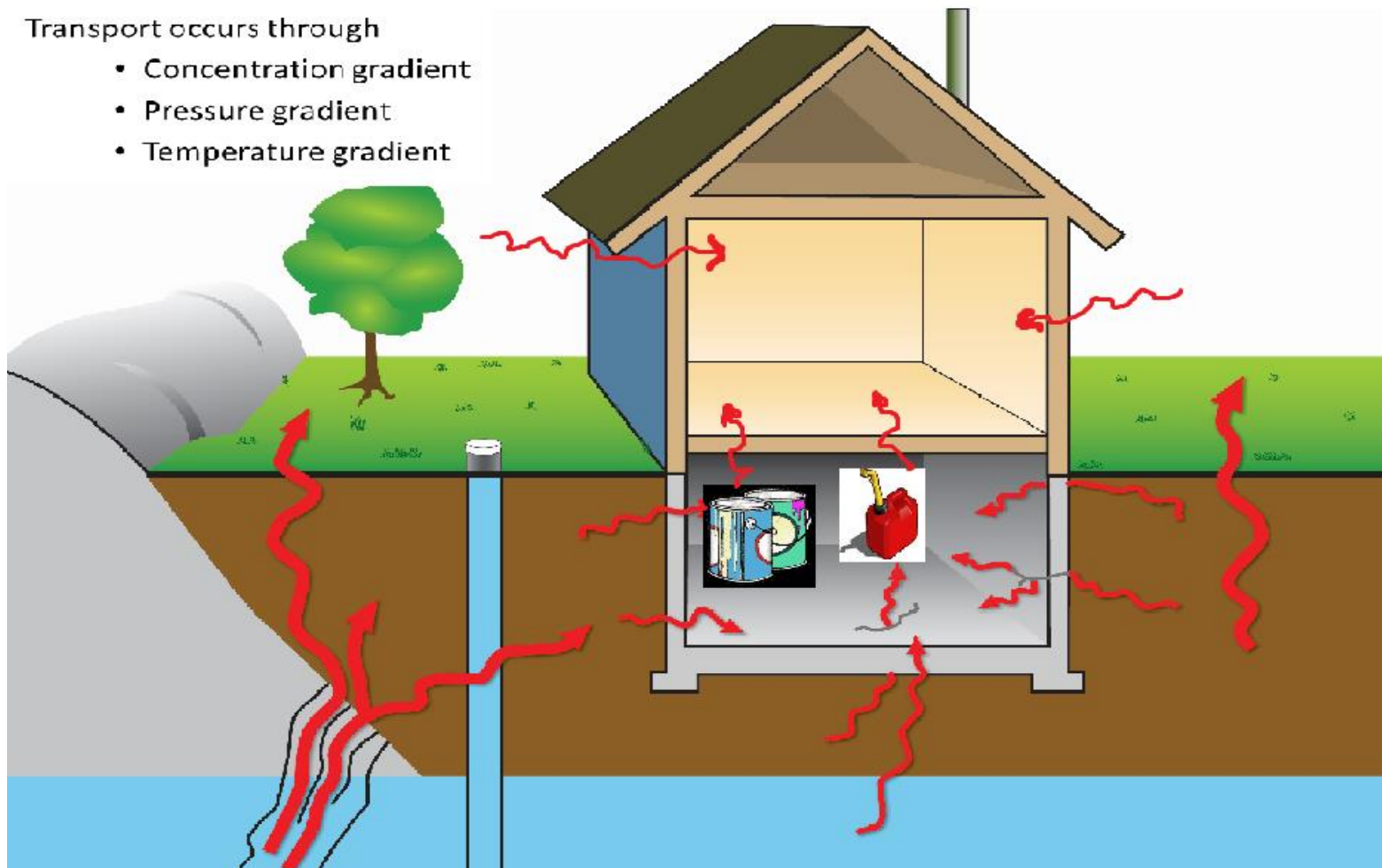
Indoor Air VI Sources

- Indoor sources (i.e.
 - attached garages,
 - basements, etc.)
- Ambient Air
 - Downwind of VOC source
- Vapor Intrusion
 - Soil
 - Groundwater

Vapor Intrusion Overview

Transport occurs through

- Concentration gradient
- Pressure gradient
- Temperature gradient



Vapor Intrusion Overview

Implementation of New Guidance

- Published in PA Bulletin November 19, 2016
- 60-day implementation period
- Effective January 18, 2017
- How to implement for projects mid-stream?



Vapor Intrusion Overview

Implementation of New Guidance

When Use of New Guidance is Expected:

- “...where the RI or SCR is expected to be submitted following the effective date...”
- “If this VI guidance becomes effective prior to the Department receiving an FR or RACR, then the remediator is expected to complete the FR or RACR using this VI guidance.”

(see guidance page 2)

Vapor Intrusion Overview

Implementation of New Guidance

When Old Guidance Applies:

- Reports approved by the Department will not need to be resubmitted under new guidance
- An FR or RACR has been received by the Department prior to effective date of new guidance

Vapor Intrusion Overview

Implementation of New Guidance

Application of VI guidance is the same for Act 2 sites and for storage tanks sites

- Demonstration of attainment of an Act 2 standard is required under Chapter 245
- RACR should explain how VI pathway was addressed



Vapor Intrusion Overview

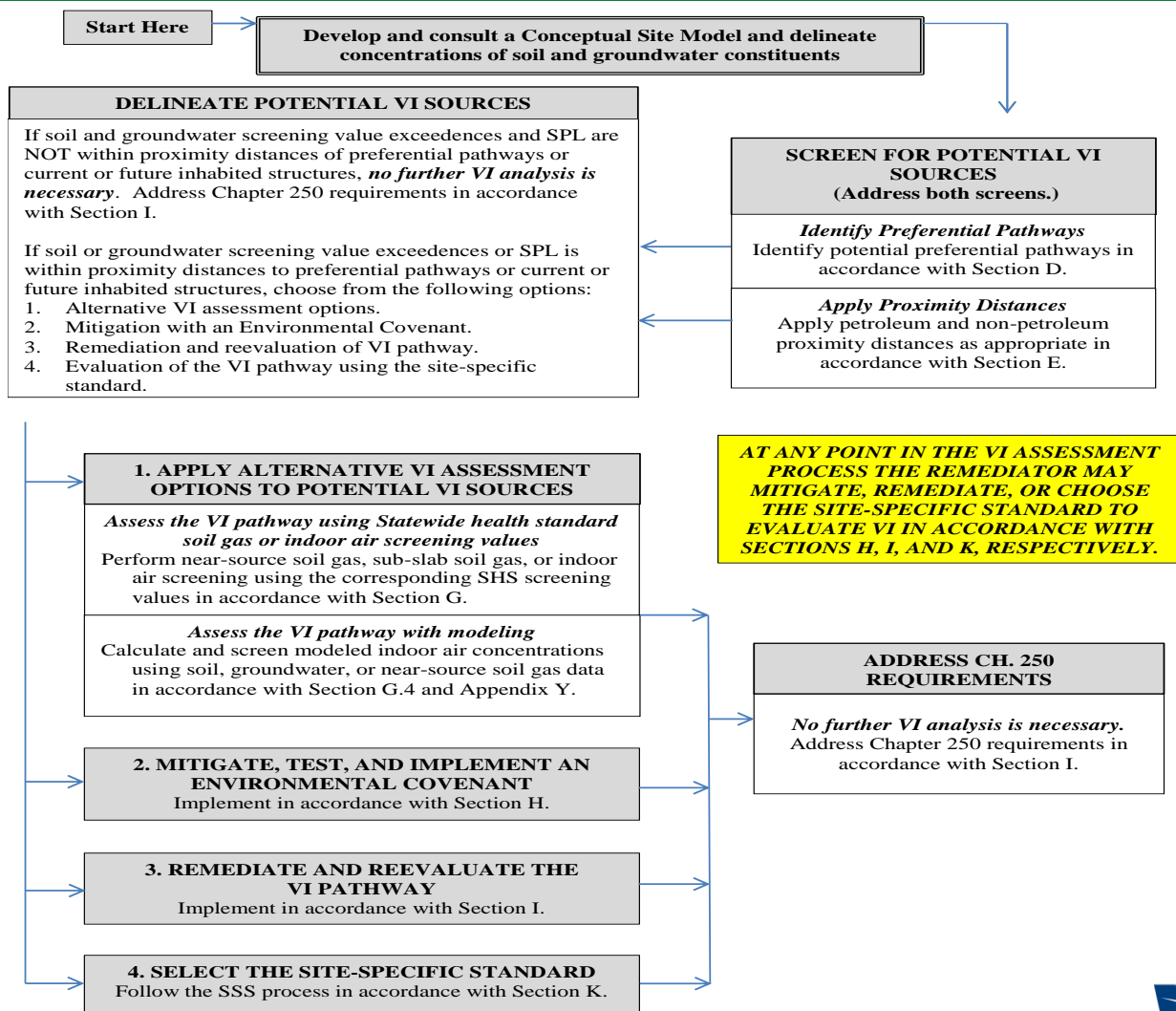
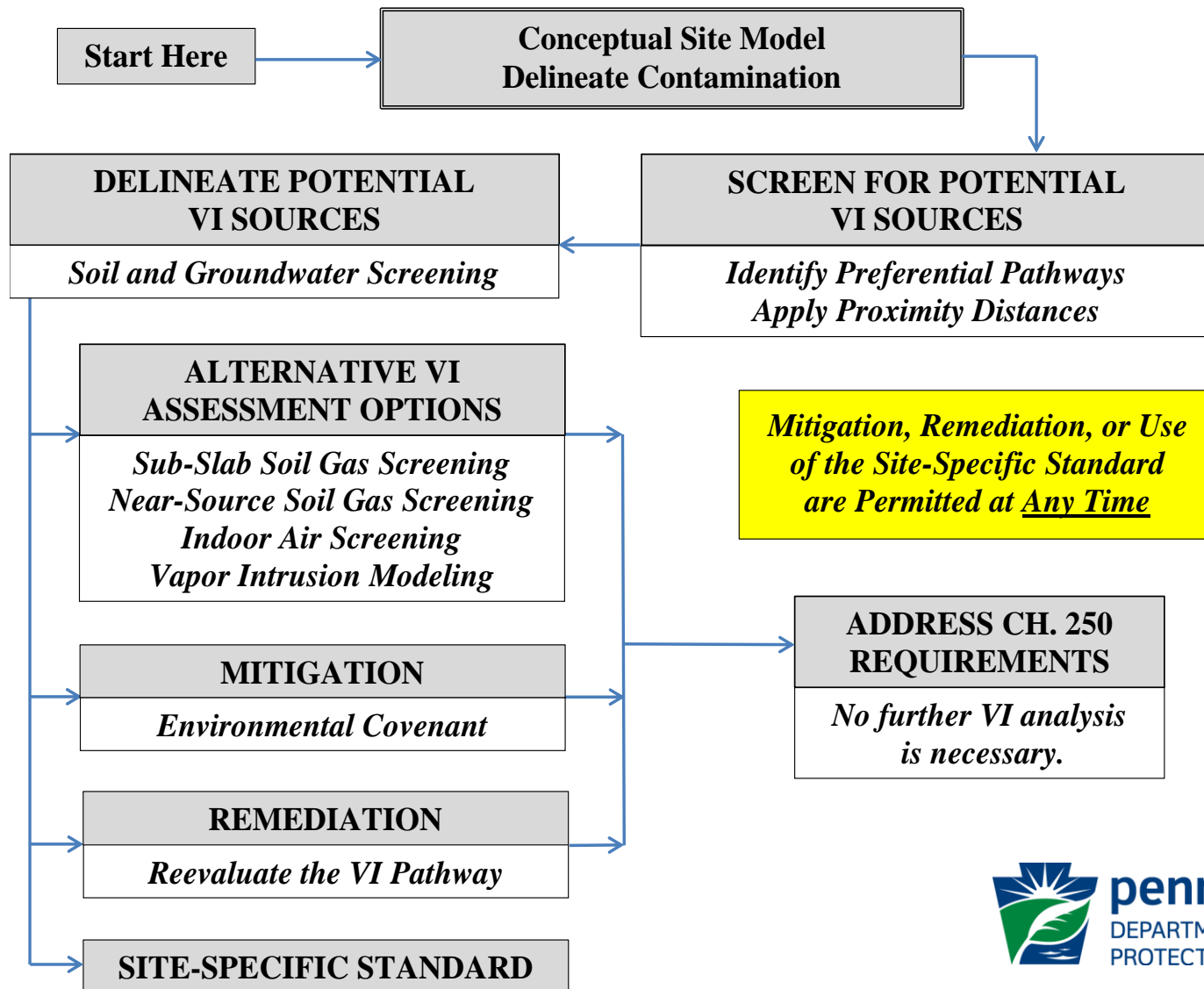


Figure 5. Statewide Health Standard Vapor Intrusion Assessment Process

Vapor Intrusion Overview



Vapor Intrusion Overview

When Can Mitigation be Done?

Mitigation may be used at any time during the evaluation.

Mitigation eliminates the complete pathway between contamination and the receptor.

Key Terms

- Hydrogeologic Zones
- Point of Application (POA)
- Acceptable Soil
- Preferential Pathway
- Proximity Distance
- Separation Distance
- Separate Phase Liquid (SPL)
- Potential VI Source

(Key terms found in Section B of guidance)

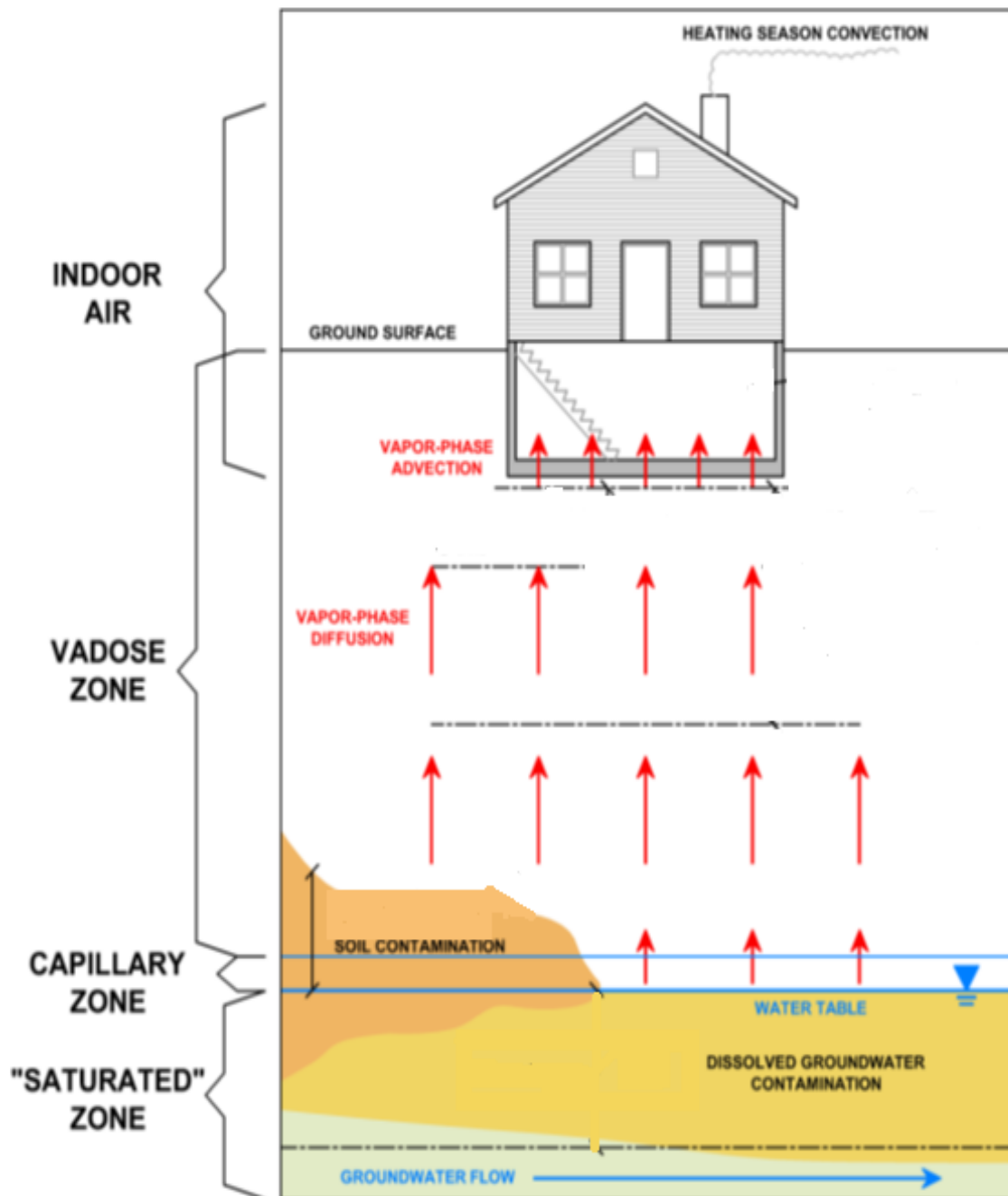
Hydrogeologic Zones

Subsurface zones used to

- Define points of application for screening values
- Define sampling intervals for soil, groundwater, and near-source soil gas

The zones also pertain to the way vapors are transported in the subsurface.

Hydrogeologic Zones



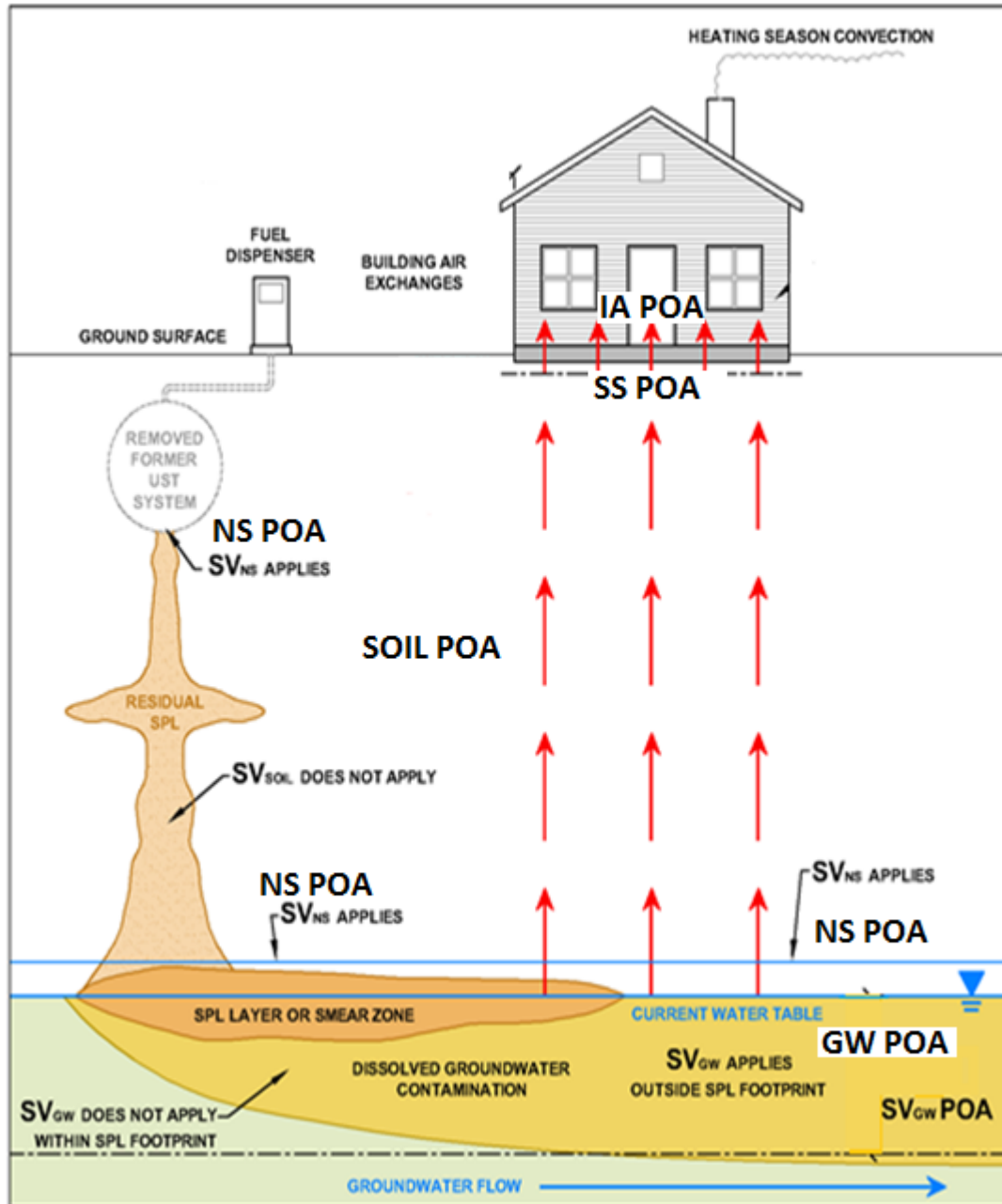
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Point of Application

A POA is the location in buildings and in the hydrogeologic zones where screening values are applied.

POAs guide the selection of sampling locations.

Point of Application



SV_{SOIL}	Soil Screening Value (SV)
SV_{GW}	Groundwater SV
SV_{IA}	Indoor Air SV
SV_{SS}	Sub-slab SV
SV_{NS}	Near-source SV

Acceptable Soil

Acceptable Soil or Soil-like Material

- Unconsolidated material in the vadose zone above a potential VI source that does not exceed the saturated hydraulic conductivity of sand or air-filled porosity of silt
- Fill material that is soil-like
- Soils and fill coarser than sand or with air-filled porosity greater than silt may not be acceptable soil

Acceptable Soil

Why is acceptable soil important?

- Impacts the use of groundwater screening values.
- Impacts the use of petroleum vertical proximity distances
- Impacts the application of separation distances for preferential pathways

Acceptable Soil

Warning signs that soil may not be acceptable:

- ✓ Show obvious signs of contamination by substances of VI concern such as staining and odor
- ✓ Exhibit field screening readings in the headspace above soil samples >100ppmv
- ✓ Show evidence of SPL
- ✓ Have exceedances of soil screening values

Acceptable Soil

- When applying the petroleum vertical proximity distances, acceptable soil also should exhibit $>2\%$ oxygen in soil gas near the building slab.



Preferential Pathways

A natural or man-made feature that enhances vapor migration from a VI source to a building.

The feature must be close to both the contamination and the building and have sufficient volume in order to be a preferential pathway.

Two types:

- ✓ External Preferential Pathway
- ✓ Significant Foundation Opening

Preferential Pathways

External Preferential Pathway

- A channel or conduit that allows greater vapor flow than ordinary diffusion through vadose zone soil.
- Sewer lines, utility trenches with permeable backfill

Preferential Pathways

Significant Foundation Opening (SFO)

- A breach in the building foundation or basement wall that increases the entry of subsurface vapors.
- Common foundation openings (sumps, French drains, floor drains) are NOT SFOs
- Large foundation cracks, dirt floors, etc. are considered SFOs

Preferential Pathways

Impact of Preferential Pathways

- VI pathway evaluation options are limited if preferential pathways are identified
 - Restricted use of proximity distances
 - Restricted use of some screening values

Proximity Distances

The minimum distance which a potential VI source must be from a building to not pose a potential unacceptable VI risk.

- Applies to current and planned future buildings
- Cannot be used if a preferential pathway is present

Proximity Distances

Horizontal:

30 feet for petroleum substances

100 feet for non-petroleum substances

Vertical:

5 feet for petroleum adsorbed-phase or
dissolved-phase

15 feet for petroleum SPL

None for non-petroleum substances

Separation Distances

Separation Distance – The minimum distance which a potential VI source must be from an underground feature for it not to be considered to be a preferential pathway

30 feet horizontal

5 feet vertical

Separation distances are the same for petroleum and non-petroleum constituents

Separate Phase Liquid

Comprised of non-aqueous phase liquid (NAPL) present in the void space in a contaminated medium such as soil or bedrock

Separate phase liquid (SPL) is physically separate from the portion of the substances that are adsorbed onto or diffused into soil, bedrock, water or air

Separate Phase Liquid

Importance of SPL

- SPL may be a potential VI source if it contains substances of VI concern.
- SPL can limit the applicability of some screening values within applicable proximity distances.
- SPL limits the use of modeling.



Separate Phase Liquid

Importance of SPL

SPL limitations to SV use and modeling

- SPL on water table or in associated smear zone – SV_{GW} and modeling unavailable for GW data collected from SPL footprint area
- Residual SPL in soil – SV_{SOIL} and modeling unavailable for data collected from residual SPL impacted soil
- SV_{GW} , SV_{SOIL} , and modeling can be used on data collected outside limits of the SPL

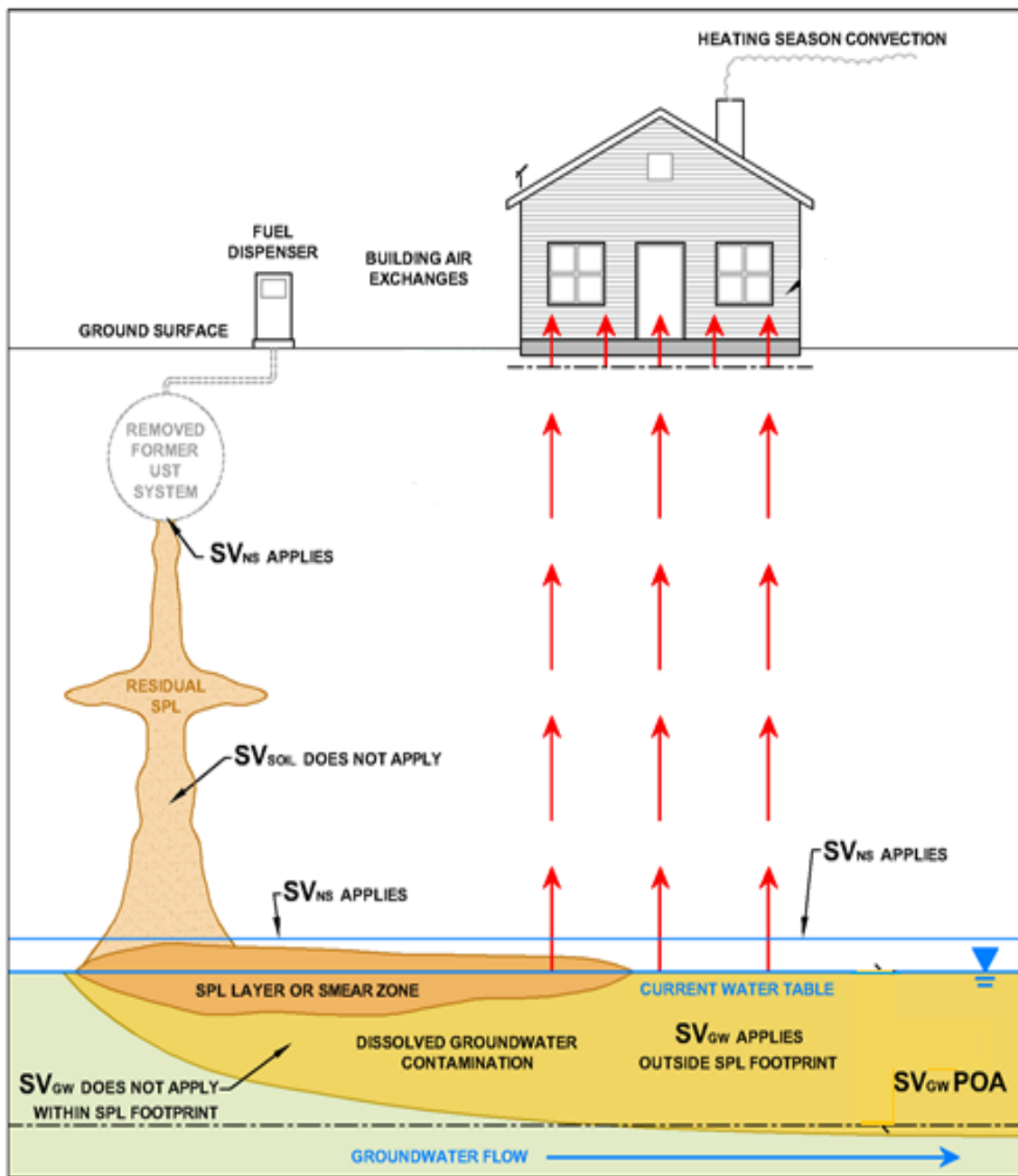
Separate Phase Liquid

Importance of SPL

Residual Soil SPL

- Partitioning model used to calculate SV_{SOIL} and soil-to-GW values based on partitioning from soil \rightarrow pore water \rightarrow gas, not directly from SPL
- SV_{NS} can be used for samples collected in soil collected directly above the residual soil SPL

Separate Phase Liquid



Potential VI Source

Contamination by a substance of VI concern under at least one of the following conditions:

- ✓ Soil and/or groundwater exceeding SHS VI screening values within proximity distances
- ✓ SPL within proximity distances
- ✓ In the presence of a preferential pathway

Potential VI Source

A Potential VI Source identifies the areas of a site where VI should be addressed.

Can be addressed through alternative assessment options, remediation, mitigation, or an activity and use limitation (AUL).

Key Terms Review

TRUE or FALSE

1. A gravel or stone bed beneath a foundation would be considered acceptable soil or soil-like material.

Key Terms Review

TRUE or FALSE

1. A gravel or stone bed beneath a foundation would be considered acceptable soil or soil-like material.

FALSE

Gravel or stone exceeds the saturated hydraulic conductivity of sand or the air-filled porosity of silt.

Key Terms Review

TRUE or FALSE

2. The presence/absence of preferential pathways impacts the use of vertical proximity distances.

Key Terms Review

TRUE or FALSE

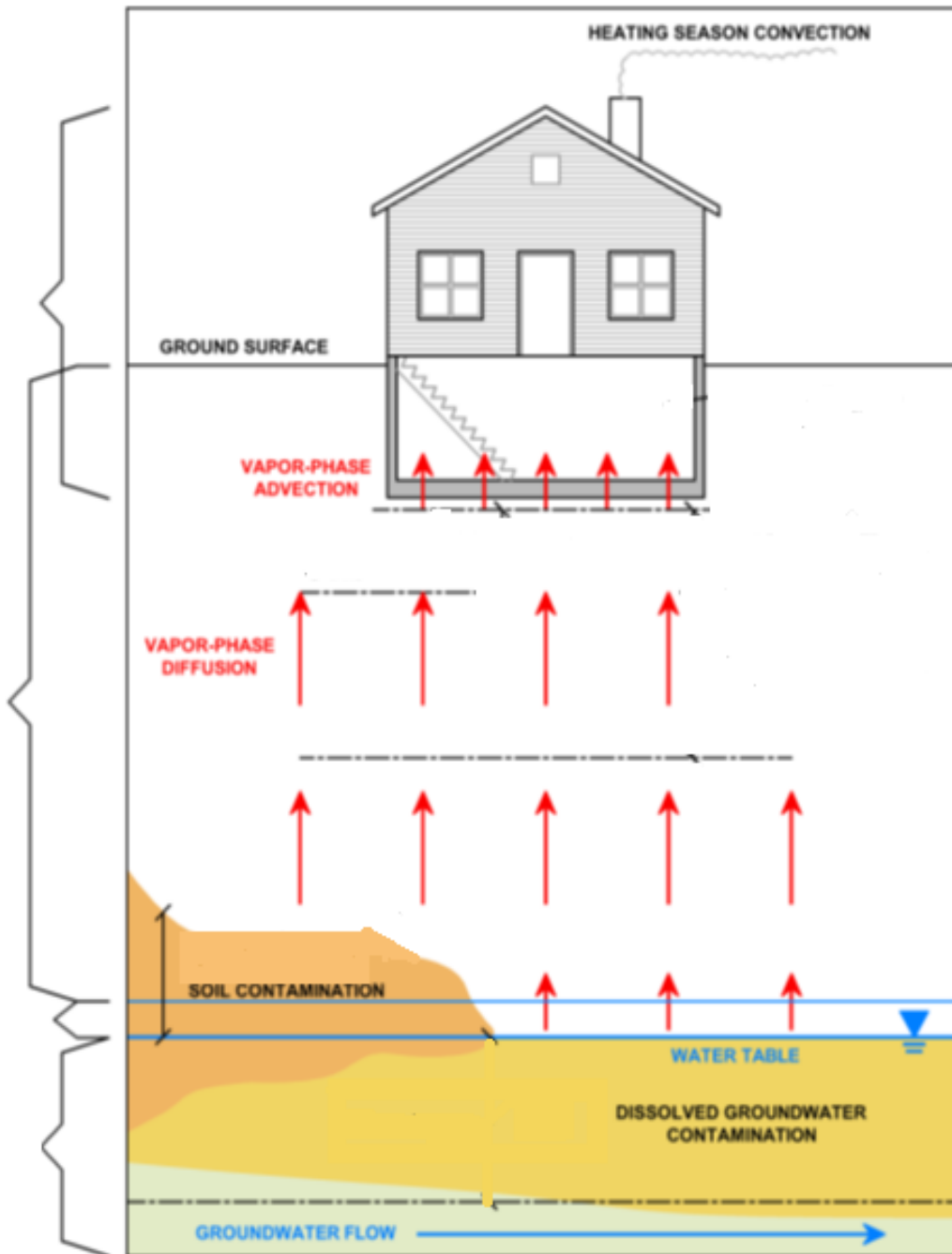
2. The presence/absence of preferential pathways impacts the use of proximity distances.

TRUE

Proximity distances are based on attenuation through soil.

Key Terms Review

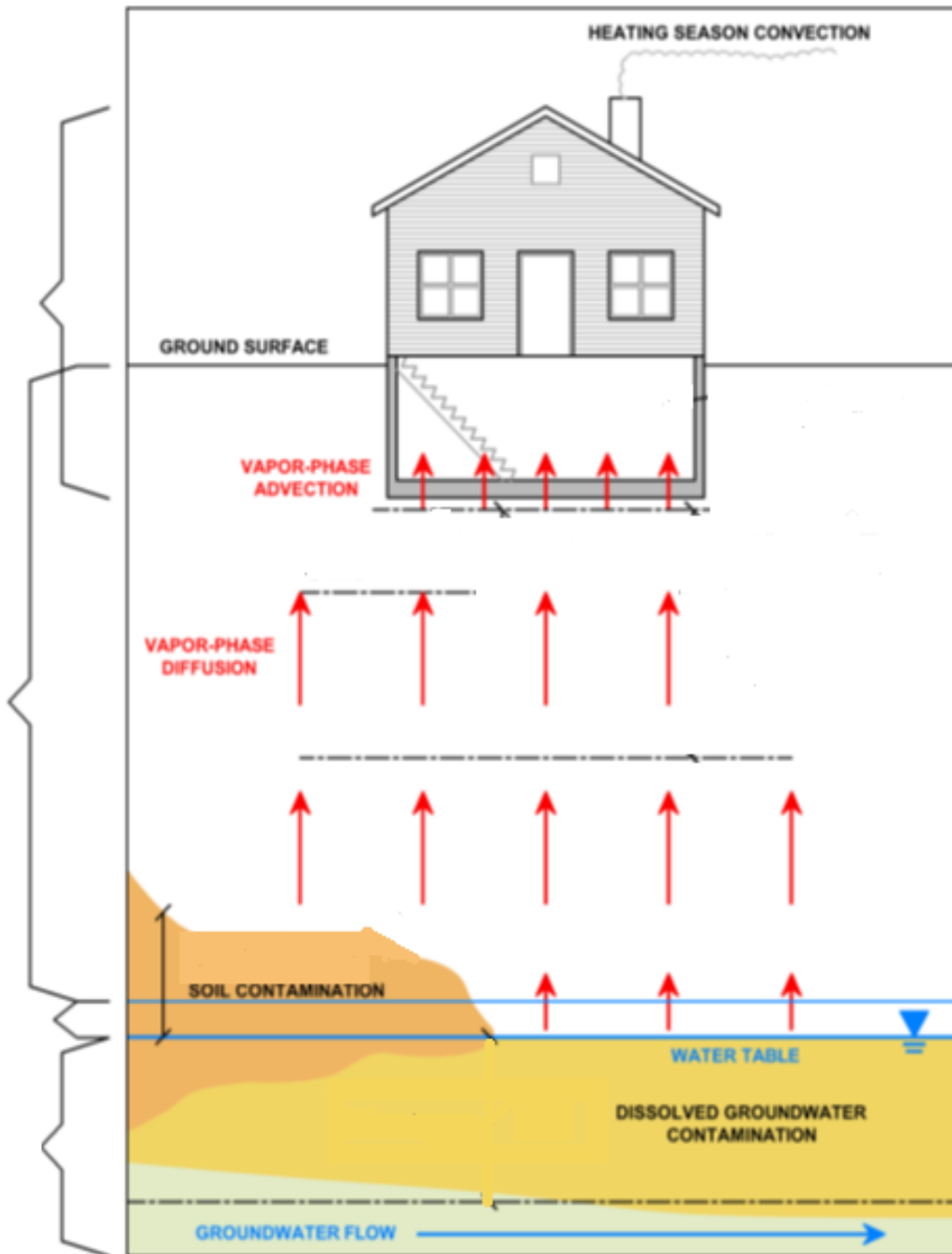
Where is the Vadose Zone?



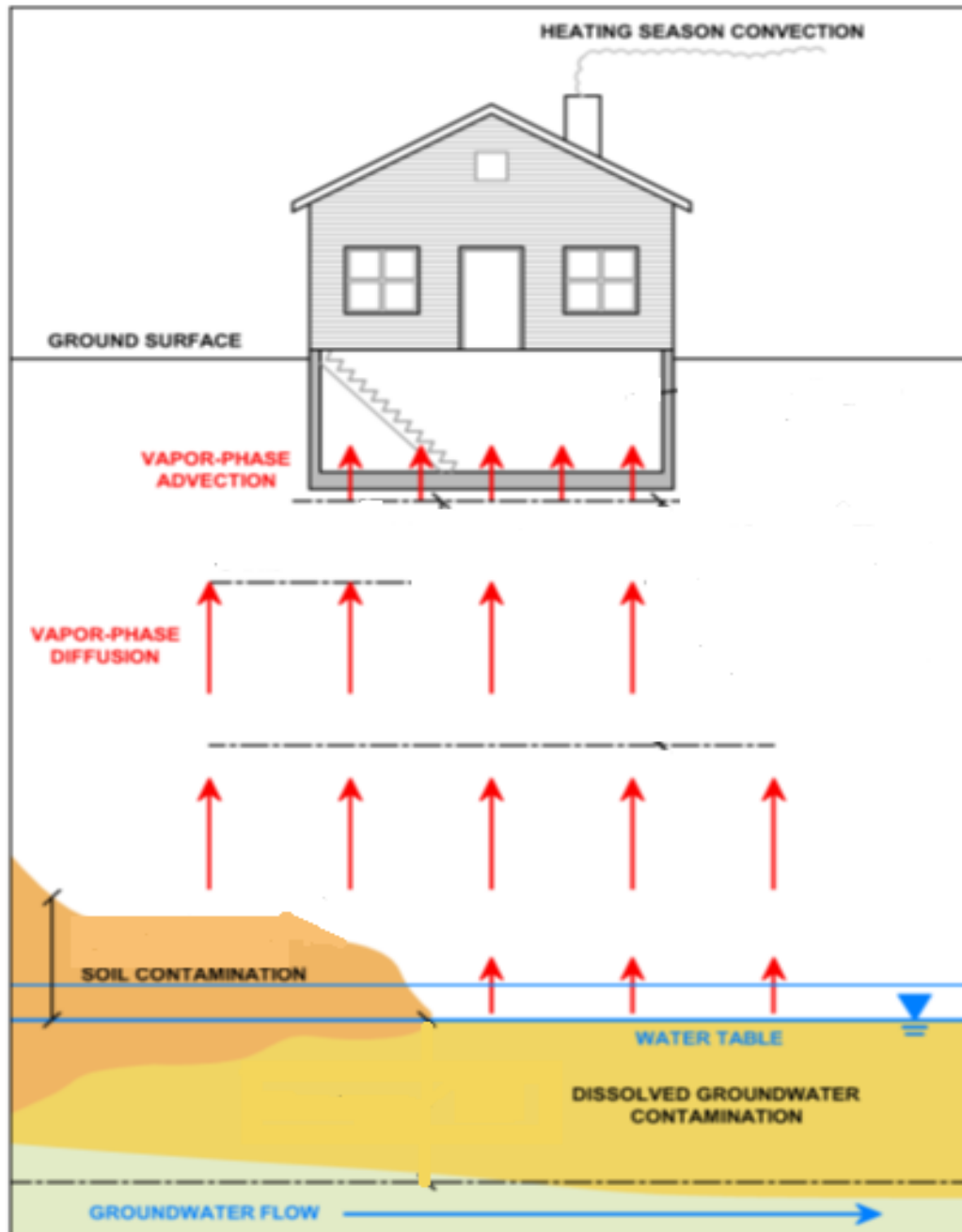
Key Terms Review

Where is the Vadose Zone?

Vadose Zone

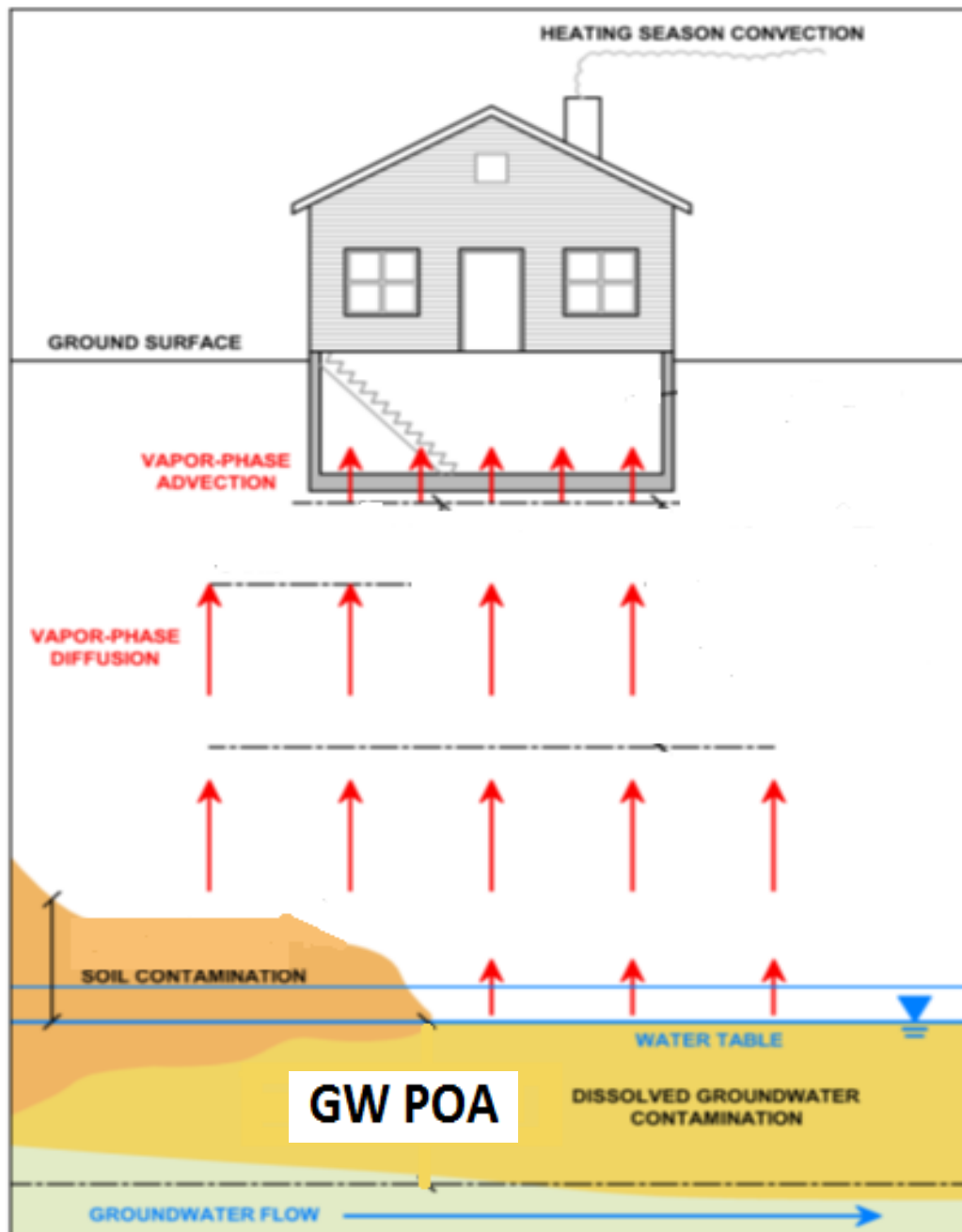


Key Terms Review



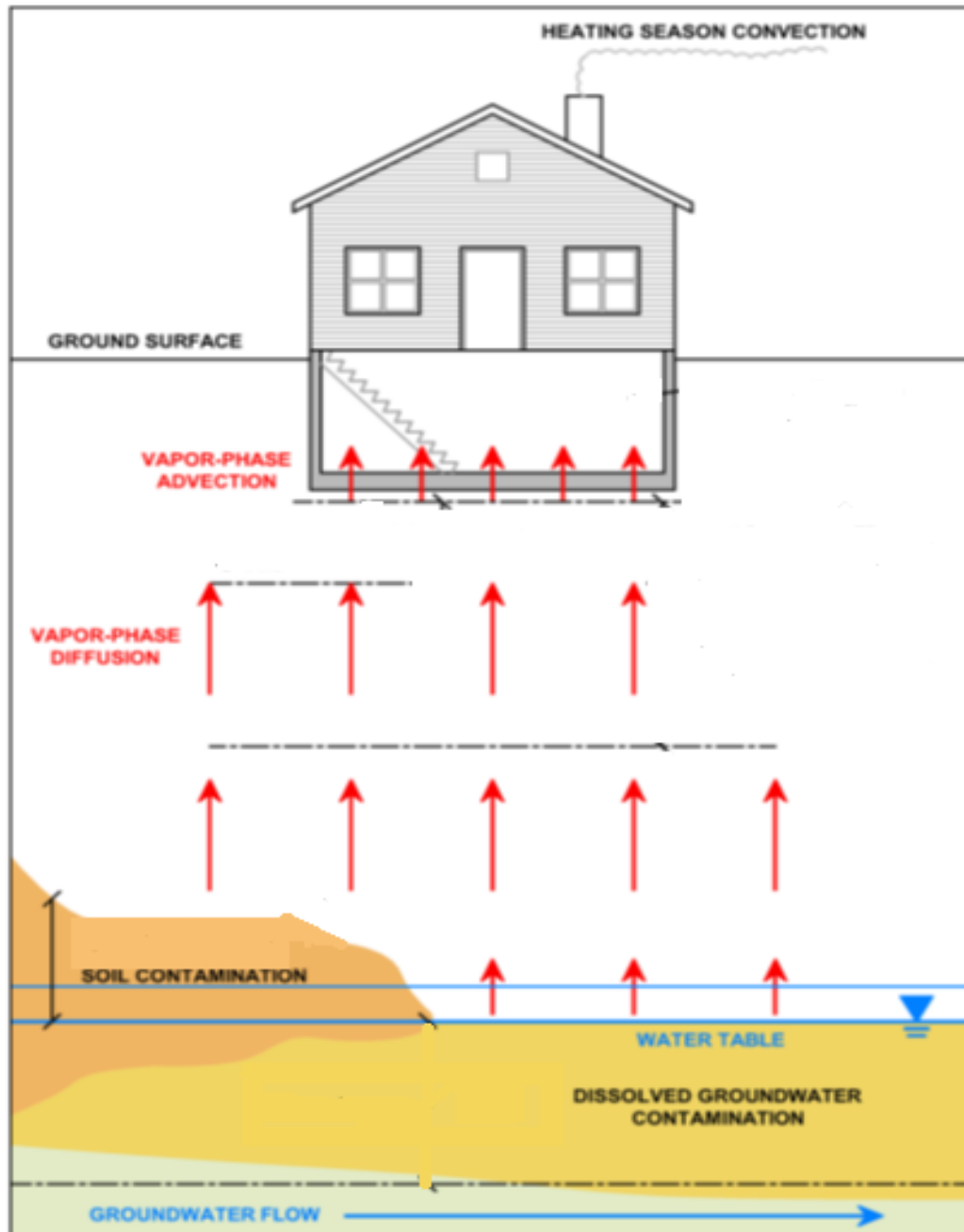
**Where is the
POA for GW?**

Key Terms Review



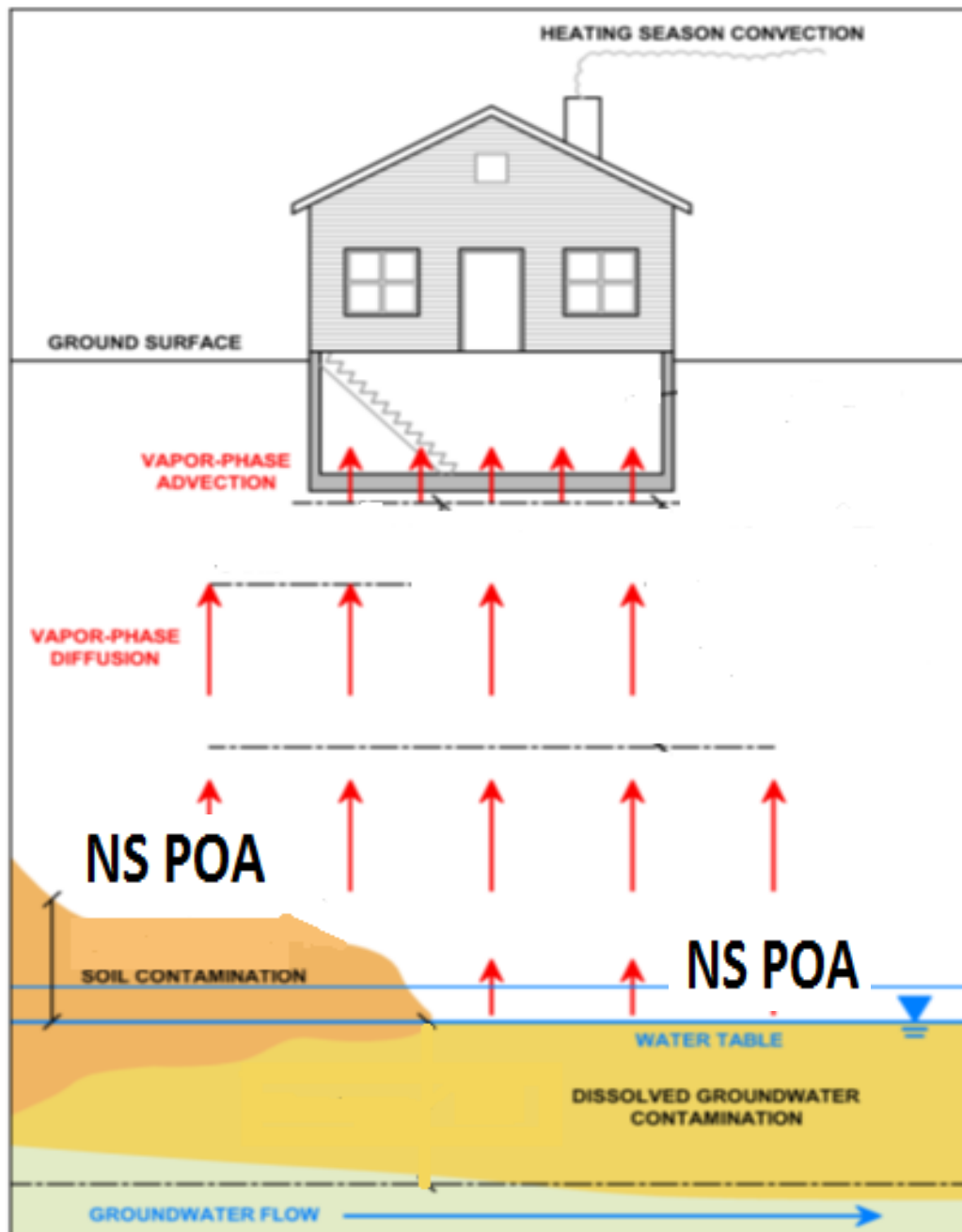
**Where is the
POA for GW?**

Key Terms Review



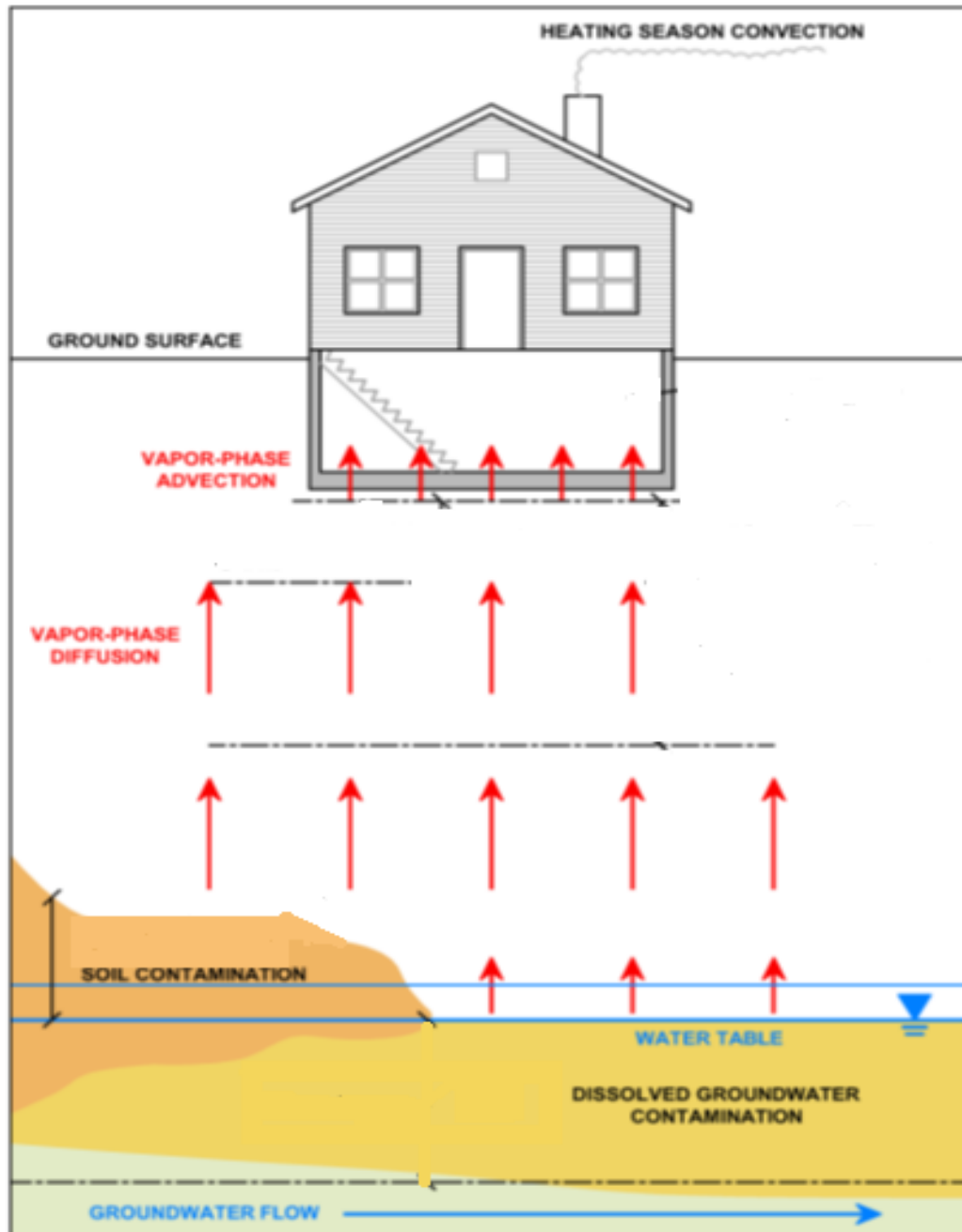
**Where is the
POA for NS?**

Key Terms Review



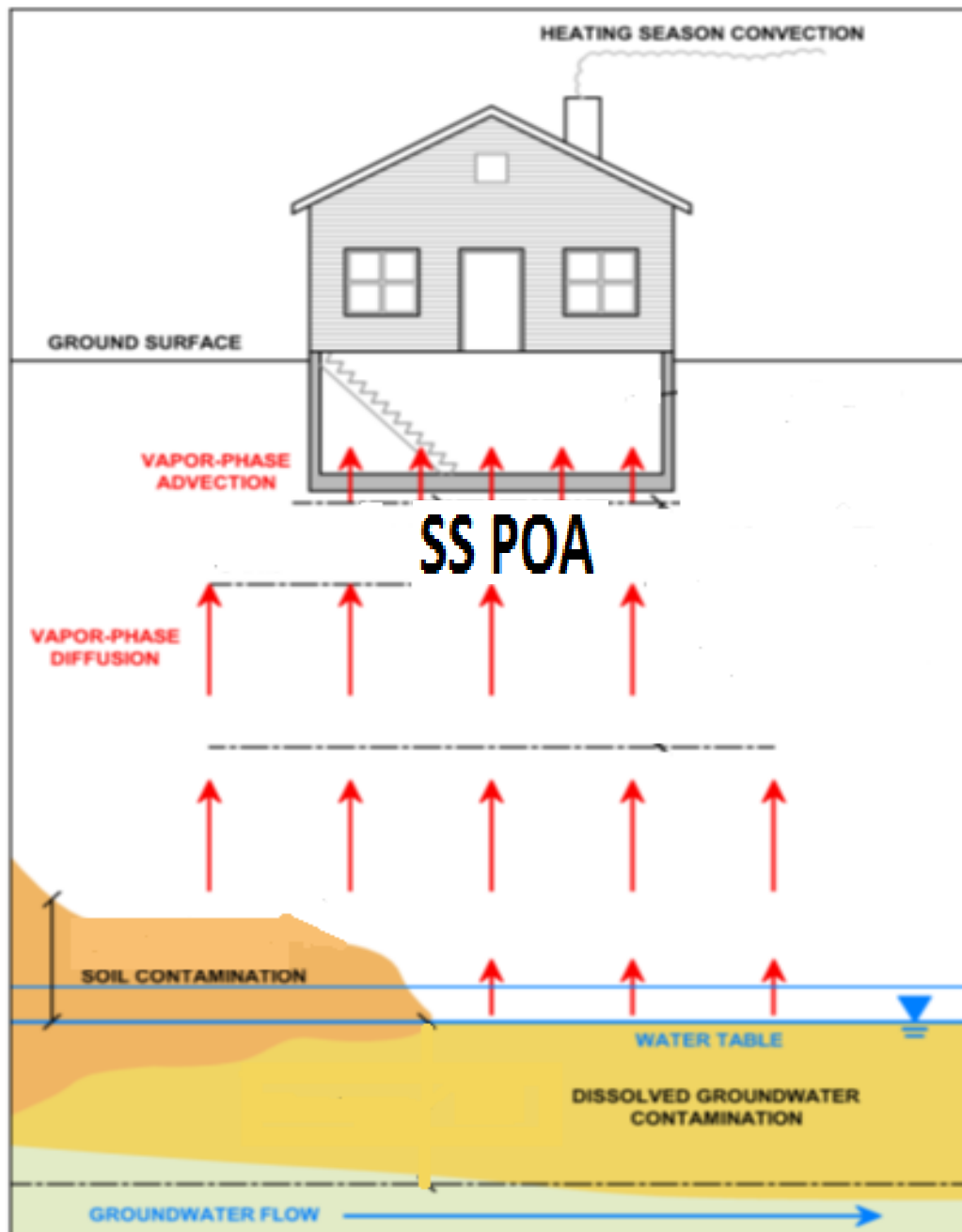
Where is the
POA for NS?

Key Terms Review



Where is the
POA for SS?

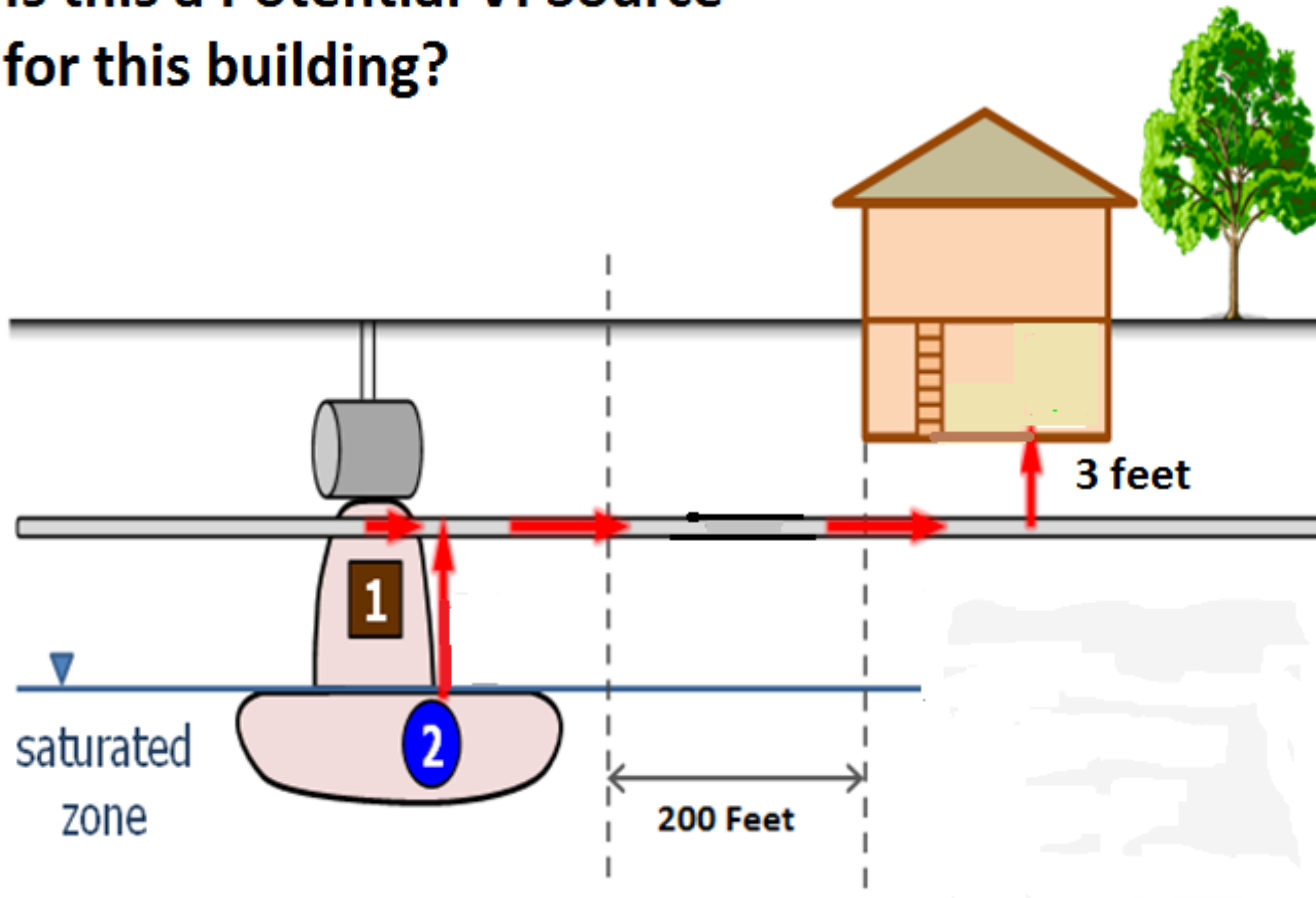
Key Terms Review



Where is the
POA for SS?

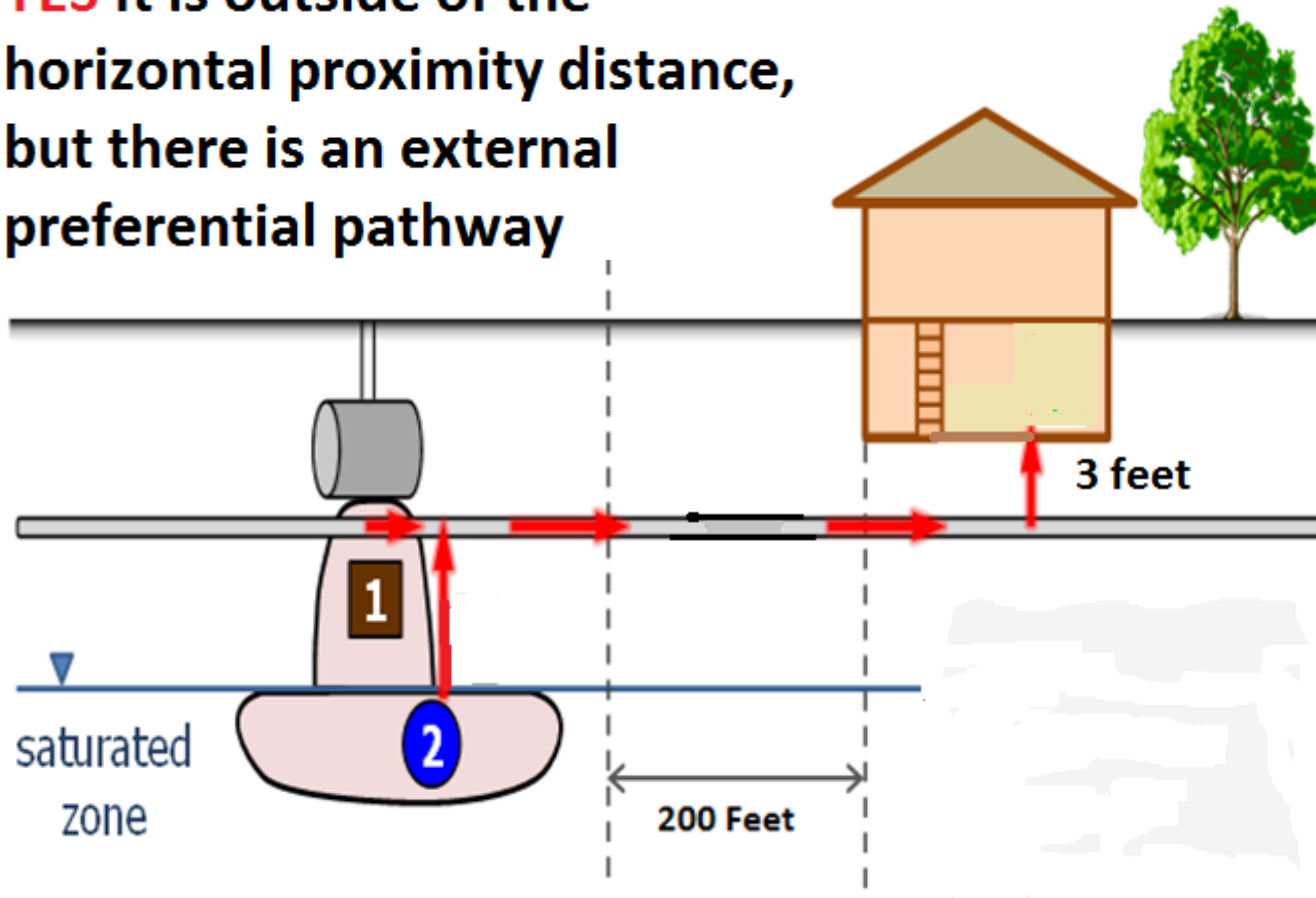
Key Terms Review

Is this a Potential VI Source for this building?



Key Terms Review

YES It is outside of the horizontal proximity distance, but there is an external preferential pathway



Limitations

- Outdated soil and GW VI screening values
- Limited options if data did not screen out
- VI Modeling guidance is limited
- No distinction between petroleum and non-petroleum VI
- Minimal sampling guidance
- Addressed only existing buildings

What Has Changed

- Eliminated 5-ft depth limit for use of screening values when not applicable
- Added detailed guidance for sampling
- Added detailed guidance for modeling
- Added discussion of petroleum VI
- Added alternative assessment options: sub-slab and near-source soil gas screening

What Has Changed

- Introduction of petroleum and vertical proximity distances
- Detailed information on preferential pathways
- Improved method of calculating screening values – accurate, up to date values
- More screening options
 - near-source soil gas,
 - sub-slab soil gas

What Has Changed

- Detailed explanation of how to address VI under the SSS
- Guidance for using a combination of standards
- Explanation of how to use AULs/ECs for VI

What Has Changed

Ability to Address Future Buildings

- Planned future buildings treated the same as existing buildings – should be addressed
- Can address future VI issues using near-source soil gas sampling, AULs, and modeling
- Unplanned future buildings can be addressed with AUL – at the remediator's discretion; is not required



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Questions?





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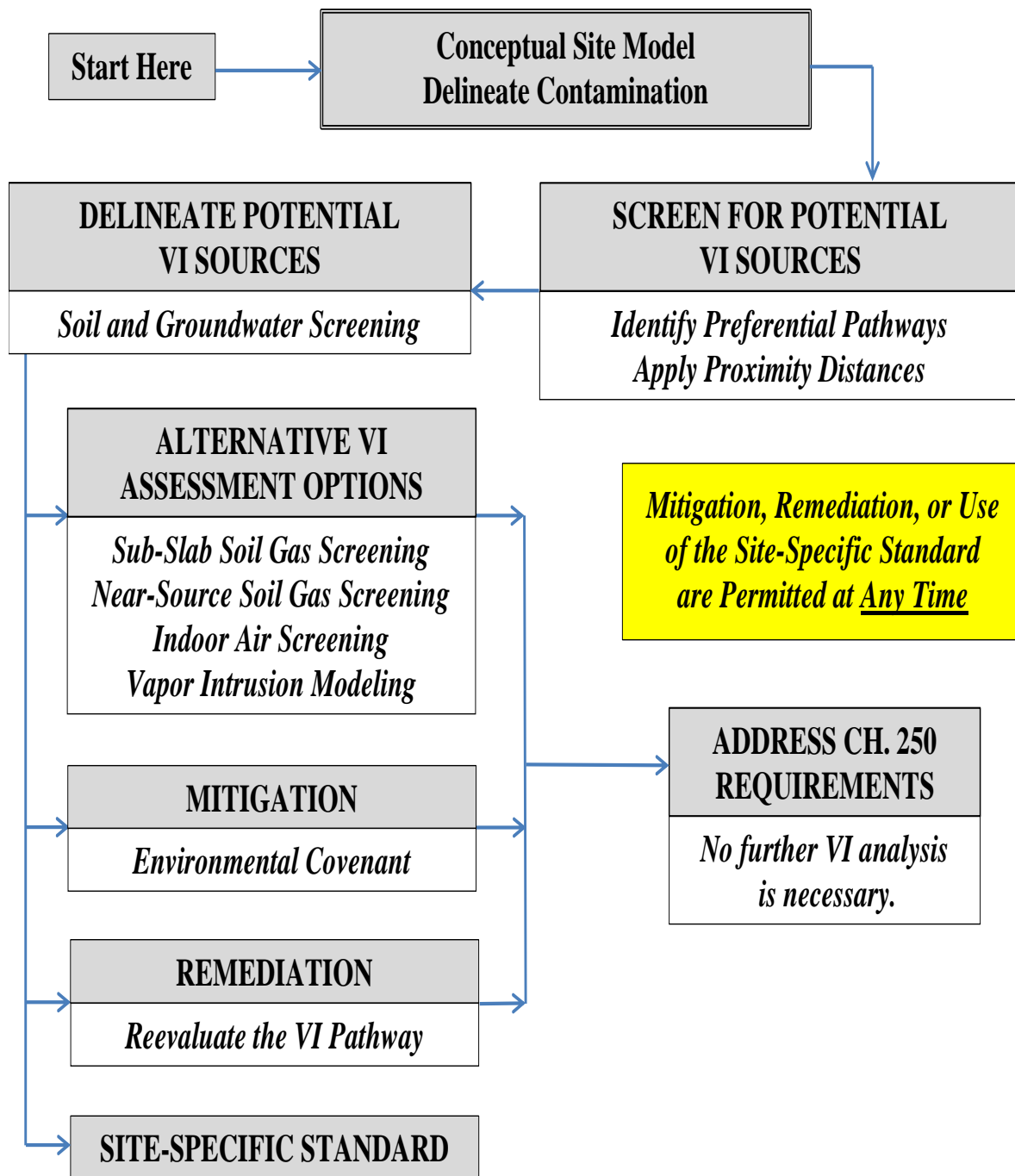
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Evaluating the VI Pathway

Carolyn Fair (DEP) Vapor Intrusion Training

January 10, 2017
Malvern, PA

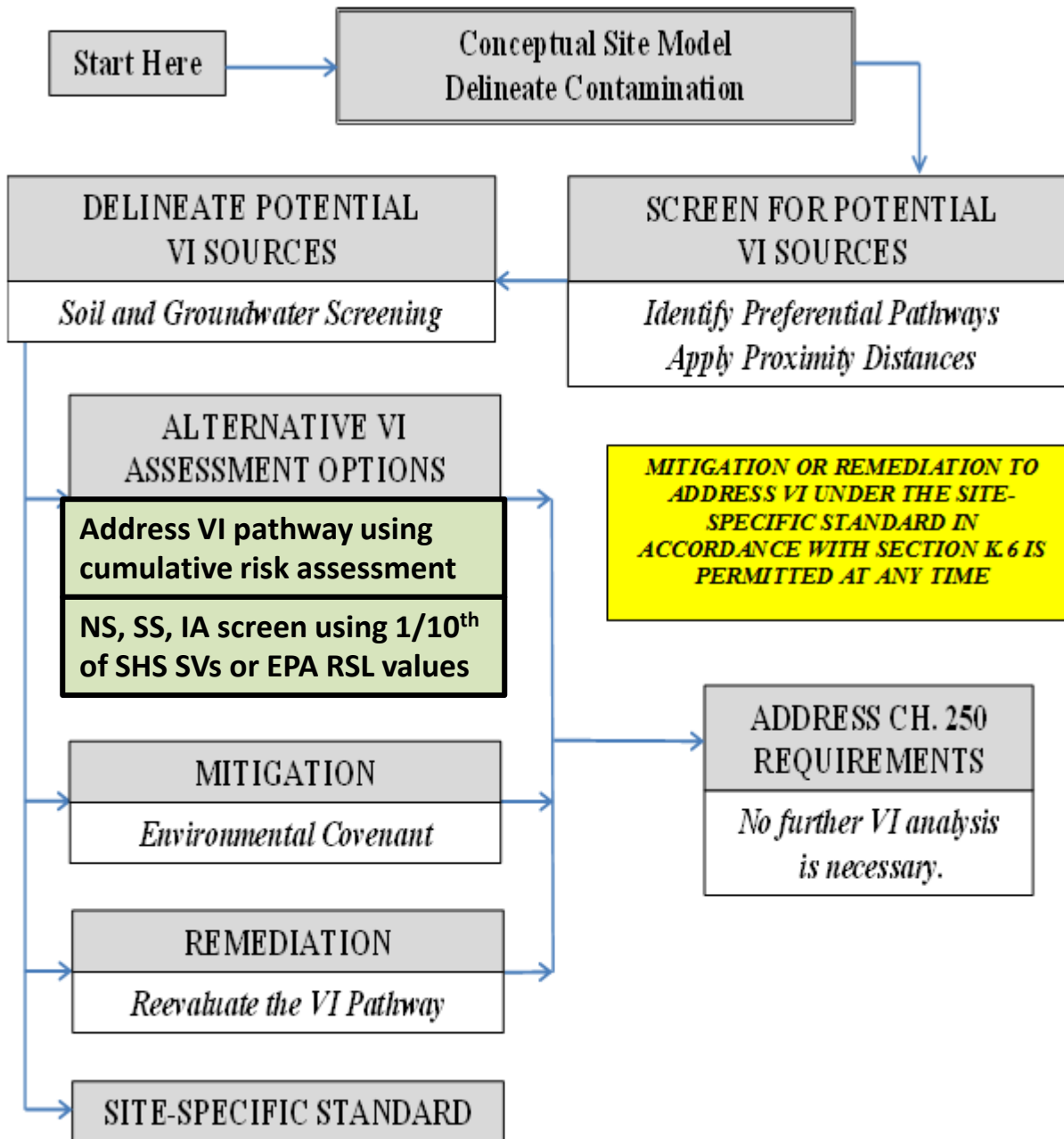


SHS VI Evaluation Process

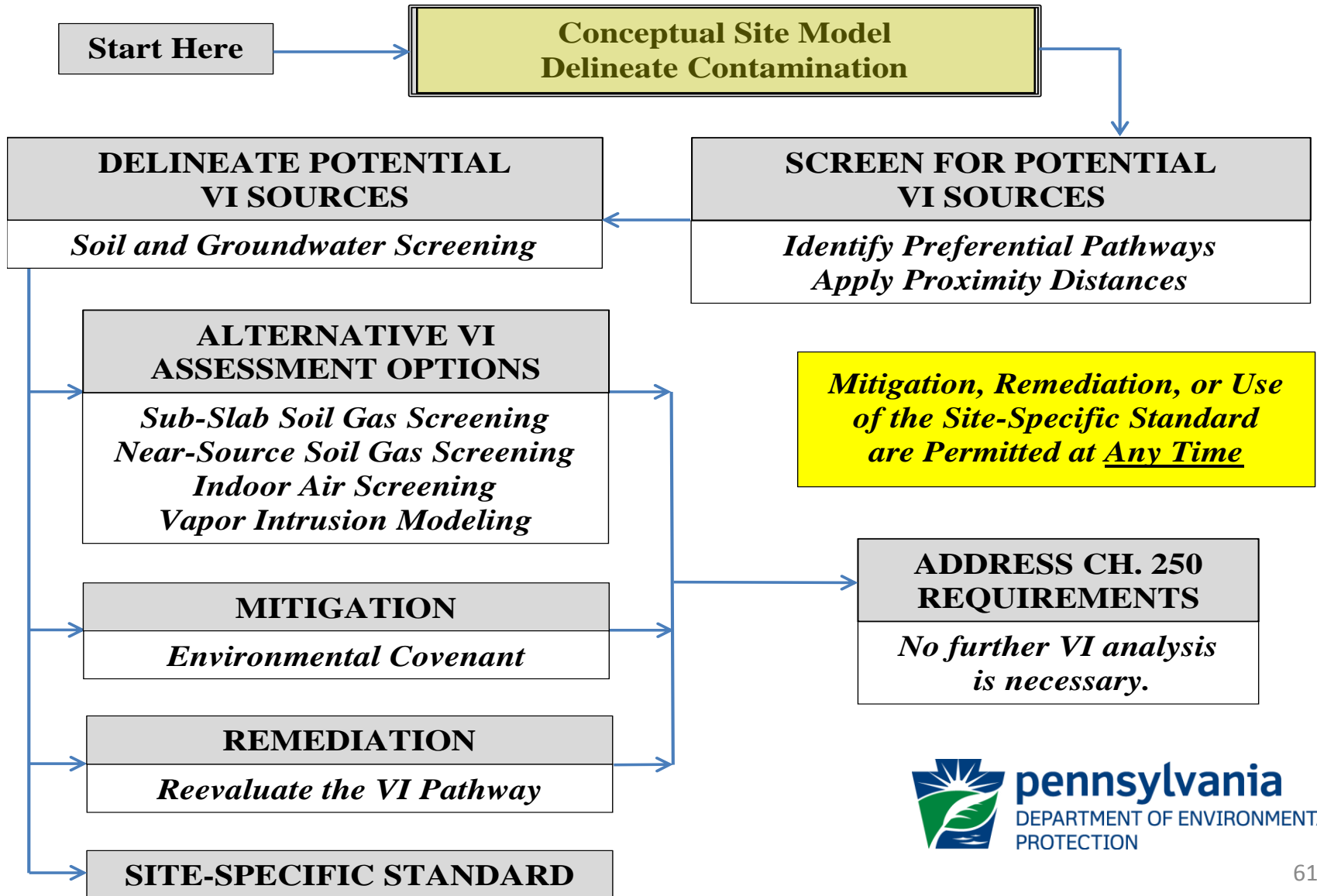
Not all steps will be necessary.

The process does not have to be followed sequentially.

SSS VI Evaluation Process



SHS VI Evaluation



SHS VI Evaluation

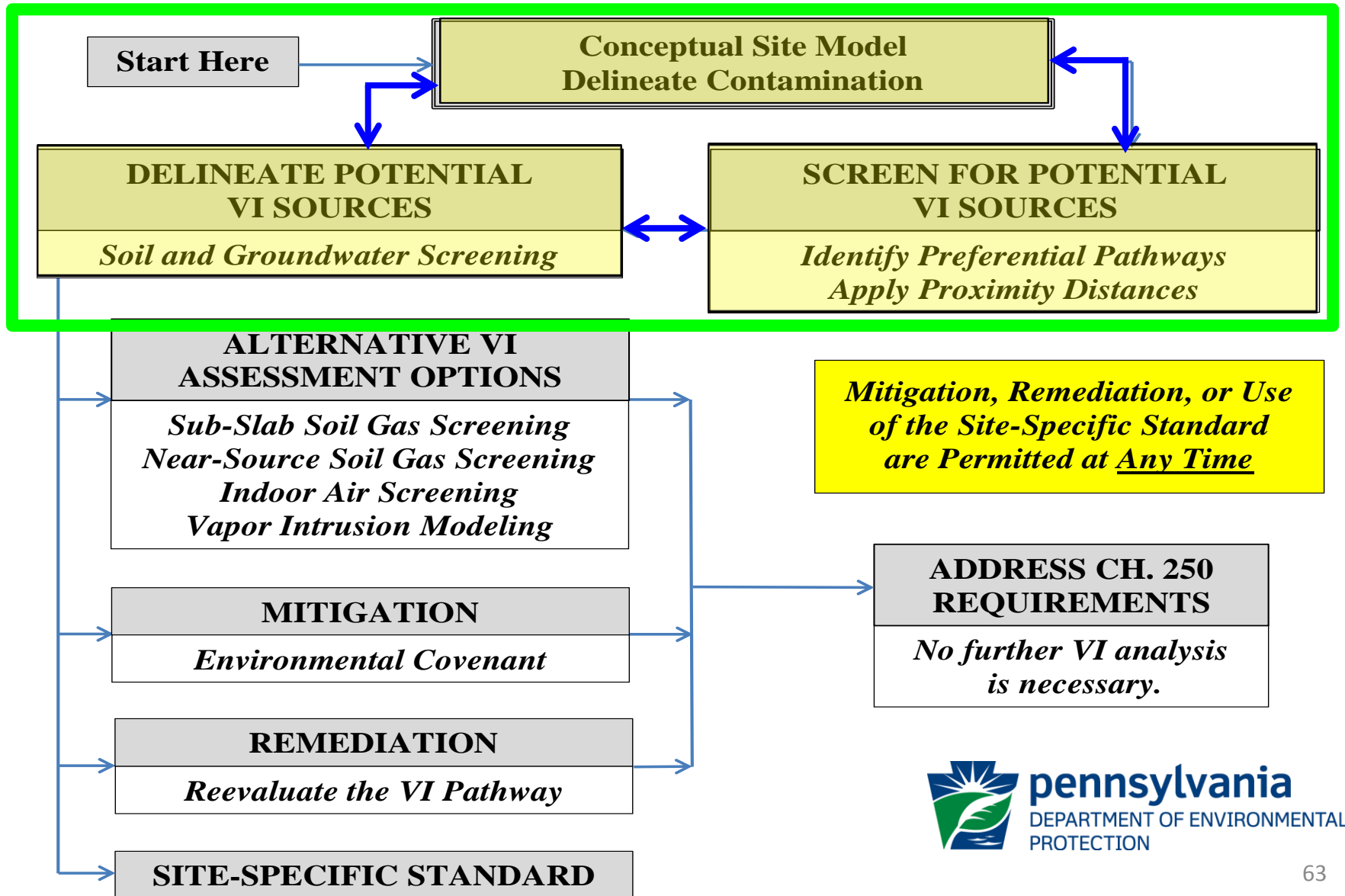
Small Petroleum Releases

- ✓ petroleum release to surface or subsurface soil
- ✓ full site characterization has not been performed

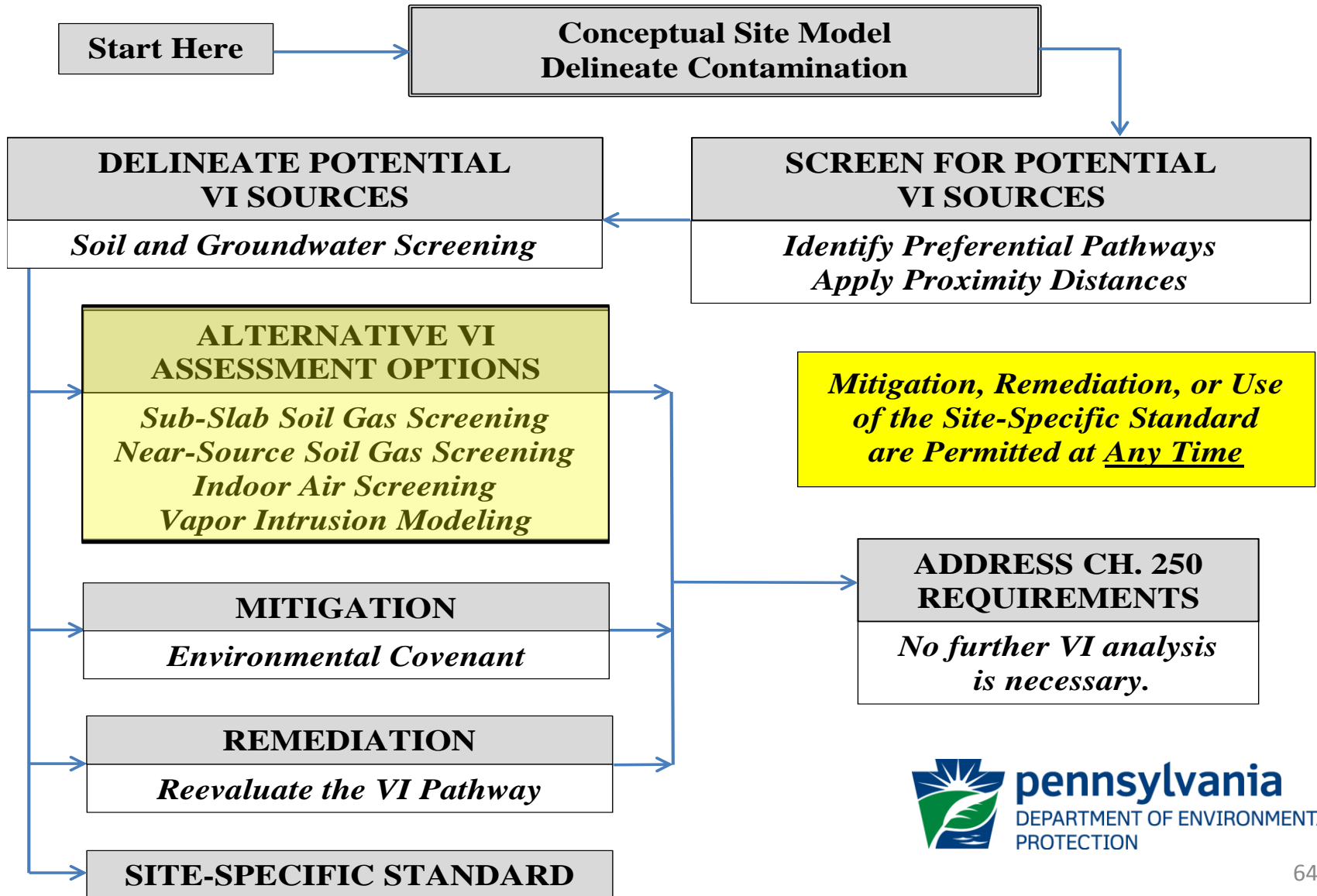
Remediator may attain the Statewide health standard through § 250.707(b)(1)(iii)

No VI Evaluation

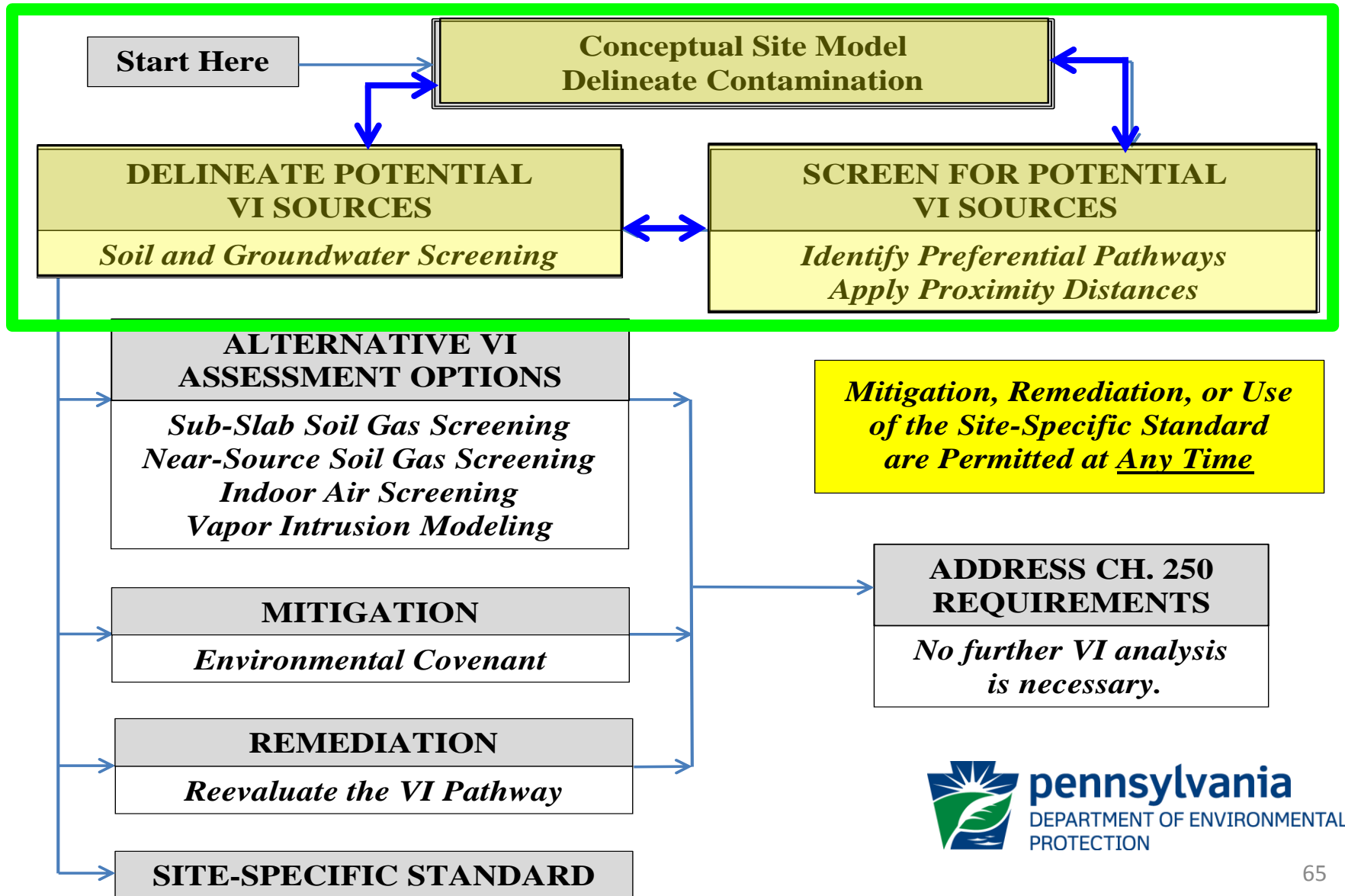
SHS VI Evaluation



SHS VI Evaluation



SHS VI Evaluation



Conceptual Site Model

CSM Goal:

To describe how site characteristics influence the distribution of VOCs in soil gas and indoor air.

Identify/Delineate whether a potential VI source is present

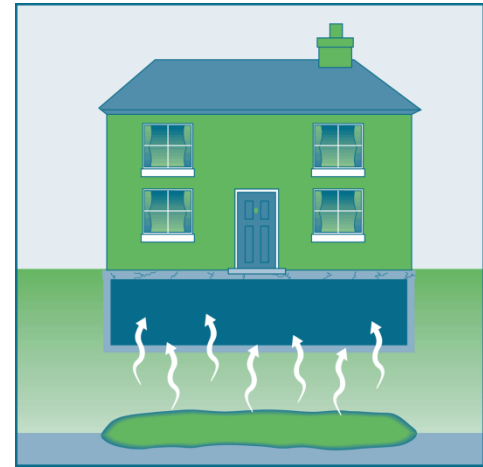
What is a potential VI source?

[Section C.1]

Conceptual Site Model

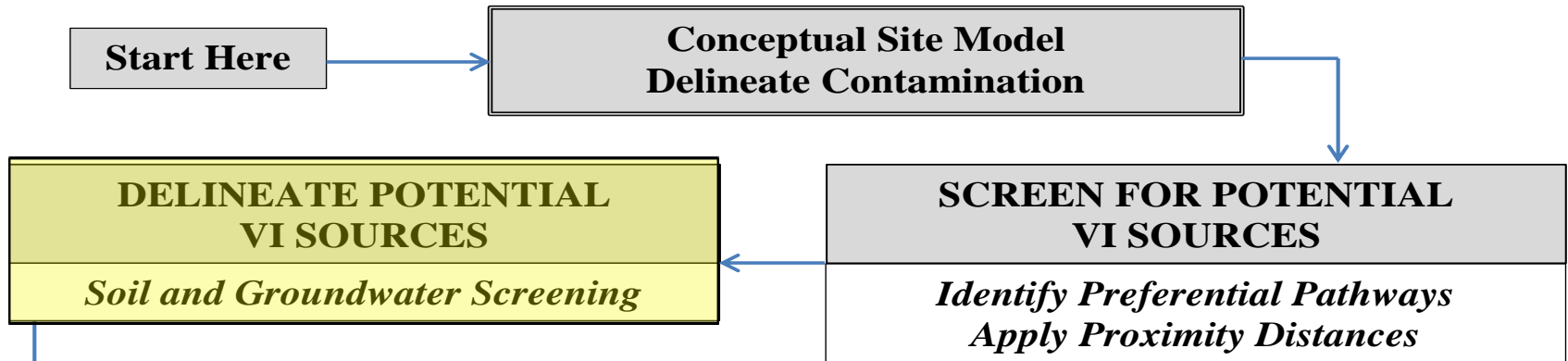
CSM represents:

- contaminant sources
- migration pathways
- exposure mechanisms
- potential receptors



Determine if a potential VI source is present by investigating proximity distances, external preferential pathways, and significant openings.

SHS VI Evaluation



This screening step is performed concurrently with the previous step because the proximity distances apply to locations where the soil and groundwater VI screening values are exceeded.

Conceptual Site Model

Components of the CSM

- Source description
- Contaminants of Concern
- Soil and Groundwater Data
- Migration pathways
- Preferential pathways
- Fate and transport
- Building construction/characteristics
- Receptors



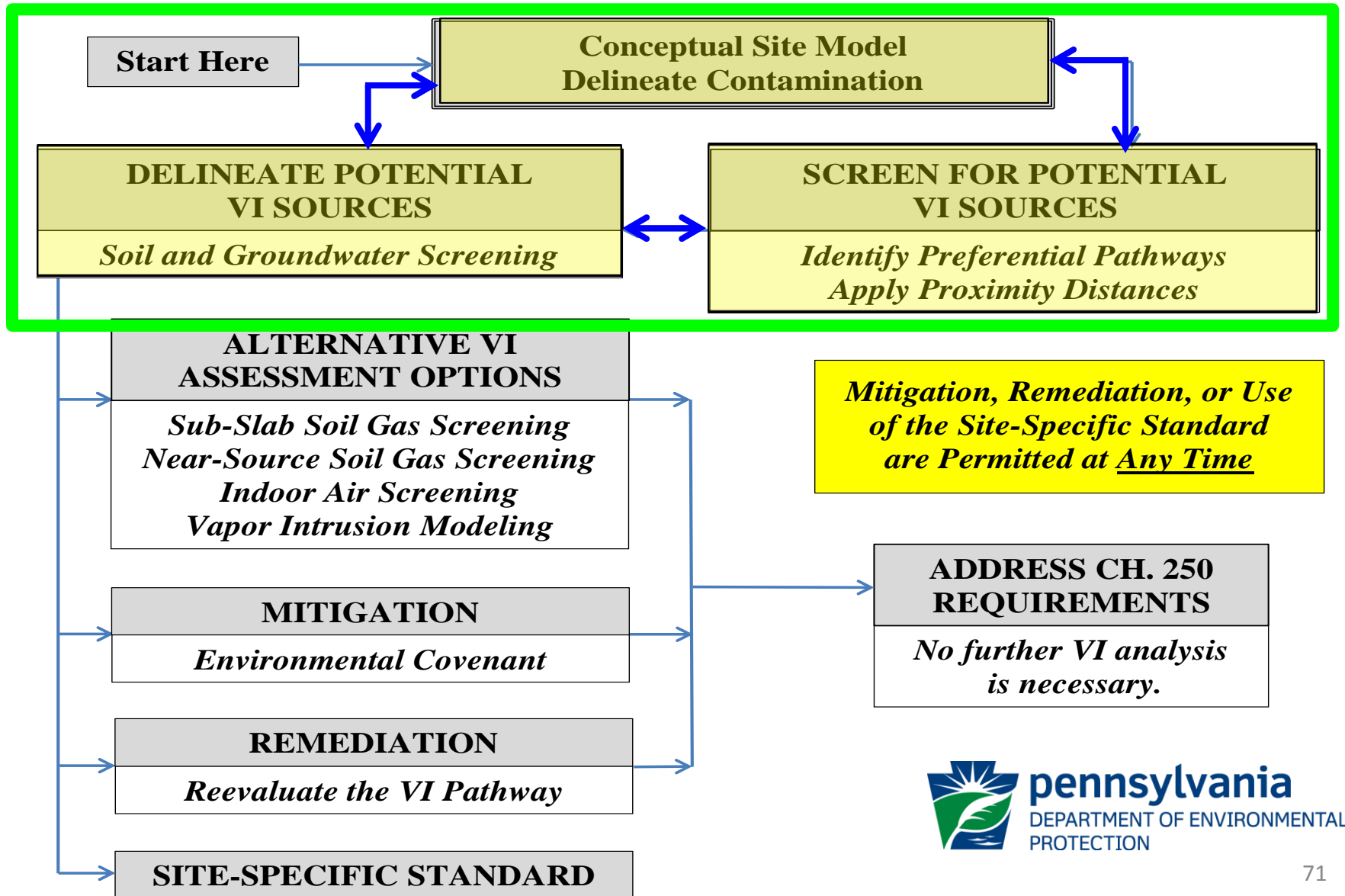
Conceptual Site Model

Additional CSM Considerations

- VOC concentrations decrease as the VOCs move away from the source.
- The degree of decrease is related to
 - ✓ site conditions
 - ✓ building characteristics
 - ✓ chemical properties

[Section C.1]

SHS VI Evaluation



Conceptual Site Model

Additional CSM Considerations

- Result in a more rigorous CSM development process than you may be accustomed to
- The level of detail in the CSM should reflect the complexity of the site
- CSM is a **DYNAMIC** tool
updated as new information becomes available during site characterization

Conceptual Site Model

Additional CSM Considerations

- ✓ Preferential Pathways
- ✓ Proximity Distances
- ✓ Future Buildings

To decide whether VI source is present or not

Proximity Distances

Horizontal:

- 30 feet for petroleum substances
- 100 feet for non-petroleum substances

Vertical:

- 5 feet for petroleum
- 15 feet for petroleum SPL
- None for non-petroleum substances



Proximity Distances

Petroleum

substances are treated differently than non-petroleum substances because of their

higher rates of biodegradation



Proximity Distances

Acceptable soil

is defined as having greater than 2% oxygen for the purpose of applying proximity distances to petroleum substances – **aerobic condition is required to support biodegradation**

- Not necessary to measure oxygen content unless there is reason to believe it is anaerobic.
(large SPL plume or a very large building over SPL)

Use of Proximity Distances

How Do I Use Them?

- Assess distance from the potential VI source to any existing or planned buildings and
- Assess distance from buildings towards the potential VI source

Use of Proximity Distances

- Evaluate VI for the portion of the exceedances within the proximity distance to the building

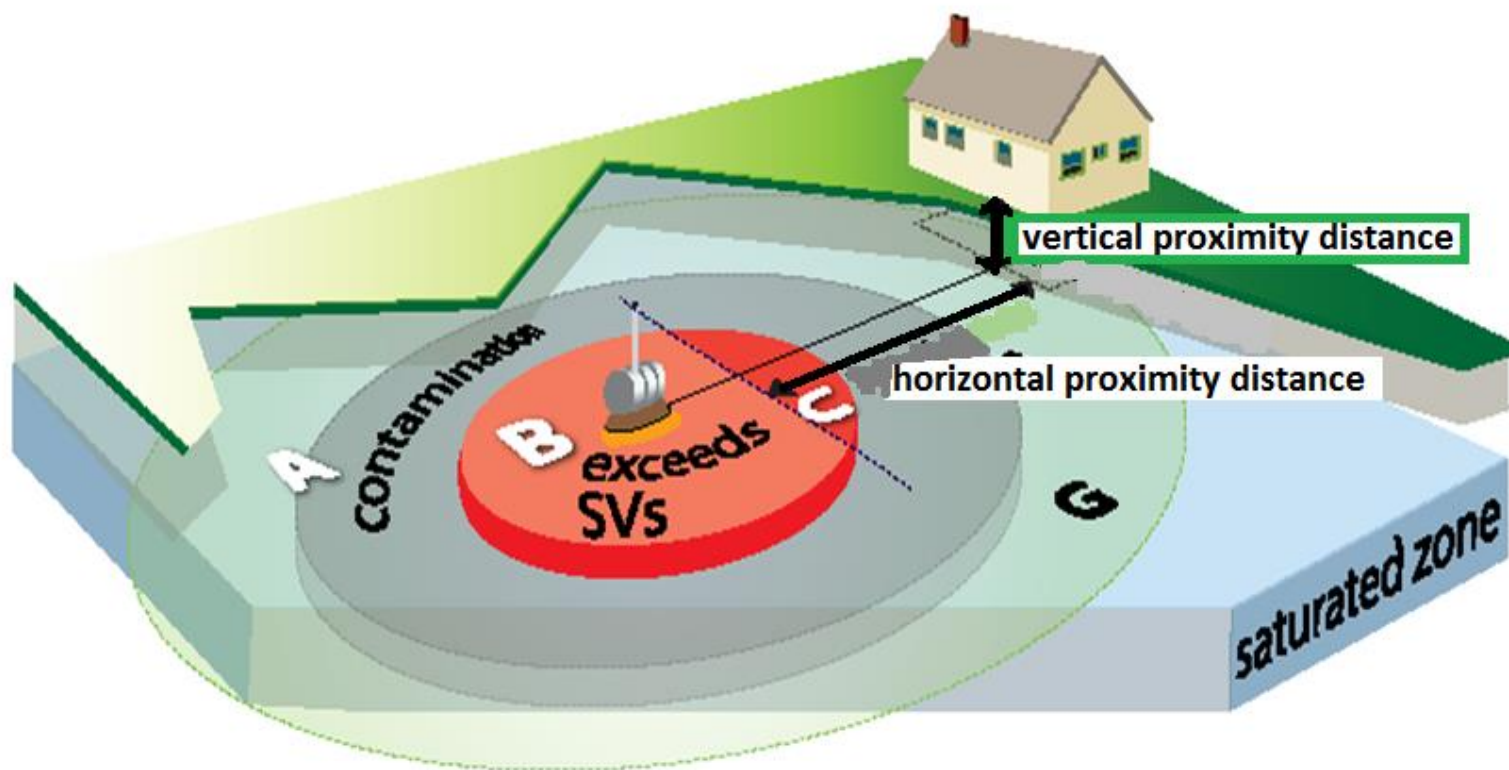


the Portion is now your Potential VI Source

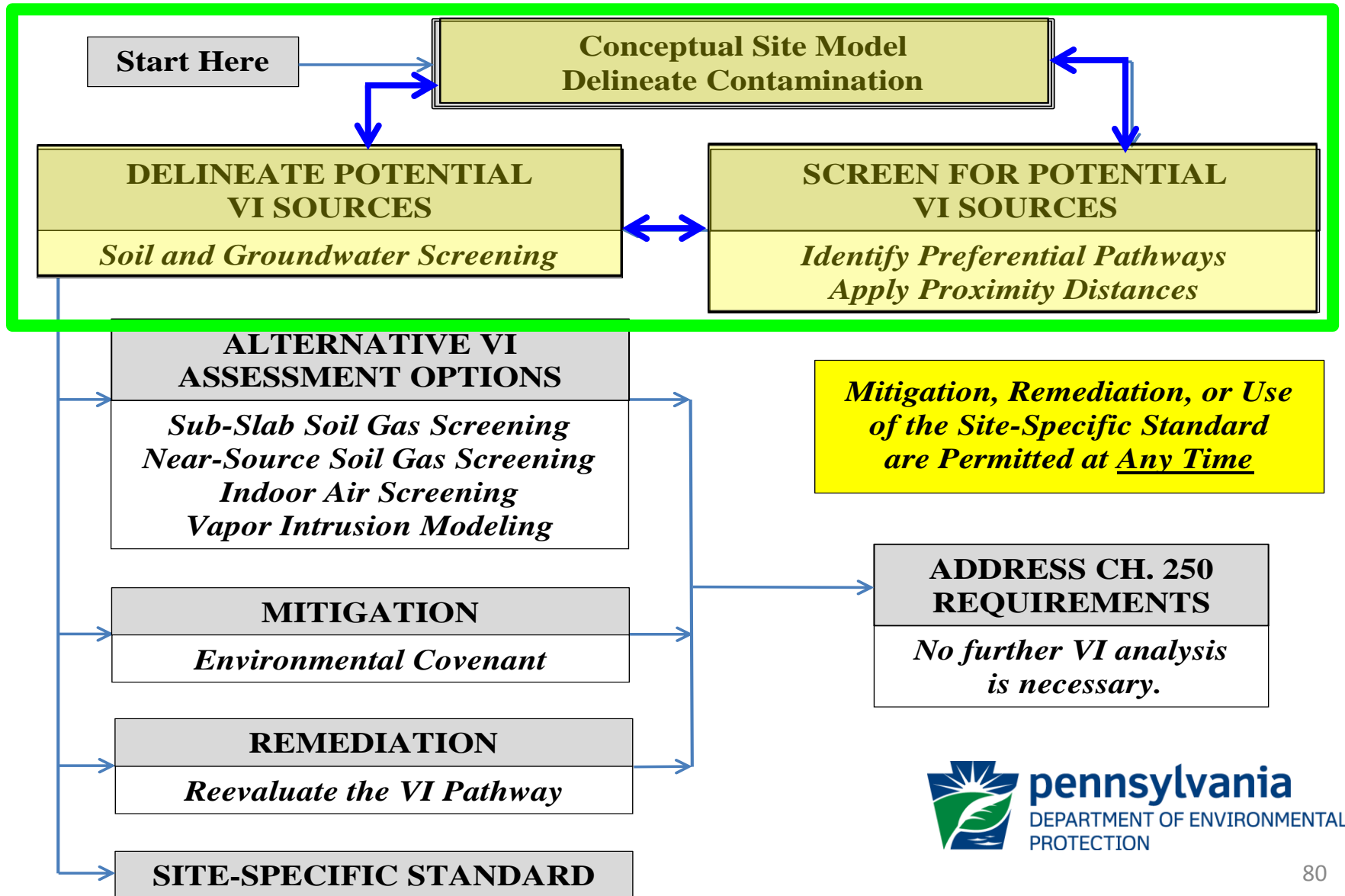
- Proximity distances are not applicable if there are no buildings onsite and no future plans for buildings to be constructed

Use of Proximity Distances

Figure 3



SHS VI Evaluation



Use of Proximity Distances

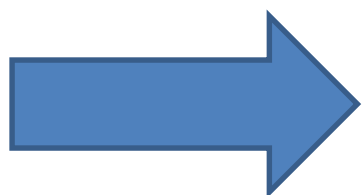
Restrictions

- Acceptable soil or soil-like material is needed to be able to use petroleum vertical proximity distances
- Proximity distances cannot be used in the presence of an external preferential pathway
- If a significant foundation opening is present, the petroleum vertical proximity distances cannot be used

Role of Preferential Pathways

Why are Preferential Pathways Important?

Preferential pathways



increase the rate of vapor migration between a source and an inhabited building.

- Less vapor attenuation through soil
- Increased rate of vapor flow to receptors

Role of Preferential Pathways

Professional Judgment and Communication

It is not necessary for remediators to prove the absence of preferential pathways, but a reasonable effort should be made to determine if they are present.



Remediators and PO's should discuss how preferential pathways should be evaluated at each site.

Preferential Pathways

Professional Judgment

Some assumptions can be made about buildings and utilities that would allow for an accurate analysis without an overly burdensome intrusive investigation.

- Size and type of utility
- Age of buildings/neighborhoods
- Progressive approach for evaluating external preferential pathways when feasible

Preferential Pathways

Example: High Permeability Backfilled Utility Line

- Remediators *do not* have to *prove the absence* of high-permeability backfill or intact utility lines.
- However, if there is *an indication that these conditions exist* then remediator should evaluate further.
 - Trench for large diameter water line – evaluate further
 - Fiber optic cable line – unlikely to be an issue



Preferential Pathways

Example: Older vs. Newer Housing Development

- Remediators *do not* have to *prove the absence* of dirt floors in a development.
- However, if there is *an indication that these conditions exist* then remediator should evaluate further.
 - Older homes where dirt floors are likely – evaluate further
 - Newer development – dirt floors unlikely to be an issue



Preferential Pathways

TWO TYPES

1. External Preferential Pathway

2. Significant Foundation Opening

External Preferential Pathways

External preferential pathway: a channel or conduit that allows for a greater vapor flux than ordinary diffusion through vadose zone soil

- ✓ Proximity Distances are insufficient to eliminate the source from consideration.
- ✓ Proximity Distances are based on movement of vapors through soil. In this case, vapors move through material with less attenuation than soil.

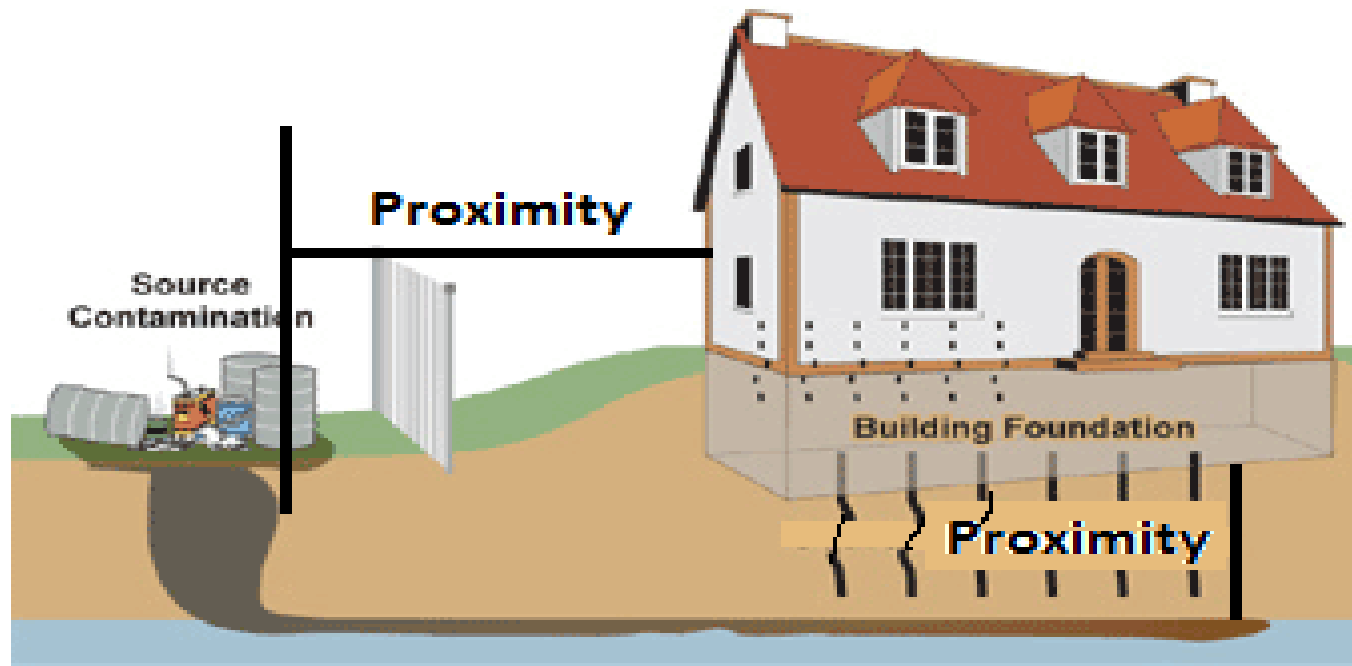
External Preferential Pathways

Proximity Distance – Measured between potential VI source and building

Separation Distance – Measure between potential VI source and underground feature to determine if that feature is an external preferential pathway

External Preferential Pathways

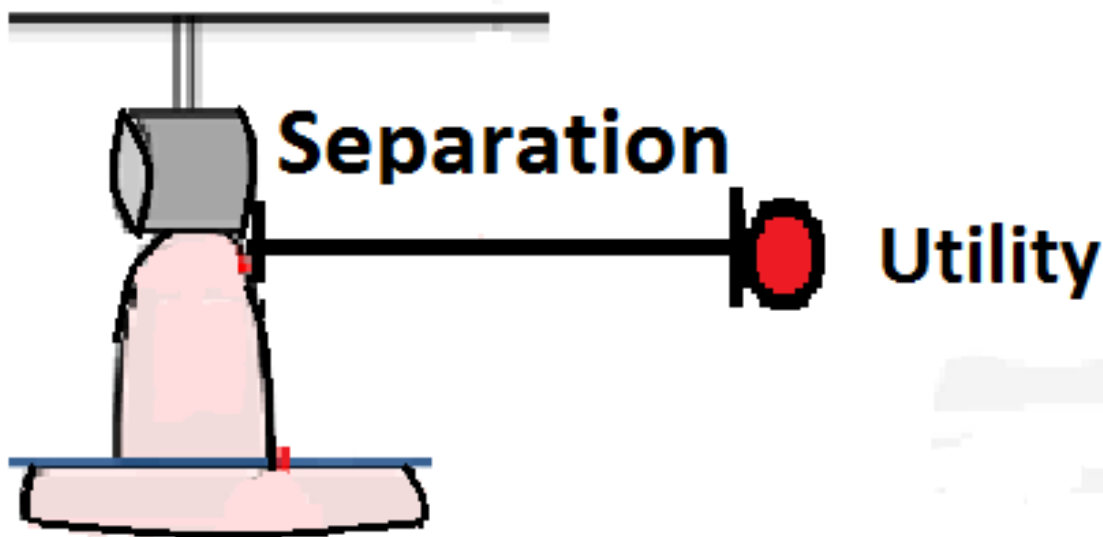
Proximity Distance – Between potential VI source and building



External Preferential Pathways

Separation Distance – Between potential VI source and underground feature

- to determine if that feature is an external preferential pathway



External Preferential Pathways

A feature can be excluded as an external preferential pathway if:

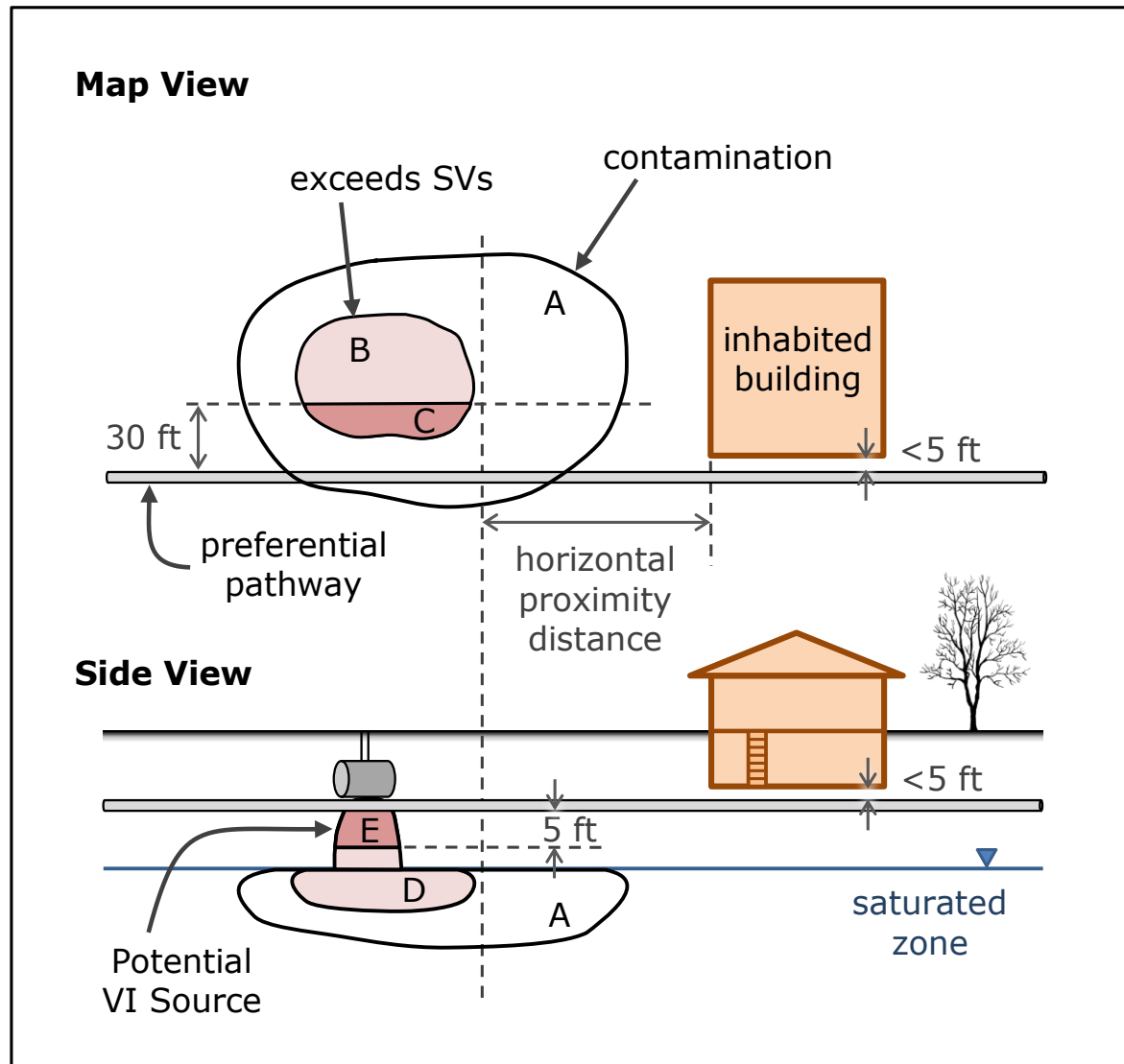
- Any soil or GW contamination exceeding VI screening values is at least 30 horizontal or 5 vertical feet from the feature.
- SPL is at least 30 horizontal or 15 vertical feet from the feature.

OR

- The feature is at least 5 feet away from the foundation.

External Preferential Pathways

Figure 2



Significant Foundation Openings

Significant foundation opening : enhances vapor entry into buildings

- ✓ Large cracks/gaps in the foundation and dirt floors
- ✓ **NOT** : Typical cracks, gaps, utility line penetrations – all buildings have them
- ✓ **NOT** : Common foundation openings such as sumps, French drains, and floor drains

Significant Foundation Openings

Significant foundation openings have **one or more** of the following:

- Combined area of openings in foundation surface is $\geq 5\%$ of the total foundation area
- Direct indications of contaminant entry into the building (seepage of SPL or groundwater, chemical odors)
- Opening is directly connected to an external preferential pathway (gap around utility line)

Significant Foundation Openings

VI Evaluation Options when Significant Openings are Present

Visually inspect the foundation and basement walls when possible.

- Sub-slab soil gas samples screened with indoor air screening values (if no dirt floor)
- Indoor air screening – even if contaminated soil, GW, or SPL is in the building

(See Figure 7 for screening value restrictions)

Significant Foundation Openings

Significant Foundation Openings can be sealed to inhibit the pathway.

Proper Sealing is performed with durable materials so that the former openings are not more transmissive than the rest of the foundation.



Significant Foundation Openings

VI Evaluation Options when Significant Openings are Present

IF foundation openings are sealed:

- Soil and GW may be screened with standard screening values
- Near-source soil gas can be screened with near-source screening values
- Sub-slab soil gas can be screened with sub-slab screening values

(See Figure 7 for screening value restrictions)

Significant Foundation Openings

VI Evaluation Options

When Building Access is Not Possible

- Can still use horizontal proximity distances to evaluate VI even if significant foundation openings are present.
 - ✓ This only works if there is no external preferential pathway present.
 - ✓ Vertical proximity distances do not apply – based on attenuation across an intact slab.
- Soil data may be screened against generic soil-to-GW values

(Section D.2, page 18)

Significant Foundation Openings

VI Evaluation Options

When Building Access is Not Possible

- GW may be screened against used aquifer MSCs
- Near-source soil gas may be screened against Sub-slab values or modeled to predict indoor air
- Modeling may be used by assuming that no slab is present

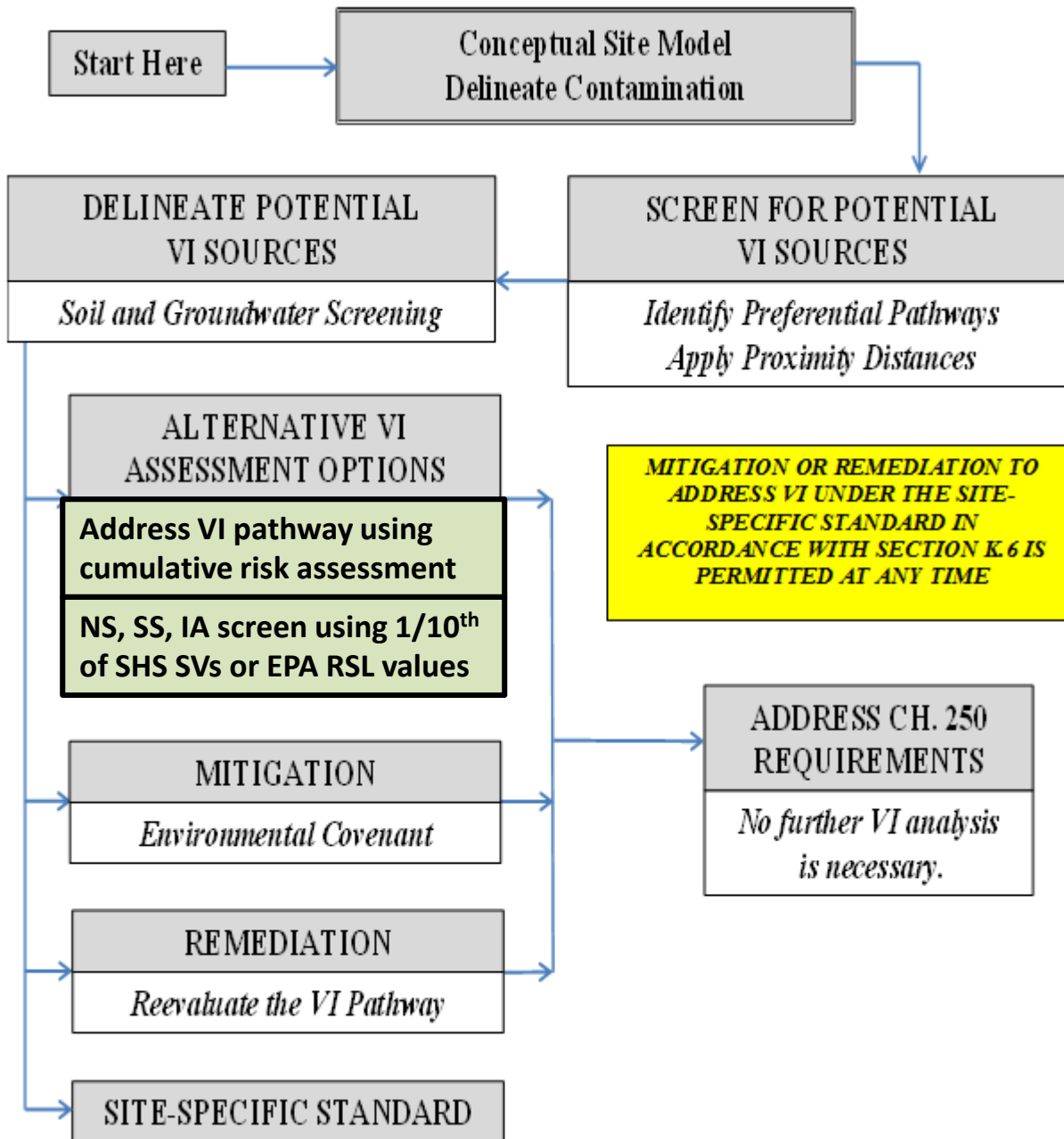


(Section D.2, page 18)

SSS Evaluation

- Proximity Distances and Preferential Pathways are evaluated in the same manner as under SHS
- SHS screening values still define potential VI source
- Acceptable soil or soil-like materials is also based on SHS screening values

SSS VI Evaluation Process



SSS VI Evaluation

SSS Evaluation

- SHS SV_{SOIL} and SV_{GW}

still define

potential VI source

SSS VI Evaluation

Act 2 Standard Used to Address Soil and Groundwater	VI Evaluation Tools					
	Use Screening Values in Tables 1–5	Use 1/10 Screening Values in Tables 1–5	Modeling	Risk Assessment	Mitigation with EC (i.e., pathway elimination)	Remediation
Statewide Health Standard (SHS)	✓		✓		✓	✓
Site-Specific Standard (SSS)		✓	✓	✓	✓	✓
Combination of Standards*	✓	✓	✓	✓	✓	✓

- Some media and/or substances may attain the SHS while others may attain the SSS.

[Section C.3]



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Questions?





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Vapor Intrusion Screening

Colleen Costello (GHD)

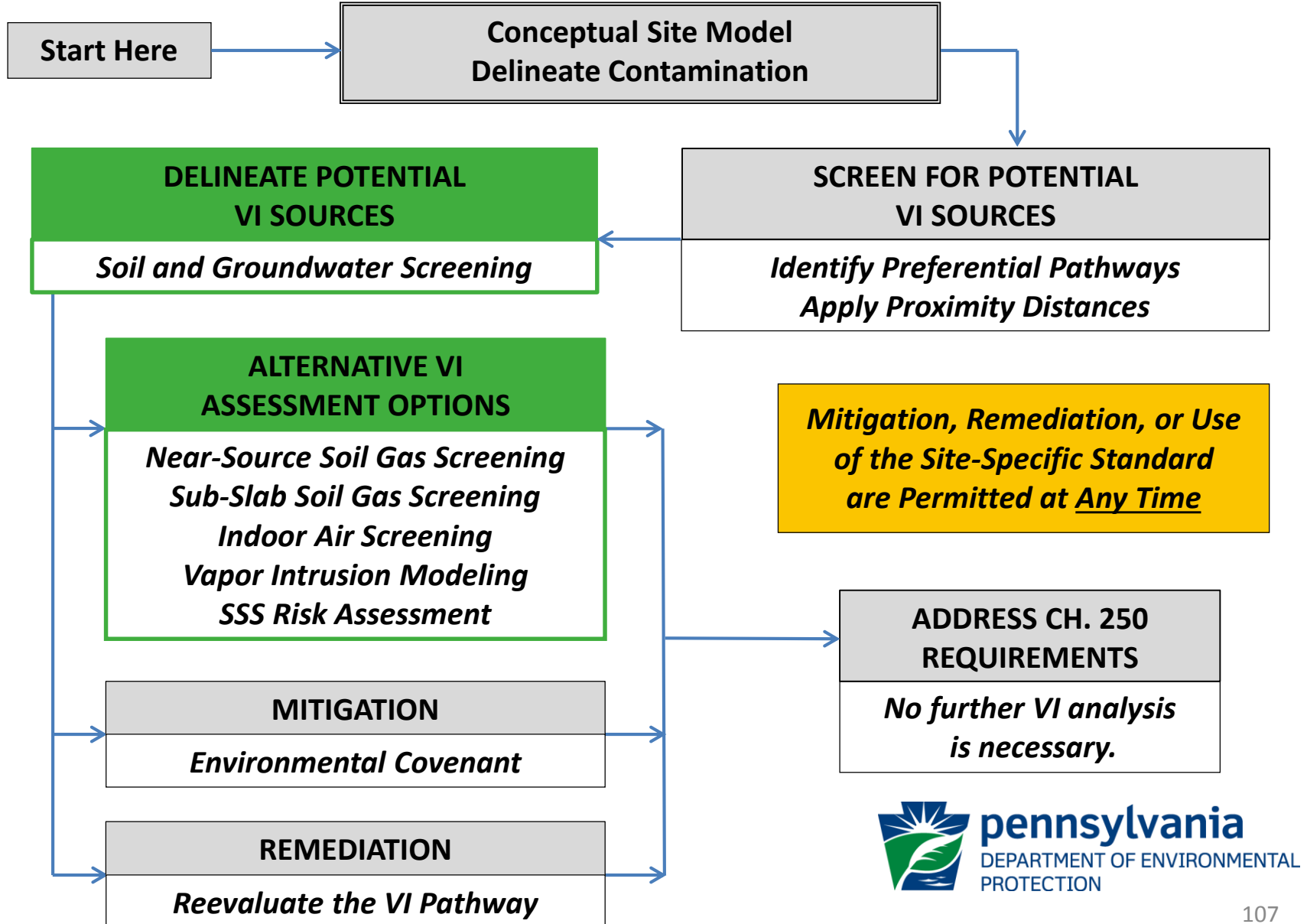
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Vapor Intrusion Guidance Training

January 10, 2017

Malvern, PA

VI Screening



VI Screening

- Purpose of vapor intrusion screening:
 - Determine if a Potential VI source is present
 - Screen pathway from source to receptor
- VI Guidance Sections F and G
- Tables 1–5 contain screening values for each of the five POAs
 - Groundwater, Soil, Near-Source Soil Gas, Sub-Slab Soil Gas, and Indoor Air

VI Screening

Main Points (What's New)

- All screening values have been recalculated
- Most values are now lower
- New, scientifically stronger, methods for determining screening values (SVs)
- New screening value tables for near-source soil gas and sub-slab soil gas
- Site-specific standard SVs established
- New criteria for applying SVs

Overview: Screening Presentation

- General information
- Basis of each type of screening value
- Data requirements
- Limitations
- Application of SVs
- Site-specific standard screening
- Combination of standards
- Site-specific standard RSL tutorial

VI Screening

Appendix A

- Derivation of new Statewide health standard VI screening values (SVs)
- Methodology, equations
- Chemical and toxicological parameters
- New attenuation factors

VI Screening

Some chemicals do not have inhalation toxicity values

- Example: cis-1,2-Dichloroethylene
- VI evaluations are **not required**
- VI can optionally be addressed with PQLs, mitigation, or remediation
- Remediator might be able to perform a SSS risk assessment (alternative toxicity information)

[Section C.2, Table A-1]

VI Screening

Attenuation is the process by which vapor concentrations decrease during migration

- Diffusion in soil
- Soil moisture
- Low-permeability zones in soil
- Biodegradation
- Dilution in indoor air

VI Screening

- **What is an attenuation factor?**

- The ratio between a vapor concentration in indoor air and in the subsurface

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

- Concentration units: $\mu\text{g}/\text{m}^3$
 - Attenuation factors are less than 1
 - Smaller $\alpha \rightarrow$ more attenuation
- DEP's SVs are calculated from SV_{IA} and α

VI Screening

Sample Type	Attenuation Factor		
	Residential α_R	Non-Residential α_{NR}	Converted Residential α_{CR}
Groundwater	0.0009	0.0003	0.0009
Soil	0.01	0.002	0.01
Near-source soil gas	0.005	0.001	0.005
Sub-slab soil gas	0.026	0.0078	0.026

[Table A-4]

VI Screening

Exposure scenarios

- Residential
- Nonresidential
- Converted residential: A building constructed for residential use that is currently used for nonresidential purposes only
e.g., a home now used for a shop
- Mixed use: may require using both residential and nonresidential SVs

VI Screening

Data for Screening

- Collect an appropriate amount of data
- Account for spatial, temporal variability
- Use data collection criteria in Table 6
- Recommendations in Appendix C, Section 2
- Satisfy screening conditions in Table 7
- Data may be from characterization, attainment, and/or monitoring

VI Screening – Figure 7

Source	Data Type	Screening Value	Screening Value Use Restriction	Reason for Restriction
Groundwater within proximity distances	Groundwater	SV _{GW}	<ol style="list-style-type: none"> 1. Presence of SPL within appropriate horizontal proximity distance 2. Presence of a significant foundation opening 3. Contaminated GW enters an external preferential pathway 4. GW < 5 feet below foundation level 	<ol style="list-style-type: none"> 1. SV_{GW} values or the used aquifer GW MSCs cannot be used in the presence of SPL because both values assume no SPL is present. 2. SV_{GW} values cannot be used in the presence of significant foundation openings because the calculated SV_{GW} values assume the presence of a slab. 3. SV_{GW} values cannot be used when GW enters a preferential pathway because the calculated SV_{GW} values assume attenuation through soil. 4. SV_{GW} values cannot be used when GW < 5 feet below foundation level because the calculated SV_{GW} values require at least 5 feet of soil. <p>• NOTE: For site-specific standard screening, use 1/10th of the Table 1 or MSC values.</p>
		Used Aquifer GW MSC	<ol style="list-style-type: none"> 1. Presence of SPL within appropriate horizontal proximity distance 	
Soil within proximity distances	Soil	SV _{SOIL}	<ol style="list-style-type: none"> 1. Presence of SPL within appropriate horizontal proximity distance 2. Presence of a significant foundation opening 	<ol style="list-style-type: none"> 1. SV_{SOIL} values and the generic soil-to-GW numeric values cannot be used in the presence of SPL because both values assume no SPL is present. 2. SV_{SOIL} values cannot be used in the presence of a significant foundation opening because the calculated SV_{SOIL} values assume a slab is present. <p>• NOTE: For SSS screening, use 1/10th of the Table 2 or MSC values.</p>
		Generic Soil-to-GW Numeric Value	<ol style="list-style-type: none"> 1. Presence of SPL within appropriate horizontal proximity distance 	
Groundwater or Soil within proximity distances	Near-Source Soil Gas	SV _{NS}	<ol style="list-style-type: none"> 1. Contaminated GW or SPL enters a preferential pathway 2. Presence of a significant foundation opening 3. External preferential pathway penetrates the building foundation 4. Potential VI source is < 5 feet below foundation level 	<ol style="list-style-type: none"> 1. SV_{NS} values cannot be used when contaminated GW or SPL enters an external preferential pathway because the SV_{NS} values assume attenuation through soil. 2. SV_{NS} values cannot be used in the presence of a significant foundation opening because the SV_{NS} values assume the presence of a slab. 3. SV_{NS} values cannot be used if an external preferential pathways penetrates the building foundation because the SV_{NS} values assume the presence of a slab. 4. SV_{NS} values cannot be used if the potential VI source is < 5 feet below foundation level because the SV_{NS} values assume 5 feet of soil between the source and the foundation. 5. A comparison of near-source soil gas data to SV_{SS} values cannot be performed if the potential VI source is < 5 feet below grade because shallow soil gas data can be unreliable. <p>• NOTE: For SSS screening, use 1/10th of the Table 3 values or use EPA indoor air RSLs with an appropriate attenuation factor.</p>
		SV _{SS}	<ol style="list-style-type: none"> 1. Potential VI source is < 5 feet below grade 	
	Sub-Slab Soil Gas	SV _{SS}	<ol style="list-style-type: none"> 1. Presence of a significant foundation opening 2. Preferential pathway penetrates the building foundation 	<ol style="list-style-type: none"> 1. The comparison of sub-slab data to SV_{SS} is not available in the presence of a significant foundation opening because the calculation of the SV_{SS} values assumes the presence of an intact slab. 2. The comparison of sub-slab data to SV_{SS} is not available if an external preferential pathway penetrates the building foundation because the SV_{SS} values presume the presence of soil between the source and foundation. <p>• NOTE: For SSS screening, use 1/10th of the Table 4 values or use EPA indoor air RSLs with an appropriate attenuation factor.</p>
		SV _{IA}	No Restrictions	
	Indoor Air	SV _{IA}	No Restrictions	<p>• NOTE: For SSS screening, use 1/10th of the Table 5 values or use EPA indoor air RSLs.</p>
		SV _{IA}	No Restrictions	

Groundwater Screening Values

Basis of Groundwater SVs

- Attenuation factors from EPA's VI database
- Groundwater VI screening values are no lower than Ch. 250 used aquifer MSCs
- Calculated values or MSCs for ≥ 5 feet depth
- If GW < 5 feet below foundation, only MSCs
- *Note: Table 1 VI SVs have changed since July 2015 draft!*

[Table 1; Appendix A, Section 5]

Groundwater Screening Values

Data Requirements

- Properly constructed monitoring wells
- Well screens cross the water table
- Wetted length of screen ≤ 10 feet
- Acceptable soil or soil-like material present vertically between groundwater and building
- At least two rounds of data

[Table 6]

Groundwater Screening Values

Screening Limitations

- No SPL (NAPL) is present
- If groundwater enters an external preferential pathway:
 - Use groundwater MSCs only
- If a significant foundation opening is present:
 - Use groundwater MSCs only

[Section F, Figure 7]

Groundwater Screening Values— SV_{GW}

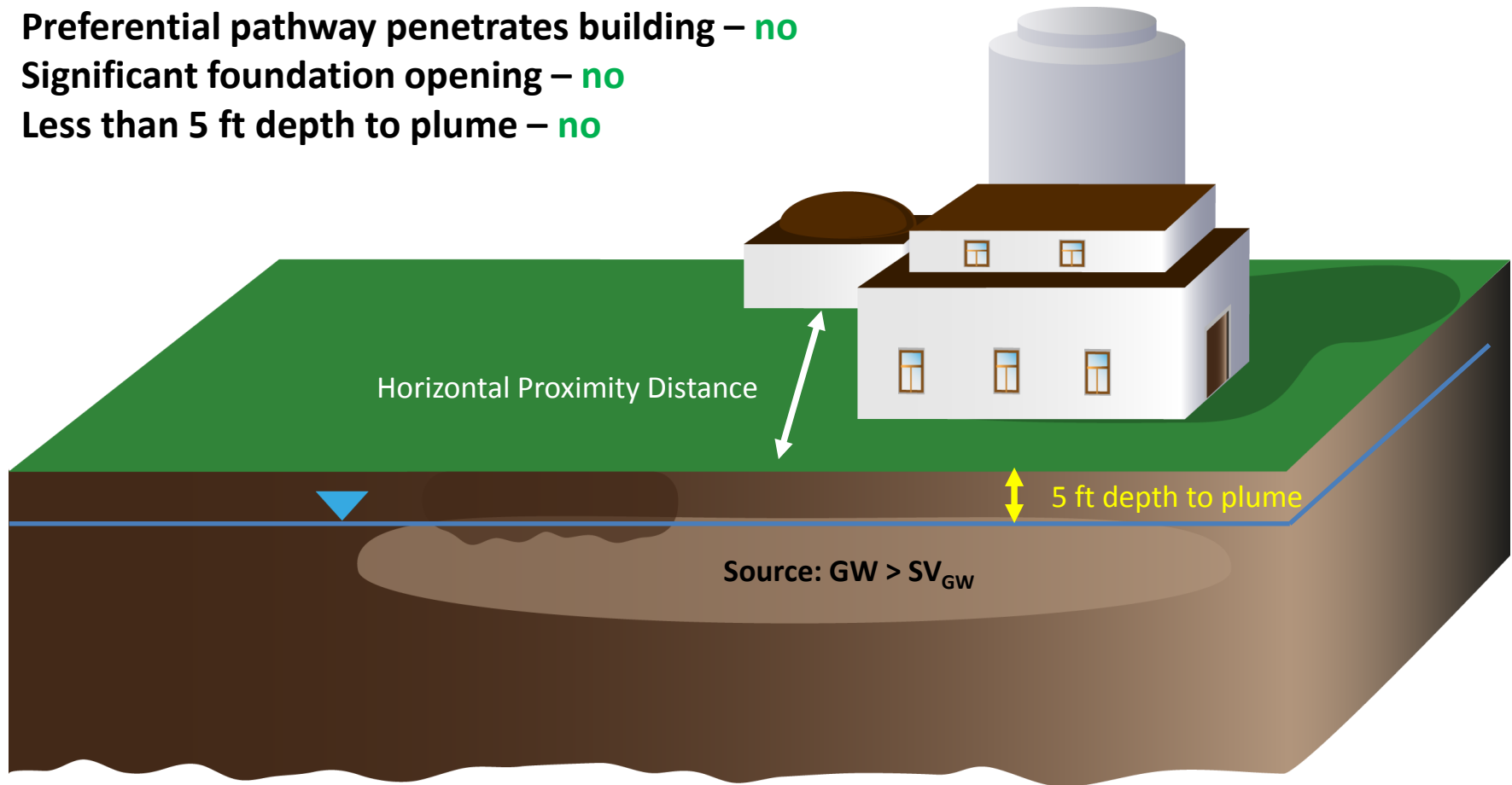
SPL present – **no**

Preferential pathway w/in 5 ft of building – **no**

Preferential pathway penetrates building – **no**

Significant foundation opening – **no**

Less than 5 ft depth to plume – **no**



**NO RESTRICTIONS – GW screening values based on
HIGHER of the Ch. 250 Used Aquifer MSC or the Calculated SV_{GW}
(which is based on EPA attenuation factors from GW to indoor air)**

Groundwater Screening Values— SV_{GW}

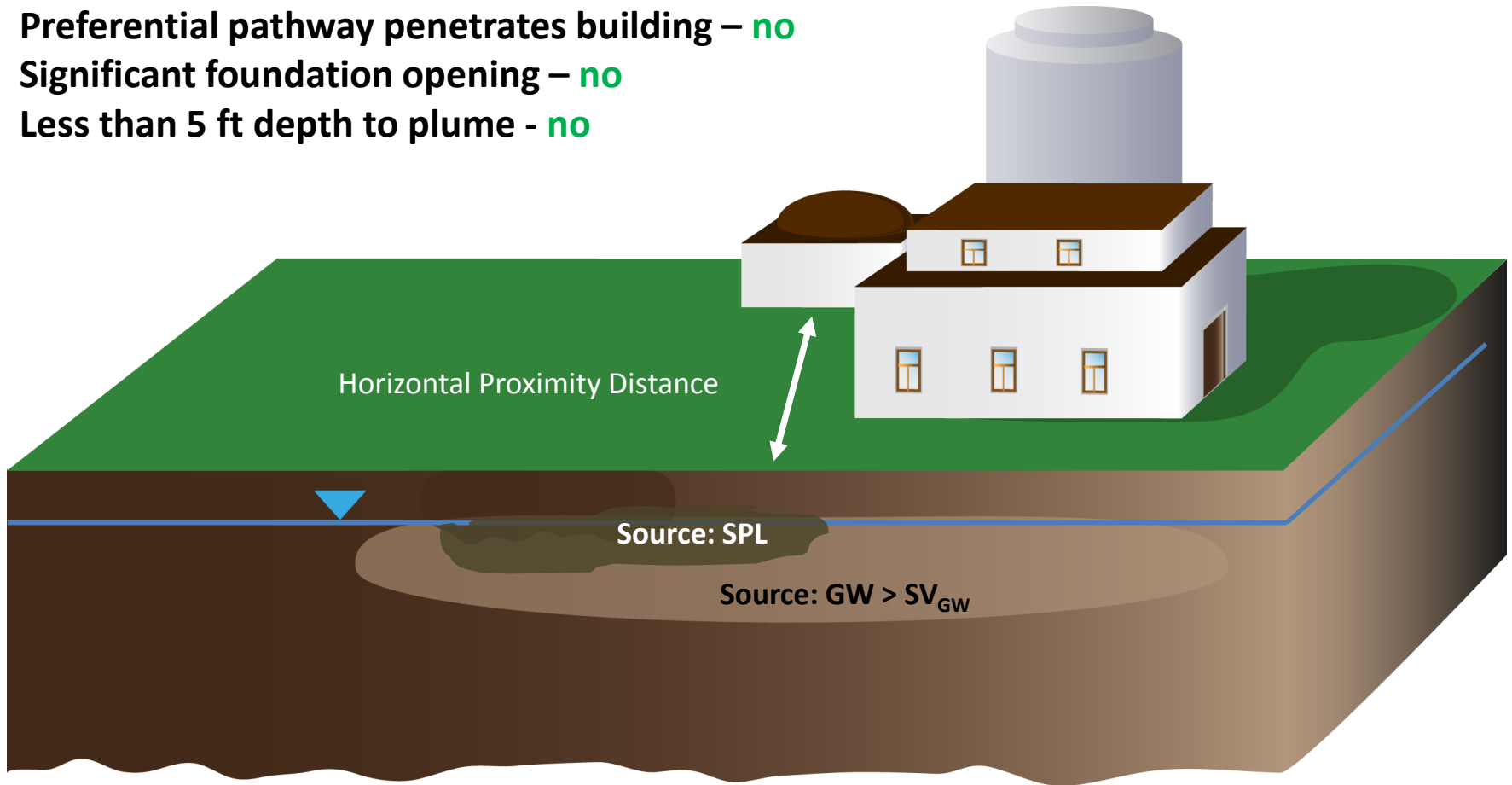
SPL present – **YES**

Preferential pathway w/in 5 ft of building – **no**

Preferential pathway penetrates building – **no**

Significant foundation opening – **no**

Less than 5 ft depth to plume - **no**



You cannot use *any* GW screening value (SV_{GW}) within SPL areas
but you can use alternative assessment options

Groundwater Screening Values— SV_{GW}

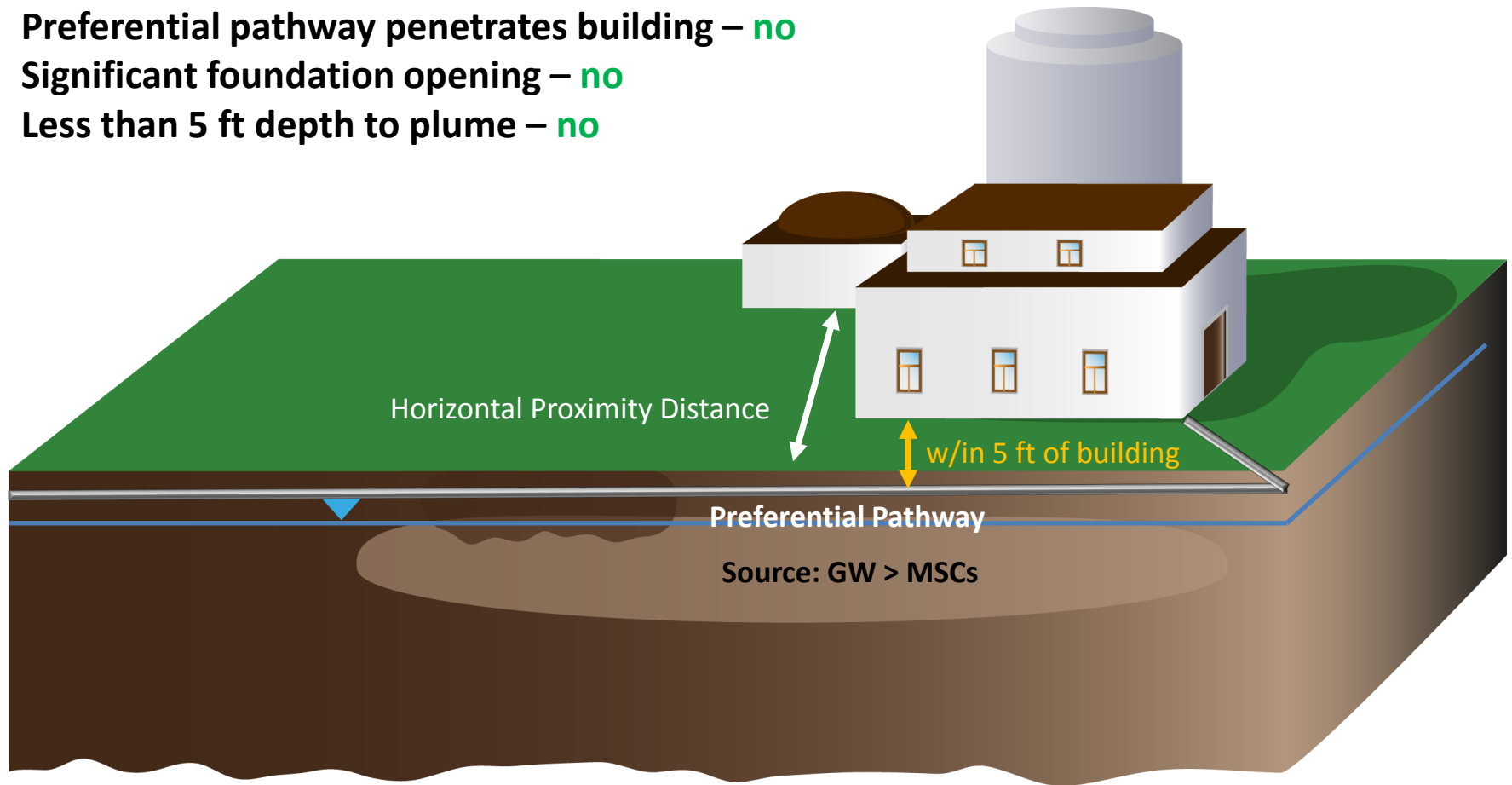
SPL present – **no**

Contamination inside preferential pathway w/in 5 ft of building – **YES**

Preferential pathway penetrates building – **no**

Significant foundation opening – **no**

Less than 5 ft depth to plume – **no**



You cannot use the calculated GW screening value (SV_{GW})
but you can use GW Used Aquifer MSC

Groundwater Screening Values— SV_{GW}

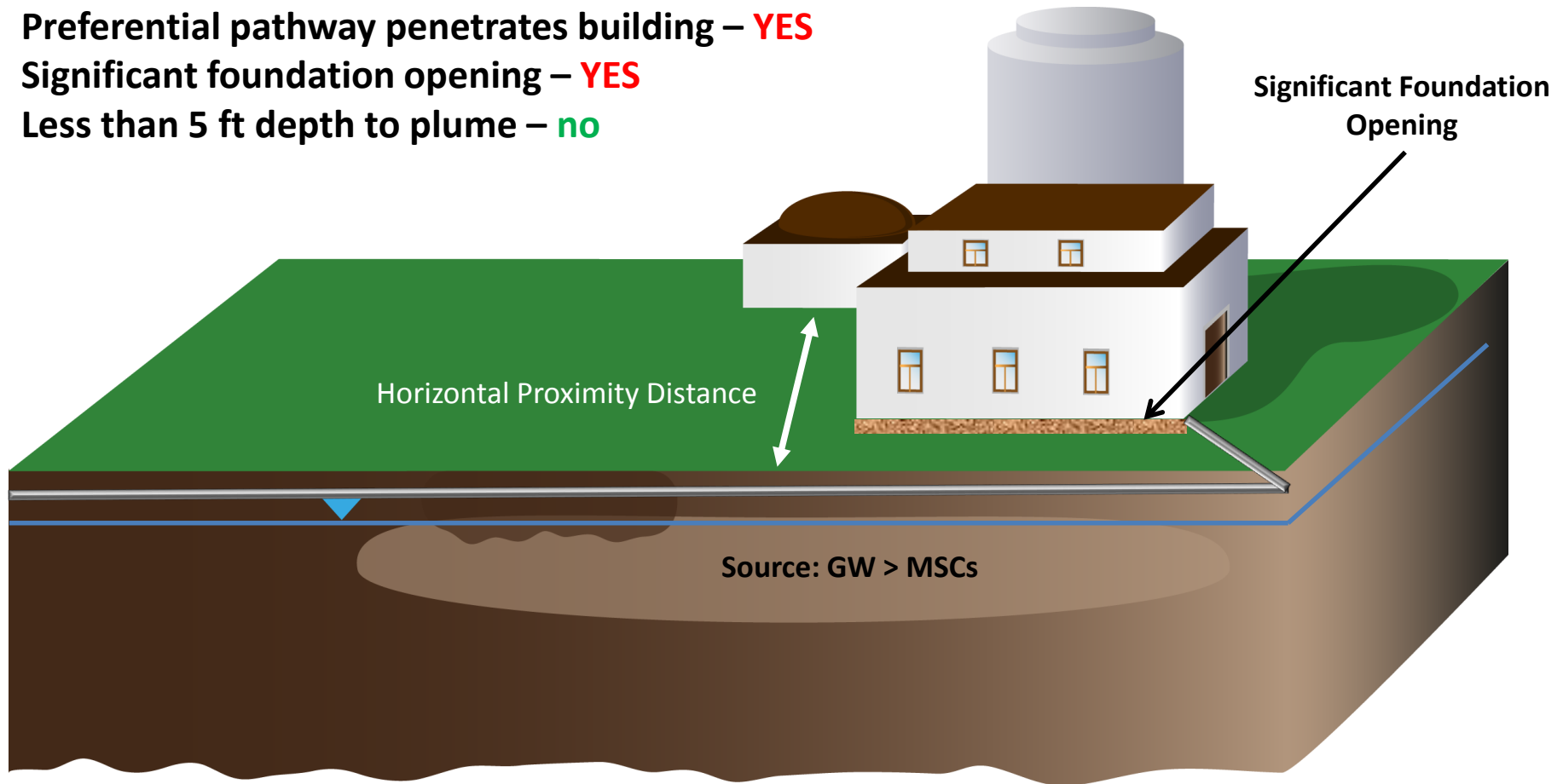
SPL present – **no**

Preferential pathway w/in 5 ft of building – **no**

Preferential pathway penetrates building – **YES**

Significant foundation opening – **YES**

Less than 5 ft depth to plume – **no**



You cannot use the calculated GW screening value (SV_{GW})
but you can use GW Used Aquifer MSC

Groundwater Screening Values— SV_{GW}

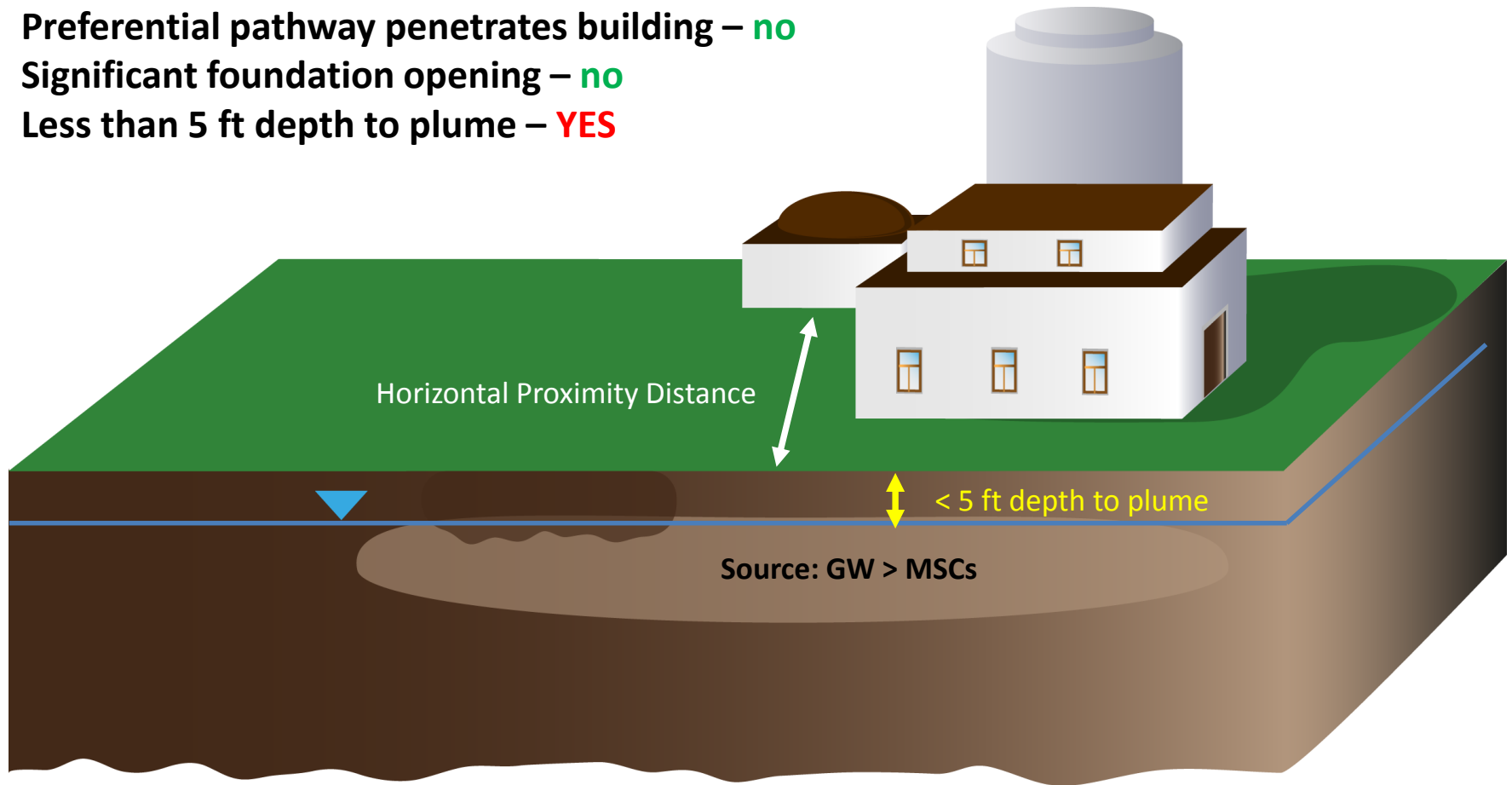
SPL present – **no**

Preferential pathway w/in 5 ft of building – **no**

Preferential pathway penetrates building – **no**

Significant foundation opening – **no**

Less than 5 ft depth to plume – **YES**



You cannot use the calculated GW screening value (SV_{GW})
but you can use GW Used Aquifer MSC

Groundwater Screening Values

Application of SVs

- With characterization data: no exceedences
- Suitable statistical tests of attainment data
 - Statewide health standard **only**
 - 75%/10x and/or 75%/2x or 95% UCL tests
 - No exceedences if less than eight rounds
- Remember—groundwater screening is performed at appropriate POAs, **not POC!**

[Section F.2, Table 7]

Soil Screening Values

Basis of Soil SVs

- Attenuation factors derived from Johnson & Ettinger model simulations
- Soil VI screening values are no lower than generic soil-to-groundwater numeric values
- *Note: Table 2 VI SVs have changed since July 2015 draft!*

[Table 2; Appendix A, Section 4]

Soil Screening Values

Data Requirements

- Samples collected in unsaturated zone

[Table 6]

Soil Screening Values

Screening Limitations

- No SPL (NAPL) is present
- If a significant foundation opening is present:
 - Use generic soil-to-groundwater numeric values only
- ***There is no 5-foot depth limitation!***
 - Soil screening values apply to shallow soil (e.g., immediately below foundation)

[Section F, Figure 7]

Soil Screening Values— SV_{SOIL}

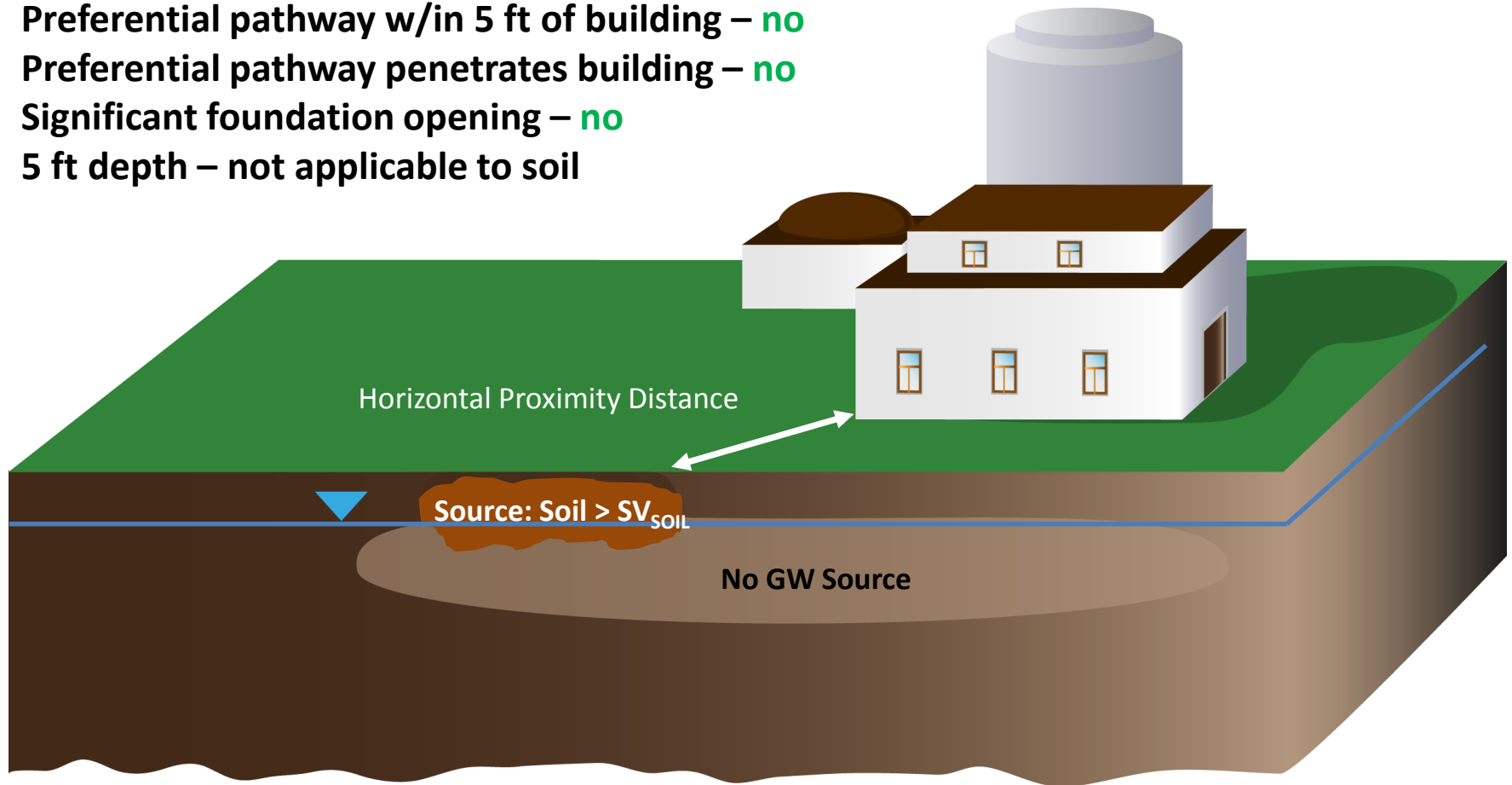
SPL Present – **no**

Preferential pathway w/in 5 ft of building – **no**

Preferential pathway penetrates building – **no**

Significant foundation opening – **no**

5 ft depth – not applicable to soil



**NO RESTRICTIONS – Soil Screening values based on
HIGHER of the Ch. 250 Generic Soil-to-GW values or the Calculated SV_{SOIL}
(which is based on attenuation factors derived from J&E model)**

Soil Screening Values— SV_{SOIL}

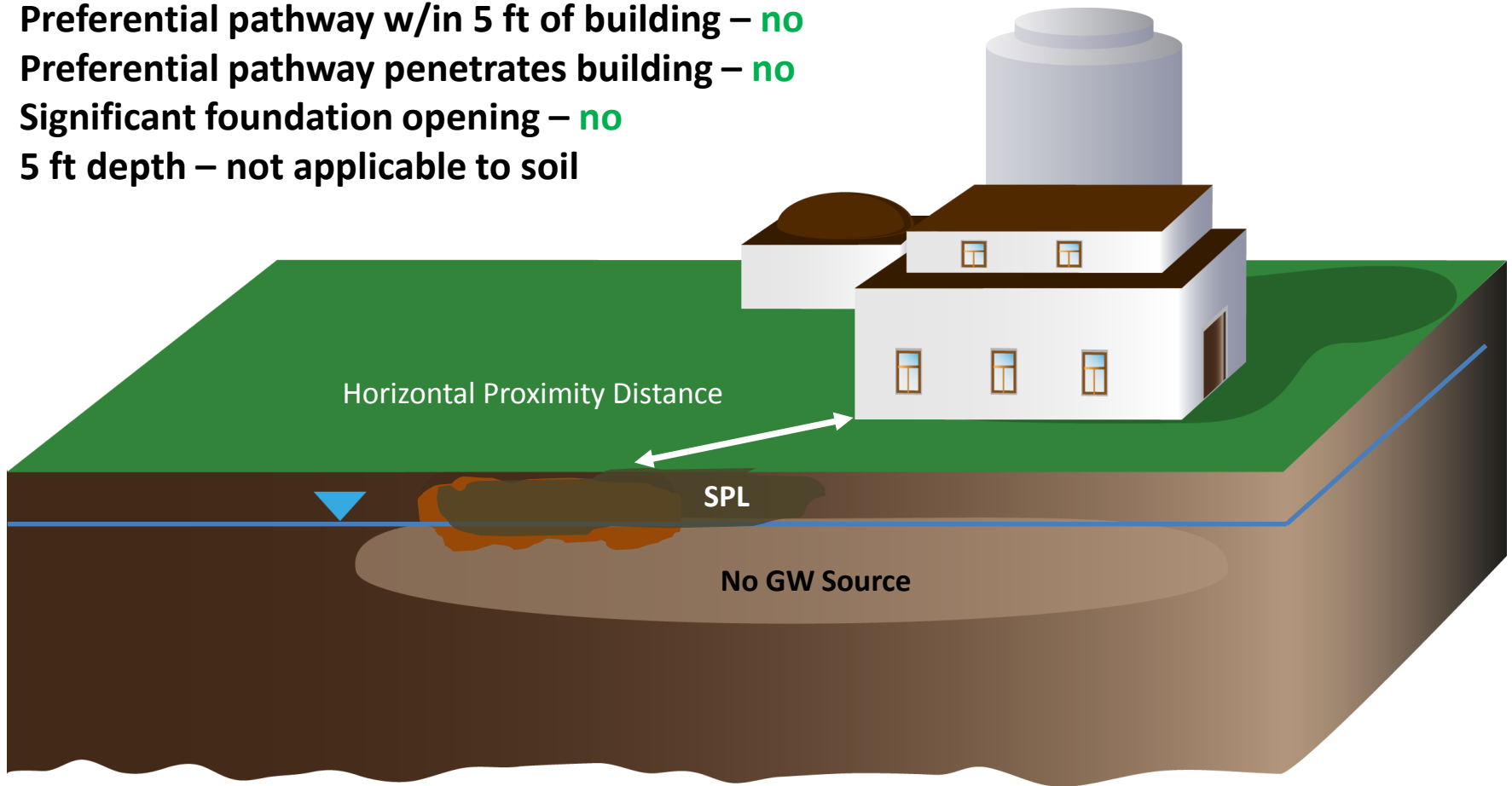
SPL Present – **YES**

Preferential pathway w/in 5 ft of building – **no**

Preferential pathway penetrates building – **no**

Significant foundation opening – **no**

5 ft depth – not applicable to soil



You cannot use *any* soil screening value (SV_{SOIL})
but you can use alternative assessment options

Soil Screening Values— SV_{SOIL}

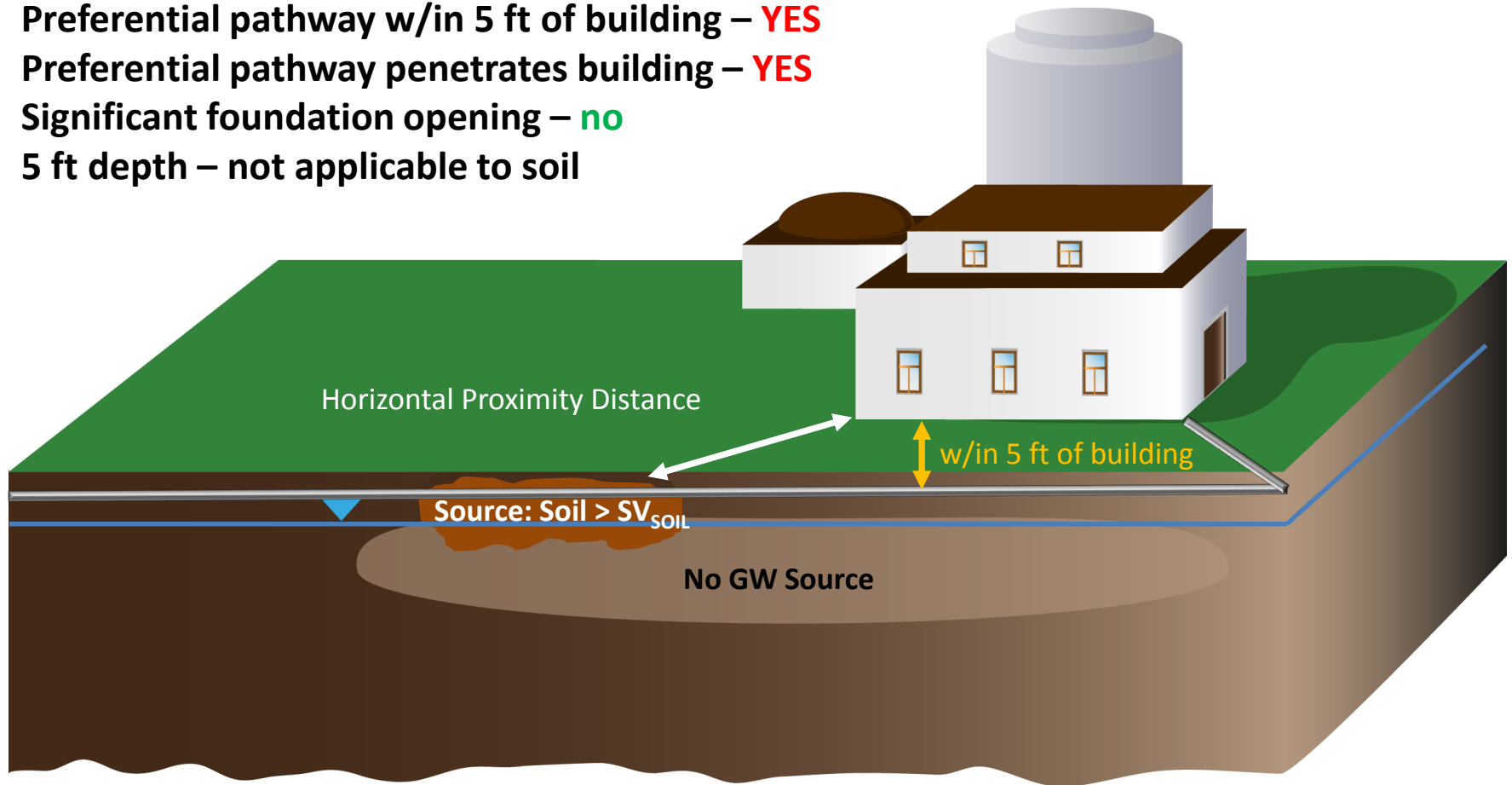
SPL Present – **no**

Preferential pathway w/in 5 ft of building – **YES**

Preferential pathway penetrates building – **YES**

Significant foundation opening – **no**

5 ft depth – not applicable to soil



**NO RESTRICTIONS – Soil Screening values based on
HIGHER of the Ch. 250 Generic Soil-to-GW values or the Calculated SV_{SOIL}
(which is based on attenuation factors derived from J&E model)**

Soil Screening Values— SV_{SOIL}

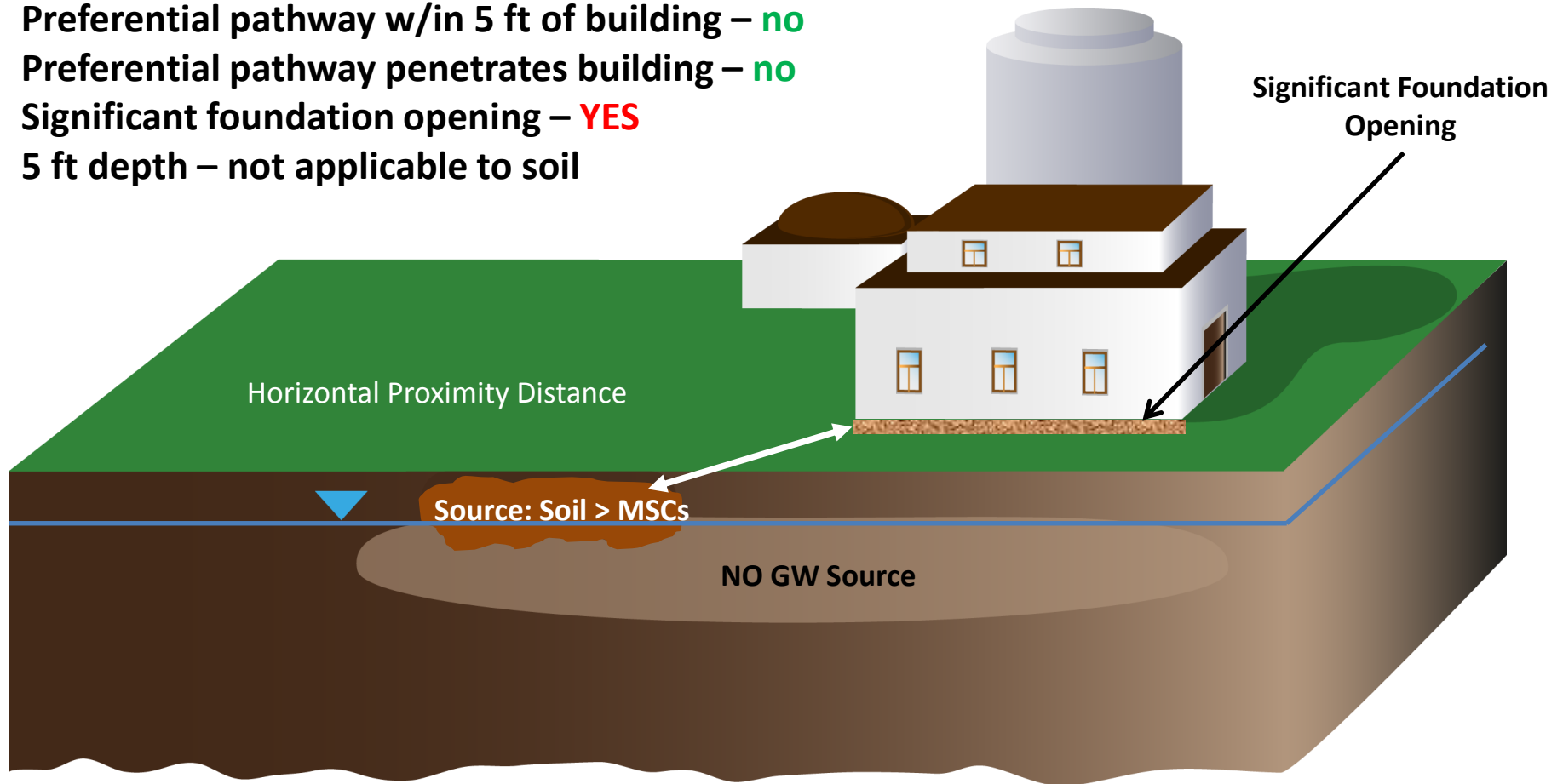
SPL Present – **no**

Preferential pathway w/in 5 ft of building – **no**

Preferential pathway penetrates building – **no**

Significant foundation opening – **YES**

5 ft depth – not applicable to soil



You cannot use the calculated soil screening value (SV_{SOIL})
but you can use generic soil-to-GW numeric values

Soil Screening Values

Application of SVs

- With characterization data: no exceedences
- Suitable statistical tests of attainment data
 - Statewide health standard **only**
 - 75%/10x or 95% UCL tests
- POA for soil screening is throughout the volume of soil contamination
 - Base and sidewalls of excavation (attainment)

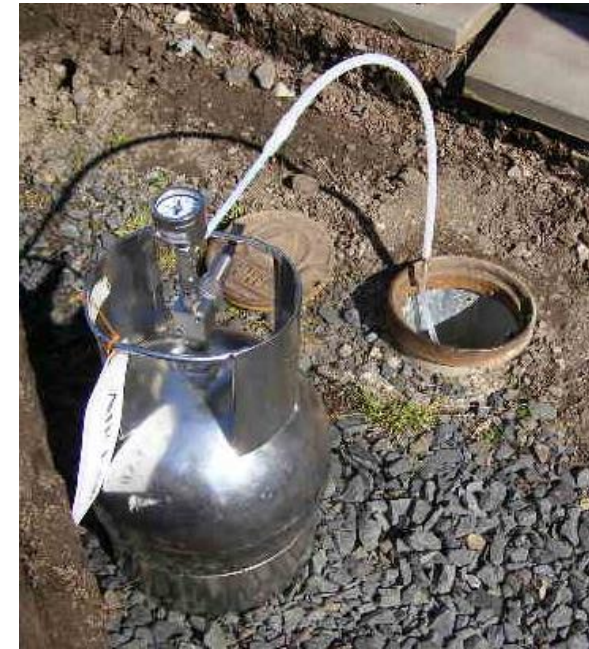
[Section F.2, Table 7]

Near-Source Soil Gas SVs

Basis of Near-Source Soil Gas SVs

- Attenuation factors derived from Johnson & Ettinger model simulations
- Near-source data is preferred because of variability in shallower soil gas concentrations
- SV_{NS} available for evaluation of future use

[Table 3; Appendix A, Section 3]



Near-Source Soil Gas SVs

Data Requirements

- Sample about 1 foot above the source
 - Above capillary fringe
 - Above bedrock
- Sample at least 5 feet below ground surface
- Acceptable soil or soil-like material present vertically between source and building
- At least two sample locations and two rounds
 - Sample events ≥ 45 days apart

[Table 6, Appendix C]

Screening Limitations

- SV_{NS} not available if:
 - SPL or contaminated groundwater present in an external preferential pathway
 - External preferential pathway penetration
 - Significant foundation opening present
 - Potential VI source is < 5 feet below foundation
- Alternatively, use SV_{SS} if any of the above conditions occur

[Section G, Figure 7]

Screening Limitations

- **Important:** If soil gas data is not near-source, then use of SV_{NS} values is not allowed
 - Under certain circumstances, SV_{SS} might be acceptable
 - But the samples still must be collected at least 5 feet below ground surface

Near-Source Screening Values— SV_{NS}

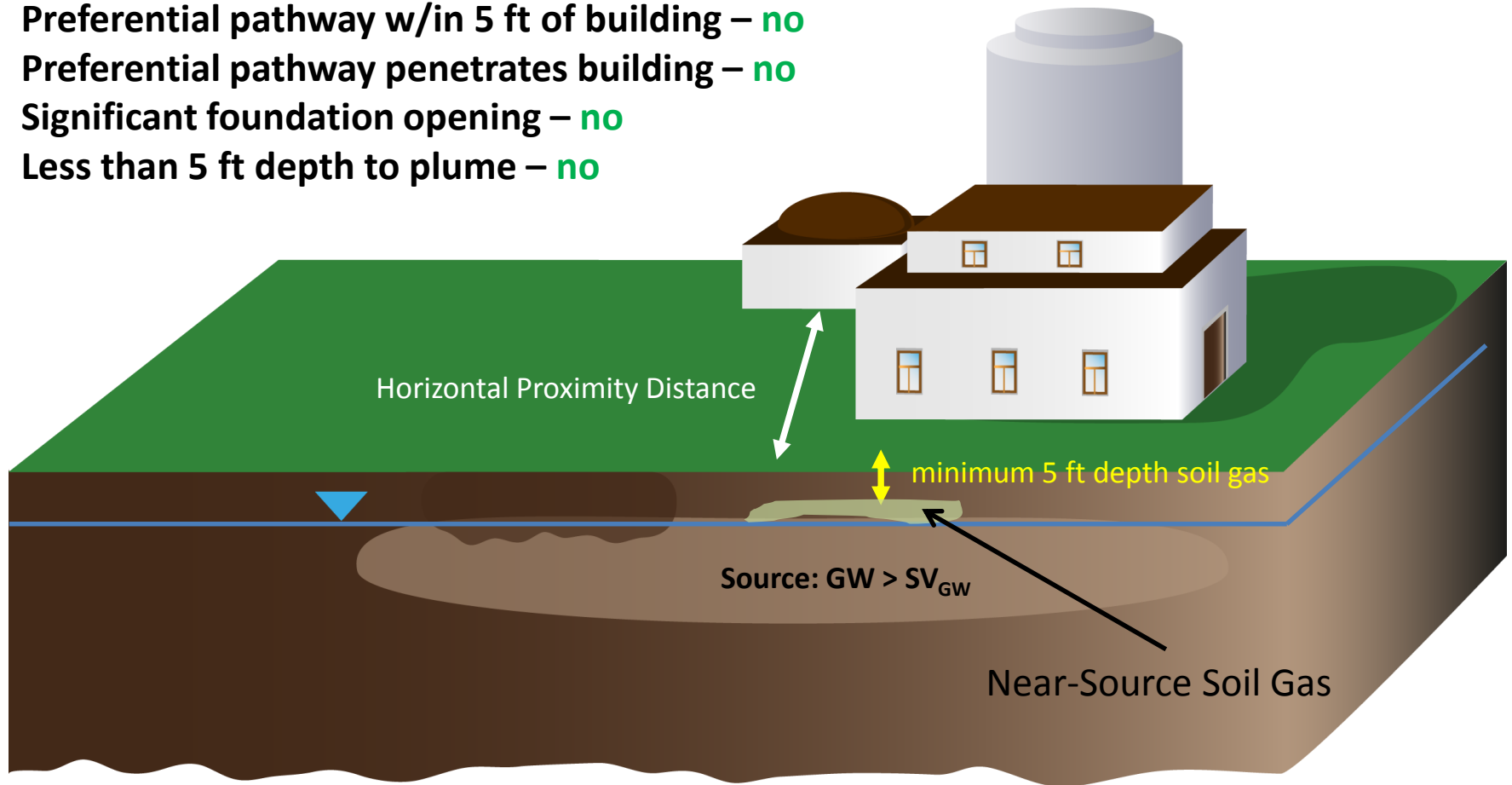
SPL Present – **no**

Preferential pathway w/in 5 ft of building – **no**

Preferential pathway penetrates building – **no**

Significant foundation opening – **no**

Less than 5 ft depth to plume – **no**



NO RESTRICTIONS – Near-source soil gas screening values based on attenuation factors derived from J& E model simulations

Near-Source Screening Values— SV_{NS}

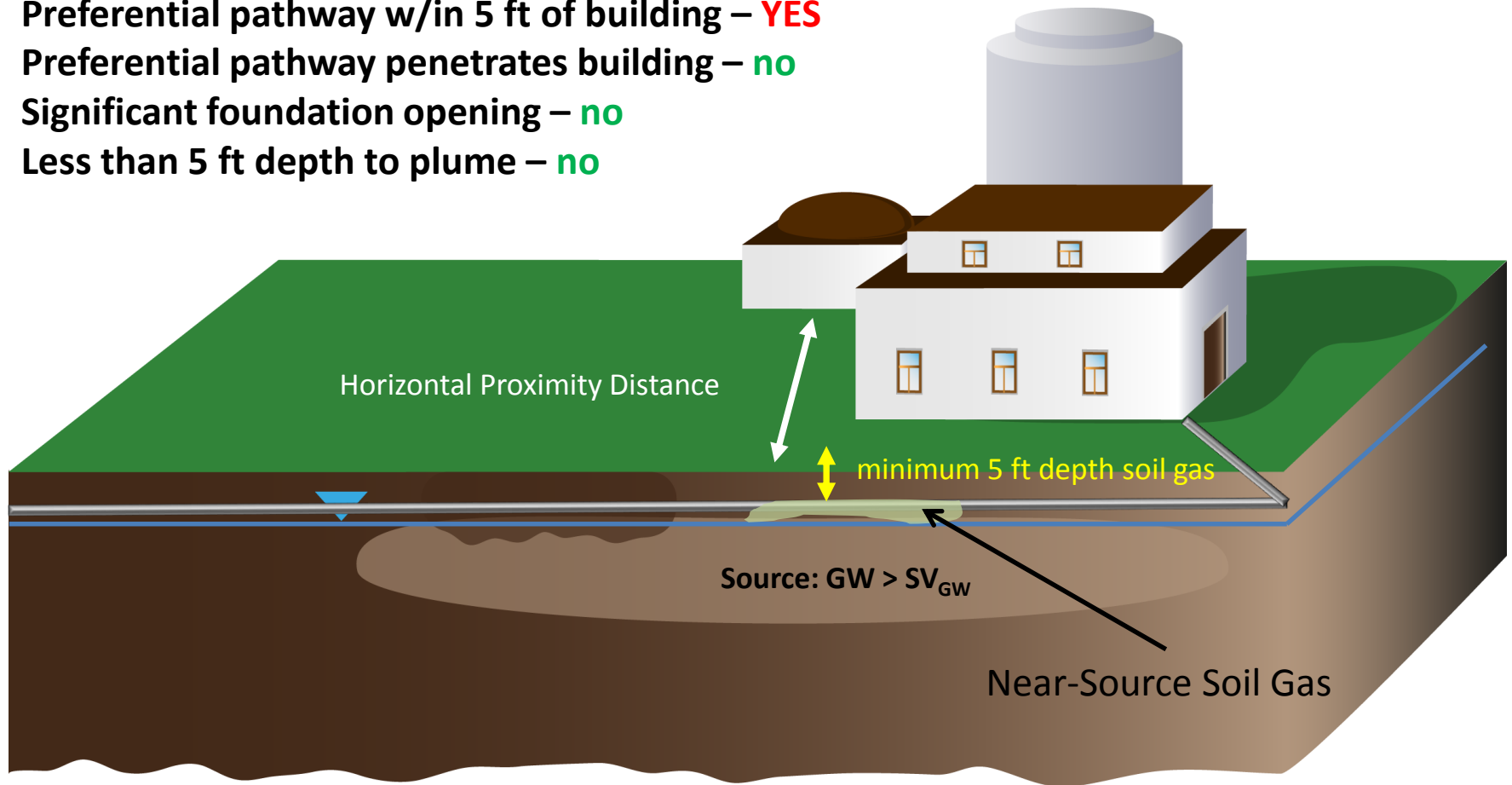
SPL Present – **no**

Preferential pathway w/in 5 ft of building – **YES**

Preferential pathway penetrates building – **no**

Significant foundation opening – **no**

Less than 5 ft depth to plume – **no**



NO RESTRICTIONS – You can use near-source soil gas screening value (SV_{NS})

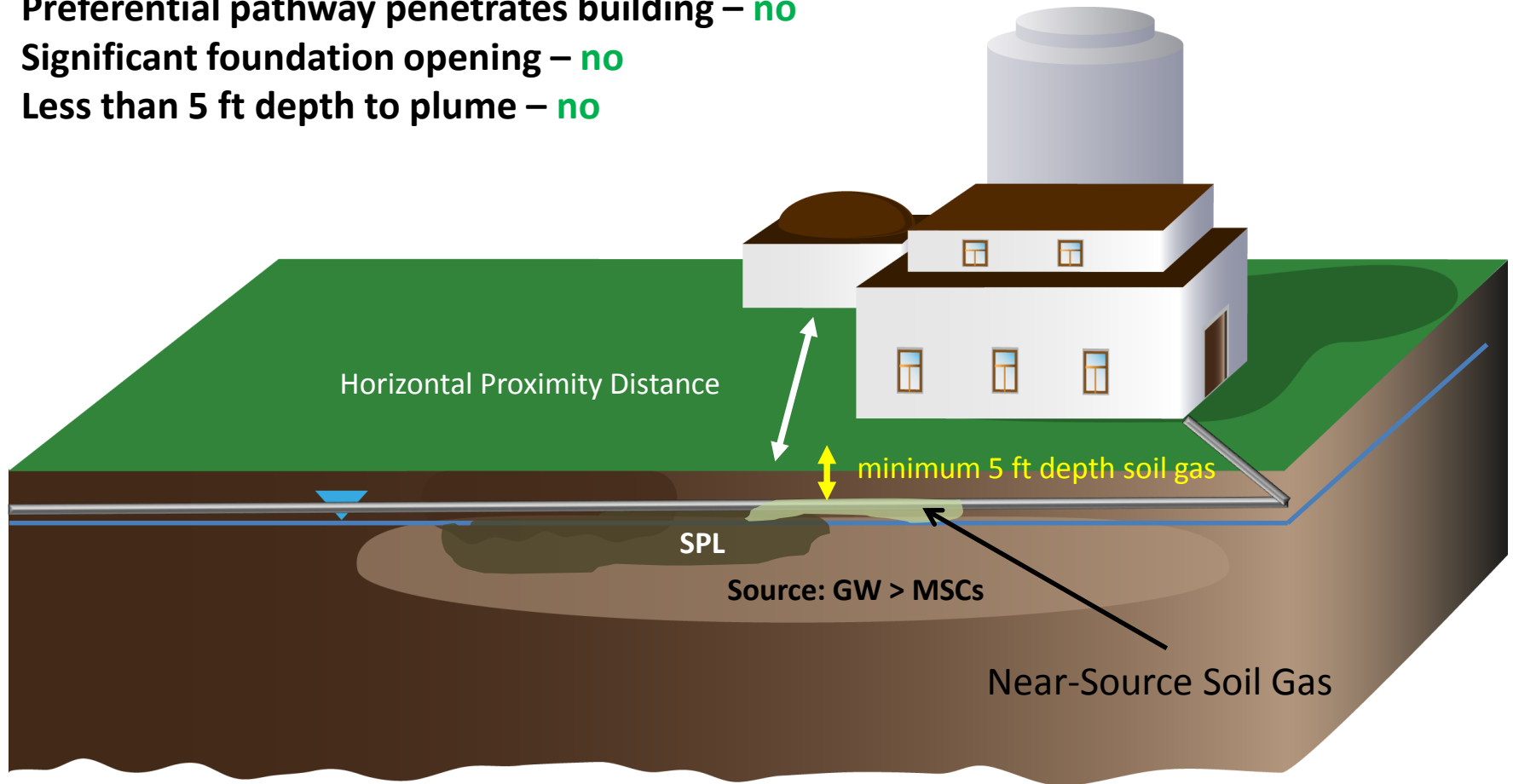
Near-Source Screening Values— SV_{NS}

SPL or GW > MSCs present in a preferential pathway w/in 5 ft of building – **YES**

Preferential pathway penetrates building – **no**

Significant foundation opening – **no**

Less than 5 ft depth to plume – **no**



**You cannot use the near-source soil gas screening value (SV_{NS})
but you can compare to sub-slab screening value (SV_{SS})**

Near-Source Screening Values— SV_{NS}

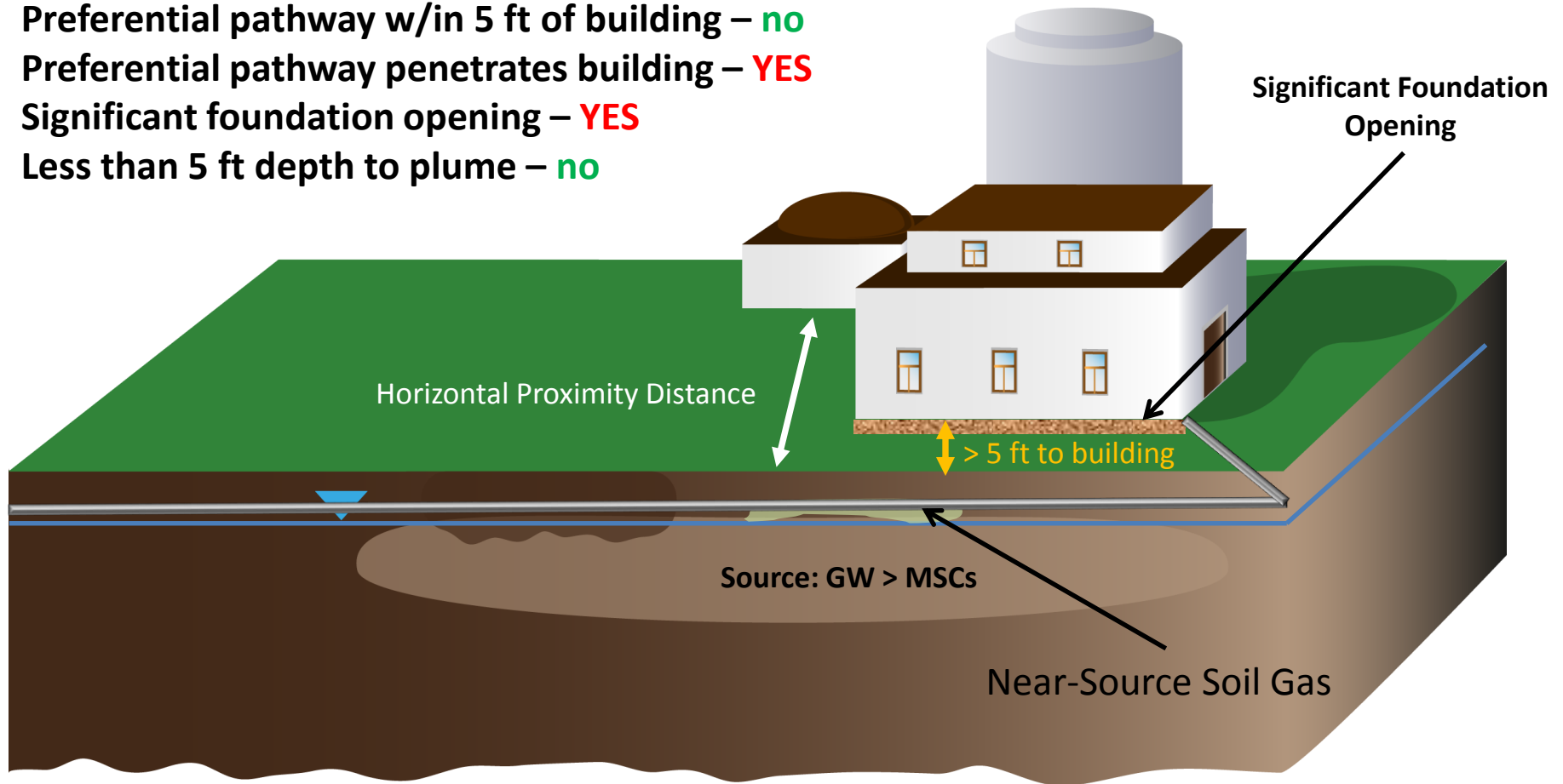
SPL Present – **no**

Preferential pathway w/in 5 ft of building – **no**

Preferential pathway penetrates building – **YES**

Significant foundation opening – **YES**

Less than 5 ft depth to plume – **no**



**You cannot use the near-source soil gas screening value (SV_{NS})
but you can compare to sub-slab screening value (SV_{SS})**

Near-Source Screening Values— SV_{NS}

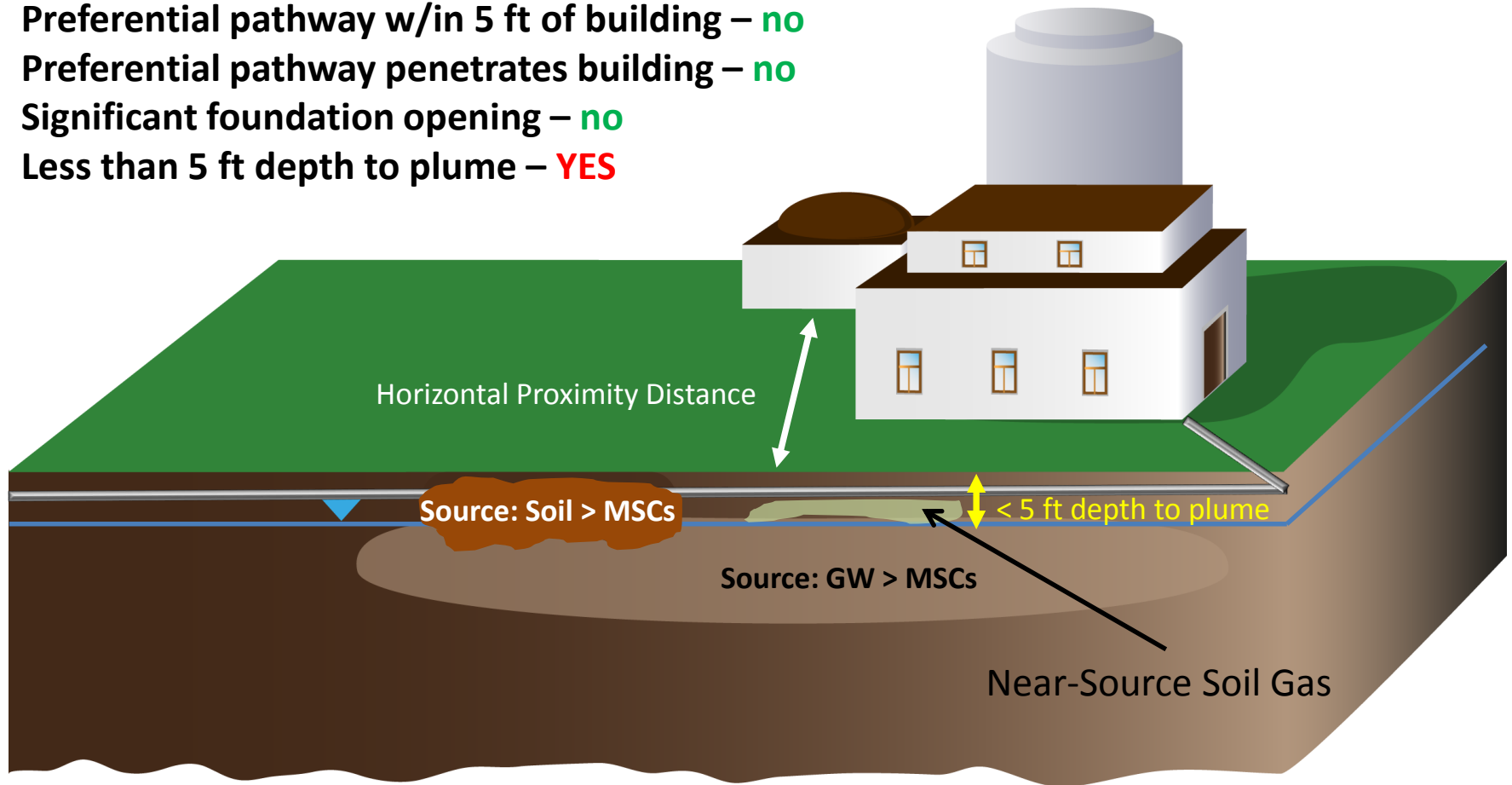
SPL Present – **no**

Preferential pathway w/in 5 ft of building – **no**

Preferential pathway penetrates building – **no**

Significant foundation opening – **no**

Less than 5 ft depth to plume – **YES**



You cannot use the near-source soil gas screening value (SV_{NS})
but you can compare to sub-slab screening value (SV_{SS})

Sub-Slab Soil Gas SVs

Basis of Sub-Slab Soil Gas SVs

- Attenuation factors based on EPA's analysis of their VI database
- SV_{ss}
- Sub-slab soil gas is closer to receptors
 - More indicative of potential exposures
 - Avoids conflicting background sources

[Table 4; Appendix A, Section 2]

Sub-Slab Soil Gas SVs

Data Requirements

- At least two sample locations and two rounds
 - Sample events ≥ 45 days apart
- Bias sample points towards areas of greatest expected impact
- Sample collection immediately below slab
 - Basement walls may be appropriate
 - Large, intact outdoor paved areas acceptable

[Table 6, Appendix C]

Sub-Slab Soil Gas SVs

Screening Limitations

- SV_{ss} not available if:
 - An external preferential pathway penetrates the building foundation
 - A significant foundation opening is present
- Alternatively, use SV_{IA} if either of the above conditions occur

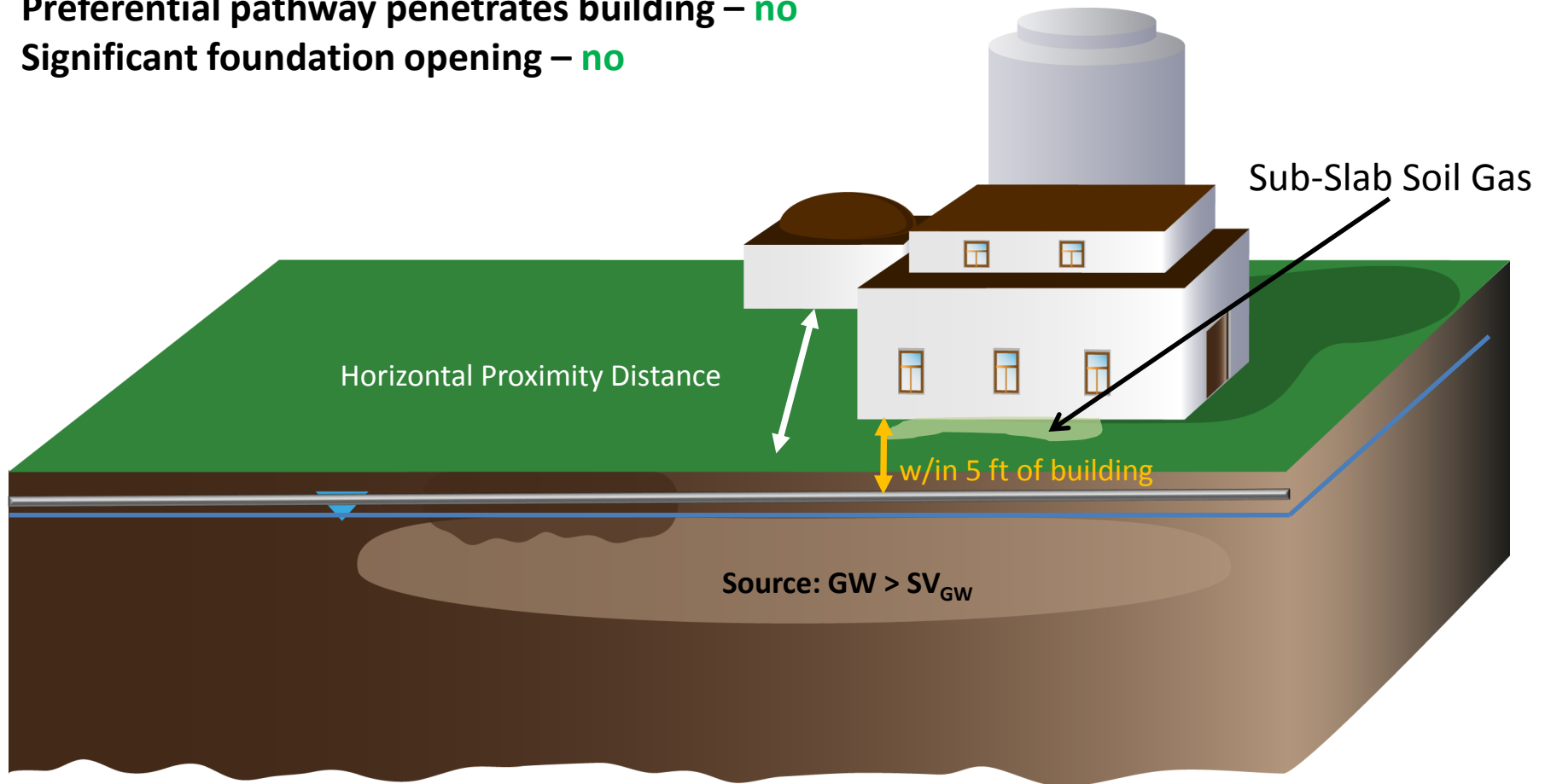
[Section G, Figure 7]

Sub-Slab Screening Values— SV_{ss}

Preferential pathway w/in 5 ft of building – **YES**

Preferential pathway penetrates building – **no**

Significant foundation opening – **no**



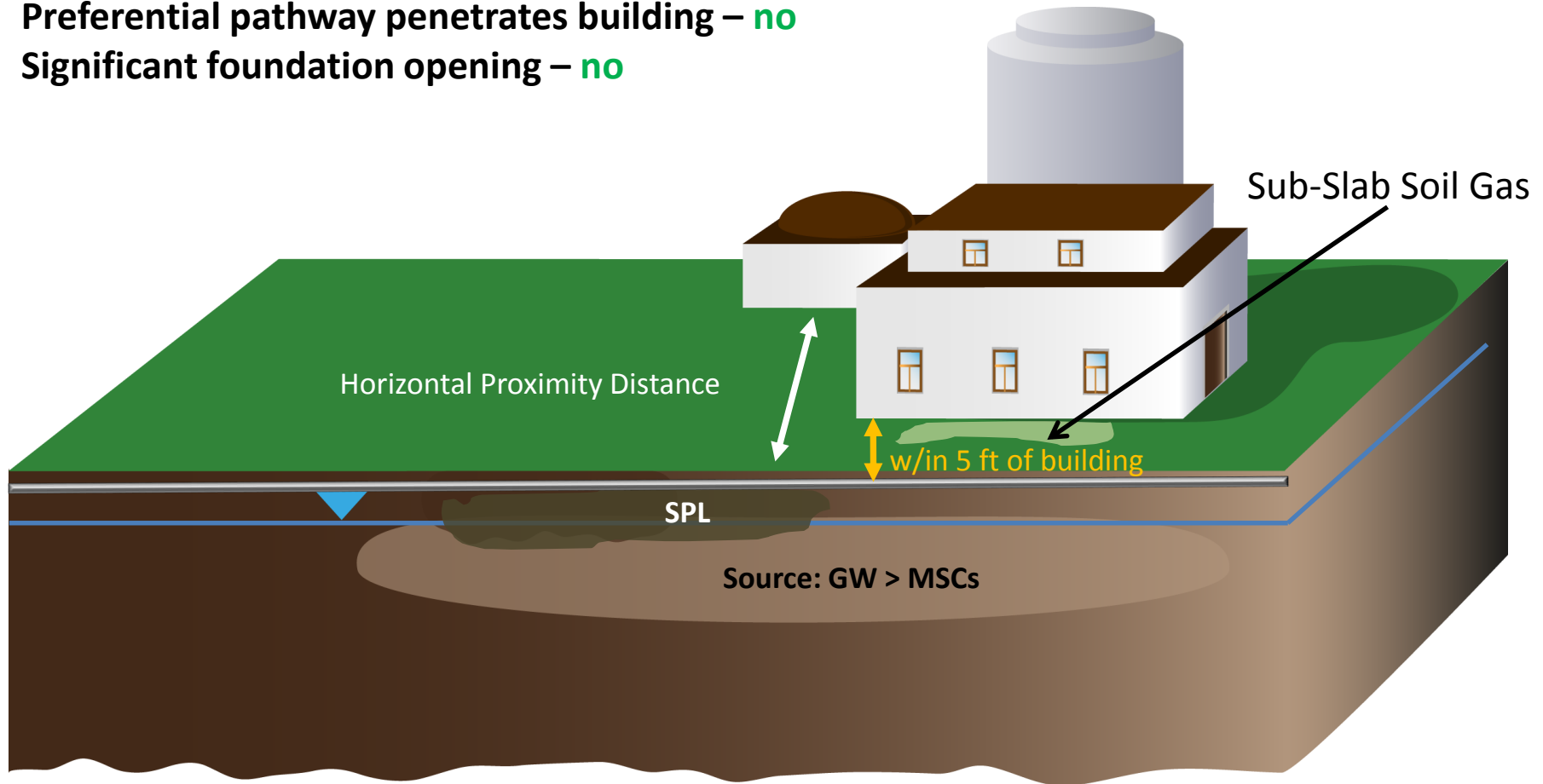
NO RESTRICTIONS – You can use sub-slab soil gas screening value (SV_{ss})

Sub-Slab Screening Values— SV_{ss}

SPL or GW > MSCs present in a preferential pathway w/in 5 ft of building – **YES**

Preferential pathway penetrates building – **no**

Significant foundation opening – **no**



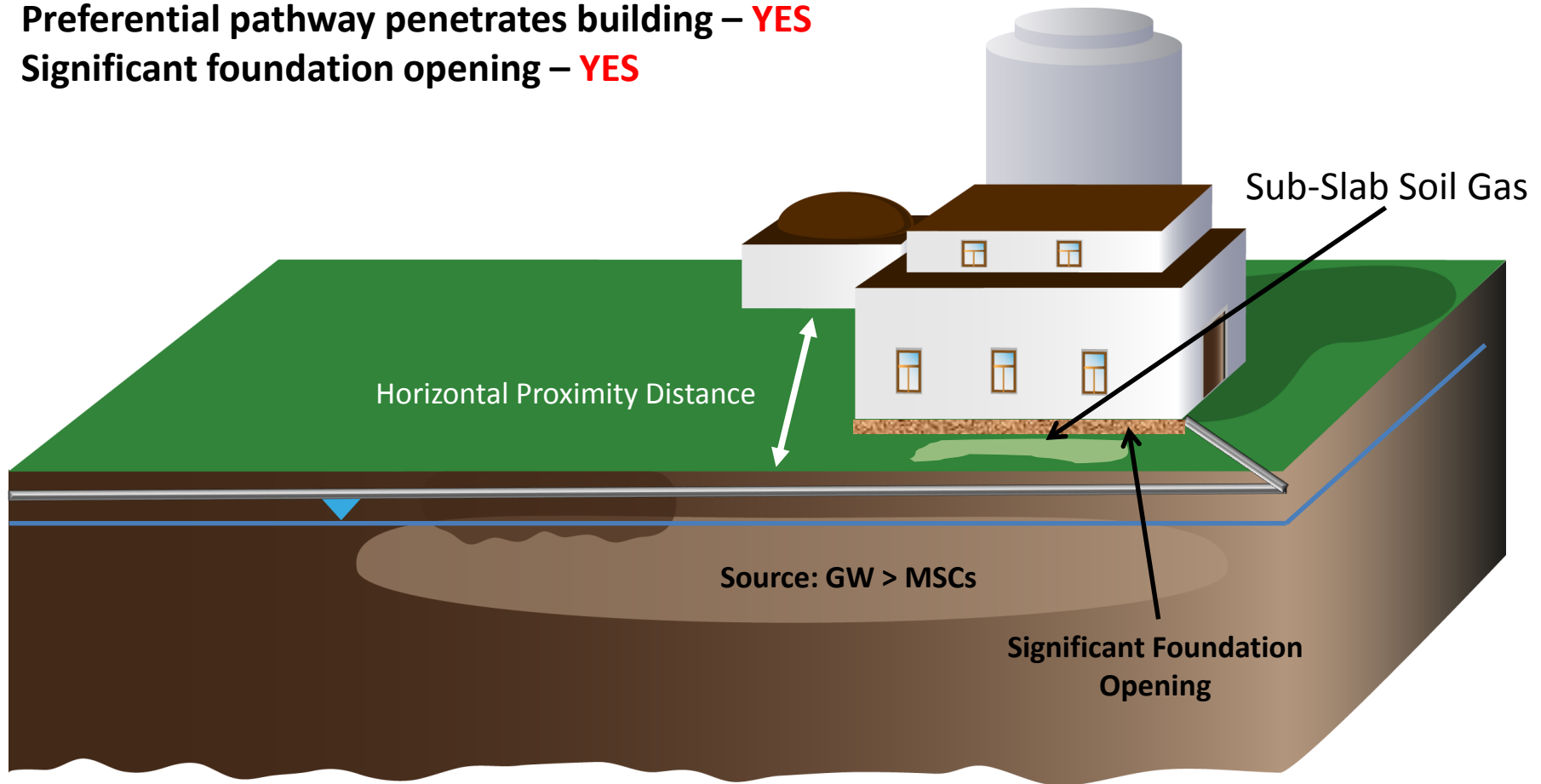
NO RESTRICTIONS – You can use sub-slab soil gas screening value (SV_{ss})

Sub-Slab Screening Values— SV_{ss}

Preferential pathway w/in 5 ft of building – **no**

Preferential pathway penetrates building – **YES**

Significant foundation opening – **YES**



You cannot use the sub-slab soil gas screening value (SV_{ss})
but you can compare to indoor air screening value (SV_{IA})

Indoor Air Screening Values

Basis of Indoor Air SVs

- Calculated SV_{IA} from EPA's standard inhalation risk equations
- Input DEP's toxicological values
- Select lower of carcinogenic, non-carcinogenic, and mutagenic SVs
- POA is the breathing zone in the lowest occupied level of the building

[Table 5; Appendix A, Section 1]



Indoor Air Screening Values

Data Requirements

- At least two sample locations and two rounds
 - Sample events ≥ 45 days apart
- Sample on lowest floor (e.g., basement)
- Daily average outdoor temperature should be at least 15°F below the minimum indoor temperature of the occupied space
 - More likely to be representative of long-term

[Table 6, Appendix C]

Indoor Air Screening Values

Screening Limitations

- No restrictions on indoor air sampling
- However, important to be aware of potential indoor sources and outdoor background

[Section G, Appendix C]

- Note that modeled indoor air concentrations may also be screened (**SHS only**)

[Section G.3]

Alternative Assessment Options

Application of SVs:

Near-Source, Sub-Slab, and Indoor Air

- No exceedences of characterization data
- May perform long-term monitoring
 - Once or twice per quarter
 - Statistical tests allowed if there is a combination of at least eight locations and rounds (**SHS only**)
 - May apply 75%/10x and/or 75%/2x or 95% UCL tests
 - Otherwise no exceedences (SSS)

Summary of Restrictions with SPL

- SV_{GW} and groundwater MSCs not available
- SV_{SOIL} and generic soil-to-groundwater numeric values not available
- SV_{NS} not available if SPL enters a preferential pathway
- Modeling of soil and groundwater data not available

Site-Specific Standard SVs

Use of Site-Specific Standard SVs

- Default SSS screening values are one-tenth the tabulated SHS screening values
- May use EPA's regional screening levels as basis for SSS SV_{IA} , SV_{SS} , and SV_{NS}
- Pass only with no exceedences
 - SHS statistical tests are not available
- SSS alternatives are modeling and/or risk assessment

[Section K.4]

Site-Specific Standard SVs

SSS Potential VI Source

- **Important:** A potential VI source is defined by exceedences of *Statewide health standard* screening values (SV_{GW} and SV_{SOIL})
- The SSS soil and groundwater SVs based on one-tenth of SHS SVs will rarely be used
 - Example: evaluation of SSS post-remediation attainment data

[Section B, Section K.3]

Combination of Standards

- Background standard does not require VI
- VI pathway must be evaluated along with all of the other requirements of each standard
- Act 2 standards are attained only for soil or groundwater, not vapor
 - VI is a pathway, not an environmental medium
 - If the site-specific standard is selected, then the remediator **cannot** use the SHS VI process

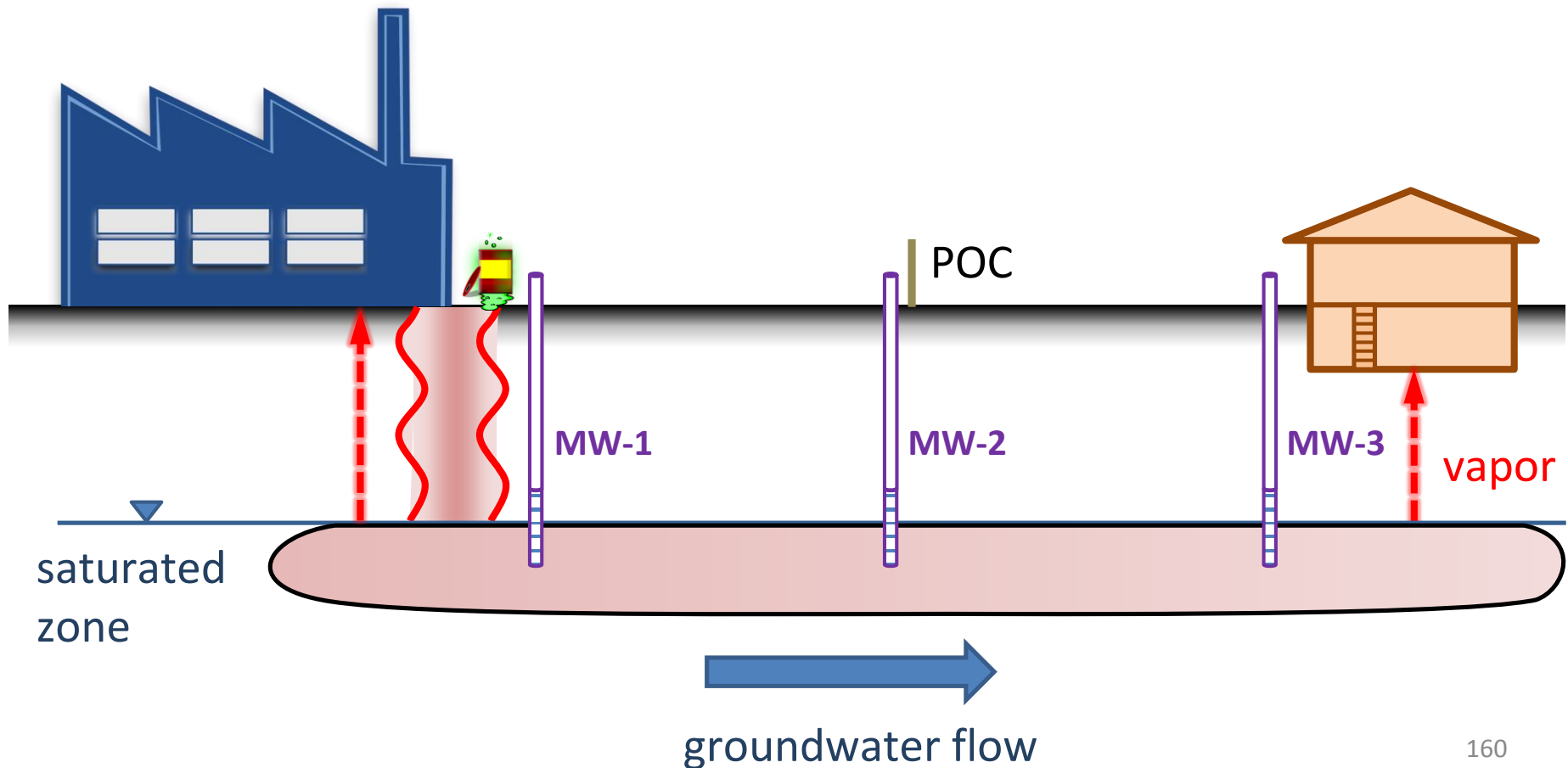
Combination of Standards

- Screening values from Tables 1 to 5 for SHS
 - But SV_{GW} and SV_{SOIL} allowed for SSS (VI source)
 - SV_{NS} , SV_{SS} , SV_{IA} must be adjusted for SSS
- Can evaluate VI under SHS only when attaining the SHS for soil and groundwater
- Can evaluate VI under SSS when attaining either the SHS or SSS for soil and groundwater
- Differences with modeling output

[Section C.3]

Combination of Standards

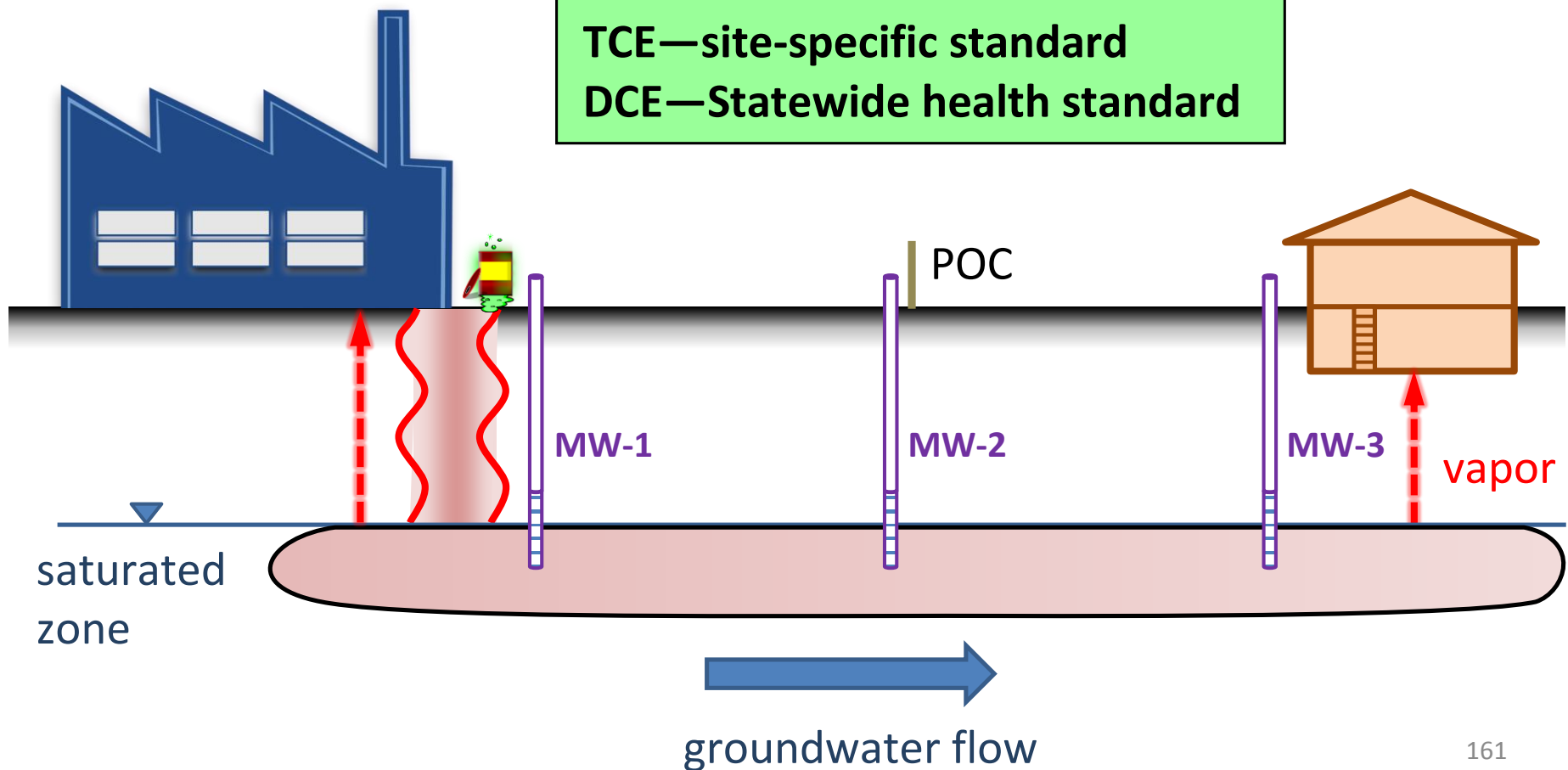
Example: Chlorinated VOC Plume with Offsite Impacts



Groundwater Attainment (MSCs)

Substance	MW-1	MW-2	MW-3	MSC
TCE ($\mu\text{g/L}$)	8000	400	20	5
1,1-DCE ($\mu\text{g/L}$)	90	5	ND	7

TCE—site-specific standard
DCE—Statewide health standard



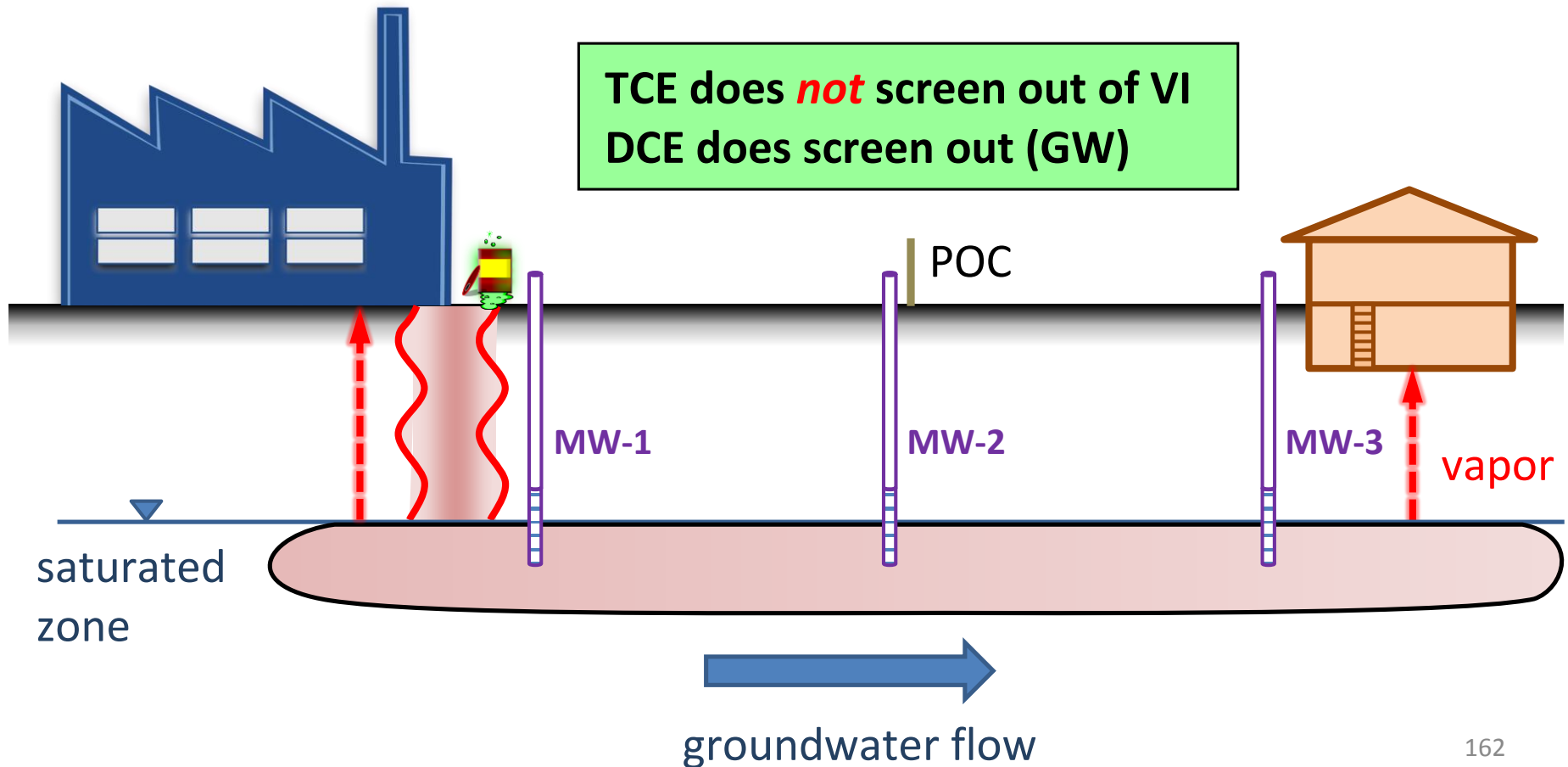
Vapor Intrusion Groundwater Screening

Substance	MW-1	SV _{GW}	MW-2		MW-3	SV _{GW}
TCE (µg/L)	8000	110	400		20	9
1,1-DCE (µg/L)	90	3800	5		ND	300

NR

R

TCE does *not* screen out of VI
DCE does screen out (GW)



Vapor Intrusion Near-Source Soil Gas Screening

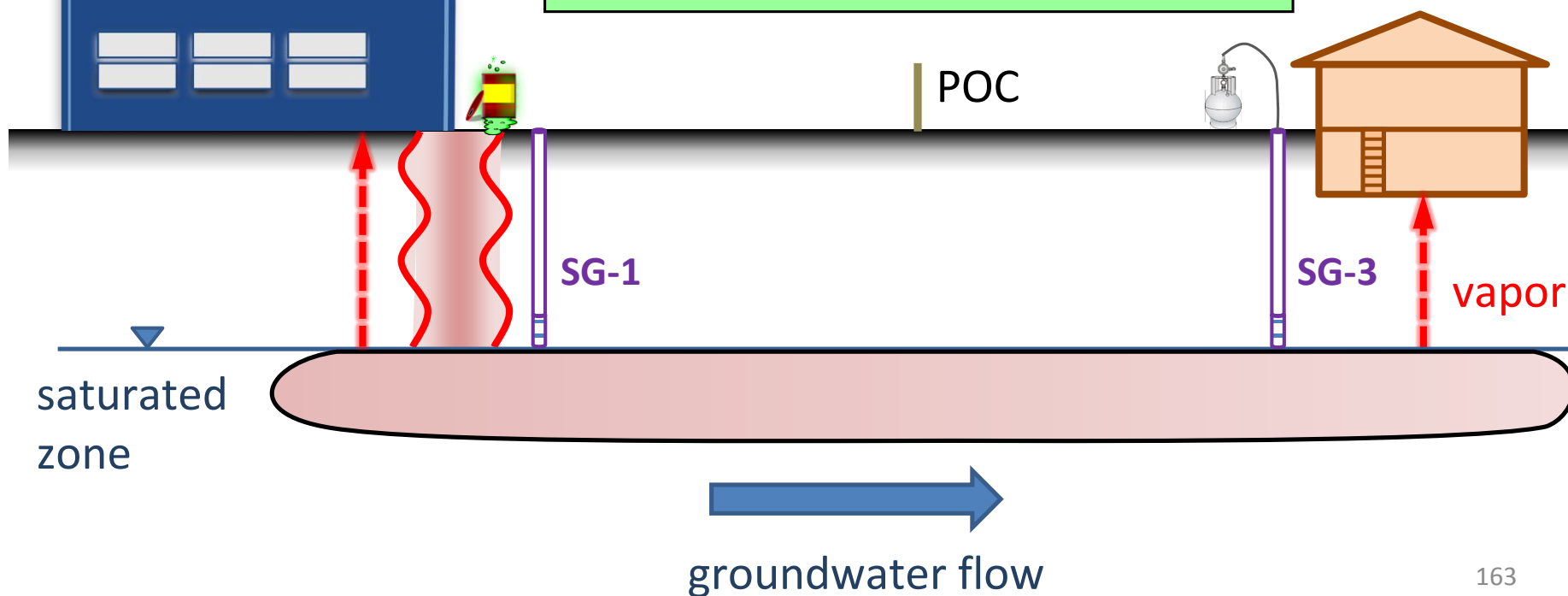
Substance	SG-1	SV _{NS}		SG-3	SV _{NS}
TCE ($\mu\text{g}/\text{m}^3$)	1,000,000	880*		300	42*
1,1-DCE ($\mu\text{g}/\text{m}^3$)	50,000	880,000		40	42,000

NR

R

*SSS SV_{NS} = one-tenth SHS SV_{NS}

TCE does **not** screen out of VI (NS)



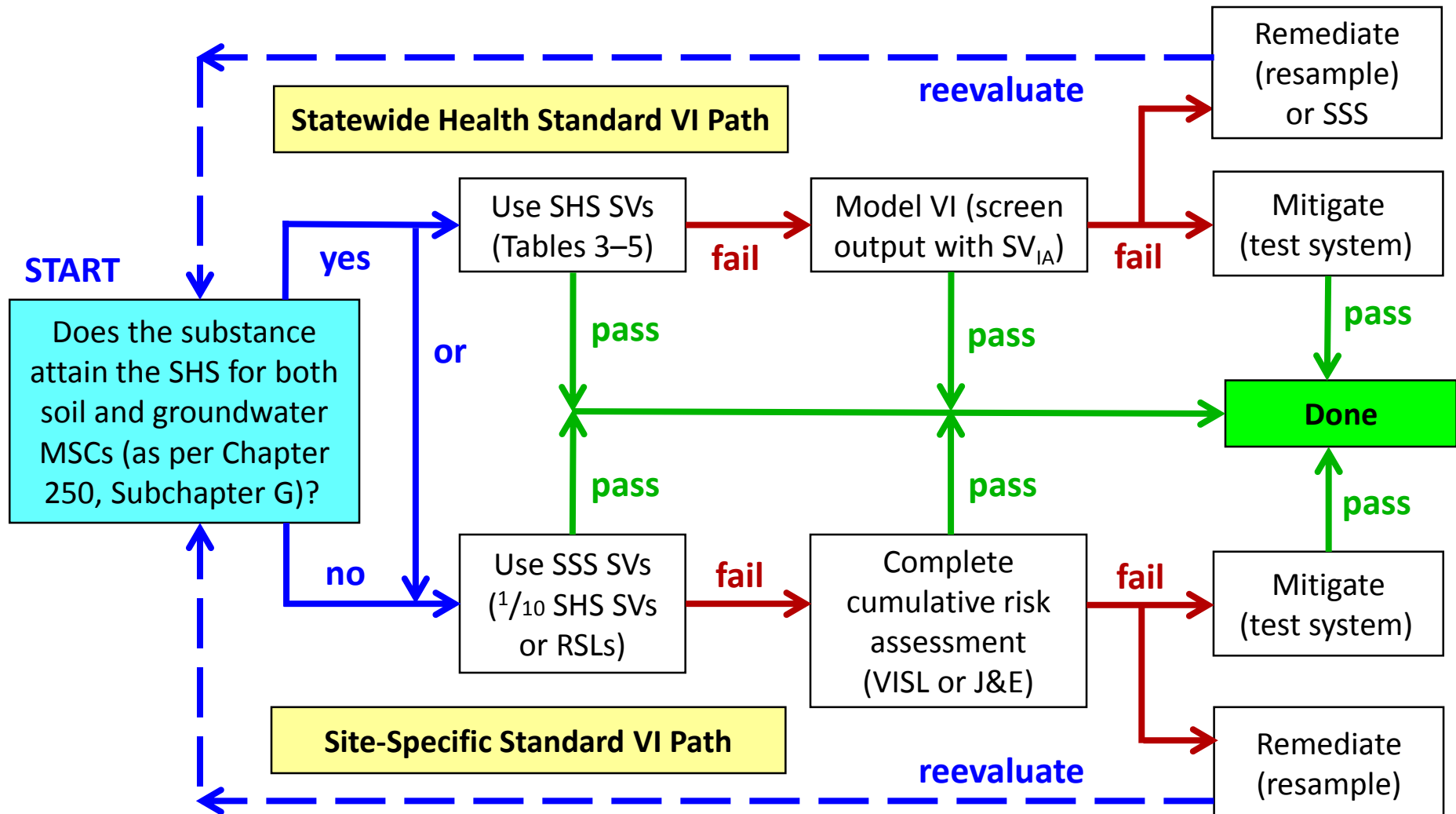
Combination of Standards

Example Conclusions

- The TCE plume is a potential VI source
 - But 1,1-DCE is not based on SV_{GW}
- Must apply one-tenth SV_{NS} for screening of TCE soil gas data
- What are alternatives for addressing TCE?
 - Risk calculation (offsite TCE HQ < 1)
 - Sub-slab soil gas sampling
 - Indoor air sampling
 - Mitigation

Representative Process to Evaluate Vapor Intrusion With a Combination of Standards

For each substance that is a potential VI source:





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Tutorial: Calculation of Site-Specific Standard Vapor Intrusion Screening Values from EPA Indoor Air RSLs

Colleen Costello (GHD)

C. David Brown (DEP)

Vapor Intrusion Guidance Training

January 10, 2017

Malvern, PA

EPA RSLs Background

- EPA RSLs are available online at:
www.epa.gov/risk/regional-screening-levels-rsls
- RSLs are revised approximately every 6 months (May and November)
- Click the “Generic Tables” link
- Access the “Resident Air” and “Composite Worker Air” tables for THQ = 0.1

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Recent Additions

Regional Screening Levels (RSLs) – Generic Tables (May 2016)

For assistance/questions please use the [Regional Screening Levels \(RSLs\) contact us](#) page.

You will need Adobe Reader to view some of the files on this page. See [EPA's About PDF page](#) to learn more.

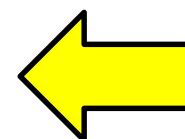
The screening level (SL) tables are available for download in Excel and PDF formats. All tables are presented with target cancer risk (TR) of 1E-06, however, tables are presented with target hazard quotients (THQ) of 1.0 and 0.1. Use the tables appropriate for your region. These tables are considered ready for use. The tables contain both SL calculations and the toxicity values that were used.

The download tables do not include the ingestion of fish exposure pathway, the outdoor worker and the indoor worker exposure to soil exposure pathway that are presented in the User's Guide. These exposure pathways can be considered on a site-specific basis in the [Calculator](#).

Regional Screening Levels (RSLs)

- [Home Page](#)
- [User's Guide](#)
- [What's New](#)
- [Frequent Questions](#)
- [Equations](#)
- [Calculator](#)
- [Generic Tables](#)
- [Contact Us](#)

	(TR=1E-06 THQ=1.0)	(TR=1E-06 THQ=1.0)	(TR=1E-06 THQ=0.1)	(TR=1E-06 THQ=0.1)
Summary Table	(PDF)	XLS	(PDF)	XLS
Resident Soil	(PDF)	XLS	(PDF)	XLS
Composite Worker Soil	(PDF)	XLS	(PDF)	XLS
Resident Air	(PDF)	XLS	(PDF)	XLS
Composite Worker Air	(PDF)	XLS	(PDF)	XLS
Resident Tapwater	(PDF)	XLS	(PDF)	XLS
Resident Soil to Groundwater	(PDF)	XLS	(PDF)	XLS
Chemical Specific Parameters	(PDF)	XLS	(PDF)	XLS
Composite Table (Every Table)	(PDF)	XLS	(PDF)	XLS



Sample Type

- RSLs for soil and water do not account for VI and are not available for SSS VI evaluations
- Use residential and worker indoor air RSLs
- RSLs may be converted to soil gas and sub-slab SVs using DEP's attenuation factors:

Sample Type	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

[Table A-4]

RSL Selection

- RSLs are calculated for a cancer risk of **10^{-6}**
- But if VI is the *only complete exposure pathway* for the receptor, then a cancer risk of **10^{-5}** is acceptable
- Must use RSLs for a hazard quotient (HQ) of **0.1**
- Intent of screening is to maintain a factor of 10 risk margin relative to SSS cumulative thresholds (cancer risk $\leq 10^{-4}$ & hazard index ≤ 1.0)

Additional RSL Notes

- Some substances are carcinogens, some are noncarcinogens, some are both
- The lower of the cancer and non-cancer RSLs is used as the screening value
- EPA residential RSLs are calculated with a 26-yr exposure duration in contrast to DEP's 30 yr
- For the SSS, substances that don't screen out are carried through a risk assessment

Example for Four Substances

EPA Residential Indoor Air RSLs

Substance	Cancer 10^{-6}	HQ = 0.1
Benzene	0.36	3.1
Naphthalene	0.083	0.31
1,2,4-trimethylbenzene		0.73
Trichloroethylene	0.48	0.21

Note: All concentration units in this and subsequent tables are $\mu\text{g}/\text{m}^3$

Example for Four Substances

EPA Residential Indoor Air RSLs

Select lower of the two RSLs

Substance	Cancer 10^{-6}	HQ = 0.1
Benzene	0.36	3.1
Naphthalene	0.083	0.31
1,2,4-trimethylbenzene		0.73
Trichloroethylene	0.48	0.21

Example for Four Substances

Compare to DEP's SSS SVs

Substance	EPA RSL	DEP SV
Benzene	0.36	0.31
Naphthalene	0.083	0.072
1,2,4-trimethylbenzene	0.73	0.73
Trichloroethylene	0.21	0.21

- DEP's site-specific standard SVs are one-tenth of Statewide health standard SVs
- Pick higher of two values

Example for Four Substances

EPA Residential IA RSLs @ 10^{-5} Risk

Substance	Cancer 10^{-5}	HQ = 0.1
Benzene	3.6	3.1
Naphthalene	0.83	0.31
1,2,4-trimethylbenzene		0.73
Trichloroethylene	4.8	0.21

Use cancer risk of 10^{-5} when vapor intrusion is the only complete exposure pathway for the receptor

Example for Four Substances

Compare to DEP's SSS SVs (residential)

Substance	EPA RSL	DEP SV
Benzene	3.1 _{NC}	0.31 _C
Naphthalene	0.31 _{NC}	0.072 _C
1,2,4-trimethylbenzene	0.73 _{NC}	0.73 _{NC}
Trichloroethylene	0.21 _{NC}	0.21 _{NC}

- RSLs selected with 10^{-5} cancer risk
- DEP's SSS SVs are one-tenth of SHS SVs
- Notation: C—cancer
NC—noncancer

RSL Screening Value Exercise

Exercise Objective

- Determine RSL-based site-specific standard vapor intrusion screening values for several common contaminants
- We will use RSL-based SVs in a case study this afternoon

Abbreviated lookup table of EPA indoor air RSLs

Group Exercise

US EPA Indoor Air Regional Screening Levels (RSLs)
May 2016

Residential

Key: I = IRIS; P = PPRTV; A = ATSDR; C = Cal EPA; X = APPENDIX PPRTV SCREEN (See FAQ #27); H = HEAST; F = See FAQ; J = New Jersey; O = EPA Office of Water; E = see user guide Section 2.3.5; L = see user guide on lead; M = mutagen; S = see user guide Section 5; V = volatile; R = RBA applied (See User Guide for Arsenic notice) ; c = cancer; n = noncancer; * = where: n SL < 100X c SL; ** = where n SL < 10X c SL; SSL values are based on DAF=1; m = Concentration may exceed ceiling limit (See User Guide); s = Concentration may exceed Csat (See User Guide)

Toxicity and Chemical-specific Information						Contaminant		Carcinogenic Target Risk (TR) = 1E-06	Noncancer Hazard Index (HI) = 0.1
IUR (ug/m ³) ⁻¹	k e y	RfCi (mg/m ³)	k e y	v o l	mutagen	Analyte	CAS No.	Carcinogenic SL TR=1E-06 (ug/m ³)	Noncarcinogenic SL THI=0.1 (ug/m ³)
7.8E-06	I	3.0E-02	I	V		Benzene	71-43-2	3.6E-01	3.1E+00
		4.0E-01	I	V		Cumene	98-82-8		4.2E+01
6.0E-04	I	9.0E-03	I	V		Dibromoethane, 1,2-	106-93-4	4.7E-03	9.4E-01
1.6E-06	C			V		Dichloroethane, 1,1-	75-34-3	1.8E+00	
2.6E-05	I	7.0E-03	P	V		Dichloroethane, 1,2-	107-06-2	1.1E-01	7.3E-01
		2.0E-01	I	V		Dichloroethylene, 1,1-	75-35-4		2.1E+01
				V		Dichloroethylene, 1,2-cis-	156-59-2		
2.5E-06	C	1.0E+00	I	V		Dichloroethylene, 1,2-trans-	156-60-5		
2.6E-07	C	3.0E+00	I	V		Ethylbenzene	100-41-4	1.1E+00	1.0E+02
						Methyl tert-Butyl Ether (MTBE)	1634-04-4	1.1E+01	3.1E+02
3.4E-05	C	3.0E-03	I	V		~Naphthalene	91-20-3	8.3E-02	3.1E-01
2.6E-07	I	4.0E-02	I	V		Tetrachloroethylene	127-18-4	1.1E+01	4.2E+00
		5.0E+00	I	V		Toluene	108-88-3		5.2E+02
		5.0E+00	I	V		Trichloroethane, 1,1,1-	71-55-6		5.2E+02
1.6E-05	I	2.0E-04	X	V		Trichloroethane, 1,1,2-	79-00-5	1.8E-01	2.1E-02
4.1E-06	I	2.0E-03	I	V	M	Trichloroethylene	79-01-6	4.8E-01	2.1E-01
		5.0E-03	P	V		Trimethylbenzene, 1,2,3-	526-73-8		5.2E-01
		7.0E-03	P	V		Trimethylbenzene, 1,2,4-	95-63-6		7.3E-01
				V		Trimethylbenzene, 1,3,5-	108-67-8		
4.4E-06	I	1.0E-01	I	V	M	Vinyl Chloride	75-01-4	1.7E-01	1.0E+01
		1.0E-01	I	V		Xylenes	1330-20-7		1.0E+01

Group Exercise: RSL-Based Site-Specific Standard VI Screening Values

Note: RSLs at a 10^{-5} cancer risk are acceptable only when VI is the sole potential exposure pathway

Regulated Substance	EPA Residential Indoor Air RSLs ($\mu\text{g}/\text{m}^3$)				PA DEP IA SVs ($\mu\text{g}/\text{m}^3$)	
	Carcinogenic	Carcinogenic	Noncarcinogenic	Minimum	SHS	SSS
	10^{-6} Risk	10^{-5} Risk	HQ = 0.1	$(10^{-5} / 0.1)$	(residential)	(residential)
Petroleum Short List						
Benzene	0.36		3.1		3.1	
Toluene					5,200	
Ethylbenzene					9.7	
Xylenes (total)					100	
Methyl tert-Butyl Ether (MTBE)					94	
Cumene (isopropylbenzene)					420	
Naphthalene	0.083	0.83	0.31	0.31	0.72	0.072
Trimethylbenzene, 1,2,4- (1,3,4-TMB)			0.73	0.73	7.3	0.73
Trimethylbenzene, 1,3,5-					7.3	
Dibromoethane, 1,2- (ethylene dibromide) (EDB)					0.041	
Dichloroethane, 1,2- (EDC)					0.94	
Common Chlorinated VOCs						
Tetrachloroethylene (PCE)					42	
Trichloroethylene (TCE)	0.48	4.8	0.21	0.21	2.1	0.21
Dichloroethylene, cis-1,2-					—	
Vinyl Chloride					0.79	180

1

Look up RSLs

Group Exercise: RSL-Based Site-Specific Standard VI Screening Values

Note: RSLs at a 10⁻⁵ cancer risk are acceptable only when VI is the sole potential exposure pathway

Regulated Substance	EPA Residential Indoor Air RSLs (µg/m³)				PA DEP IA SVs (µg/m³)	
	Carcinogenic	Carcinogenic	Noncarcinogenic	Minimum	SHS	SSS
	10 ⁻⁶ Risk	10 ⁻⁵ Risk	HQ = 0.1	(10 ⁻⁵ / 0.1)	(residential)	(residential)
Petroleum Short List						
Benzene	0.36	3.6	3.1		3.1	
Toluene					5,200	
Ethylbenzene					9.7	
Xylenes (total)					100	
Methyl tert-Butyl Ether (MTBE)					94	
Cumene (isopropylbenzene)					420	
Naphthalene	0.083	0.83	0.31	0.31	0.72	0.072
Trimethylbenzene, 1,2,4- (1,3,4-TMB)			0.73	0.73	7.3	0.73
Trimethylbenzene, 1,3,5-					7.3	
Dibromoethane, 1,2- (ethylene dibromide) (EDB)					0.041	
Dichloroethane, 1,2- (EDC)					0.94	
Common Chlorinated VOCs						
Tetrachloroethylene (PCE)					42	
Trichloroethylene (TCE)	0.48	4.8	0.21	0.21	2.1	0.21
Dichloroethylene, cis-1,2-					—	
Vinyl Chloride					0.79	181

Group Exercise: RSL-Based Site-Specific Standard VI Screening Values

Note: RSLs at a 10^{-5} cancer risk are acceptable only when VI is the sole potential exposure pathway

Regulated Substance	EPA Residential Indoor Air RSLs ($\mu\text{g}/\text{m}^3$)				PA DEP IA SVs ($\mu\text{g}/\text{m}^3$)	
	Carcinogenic	Carcinogenic	Noncarcinogenic	Minimum	SHS	SSS
	10^{-6} Risk	10^{-5} Risk	HQ = 0.1	($10^{-5} / 0.1$)	(residential)	(residential)
Petroleum Short List						
Benzene	0.36	3.6	3.1	3.1	3.1	
Toluene					5,200	
Ethylbenzene					9.7	
Xylenes (total)					100	
Methyl tert-Butyl Ether (MTBE)					94	
Cumene (isopropylbenzene)					420	
Naphthalene	0.083	0.83	0.31	0.31	0.72	0.072
Trimethylbenzene, 1,2,4- (1,3,4-TMB)			0.73	0.73	7.3	0.73
Trimethylbenzene, 1,3,5-					7.3	
Dibromoethane, 1,2- (ethylene dibromide) (EDB)					0.041	
Dichloroethane, 1,2- (EDC)					0.94	
Common Chlorinated VOCs						
Tetrachloroethylene (PCE)					42	
Trichloroethylene (TCE)	0.48	4.8	0.21	0.21	2.1	0.21
Dichloroethylene, cis-1,2-					—	
Vinyl Chloride					0.79	182

3

Pick lower value

Group Exercise: RSL-Based Site-Specific Standard VI Screening Values

Table 5

Note: RSLs at a 10⁻⁵ cancer risk are acceptable only when VI is the sole potential exposure pathway

Regulated Substance	EPA Residential Indoor Air RSLs (µg/m³)				PA DEP IA SVs (µg/m³)	
	Carcinogenic	Carcinogenic	Noncarcinogenic	Minimum	SHS	SSS
	10 ⁻⁶ Risk	10 ⁻⁵ Risk	HQ = 0.1	(10 ⁻⁵ / 0.1)	(residential)	(residential)
Petroleum Short List						
Benzene	0.36	3.6	3.1	3.1	3.1	0.31
Toluene					5,200	
Ethylbenzene					9.7	
Xylenes (total)					100	
Methyl tert-Butyl Ether (MTBE)					94	
Cumene (isopropylbenzene)					420	
Naphthalene	0.083	0.83	0.31	0.31	0.72	0.072
Trimethylbenzene, 1,2,4- (1,3,4-TMB)			0.73	0.73	7.3	0.73
Trimethylbenzene, 1,3,5-					7.3	
Dibromoethane, 1,2- (ethylene dibromide) (EDB)					0.041	
Dichloroethane, 1,2- (EDC)					0.94	
Common Chlorinated VOCs						
Tetrachloroethylene (PCE)					42	
Trichloroethylene (TCE)	0.48	4.8	0.21	0.21	2.1	0.21
Dichloroethylene, cis-1,2-					—	
Vinyl Chloride					0.79	183

Group Exercise: RSL-Based Site-Specific Standard VI Screening Values

Note: RSLs at a 10^{-5} cancer risk are acceptable only when VI is the sole potential exposure pathway

Regulated Substance	EPA Residential Indoor Air RSLs ($\mu\text{g}/\text{m}^3$)				PA DEP IA SVs ($\mu\text{g}/\text{m}^3$)	
	Carcinogenic 10^{-6} Risk	Carcinogenic 10^{-5} Risk	Noncarcinogenic HQ = 0.1	Minimum ($10^{-5} / 0.1$)	SHS (residential)	SSS (residential)
Petroleum Short List						
Benzene	0.36	3.6	3.1	3.1	3.1	0.31
Toluene					5,200	
Ethylbenzene					9.7	
Xylenes (total)					100	
Methyl tert-Butyl Ether (MTBE)					94	
Cumene (isopropylbenzene)					420	
Naphthalene	0.083	0.83	0.31	0.31	0.72	0.072
Trimethylbenzene, 1,2,4- (1,3,4-TMB)			0.73	0.73	7.3	0.73
Trimethylbenzene, 1,3,5-					7.3	
Dibromoethane, 1,2- (ethylene dibromide) (EDB)					0.041	
Dichloroethane, 1,2- (EDC)					0.94	
Common Chlorinated VOCs						
Tetrachloroethylene (PCE)					42	
Trichloroethylene (TCE)	0.48	4.8	0.21	0.21	2.1	0.21
Dichloroethylene, cis-1,2-					—	
Vinyl Chloride					0.79	184

5

Pick higher value

RSL Screening Value Exercise

Exercise Instructions

- You have a sheet of excerpted residential indoor air RSLs from EPA's table
- You have an exercise sheet to fill in RSLs
 1. Look up and enter the RSLs for cancer (10^{-6}) and noncancer (0.1) toxicity
 2. Adjust cancer RSLs to a 10^{-5} risk
 3. Determine the lower RSL
 4. Compare to DEP's SSS screening values
 5. Pick higher value

RSL Exercise: RSL-Based Site-Specific Standard VI Screening Values

Answers

Note: RSLs at a 10^{-5} cancer risk are acceptable only when VI is the sole potential exposure pathway

Regulated Substance	EPA Residential Indoor Air RSLs ($\mu\text{g}/\text{m}^3$)				PA DEP IA SVs ($\mu\text{g}/\text{m}^3$)	
	Carcinogenic	Carcinogenic	Noncarcinogenic	Minimum	SHS	SSS
	10^{-6} Risk	10^{-5} Risk	HQ = 0.1	($10^{-5} / 0.1$)	(residential)	(residential)
Petroleum Short List						
Benzene	0.36	3.6	3.1	3.1	3.1	0.31
Toluene			520	520	5,200	520
Ethylbenzene	1.1	11	100	11	9.7	0.97
Xylenes (total)			10	10	100	10
Methyl tert-Butyl Ether (MTBE)	11	110	310	110	94	9.4
Cumene (isopropylbenzene)			42	42	420	42
Naphthalene	0.083	0.83	0.31	0.31	0.72	0.072
Trimethylbenzene, 1,2,4- (1,3,4-TMB)			0.73	0.73	7.3	0.73
Trimethylbenzene, 1,3,5-			—	—	7.3	0.73
Dibromoethane, 1,2- (ethylene dibromide) (EDB)	0.0047	0.047	0.94	0.047	0.041	0.0041
Dichloroethane, 1,2- (EDC)	0.36	3.6	3.1	0.73	0.94	0.094
Common Chlorinated VOCs						
Tetrachloroethylene (PCE)	11	110	4.2	4.2	42	4.2
Trichloroethylene (TCE)	0.48	4.8	0.21	0.21	2.1	0.21
Dichloroethylene, cis-1,2-			—	—	—	—
Vinyl Chloride	0.17	1.7	10	1.7	0.79	0.079

Example for Four Substances

Residential Sub-Slab Soil Gas

Substance	EPA RSL	DEP SV
Benzene	120	12
Naphthalene	12	2.8
1,2,4-trimethylbenzene	28	28
Trichloroethylene	8.1	8.0

Divide indoor air RSL by attenuation factor

$$\alpha_{SS} = 0.026 \text{ (SV units } \mu\text{g/m}^3\text{)}$$

Example for Four Substances

Residential Near-Source Soil Gas

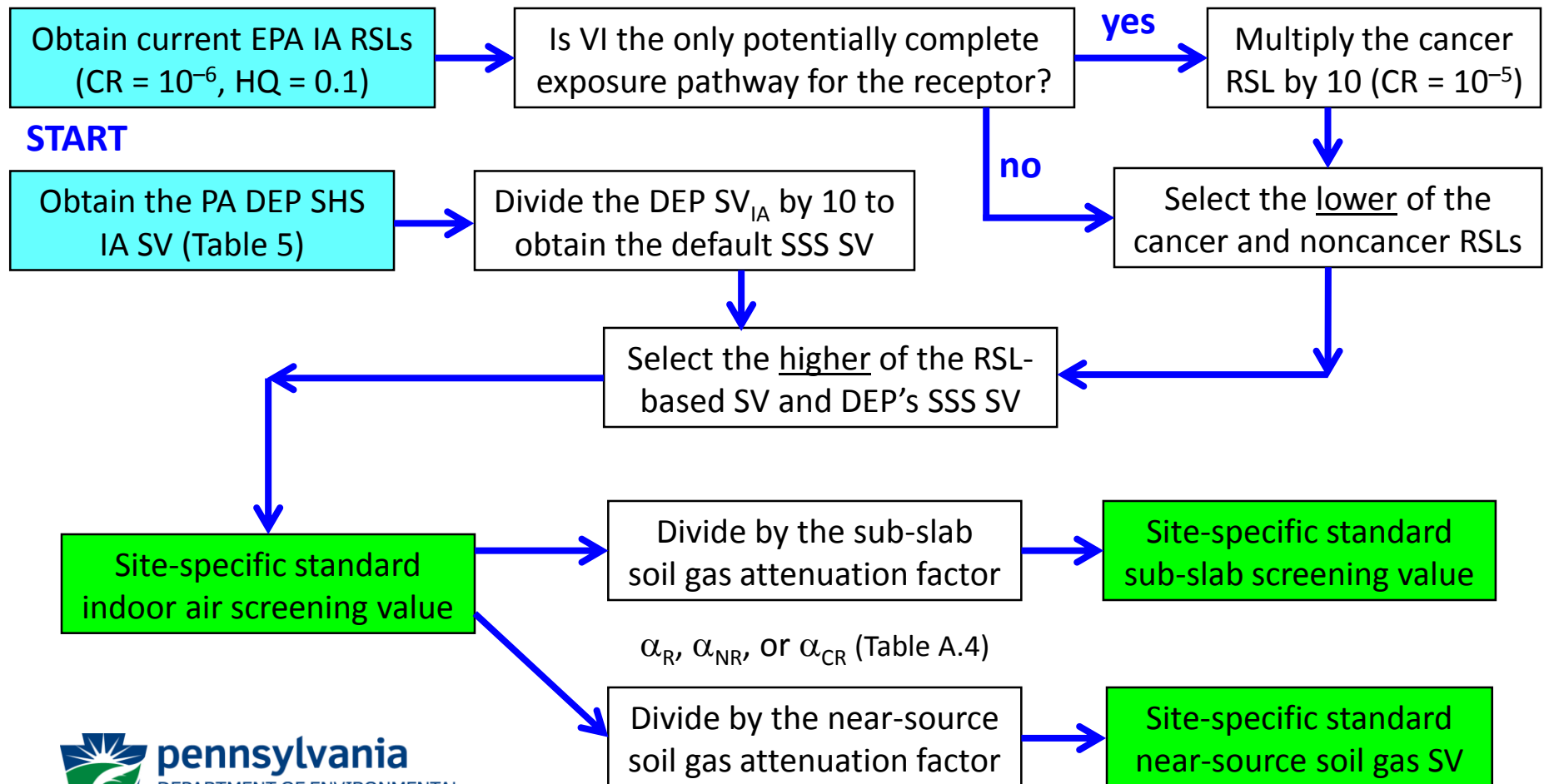
Substance	EPA RSL	DEP SV
Benzene	620	62
Naphthalene	62	14
1,2,4-trimethylbenzene	150	150
Trichloroethylene	42	42

Divide indoor air RSL by attenuation factor

$$\alpha_{NS} = 0.005 \text{ (SV units } \mu\text{g/m}^3\text{)}$$

Process to Determine Site-Specific Standard Vapor Intrusion Screening Values

For each site-specific standard substance:



Site-Specific Standard Vapor Intrusion Screening Values Based on EPA RSLs

Residential Conditions for a 10^{-5} Screening Value Cancer Risk

Note: May 2016 RSL values



Substance	CAS No.	Cancer RSL ($\mu\text{g}/\text{m}^3$)	Non-Cancer RSL ($\mu\text{g}/\text{m}^3$)	Indoor Air RSL-Based SV ($\mu\text{g}/\text{m}^3$)	Sub-Slab Soil Gas RSL-Based SV ($\mu\text{g}/\text{m}^3$)	Near-Source Soil Gas RSL-Based SV ($\mu\text{g}/\text{m}^3$)
Risk Basis		CR = 10^{-6}	HQ = 0.1	CR = 10^{-5} and HQ = 0.1		
Benzene	71-43-2	3.6E-01	3.1E+00	3.1	120	620
Cumene	98-82-8		4.2E+01	42	1,600	8,400
Dibromoethane, 1,2-	106-93-4	4.7E-03	9.4E-01	0.047	1.8	9.4
Dichloroethane, 1,1-	75-34-3	1.8E+00		18	690	3,600
Dichloroethane, 1,2-	107-06-2	1.1E-01	7.3E-01	0.73	28	150
Dichloroethylene, 1,1-	75-35-4		2.1E+01	21	810	4,200
Dichloroethylene, 1,2-cis-	156-59-2					
Dichloroethylene, 1,2-trans-	156-60-5					
Ethylbenzene	100-41-4	1.1E+00	1.0E+02	11	420	2,200
Methyl tert-Butyl Ether (MTBE)	1634-04-4	1.1E+01	3.1E+02	110	4,200	22,000
Naphthalene	91-20-3	8.3E-02	3.1E-01	0.31	12	62
Tetrachloroethylene (PCE)	127-18-4	1.1E+01	4.2E+00	4.2	160	840
Toluene	108-88-3		5.2E+02	520	20,000	100,000
Trichloroethane, 1,1,1-	71-55-6		5.2E+02	520	20,000	100,000
Trichloroethane, 1,1,2-	79-00-5	1.8E-01	2.1E-02	0.021	0.81	4.2
Trichloroethylene (TCE)	79-01-6	4.8E-01	2.1E-01	0.21	8.1	42
Trimethylbenzene, 1,2,3-	526-73-8		5.2E-01	0.52	20	100
Trimethylbenzene, 1,2,4-	95-63-6		7.3E-01	0.73	28	150
Trimethylbenzene, 1,3,5-	108-67-8					
Vinyl Chloride	75-01-4	1.7E-01	1.0E+01	1.7	65	340
Xylenes	1330-20-7		1.0E+01	10	380	2,000

Site-Specific Standard Screening

Summary: RSL Screening Values

- Use current EPA RSL tables
- Adjust cancer RSL to 10^{-5} if VI only pathway
- Minimum of cancer/noncancer RSL
- RSL-based screening values may be higher than one-tenth of DEP's SVs—advantage
- Calculate soil gas RSL-based screening values using DEP's attenuation factors



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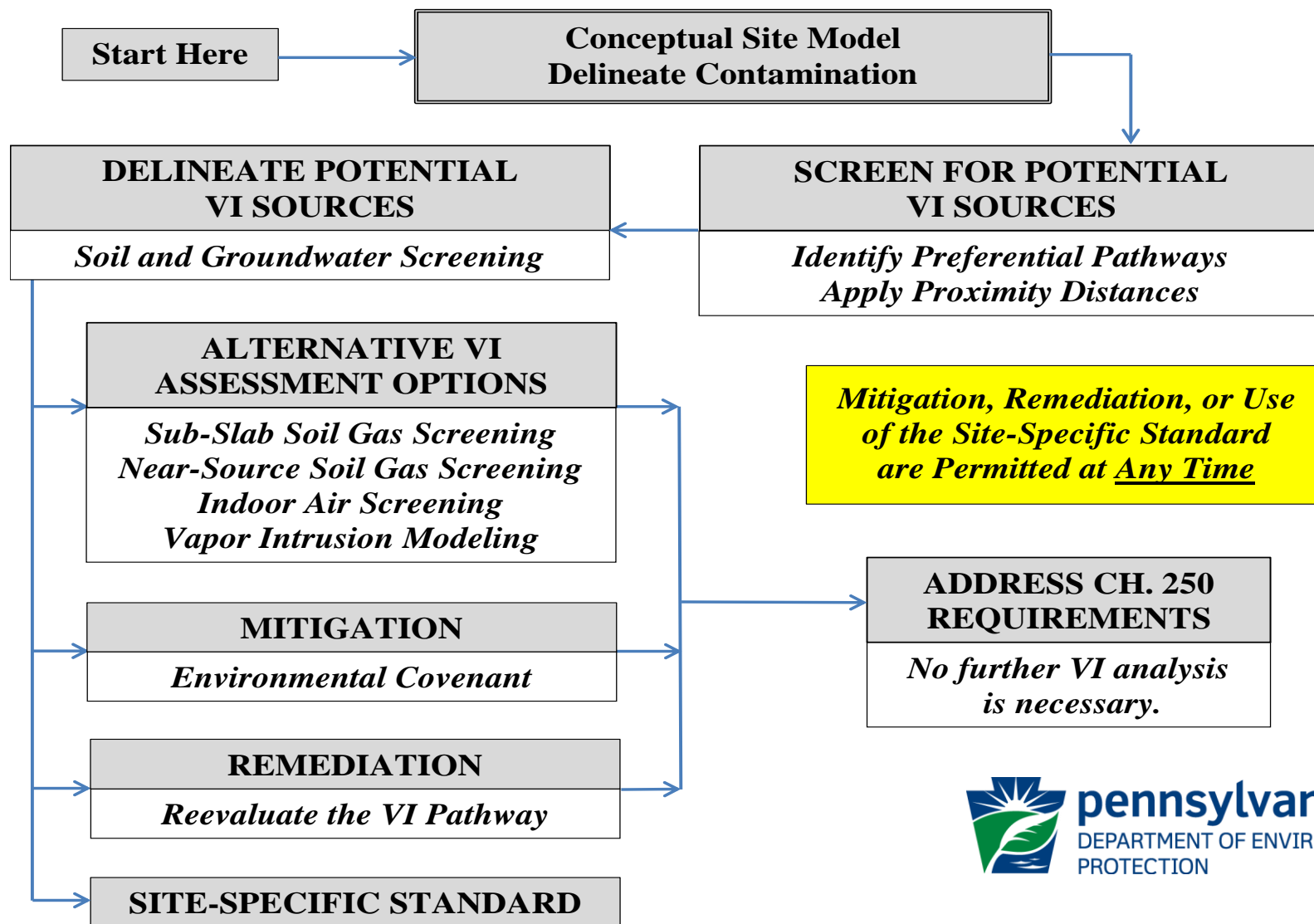


Mitigation, Remediation, Modeling

Charles Campbell (Leidos)
Vapor Intrusion Training

January 10, 2017
Malvern, PA

Evaluating the VI Pathway



Mitigation

When Can Mitigation be Done?

At any time during the evaluation

Eliminates the complete pathway between contamination and the receptor

Most Common Systems:

- Sub-Slab Depressurization System
- Vapor Barrier
- Clay Barrier



[Section H]

Performing Mitigation

- Protective regardless of changes in subsurface concentrations or screening values
- Performance testing requirements in Appendix C
 - Indoor air confirmation sampling not required
- EC needed to ensure maintenance of the system

[Section H]

Sub-Slab Depressurization System

(commonly called a radon mitigation system)

Mitigation Systems



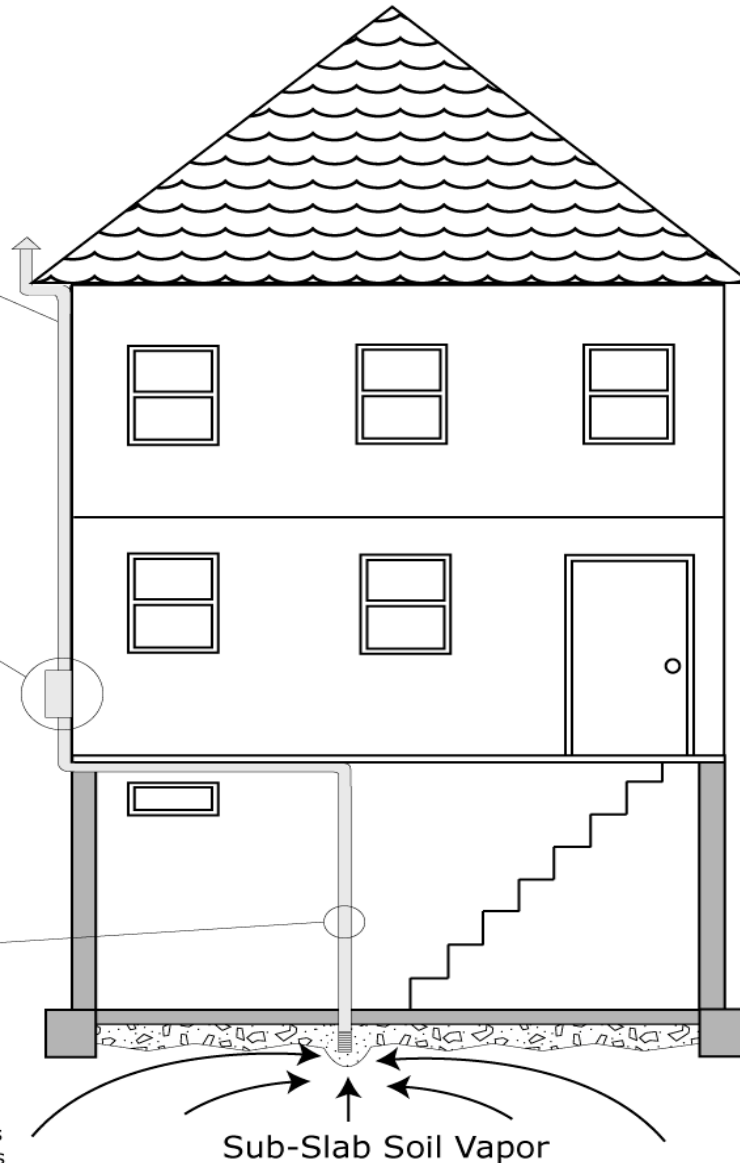
The vent pipe is routed up the side of the structure to a location above the roof line.



A fan is used to draw soil vapor from beneath the slab.



A liquid gauge, or manometer is used to verify that the system is operating properly



A sub-slab depressurization system vents contaminated soil vapor before it enters a structure. The fan draws vapor from beneath the building outside to the roof line where it is released to the outside air.



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Google

Background

- Former dry cleaner
- Commercial and residential building
- Petroleum and PCE soil impacts
- PCE and TCE groundwater impacts

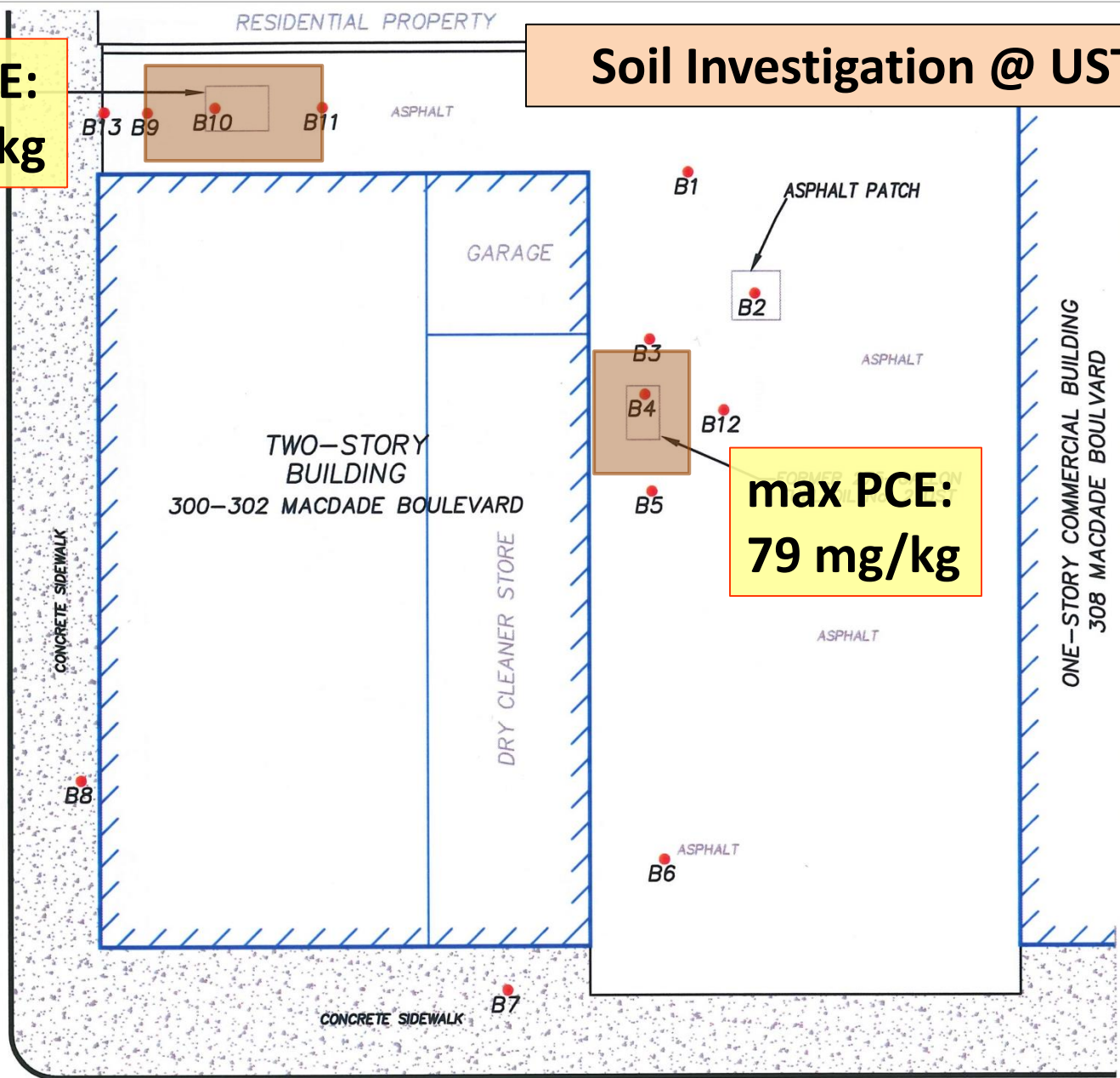
Soil Investigation

- Two heating oil USTs removed
 - January 2013
 - corrosion holes and soil staining
 - closure sampling
 - silt/clay soil
 - trimethylbenzene exceedences
 - maximum PCE 79 mg/kg
 - residential $SV_{\text{SOIL}} = 0.43 \text{ mg/kg}$

Soil Investigation @ USTs

max PCE:
22 mg/kg

max PCE:
79 mg/kg



MACDADE BOULEVARD

Soil Investigation

- Soil borings to characterize and delineate
- Remedial actions: additional soil excavated around each former UST
 - May 2013
- Eight attainment samples at each
- Statewide health standard attained for fuel oil short list, but not for PCE
 - No exceedences of petroleum soil SVs

VI Case Study

Example: Soil VI **Non-Attainment**

PCE in soil (mg/kg)

A1-1	A1-2	A1-3	A1-4	A1-5	A1-6	A1-7	A1-8
0.37	9.6	0.31	0.54	0.37	0.38	0.024	0.016

Soil-to-groundwater MSC 0.50 mg/kg

Vapor intrusion SV_{SOIL} 0.43 mg/kg

Result: **Fails** 75%/10x test

because 9.6 mg/kg is $>10x$ MSC and $>10x$ SV_{SOIL}

VI Case Study

Example: Soil VI Attainment

PCE in soil (mg/kg)

A2-1	A2-2	A2-3	A2-4	A2-5	A2-6	A2-7	A2-8
<0.001	0.0028	0.030	0.31	0.32	0.22	0.61	0.015

Soil-to-groundwater MSC 0.50 mg/kg

Vapor intrusion SV_{SOIL} 0.43 mg/kg

Result: **Passes** 75%/10x test

Groundwater Investigation

- Four overburden monitoring wells installed
 - 20 feet deep, 15-foot screens
 - Depth to water ~9 feet
 - Wetted length of well screen ~10 feet or less
 - No NAPL observed
- Five rounds of sampling (2013–2015)

Substance	Data ($\mu\text{g/L}$)	SV_{GW} ($\mu\text{g/L}$)
PCE	40–130	110
TCE	~80	9

Groundwater Investigation

FORMER 1,000-GALLON
FUEL OIL No. 2 UST
(AOC No. 1)

RHODES AVENUE

CONCRETE SIDEWALK

MW-3
(87.73)

MW-1
(91.26)

TWO-STORY BUILDING
300-302 MACDADE BOULEVARD

ASPHALT

91.00

90.50

90.00

89.50

89.00

MW-2
(88.50)

87.50

87.00

CONCRETE SIDEWALK MW-4
(86.96)

ASPHALT

ONE-STORY COMMERCIAL BUILDING
308 MACDADE BOULEVARD

maximum
concentrations:
PCE 130 $\mu\text{g/L}$
TCE $\sim 80 \mu\text{g/L}$

30 feet



MACDADE BOULEVARD

Soil Gas Investigation

- Two soil gas samples
 - collected beneath the building
 - 5 feet deep
 - helium leak tests
 - 1-hr samples
 - collected 1-month apart
 - March–April 2013
- Appropriate screening is with sub-slab SVs, not near-source SVs

VI Case Study

Soil Gas Investigation

Results:

Substance	March ($\mu\text{g}/\text{m}^3$)	April ($\mu\text{g}/\text{m}^3$)	RSL/SV _{SS} ($\mu\text{g}/\text{m}^3$)
PCE	100,000	2,200,000	160
TCE	2,200	5,700	8.0

(Site-specific standard residential screening values)

Mitigation System Installation

- Sub-slab depressurization system
 - Installed by certified radon mitigator
 - Two vapor collection sumps placed at back end of building
 - One blower
 - June 2013
 - Indoor air testing instead of differential pressure testing

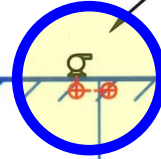


SSD Mitigation System

RESIDENTIAL PROPERTY

CONCRETE BLOCK RETAINING WALL

SUB-SLAB DEPRESSURIZATION SYSTEM
INSTALLED ON JUNE 4, 2013



GARAGE

ASPHALT

TWO-STORY
BUILDING

300-302 MACDADE BOULEVARD

DRY CLEANER STORE

ASPHALT

ONE-STORY COMMERCIAL BUILDING
308 MACDADE BOULEVARD

CONCRETE SIDEWALK

CONCRETE SIDEWALK

30 feet



MACDADE BOULEVARD

Mitigation System Testing

- Initial indoor air testing round
 - June 2013
 - two indoor locations
 - one outdoor ambient sample
 - 24-hr samples

Mitigation System Testing

Results of initial indoor air testing round:

Substance	Indoor 300 ($\mu\text{g}/\text{m}^3$)	Garage ($\mu\text{g}/\text{m}^3$)	Outdoor ($\mu\text{g}/\text{m}^3$)	RSL/SV _{IA} ($\mu\text{g}/\text{m}^3$)
PCE	4.7	< 3.4	< 3.4	4.2
TCE	< 2.7	< 2.7	< 2.7	0.21

(Site-specific standard residential screening values)

PCE concentration of $4.7 \mu\text{g}/\text{m}^3$ *alone* does not pose an excess risk (VISL)

Mitigation System Testing

- Second indoor air testing round
 - July 2013
 - Same three indoor/outdoor locations

Substance	Indoor 300 ($\mu\text{g}/\text{m}^3$)	Garage ($\mu\text{g}/\text{m}^3$)	Outdoor ($\mu\text{g}/\text{m}^3$)	RSL/SV _{IA} ($\mu\text{g}/\text{m}^3$)
PCE	56	< 3.4	< 3.4	4.2
TCE	< 2.7	< 2.7	< 2.7	0.21

PCE concentration of $56 \mu\text{g}/\text{m}^3$ **does** pose an excess risk (HQ = 1.3)

Mitigation System Testing

- Third indoor air testing round
 - August 2013
 - Three indoor locations
 - Sealed cracks, floor drain before sampling

Substance	Indoor 300 ($\mu\text{g}/\text{m}^3$)	Indoor 302 ($\mu\text{g}/\text{m}^3$)	Garage ($\mu\text{g}/\text{m}^3$)	RSL/SV _{IA} ($\mu\text{g}/\text{m}^3$)
PCE	250	< 3.4	14	4.2
TCE	< 2.7	< 2.7	< 2.7	0.21

Indoor Air Sampling

indoor air (garage)
PCE ND-14 $\mu\text{g}/\text{m}^3$

outdoor air
PCE nondetect

indoor air (302)
PCE nondetect

soil gas point
max PCE:
2,200,000 $\mu\text{g}/\text{m}^3$

indoor air (300)
PCE 4.9-250 $\mu\text{g}/\text{m}^3$

RHODES AVENUE

CONCRETE SIDEWALK

GARAGE

TWO-STORY BUILDING
300-302 MACDADE BOULEVARD

DRY CLEANER STORE

ONE-STORY COMMERCIAL BUILDING
308 MACDADE BOULEVARD

ASPHALT

CONCRETE SIDEWALK

30 feet



MACDADE BOULEVARD

Mitigation System Modification

- Expanded SSD system
 - Two additional vapor collection sumps, in tenant space adjacent to dry cleaner
 - One additional blower
 - September 2013

RESIDENTIAL PROPERTY

CONCRETE BLOCK RETAINING WALL

SUB-SLAB DEPRESSURIZATION SYSTEM
INSTALLED ON SEPTEMBER 18, 2013

Modified SSD System

RHODES AVENUE

CONCRETE SIDEWALK

GARAGE

ASPHALT

TWO-STORY
BUILDING

300-302 MACDADE BOULEVARD

DRY CLEANER STORE

indoor air
 $\text{PCE} < 3.4 \mu\text{g}/\text{m}^3$

ONE-STORY COMMERCIAL BUILDING
308 MACDADE BOULEVARD

ASPHALT

CONCRETE SIDEWALK

30 feet



MACDADE BOULEVARD

Mitigation System Testing

- Fourth indoor air testing round
 - October 2013
 - Two indoor, one outdoor locations

Substance	Indoor 300 ($\mu\text{g}/\text{m}^3$)	Garage ($\mu\text{g}/\text{m}^3$)	Outdoor ($\mu\text{g}/\text{m}^3$)	RSL/SV _{IA} ($\mu\text{g}/\text{m}^3$)
PCE	< 3.4	< 3.4	< 3.4	4.2
TCE	< 2.7	< 2.7	< 2.7	0.21

No exceedences

Conclusions

- ▶ Mitigation system designs may be deficient
 - Needs to be installed in a location where it is most effective
 - Even in a relatively small building
- Some substances (e.g., TCE, naphthalene) have very low indoor air screening values
 - Consultants should communicate with labs on options for analysis

Remediation

When Can Remediation be Done?

At any time during the evaluation

Remediation should result in resampling and reevaluation



Remediation

Performing Remediation

- Remediator may choose soil and/or GW remediation.
- Data must be collected following remediation for VI screening.
- Remediator must implement interim measures to protect human health if remediation will be a long-term activity.

[Section I]

Environmental Covenants

Institutional Controls – prevent exposure

(can be used to maintain the Statewide Health Standard, but NOT to attain it)

Engineering Controls – contain or control migration



Is An Environmental Covenant Needed

- Required for active mitigation (engineering control)
- Required for institutional controls for future use:
 - prohibiting new buildings or basements
 - requiring a VI evaluation for new construction
 - requiring mitigation for new construction
 - for the ongoing applicability of an OSHA program

[Sections H and J]

When Evaluating Indoor Air:

- Difficult to evaluate the effect of the VI source when the same chemicals are being used in the building.
- Remediator may choose to use OSHA program to address VI because the PEL values are much higher than indoor air screening values.
- <https://www.osha.gov/dsg/annotated-pels/index.html>

OSHA Program

Using OSHA to Address VI:

- May use OSHA program to address VI under Act 2 only if:
 1. COC in GW or soil is currently used in on-site industrial processes
 2. OSHA regulations are fully implemented and documented in ALL areas of the building for ALL possible receptors
- Quantitative analysis of indoor air data using occupational screening values is expected
- EC required if using OSHA program to evaluate VI

OSHA Program

Demonstrating that OSHA regulations are fully implemented:

- Appendix D
 - Checklist of elements to document the OSHA program on the site
 - All elements on the checklist should be present in the report to prove the OSHA program is adequately implemented for all receptors

Appendix D: OSHA Program Vapor Intrusion Checklist

List the chemical(s) of concern that the facility uses:

Chemical:

CAS Registry Number:

_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

- ☐ Facility provided Material Safety Data Sheet(s) (MSDS) or Safety Data Sheet(s) (SDS) for the chemical(s) of concern listed above that they have identified as using.
- ☐ Facility identified where the chemical(s) are used in the facility and how they are used.
- ☐ The facility has performed air monitoring (industrial hygiene) of the identified chemical(s) of concern.
- ☐ The facility has provided the results of the air monitoring to the Department.
- ☐ The air monitoring has been conducted in all areas of the plant or facility.
- ☐ The facility has provided documentation showing that all employees in the facility have completed safety training associated with the chemicals of concern.

OSHA Checklist



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OSHA Checklist

List the chemical(s) of concern that the facility uses:

Chemical:

CAS Registry Number:

– Regulated substances in the VI pathway must also be used in the workplace

OSHA Checklist

- ❑ Facility provided Material Safety Data Sheet(s) (MSDS) or Safety Data Sheet(s) (SDS) for the chemical(s) of concern listed above that they have identified as using.
- ❑ Facility identified where the chemical(s) are used in the facility and how they are used.
- ❑ The facility has performed air monitoring (industrial hygiene) of the identified chemical(s) of concern.

OSHA Checklist

- ☐ The facility has provided the results of the air monitoring to the Department.
- ☐ The air monitoring has been conducted in all areas of the plant or facility.
- ☐ The facility has provided documentation showing that all employees in the facility have completed safety training associated with the chemicals of concern.

OSHA Checklist

- Pictures provided by the facility show PPE and signage use associated with the chemicals of concern.
 - ❖ Include Annual assessments and medical clearances



OSHA Checklist

Occupational Exposure Values for Chemicals of Concern

Occupational Safety and Health Administration Permissible Exposure Limits (OSHA PEL) or American Conference of Governmental Industrial Hygienist Threshold Limit Values (ACGIH TLV).

Chemical of Concern	OSHA PEL	ACGIH TLV

OSHA exposure limits are available at: 29 CFR Subpart Z; 29 CFR 1910.1000–1052

<https://www.osha.gov/dsg/annotated-pels/index.html>

ACGIH TLVs are available from the purchased publication. All of these values should be available from the MSDS/SDS.

Status: (All of the above items must be included in order for the facility to qualify to use an OSHA program to address VI.)

☐ Qualified

☐ Not Qualified

Consultant or Reviewer:

(Print) _____

(Signature) _____ Date: _____

Appendix B

- Description of DEP's modeling expectations
- SHS and SSS modeling approaches
- Report contents—what information the consultant should submit

Why use Modeling?

- Screening of predicted indoor air
 - For SHS
 - Indoor air measurements may not be possible:
 - Access Issues
 - Presence of chemicals indoors that will interfere with measurement
 - Undeveloped sites or areas

[Section G.3]

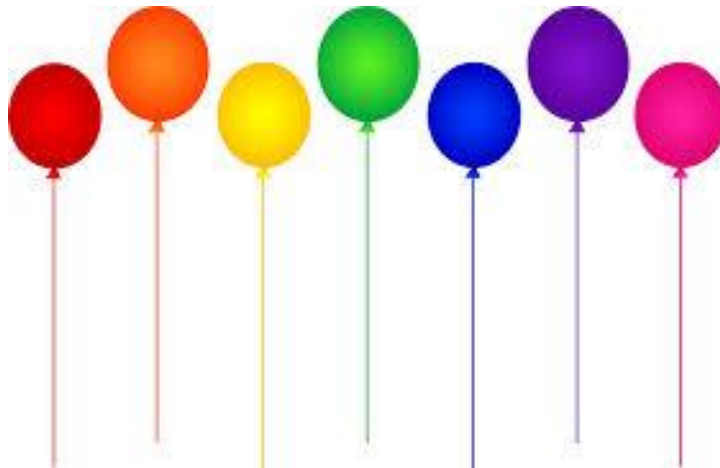
Why use Modeling?

- Screening of predicted indoor air
 - Model generates a predicted indoor air concentration
 - Predicted indoor air concentration is compared to the indoor air screening value

[Section G.3]

Why use Modeling?

- Calculate predicted inhalation risks
(Risk Assessment)
 - For SSS ONLY

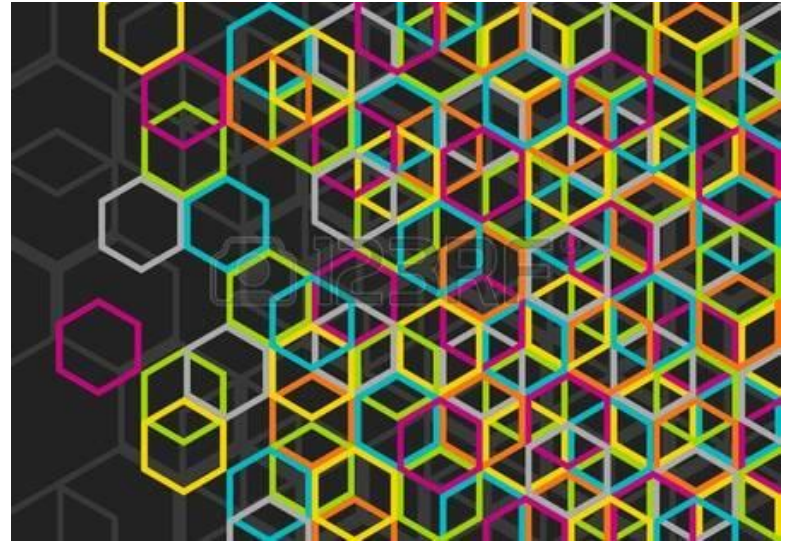


[Section K.5]

VI Modeling

Models Available

- J&E Model
- BioVapor model
 - Best for petroleum VI sites because J&E does not account for bioattenuation of petroleum



[Section G.3]

Restrictions for J&E Model

- Can't model Soil/ GW data when external preferential pathway or SPL is present
- Can't model Near-Source soil gas data when external preferential pathway is present

[Section G3]

J&E Model

- Should only use DEP versions of J&E
 - Posted on the DEP website on the Vapor Intrusion page
 - PA versions have the DEP default input parameters, physical/chemical properties, and toxicological values

[Appendix B]

J&E Model

- Six PA DEP J&E models, based on source data and land use:
 - Groundwater Residential and Non-residential
 - Soil Residential and Non-residential
 - Soil Gas Residential and Non-residential

[Appendix B]

Modeling Under SHS

- Predicted Indoor Air concentration on RESULTS tab
- Compared to the indoor air screening value

[Appendix B]

VI Modeling

Modeling Under SSS

- Inhalation Risks (carcinogenic and noncarcinogenic) on the RESULTS tab are added with all risks for the given receptor
- Compared to the Act 2 thresholds

[Appendix B]

RESULTS

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

Indoor exposure groundwater conc., carcinogen (µg/L)	Indoor exposure groundwater conc., noncarcinogen (µg/L)	Risk-based indoor exposure groundwater conc., (µg/L)	Pure component water solubility, S (µg/L)	Final indoor exposure groundwater conc., (µg/L)
NA	NA	NA	1.10E+06	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

MESSAGE: Mutagenic adjustment factor applied to cancer risk calculation.

Groundwater Results

PA DEP J&E
version 6.2R
September 2016

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
1.2E-04	2.5E+01

INDOOR AIR CALCULATIONS:

Infinite source bldg. conc., C_{building} (µg/m ³)
5.3E+01

SSS: Inhalation risks

SHS: Indoor air concentration

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES Not available for PA DEP models.

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION (enter "X" in "YES" box and initial groundwater conc. below)

YES

☒

ENTER

ENTER

Chemical
CAS No.
(numbers only,
no dashes)

Initial
groundwater
conc.,
 C_w
($\mu\text{g/L}$)

79016

1.00E+03

Chemical

TRICHLOROETHYLENE (TCE)

Entries highlighted in yellow should be verified and updated with site-specific information by the user, if appropriate. (Other parameters may also be modified.) Refer to the PA DEP Technical Guidance Manual for Vapor Intrusion, Appendix B.

ENTER

ENTER

ENTER

ENTER

ENTER

ENTER

ENTER

ENTER

ENTER

ENTER

Average
soil/
groundwater
temperature,
 T_s
($^{\circ}\text{C}$)

Depth
below grade
to bottom
of enclosed
space floor,
 L_F
(cm)

Depth
below grade
to water table,
 L_{WT}
(cm)

Thickness
of soil
stratum A,
 h_A
(cm)

Thickness
of soil
stratum B,
(Enter value or 0)
 h_B
(cm)

Thickness
of soil
stratum C,
(Enter value or 0)
 h_C
(cm)

Soil
stratum
directly above
water table,
(Enter A, B, or C)

SCS
soil type
directly above
water table

Soil
stratum A
SCS
soil type
(used to estimate
soil vapor
permeability)

OR

User-defined
stratum A
soil vapor
permeability,
 k_v
(cm^2)

16

15

150

150

0

0

A

SL

SL

ENTER

ENTER

ENTER

ENTER

ENTER

ENTER

ENTER

ENTER

ENTER

ENTER

ENTER

ENTER

Stratum A
SCS
soil type
Lookup Soil
Parameters

Stratum A
soil dry
bulk density,
 ρ_b^A
(g/cm^3)

Stratum A
soil total
porosity,
 n^A
(unitless)

Stratum A
soil water-filled
porosity,
 θ_w^A
(cm^3/cm^3)

Stratum B
SCS
soil type
Lookup Soil
Parameters

Stratum B
soil dry
bulk density,
 ρ_b^B
(g/cm^3)

Stratum B
soil total
porosity,
 n^B
(unitless)

Stratum B
soil water-filled
porosity,
 θ_w^B
(cm^3/cm^3)

Stratum C
SCS
soil type
Lookup Soil
Parameters

Stratum C
soil dry
bulk density,
 ρ_b^C
(g/cm^3)

Stratum C
soil total
porosity,
 n^C
(unitless)

Stratum C
soil water-filled
porosity,
 θ_w^C
(cm^3/cm^3)

SL

1.62

0.387

0.1

SL

1.62

0.387

0.1

SL

1.62

0.387

0.1

ENTER

ENTER

ENTER

ENTER

ENTER

ENTER

ENTER

ENTER

Enclosed
space
floor
thickness,
 L_{crack}
(cm)

Soil-bldg.
pressure
differential,
 ΔP
(g/cm-s^2)

Enclosed
space
floor
length,
 L_B
(cm)

Enclosed
space
floor
width,
 W_B
(cm)

Enclosed
space
height,
 H_B
(cm)

Floor-wall
seam crack
width,
 w
(cm)

Indoor
air exchange
rate,
 ER
(1/h)

Average vapor
flow rate into bldg.
OR
Leave blank to calculate
 Q_{soil}
(L/m)

10

40

1000

1000

244

0.1

0.18

5

ENTER

ENTER

ENTER

ENTER

ENTER

ENTER

ENTER

Averaging
time for
carcinogens,
 AT_C
(yrs)

Averaging
time for
noncarcinogens,
 AT_{NC}
(yrs)

Exposure
duration,
 ED
(yrs)

Exposure
frequency,
 EF
(days/yr)

Exposure
time,
 ET
(hr/day)

Target
risk for
carcinogens,
 TR
(unitless)

Target hazard
quotient for
noncarcinogens,
 THQ
(unitless)

70

30

30

350

24

1.0E-05

1

Residential Exposure Factors. Use default residential or nonresidential values for Statewide health standard models.

Used to calculate risk-based groundwater concentration.

DATENTER

Shading for
parameters requiring
site-specific
information

Soil Properties Lookup Table							Mean Grain	Bulk Density		SCS Soil Name
SCS Soil Type	K _s (cm/h)	α _i (1/cm)	N (unitless)	M (unitless)	n (cm ³ /cm ³)	θ _r (cm ³ /cm ³)	Diameter (cm)	ρ _s (g/cm ³)	θ _w (cm ³ /cm ³)	
C	0.61	0.01496	1.253	0.2019	0.459	0.098	0.0092	1.43	0.100	Clay
CL	0.34	0.01581	1.416	0.2938	0.442	0.079	0.016	1.48	0.100	Clay Loam
L	0.50	0.01112	1.472	0.3207	0.399	0.061	0.020	1.59	0.100	Loam
LS	4.38	0.03475	1.746	0.4273	0.390	0.049	0.040	1.62	0.100	Loamy Sand
S	26.78	0.03524	3.177	0.6852	0.375	0.053	0.044	1.66	0.100	Sand
SC	0.47	0.03342	1.208	0.1722	0.385	0.117	0.025	1.63	0.117	Sandy Clay
SCL	0.55	0.02109	1.330	0.2481	0.384	0.063	0.029	1.63	0.100	Sandy Clay Loam
SI	1.82	0.00658	1.679	0.4044	0.489	0.050	0.0046	1.35	0.100	Silt
SIC	0.40	0.01622	1.321	0.2430	0.481	0.111	0.0039	1.38	0.111	Silty Clay
SICL	0.46	0.00839	1.521	0.3425	0.482	0.090	0.0056	1.37	0.100	Silty Clay Loam
SIL	0.76	0.00506	1.663	0.3987	0.439	0.065	0.011	1.49	0.100	Silt Loam
SL	1.60	0.02667	1.449	0.3099	0.387	0.039	0.030	1.62	0.100	Sandy Loam

VLOOKUP

Chemical Properties Lookup Table

<div>PA DEP J&E version 6.2R</div> <div>chem/tox parameters</div> <div>27 August 2016</div>		Organic carbon partition coefficient, K _{oc} (cm ³ /g)	Diffusivity in air, D _a (cm ² /s)	Diffusivity in water, D _w (cm ² /s)	Pure component water solubility, S (mg/L)	Henry's law constant at reference temperature, H' (unitless)	Henry's law constant at reference temperature, H (atm-m ³ /mol)	Henry's law constant reference temperature, T _R (°C)	Normal boiling point, T _B (°K)	Critical temperature, T _C (°K)	Enthalpy of vaporization at the normal boiling point, ΔH _{v,b} (cal/mol)	Unit risk factor, URF (μg/m ³) ⁻¹	Reference conc., RfC (μg/m ³)	Mutagen indicator (M)
CAS No.	Chemical													
50000	FORMALDEHYDE	3.6	1.67E-01	1.74E-05	55000	1.38E-05	3.37E-07	25	252.15	408	5500	1.3E-05	9.8E-03	
55185	NITROSODIETHYLAMINE, N-	26	7.38E-02	9.13E-06	93000	1.48E-04	3.63E-07	25	333.15	508	6955	0.0E+00	0.0E+00	M
56235	CARBON TETRACHLORIDE	160	5.71E-02	9.78E-06	795	1.13E+00	2.76E-07	25	346.1	569	6988	1.0E-01	1.0E-01	
57578	BETA PROPIOLACTONE	4	1.25E-01	1.14E-05	370000	5.25E+02	1.28E-07	25	340.1	508	6955	0.0E+00	0.0E+00	
60344	METHYL HYDRAZINE	1	2.53E-01	1.39E-05	1000000	1.23E-04	3.00E-07	25	330.1	508	6955	2.0E-05	2.0E-05	
62533	ANILINE	190	8.30E-02	1.01E-05	33800	8.26E-05	2.02E-07	25	353.15	508	6955	1.0E-03	1.0E-03	
62759	NITROSODIMETHYLAMINE, N-	8.5	9.88E-02	1.15E-05	1000000	7.44E-05	1.82E-07	25	353.15	508	6955	4.0E-05	4.0E-05	M
64186	FORMIC ACID	0.54	1.48E-01	1.72E-05	1000000	6.83E-06	1.67E-07	25	353.15	508	6955	3.0E-04	3.0E-04	
67561	METHANOL	2.8	1.58E-01	1.65E-05	1000000	1.86E-04	4.55E-07	25	330.1	508	6955	4.0E+00	4.0E+00	
67630	PROPANOL, 2- (ISOPROPYL ALCOHOL)	25	1.03E-01	1.12E-05	1000000	3.31E-04	8.10E-06	25	355.15	508	6955	0.0E+00	2.0E-01	
67641	ACETONE	0.31	1.06E-01	1.15E-05	1000000	1.43E-03	3.50E-05	25	329.22	508	6955	0.0E+00	3.1E+01	
67663	CHLOROFORM	56	7.69E-02	1.09E-05	8000	1.50E-01	3.67E-03	25	334.33	536	6988	2.3E-05	9.8E-02	
67721	HEXACHLOROETHANE	2200	3.21E-02	8.89E-06	50	1.59E-01	3.89E-03	25	459.95	695	9510	1.0E-05	3.0E-02	
71432	BENZENE	58	8.95E-02	1.03E-05	1780.5	2.27E-01	5.55E-03	25	354.05	562	7342	7.8E-06	3.0E-02	
71556	TRICHLOROETHANE, 1,1,1-	100	6.48E-02	9.60E-06	1495	7.03E-01	1.72E-02	25	347.23	545	7136	0.0E+00	5.0E+00	
74839	BROMOMETHANE	170	1.00E-01	1.35E-05	17500	3.00E-01	7.34E-03	25	276.7	467	5714	0.0E+00	5.0E-03	
74873	METHYL CHLORIDE	6	1.24E-01	1.36E-05	6180	3.61E-01	8.82E-03	25	248.95	416	5115	1.8E-06	9.0E-02	
74953	DIBROMOMETHANE	110	5.51E-02	1.19E-05	11400	3.36E-02	8.22E-04	25	369.4	583	7868	0.0E+00	4.0E-03	
74975	BROMOCHLOROMETHANE	27	7.87E-02	1.22E-05	16700	5.97E-02	1.46E-03	25	341.15	512	7168	0.0E+00	4.0E-02	
75003	CHLOROETHANE	42	1.04E-01	1.16E-05	5700	4.54E-01	1.11E-02	25	285.42	460	5879	0.0E+00	1.0E+01	
75014	VINYL CHLORIDE	10	1.07E-01	1.20E-05	2700	1.14E+00	2.78E-02	25	259.78	432	5250	9.0E-06	1.0E-01	VC
75058	ACETONITRILE	0.5	1.34E-01	1.41E-05	1000000	1.41E-03	3.45E-05	25	354.75	546	7110	0.0E+00	6.0E-02	
75070	ACETALDEHYDE	4	1.03E-01	1.16E-05	4000	1.16E-03	2.72E-05	25	293.55	466	6157	2.2E-06	9.0E-03	
75092	DICHLOROMETHANE (METHYLENE CHLORIDE)	16	1.03E-01	1.16E-05	4000	1.16E-03	2.72E-05	25	312.79	510	6706	1.0E-08	6.0E-01	M
75150	CARBON DISULFIDE	300	1.03E-01	1.16E-05	4000	1.16E-03	2.72E-05	25	319.35	552	6391	0.0E+00	7.0E-01	
75252	TRIBROMOMETHANE (BROMOFORM)	130	1.03E-01	1.16E-05	4000	1.16E-03	2.72E-05	25	422.35	696	9479	1.1E-06	0.0E+00	
75274	BROMODICHLOROMETHANE	93	1.03E-01	1.16E-05	4000	1.16E-03	2.72E-05	25	360.15	586	7800	3.7E-05	0.0E+00	
75296	CHLOROPROPANE, 2-	260	1.16E-01	1.01E-05	3100	7.18E-01	1.75E-02	25	320.15	485	6286	0.0E+00	1.0E-01	
75343	DICHLOROETHANE, 1,1-	52	8.36E-02	1.06E-05	5000	2.30E-01	5.62E-03	25	330.45	523	6895	1.6E-06	5.0E-01	
75354	DICHLOROETHYLENE, 1,1-	65	8.63E-02	1.10E-05	2500	1.07E+00	2.61E-02	25	304.71	576	6247	0.0E+00	2.0E-01	
75456	CHLORODIFLUOROMETHANE	59	1.03E-01	1.33E-05	2899	1.66E+00	4.06E-02	25	232.35	369	4836	0.0E+00	5.0E+01	

DEP parameter values

DEP COC list

Evaluating the VI Pathway

Addressing Chapter 250 Requirements

- Final step necessary to demonstrate compliance
- Ch. 250 VI requirements can be achieved by:
 1. Soil and GW screening within proximity distances
 2. Using one or more of the alternative assessment options
 3. Mitigation with an Environmental Covenant (EC)
 4. A Risk Assessment that demonstrates that the health risks are within acceptable limits
- Remediation should result in resampling and reevaluation to meet one of the requirements listed above

Evaluating the VI Pathway

Addressing Chapter 250 Requirements

- Final step necessary to demonstrate compliance
- Ch. 250 VI requirements can be achieved by:

SHS

1. Soil and GW screening within proximity distances
2. Using one or more of the alternative assessment options
3. Mitigation with an Environmental Covenant (EC)
4. A Risk Assessment that demonstrates that the health risks are within acceptable limits

[Section J]

Evaluating the VI Pathway

Addressing Chapter 250 Requirements

- Final step necessary to demonstrate compliance
- Ch. 250 VI requirements can be achieved by:

SSS

1. Soil and GW screening within proximity distances
2. Using one or more of the alternative assessment options
3. Mitigation with an Environmental Covenant (EC)
4. A Risk Assessment that demonstrates that the health risks are within acceptable limits

[Section J]

Addressing Ch. 250 Requirements

SHS

Soil and GW screening within proximity distances

- ✓ Screen data that is within the proximity distance from the contamination
- ✓ If data is below screening values then no Potential VI source is identified
- ✓ Diagrams showing data points, buildings, proximity distances should be included in report

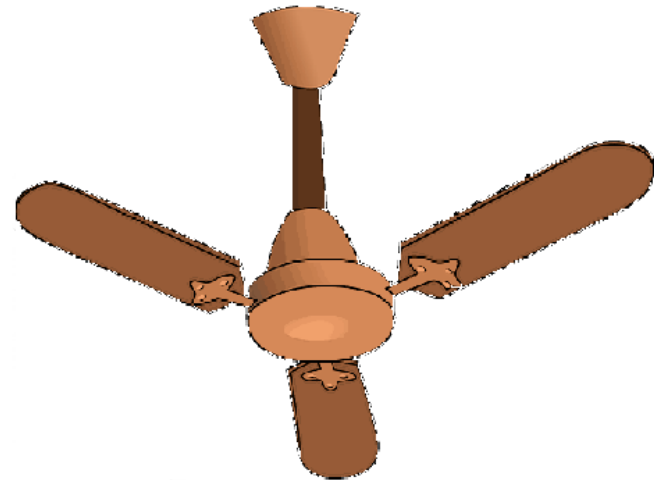
[Section J]

Addressing Ch. 250 Requirements

SHS

Using Alternative Assessment Options

- ✓ Screening Near-Source, Sub-slab, and/or indoor air data
- ✓ Modeling indoor air



[Section J]

Addressing Ch. 250 Requirements

SHS

Using Alternative Assessment Options

- ✓ If data is below screening values then no further analysis is required
- ✓ Diagrams showing sampling points, buildings, Potential VI Sources should be included in report



[Section J]

Addressing Ch. 250 Requirements

SHS

Mitigation with EC

- ✓ Install mitigation system
- ✓ Installer certification, manufacturer's specifications, plans should be included in report
- ✓ Testing of the system should be performed and results documented

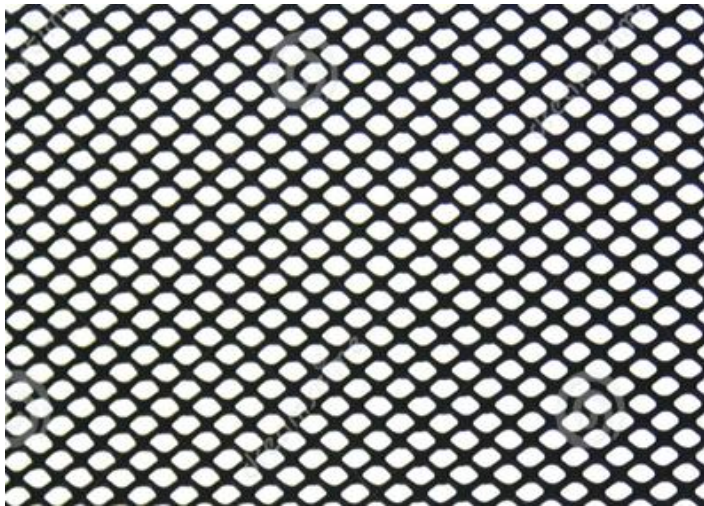


[Section J]

Addressing Ch. 250 Requirements

SSS (Compared to SHS)

- Screening values are different
- Risk Assessment may be required



[Section K.1]



Addressing Ch. 250 Requirements

Act 2 Standard Used to Address Soil and Groundwater	VI Evaluation Tools					
	Use Screening Values in Tables 1–5	Use 1/10 Screening Values in Tables 1–5	Modeling	Risk Assessment	Mitigation with EC (i.e., pathway elimination)	Remediation
Statewide Health Standard (SHS)	✓		✓		✓	✓
Site-Specific Standard (SSS)		✓	✓	✓	✓	✓
Combination of Standards*	✓	✓	✓	✓	✓	✓

- Some media and/or substances may attain the SHS while others may attain the SSS.

[Section C.3]

Addressing Ch. 250 Requirements

SSS

VI evaluation performed under SSS when:

- Substances of VI concern in soil and/or groundwater are evaluated under the SSS
- Soil and groundwater meet SHS, but VI pathway does not meet SHS
- Choosing to evaluate substances such as mercury, cyanide or organics with no inhalation toxicity values

[Section K.1]

Addressing Ch. 250 Requirements

SSS

Risk Assessment demonstrating that health risks are within acceptable limits

- Sum risks for all substances and for **all pathways** for each receptor
- Compare cumulative risk to acceptable thresholds: 10^{-4} cancer risk, hazard index 1.0

[Section K.1]



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VI Sampling

Charles Campbell (Leidos)
Vapor Intrusion Training

January 10, 2017
Malvern, PA

Appendix C

❖ Information and recommendations on sampling methods

- Best practices
- **Not requirements**

Sampling Guidance

- ❖ Variability of Data
- ❖ Sampling Locations
- ❖ Sampling Methods
 - Oxygen content
 - SPL
 - Leak testing
 - Sub-slab depressurization testing

Variability of VI Data

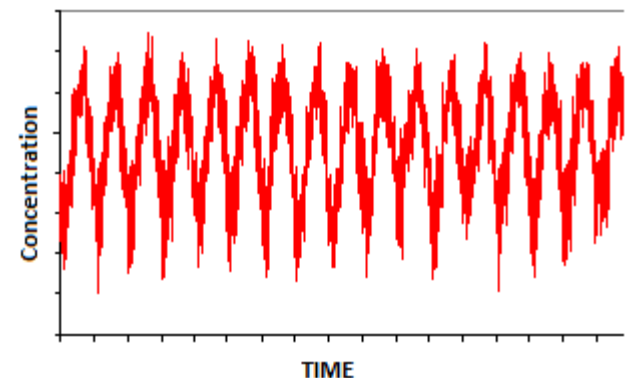
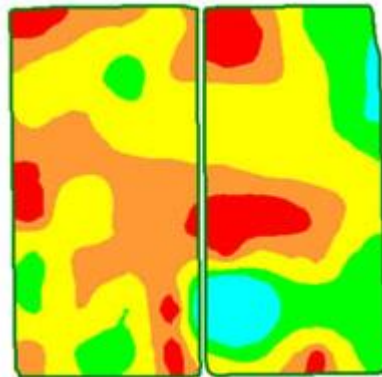
Variability of Data

- In Soil gas, Sub-slab, and Indoor air measurements
- Should be considered in sampling
- Variability range can be an order of magnitude, or more

Variability of VI Data

Variability of Data

- ✓ Spatial variability
- ✓ Temporal variability



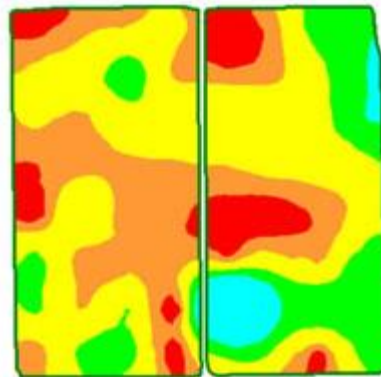
[Appendix C]

Variability of VI Data

Spatial variability

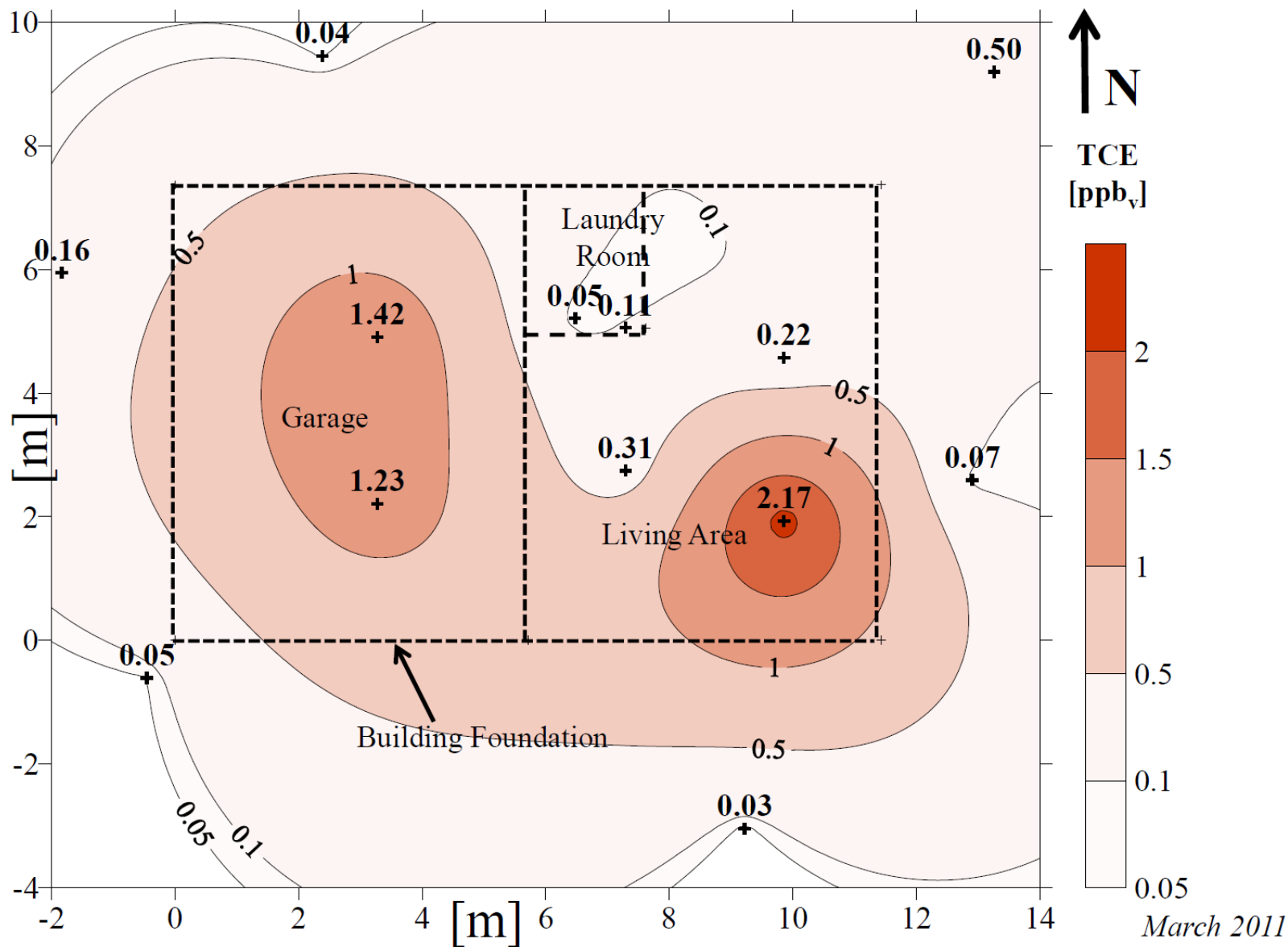
Non-uniform concentrations at different locations within or beneath a building

- Source distribution, building structure, oxygen content of soil



[Appendix C]

TCE in Soil Gas—Layton, Utah Study Site



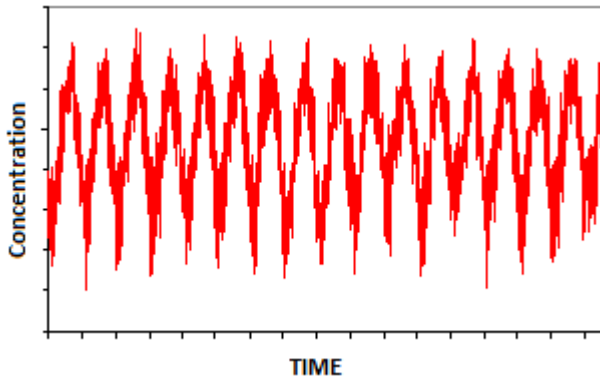
Source: Johnson *et al.* [2011]

Variability of VI Data

Temporal variability

Concentrations that change from one sampling event to the next.

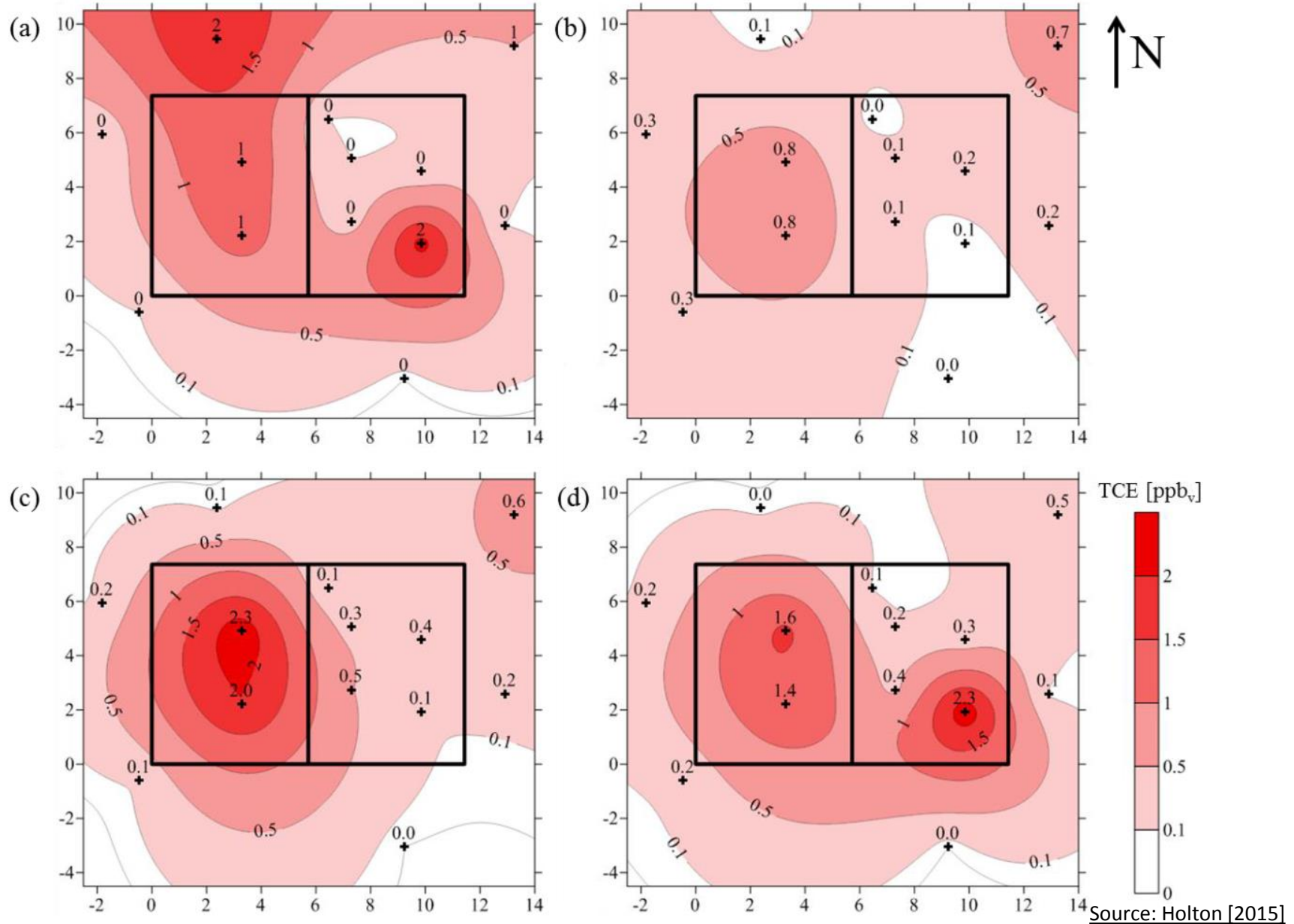
- Pressure and temperature differences, building ventilation, sampling leaks



[Appendix C]

Sub-Slab TCE—Layton, Utah Study Site

Concentrations at four times



Variability of VI Data

How do we address variability?

- Install sufficient sample points—at least two per building
- Perform enough sampling rounds—at least two
- Indoor air sampling during heating season
- VI sampling plan should reflect CSM

Professional judgment

- If DEP's review concludes that sampling is insufficient, discuss doing more

Sampling Locations

Sampling Locations:

- ✓ Near-source soil gas
- ✓ Sub-slab soil gas
- ✓ Indoor Air



[Appendix C]

Sampling Locations

Near-source soil gas

- At least five feet below foundation level to use SV_{NS}
- For a GW source, within one foot of the top of the capillary fringe, or soil-bedrock interface
- Permanent points recommended
- Minimize disturbance to formation

Sampling Locations

Sub-slab soil gas

- Perform pre-sampling survey
- In areas of the building with the greatest expected VI impact
- Intact areas of the slab
- Avoid perimeter (> 5 ft)



[Appendix C]

Sampling Locations

Indoor Air

- Perform pre-sampling survey
 - Visual review of lowest level
 - Conditions of floor slab, floor cracks
 - Heating & Ventilation systems
 - VOC sources in lowest level – paint, solvents, fuel containers
 - VOC sources outside – mowing, paving
 - Occupant activities – painting, smoking

[Appendix C]

Sampling Locations

Indoor Air

- Sample from the lowest occupied level
- Beware of background and indoor sources
- Collect a concurrent ambient air sample
- Use 6-L Summa canisters
 - Sample rate < 200 mL/min; duration 8 or 24 hr

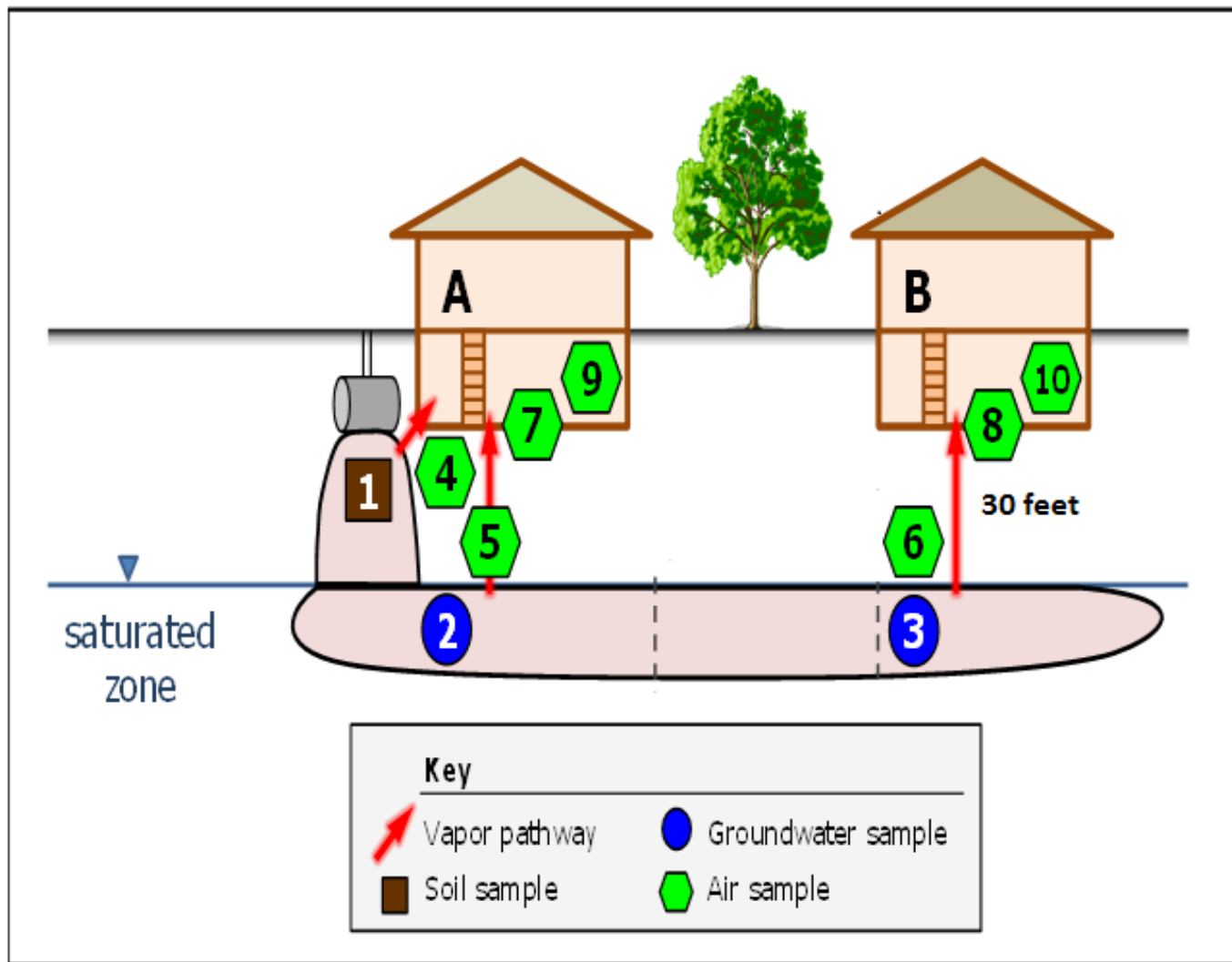
Sampling Locations

Indoor Air

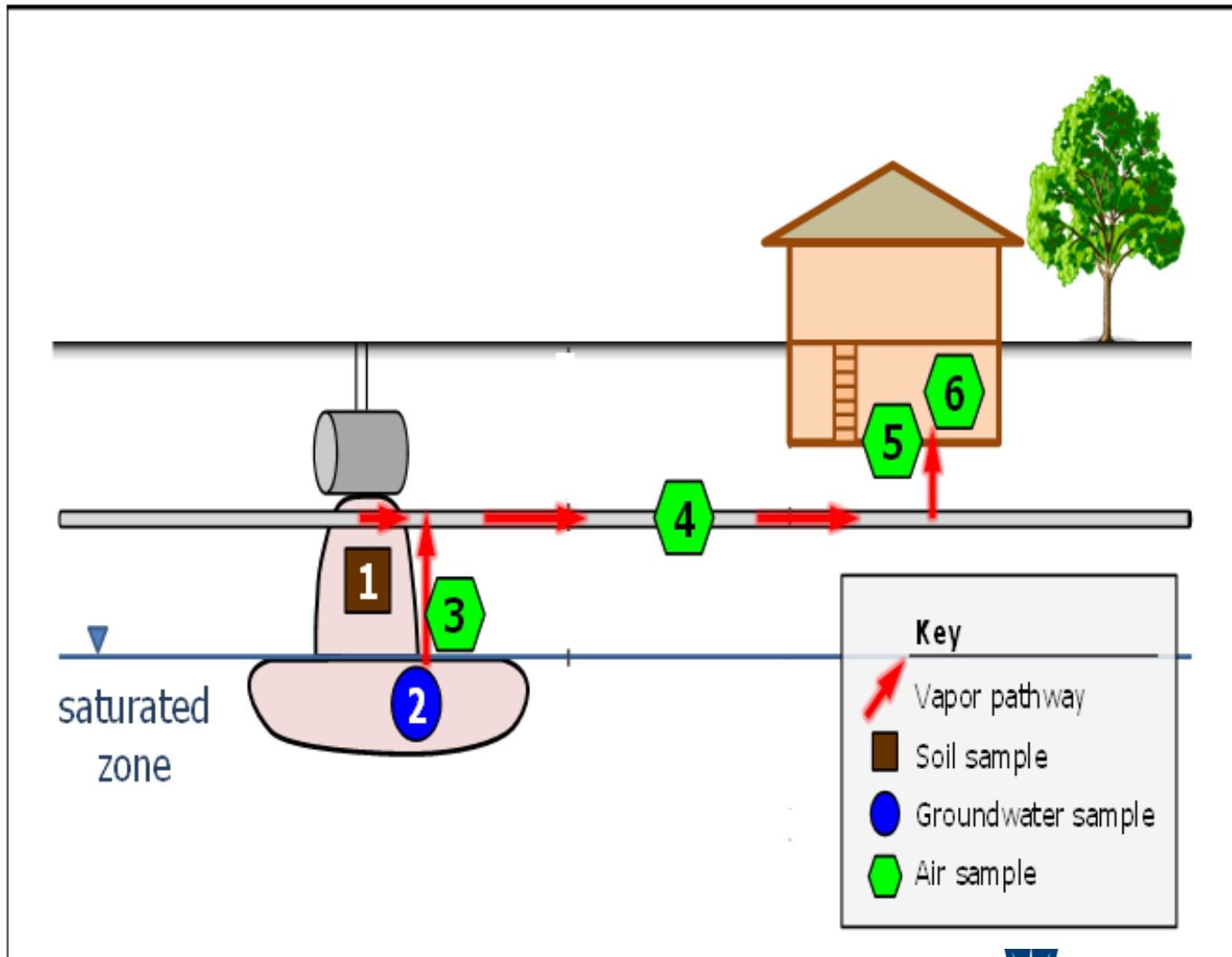
- The indoor temperature should be at least 15°F greater than the outdoor temperature
- Samples collected in warmer seasons should be used for information only and not to screen
- If building is not heated, samples can be collected in any season

[Section G2]

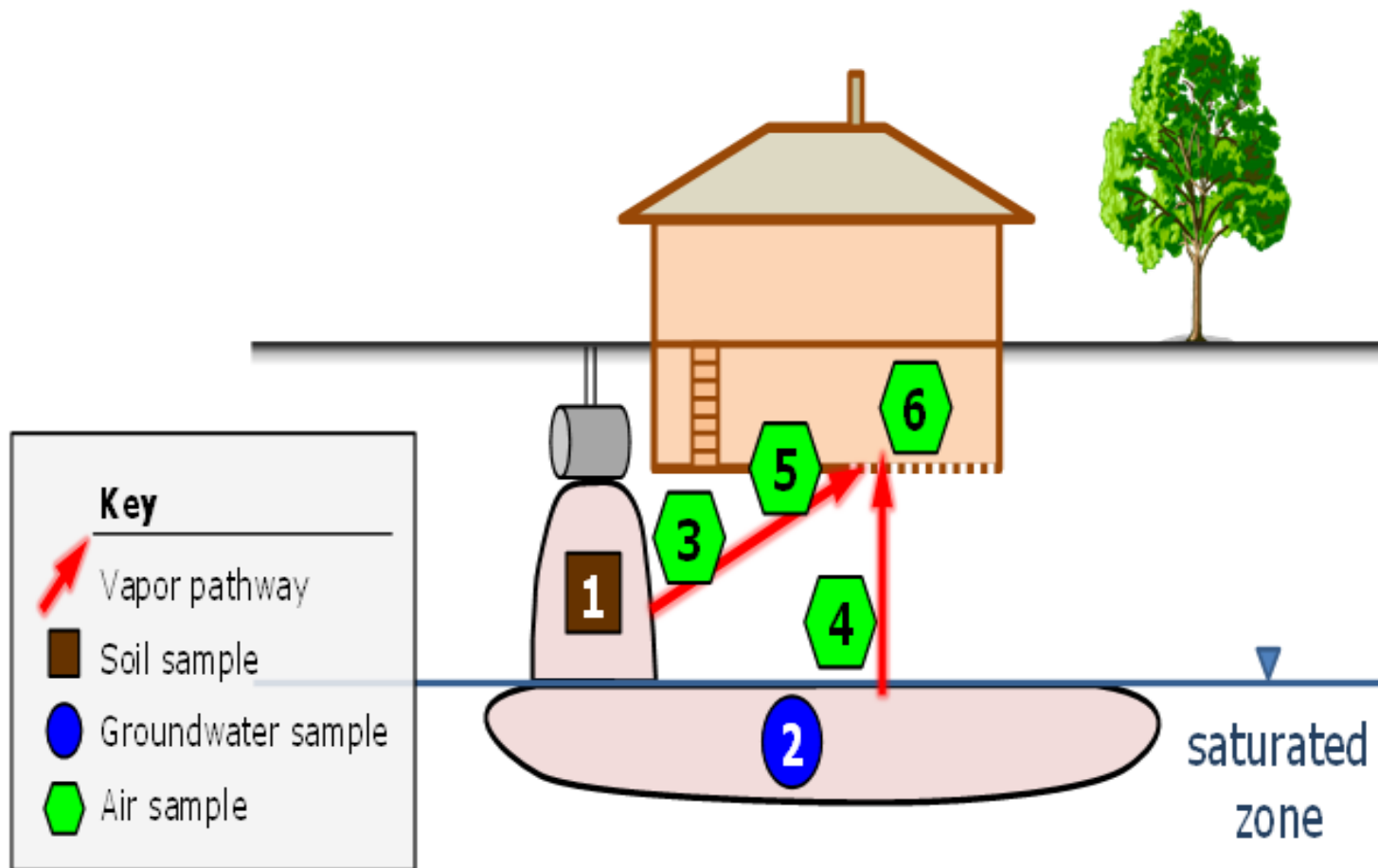
Sampling Locations



Sampling Locations



Sampling Locations



Sampling Methods

Soil Gas

- At least two locations per building
- At least two rounds, at least 45 days apart



Sampling Methods

Soil Gas

- Use appropriate, nonreactive materials
 - No polyethylene tubing
- Point must equilibrate after construction 2-24 hr
- Use passivated canisters (Summa)
 - 1-L volume normally adequate
- Purge about three volumes; Flow rate < 200 mL/min; Sample duration ~30 min

[Appendix C]

Sampling Methods

Using Statistical Tests to screen data:

SHS only

- At least eight data points
- Combination of sampling locations and sampling rounds
- All eight points from one type of sample (NS, SS, IA)
- Sampling rounds performed in subsequent quarters or twice per quarter – At least 45 days apart.

[Section G2]

Oxygen Content

- Demonstrates Acceptable Soil (greater than 2% oxygen content)



[Appendix C]

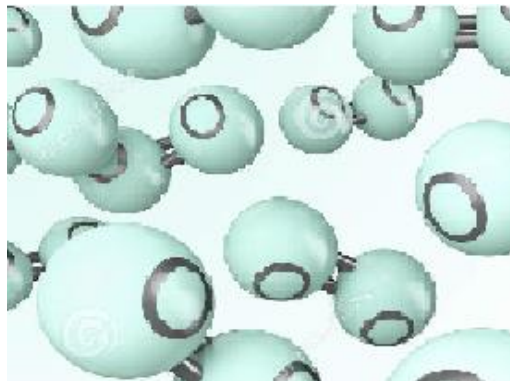
Sampling Methods

Oxygen Content

- Recommended when the soil is suspected to be anaerobic
 - Petroleum substances will not biodegrade at expected rates
- Only needed when using vertical proximity distances for petroleum substances

Oxygen Content

- Sub-slab sample ~12 inches below the slab
- Near-slab no farther than 10 feet from the building (if Sub-slab is not possible)
- One grab sample at one location



[Appendix C]

SPL Sampling

- SPL places limitations on screening, modeling, and use of proximity distances
- Can perform testing of SPL for presence of VOCs that pose a VI risk
- Concentrations of VOCs are evaluated with Near-source screening values to determine if a VI risk is present

Sampling Methods

Leak Testing – recommended

- Leaking during soil gas sampling may dilute samples with ambient air
- ✓ Shut-in test
 - Demonstrates integrity of the sampling assembly using vacuum
- ✓ Leak check
 - Demonstrates surface seal integrity using helium shroud

Sampling Methods

Sub-slab Depressurization Systems

- Differential pressure measurements across the slab
 - More than one location, corners and edges
 - Use a digital micromanometer
 - Demonstrate vacuum of $\geq 0.004''$ H₂O (1 Pa)
- Alternative: indoor air sampling – not required

[Appendix C]



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Vapor Intrusion Case Study Urban Petroleum Site

C. David Brown (DEP)

Vapor Intrusion Guidance Training

January 10, 2017

Malvern, PA

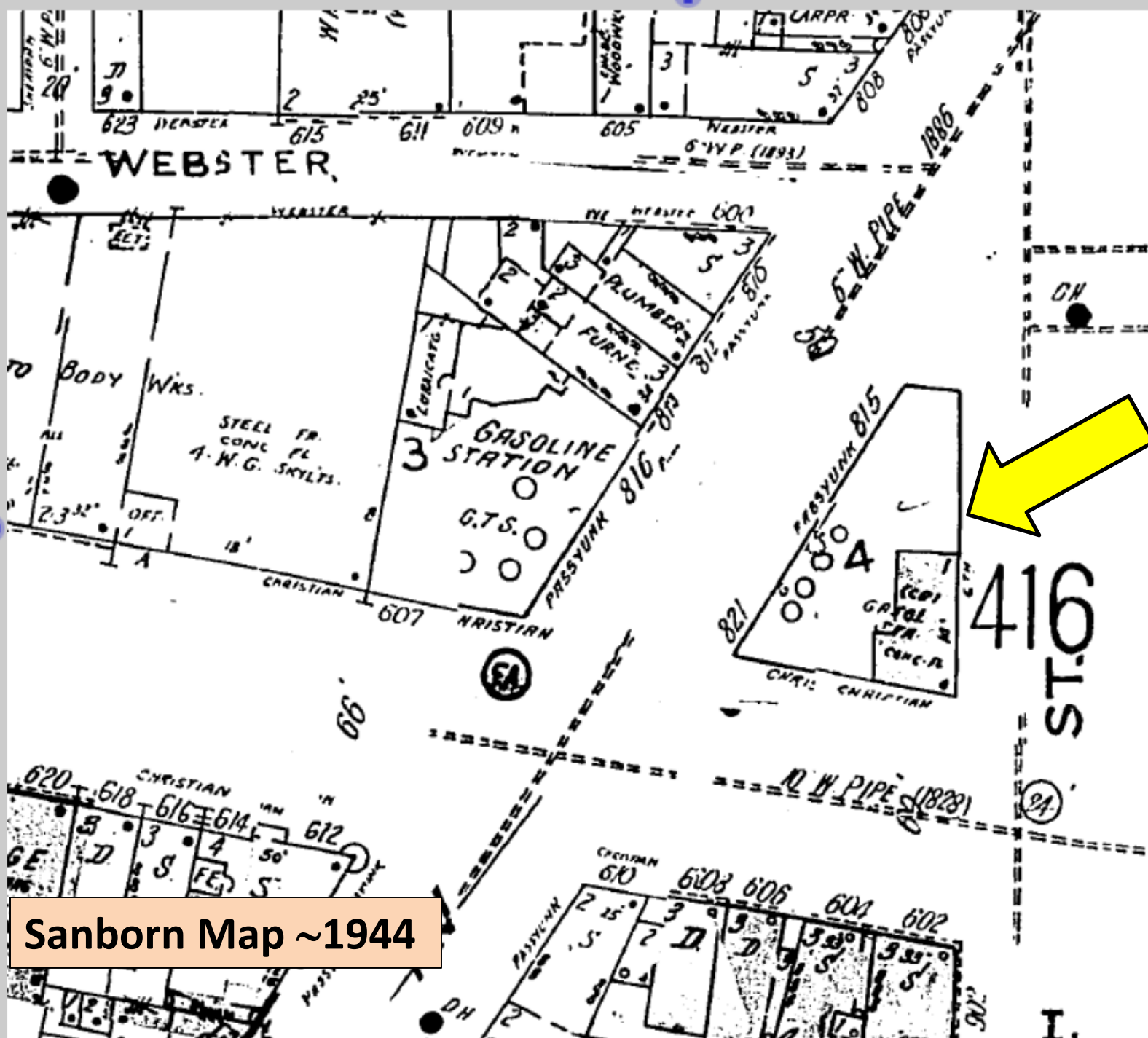
VI Case Study

- Application of the VI evaluation process
- Conceptual site model
- Preferential pathways
- Proximity distances
- Combination of standards
- Soil and groundwater screening
- Soil gas sampling and screening
- SSS risk assessment
- VI modeling

Background

- Former gas station; closed in 1998
- USTs removed in 2006
- Notification of release, soil & groundwater
- Incomplete site characterization
- Potential vapor intrusion receptors
- DEP state lead tank site 2013–



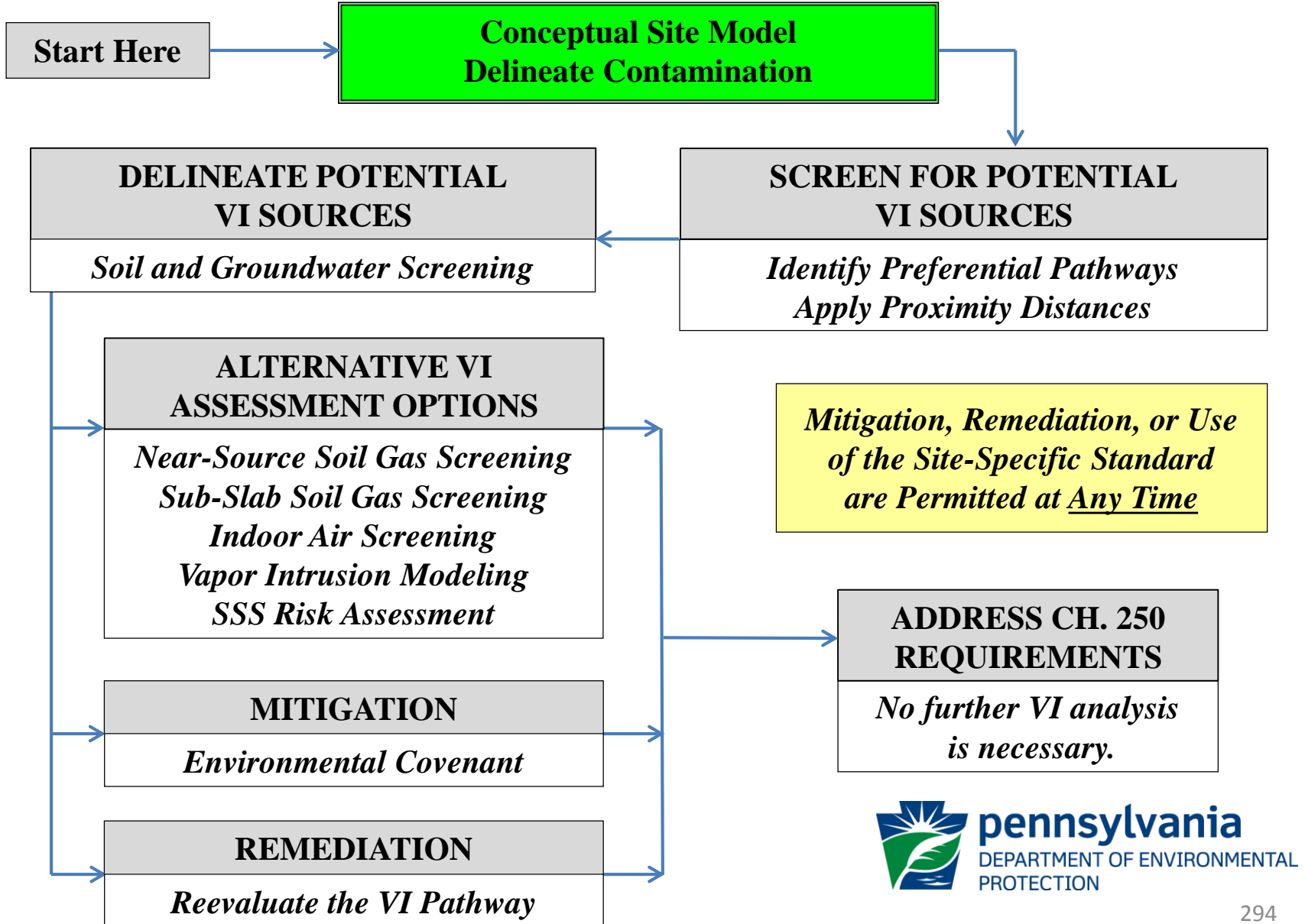


Sanborn Map ~1944





Vapor Intrusion Evaluation Process



Soil Sampling Data

SB-6 10.0-10.5 12/17/13		
Benzene	15	
Ethylbenzene	210	
Naphthalene	59	
Toluene	670	
1,2,4-TMB	640	
1,3,5-TMB	170	
Xylene (Total)	1500	

SB-8 10.0-10.5 12/17/13		
Benzene	57	
Ethylbenzene	270	
Naphthalene	87	
Toluene	1200	
1,2,4-TMB	790	
1,3,5-TMB	220	
Xylene (Total)	1800	

SB-1 10.0-10.5 12/16/13		
1,2,4-TMB	110	
1,3,5-TMB	44	

SB-7 9.0-9.5 12/17/13		
Benzene	2.5	
Ethylbenzene	180	
Naphthalene	76	
Toluene	260	
1,2,4-TMB	830	
1,3,5-TMB	240	
Xylene (Total)	1400	

SB-10 9.0-9.5 12/18/13		
Benzene	17	
Ethylbenzene	150	
Naphthalene	67	
Toluene	480	
1,2,4-TMB	540	
1,3,5-TMB	170	
Xylene (Total)	1300	

MW-1	12/11/13	7.5-8.0	12.5-13.0
Benzene	5.2	55	
Ethylbenzene	73	94	
Naphthalene	26	31	
Toluene	150	510	
1,2,4-TMB	210	230	
1,3,5-TMB	59	71	

SB-9 9.0-9.5 12/18/13		
Benzene	2.5	
Ethylbenzene	89	
Naphthalene	38	
Toluene	140	
1,2,4-TMB	330	
1,3,5-TMB	100	

SB-2 10.0-10.5 12/16/13		
Benzene	18	
Ethylbenzene	210	
Naphthalene	63	
Toluene	810	
1,2,4-TMB	510	
1,3,5-TMB	170	
Xylene (Total)	1200	

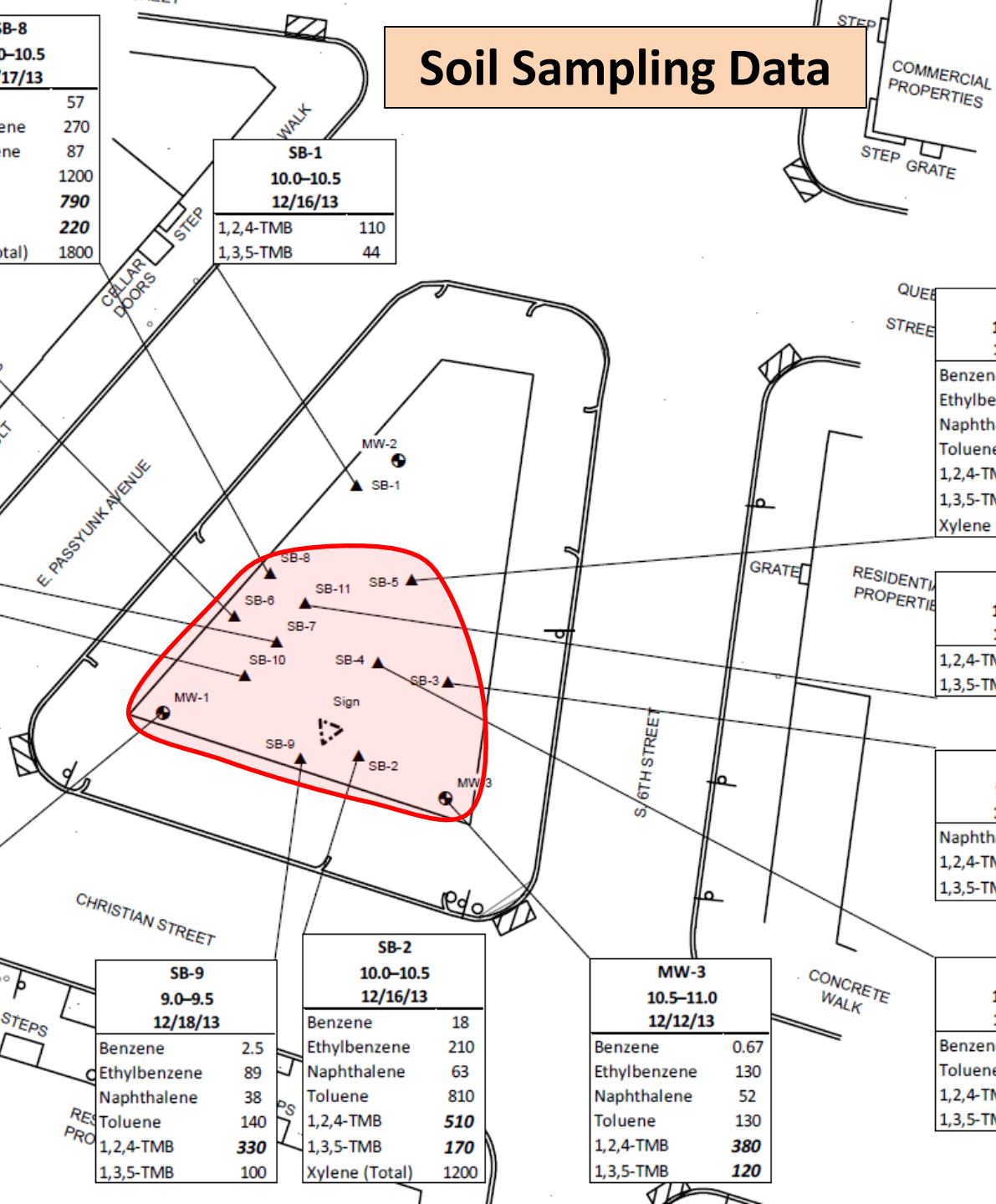
MW-3 10.5-11.0 12/12/13		
Benzene	0.67	
Ethylbenzene	130	
Naphthalene	52	
Toluene	130	
1,2,4-TMB	380	
1,3,5-TMB	120	

SB-5 10.0-10.5 12/16/13		
Benzene	51	
Ethylbenzene	190	
Naphthalene	50	
Toluene	870	
1,2,4-TMB	480	
1,3,5-TMB	140	
Xylene (Total)	1200	

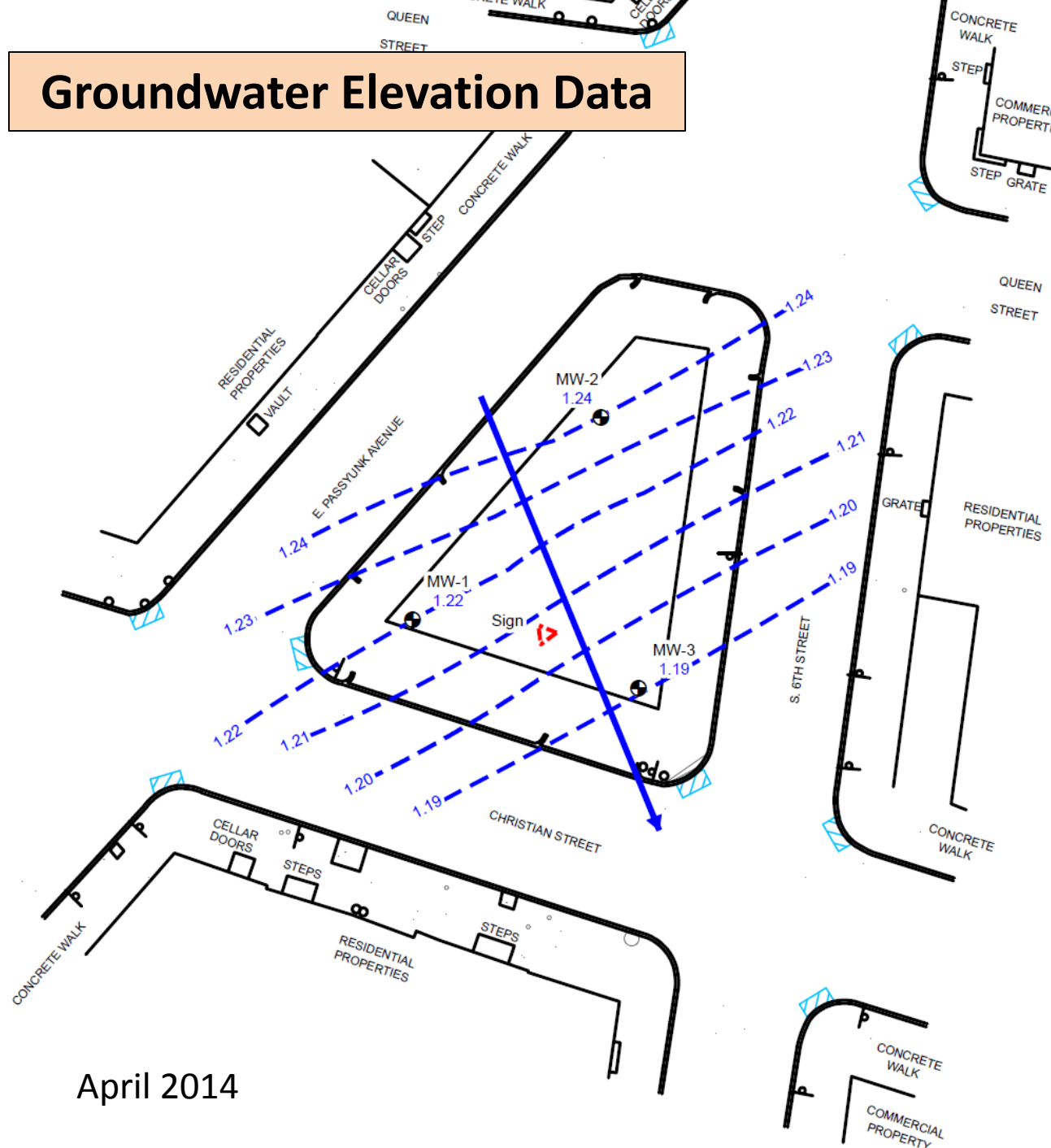
SB-11 15.5-16.0 12/18/13		
1,2,4-TMB	39	
1,3,5-TMB	10	

SB-3 9.5-10.0 12/13/13		
Naphthalene	52	
1,2,4-TMB	530	
1,3,5-TMB	160	

SB-4 10.0-10.5 12/16/13		
Benzene	2	
Toluene	210	
1,2,4-TMB	110	
1,3,5-TMB	33	

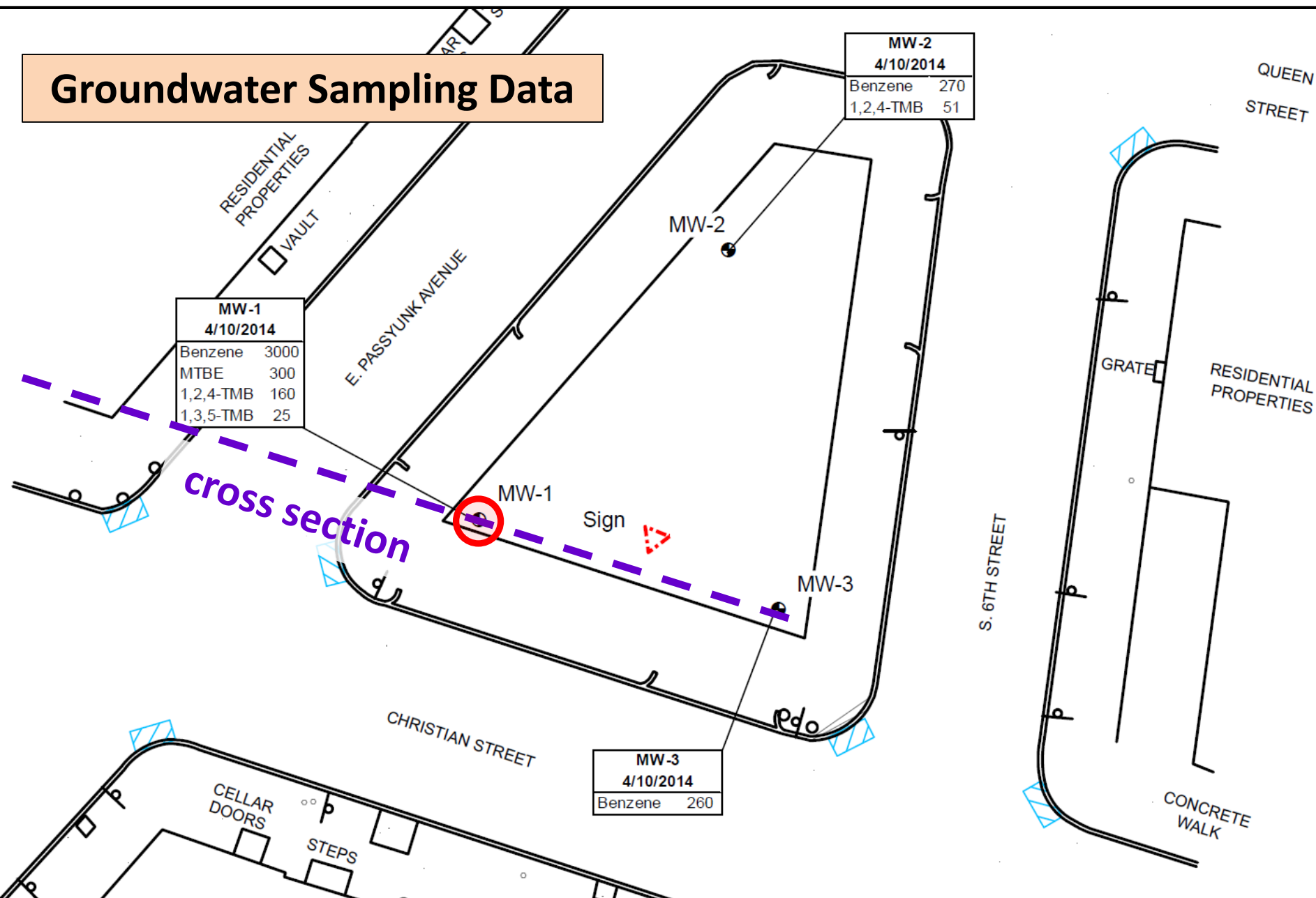


Groundwater Elevation Data

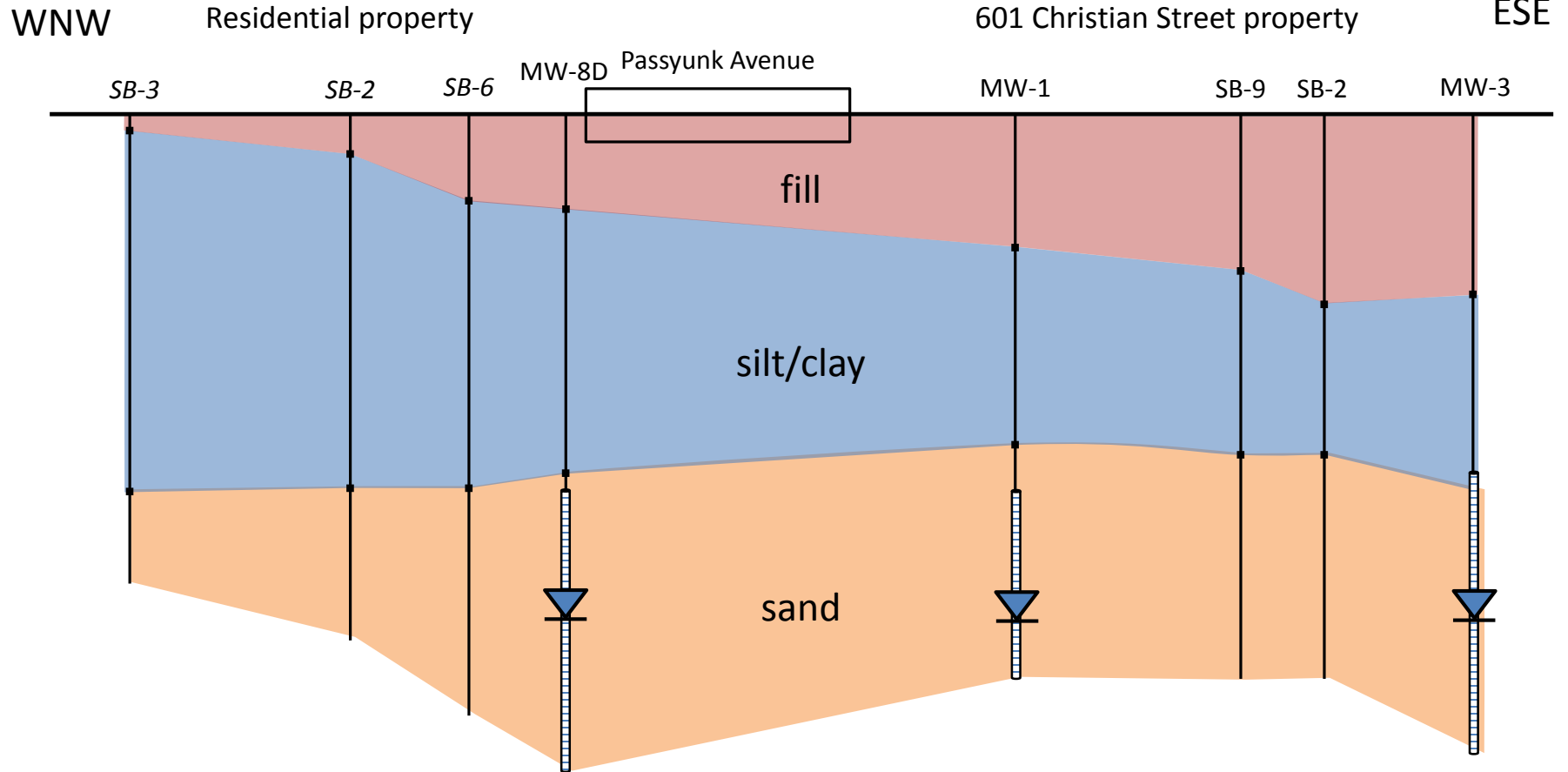


April 2014

Groundwater Sampling Data



Cross Section



Conceptual Site Model

- Gasoline released at least 18 years ago
- Urban fill, silt/clay soil, deeper sand unit
- Groundwater ~27 feet deep
- Groundwater flow to south and southeast
- Soil impact ~7–16 feet deep in silt/clay
- Direct contact MSC exceedences
- Significant groundwater impact in southwest
- No mobile LNAPL; possibly residual LNAPL

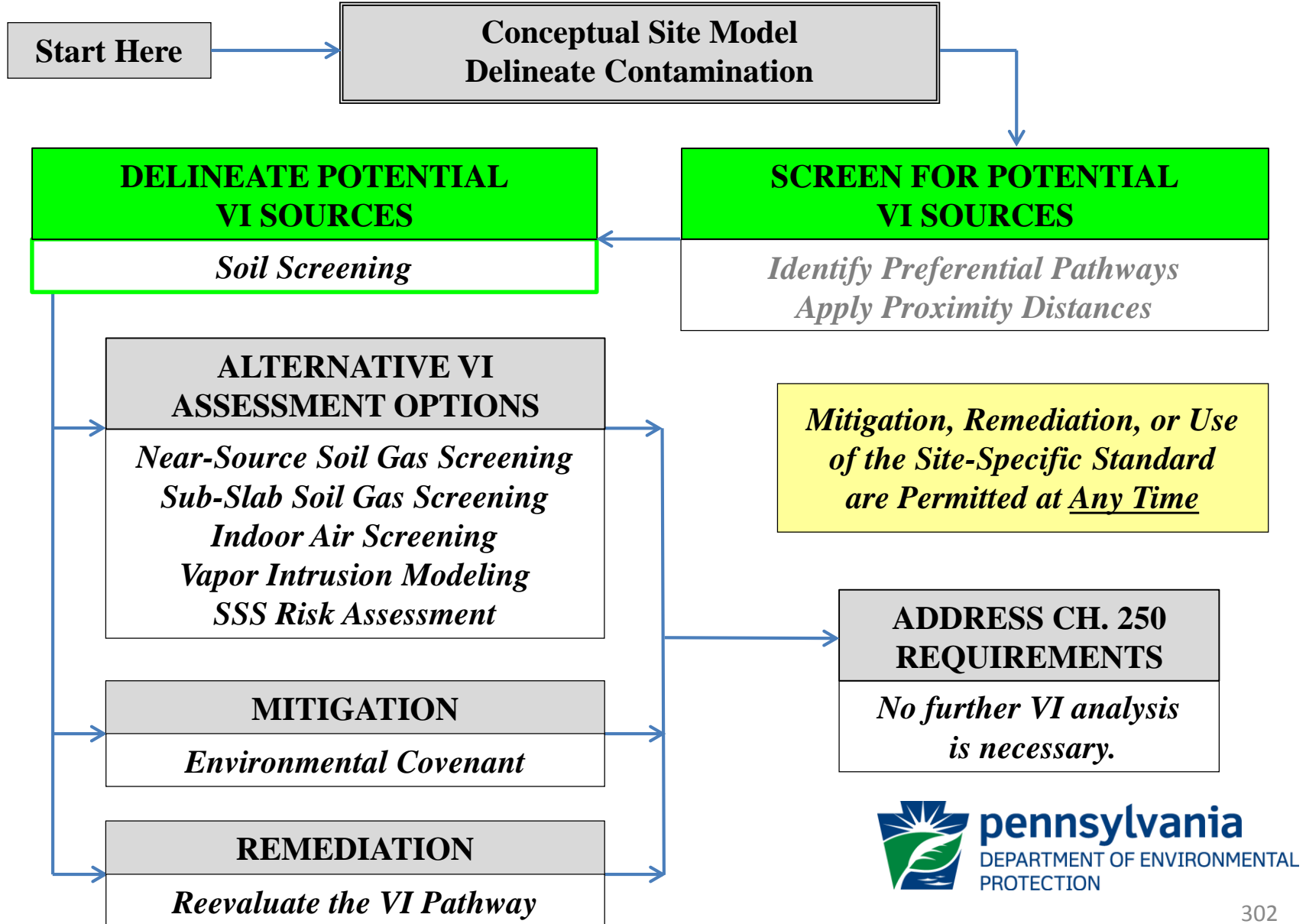
CSM (continued)

- Water, sewer, and gas utility lines
- Some subsurface electric and telephone lines
- Combined sewer main to south of property
- Property is a vacant lot
- But unrestricted access
- No groundwater use in area
- No nearby surface water
- Potential VI at neighboring buildings

Site Characterization Deficiencies

- Further characterization is required
- Extent of soil impact under sidewalks and streets is unknown
- Groundwater plume is not delineated
- Cleanup standard(s) must be selected
- Vapor intrusion pathway requires evaluation

Screen Soil Data for Vapor Intrusion



Exercise Objective: Soil Screening

- Soil is characterized on the source property
- Are there potential VI sources in soil?
- Are any substances in soil excluded from further VI evaluation?
- Remember: a potential VI source is defined by exceedences of SHS screening values
 - Soil screening doesn't depend on standard used
 - Refer to Table 2 screening values

Conditions for Soil Screening

Conditions from VI Guidance Table 6:

- ☒ Collect sufficient samples to characterize source(s)
- ☒ Samples are from unsaturated soil
- ☒ No SPL has been observed

Restrictions on Soil Screening

Restrictions from VI Guidance Figure 7:

- ☑ SPL not identified within horizontal proximity distance
- ☑ Significant foundation openings not present—property is undeveloped

If VI screening values are exceeded, then these restrictions may not pertain

Table 2. Soil Statewide Health Standard Vapor Intrusion Screening Values (SV _{SOIL})							
Regulated Substance	CAS No.	Residential (mg/kg)	Type	Nonresidential (mg/kg)	Type	Converted Residential (mg/kg)	Type
ACETALDEHYDE	75-07-0	0.23	SGN	0.96	SGN	0.96	SGN
ACETONE	67-64-1	430	SGN	4,700	SV	1,200	SGN
ACETONITRILE	75-05-8	1.5	SGN	9.6	SV	6.0	SGN
ACROLEIN	107-02-8	0.00047	SGN	0.0020	SGN	0.0020	SGN
ACRYLAMIDE	79-06-1	37	SV	2,400	SV	480	SV
ACRYLIC ACID	79-10-7	1.9	SV	40	SV	8.1	SV
ACRYLONITRILE	107-13-1	0.010	SGN	0.051	SGN	0.051	SGN
ALLYL ALCOHOL	107-18-6	0.0068	SV	0.14	SV	0.029	SV
AMMONIA	7664-41-7	360	SGN	360	SGN	360	SGN
ANILINE	62-53-3	1.3	SV	27	SV	5.4	SV
BENZENE	71-43-2	0.13	SGN	0.13	SGN	0.13	SGN
BENZYL CHLORIDE	100-44-7	0.059	SGN	0.30	SGN	0.30	SGN
BETA PROPIOLACTONE	57-57-8	0.00015	SGN	0.00076	SGN	0.00076	SGN
BIPHENYL, 1,1-	92-52-4	40	SGN	190	SGN	190	SGN
BIS(2-CHLOROETHYL)ETHER	111-44-4	0.0056	SV	0.14	SV	0.028	SV
BIS(2-CHLORO-ISOPROPYL)ETHER	108-60-1	8.0	SGN	8.0	SGN	8.0	SGN
BIS(CHLOROMETHYL)ETHER	542-88-1	0.000012	SGN	0.000060	SGN	0.000060	SGN
BROMOCHLOROMETHANE	74-97-5	1.6	SGN	1.6	SGN	1.6	SGN
BROMODICHLOROMETHANE	75-27-4	2.7	SGN	2.7	SGN	2.7	SGN
BROMOMETHANE	74-83-9	0.54	SGN	0.54	SGN	0.54	SGN
BUTADIENE, 1,3-	106-99-0	0.0086	SGN	0.041	SGN	0.041	SGN
CARBON DISULFIDE	75-15-0	130	SGN	530	SGN	530	SGN
CARBON TETRACHLORIDE	56-23-5	0.26	SGN	0.26	SGN	0.26	SGN
CHLORO-1,1-DIFLUOROETHANE, 1-	75-68-3	1,800	SGN	7,300	SGN	7,300	SGN
CHLORO-1-PROPENE, 3- (ALLYL CHLORIDE)	107-05-1	0.049	SGN	0.20	SGN	0.20	SGN
CHLOROBENZENE	108-90-7	6.1	SGN	6.1	SGN	6.1	SGN
CHLORODIBROMOMETHANE	124-48-1	2.5	SGN	2.5	SGN	2.5	SGN
CHLORODIFLUOROMETHANE	75-45-6	2,800	SGN	10,000	SAT	10,000	SAT
CHLOROETHANE	75-00-3	5.4	SGN	26	SGN	26	SGN
CHLOROFORM	67-66-3	2.0	SGN	2.0	SGN	2.0	SGN
CHLOROPRENE	126-99-8	0.0038	SGN	0.020	SGN	0.020	SGN
CHLOROPROPANE, 2-	75-29-6	16	SGN	67	SGN	67	SGN
CRESOL(S)	1319-77-3	310	SV	6,600	SV	1,300	SV

Exercise #1: Soil Vapor Intrusion Screening (Case Study)

SB-2—Analytical Data

Substance		CAS No.	SB-2	SHS MSCs		VI Screening Values	
Depth (ft)			10.0–10.5	Soil–	Direct	Soil Screening Value	Exceed?
Date Collected			12/16/2013	Ground-	Contact		
Soil Type (USCS)			ML	water	(0–15 ft)		
Units			mg/kg	mg/kg	mg/kg		
Benzene	71-43-2		18	0.5	57		
1,2-Dibromoethane	106-93-4		1 U	0.005	0.74		
1,2-Dichloroethane	107-06-2		1 U	0.5	17		
Ethylbenzene	100-41-4		210	70	180		
Cumene	98-82-8		26	600	7,700		
Methyl tert-Butyl Ether	1634-04-4		0.51 U	2	1,700		
Naphthalene	91-20-3		63	25	160		
Toluene	108-88-3		810	100	10,000		
1,2,4-Trimethylbenzene	95-63-6		510	8.4	130		
1,3,5-Trimethylbenzene	108-67-8		170	74	2,200		
Xylene (Total)	1330-20-7		1,200	1,000	1,900		

Bolded data entries indicate exceedences of Statewide health standard MSCs.

Exercise #1

Exercise Instructions

- You have soil data from one sample (SB-2)
- Determine the residential soil VI screening value for each substance
- Are there potential VI sources in soil?
- Which substances exceed?
- Which don't?

Exercise #1

Answers

Exercise #1: Soil Vapor Intrusion Screening (Case Study)

Substance	CAS No.	SB-2	SHS MSCs		VI Screening Values	
Depth (ft)		10.0–10.5	Soil–	Direct	Soil Screening	Exceed?
Date Collected		12/16/13	Ground-	Contact	Value	
Soil Type (USCS)		ML	water	(0–15 ft)		
Units		mg/kg	mg/kg	mg/kg	mg/kg	(yes/no)
Benzene	71-43-2	18	0.5	57	0.13	yes
1,2-Dibromoethane	106-93-4	1 U	0.005	0.74	0.0012	MDL
1,2-Dichloroethane	107-06-2	1 U	0.5	17	0.10	MDL
Ethylbenzene	100-41-4	210	70	180	46	yes
Cumene	98-82-8	26	600	7,700	600	no
Methyl tert-Butyl Ether	1634-04-4	0.51 U	2	1,700	0.28	MDL
Naphthalene	91-20-3	63	25	160	25	yes
Toluene	108-88-3	810	100	10,000	44	yes
1,2,4-Trimethylbenzene	95-63-6	510	8.4	130	8.4	yes
1,3,5-Trimethylbenzene	108-67-8	170	74	2,200	74	yes
Xylene (Total)	1330-20-7	1,200	1,000	1,900	990	yes

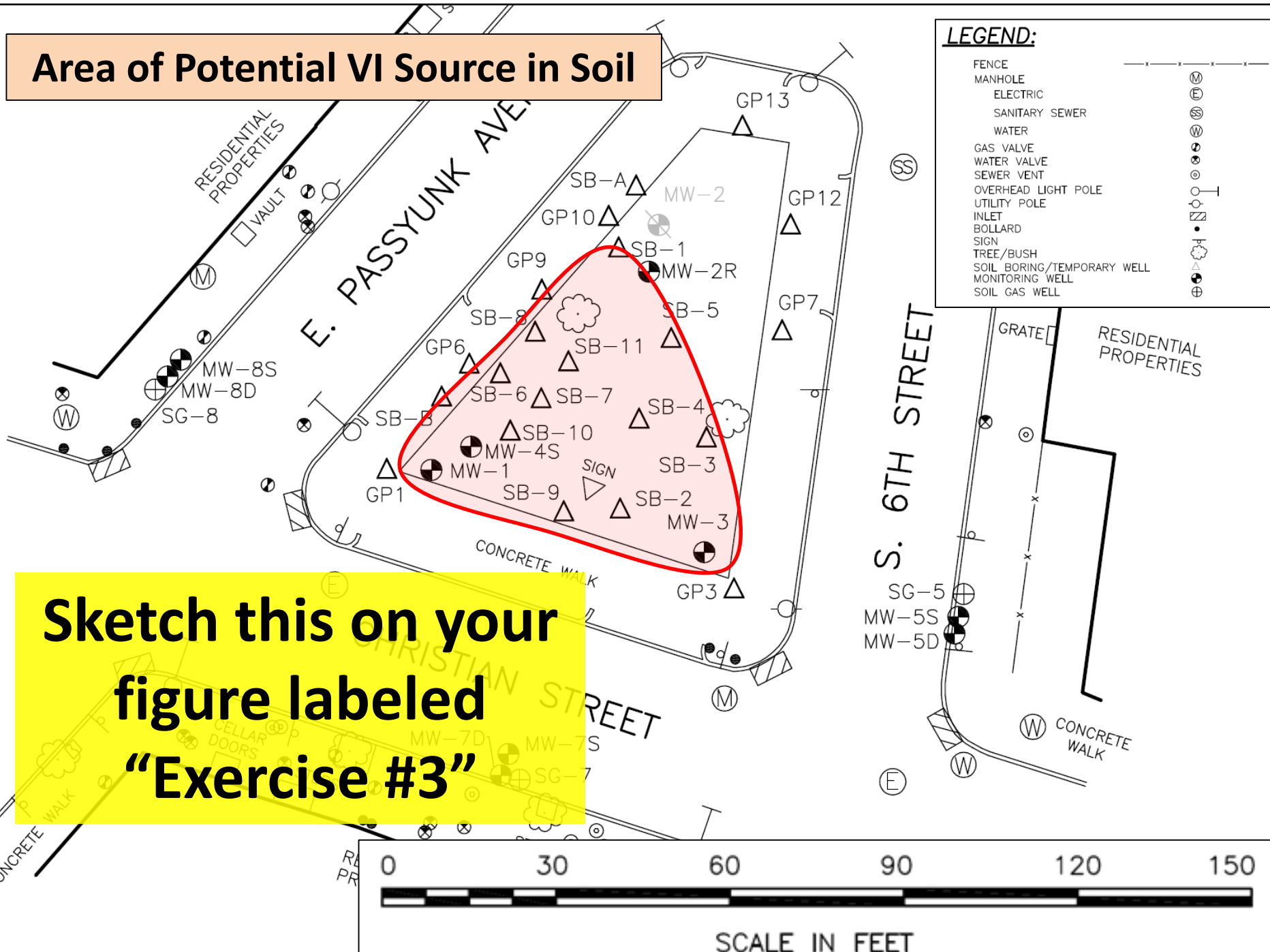
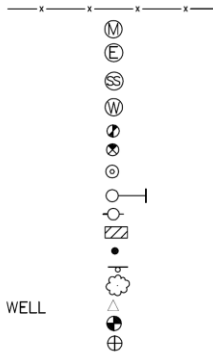
VI Soil Screening Results

- There is a potential VI source in soil
 - Benzene, toluene, ethylbenzene, xylenes, naphthalene, 1,2,4-TMB, 1,3,5-TMB
- Cumene is not a potential VI source
- The method detection limits for three substances exceed SV_{SOIL}
 - MTBE, EDB, EDC
 - They must be retained in the VI evaluation

Area of Potential VI Source in Soil

LEGEND:

FENCE
MANHOLE
ELECTRIC
SANITARY SEWER
WATER
GAS VALVE
WATER VALVE
SEWER VENT
OVERHEAD LIGHT POLE
UTILITY POLE
INLET
BOLLARD
SIGN
TREE/BUSH
SOIL BORING/TEMPORARY WELL
MONITORING WELL
SOIL GAS WELL



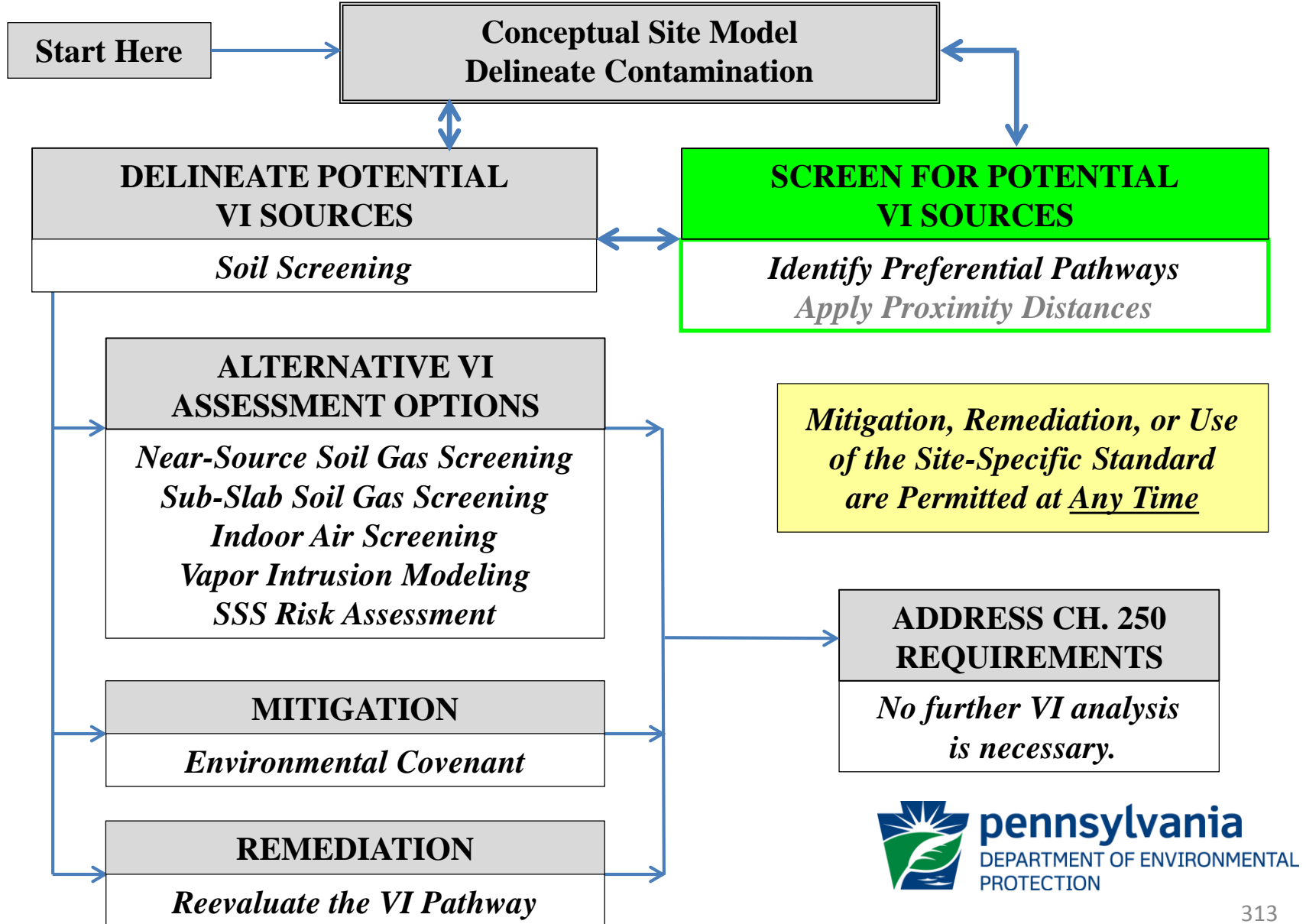
Sketch this on your
figure labeled
"Exercise #3"

VI Case Study Exercise #1

Questions/Discussion



Consider Preferential Pathways



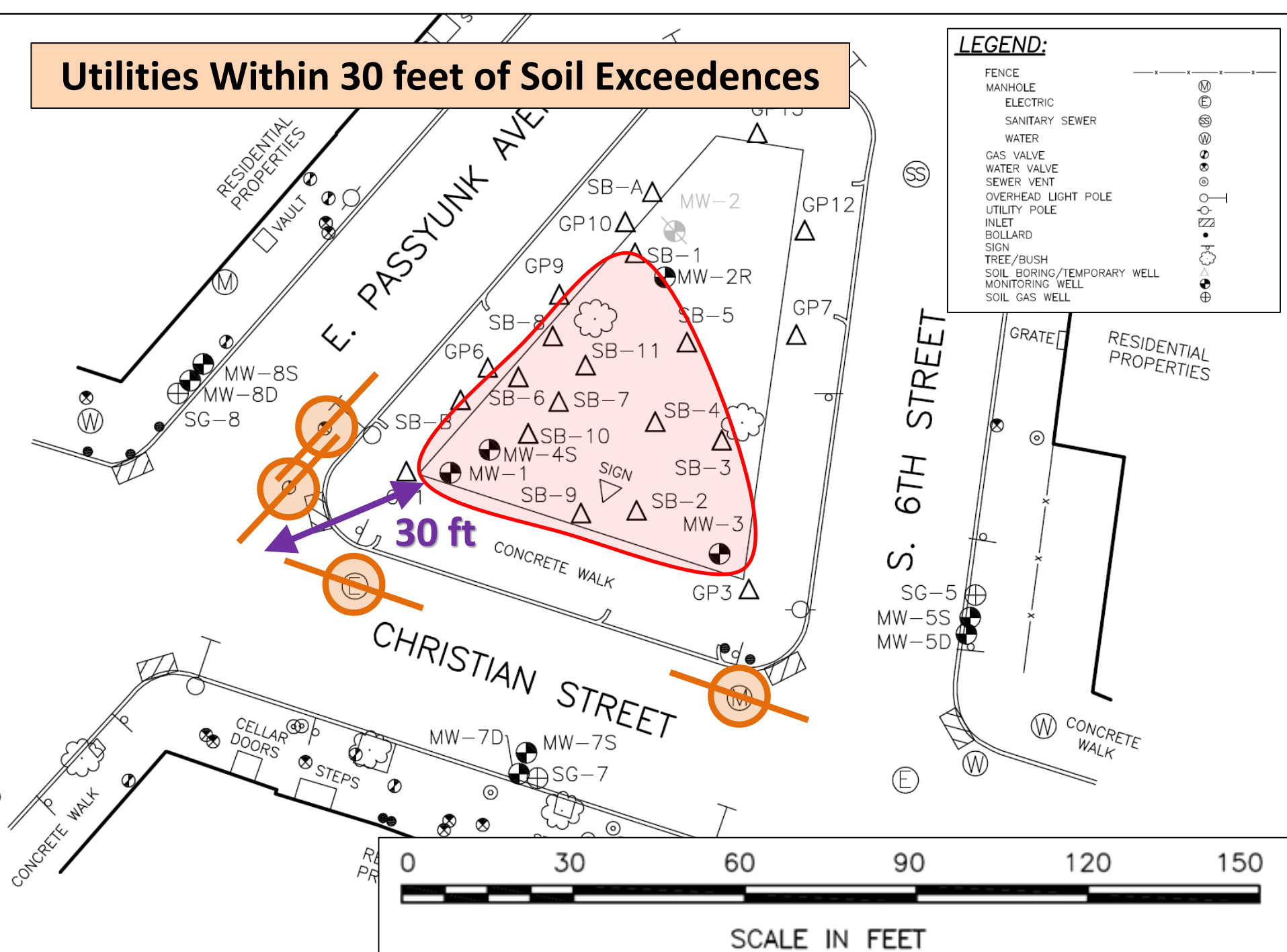
External Preferential Pathway Evaluation

- Sewer, water, and electric utilities
- No connections at source property
- Utility lines/vaults likely present within 30 feet horizontally of soil exceeding SVs
- Utility lines/vaults likely present within 5 feet vertically of soil exceeding SVs
- Therefore, utilities are potential external preferential pathways

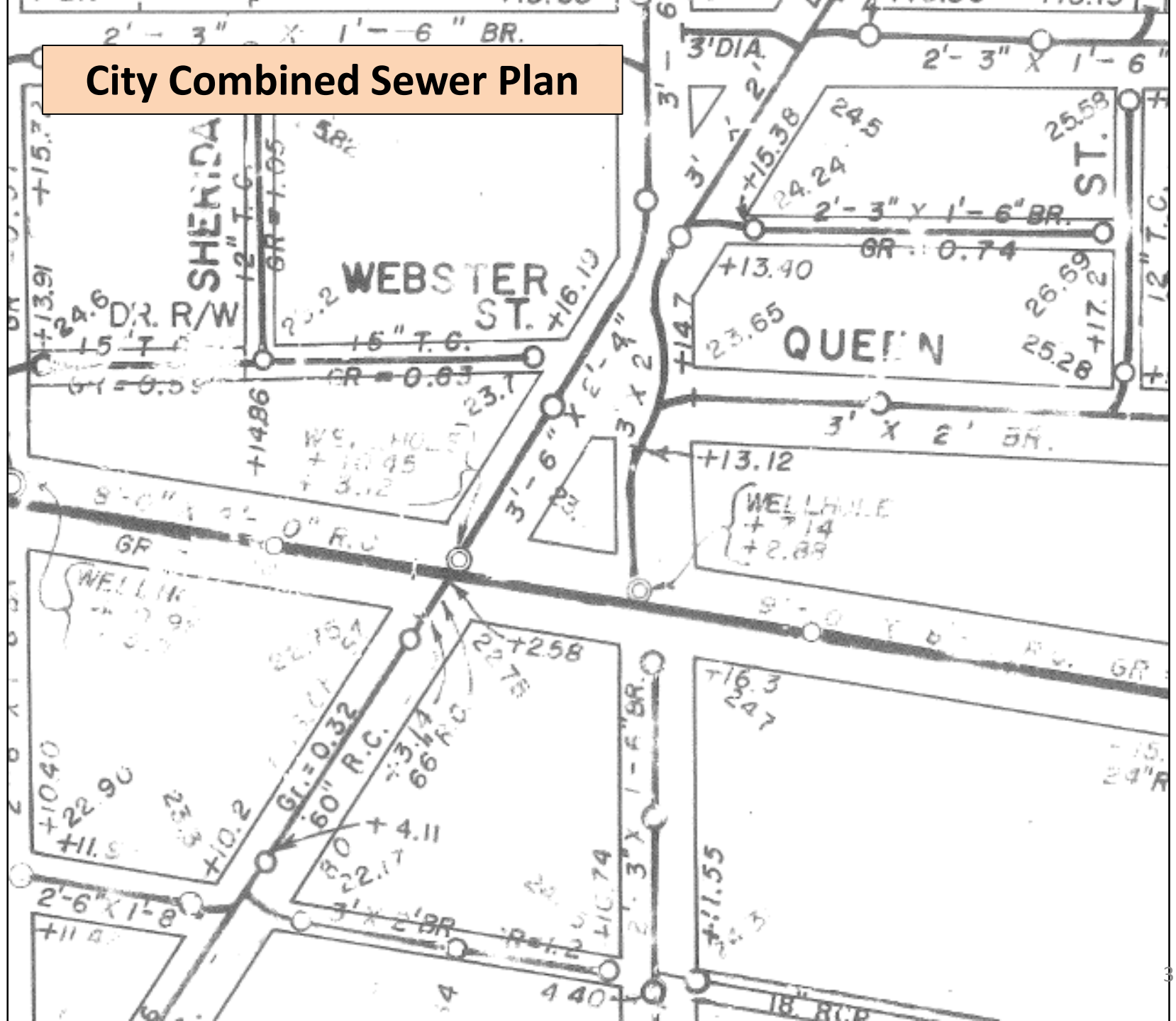
Utilities Within 30 feet of Soil Exceedences

LEGEND:

- FENCE
- MANHOLE
- ELECTRIC
- SANITARY SEWER
- WATER
- GAS VALVE
- WATER VALVE
- SEWER VENT
- OVERHEAD LIGHT POLE
- UTILITY POLE
- INLET
- BOLLARD
- SIGN
- TREE/BUSH
- SOIL BORING/TEMPORARY WELL
- MONITORING WELL
- SOIL GAS WELL



City Combined Sewer Plan



Preferential Pathways, continued

- Reinforced concrete sewer main to south
- Box culvert, ~10 x 10 feet
- Depth to top ~10 feet
depth to bottom ~20 feet
- Groundwater plume > 5 feet below sewer
 - Not a preferential pathway for groundwater
- Soil exceedences are present within 30 feet horizontally and 5 feet vertically of sewer

Preferential Pathway Options

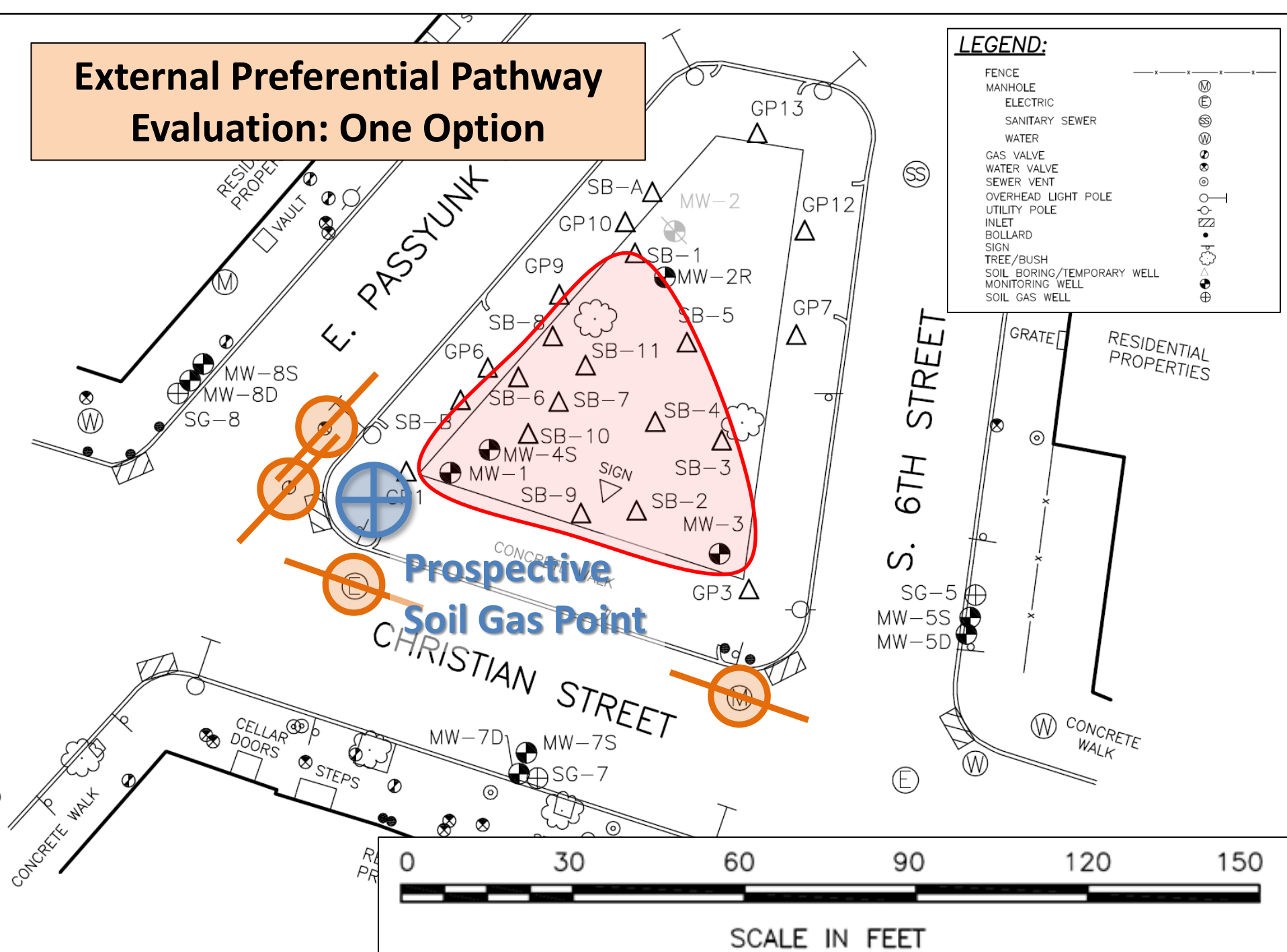
- Near-source soil gas sampling
- Soil gas sampling in trenches
- Sample vapor in sewer line
- Residential sub-slab sampling
- Inspect residences for utility penetrations
- Residential indoor air sampling

[See VI Guidance Section D.1]

External Preferential Pathway Evaluation: One Option

LEGEND:

- FENCE
- MANHOLE
- ELECTRIC
- SANITARY SEWER
- WATER
- GAS VALVE
- WATER VALVE
- SEWER VENT
- OVERHEAD LIGHT POLE
- UTILITY POLE
- INLET
- BOLLARD
- SIGN
- TREE/BUSH
- SOIL BORING/TEMPORARY WELL
- MONITORING WELL
- SOIL GAS WELL



Preferential Pathway Considerations

- No mobile LNAPL present
- Only petroleum contaminants of concern
- Utility line trenches likely backfilled with soil-like material → vapor attenuation
 - From site observations and utility contractor info
- Volume of sewer main is large relative to area of contamination
 - Petroleum vapors would be substantially diluted

Significant Foundation Openings

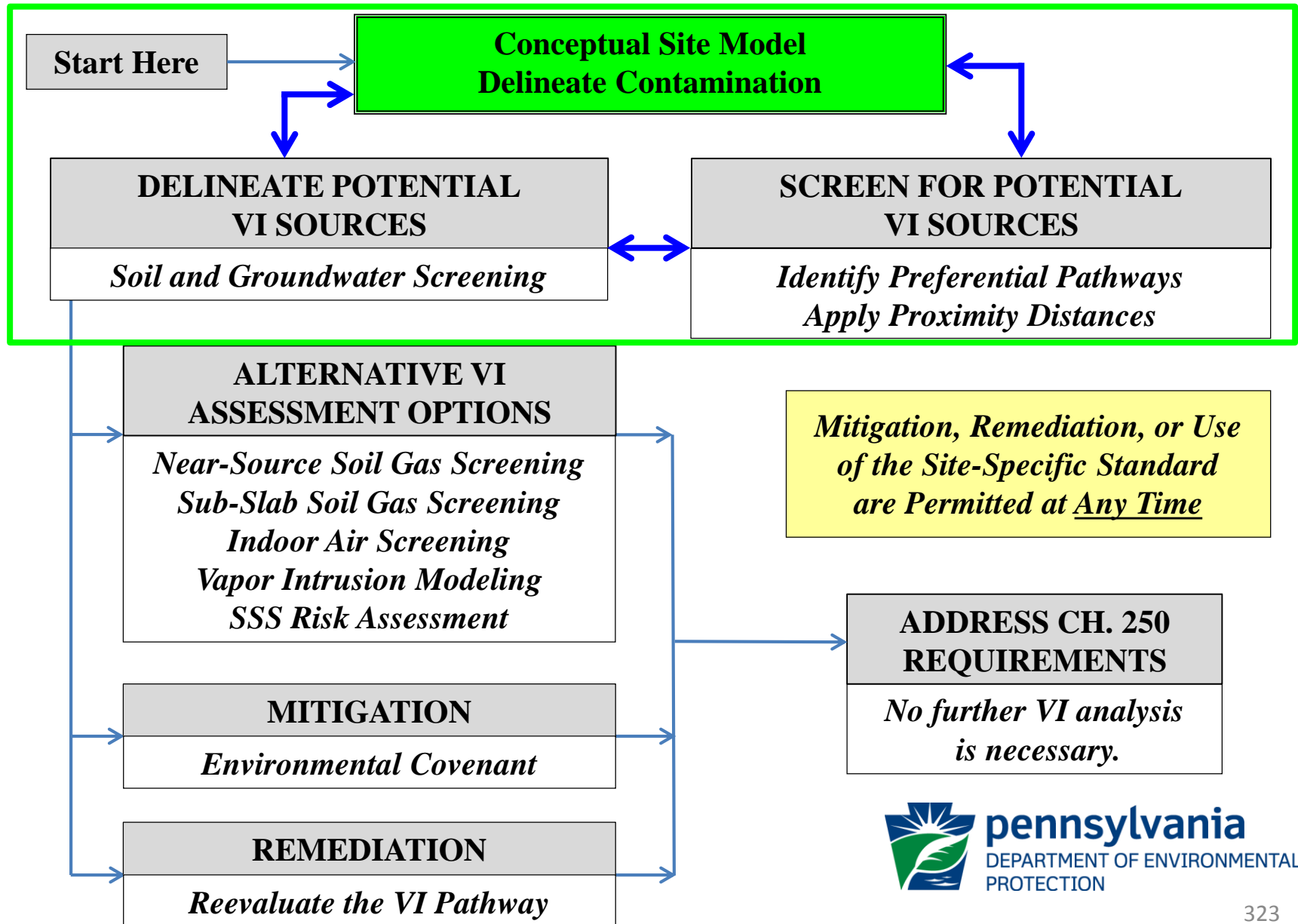
- Residences have not been accessed to inspect basements
- Nonintrusive evaluation options:
 - Horizontal proximity distance
 - Soil and groundwater screening
 - Near-source soil gas sampling
 - VI modeling

[See VI Guidance Section D.2]

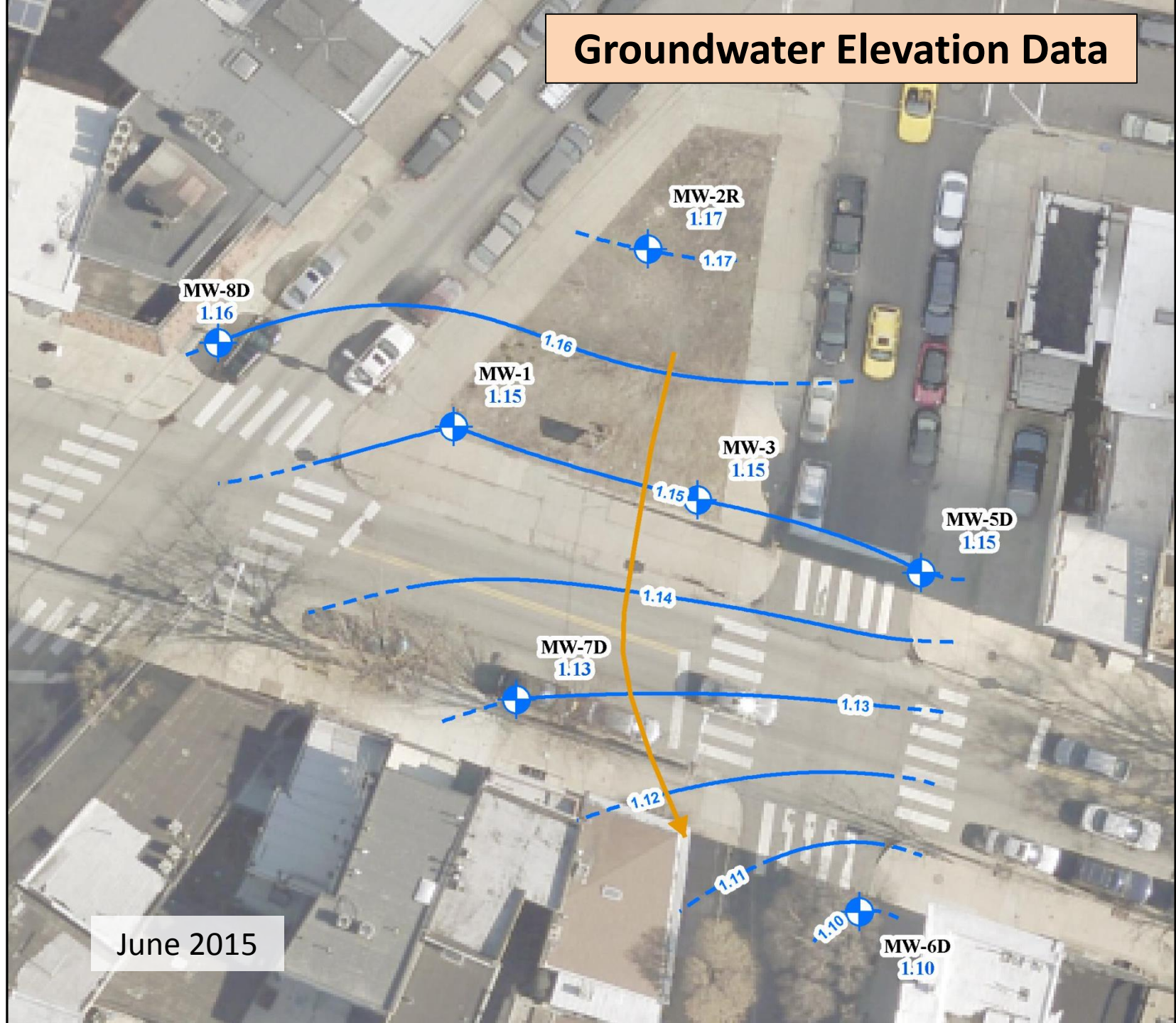
Preferential Pathway Status

- Site data does not indicate a heightened concern for preferential pathways
- Further investigation could be performed for potential external preferential pathways
 - For example, soil gas sampling
- Further assessment of potential significant openings should also be conducted
 - Offsite soil, groundwater, soil gas sampling

Further Groundwater Characterization



Groundwater Elevation Data



Groundwater Sampling Data

MW-8D 6/5/2015	
Analyte	Result (µg/L)
Benzene	200
Naphthalene	214
1,2,4-TMB	539

MW-2R 6/4/2015	
Analyte	Result (µg/L)
Benzene	19
1,2,4-TMB	27

MW-1 6/5/2015	
Analyte	Result (µg/L)
Benzene	2400
MTBE	97
1,2,4-TMB	66

MW-3 6/4/2015	
Analyte	Result (µg/L)
Benzene	22

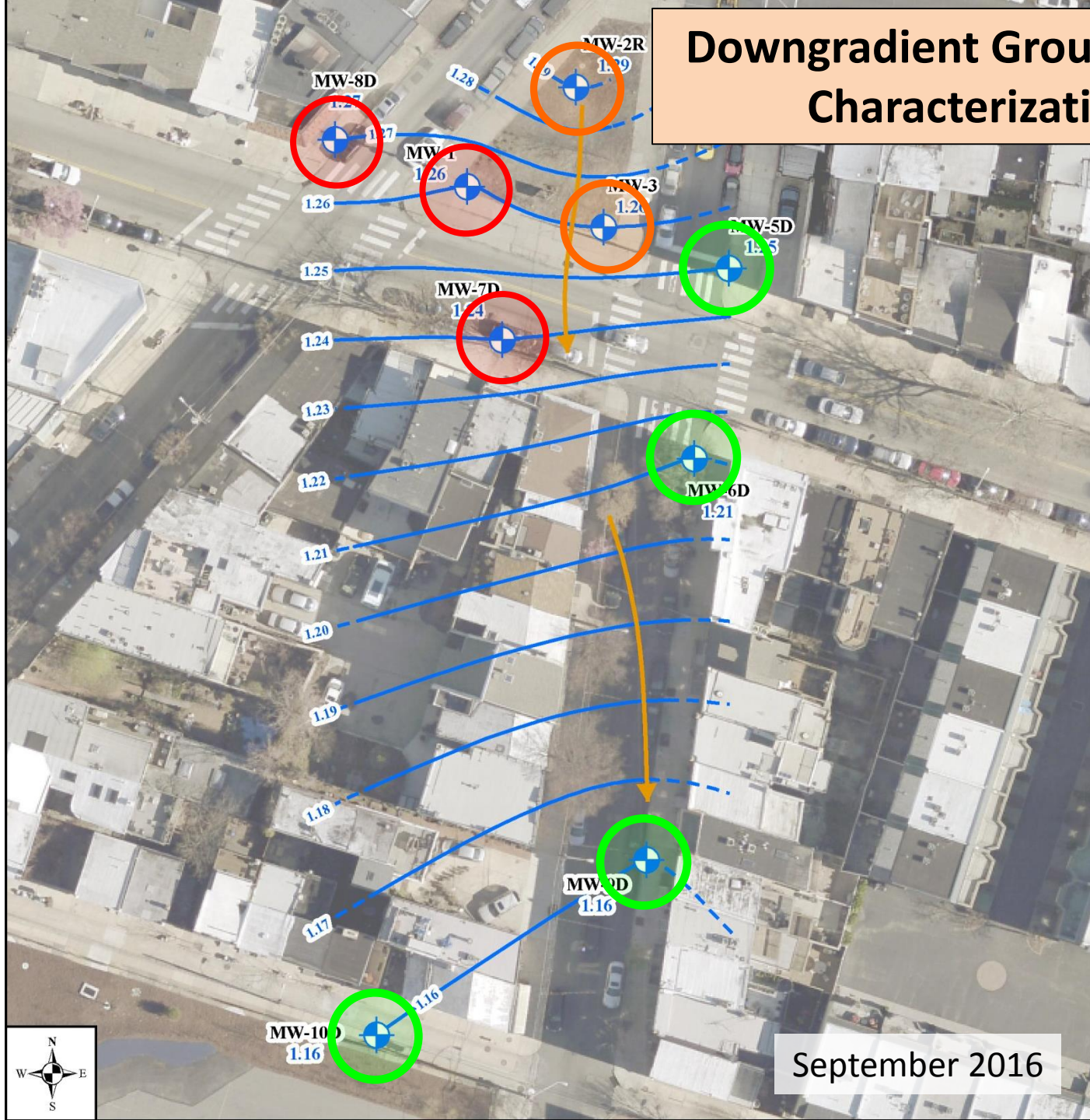
MW-7D 6/5/2015	
Analyte	Result (µg/L)
Benzene	524
MTBE	30
Naphthalene	373
1,2,4-TMB	1080

MW-5D 6/4/2015	
Analyte	Result (µg/L)

June 2015

MW-6D 6/4/2015	
Analyte	Result (µg/L)

Downgradient Groundwater Characterization



September 2016

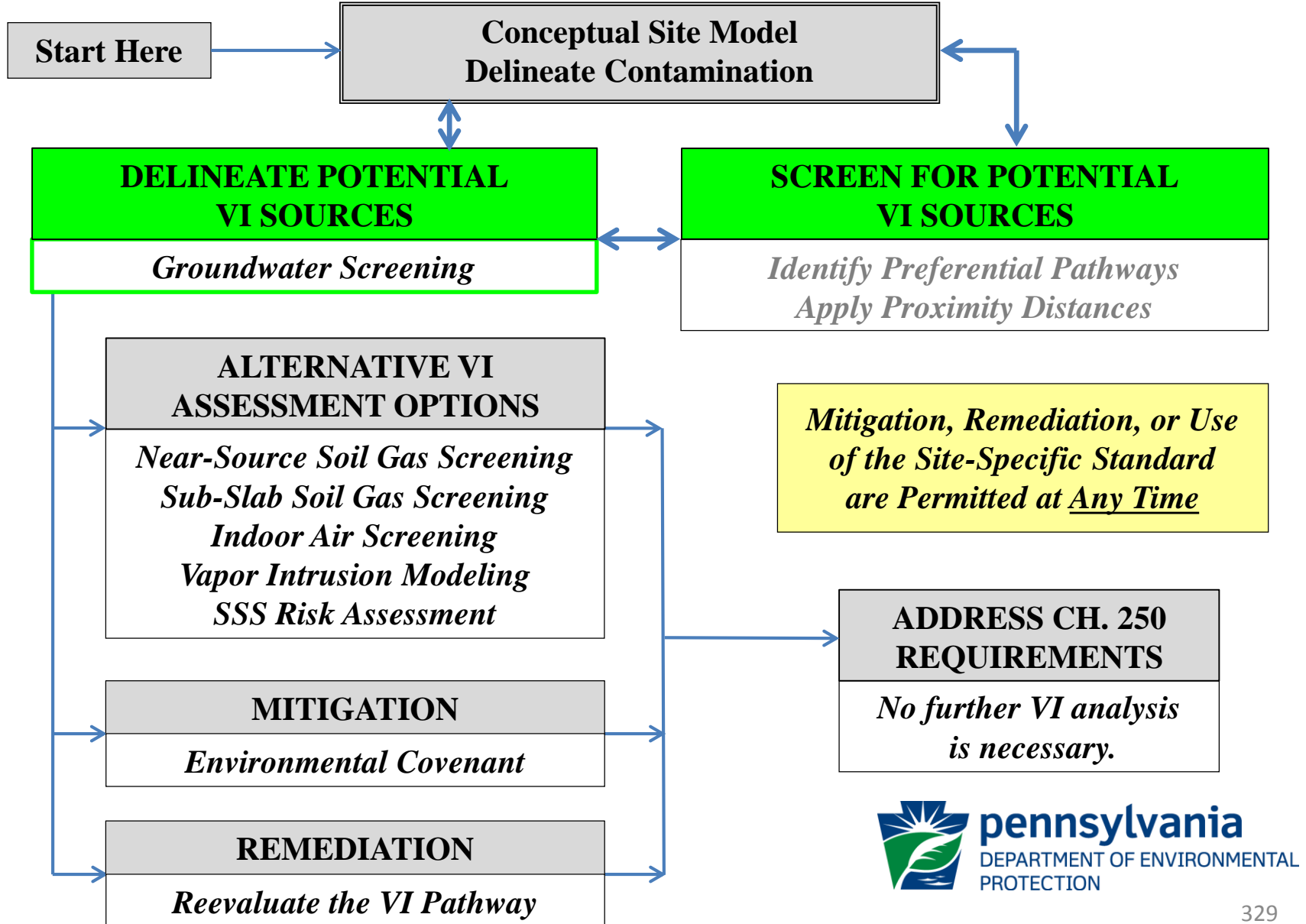
Conceptual Site Model Update

- There is a potential VI source in soil onsite
- Another source property exists to the west
 - Also a former gas station, closed Act 2 site
 - VI was mitigated in new construction (2004)
- Soil samples from the offsite wells do not indicate impacts from the source property
 - Soil contamination is delineated

CSM Update (continued)

- The groundwater plume has been delineated
 - Extends to the south, beneath offsite residences
 - Is it a potential VI source?
- Significant foundation openings remain a potential pathway offsite
- Vapor intrusion requires further evaluation

Screen Groundwater Data for VI



Exercise Objective: Groundwater Screening

- Is the groundwater plume a potential VI source? Where?
- Are any substances in groundwater excluded?
- Remember: a potential VI source is defined by exceedences of SHS screening values
 - Independent of standard
 - Refer to Table 1 screening values

Conditions for Groundwater Screening

Conditions from VI Guidance Table 6

- ☑ Install sufficient monitoring wells
- ☑ Properly construct monitoring wells
- ☑ MW screens cross the water table
- ☑ Wetted length ≤ 10 feet
- ☑ Groundwater > 5 feet from buildings
- ☑ Acceptable soil or soil-like material present
- ☑ No SPL is present

Exercise #2

Restrictions on Groundwater Screening

Restrictions from VI Guidance Figure 7:

- ☒ No SPL observed in monitoring wells within horizontal proximity distance
- ☐ Significant foundation openings—
not suspected (could screen with MSCs)
- ☒ Contamination does not enter external preferential pathways—GW too deep
- ☒ Groundwater is > 5 feet below foundations

Table 1. Groundwater Statewide Health Standard Vapor Intrusion Screening Values (SV_{GW})

Regulated Substance	CAS No.	Residential (µg/L)	Type	Nonresidential (µg/L)	Type	Converted Residential (µg/L)	Type
ACETALDEHYDE	75-07-0	5,300	SV	67,000	SV	22,000	SV
ACETONE	67-64-1	37,000,000	SV	470,000,000	SV	160,000,000	SV
ACETONITRILE	75-05-8	75,000	SV	940,000	SV	310,000	SV
ACROLEIN	107-02-8	6.8	SV	86	SV	29	SV
ACRYLAMIDE	79-06-1	3,200,000	SV	120,000,000	SV	41,000,000	SV
ACRYLIC ACID	79-10-7	150,000	SV	1,900,000	SV	650,000	SV
ACRYLONITRILE	107-13-1	110	SV	1,700	SV	560	SV
ALLYL ALCOHOL	107-18-6	1,000	SV	13,000	SV	4,300	SV
AMMONIA	7664-41-7	230,000	SV	2,900,000	SV	960,000	SV
ANILINE	62-53-3	27,000	SV	340,000	SV	110,000	SV
BENZENE	71-43-2	23	SV	350	SV	120	SV
BENZYL CHLORIDE	100-44-7	58	SV	870	SV	290	SV
BETA PROPIOLACTONE	57-57-8	0.012	MSC	0.063	MSC	0.063	MSC
BIPHENYL, 1,1-	92-52-4	91	MSC	970	SV	430	MSC
BIS(2-CHLOROETHYL)ETHER	111-44-4	240	SV	3,600	SV	1,200	SV
BIS(2-CHLORO-ISOPROPYL)ETHER	108-60-1	1,700	SV	25,000	SV	8,500	SV
BIS(CHLOROMETHYL)ETHER	542-88-1	0.0040	SV	0.060	SV	0.020	SV
BROMOCHLOROMETHANE	74-97-5	1,200	SV	15,000	SV	5,000	SV
BROMODICHLOROMETHANE	75-27-4	80	MSC	200	SV	80	MSC
BROMOMETHANE	74-83-9	26	SV	330	SV	110	SV
BUTADIENE, 1,3-	106-99-0	0.39	SV	5.9	SV	2.0	SV
CARBON DISULFIDE	75-15-0	2,000	SV	25,000	SV	8,200	SV
CARBON TETRACHLORIDE	56-23-5	6.0	SV	91	SV	30	SV
CHLORO-1,1-DIFLUOROETHANE, 1-	75-68-3	330,000	SV	1,400,000	Sol.	1,400,000	SV
CHLORO-1-PROPENE, 3- (ALLYL CHLORIDE)	107-05-1	3.8	SV	48	SV	16	SV
CHLOROBENZENE	108-90-7	760	SV	9,600	SV	3,200	SV
CHLORODIBROMOMETHANE	124-48-1	80	MSC	670	SV	220	SV
CHLORODIFLUOROMETHANE	75-45-6	110,000	MSC	540,000	SV	440,000	MSC
CHLOROETHANE	75-00-3	35,000	SV	440,000	SV	150,000	SV
CHLOROFORM	67-66-3	80	MSC	180	SV	80	MSC
CHLOROPRENE	126-99-8	0.16	MSC	0.90	SV	0.83	MSC
CHLOROPROPANE, 2-	75-29-6	230	SV	2,900	SV	970	SV
CRESOL(S)	1319-77-3	20,000,000	Sol.	20,000,000	Sol.	20,000,000	Sol.

Exercise #2: Groundwater VI Screening

MW-8D 6/5/2015	
Analyte	Result (µg/L)
Benzene	200
Naphthalene	214
1,2,4-TMB	539

MW-2R 6/4/2015	
Analyte	Result (µg/L)
Benzene	19
1,2,4-TMB	27

MW-1 6/5/2015	
Analyte	Result (µg/L)
Benzene	2400
MTBE	97
1,2,4-TMB	66

MW-3 6/4/2015	
Analyte	Result (µg/L)
Benzene	22

MW-5D 6/4/2015	
Analyte	Result (µg/L)

MW-7D 6/5/2015	
Analyte	Result (µg/L)
Benzene	524
MTBE	30
Naphthalene	373
1,2,4-TMB	1080

MW-6D 6/4/2015	
Analyte	Result (µg/L)

June 2015

Exercise #2: Groundwater Vapor Intrusion Screening (Case Study)

MW-7D—Analytical Data

Substance	Benzene	Ethyl-benzene	Cumene	MTBE	Naphthalene	Toluene	1,2,4-TMB	1,3,5-TMB	Xylenes
CAS No.	71-43-2	100-41-4	98-82-8	1634-04-4	91-20-3	108-88-3	95-63-6	108-67-8	1330-20-7
SHS MSC	5	700	840	20	100	1,000	15	420	10,000
Units	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Date									
6/5/2015	524	472	96	30	373	2.6	1080	410	952
9/15/2015	556	822	116	28	411	0.5 U	1550	460	1587
12/16/2015	374	623	95	31	298	3.3	1210	336	1320
3/8/2016	554	444	76	32	371	4.9	1170	346	1405
6/9/2016	889	1900	202	25	778	7.8	2670	794	4710
9/14/2016	802	1390	161	0.5 U	602	6.4	1700	510	2954
VI Screening Values									
Ground-water Screening Value									
Exceed? (yes/no)									

Bolded data entries indicate exceedences of Statewide health standard MSCs.

Exercise #2

Exercise Instructions

- You have VOC analytical data from one monitoring well (MW-7D)
- Determine the residential groundwater VI screening value for each substance
- Are there potential VI sources in groundwater?
- Which substances exceed?
- Which don't?

Exercise #2

Exercise #2: Groundwater Vapor Intrusion Screening (Case Study)

Answers

MW-7D—Analytical Data

Substance	Benzene	Ethyl-benzene	Cumene	MTBE	Naphthalene	Toluene	1,2,4-TMB	1,3,5-TMB	Xylenes
CAS No.	71-43-2	100-41-4	98-82-8	1634-04-4	91-20-3	108-88-3	95-63-6	108-67-8	1330-20-7
SHS MSC	5	700	840	20	100	1,000	15	420	10,000
Units	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Date									
6/5/2015	524	472	96	30	373	2.6	1080	410	952
9/15/2015	556	822	116	28	411	0.5 U	1550	460	1587
12/16/2015	374	623	95	31	298	3.3	1210	336	1320
3/8/2016	554	444	76	32	371	4.9	1170	346	1405
6/9/2016	889	1900	202	25	778	7.8	2670	794	4710
9/14/2016	802	1390	161	0.5 U	602	6.4	1700	510	2954

VI Screening Values

Ground-water Screening Value	23	700	1,900	6,300	100	34,000	59	420	10,000
Exceed? (yes/no)	yes	yes	no	no	yes	no	yes	yes	no

VI Groundwater Screening Results

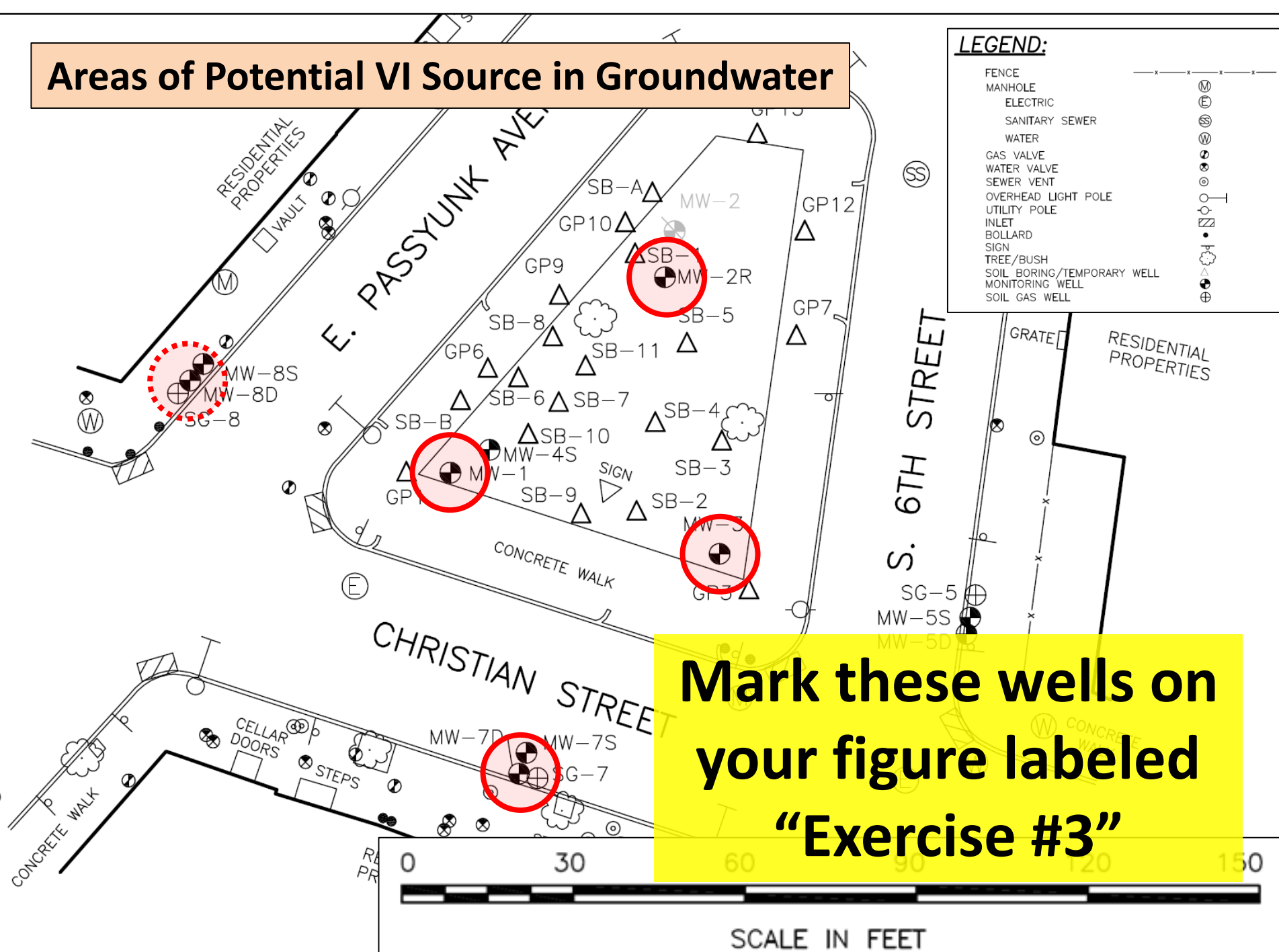
- There is a potential VI source in groundwater
 - Benzene, ethylbenzene, naphthalene, TMBs
 - Extends offsite
- Cumene, MTBE, toluene, and xylenes are not potential VI sources
- Characterization samples from three onsite wells were analyzed for EDB and EDC
 - Data did not exceed SV_{GW}

Areas of Potential VI Source in Groundwater

LEGEND:

- FENCE
- MANHOLE
- ELECTRIC
- SANITARY SEWER
- WATER
- GAS VALVE
- WATER VALVE
- SEWER VENT
- OVERHEAD LIGHT POLE
- UTILITY POLE
- INLET
- BOLLARD
- SIGN
- TREE/BUSH
- SOIL BORING/TEMPORARY WELL
- MONITORING WELL
- SOIL GAS WELL

**Mark these wells on
your figure labeled
“Exercise #3”**



VI Case Study

Intermittent Screening Value Exceedences

Date	Benzene (µg/L)
1/23/2014	22
4/10/2014	260
7/21/2014	109
10/7/2014	15
1/21/2015	6.9
6/4/2015	22
9/16/2015	20
12/16/2015	0.9
3/9/2016	8.9
6/9/2016	0.8
SHS R SV _{GW}	23

VI Case Study

If this is an **interior** well, and GW attains the **SHS** at the POC, then the last eight quarters of data **pass** the 75%/10x test for VI screening

Date	Benzene (µg/L)
1/23/2014	22
4/10/2014	260
7/21/2014	109
10/7/2014	15
1/21/2015	6.9
6/4/2015	22
9/16/2015	20
12/16/2015	0.9
3/9/2016	8.9
6/9/2016	0.8
SHS R SV _{GW}	23

VI Case Study

If this is a **POC** well, the last eight quarters of data does **not** pass the 75%/10x test for the MSC
→ SSS

Date	Benzene (µg/L)
1/23/2014	22
4/10/2014	260
7/21/2014	109
10/7/2014	15
1/21/2015	6.9
6/4/2015	22
9/16/2015	20
12/16/2015	0.9
3/9/2016	8.9
6/9/2016	0.8
SHS MSC	5

VI Case Study

For the SSS, screening of attainment data requires use of one-tenth SV_{GW} , no 75%/10x test → alternative assessment options

Date	Benzene ($\mu\text{g/L}$)
1/23/2014	22
4/10/2014	260
7/21/2014	109
10/7/2014	15
1/21/2015	6.9
6/4/2015	22
9/16/2015	20
12/16/2015	0.9
3/9/2016	8.9
6/9/2016	0.8
SHS MSC	2.3

GW Screening Considerations

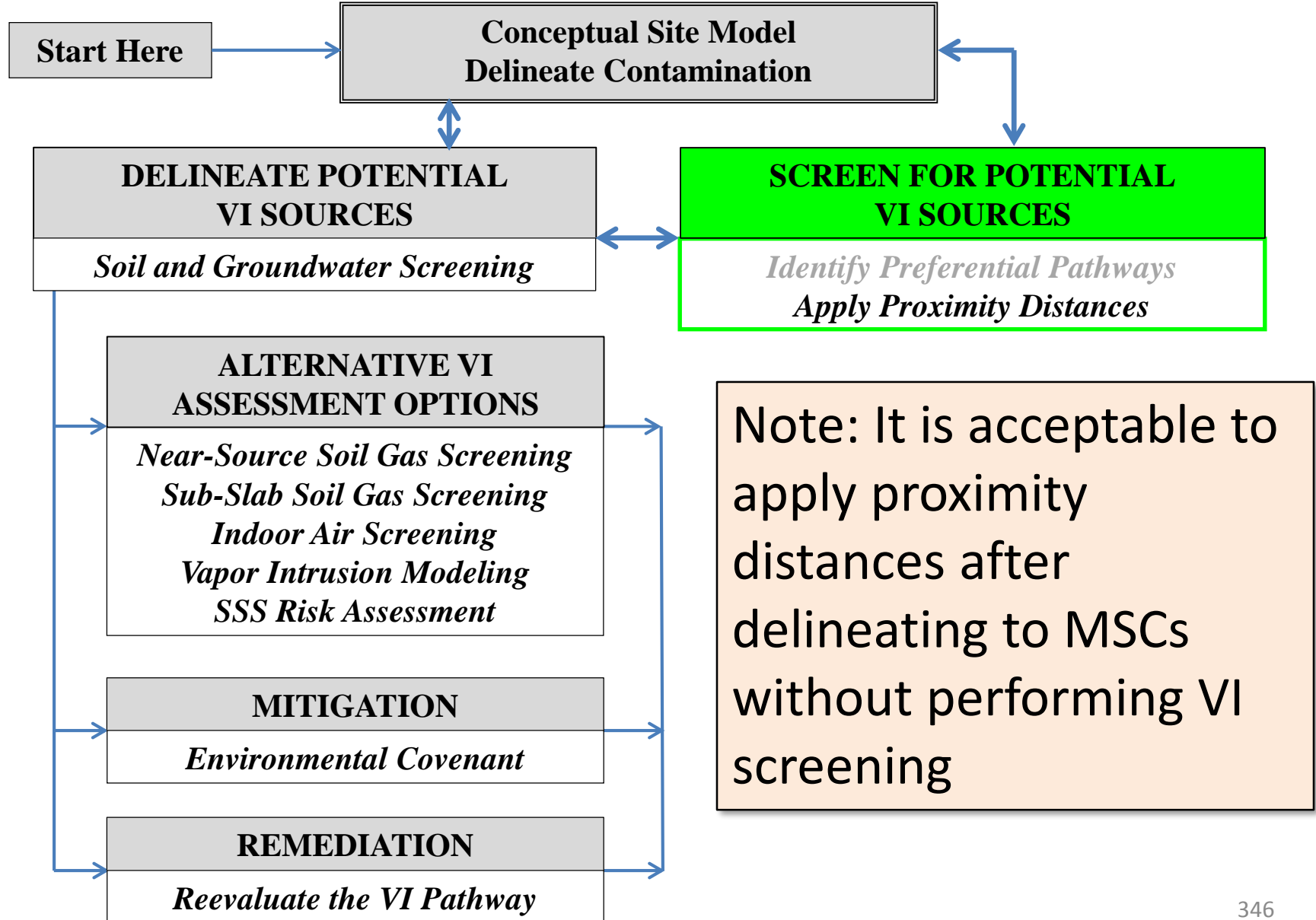
- What if GW concentrations only intermittently exceed the screening value?
 - *Any* exceedence of the SHS SV_{GW} indicates a potential VI source
- Refer to VI Guidance Table 7—for SHS only
 - No exceedences for characterization data
 - Options for statistical tests for attainment data
- Site-specific standard
 - No exceedence rule for all data

VI Case Study Exercise #2

Questions/Discussion

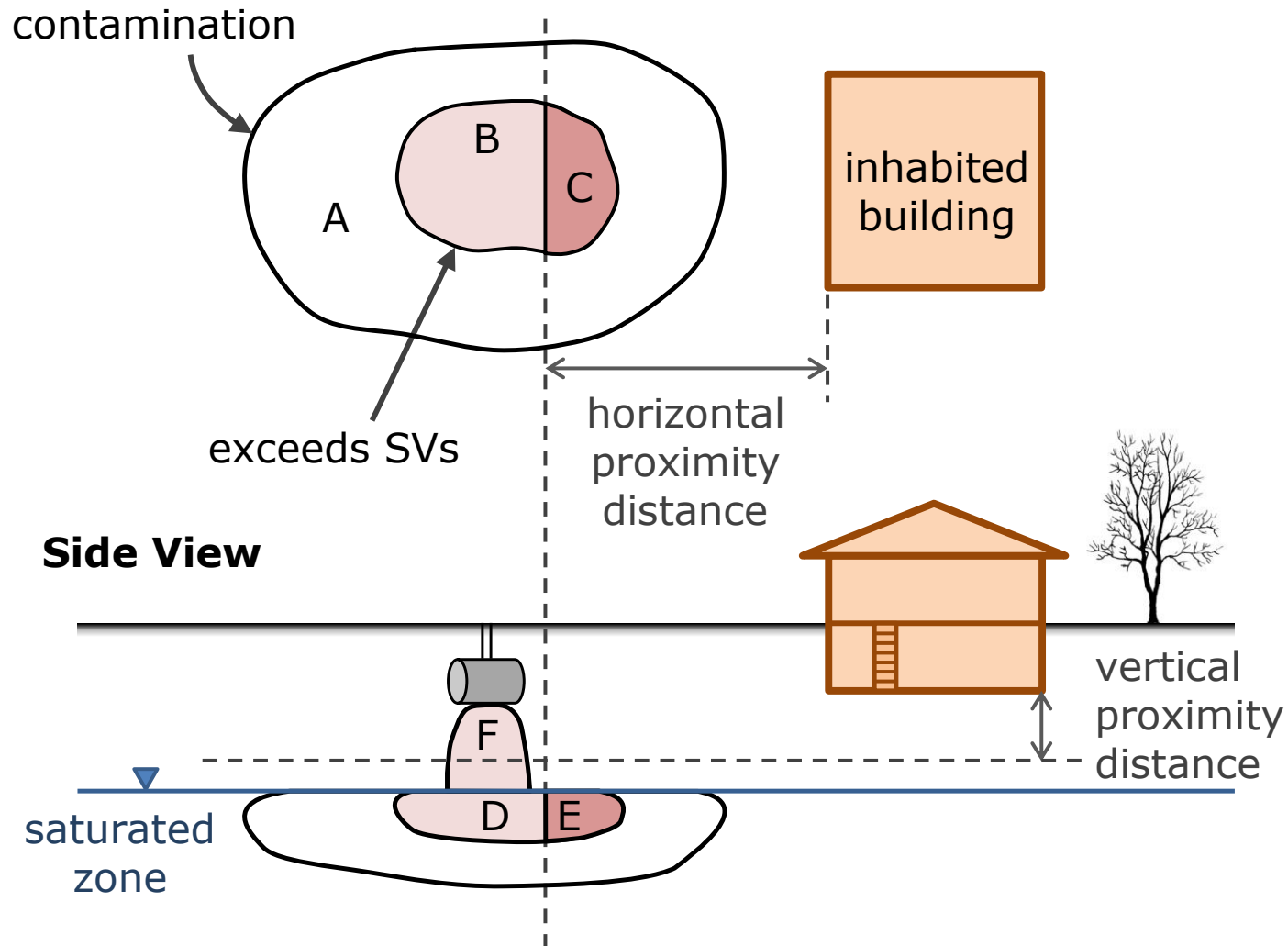


Apply Petroleum Proximity Distances



Map View

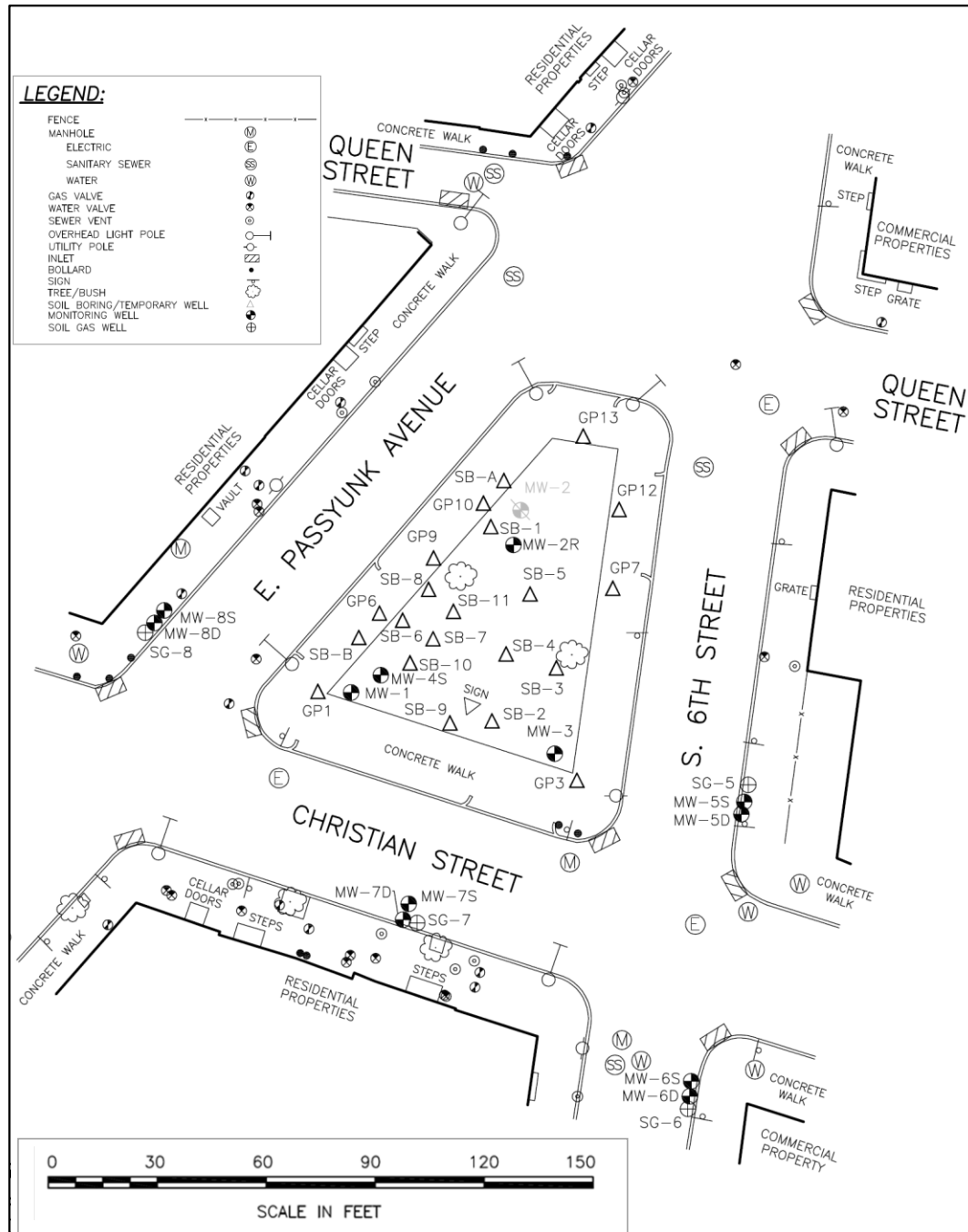
Proximity Distances



Exercise Objective: Proximity Distances

- Determine if proximity distances allow any potential receptors to be excluded for VI
- Apply petroleum proximity distances:
 - 30 feet horizontally
 - 5 feet vertically, no NAPL
 - 15 feet vertically, NAPL
- Evaluate potential VI sources in soil and groundwater

Exercise #3: Proximity Distances (Case Study)

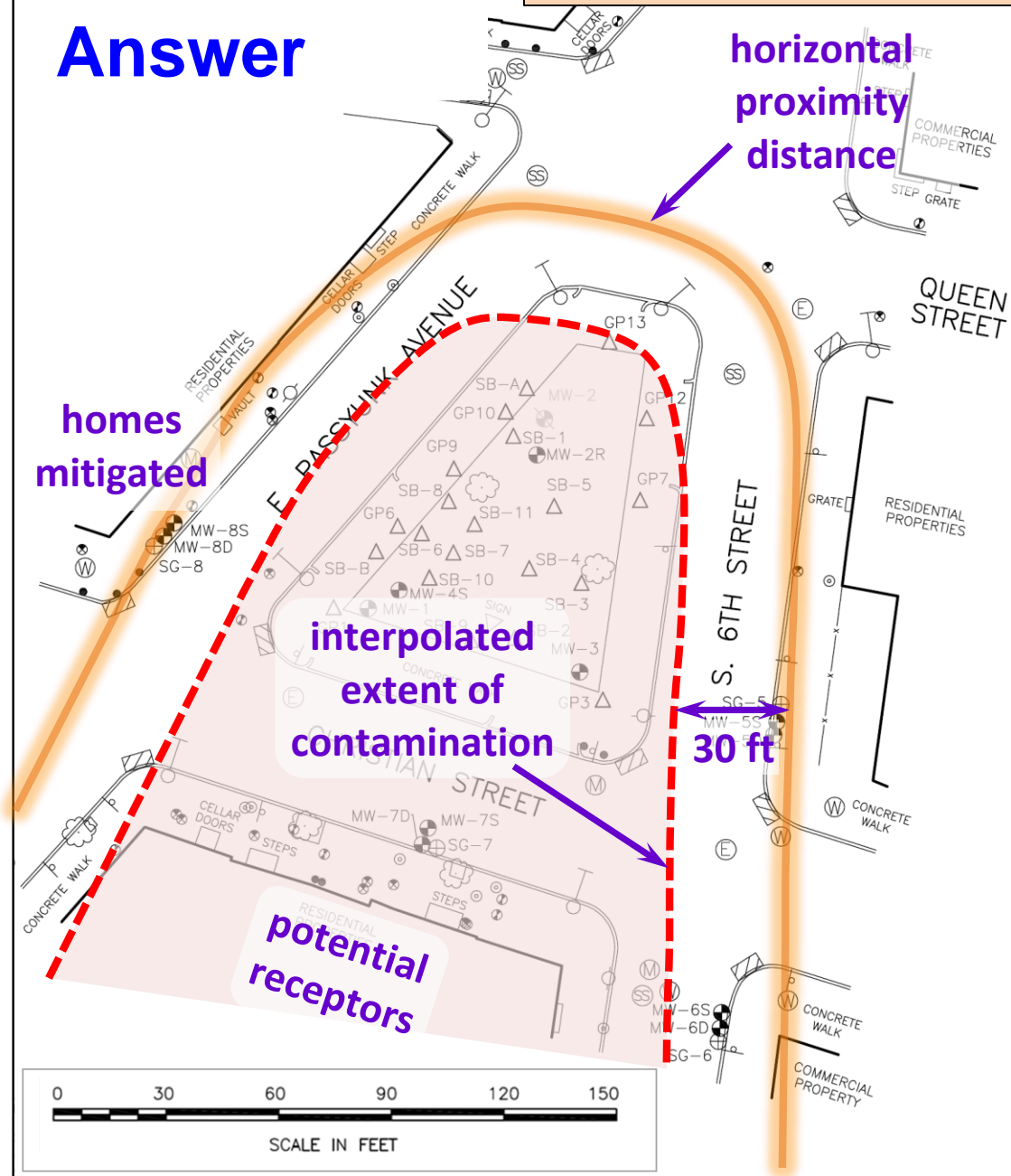


Exercise #3

Exercise Instructions

- Use the previously determined areas of potential VI sources
- Apply proximity distances around potential VI sources in soil and groundwater
- Consider the source property and neighboring properties
- For which properties is soil/groundwater contamination a potential VI source?

Horizontal Proximity Distance

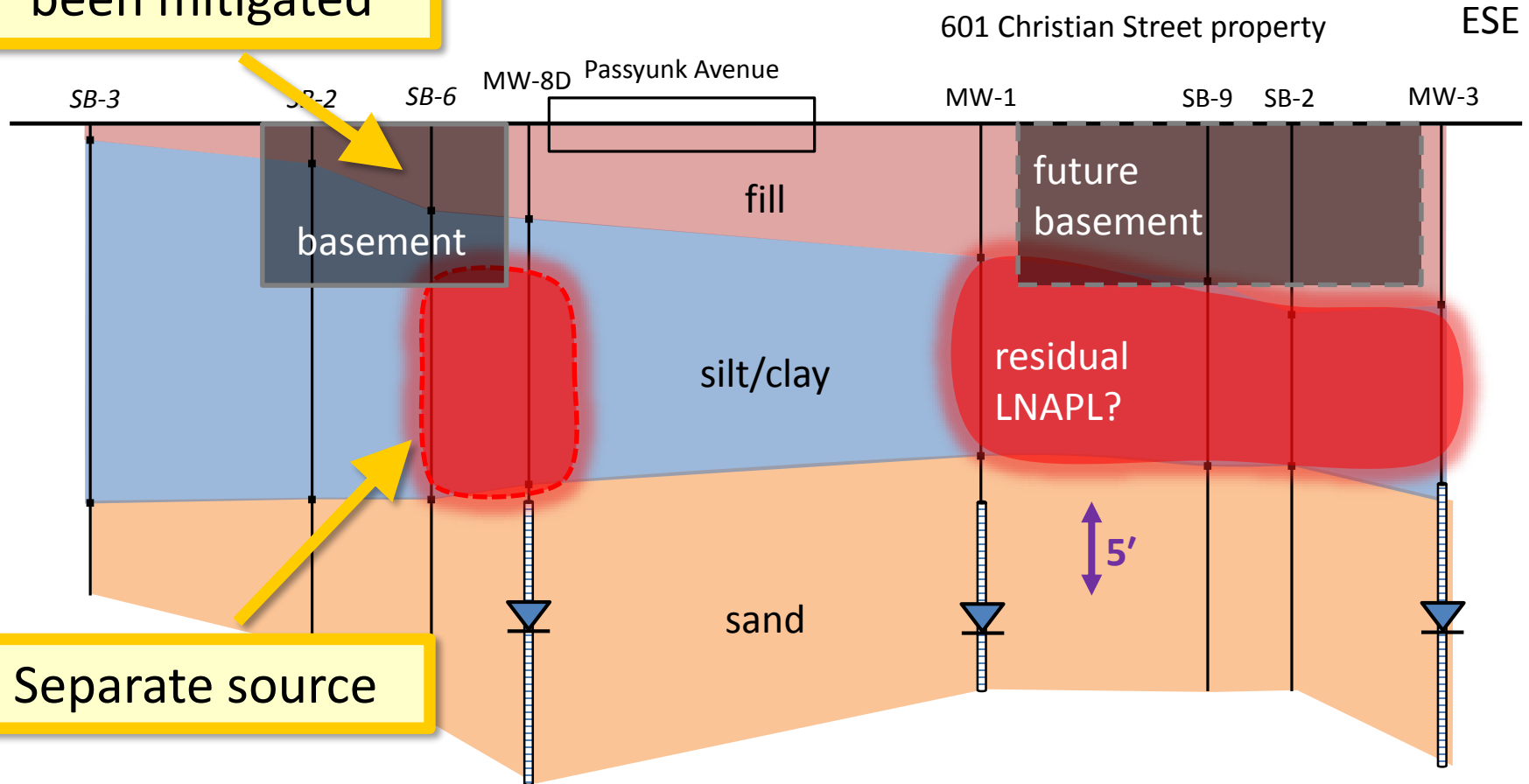


Proximity Distance Considerations

- Is LNAPL present onsite?
- No LNAPL observed soil or wells
- But maximum benzene ~50 mg/kg
- EPA's petroleum VI guidance indicates potential residual LNAPL presence for:
 - Benzene > 10 mg/kg
 - TPH > 100/250 mg/kg (gasoline)
- Don't forget potential preferential pathways

Cross Section—Vertical Proximity Distance

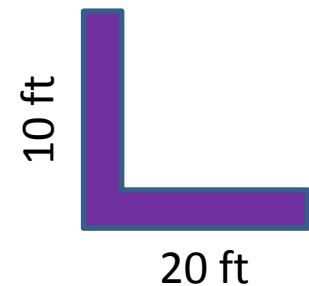
These homes have been mitigated



Separate source

(DTW June 2016)

vertical exaggeration 2x



Proximity Distance Results

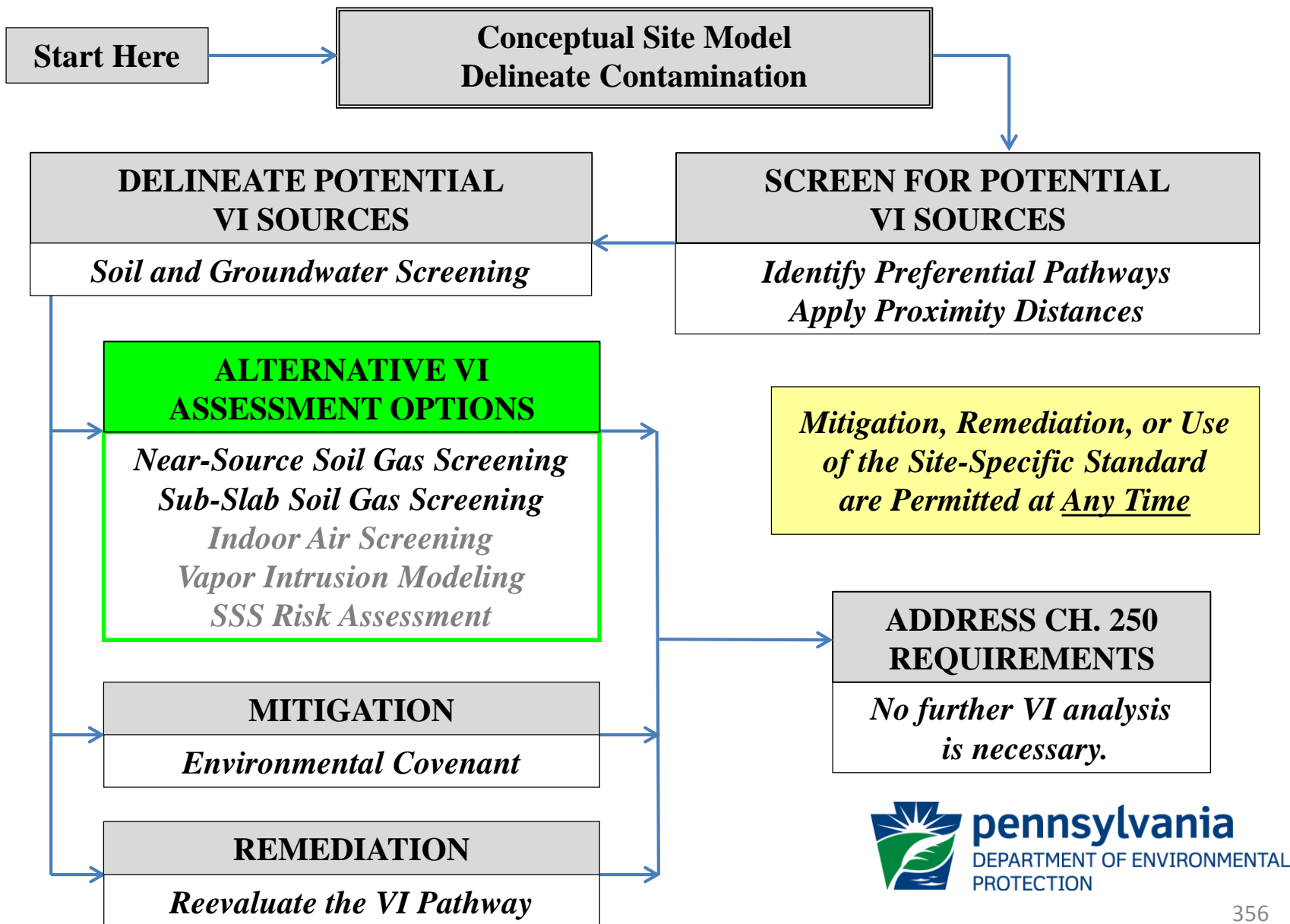
- Soil at the former gas station property is a potential VI source
 - Planned development includes a basement
 - So whether NAPL is present or not doesn't matter
- Groundwater is not a potential VI source
 - *If there are no significant foundation openings*
 - More than 5 feet of acceptable soil is present above the water table and below foundations
 - No mobile LNAPL
 - Both onsite and offsite

VI Case Study Exercise #3

Questions/Discussion



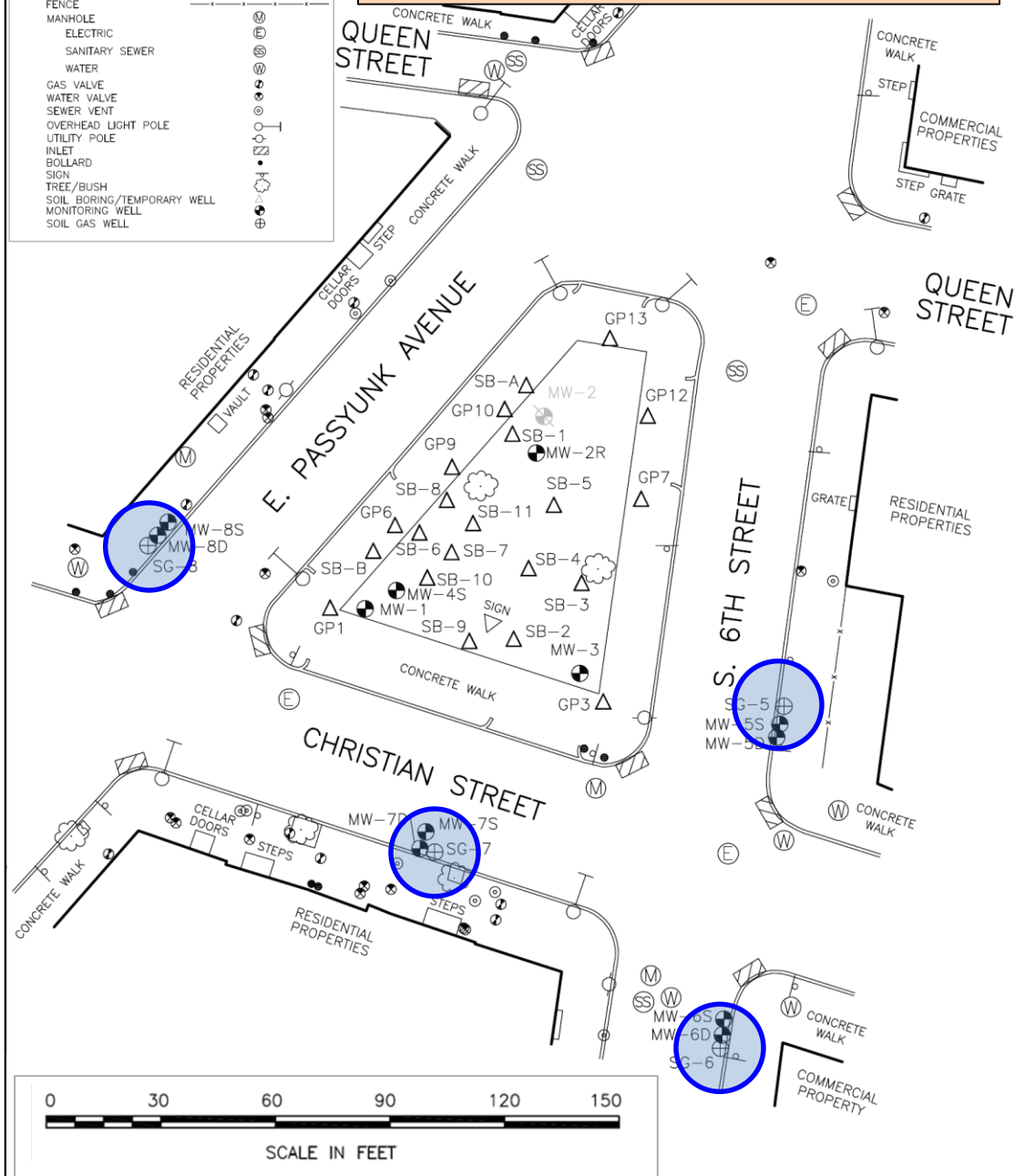
Soil Gas Investigation



Soil Gas Sample Points

LEGEND:

FENCE
MANHOLE
ELECTRIC
SANITARY SEWER
WATER
GAS VALVE
WATER VALVE
SEWER VENT
OVERHEAD LIGHT POLE
UTILITY POLE
INLET
BOLLARD
SIGN
TREE/BUSH
SOIL BORING/TEMPORARY WELL
MONITORING WELL
SOIL GAS WELL



Soil Gas Investigation

- Four soil gas points
- Screened ~9 feet deep (clayey silt unit)
- Sampled in two quarterly rounds
- Shut-in vacuum tightness test and helium tracer gas leak test at each point
- Collected 30-min samples in 1-L Summas
- Outdoor ambient air samples
- No EDB or EDC analyses

Exercise #4

Exercise Objective: Soil Gas Screening

- Apply appropriate screening values to the soil gas data
- Combination of standards
- Does the VI pathway screen out with the soil gas data?

Conditions for Soil Gas Screening

Conditions from VI Guidance Table 6

- ☒ Account for spatial variability
- ☒ Minimum two rounds, two locations
- ☒ Representative of sources and pathways
- ☐ *Sample within 1 foot of source*
- ☒ Sample at least 5 feet below grade
- ☒ Acceptable soil or soil-like material present

Restrictions on Soil Gas Screening

Restrictions from VI Guidance Figure 7:

- ☒ Contamination does not enter external preferential pathway—GW too deep
- ☐ Significant foundation openings not suspected—should confirm
- ☐ Preferential pathway foundation penetrations not suspected—should confirm
- ☒ Potential VI source is > 5 feet below foundations

Proposed Soil & Groundwater Standards

- Only **cumene** will attain the Statewide health standard for both soil and groundwater
- The site-specific standard with pathway elimination will be used for all other substances in soil
- The site-specific standard with pathway elimination will be used for groundwater
 - Benzene, ethylbenzene, MTBE, naphthalene, trimethylbenzenes

Table 3. Near-Source Soil Gas Statewide Health Standard Vapor Intrusion Screening Values (SV_{NS})

Regulated Substance	CAS No.	Residential (µg/m ³)	Nonresidential (µg/m ³)	Converted Residential (µg/m ³)
ACETALDEHYDE	75-07-0	1,900	39,000	7,900
ACETONE	67-64-1	6,500,000	140,000,000	27,000,000
ACETONITRILE	75-05-8	13,000	260,000	53,000
ACROLEIN	107-02-8	4.2	88	18
ACRYLAMIDE	79-06-1	19	1,200	250
ACRYLIC ACID	79-10-7	210	4,400	880
ACRYLONITRILE	107-13-1	72	1,800	360
ALLYL ALCOHOL	107-18-6	21	440	88
AMMONIA	7664-41-7	21,000	440,000	88,000
ANILINE	62-53-3	210	4,400	880
BENZENE	71-43-2	620	16,000	3,100
BENZYL CHLORIDE	100-44-7	99	2,500	500
BETA PROPIOLACTONE	57-57-8	1.2	31	6.1
BIPHENYL, 1,1-	92-52-4	83	1,800	350

Table 4. Sub-Slab Soil Gas Statewide Health Standard Vapor Intrusion Screening Values (SV_{SS})

Regulated Substance	CAS No.	Residential (µg/m ³)	Nonresidential (µg/m ³)	Converted Residential (µg/m ³)
ACETALDEHYDE	75-07-0	360	5,100	1,500
ACETONE	67-64-1	1,200,000	17,000,000	5,200,000
ACETONITRILE	75-05-8	2,400	34,000	10,000
ACROLEIN	107-02-8	0.80	11	3.4
ACRYLAMIDE	79-06-1	3.7	160	47
ACRYLIC ACID	79-10-7	40	560	170
ACRYLONITRILE	107-13-1	14	230	69
ALLYL ALCOHOL	107-18-6	4.0	56	17
AMMONIA	7664-41-7	4,000	56,000	17,000
ANILINE	62-53-3	40	560	170
BENZENE	71-43-2	120	2,000	610
BENZYL CHLORIDE	100-44-7	19	320	96
BETA PROPIOLACTONE	57-57-8	0.23	3.9	1.2
BIPHENYL, 1,1-	92-52-4	16	220	67

Site-Specific Standard Vapor Intrusion Screening Values Based on EPA RSLs

Residential Conditions for a 10^{-5} Screening Value Cancer Risk

Note: May 2016 RSL values



pennsylvania
DEPARTMENT OF ENVIRONMENTAL
PROTECTION

Substance	CAS No.	Cancer RSL ($\mu\text{g}/\text{m}^3$)	Non-Cancer RSL ($\mu\text{g}/\text{m}^3$)	Indoor Air RSL-Based SV ($\mu\text{g}/\text{m}^3$)	Sub-Slab Soil Gas RSL-Based SV ($\mu\text{g}/\text{m}^3$)	Near-Source Soil Gas RSL-Based SV ($\mu\text{g}/\text{m}^3$)
Risk Basis		CR = 10^{-6}	HQ = 0.1	CR = 10^{-5} and HQ = 0.1		
Benzene	71-43-2	3.6E-01	3.1E+00	3.1	120	620
Cumene	98-82-8		4.2E+01	42	1,600	8,400
Dibromoethane, 1,2-	106-93-4	4.7E-03	9.4E-01	0.047	1.8	9.4
Dichloroethane, 1,1-	75-34-3	1.8E+00		18	690	3,600
Dichloroethane, 1,2-	107-06-2	1.1E-01	7.3E-01	0.73	28	150
Dichloroethylene, 1,1-	75-35-4		2.1E+01	21	810	4,200
Dichloroethylene, 1,2-cis-	156-59-2					
Dichloroethylene, 1,2-trans-	156-60-5					
Ethylbenzene	100-41-4	1.1E+00	1.0E+02	11	420	2,200
Methyl tert-Butyl Ether (MTBE)	1634-04-4	1.1E+01	3.1E+02	110	4,200	22,000
Naphthalene	91-20-3	8.3E-02	3.1E-01	0.31	12	62
Tetrachloroethylene (PCE)	127-18-4	1.1E+01	4.2E+00	4.2	160	840
Toluene	108-88-3		5.2E+02	520	20,000	100,000
Trichloroethane, 1,1,1-	71-55-6		5.2E+02	520	20,000	100,000
Trichloroethane, 1,1,2-	79-00-5	1.8E-01	2.1E-02	0.021	0.81	4.2
Trichloroethylene (TCE)	79-01-6	4.8E-01	2.1E-01	0.21	8.1	42
Trimethylbenzene, 1,2,3-	526-73-8		5.2E-01	0.52	20	100
Trimethylbenzene, 1,2,4-	95-63-6		7.3E-01	0.73	28	150
Trimethylbenzene, 1,3,5-	108-67-8					
Vinyl Chloride	75-01-4	1.7E-01	1.0E+01	1.7	65	340
Xylenes	1330-20-7		1.0E+01	10	380	2,000

Exercise 1

LEGE	
FENCE	Ⓜ
MANHOLE	ⓔ
ELECTRIC	Ⓢ
SANITARY SEWER	Ⓜ
WATER	Ⓢ
GAS VALVE	Ⓢ
WATER VALVE	Ⓢ
SEWER VENT	Ⓢ
OVERHEAD LIGHT POLE	Ⓢ
UTILITY POLE	Ⓢ
INLET	Ⓢ
BOLLARD	Ⓢ
SIGN	Ⓢ
TREE/BUSH	Ⓢ
SOIL BORING/TEMPORARY WELL	Ⓢ
MONITORING WELL	Ⓢ
SOIL GAS WELL	Ⓢ



Exercise #4: Soil Gas Vapor Intrusion Screening (Case Study)

SG-5—Analytical Data (sample depth 9.5')

Substance	Benzene		Ethyl-benzene		Cumene		MTBE		Naphthalene		Toluene		1,2,4-TMB		1,3,5-TMB		Xylenes	
CAS No.	71-43-2		100-41-4		98-82-8		1634-04-4		91-20-3		108-88-3		95-63-6		108-67-8		1330-20-7	
Units	µg/m³		µg/m³		µg/m³		µg/m³		µg/m³		µg/m³		µg/m³		µg/m³		µg/m³	
Date																		
6/5/2015	7.5		15		8.1	J	3.2	J	8.9	J	31		30		14		72	
9/16/2015	13		110		12		2.2	J	11		260		200		65		480	
Outdoor Ambient Sample Data																		
6/5/2015	1.5	J	2.0	J	2.0	U	1.4	U	5.2	U	2.7	J	2.0	J	2.0	U	6.3	J
9/16/2015	1.0	J	8.1		1.0	U	2.1	J	2.6	U	7.6		2.1	J	1.0	U	33	
VI Screening Values																		
Standard	SSS		SSS		SHS		SSS		SSS		SSS		SSS		SSS		SSS	
Statewide Health Standard SV																		
Site-Specific Standard SV																		
RSL-based Site-Specific Standard SV																		
Exceed? (yes/no)																		

Exercise #4: Soil Gas Vapor Intrusion Screening (Case Study)

SG-5—Analytical Data (sample depth 9.5')

Substance	Benzene		Ethyl-benzene		Cumene		MTBE		Naphthalene		Toluene		1,2,4-TMB		1,3,5-TMB		Xylenes	
CAS No.	71-43-2		100-41-4		98-82-8		1634-04-4		91-20-3		108-88-3		95-63-6		108-67-8		1330-20-7	
Units	µg/m³		µg/m³		µg/m³		µg/m³		µg/m³		µg/m³		µg/m³		µg/m³		µg/m³	
Date																		
6/5/2015	7.5		15		8.1	J	3.2	J	8.9	J	31		30		14		72	
9/16/2015	13		110		12		2.2	J	11		260		200		65		480	
Outdoor Ambient Sample Data																		
6/5/2015	1.5	J	2.0	J	2.0	U	1.4	U	5.2	U	2.7	J	2.0	J	2.0	U	6.3	J
9/16/2015	1.0	J	8.1		1.0	U	2.1	J	2.6	U	7.6		2.1	J	1.0	U	33	
VI Screening Values																		
Standard	SSS		SSS		SHS		SSS		SSS		SSS		SSS		SSS		SSS	
Statewide Health Standard SV	120																	
Site-Specific Standard SV																		
RSL-based Site-Specific Standard SV																		
Exceed? (yes/no)																		

1 Look up SHS SV_{ss}

Exercise #4: Soil Gas Vapor Intrusion Screening (Case Study)

SG-5—Analytical Data (sample depth 9.5')

Substance	Benzene		Ethyl-benzene		Cumene		MTBE		Naphthalene		Toluene		1,2,4-TMB		1,3,5-TMB		Xylenes	
CAS No.	71-43-2		100-41-4		98-82-8		1634-04-4		91-20-3		108-88-3		95-63-6		108-67-8		1330-20-7	
Units	µg/m³		µg/m³		µg/m³		µg/m³		µg/m³		µg/m³		µg/m³		µg/m³		µg/m³	
Date																		
6/5/2015	7.5		15		8.1	J	3.2	J	8.9	J	31		30		14		72	
9/16/2015	13		110		12		2.2	J	11		260		200		65		480	
Outdoor Ambient Sample Data																		
6/5/2015	1.5	J	2.0	J	2.0	U	1.4	U	5.2	U	2.7	J	2.0	J	2.0	U	6.3	J
9/16/2015	1.0	J	8.1		1.0	U	2.1	J	2.6	U	7.6		2.1	J	1.0	U	33	
VI Screening Values																		
Standard	SSS		SSS		SHS		SSS		SSS		SSS		SSS		SSS		SSS	
Statewide Health Standard SV	120																	
Site-Specific Standard SV	12																	
RSL-based Site-Specific Standard SV																		
Exceed? (yes/no)																		

2 Divide by 10 for SSS SV_{SS}

Exercise #4: Soil Gas Vapor Intrusion Screening (Case Study)

SG-5—Analytical Data (sample depth 9.5')

Substance	Benzene		Ethyl-benzene		Cumene		MTBE		Naphthalene		Toluene		1,2,4-TMB		1,3,5-TMB		Xylenes	
CAS No.	71-43-2		100-41-4		98-82-8		1634-04-4		91-20-3		108-88-3		95-63-6		108-67-8		1330-20-7	
Units	µg/m³		µg/m³		µg/m³		µg/m³		µg/m³		µg/m³		µg/m³		µg/m³		µg/m³	
Date																		
6/5/2015	7.5		15		8.1	J	3.2	J	8.9	J	31		30		14		72	
9/16/2015	13		110		12		2.2	J	11		260		200		65		480	
Outdoor Ambient Sample Data																		
6/5/2015	1.5	J	2.0	J	2.0	U	1.4	U	5.2	U	2.7	J	2.0	J	2.0	U	6.3	J
9/16/2015	1.0	J	8.1		1.0	U	2.1	J	2.6	U	7.6		2.1	J	1.0	U	33	
VI Screening Values																		
Standard	SSS		SSS		SHS		SSS		SSS		SSS		SSS		SSS		SSS	
Statewide Health Standard SV	120																	
Site-Specific Standard SV	12																	
RSL-based Site-Specific Standard SV	120																	
Exceed? (yes/no)																		

3 Look up RSL-based SV_{ss}

Exercise #4: Soil Gas Vapor Intrusion Screening (Case Study)

SG-5—Analytical Data (sample depth 9.5')

Substance	Benzene		Ethyl-benzene		Cumene		MTBE		Naphthalene		Toluene		1,2,4-TMB		1,3,5-TMB		Xylenes	
CAS No.	71-43-2		100-41-4		98-82-8		1634-04-4		91-20-3		108-88-3		95-63-6		108-67-8		1330-20-7	
Units	µg/m ³		µg/m ³		µg/m ³		µg/m ³		µg/m ³		µg/m ³		µg/m ³		µg/m ³		µg/m ³	
Date																		
6/5/2015	7.5		15		8.1	J	3.2	J	8.9	J	31		30		14		72	
9/16/2015	13		110		12		2.2	J	11		260		200		65		480	
Outdoor Ambient Sample Data																		
6/5/2015	1.5	J	2.0	J	2.0	U	1.4	U	5.2	U	2.7	J	2.0	J	2.0	U	6.3	J
9/16/2015	1.0	J	8.1		1.0	U	2.1	J	2.6	U	7.6		2.1	J	1.0	U	33	
VI Screening Values																		
Standard	SSS		SSS		SHS		SSS		SSS		SSS		SSS		SSS		SSS	
Statewide Health Standard SV	120																	
Site-Specific Standard SV	12																	
RSL-based Site-Specific Standard SV	120																	
Exceed? (yes/no)																		

4 Select higher of values

Exercise #4: Soil Gas Vapor Intrusion Screening (Case Study)

SG-5—Analytical Data (sample depth 9.5')

Substance	Benzene		Ethyl-benzene		Cumene		MTBE		Naphthalene		Toluene		1,2,4-TMB		1,3,5-TMB		Xylenes	
CAS No.	71-43-2		100-41-4		98-82-8		1634-04-4		91-20-3		108-88-3		95-63-6		108-67-8		1330-20-7	
Units	µg/m ³		µg/m ³		µg/m ³		µg/m ³		µg/m ³		µg/m ³		µg/m ³		µg/m ³		µg/m ³	
Date																		
6/5/2015	7.5		15		8.1	J	3.2	J	8.9	J	31		30		14		72	
9/16/2015	13		110		12		2.2	J	11		260		200		65		480	
Outdoor Ambient Sample Data																		
6/5/2015	1.5	J	2.0	J	2.0	U	1.4	U	5.2	U	2.7	J	2.0	J	2.0	U	6.3	J
9/16/2015	1.0	J	8.1		1.0	U	2.1	J	2.6	U	7.6		2.1	J	1.0	U	33	
VI Screening Values																		
Standard	SSS		SSS		SHS		SSS		SSS		SSS		SSS		SSS		SSS	
Statewide Health Standard SV	120																	
Site-Specific Standard SV	12																	
RSL-based Site-Specific Standard SV	120																	
Exceed? (yes/no)	NO																	

5 Screen soil gas data

Exercise #4

Exercise Instructions

- You have VOC analytical data from soil gas sampling at one location (SG-5)
- Determine the appropriate VI residential SVs
 - Statewide health or site-specific standard?
 - Near-source soil gas or sub-slab soil gas?
 - Utilize RSL-based screening values
- Which substances exceed? Which don't?
- Are there receptors of concern for VI?

Soil Gas Screening Considerations

- Can you screen soil gas data that isn't from a near-source sample point?
 - Yes, but you must use **sub-slab screening values**
 - Sample data is used to assess receptor exposure
- The deeper the point the better
 - Concern with temporal variability of shallow data
 - Surface pavement is beneficial
- Be aware of basements so screens are installed at proper depths

Soil Gas Considerations (continued)

- Use of sub-slab screening values presumes the absence of significant foundation openings
 - Alternative: Screen with SV_{IA}
 - Or determine if significant foundation openings are present
 - This will be assessed next

Exercise #4

Exercise #4: Soil Gas Vapor Intrusion Screening (Case Study)

Answers

SG-5—Analytical Data (sample depth 9.5')

Substance	Benzene		Ethyl-benzene		Cumene		MTBE		Naphthalene		Toluene		1,2,4-TMB		1,3,5-TMB		Xylenes	
CAS No.	71-43-2		100-41-4		98-82-8		1634-04-4		91-20-3		108-88-3		95-63-6		108-67-8		1330-20-7	
Units	µg/m ³		µg/m ³		µg/m ³		µg/m ³		µg/m ³		µg/m ³		µg/m ³		µg/m ³		µg/m ³	
Date																		
6/5/2015	7.5		15		8.1	J	3.2	J	8.9	J	31		30		14		72	
9/16/2015	13		110		12		2.2	J	11		260		200		65		480	
Outdoor Ambient Sample Data																		
6/5/2015	1.5	J	2.0	J	2.0	U	1.4	U	5.2	U	2.7	J	2.0	J	2.0	U	6.3	J
9/16/2015	1.0	J	8.1		1.0	U	2.1	J	2.6	U	7.6		2.1	J	1.0	U	33	
VI Screening Values																		
Standard	SSS		SSS		SHS		SSS		SSS		SSS		SSS		SSS		SSS	
Statewide Health Standard SV					16,000													
Site-Specific Standard SV	12		37				360		2.8		20,000		28		28		400	
RSL-based Site-Specific Standard SV	120		420				4,200		12		20,000		28				380	
Exceed? (yes/no)	no		no		no		no		no		no		yes		yes		yes	

Soil Gas Screening Exceedences

LEGEND:

FENCE
MANHOLE
ELECTRIC
SANITARY SEWER
WATER
GAS VALVE
WATER VALVE
SEWER VENT
OVERHEAD LIGHT POLE
UTILITY POLE
INLET
BOLLARD
SIGN
TREE/BUSH
SOIL BORING/TEMPORARY WELL
MONITORING WELL
SOIL GAS WELL

SG-8

SG-5

SG-7

SG-6

Impacted by an
offsite source;
existing
mitigation

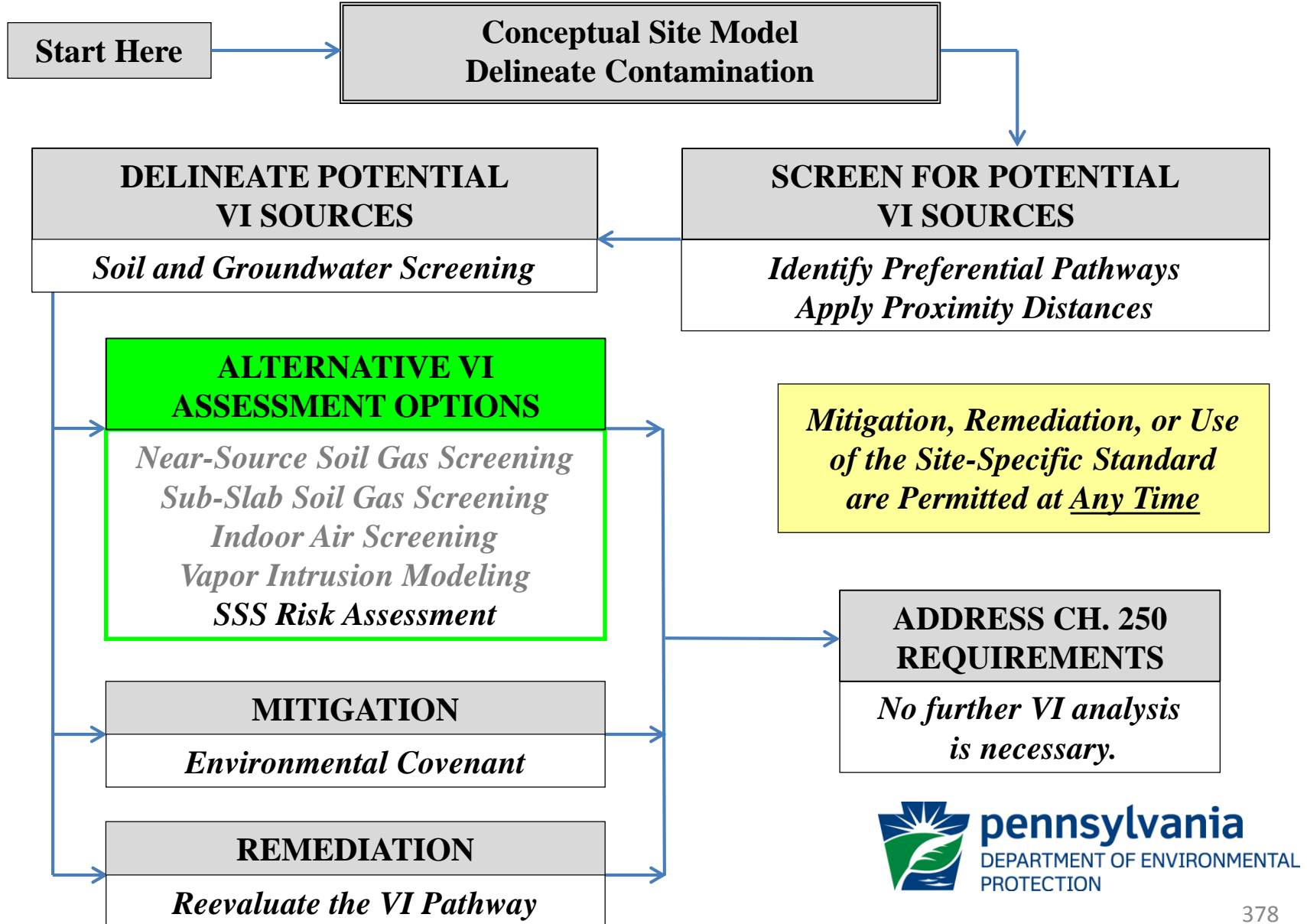
0 30 60 90 120 150
SCALE IN FEET

VI Case Study Exercise #4

Questions/Discussion



Perform a VI Risk Assessment



Vapor Intrusion Risk Assessment

- Evaluate VI inhalation risks using EPA's [VISL Calculator](#) spreadsheet
- Input maximum soil gas concentrations
- Data is *not* near-source soil gas, so use sub-slab attenuation factor (0.03)—conservative
 - *Valid if no significant foundation openings*

VI Risk Assessment (continued)

- EPA updated trimethylbenzene toxicity information in IRIS (September 2016)
 - New RfC = $0.06 \mu\text{g}/\text{m}^3$
 - This is less stringent than the toxicity value used for DEP's screening values
 - Modify RfC in VISL
- User can sum TMB concentrations in VISL
 - 1,3,5-TMB not available in current VISL

VI Risk Assessment (continued)

- Determine if significant foundation openings are present
 - Surveyed property owner
 - In-person inspection not required
 - Response: no dirt floor, foundation in good condition, no basement seepage or odors
 - Conclude that it is appropriate to assume no significant foundation openings

BUILDING SURVEY FORM



Survey Completed by: _____ Date: _____

Site Name: 601 Christian Street Corrective Action Site Case No.: 51-18770

PA DEP Contact: C. David Brown (484.250.5796) cdbrown@pa.gov

Part I — Occupants

Building Address: _____

Property Contact: _____ Owner / Renter / other: _____

Contact's Phone: _____

Part II — Building Characteristics

Building type: single-family residential / multi-family residential / office / strip mall / commercial / industrial

Describe building: _____

Number of floors—below grade: _____ (full basement / crawl space / slab) at or above grade: _____

Basement floor: concrete / dirt / floating / other (specify): _____

Foundation type: poured concrete / cinder block / stone / other (specify): _____

Condition of foundation and floor (e.g., large cracks, gaps, or other openings): _____

Basement sump present? *Yes / No* Sump pump? *Yes / No* Standing water? *Yes / No*

Basement French drain present? *Yes / No* Basement floor drain present? *Yes / No*

Basement used as living space? *Yes / No* Describe: _____

Existing sub-slab depressurization (radon) system in place? *Yes / No* Operating? *Yes / No*

Part III — Miscellaneous Items

Have the occupants noticed any unusual odors in the building? *Yes / No*

Describe (with location): _____

Is there any seepage of water or other liquid in the basement? *Yes / No*

Describe (with location): _____

Any known spills of a fuel or chemical immediately outside or inside the building? *Yes / No*

Describe (with location): _____

VI Case Study

VISL Example Results—SG-5

EPA-OLEM VAPOR INTRUSION ASSESSMENT

Sub-slab or Exterior Soil Gas Concentration to Indoor Air Concentration (SGC-IAC) Calculator Version 3.5.1 (May 2016 RSLs)

Parameter	Symbol	Value	Instructions
Exposure Scenario	Scenario	Residential	Select residential or commercial s
Target Risk for Carcinogens	TCR_SG	1.00E-05	Enter target risk for carcinogens
Target Hazard Quotient for Non-Carcinogens	THQ_SG	0.1	Enter target hazard quotient for n

CAS	Chemical Name	Site Sub-slab or Exterior Soil Gas Concentration	Calculated Indoor Air Concentration	VI Carcinogenic Risk	VI Hazard
		Csg	Cia	CR	HQ
		($\mu\text{g}/\text{m}^3$)	($\mu\text{g}/\text{m}^3$)		
71-43-2	Benzene	13	0.39	1.1E-06	1.2E-02
98-82-8	Cumene	12	0.36	No IUR	8.6E-04
100-41-4	Ethylbenzene	110	3.3	2.9E-06	3.2E-03
1634-04-4	Methyl tert-Butyl Ether (MTBE)	3.2	0.096	8.9E-09	3.1E-05
91-20-3	Naphthalene	11	0.33	4.0E-06	1.1E-01
108-88-3	Toluene	260	7.8	No IUR	1.5E-03
95-63-6	Trimethylbenzene, 1,2,4-	200	6	No IUR	9.6E-02
108-67-8	Trimethylbenzene, 1,3,5-	65	1.95	No IUR	3.1E-02
1330-20-7	Xylenes	480	14.4	No IUR	1.4E-01

Notes:

Cumulative Risks: **8.0E-06** **0.39**

(Note Afss_R = 0.026)

Risk Assessment Results—SG-5

- VISL demonstrates acceptable cumulative inhalation risks for receptors near SG-5
 - Cancer risk is 8.0×10^{-6} < 1.0×10^{-4} limit
 - Hazard index is 0.39 < 1.0 limit

Risk Assessment Modeling

- What if presence of significant foundation openings can't be determined?
- Alternatives:
 - VISL with sub-slab data input as indoor air data
 - J&E model with assumption of dirt floor
- Example: Residences adjacent to SG-7
- Determine if VI risk is acceptable at homes

LEGEND:

FENCE
MANHOLE
ELECTRIC
SANITARY SEWER
WATER
GAS VALVE
WATER VALVE
SEWER VENT
OVERHEAD LIGHT POLE
UTILITY POLE
INLET
BOLLARD
SIGN
TREE/BUSH
SOIL BORING/TEMPORARY WELL
MONITORING WELL
SOIL GAS WELL



VI Case Study

VISL Example Results—SG-7

EPA-OLEM VAPOR INTRUSION ASSESSMENT

Indoor Air Concentration to Risk (IAC-Risk) Calculator Version 3.5.1 (May 2016 RSLs)

Parameter	Symbol	Value	Instructions
Exposure Scenario	Scenario	Residential	Select residential
Target Risk for	TCR	1.00E-05	Enter target risk
Target Hazard	THQ	0.1	Enter target hazard

Soil gas data as indoor air data for potential significant foundation opening

CAS	Chemical Name	Site Indoor Air Concentration	VI Carcinogenic Risk	VI Hazard
		Cia (ug/m ³)	CR	HQ
71-43-2	Benzene	3.7	1.0E-05	1.2E-01
98-82-8	Cumene	2.0	No IUR	4.8E-03
100-41-4	Ethylbenzene	15	1.3E-05	1.4E-02
1634-04-4	Methyl tert-Butyl Ether (MTBE)	1.4	1.3E-07	4.5E-04
91-20-3	Naphthalene	5.2	6.3E-05	1.7E+00
108-88-3	Toluene	47	No IUR	9.0E-03
95-63-6	Trimethylbenzene	24	No IUR	3.8E-01
108-67-8	Trimethylbenzene	19	No IUR	3.0E-01
1330-20-7	Xylenes	85	No IUR	8.2E-01
		Cumulative Risks:	8.7E-05	3.31

Modeling for chemicals with HQ > 0.1

SG-7 Soil Gas Modeling

- Johnson & Ettinger models of soil gas data
 - Zero slab thickness (dirt floor)
- Use PA DEP version of spreadsheet
- Modify for current TMB toxicity
- Select site-specific inputs
- Use conservative default values where appropriate

VI Case Study

J&E Model Input Parameters

	Parameter	Value	Comments
L_F	Depth below grade to bottom of foundation	240 cm	basement 8'
L_s	Soil gas sampling depth below grade	274 cm	SG-7 9.0'
T_s	Soil temperature	18°C	default
—	Soil type	SI	silt
L_B	Building floor length	550 cm	measured (18')
W_B	Building floor width	580 cm	measured (19')
H_B	Building room height	210 cm	basement 7'
Q_{soil}	Vapor flow rate into foundation	2.8 L/min	scaled by perimeter

Soil Gas Concentration Data

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_q ($\mu\text{g}/\text{m}^3$)	OR	ENTER Soil gas conc., C_q (ppmv)	Chemical
N/A for PA DEP Model				
95636	2.40E+01			TRIMETHYLBENZENE, 1,3,4- (TRIMETHYLBENZENE, 1,2,4-)

PA DEP J&E
version 6.2R
September 2016

SG-7
601 Christian St., Phila.

Entries highlighted in yellow should be verified and updated with site-specific information by the user, if appropriate. (Other parameters may also be modified.)
Refer to the PA DEP Technical Guidance Manual for Vapor Intrusion, Appendix B.

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Soil gas sampling depth below grade, L_s (cm)	ENTER Average soil temperature, T_s ($^{\circ}\text{C}$)	ENTER Totals must add up to value of L_s (cell F24)			ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
			Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, (Enter value or 0) h_B (cm)	Thickness of soil stratum C, (Enter value or 0) h_C (cm)	OR	
240	274	18	274	0	0	SI	

ENTER Stratum A SCS soil type Lookup Soil Parameters	ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum B SCS soil type Lookup Soil Parameters	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum C SCS soil type Lookup Soil Parameters	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)
SI	1.35	0.489	0.1	SL	1.62	0.387	0.1	SL	1.62	0.387	0.1

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP ($\text{g}/\text{cm}\cdot\text{s}^2$)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)	ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
0		550	580	210	0.1	0.18	2.8

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Exposure time, ET (hr/day)
70	30	30	350	24

Residential Exposure Factors. Use default residential or nonresidential values for Statewide health standard models.

Zero slab
thickness

Near-Source Soil Gas Results

PA DEP J&E
version 6.2R
September 2016

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
--	--

NA

2.9E-02

INDOOR AIR CALCULATIONS:

Infinite
source
bldg.
conc.,
 C_{building}
($\mu\text{g}/\text{m}^3$)

1.8E+00

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

VI Case Study

SG-7 Risk Assessment Modeling Results

Substance	Cancer Risk	Hazard Quotient	Source
Toluene		9.0×10^{-3}	VISL
Ethylbenzene	1.3×10^{-5}	0.014	VISL
Cumene		4.8×10^{-3}	VISL
MTBE	1.3×10^{-7}	4.5×10^{-4}	VISL
Benzene	1.3×10^{-6}	0.013	J&E
Naphthalene	5.5×10^{-6}	0.13	J&E
1,2,4-TMB		0.029	J&E
1,3,5-TMB		0.023	J&E
Xylenes		0.084	J&E
Cumulative	2.0×10^{-5}	0.31	

With assumption of a significant foundation opening

Risk Assessment Modeling Results

- At residences adjacent to SG-7, predicted risks are acceptable even with significant foundation openings
 - Conservative assumption in VISL (soil gas as IA)
 - Simulated in J&E with a slab thickness of zero
 - Property access or owner surveys were not needed

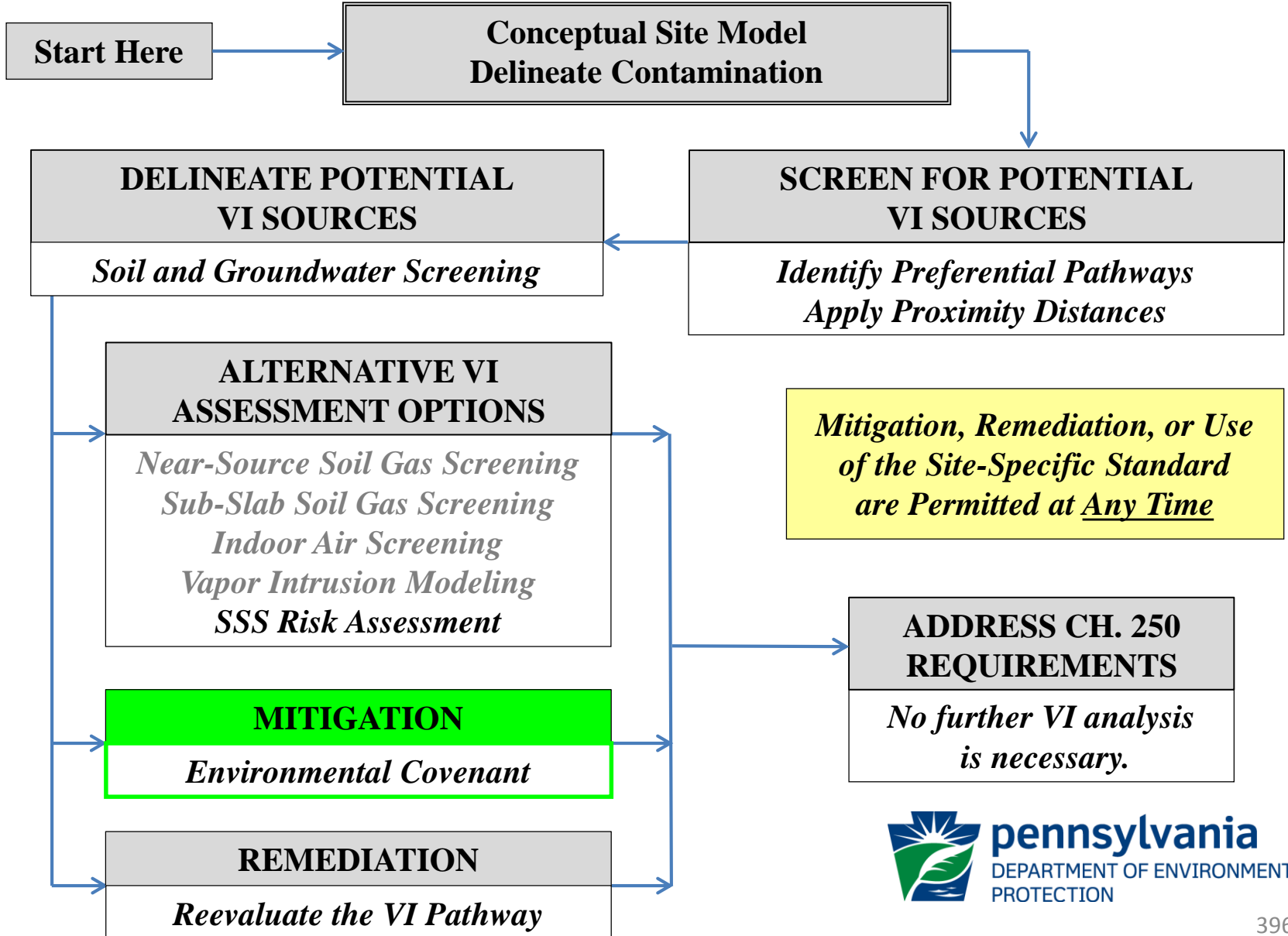
Preferential Pathway Conclusions: Potential Offsite Receptors

- External preferential pathways are unlikely to be a concern at the site
- Trench fill attenuates hydrocarbon vapors
- Absence of significant foundation openings was verified at two properties

Risk Assessment Conclusions: Potential Offsite Receptors

- Risk assessments performed with attenuation factors (VISL) and modeling (J&E)
- Accounted for potential significant foundation openings
- There do not appear to be excess inhalation risks from vapor intrusion at residences

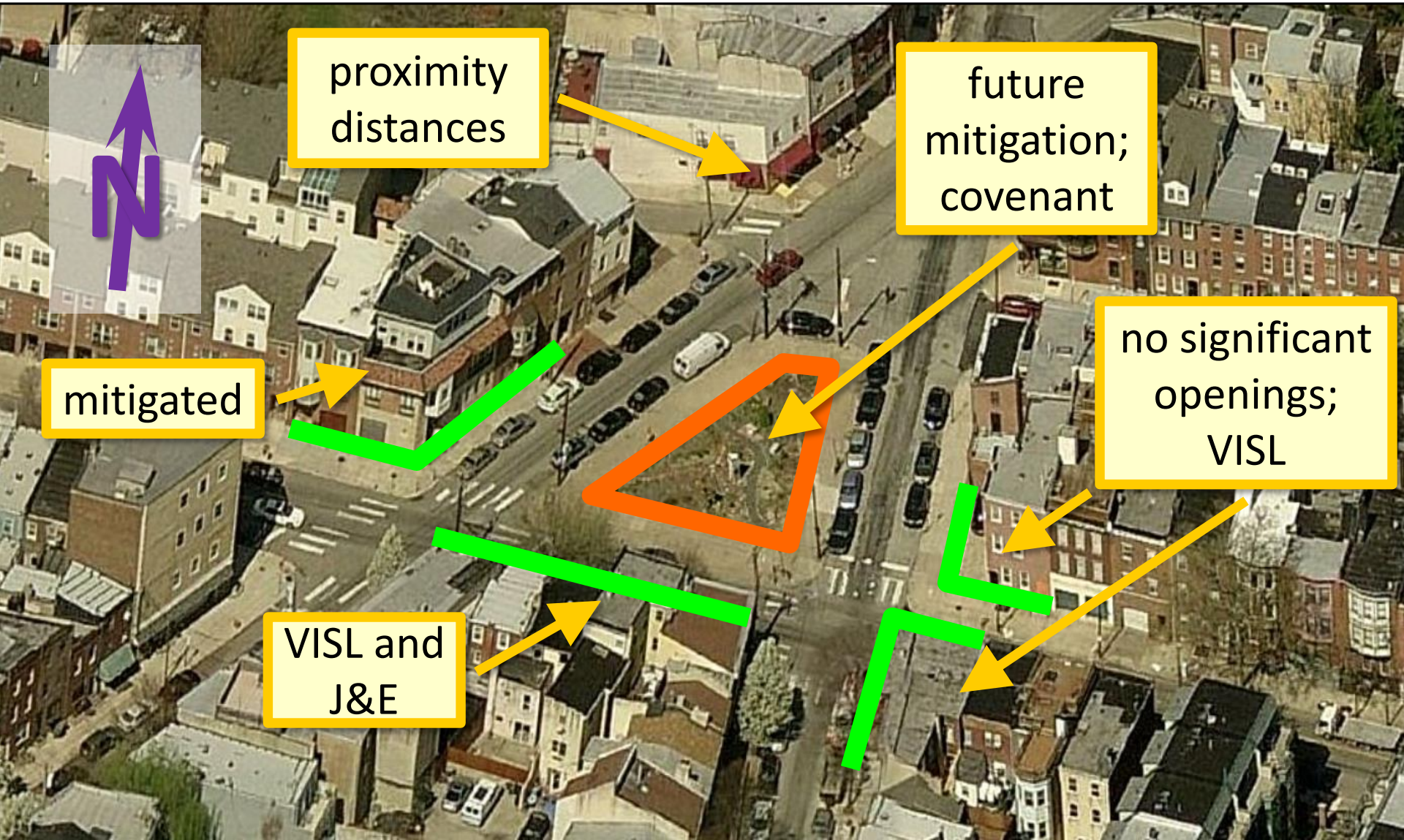
Planned Mitigation of Onsite Property



Conclusions: Onsite Receptors

- Presently no occupied building
- Developer intends to construct a mixed-use building with a basement
- Signed consent order & agreement
 - Requires installation of a vapor mitigation system
 - Requires performance testing of the system
 - Requires implementation of an environmental covenant to maintain engineering control

Vapor Intrusion Evaluation Summary



Some Key Points

- The VI evaluation process may be iterative and cyclic, not linear—Refine the CSM
- Petroleum less a concern than LNAPL, CVOCs
- “Reasonable” preferential pathway assessment; may be qualitative
 - Property access not required
- Many tools available, may be combined
 - Screening, proximity distances, VISL, J&E

VI Case Study

Questions/Discussion

