ESTCP

Project ER-201505

RISK FACTORS AND INVESTIGATION PROTOCOL FOR SEWER VAPOR INTRUSION

GSI ENVIRONMENTAL

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Battelle International Symposium on Bioremediation and Sustainable Environmental Technologies, Baltimore, MD
18 April 2019

VAPOR INTRUSION: *WHAT IS IT?*

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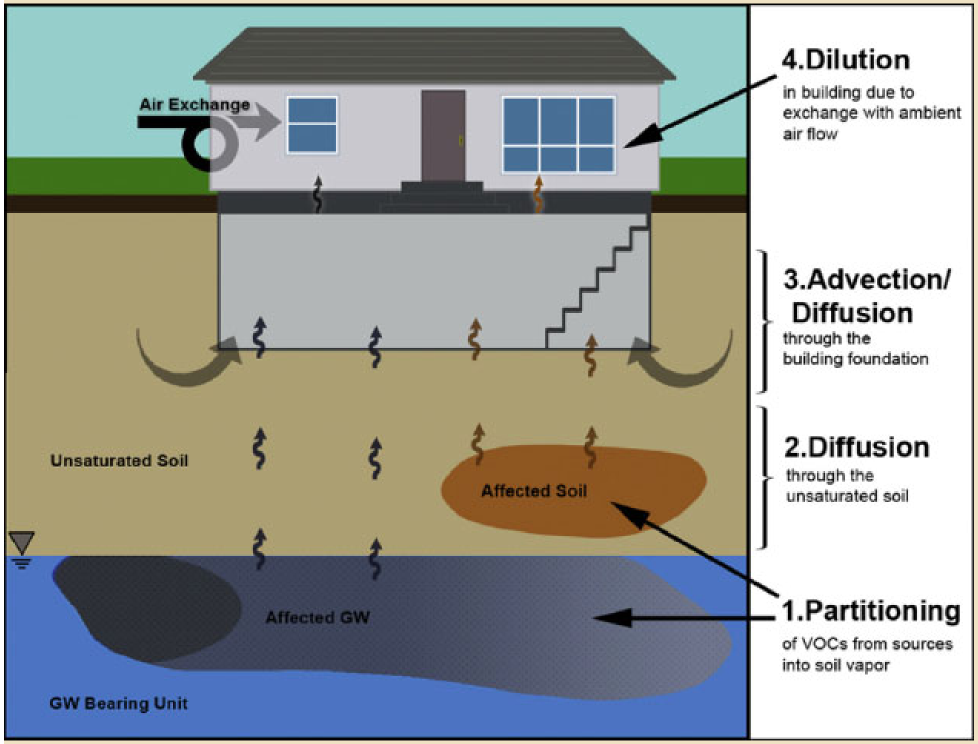
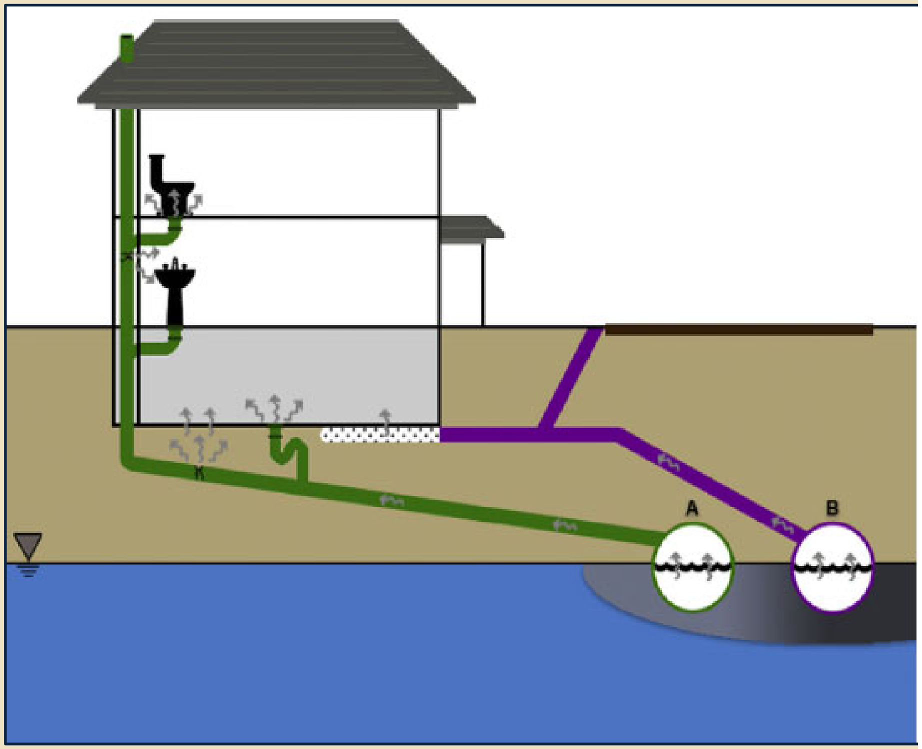
Standard Model



Through Sewer Lines



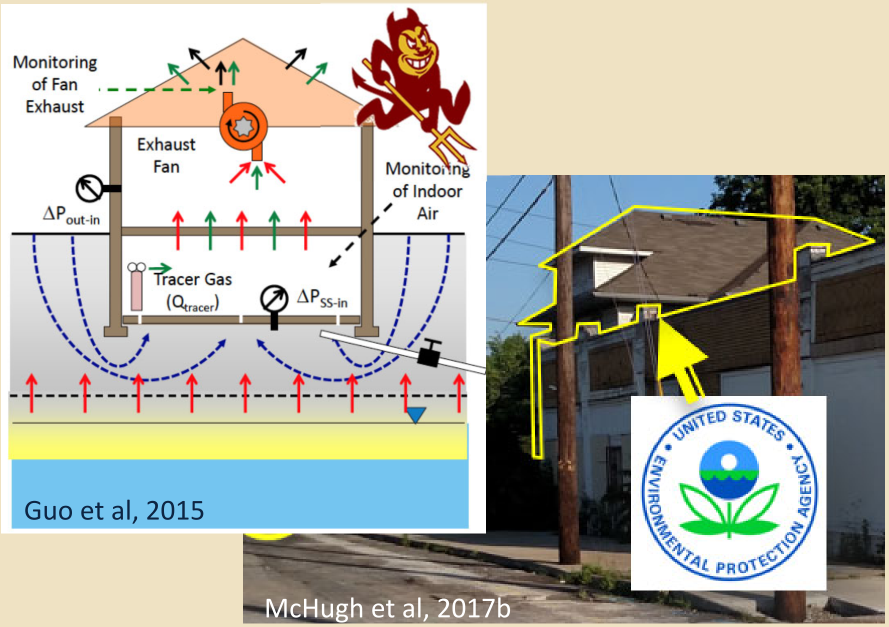
McHugh et al., 2017, Recent advances in vapor intrusion site investigations, Journal of Environmental Management

KEY POINT: **Vapor intrusion is the movement of volatile chemicals from below ground into buildings, affecting air quality.**

CONTENTS OF PRESENTATION

WHY SEWERS?

- Nationwide, guidance docs mention preferential pathways, but rarely give specifics
- Recent examples highlight the need to consider VI from sewers
- Examples include cases where pathway discovered only after extensive investigation



Guo et al, 2015
McHugh et al, 2017b

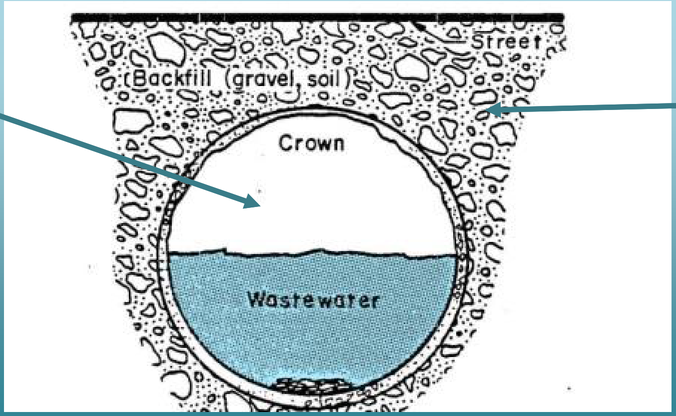
GOAL OF PRESENTATION: **To give a high-level summary of updated sewer VI conceptual model & recommended assessment approaches.**

TYPES OF SEWERS CONSIDERED

- GSI's ESTCP Research Project focused on sanitary, combined storm/sanitary, utility tunnels, etc.
  - Based on documented VI

- VOC migration through backfill
  - Significant lateral transport not expected except for specific situations, e.g., leaking natural gas lines

VOCs INSIDE Sewer: Potential concern.



VOCs in Backfill: Not so much.

CONTENTS OF PRESENTATION

1 Why Focus on Sewers?

Sewer Vapor Intrusion Conceptual Model

3 Investigation Strategies

4 Wrap-up

SEWER/UTILITY TUNNEL VI CONCEPTUAL MODEL

- **Higher Risk vs. Lower Risk Sites**
- **Migration of VOCs within Sewers**
- **Migration of VOCs into Buildings**
- **Other Considerations**

CONCEPTUAL MODEL

SEWER / UTILITY TUNNEL VI RISK

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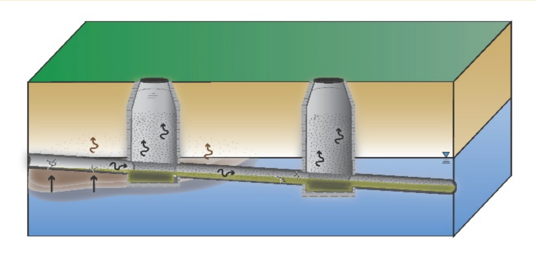
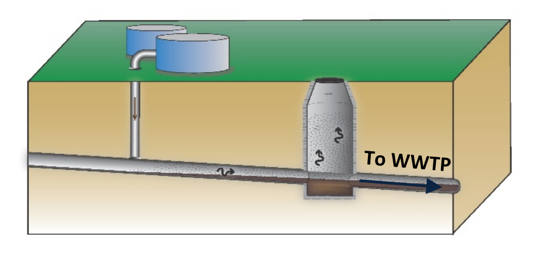
HIGHER RISK:
Liquid in Sewer

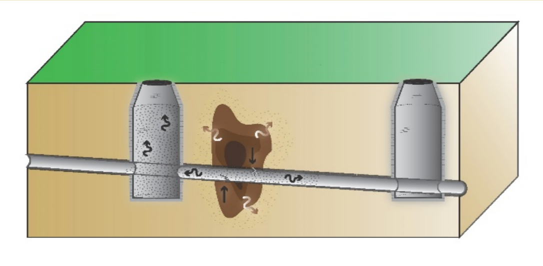
SEWER INTERSECTS CONTAMINATED GW



DISCHARGE INTO SEWER

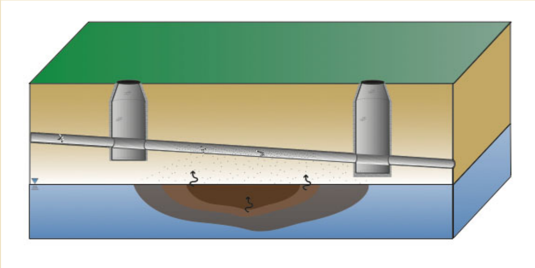


SEWER INTERSECTS NAPL



LOWER RISK:
Vapor in Sewer

SEWER IN VADOSE ZONE ABOVE CONTAMINATED GW



SIGNIFICANCE:

Higher risk sites are more likely to have VI impacts that are not detected by a conventional VI investigation.

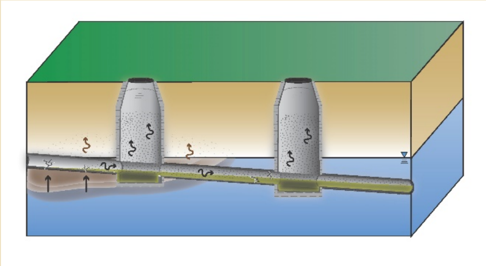
SEWER / UTILITY TUNNEL VI RISK

GW to Sewer Attenuation:

How much do VOC concentrations change?

	Range of Attenuation	Median (10% - 90%)
1) SEWER IN GW	**130 X** (15 X – 12,000 X)	
2) SEWER IN VADOSE	**7,300 X** (170 X – 490,000 X)	

1) SEWER IN GW

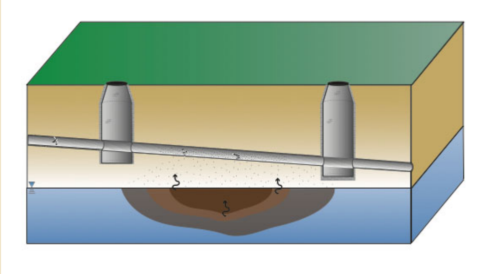


130 X

(15 X – 12,000 X)

Dataset: 6 Plumes, 65 AFs

2) SEWER IN VADOSE



7,300 X

(170 X – 490,000 X)

Dataset: 28 Plumes, 140 AFs

Attenuation = GW Conc. X H' / Sewer Vapor Conc.

SEWER/UTILITY TUNNEL VI CONCEPTUAL MODEL

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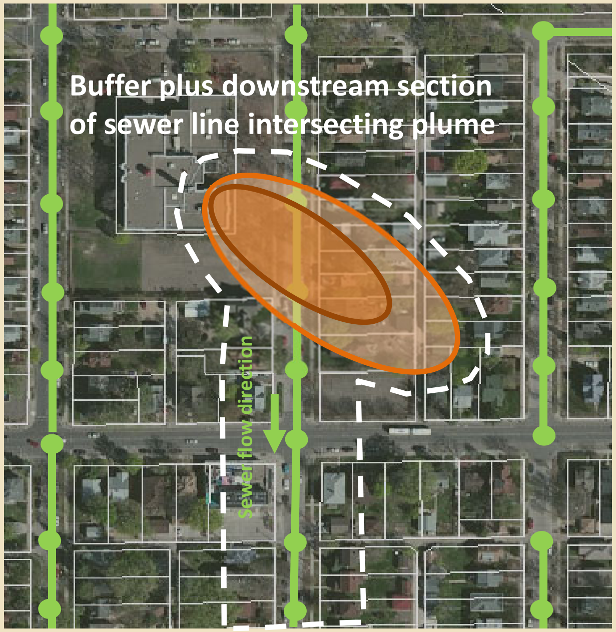
- Higher Risk vs. Lower Risk Sites
- ➡ Migration of VOCs within Sewers
- Migration of VOCs into Buildings
- Other Considerations

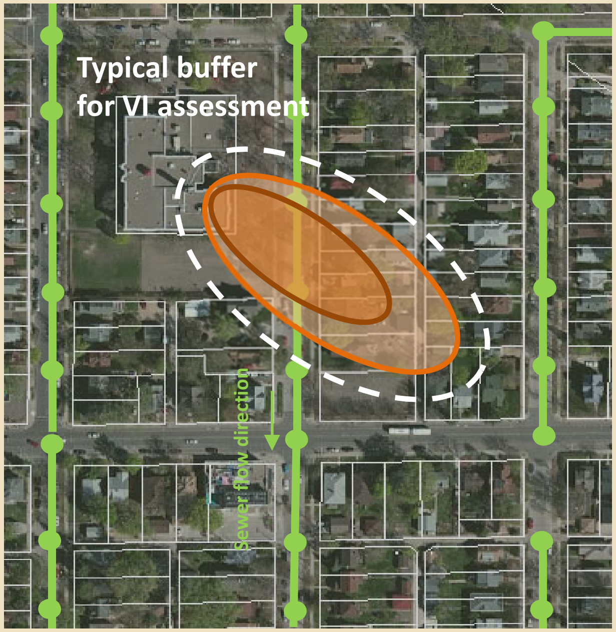
CONCEPTUAL MODEL

VOC MIGRATION IN SEWERS

Higher Risk:
VOCs in Liquids



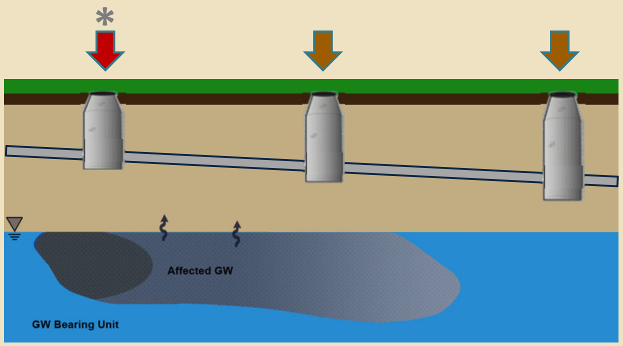
Lower Risk:
VOCs in Vapors

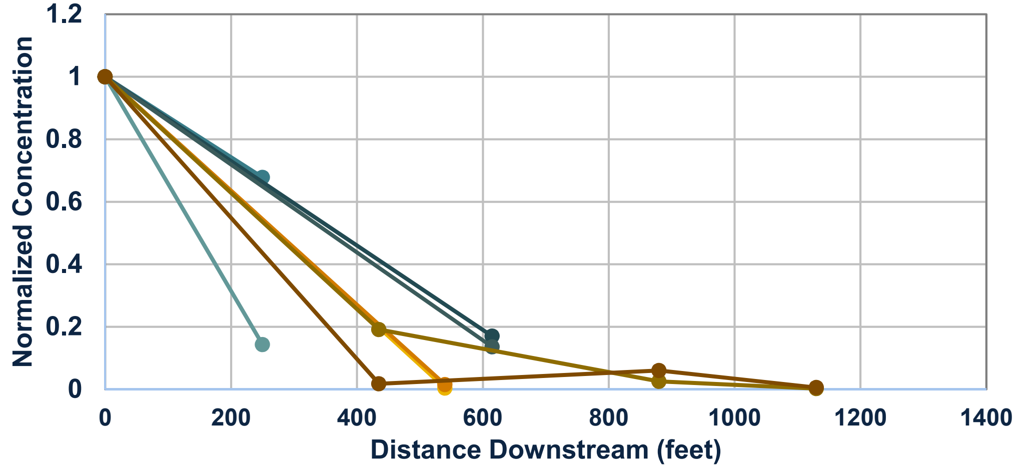


KEY POINT: **At higher risk sites, preferential pathway impacts may occur outside of the plume footprint "inclusion zone."**

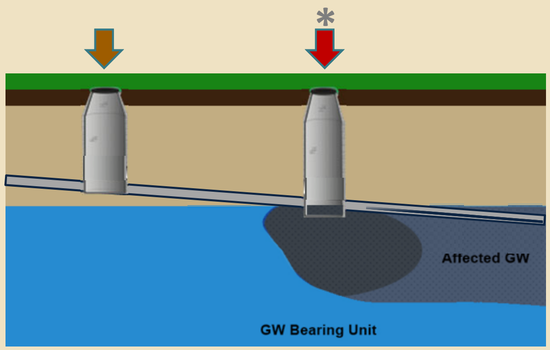
VOC VAPOR ATTENUATION IN SEWERS

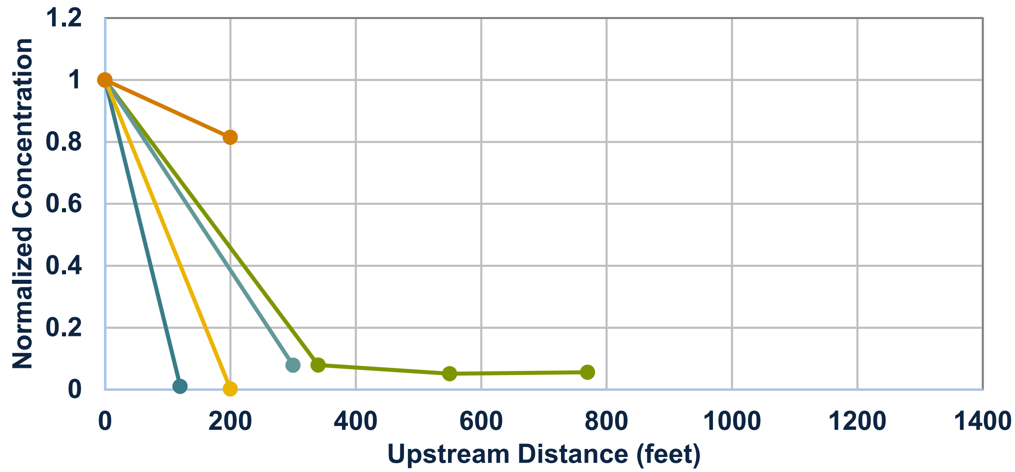
1) Vadose Zone Sewer





2) Upstream of Liquid Source





RULE OF THUMB: **80% attenuation over 500 ft from vapor source.**

SEWER/UTILITY TUNNEL VI CONCEPTUAL MODEL

- Higher Risk vs. Lower Risk Sites
- Migration of VOCs within Sewers
- Migration of VOCs into Buildings
- Other Considerations

CONCEPTUAL MODEL

HOW DO VOCS MOVE INTO BUILDINGS?

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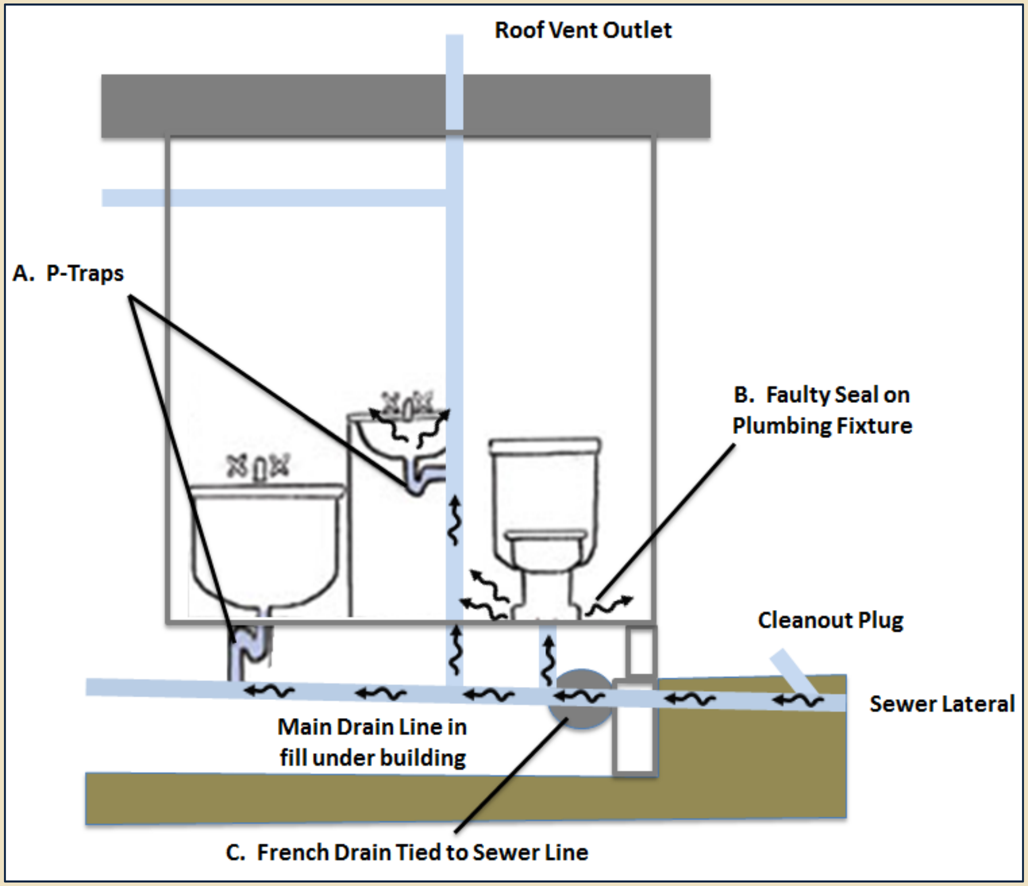
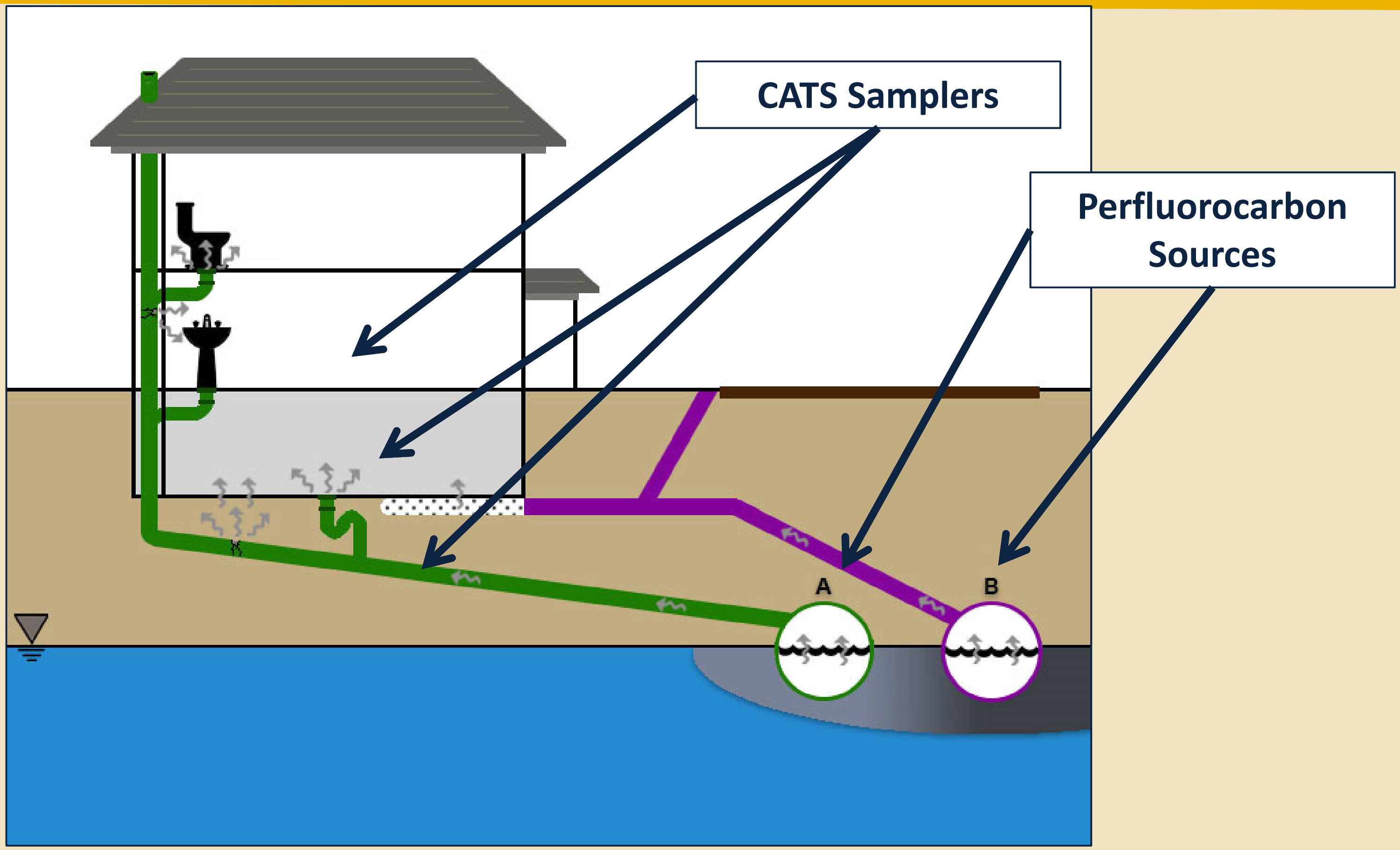
DOCUMENTED EXAMPLES

- Discharge below foundation
- Direct migration from utility tunnel
- Dry p-trap
- Faulty plumbing seal



KEY POINT: **Building-specific entry mechanisms are difficult to predict.**

SEWER TO BUILDING ATTENUATION



KEY QUESTIONS:

Gas flow from sewer line into building?
Attenuation factor?

VOC MIGRATION INTO BUILDINGS

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Building Attenuation:

Sewer to Indoor Air Attenuation?

Buildings with Known Issues	30x – 50x, or greater
Buildings with No Known Issues	2 of 12: 20x – 50x, or greater 10 of 12: 100x, or greater

KEY POINT: **Most buildings selected at random showed 100x or greater attenuation from the sewer to indoor air.**

SEWER/UTILITY TUNNEL VI CONCEPTUAL MODEL

- Higher Risk vs. Lower Risk Sites
- Migration of VOCs within Sewers
- Migration of VOCs into Buildings
- Other Considerations
  - Background Concentrations
  - Temporal Variability

CONCEPTUAL MODEL

BACKGROUND IN SEWER VAPOR

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VOC concentrations in sewer manholes not known to be over groundwater plumes?

	Detection Frequency (count)		Concentration in ug/m³ Median / 90th % / Max
Chloroform	82%	(249)	26 / 360 / 4,000
Carbon Disulfide	99%	(101)	20 / 180 / 940
Benzene	79%	(98)	1.1 / 4.3 / 89
Ethyl Benz.	74%	(99)	1.4 / 8.9 / 190
Toluene	98%	(99)	20 / 280 / 3,300
PCE	90%	(31)	3.2 / 68 / 550
TCE	70%	(30)	2.6 / 16 / 85
Cis-1,2-DCE	55%	(31)	0.7 / 7.5 / 20

SEWER/UTILITY TUNNEL VI CONCEPTUAL MODEL

- Higher Risk vs. Lower Risk Sites
- Migration of VOCs within Sewers
- Migration of VOCs into Buildings
- Other Considerations
  - Background Concentrations
  - Temporal Variability

CONCEPTUAL MODEL

TEMPORAL VARIABILITY IN SEWER VAPOR

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How Much do VOC Concentrations Change Over Time?

	Sewer Type	Median Range	Median CV
Short Term *(1-3 days)*	All	3.5 X	0.6
Longer Term: *(12-18 months)*	Sanitary (Vadose Zone)	30 X	2.3
	Sanitary (Water Table)*	34 X	3.7
	Land Drain (Water Table)*	11 X	1.1

KEY POINT: **Larger variation in VOC concentration occurs over time scale of months.**

CONTENTS OF PRESENTATION

1 **Why Focus on Sewers?**

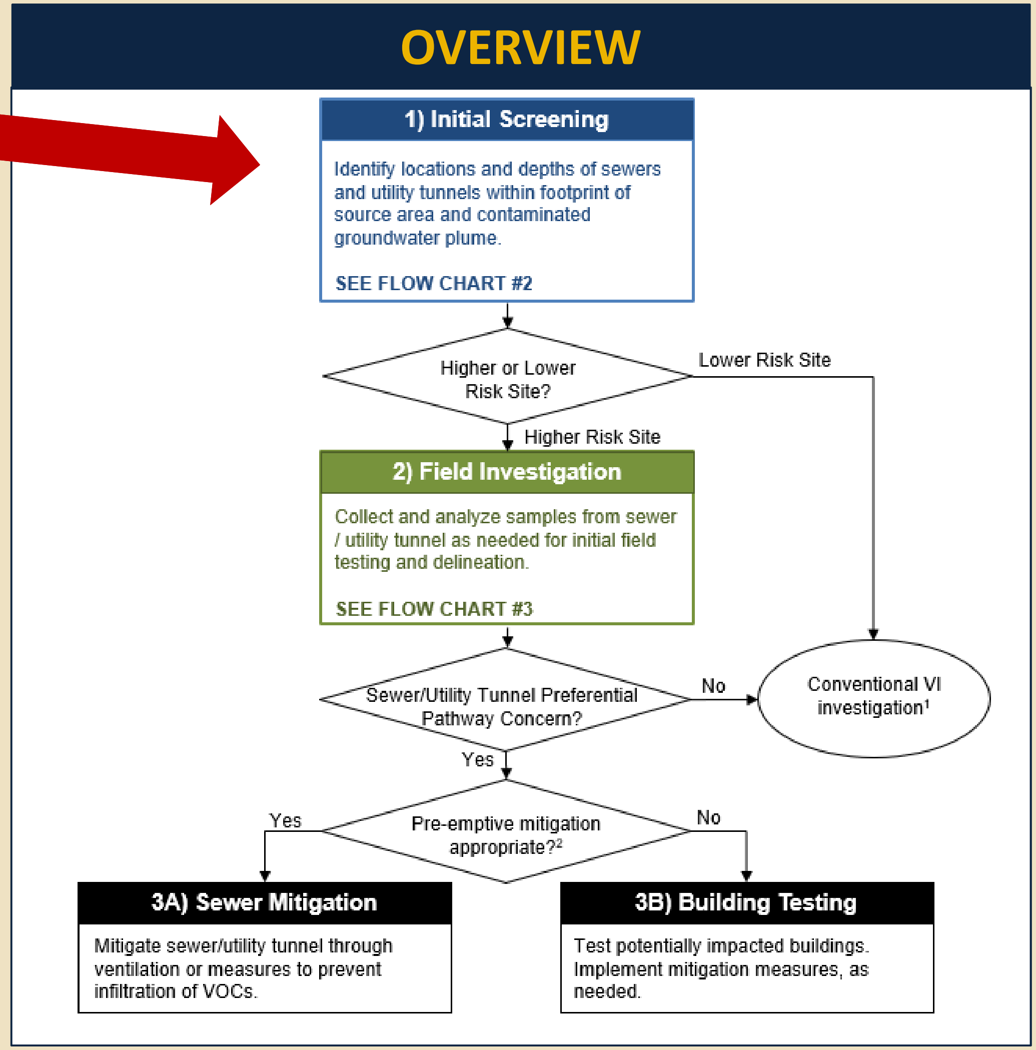
2 **Sewer Vapor Intrusion Conceptual Model**

Investigation Strategies

4 **Wrap-up**

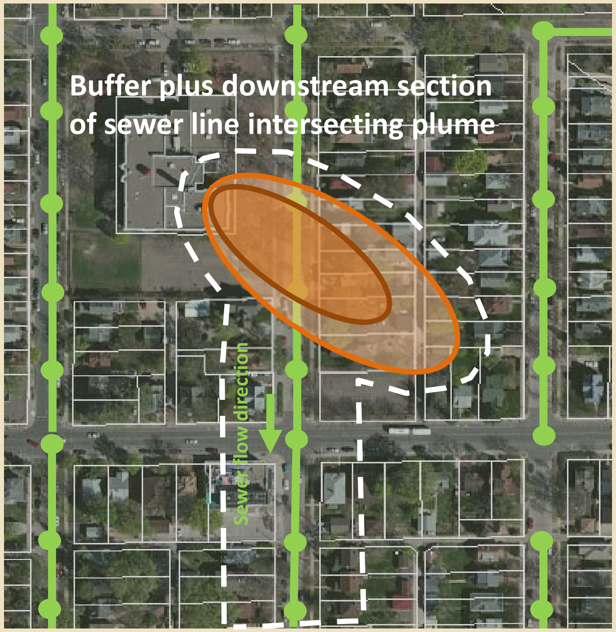
SEWER/UTILITY TUNNEL INVESTIGATION PROTOCOL

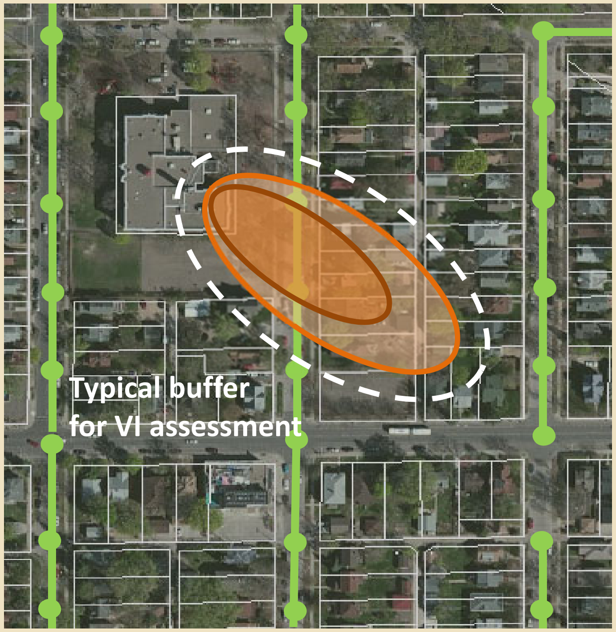
- **Initial (Desktop) Screening**
- **Initial Field Testing**
- **Delineation within Sewers**



VOC MIGRATION IN SEWERS

Higher Risk: VOCs in Liquids	Lower Risk: VOCs in Vapors





KEY POINT: At higher risk sites, preferential pathway impacts may occur outside of the plume footprint "inclusion zone". Different testing approach for higher vs. lower risk sites.

INITIAL SCREENING: *IMPACT*

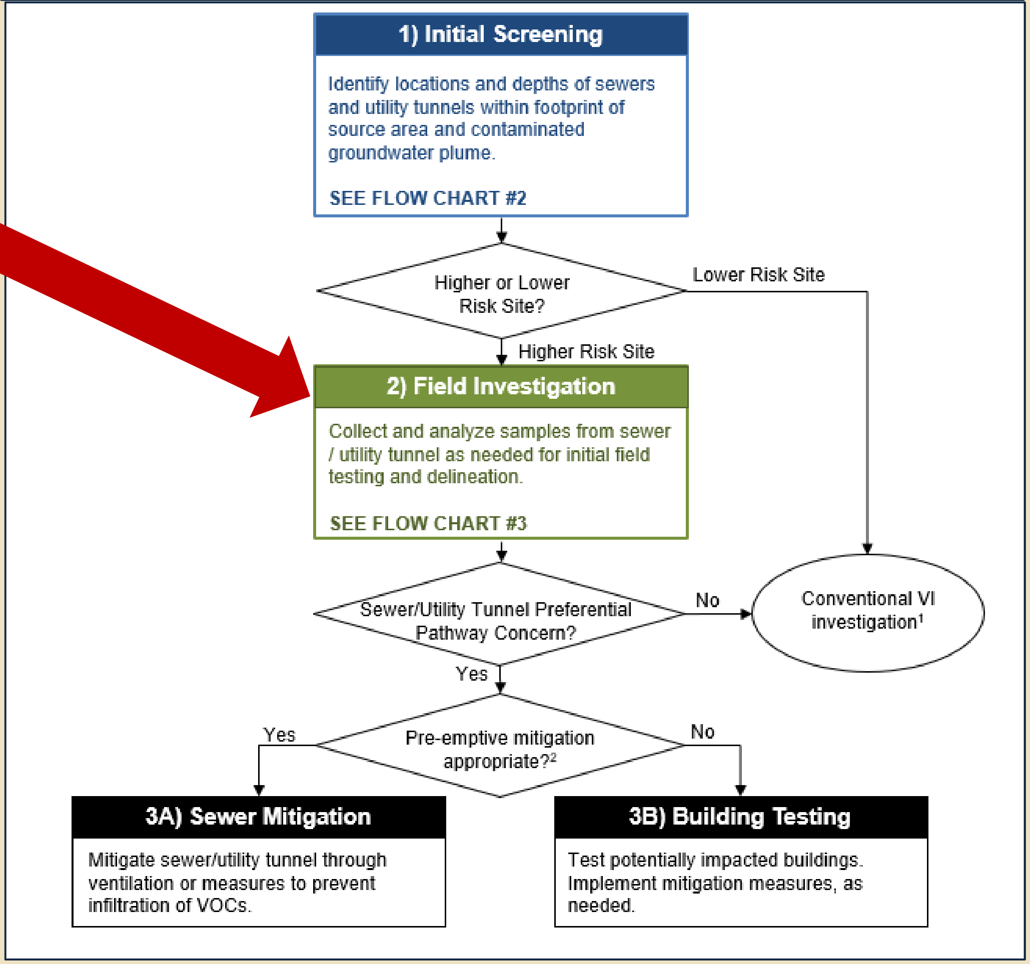
1) DESKTOP SCREENING
Interaction between GW plume and sewer/utility tunnel

HIGHER RISK: Possible Liquid in Sewer	**LOWER RISK:** Possible Vapor in Sewer
2) Initial sewer testing 3) Sewer delineation, if needed 4) Building testing/ mitigation	2) Standard VI investigation with building testing; mitigate if needed 3) Test sewer/utility tunnels as needed based on standard VI results

SEWER/UTILITY TUNNEL INVESTIGATION PROTOCOL

- Initial (Desktop) Screening
- Initial Field Testing
- Delineation within Sewers

OVERVIEW



SEWER SAMPLES: *VAPOR VS. LIQUID*

What to Sample?

Dataset:

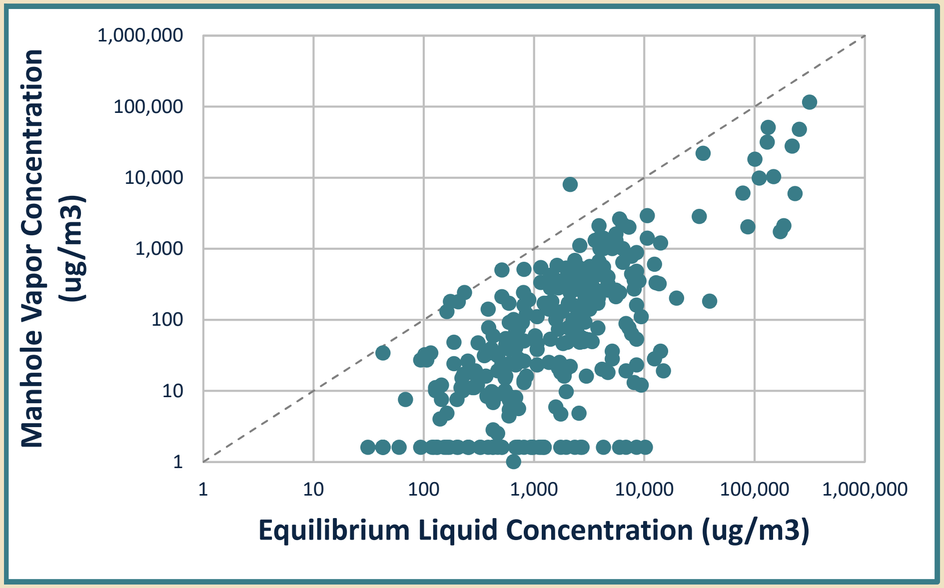
- **Paired sewer liquid-sewer vapor samples - 14 pairs (ER-201505), 263 pairs (ER-201501), 24 pairs (suppl. sites)**
- **Sewer lines known/suspected to have infiltrating GW**

Results:

- **Site COCs detected at high frequency in both liquid (95%) and vapor (83%)**
- **Liquid concentration not good predictor of vapor concentration**

RECOMMENDATION: **Collect vapor samples to characterize VOC concentrations within sewer lines.**

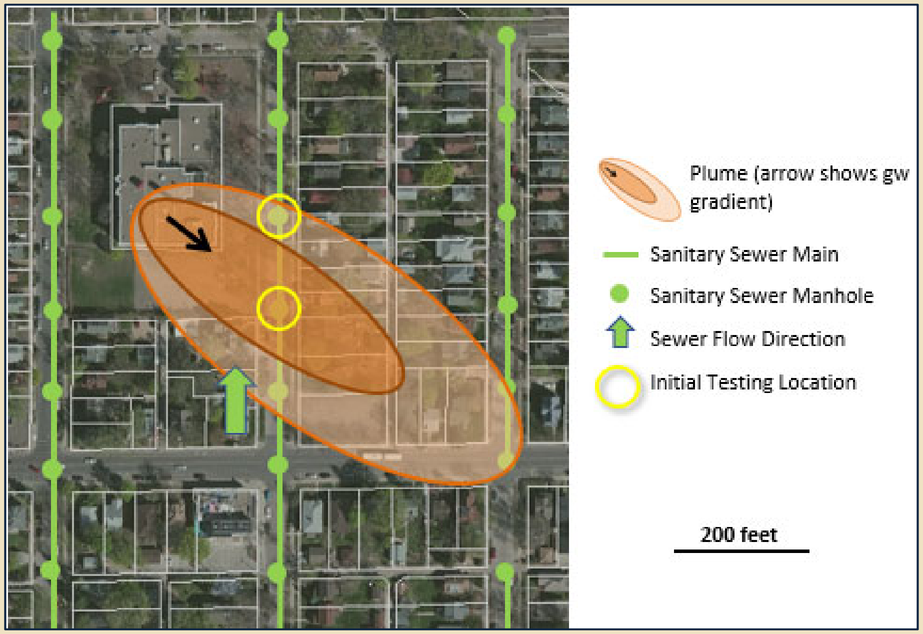
Log Scale



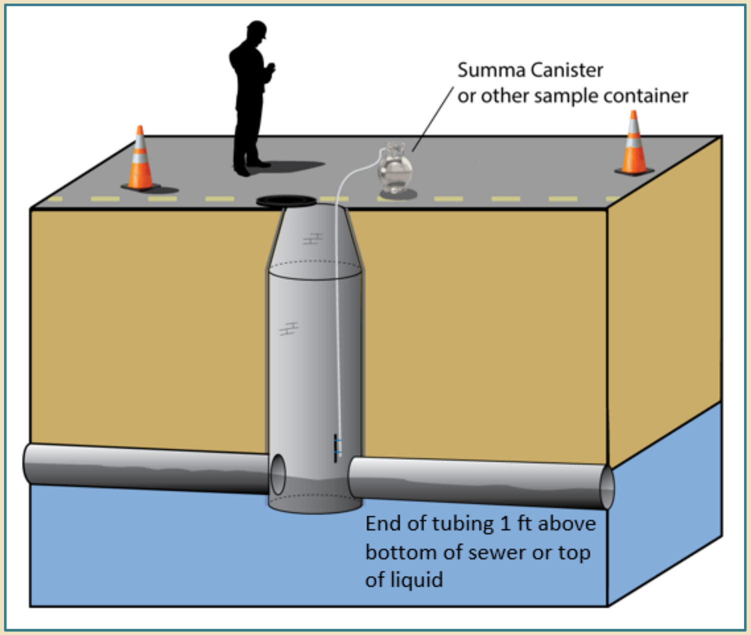
Equilibrium Concentration (ug/m3) = Concentration in Sewer Liquid (ug/L) x Henry's Constant (dimensionless) x 1000 unit conversion

SEWER PROTOCOL:
INITIAL FIELD TESTING

Where?



How?



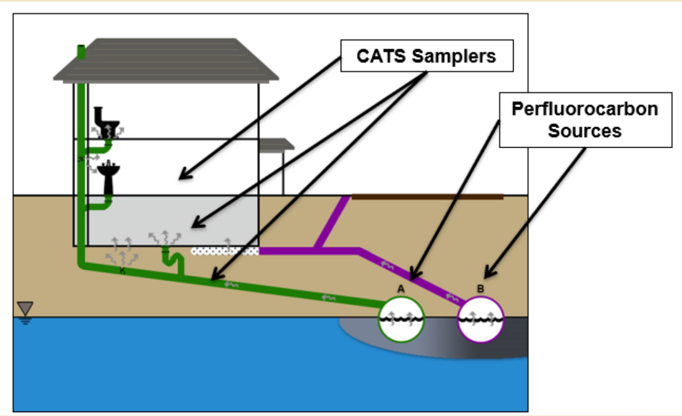
KEY QUESTION:

Are VOC concentrations above sewer screening levels?

SEWER VAPOR CONCENTRATION SCREENING

NOW WHAT?

- **Protocol recommends 0.03 as a reasonable upper bound sewer to indoor air attenuation factor.**



KEY POINT:

VI risk from sewers ≈ sub-slab. Can apply sub-slab screening values if they are based on an AF of 0.03.

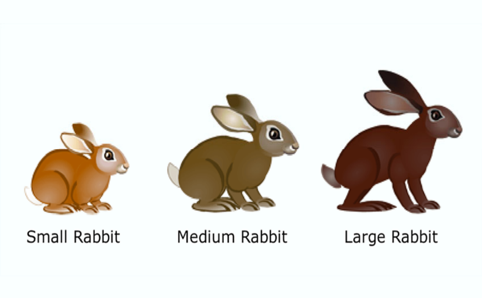
INITIAL FIELD SCREENING:
TEMPORAL VARIATION

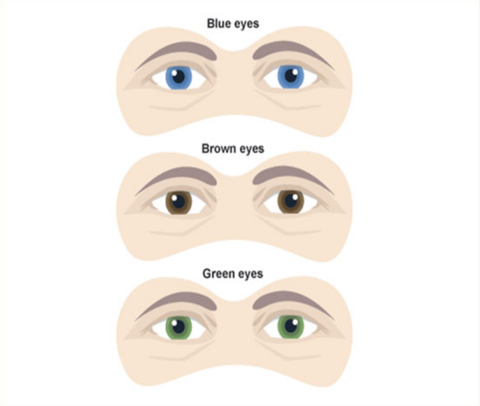
Short Term
(1-3 days)

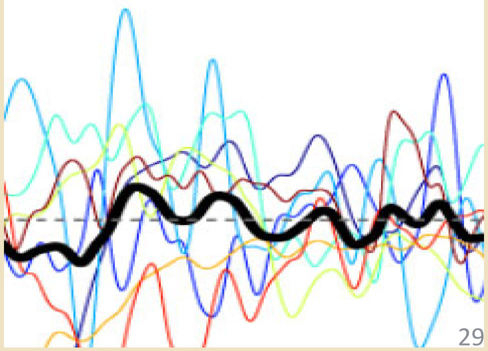
- **80% of grab samples within 2x of short-term average**
- ➢ **Little benefit to time-integrated samples.**

Longer Term:
(12-18 months)

- **About 50% of grab samples within 3x of long-term average**
- ➢ **Limited quarterly monitoring of sewer vapor may be appropriate if initial concentration is "close" to screening level.**







SEWER/UTILITY TUNNEL INVESTIGATION PROTOCOL

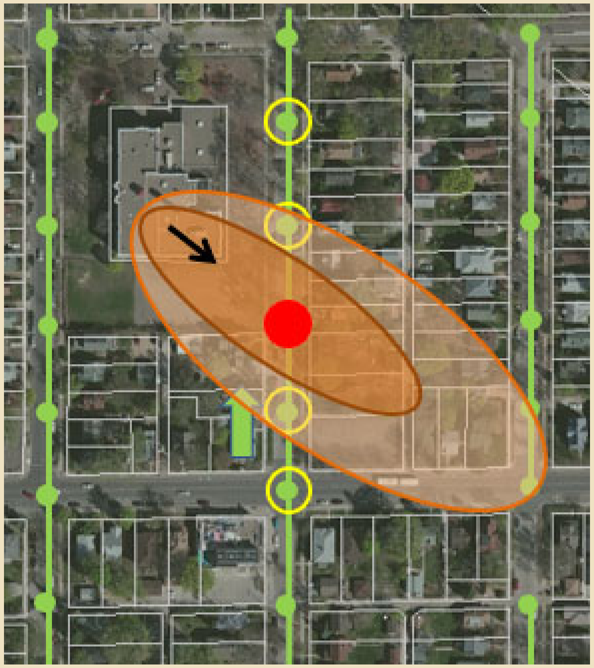
- Initial (Desktop) Screening
- Initial Field Testing
- Delineation within Sewers

INVESTIGATION TEAM

SEWER VAPOR DELINEATION

- **Vapor delineation determined by 2 consecutive manholes with VOC vapor concentrations below sewer screening levels**

- **Delineate in all directions (upstream, downstream, branch lines)**



KEY POINT: **Two-manhole recommendation consistent with observed attenuation within sewers.**

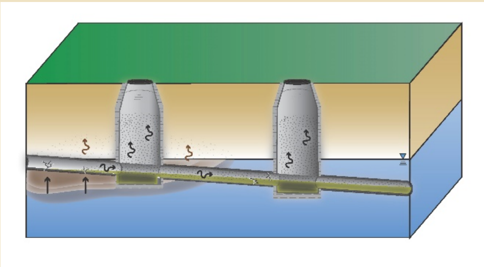
CONTENTS OF PRESENTATION

GSI ENVIRONMENTAL

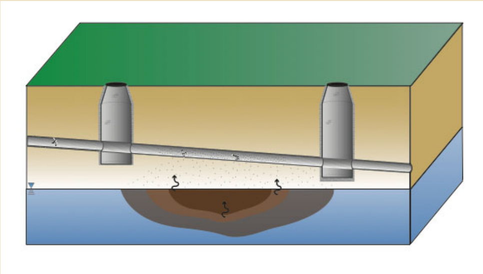
WRAP-UP

- Conceptual Model
  - Sewer/Utility Tunnel vs. utility backfill
  - Higher vs Lower Risk Sewer VI Sites

HIGHER RISK:
SEWER IN GW

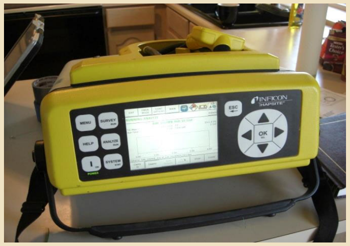


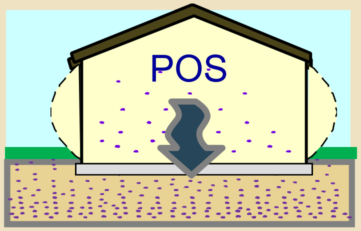
LOWER RISK:
SEWER IN VADOSE



INVESTIGATION APPROACHES

- **Prioritize sewer/utility tunnel assessment at <u>higher</u> risk sites**
- **For <u>lower</u> risk sewer VI sites, conventional VI investigation OK**
  - **Assumes indoor air testing**
  - **Consider sewers only if indicated by conventional results.**
  - **Investigation methods for distinguishing between indoor VOC sources and VI are OK for sewer VI.**





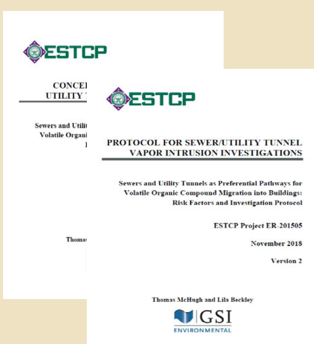
KEY POINT: **Early evaluation of sewer VI at higher risk sites may save time, money.**

ACKNOWLEDGEMENTS

- ER-201505 Project Team & Friends
- ER-201501 Project Team







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