

Refining the Vapor Intrusion Conceptual Site Model to Account for Unanticipated Sources and Pathways

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U.S. EPA “State of VI Science” Workshop *Reliable Ongoing Human Exposure Protection to Vapor Intrusion Using Cleanup as the Simplest Approach*

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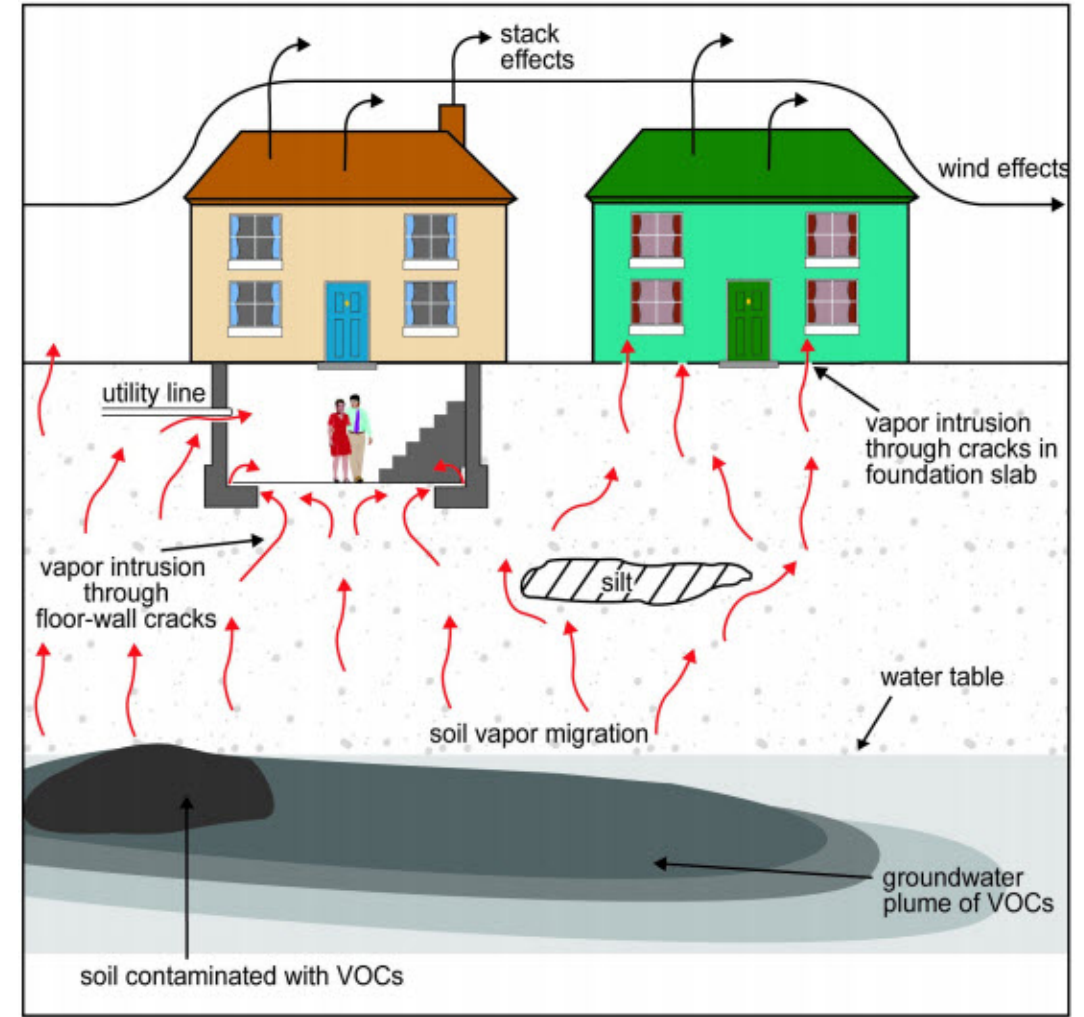


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Agenda

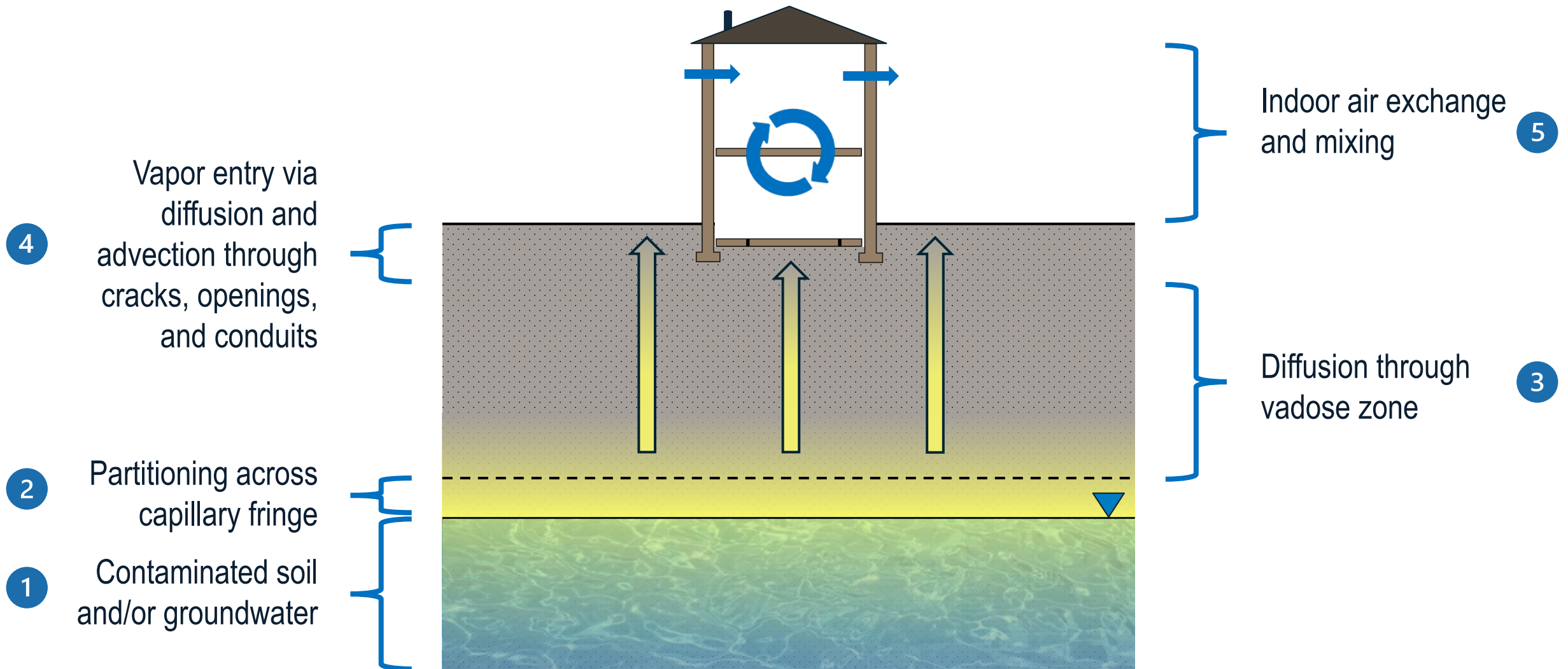
Vapor Intrusion Conceptual Site Models

- Sources
- Pathways



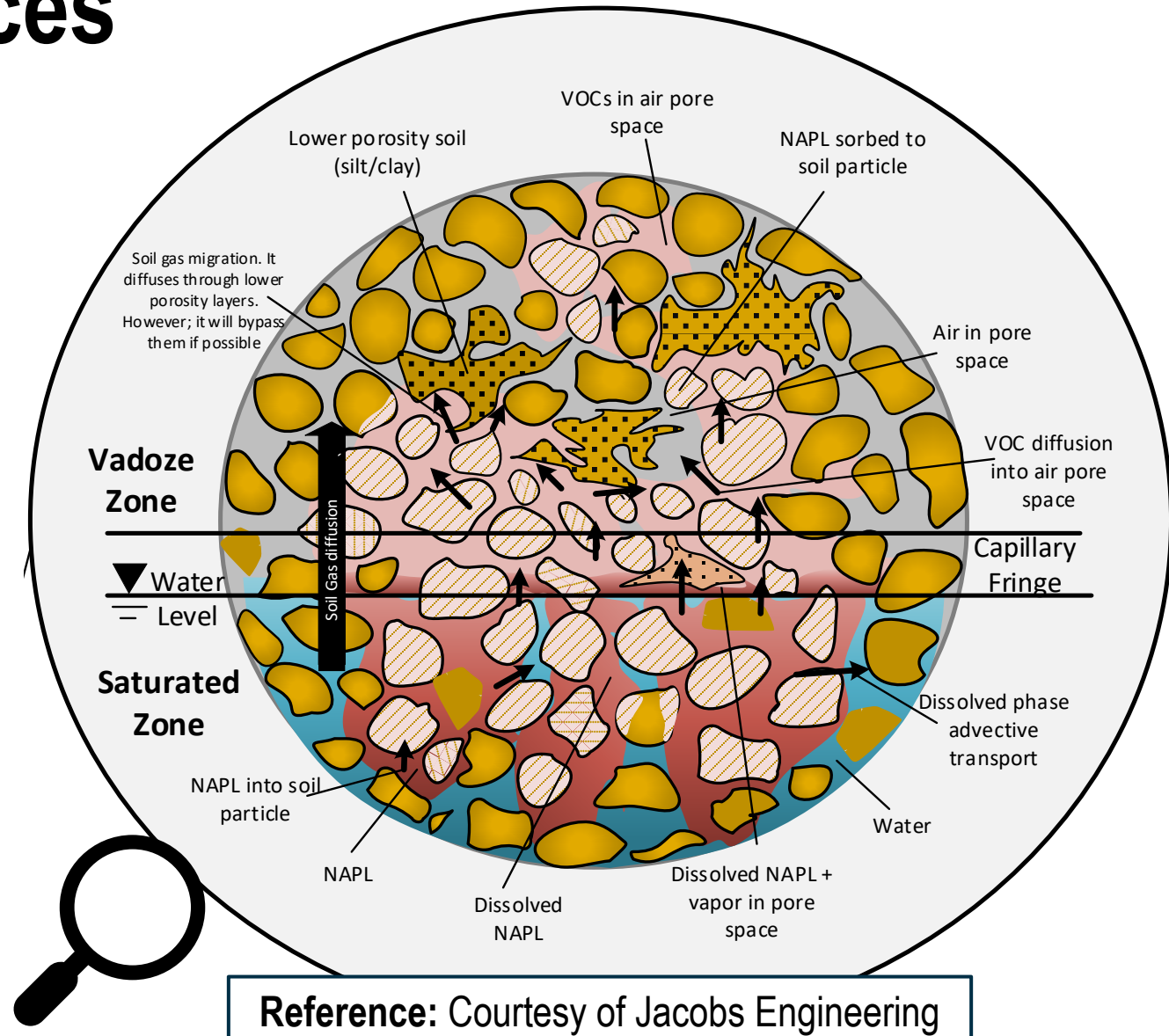
Reference: USEPA, 2015

Vapor Intrusion Conceptual Site Model



Vapor Intrusion Sources

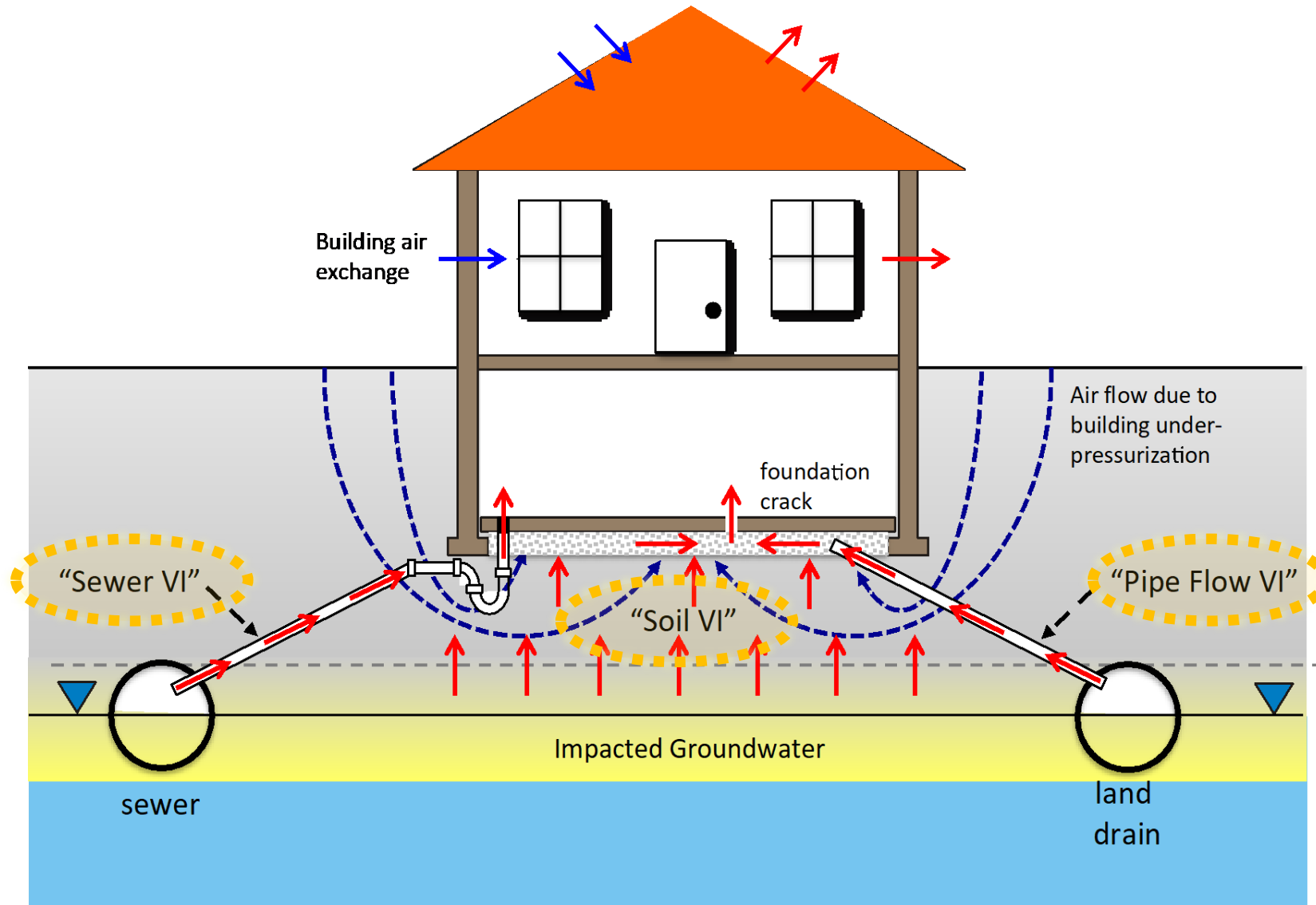
- Site characteristics to consider:
 - Site history
 - Concentration of COPCs
 - Geology and hydrogeology
 - Differences COPC properties
 - Vertical and lateral distance to source material



*COPC = chemicals of potential concern

Reference: Courtesy of Jacobs Engineering

Vapor Intrusion Pathways

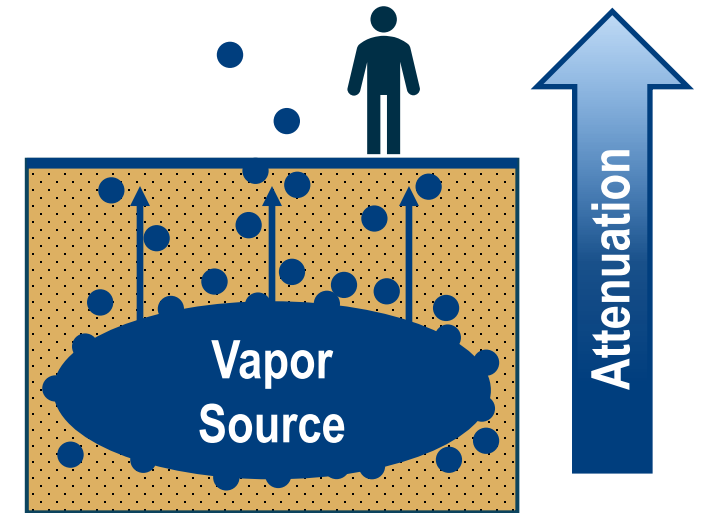


Reference: Adapted from Guo et al. (2015), *Environmental Science & Technology*

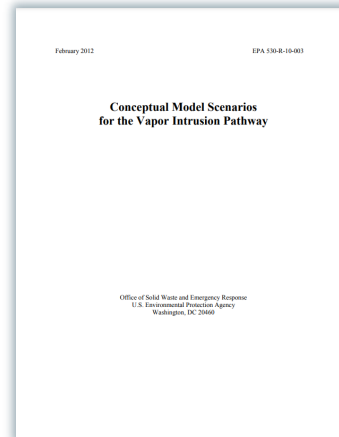
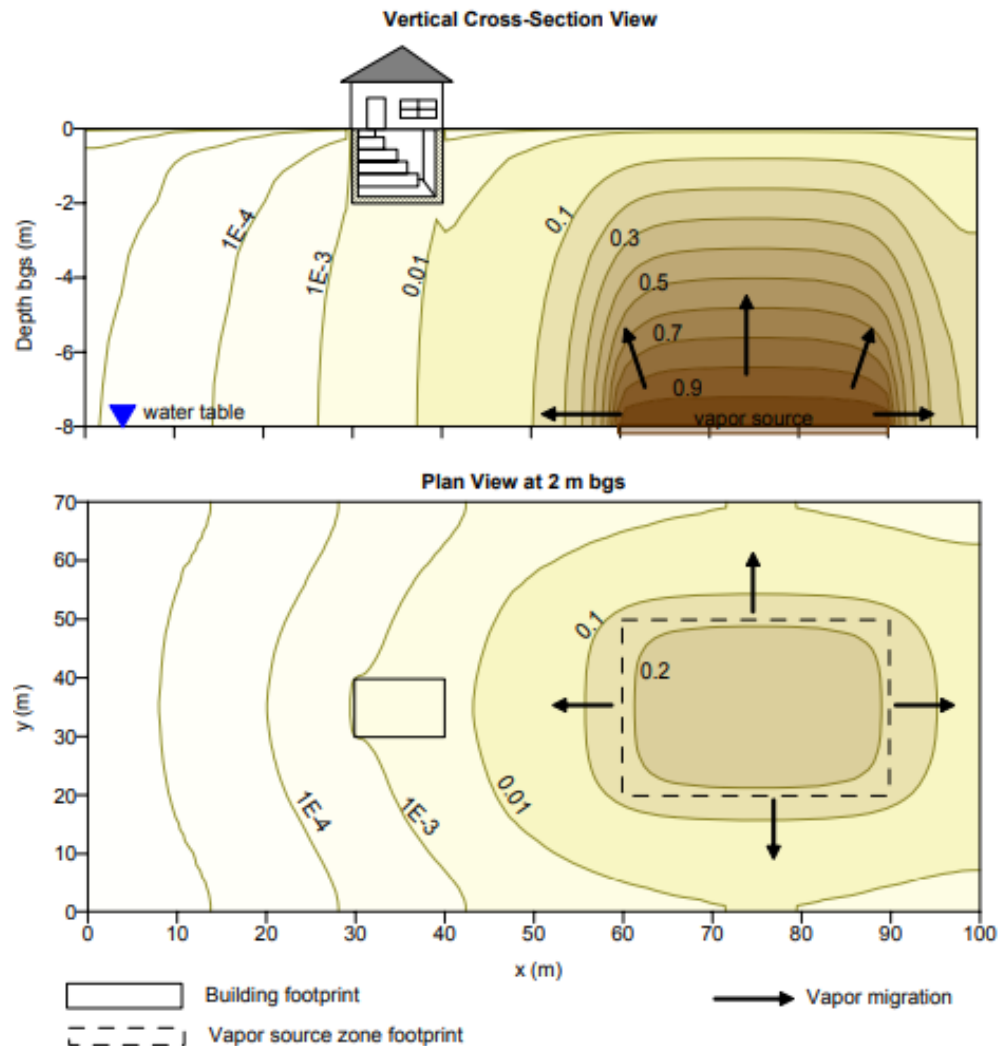
Vapor Intrusion Attenuation

The **vapor attenuation factor** (AF or α) “...defined as the ratio of the indoor air concentration arising from vapor intrusion ($[IA]$) to the subsurface soil vapor concentration ($[SV]$) at a point or depth of interest in the vapor migration pathway.” (USEPA, 2012)

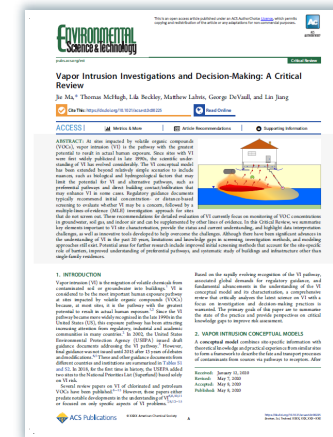
$$AF = \frac{[IA]}{[SV]} \quad \text{or} \quad [SV_{SL}] = \frac{[IA_{SL}]}{AF}$$



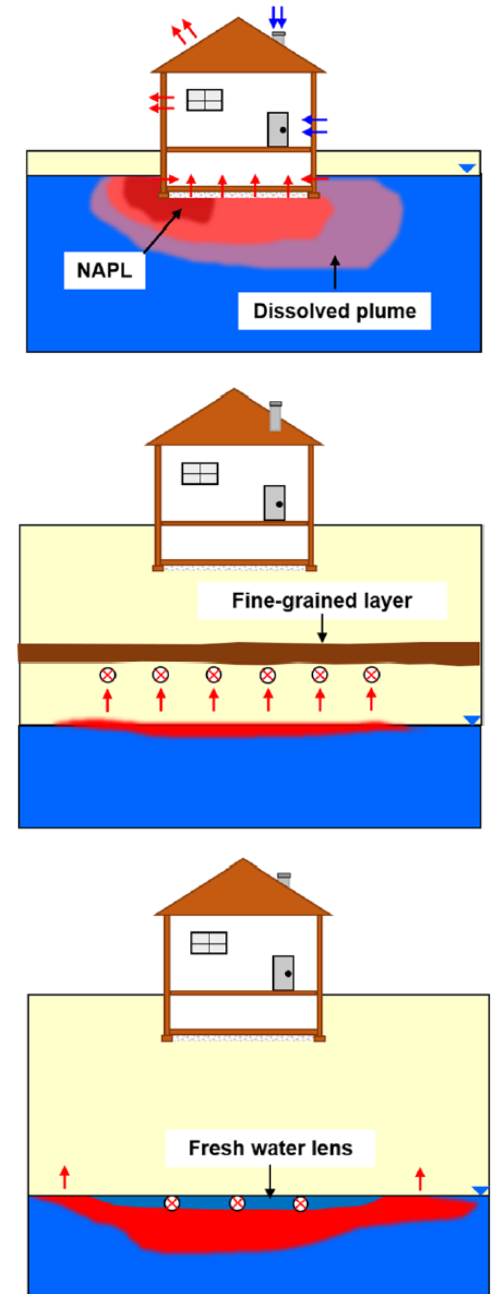
Groundwater to Indoor Air



Reference: USEPA, 2012



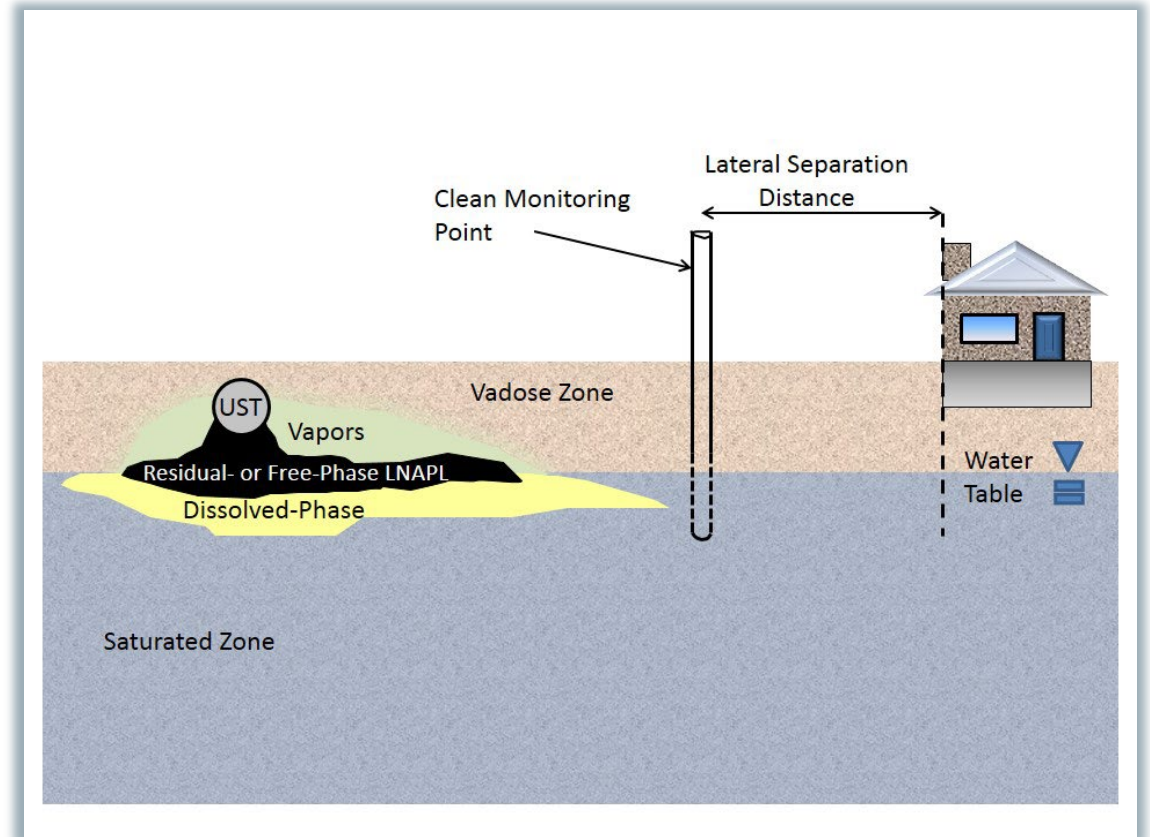
Reference: Ma et al., 2020,
Figure 1C, 2B, 2C



Reference: USEPA, 2012, Conceptual Model Scenarios of the Vapor Intrusion Pathway

Lateral Separation Distance

- The lateral separation zone for some PVI* scenarios is **30 feet** from vapor plume edge or a clean monitoring point to building foundation.
- What about chlorinated solvents and other recalcitrant compounds? Is **100 feet** sufficient?

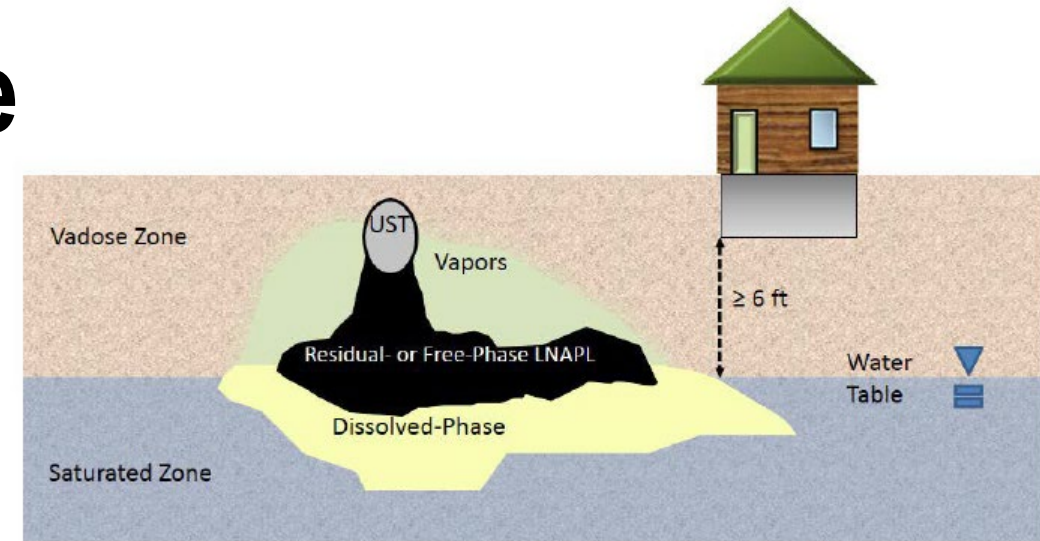


Reference: USEPA (2015), Technical Guide For Addressing Petroleum Vapor Intrusion at Leaking Underground Storage Tank Sites

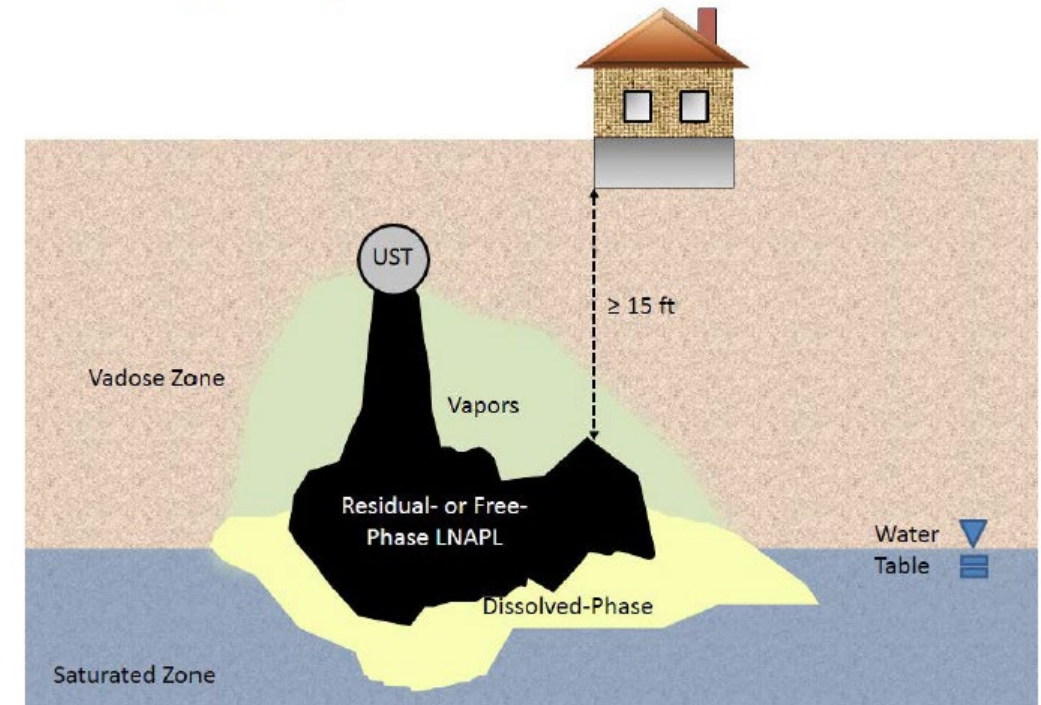
Vertical Separation Distance

- Vertical separation distance for PVI* of **6 to 15 feet** from subsurface impacts to building foundation based on source type.
- What about more recalcitrant compounds?

Reference: USEPA (2015), Technical Guide For Addressing Petroleum Vapor Intrusion at Leaking Underground Storage Tank Sites

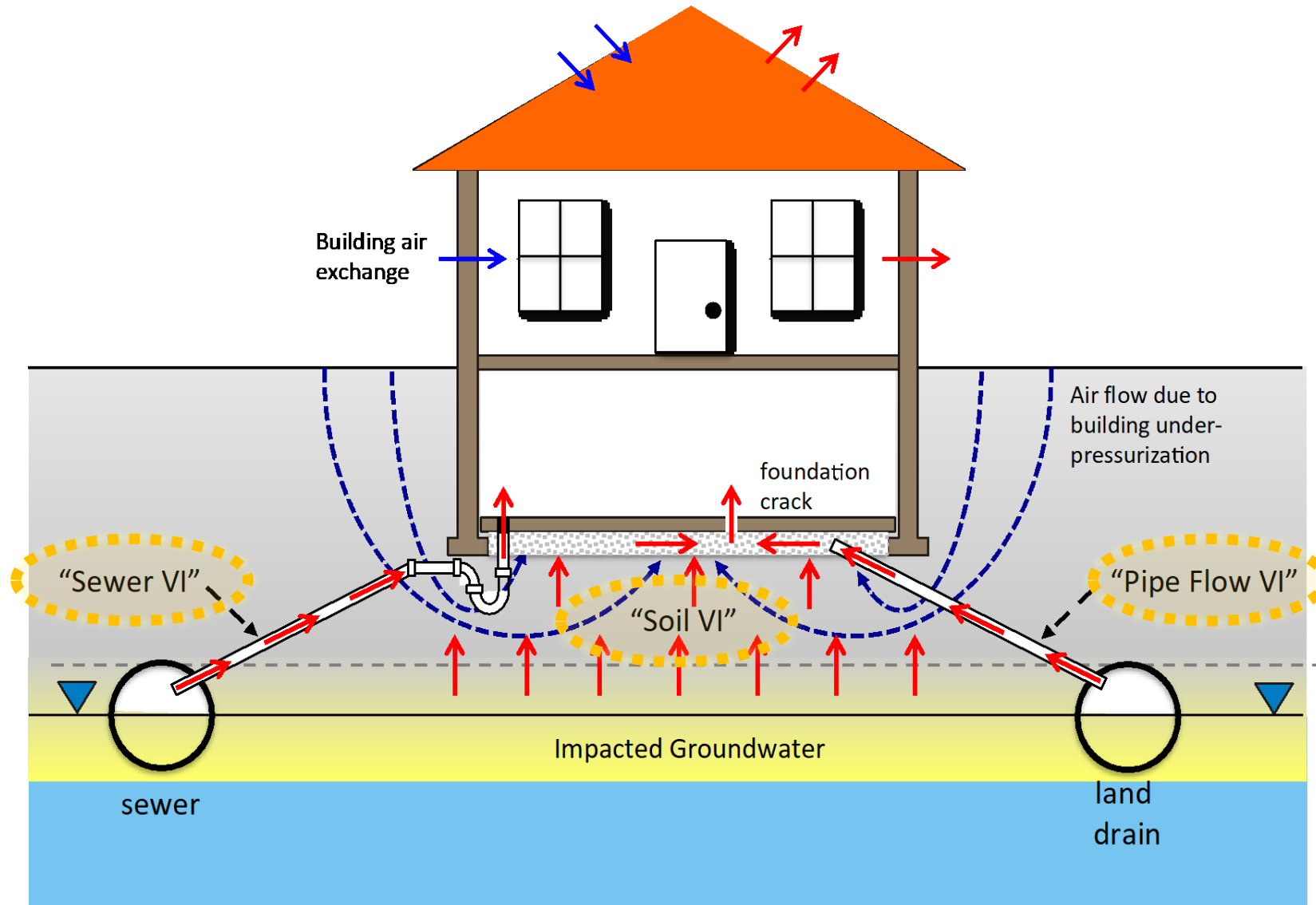


(a) Vertical separation distance for dissolved-phase source of PHCs.



(b) Vertical separation distance for LNAPL (residual or mobile phase) source of PHCs.

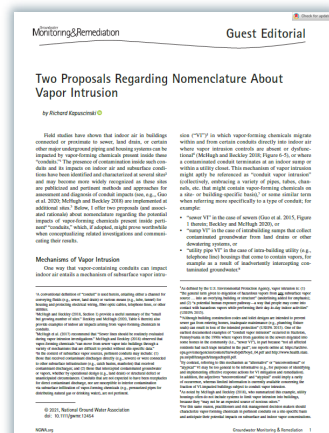
Vapor Intrusion Pathways



Reference: Adapted from Guo et al. (2015), *Environmental Science & Technology*

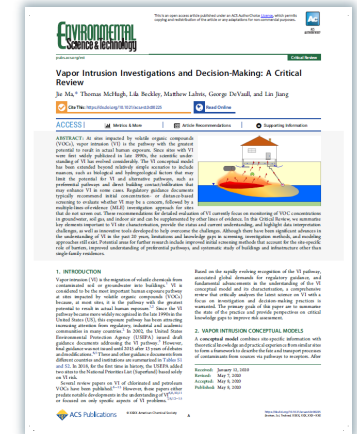
Conduit Pathways

- Preferential or **conduit pathways**, such as sanitary sewers, can serve as VI pathways and can be difficult to identify using conventional investigation tools.

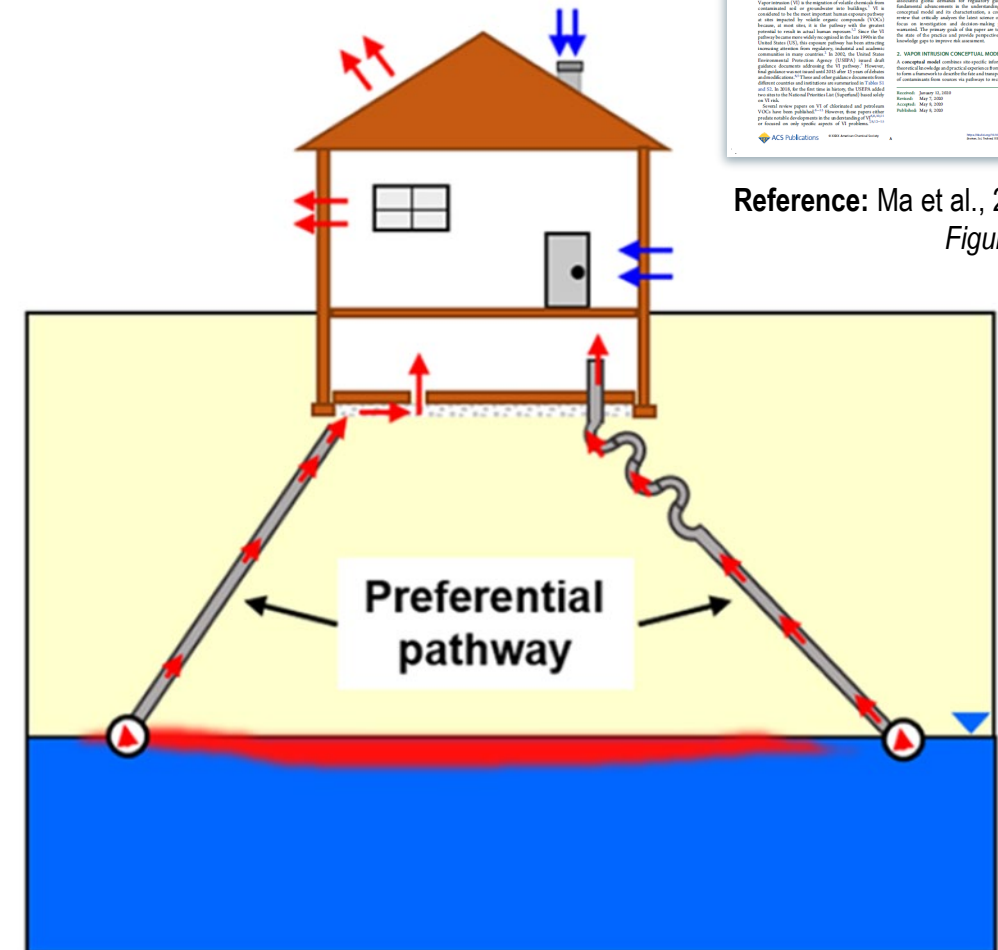


Conduit vapor intrusion “*refer[s] specifically to instances where vapor-forming chemicals migrate within and from conduits directly into indoor air.*”

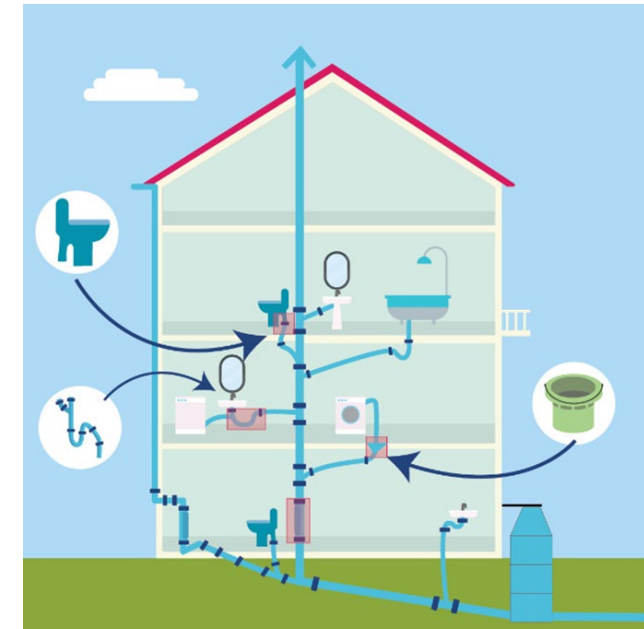
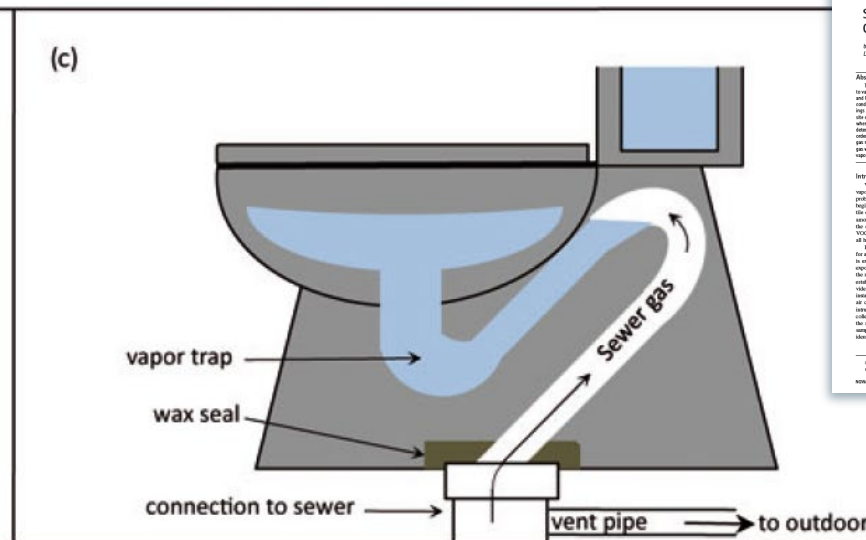
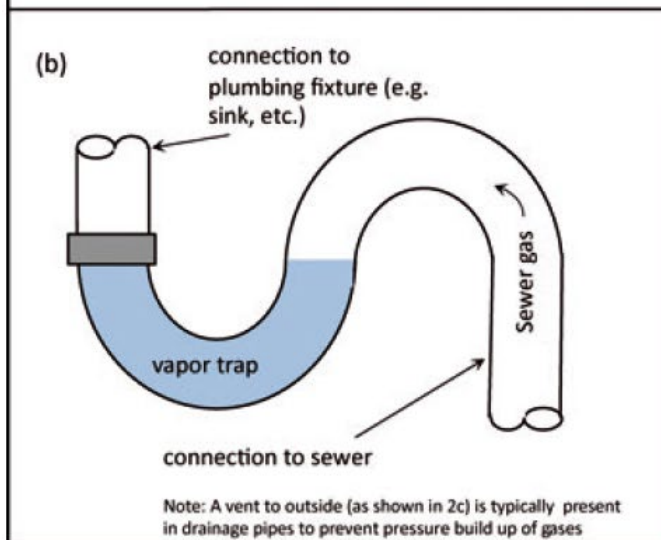
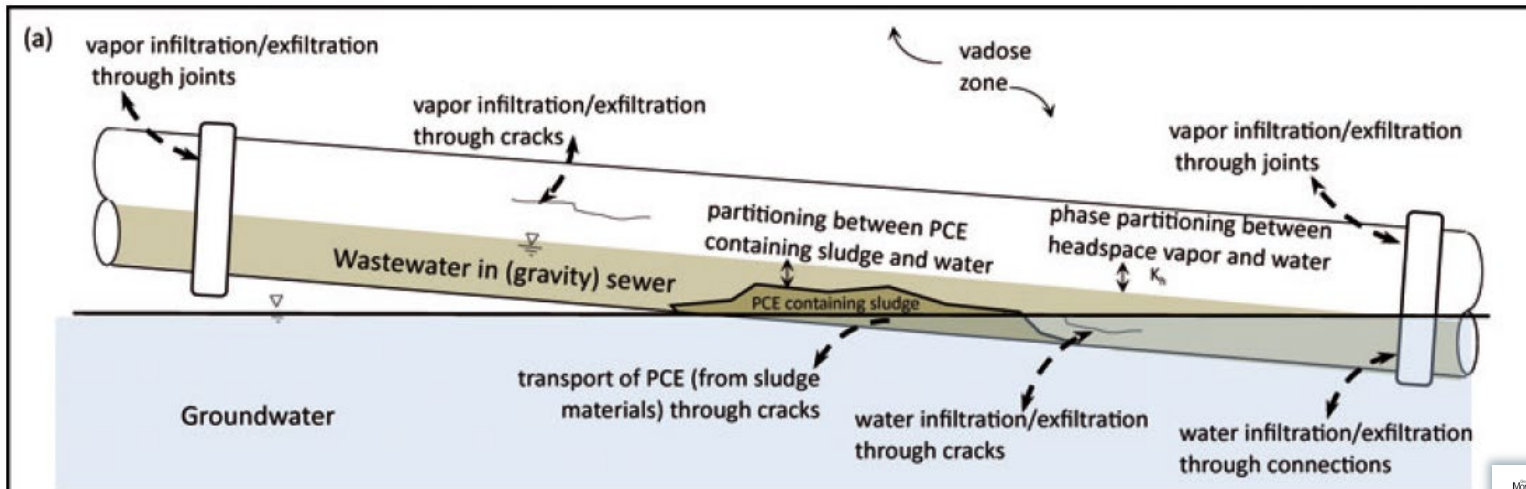
Reference: Kapuscinski, 2021



Reference: Ma et al., 2020, Figure 1B



Sewer Vapor Intrusion



Reference: Nielsen and Hvidberg, 2017

Monitoring & Remediation

Sewer Gas: An Indoor Air Source of PCE to Consider During Vapor Intrusion Investigations

by Kelly G. Pennell, Madeline K. Ranssen Scammell, Michael G. McClean, Jennifer Ames, Brittany Weldon, Leigh Friguglietti, Eric M. Sausberg, Rui Shen, Paul A. Indegalle, and Wendy J. Helger-Sorrows

Abstract
The United States Environmental Protection Agency (EPA) is faced by the task of improving risk assessments. One of the largest risks related to toxic substances is background concentrations of volatile organic compounds (VOCs) in indoor air, typically attributed to consumer products and building materials. Background concentrations can exist even in the absence of vapor intrusion and are an important consideration when conducting risk assessments. In addition, the development of accurate toxicologic models that depend on vapor entry into indoor air requires a conceptual model of how background concentrations of VOCs in indoor air are related to the outdoor environment. This paper presents a conceptual model, not routinely evaluated during vapor intrusion site assessments. The research described here identifies as an instance where vapor emanating directly from a consumer source may be the dominant source of indoor VOCs in the absence of a solvent/waterborne (PCE) source. In indoor air, concentrations of PCE in the background range from 2.1 to 100 µg/m³ and exceed background air concentrations by orders of magnitude resulting in human health risk classified as an "ambient hazard" condition. The results suggest that inhibition of solvent gas migration is PCE concentrations in indoor air that were nearly two orders of magnitude higher as compared to when inhibition of solvent gas migration is to be considered. The results suggest that the use of background air concentrations of PCE (and potentially other VOCs) are highlighted. Implications for vapor intrusion investigations are also discussed.

Introduction

Many neurons involve the regulation of extracellular volume by osmolarity-sensitive ion transporters. The osmolarity of brain tissue is maintained by the osmolyte balance, with sodium in the extracellular space and organic osmolytes in the intracellular space (for review, see Borsook and Borsook, 1995). The osmolarity of cerebrospinal fluid (CSF) is maintained by the osmolyte balance, with sodium in the CSF and organic osmolytes in the brain tissue (for review, see Borsook and Borsook, 1995). The osmolarity of the CSF is maintained by the osmolyte balance, with sodium in the CSF and organic osmolytes in the brain tissue (for review, see Borsook and Borsook, 1995). The osmolarity of the CSF is maintained by the osmolyte balance, with sodium in the CSF and organic osmolytes in the brain tissue (for review, see Borsook and Borsook, 1995).

References

Borsook D, Borsook L (1995) The osmolarity of cerebrospinal fluid (CSF) is maintained by the osmolyte balance, with sodium in the CSF and organic osmolytes in the brain tissue (for review, see Borsook and Borsook, 1995).

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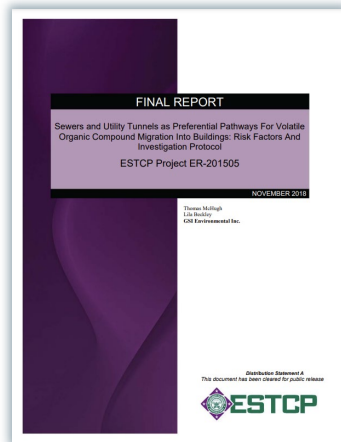
Construction Materials & Inspection 33, no. 3, Summer 2012 (New York: T&E, 2012).

Reference: Figure 2, Pennell et al., 2013, Sewer Gas: An Indoor Air Source of PCE to Consider During Vapor Intrusion Investigations.

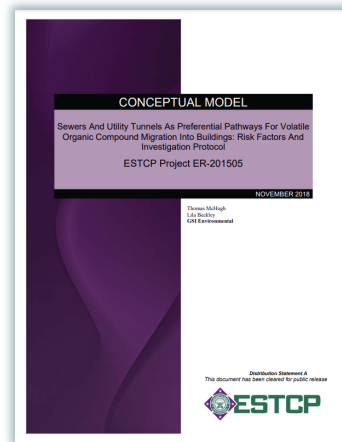
Sewer Vapor Intrusion

Results from ESTCP Project ER-201505:

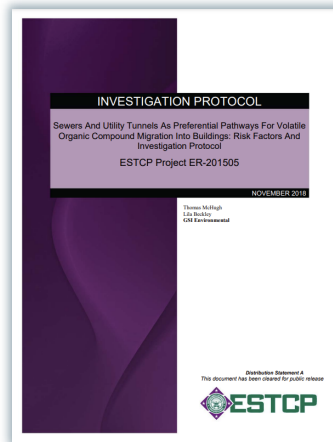
“Sewers and Utility Tunnels as Preferential Pathways for Volatile Organic Compound Migration Into Buildings: Risk Factors and Investigation Protocol”



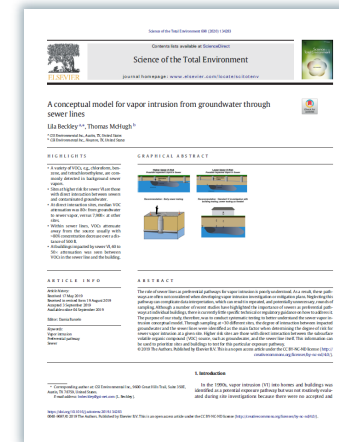
**Final Report ESTCP
Project ER-201505,
Beckley and McHugh, 2018**



**Conceptual Model
ESTCP Project ER-
201505, Beckley and
McHugh, 2018**



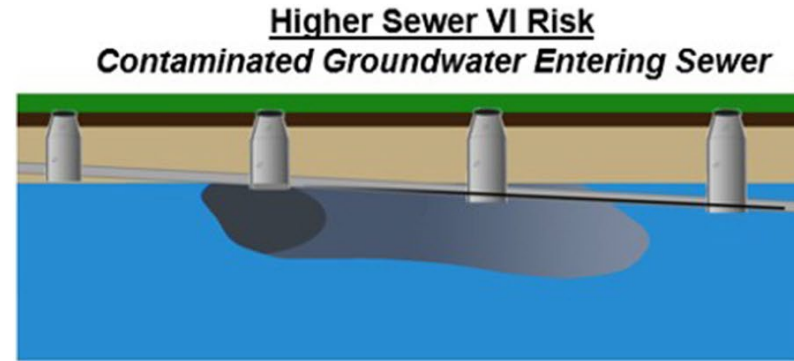
**Investigation Protocol
ESTCP Project ER-
201505, Beckley and
McHugh, 2018**



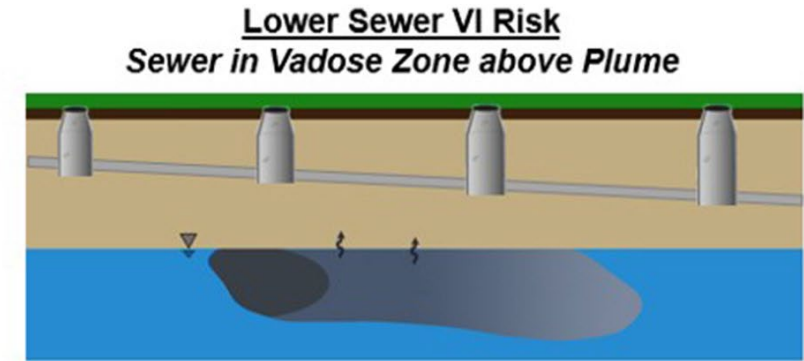
**A Conceptual Model for
VI from Groundwater
through Sewer Lines:
Beckley and McHugh 2020**

Sewer Vapor Intrusion

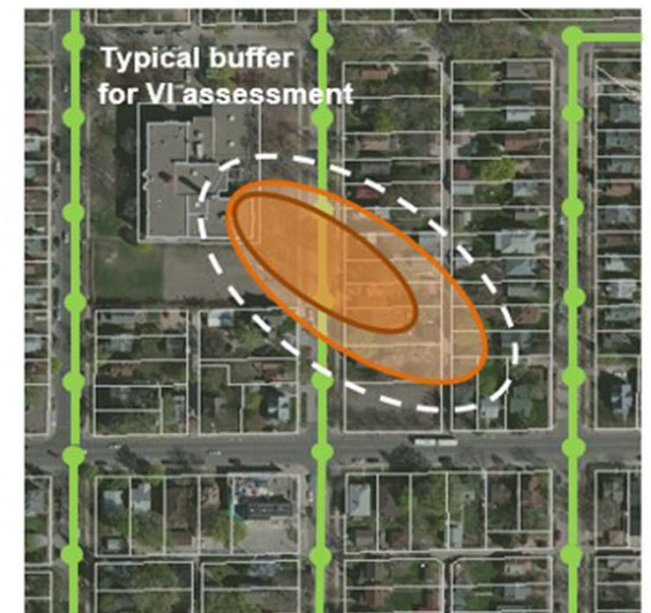
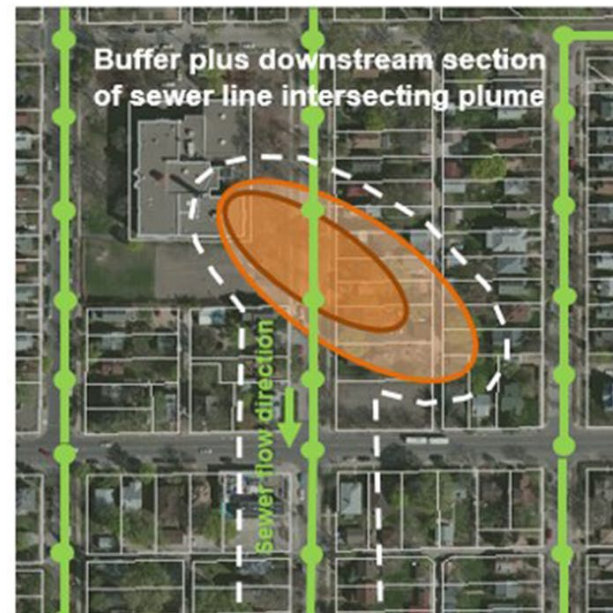
Higher and Lower VI Risk Scenarios



Area of Possible VI Concern



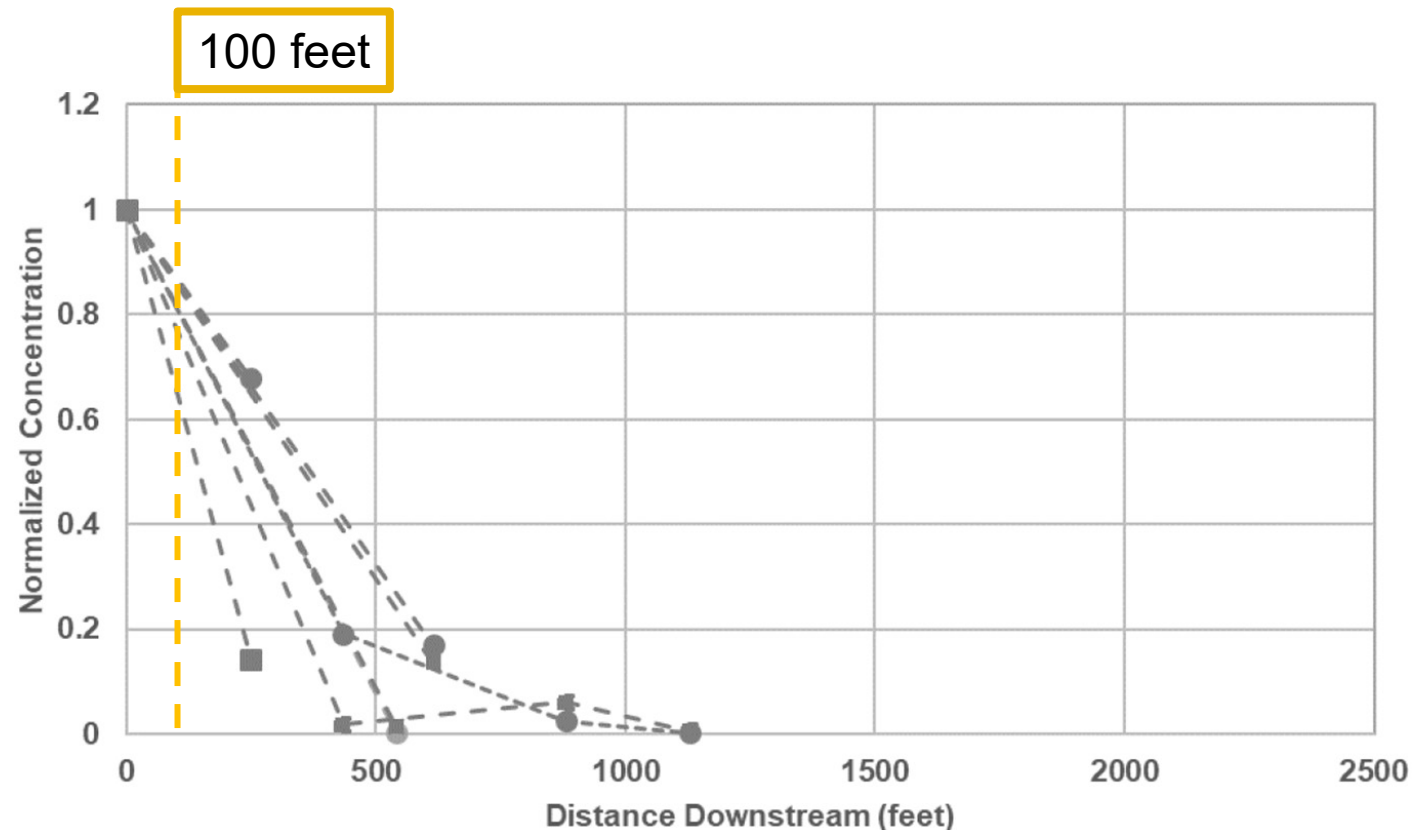
Area of Possible VI Concern



Sewer Vapor Intrusion

Downstream Attenuation – Sewer Line Above Water Table

(indirect interaction)

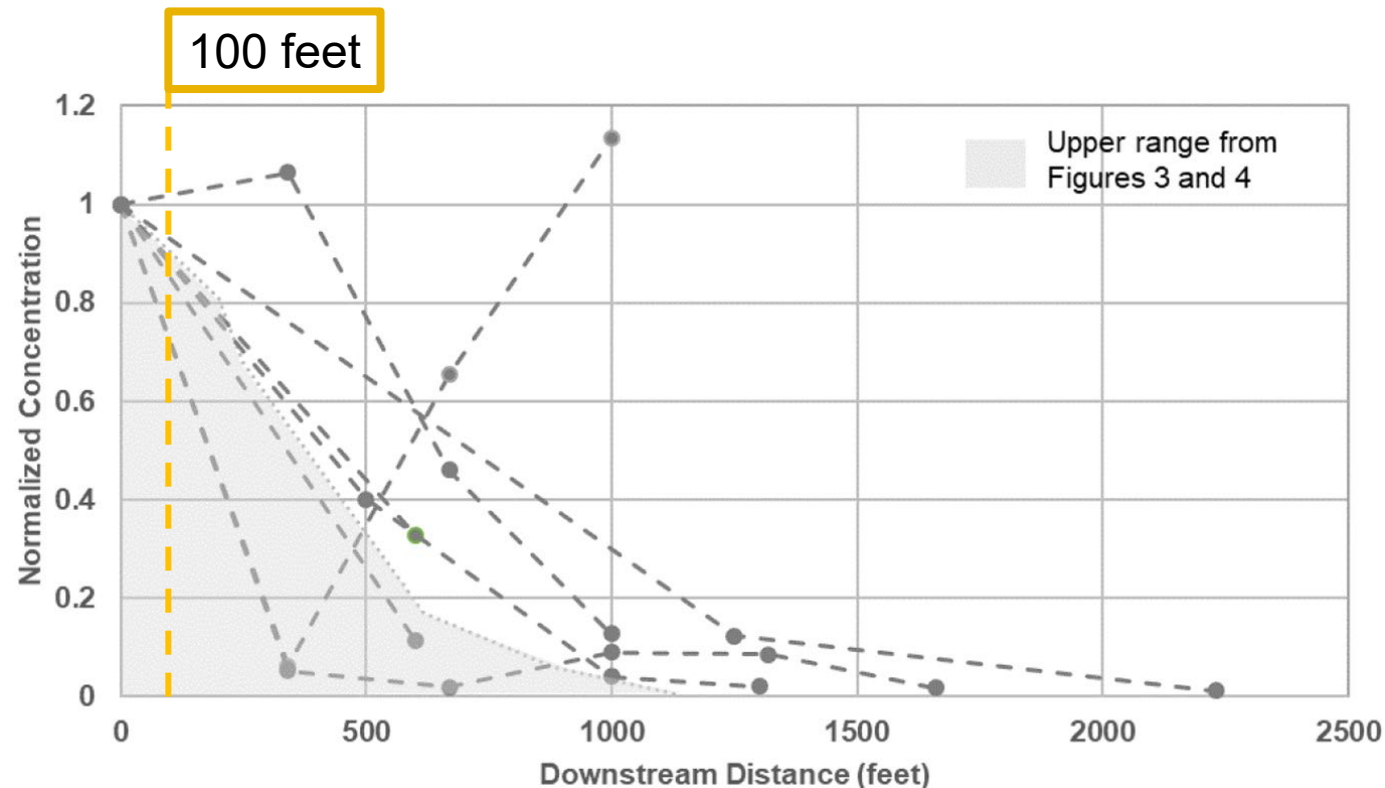


Reference: Figure 3, Beckley and McHugh, 2020, A conceptual model for vapor intrusion from groundwater through sewer lines, Science of the Total Environment, 698, 134283

Sewer Vapor Intrusion

Downstream Attenuation – Sewer Line Below Water Table

(direct interaction)



Sewer Vapor Intrusion

Groundwater-to-sewer attenuation factors

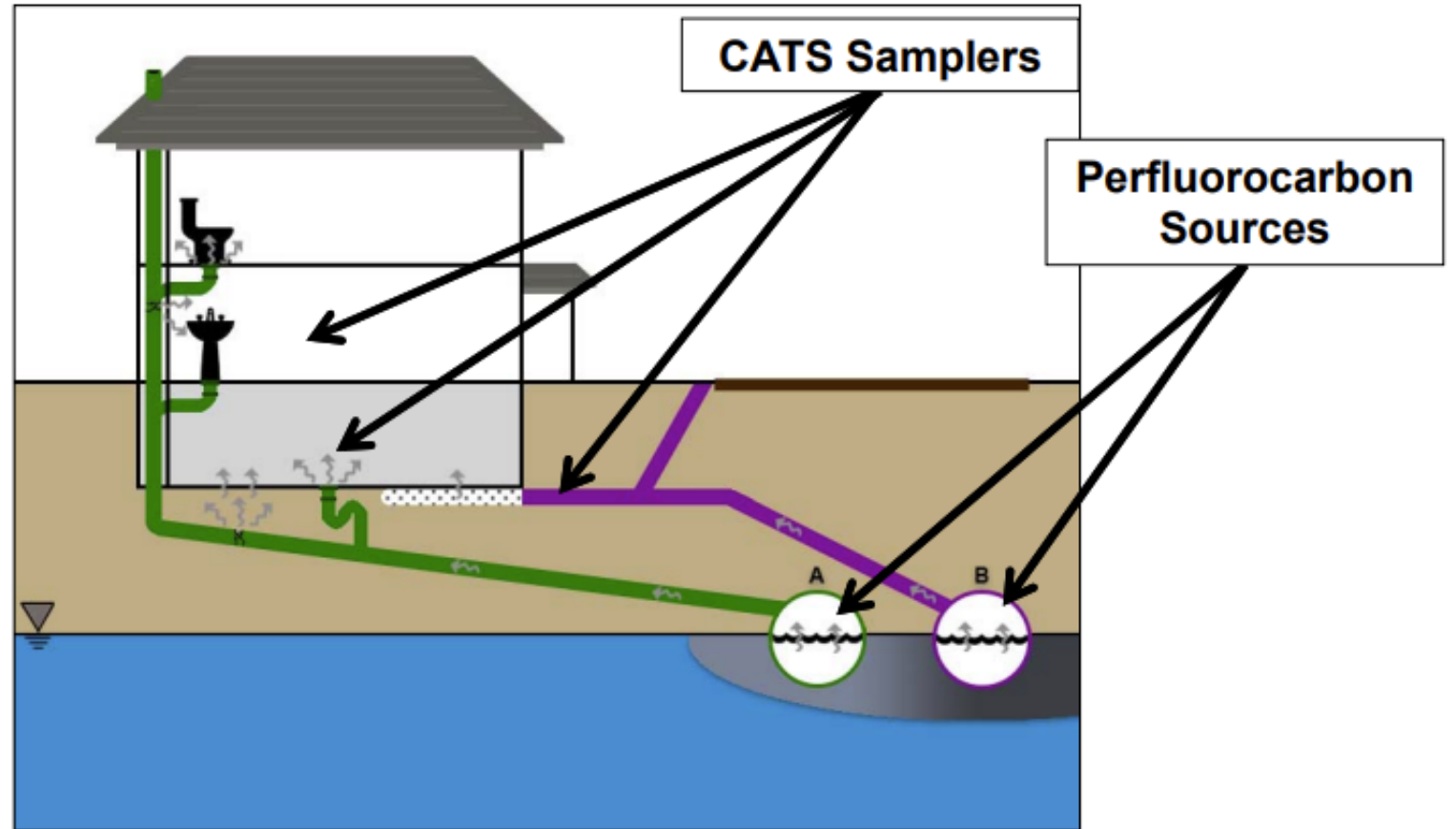


Site category	No. plumes	No. AFs	Attenuation factor	Attenuation
			Median (10th – 90th percentiles) [Note 1]	Median (10th – 90th percentiles) [Note 2]
A: direct interaction (sewer at or below water table)	6	59	1.3E–02 (6.7E–05–7.3E–02)	80× (15,000×–14×)
B: indirect interaction (sewer above water table)	28	137	1.3E–04 (1.9E–06–5.5E–03)	7900× (520,000×–180×)

Notes: 1) Attenuation factor calculated as sewer vapor concentration divided by equilibrium groundwater concentration. 2) Attenuation is the inverse of attenuation factor.

Sewer Vapor Intrusion

*Sewer-to-indoor air
attenuation factors*



Sewer Vapor Intrusion

Sewer-to-indoor air attenuation factors

Table 5

Sewer to building attenuation.

Sewer type	Building type	Range of attenuation [Note 1]
Buildings with known sewer preferential pathways (specific pathway in italics)		
<i>Land drain (upstream)</i>	<i>Residence (ASU VI research house)</i>	40–70×
<i>Sanitary sewer (upstream)</i>	<i>Residence (ASU VI research house)</i>	40–60×
Storm/sanitary sewer (upstream)	Residence (USEPA VI research duplex)	160→1000×
<i>Storm/sanitary sewer (downstream)</i>	<i>Residence (USEPA VI research duplex)</i>	50–100×
Buildings without known or suspected sewer pathways		
Sanitary sewer	Residence (Houston duplex #1)	150–790×
Sanitary sewer	Residence (Houston duplex #2)	470–590×
Sanitary sewer (upstream)	Residence (San Rafael house #1)	90–110×
Sanitary sewer (upstream)	Residence (San Rafael house #2)	20–50×
Sanitary sewer (downstream)	Residence (San Rafael house #1)	>1000×
Sanitary sewer (downstream)	Residence (San Rafael house #2)	>1000×
Sanitary sewer	Residence (NASCC area 1 apartment)	>1000×
Sanitary sewer	Office/storage building (Moffett bldg 107)	>1000×
Sanitary sewer	Office/lab building (San Diego)	>1000×
Sanitary sewer	Hospital (NASCC area 2)	>1000×
Sanitary sewer	Office building (NASCC area 3)	>1000×
Sanitary sewer	Shop building (NASCC area 3)	>1000×
Sanitary sewer	Office building (NASCC area 4)	>1000×
Sanitary sewer	Office building (Burlingame)	550→1000×
Sanitary sewer	Warehouse (Houston)	50–470×

Sewer Vapor Intrusion

Sewer-to-indoor air attenuation factors:

Sun Devil Manor, residential house,
Layton, UT

Sewer/Building Combination Tested:	<i>Land Drain Manhole to House</i>	<i>Sanitary Sewer Manhole to House</i>
Attenuation	20x – 40x	60x – 80x



Summary

- Consider all source types
- Consider conduit pathways before application of lateral and vertical separation distances
- VOCs may migrate >100 feet via conduit pathways
- Attenuation of >33x generally expected from sewer vapor to indoor air based on tracer studies

Questions and Discussion



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Extra Slides

Conduit Vapor Intrusion

