Investigation of the Conduit Vapor Intrusion Pathway

James Walden, P.G. – Hydrogeologist/Vapor Intrusion Technical Expert

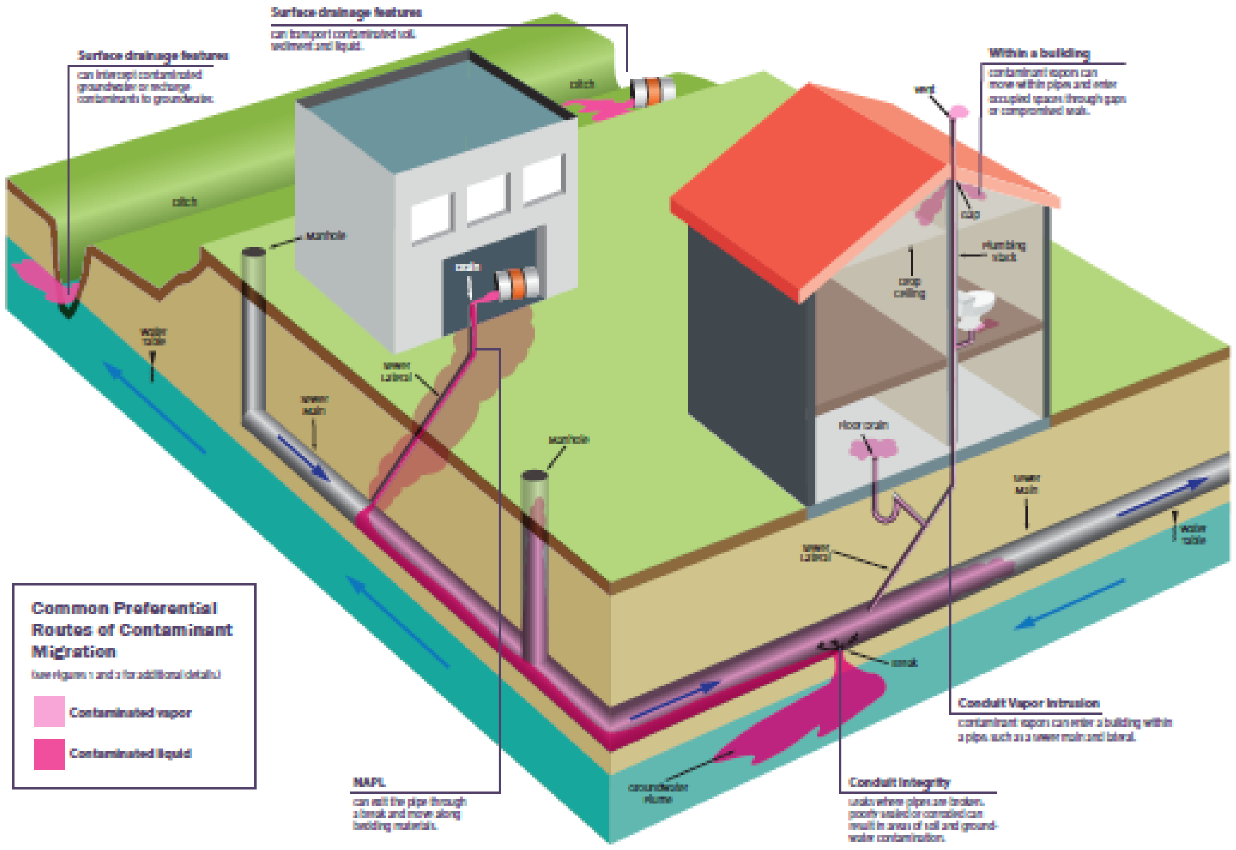
Outline

- Conceptual models for conduit vapor intrusion (VI)
- Common sampling techniques
- Snapshot of conduit data
- Investigations
- Takeaways

Wisconsin DNR – Environmental Contamination

Remediation and Redevelopment Program June 2021

Guidance for Documenting the Investigation of Human-made Preferential Pathways Including Utility Corridors



DNR.WI.GOV

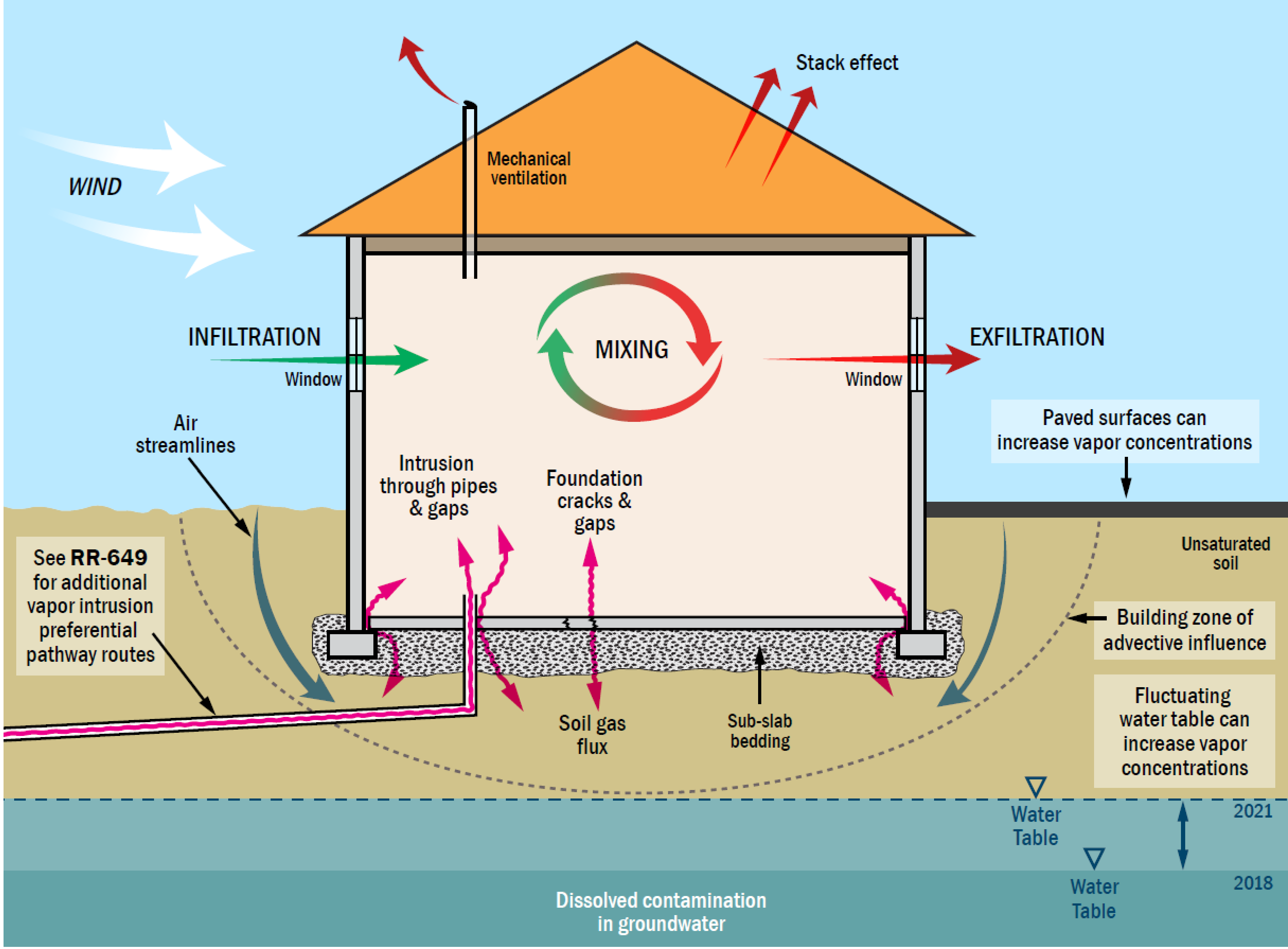
Search: DNR RR-649

Conceptual Model for Vapor Intrusion (VI)

Conventional

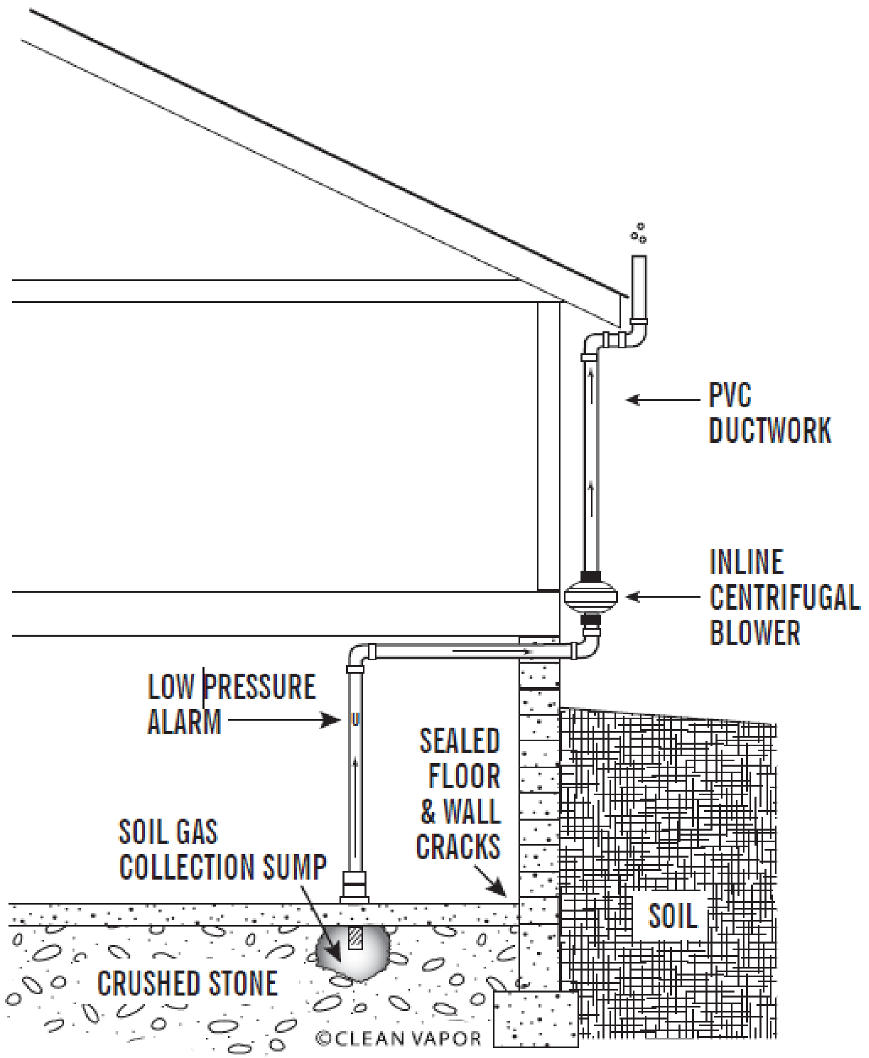
vs

Conduit

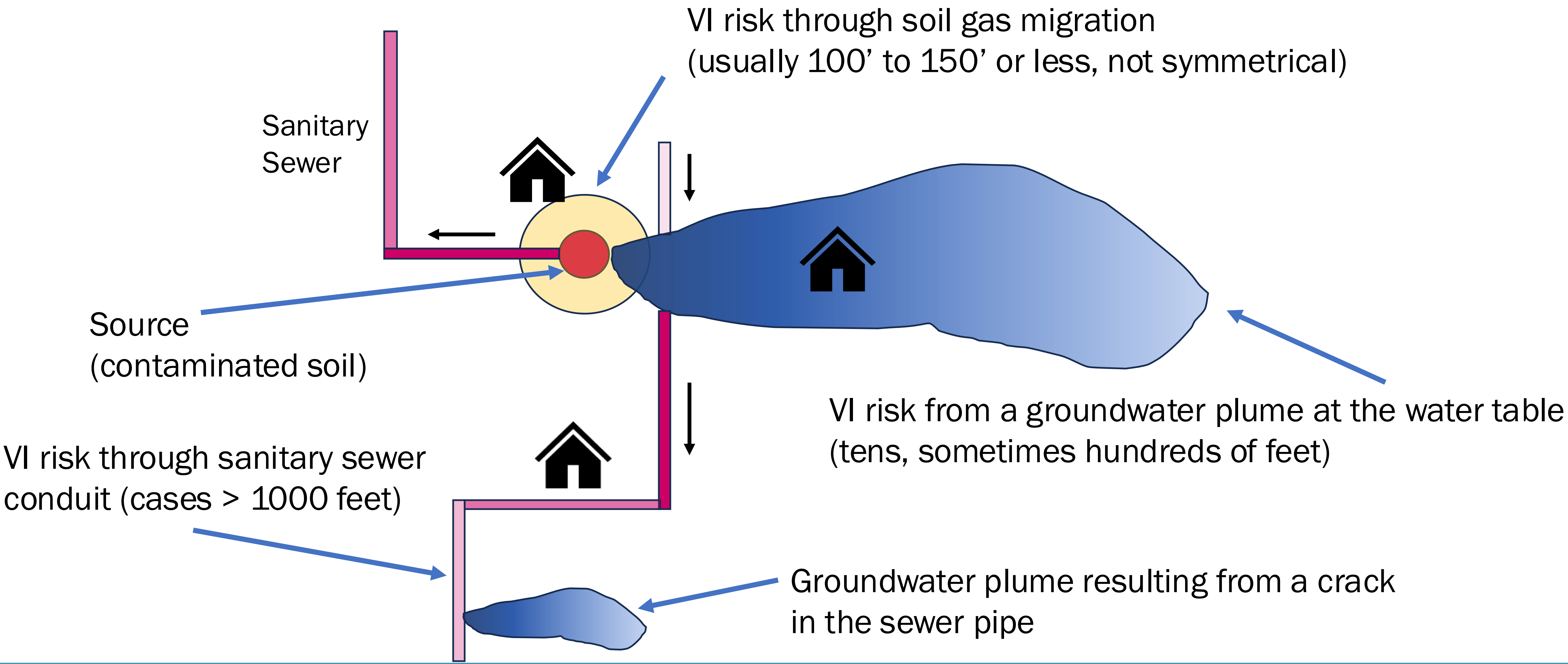


Conventional Mitigation Strategies are Unlikely to Address Conduit VI

Sub-Slab Depressurization System

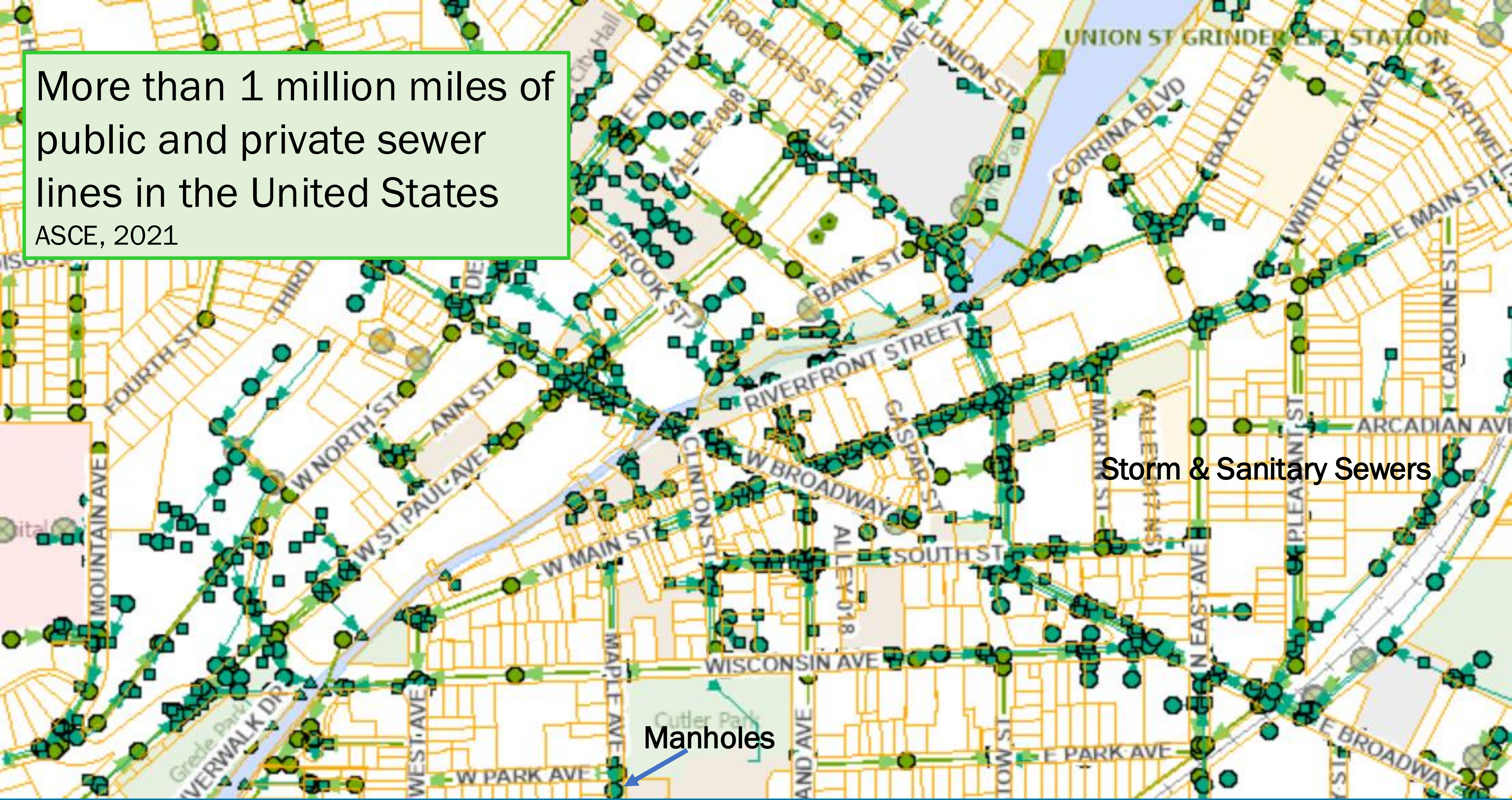


Asymmetrical VI Risk



More than 1 million miles of public and private sewer lines in the United States

ASCE, 2021



Definitions

- **Preferential pathway:** High-capacity transport pathways for vapors in the vadose zone or for groundwater flow that can be natural or human-made.

- **Conduit:** Subset of preferential pathways that provides little to no resistance to fluid or vapor flow (e.g., sanitary sewer pipes, or electrical conduits).

- **Conduit VI, Sewer VI, Atypical VI:** Vapor migration through the pipe.

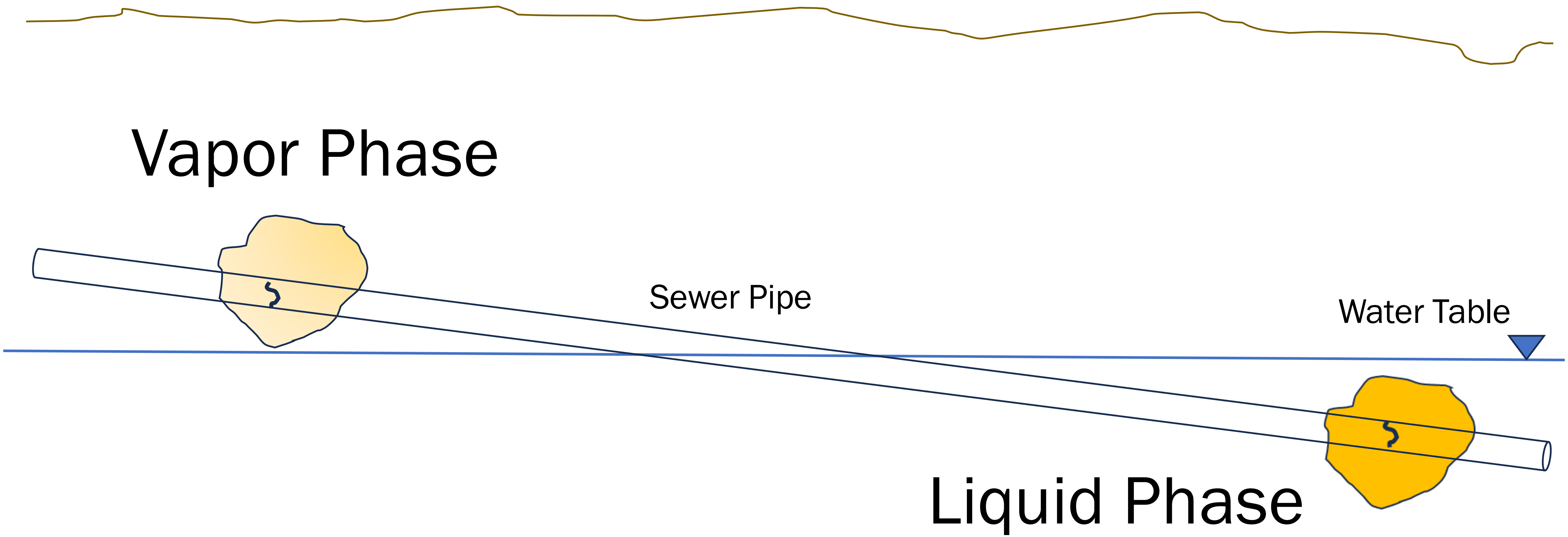
Human-made Preferential Pathways

Exterior Features
- Ditching
- Drain tile systems
- Dry wells
- Excavations
- Septic systems
- Permeable trenches
- Sanitary and storm sewers
- Tunnels
- Utility corridor bedding

Building Features
- Cisterns
- Crawl spaces
- Earthen floors
- Floor drains
- Foundations seams, joint, cracks
- Elevator shafts
- Sumps and drainage pits
- HVAC and utility penetrations
- Wall voids
- Pipes and waste lines

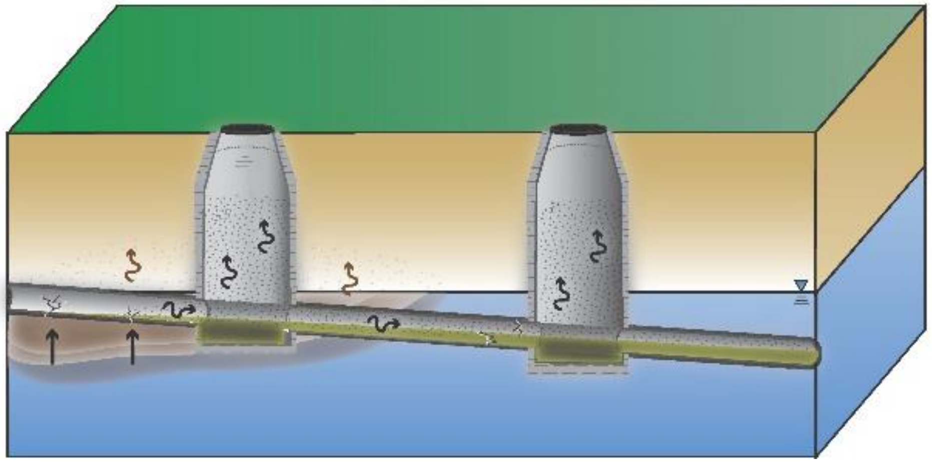
Source: RR-649

Contaminant Entry into Conduits

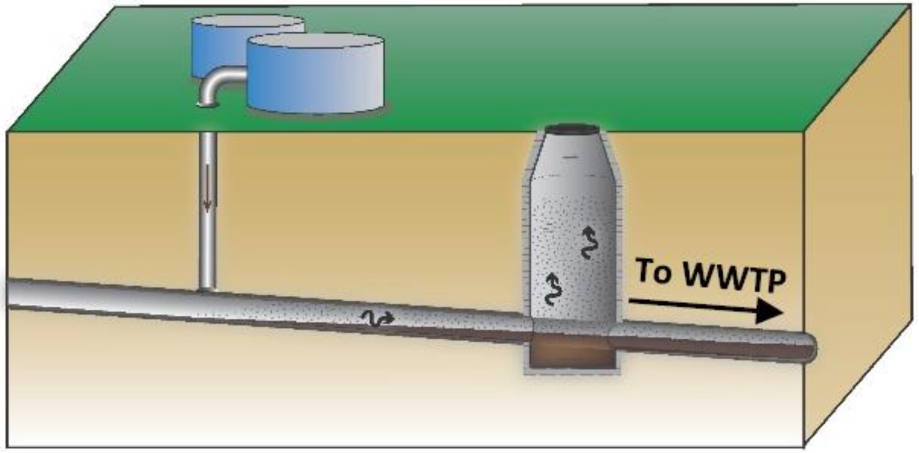


Higher Risk Scenarios

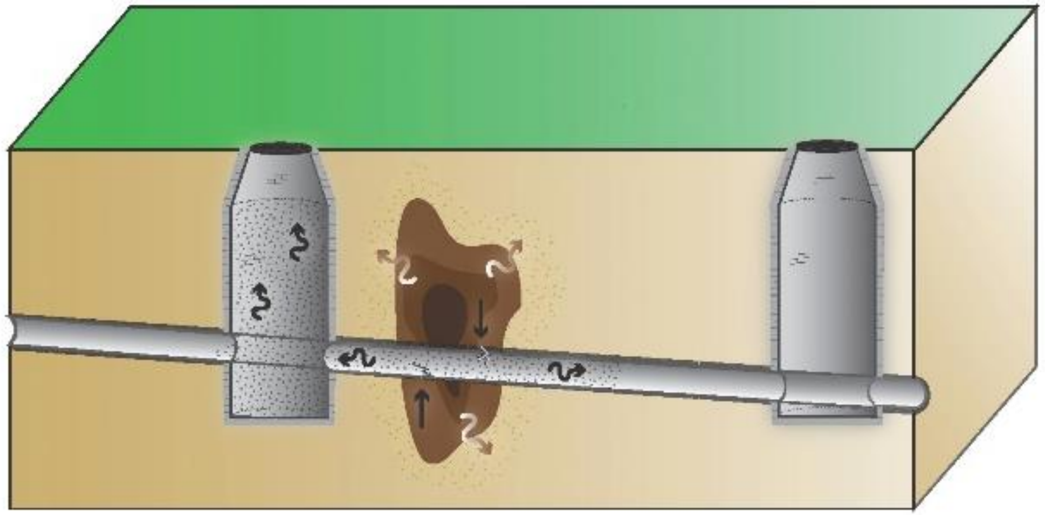
A: Sewer Intersects Contaminated Groundwater

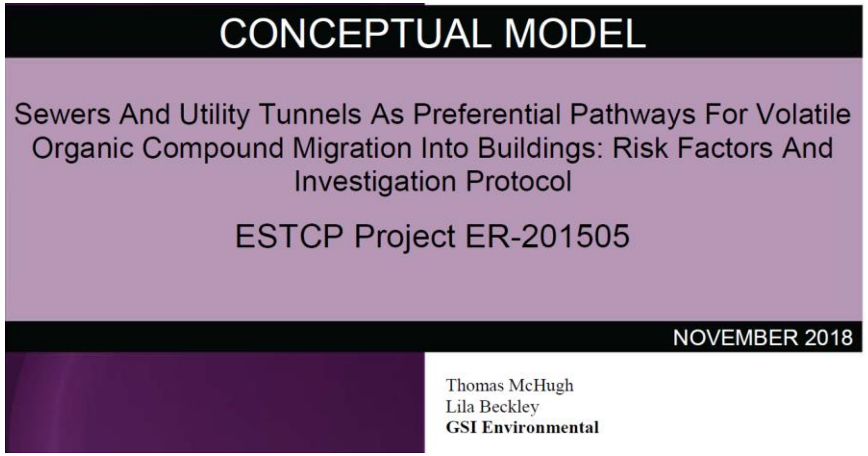


B: Discharge of Groundwater to Sewer Line



C: Sewer Intersects NAPL/Vadose Zone Source




CONCEPTUAL MODEL

Sewers And Utility Tunnels As Preferential Pathways For Volatile Organic Compound Migration Into Buildings: Risk Factors And Investigation Protocol

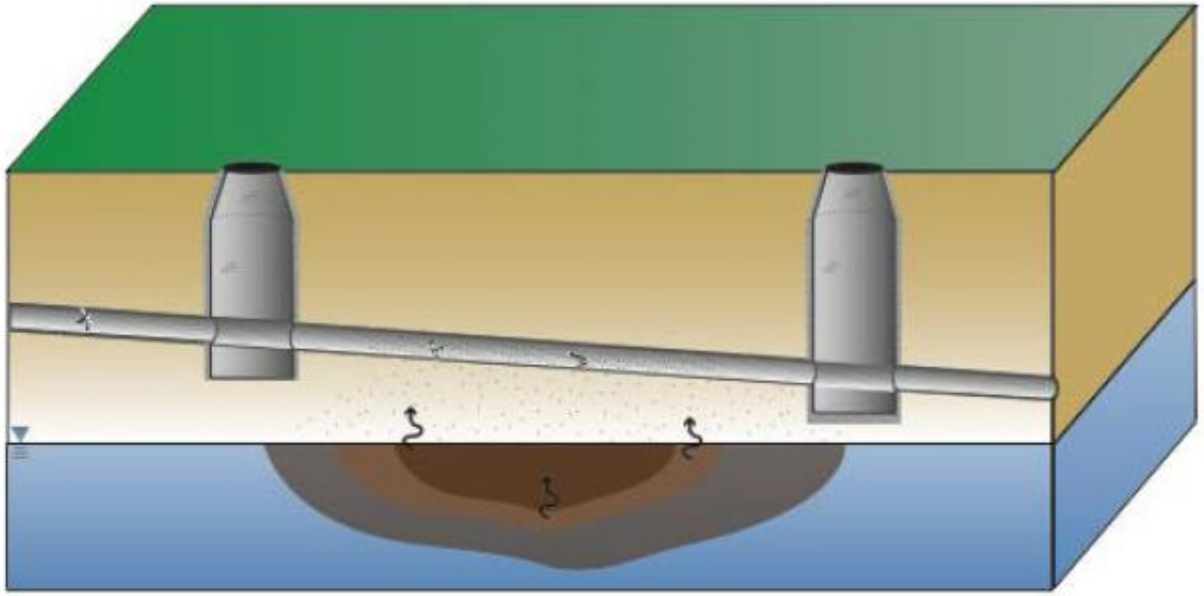
ESTCP Project ER-201505

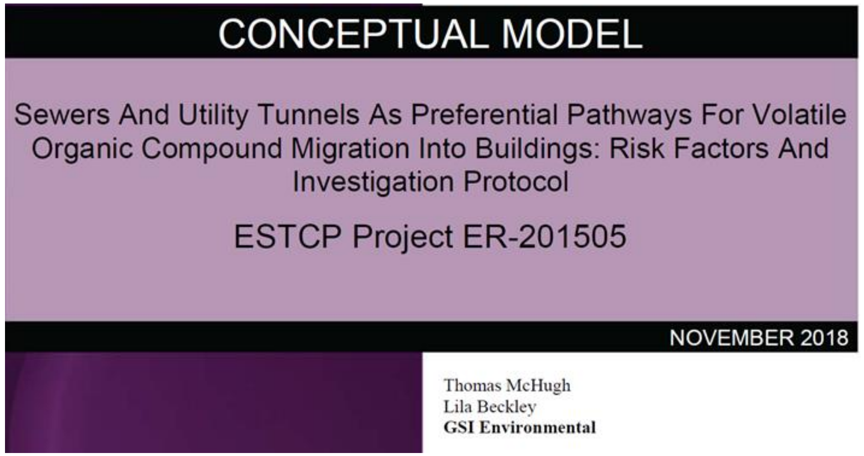
NOVEMBER 2018

Thomas McHugh
Lila Beckley
GSI Environmental

Lower Risk Scenarios

Sewer in Vadose Zone above Plume





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Sewers And Utility Tunnels As Preferential Pathways For Volatile Organic Compound Migration Into Buildings: Risk Factors And Investigation Protocol

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NOVEMBER 2018

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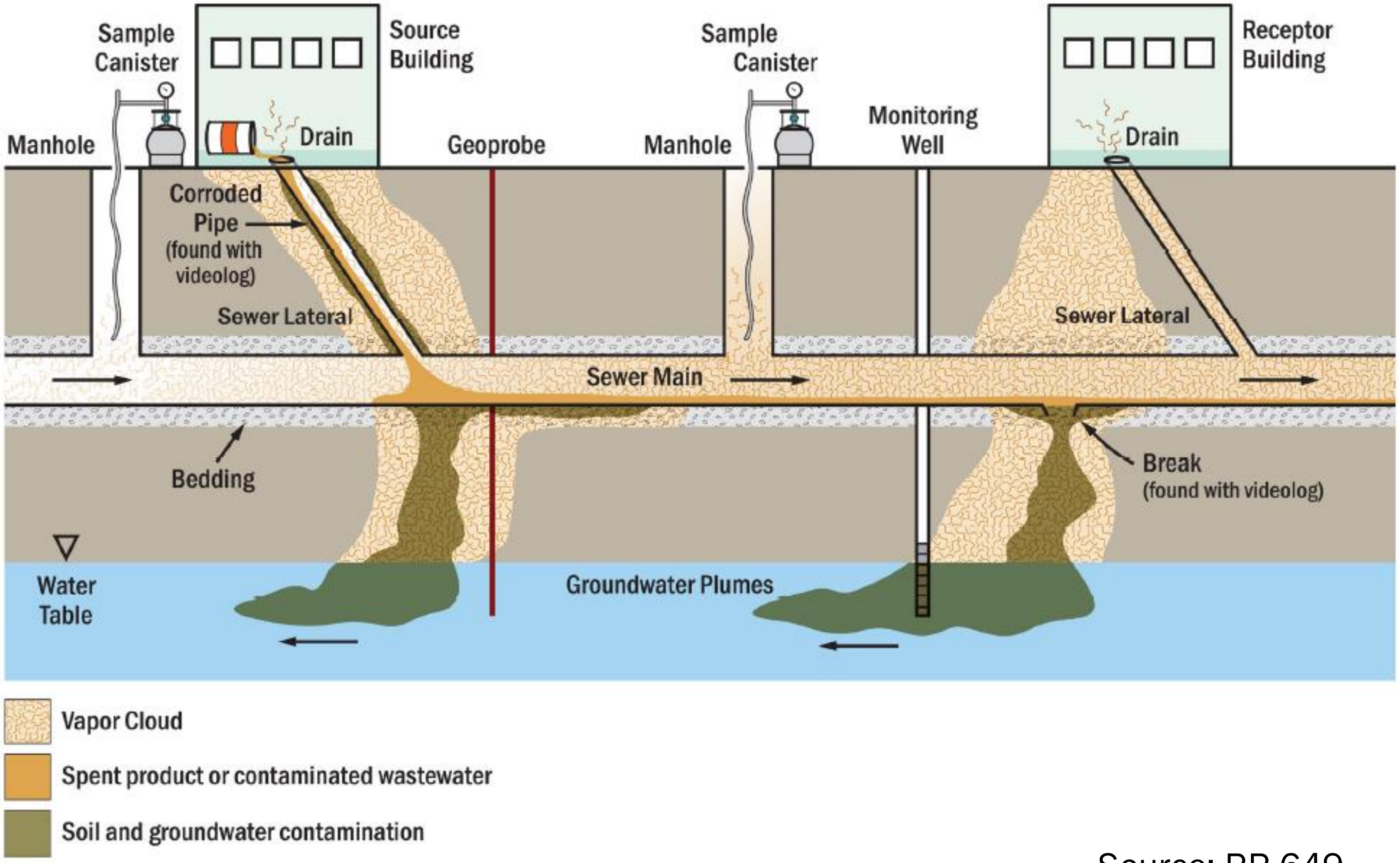
Contaminant Movement Within Conduits

Liquid: Downslope (except when there is a backup).

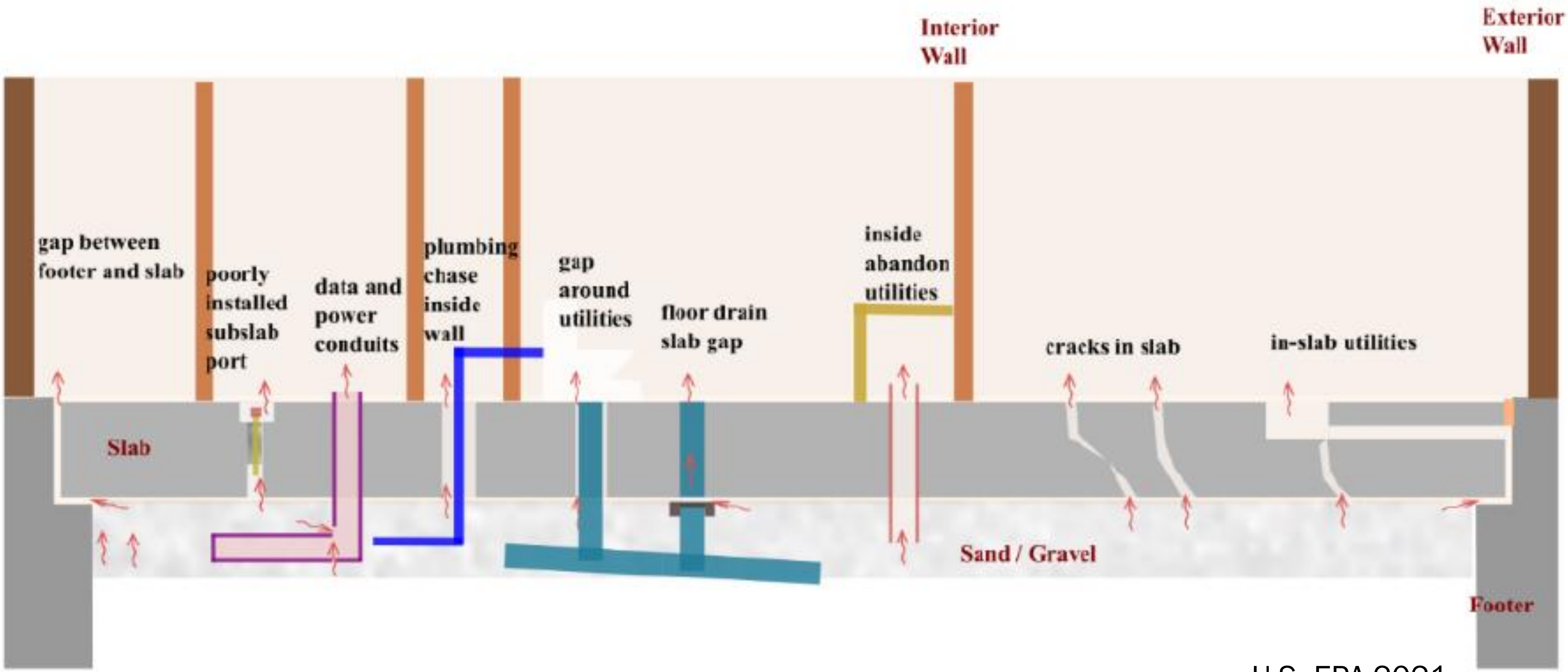
Vapor: Primarily downslope from liquid drag. Upslope possible due to diffusion and advective.



Source: RR-649

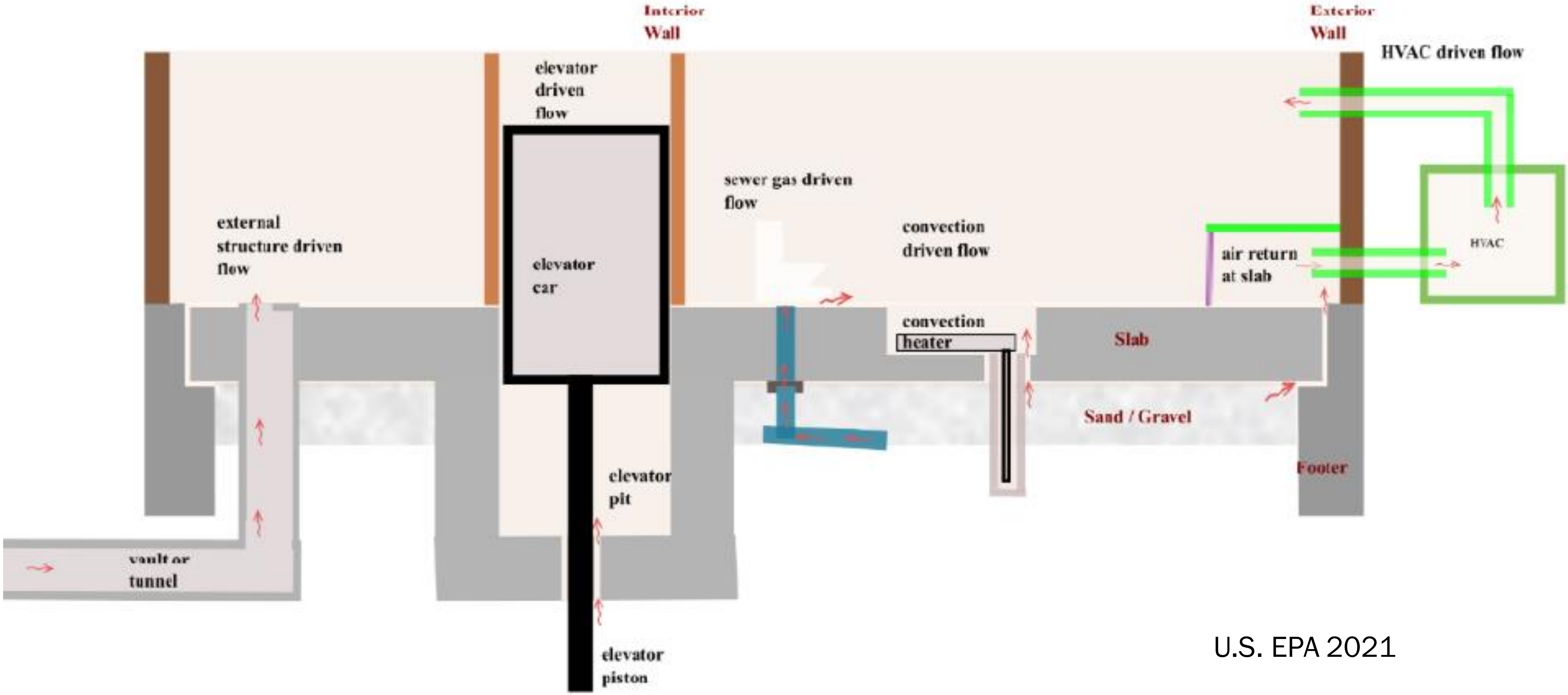
Conduit Entry into Buildings

Pathways Depend on Indoor Pressure



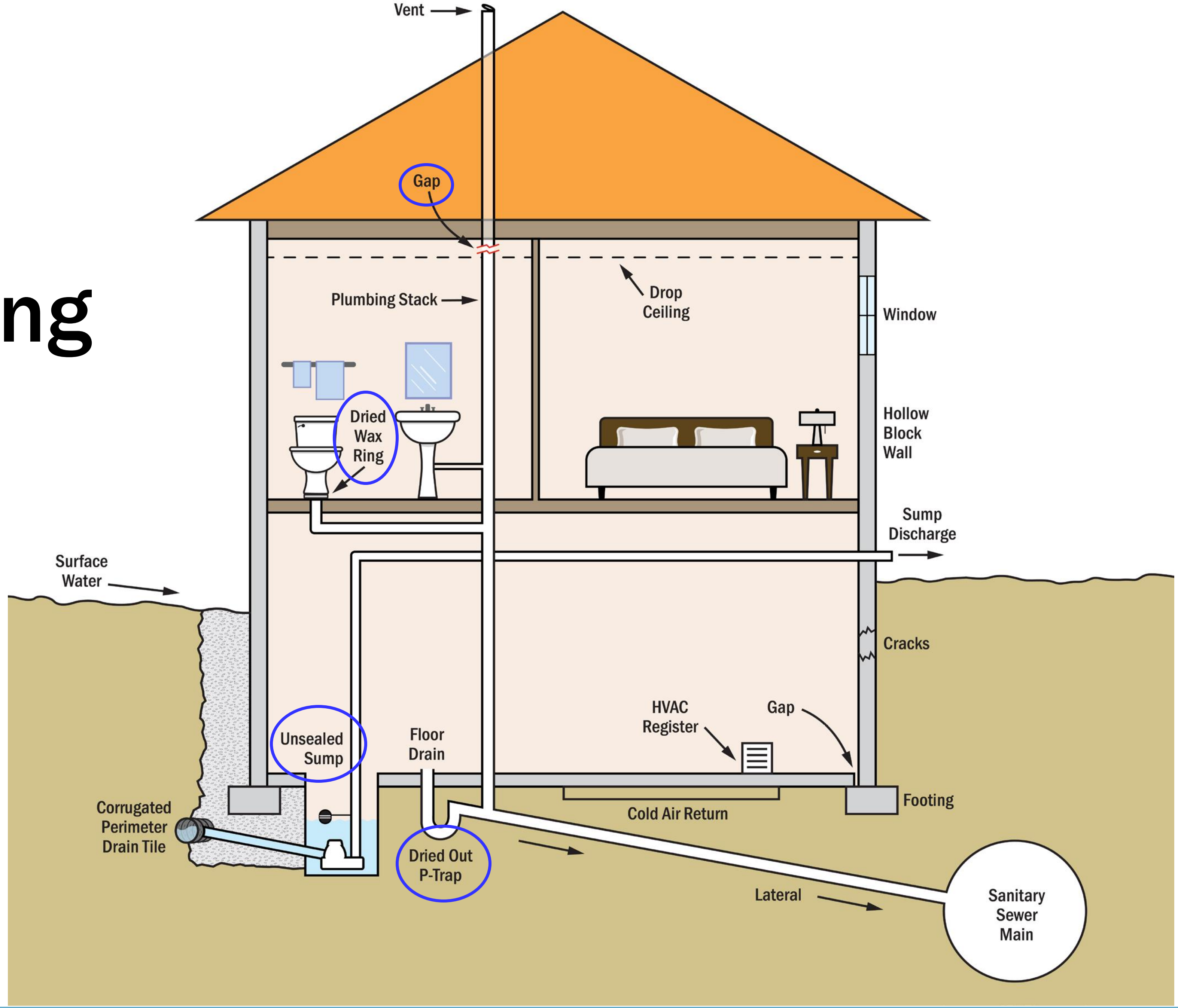
U.S. EPA 2021

Pathways with Independent Driving Forces



U.S. EPA 2021

Conduit VI - Residential Building

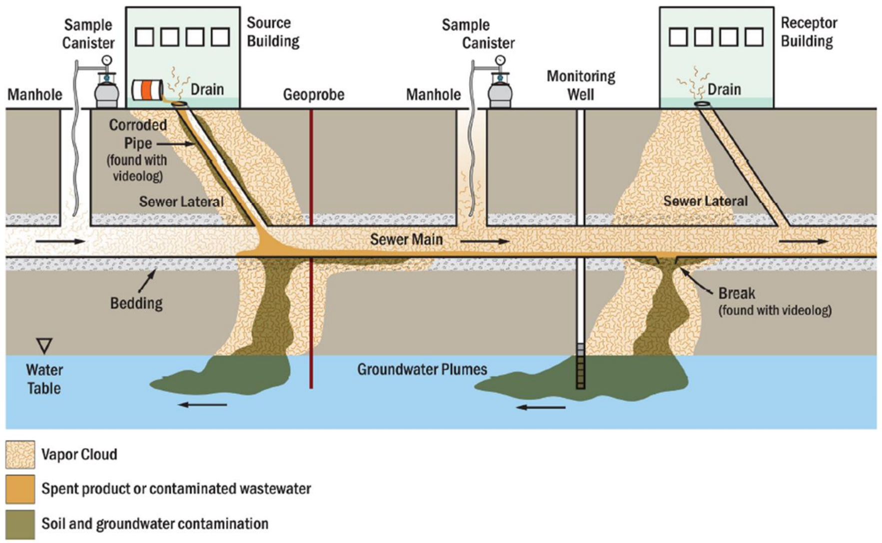


Source: RR-649

Some Factors Affecting Conduit Vapor Concentrations

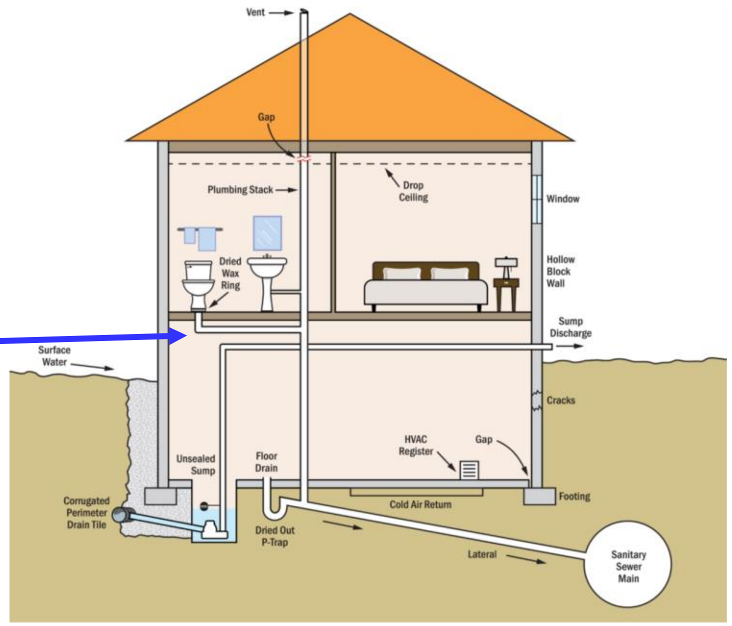
- Drop structures (sewer pipe)
- Pipe slope
- Pipe diameter
- Siphons
- Barometric pressure
- Wind
- Temperature differential (atmosphere)
- Wastewater/surface water inflow
- Sorption (organic matter)

Temporal Concentration Variability



Sanitary Sewers

- McHugh and Beckley 2018:
  - 1-3 Days: 80% within 2X of average concentrations
  - 12-18 Months: 33% within 2X of average concentrations
- Guo 2020: TCE > 10X variation at 81 of 268 locations
- Seasonal variation greater than short term (days)

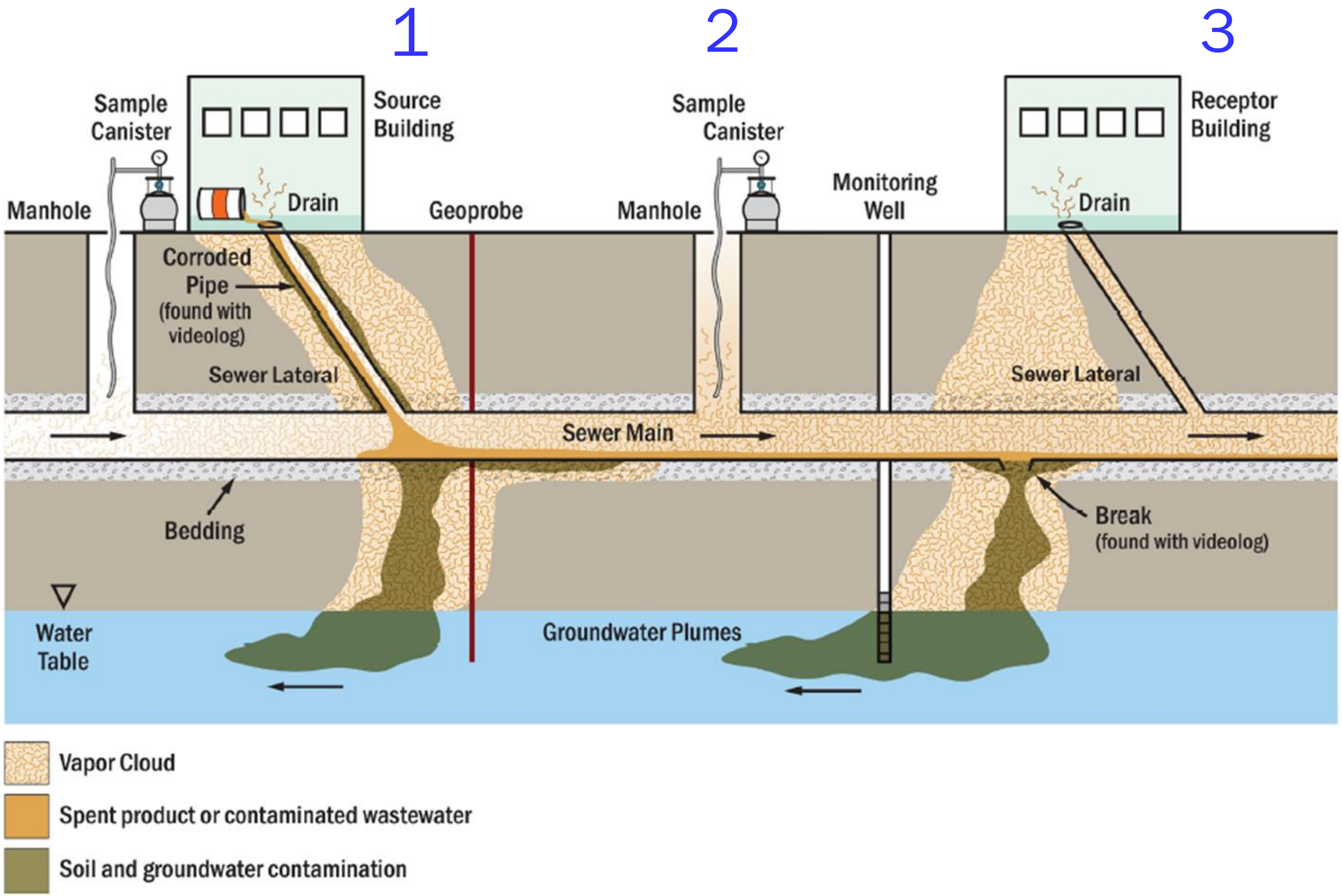


Building Plumbing

- WI: 30 X (limited data)
- Denmark: 3 to 4 orders of magnitude

Areas of Conduit VI Investigation

1) Source property/building
2) Right of way
3) Receptor building



Screening Concentrations: Sanitary Sewer Mains

Parameter - PCE	Value µg/m³	Parameter - TCE	Value µg/m³
Sewer to Building Indoor Air Attenuation Factor*	0.03 (unitless)	Sewer to Building Indoor Air Attenuation Factor*	0.03 (unitless)
PCE Sewer Screening Concentration – Residential **	1,400	TCE Sewer Screening Concentration – Residential**	70
PCE Sewer Screening Concentration- Commercial/Industrial**	5,800	TCE Sewer Screening Concentration - Commercial/Industrial**	290

*McHugh and Beckley (based on tracer testing)
**WI – dividing target indoor air concentration by 0.03 = (Sanitary Sewer Gas Screening Level (SSGSL).

PCE = tetrachloroethene
TCE = trichloroethene

Developing the Conceptual Site Model

Identify location and depth of utility conduit routes within and near the building.

- Floor drains
- Plumbing features
- Sewer vent pipes
- Clean-outs
- Sumps and drain tiles
- Sump discharges
- Sewer laterals
    - Active and abandoned
- Septic systems
- Locations where utilities penetrate foundation

Source: RR-649

Developing the Conceptual Site Model

Gather information where there is possible utility migration pathway.

- Plan view with respect to source area
- Depth of utilities
- Construction dates
- Materials (pipe and bedding)
- Flow directions
- Location of laterals and manholes
  - Existing and abandoned
- History of cleaning, repair
- Planned upgrades
- Relationship of utilities including bedding to groundwater

Source: RR-649

Conduit Sampling Techniques

Primary

- Evacuated canister
- Active Sorbent
- Passive sorbent
- On-site gas chromatograph
- Video
- Liquid sampling

Supplemental

- PID
- Induced tracer (smoke, citrus, helium, perfluorcarbon, dye)
- Differential Pressure
- Sewer compounds (e.g., chloroform)
- Building Pressure Control
- Soil gas sampling
- Soil and groundwater sampling

Manhole Sampling Depth:
PID Readings (ppb) in Manholes (MH) and Catch Basins

	Sanitary MH 1	Sanitary MH2	Sanitary MH3	Sanitary MH4	Storm MH1	Open Catch Basin1	Open Catch Basin2	Open Catch Basin3	Open Catch Basin4
Rim	7	14	15	28	32	28	9	5	11
Mid	10	261	126	482	421	2,671	18	18	10
Bottom	13	648	671	1,026	1,609	326	17	21	15
Depth (ft)	10	10	6	5.8	7	5.3	4.3	4.1	4.0

Sewer Manhole Sampling - Evacuated Canister

May not be current best practice.

Source: RR-649

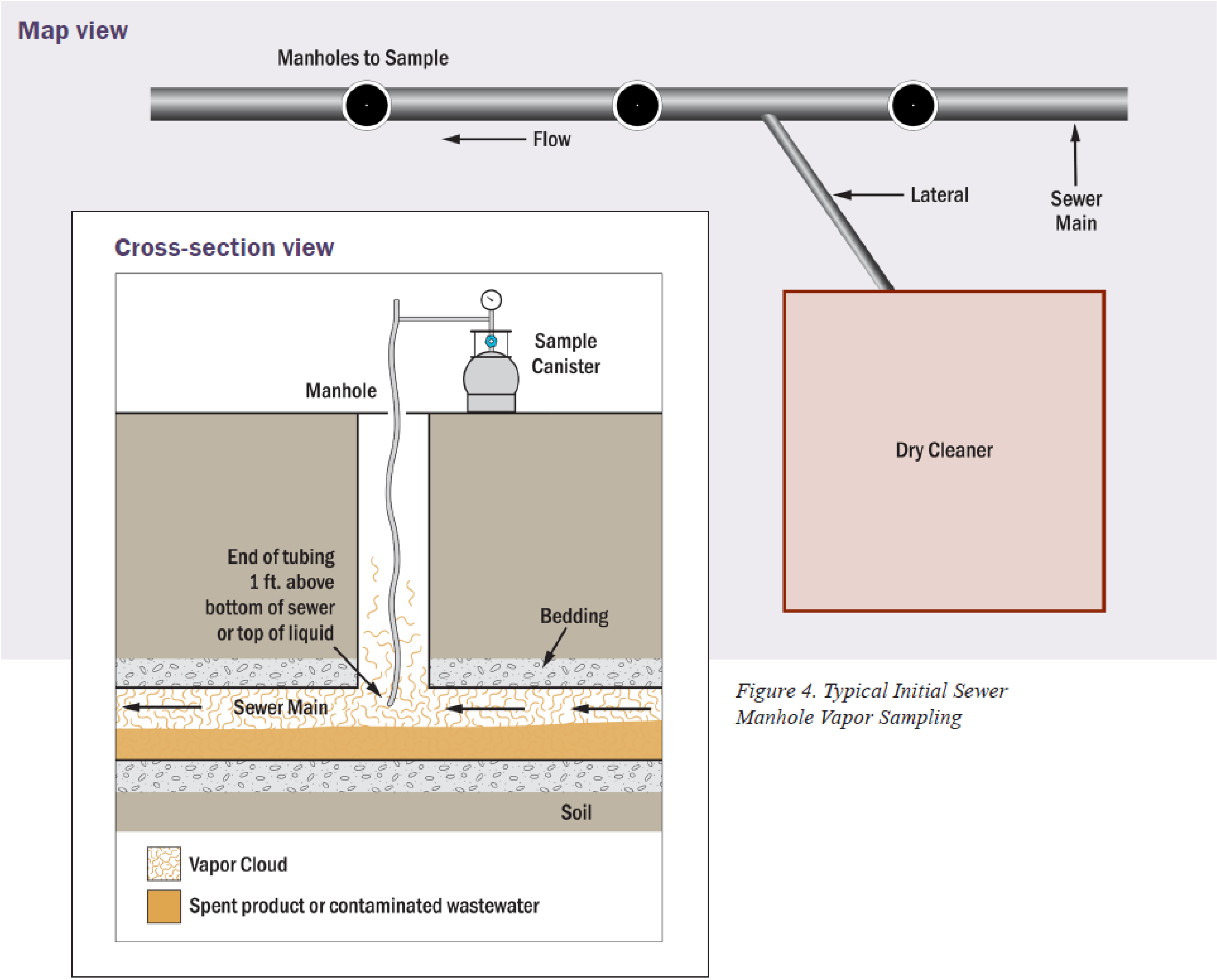


Figure 4. Typical Initial Sewer Manhole Vapor Sampling

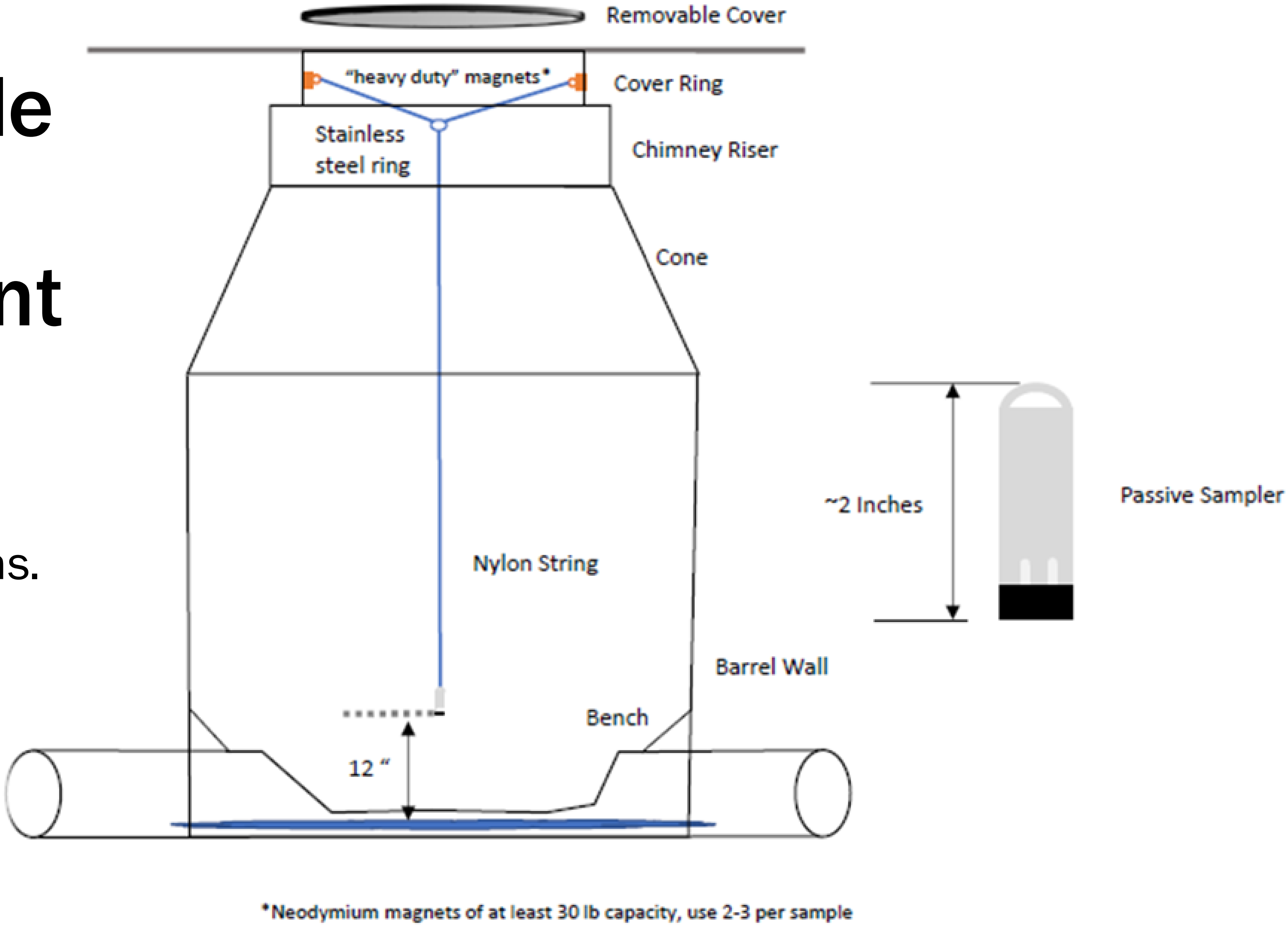
Vented Manhole

Un-Vented Manhole

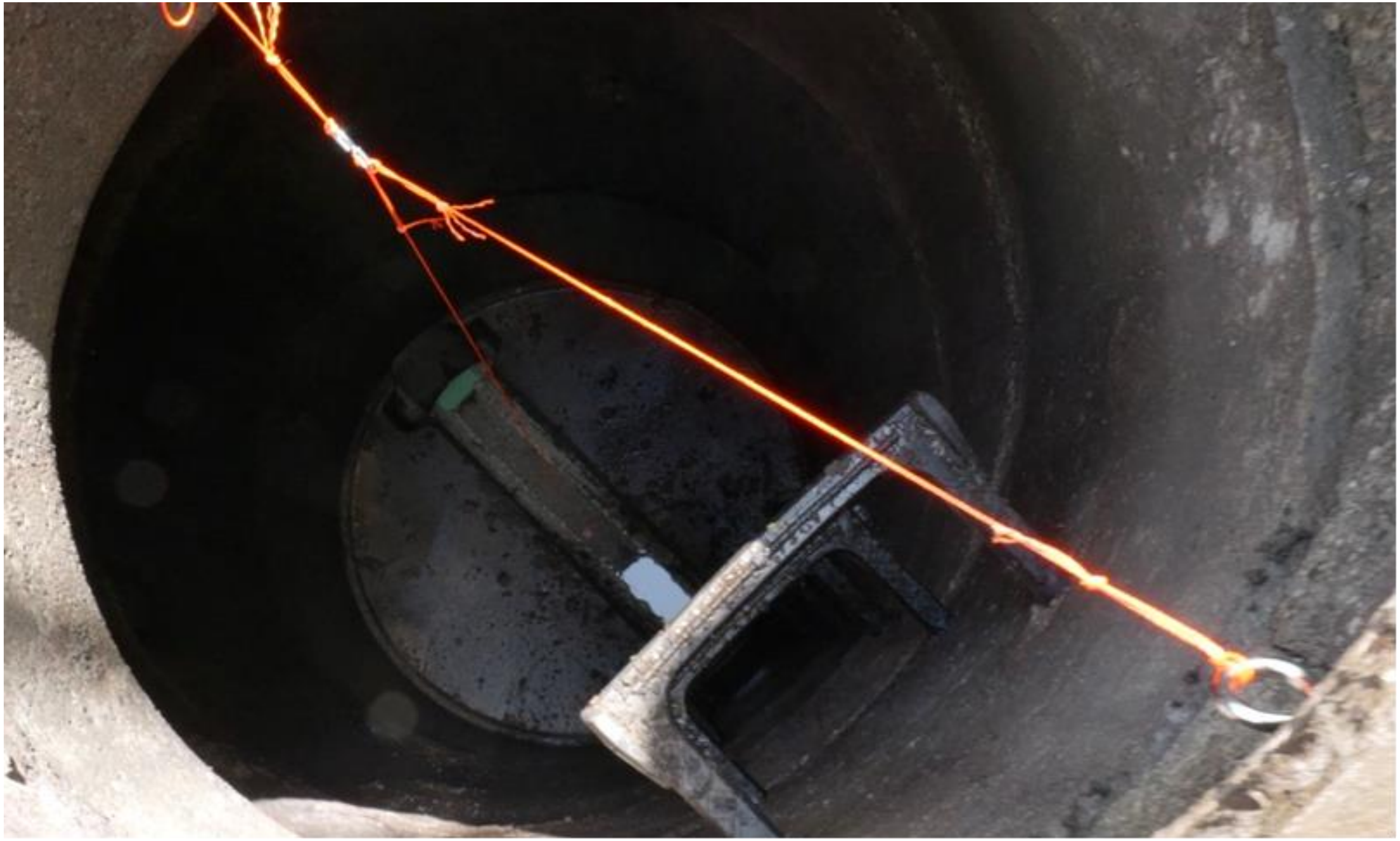
Sewer Manhole Sampling: Passive Sorbent

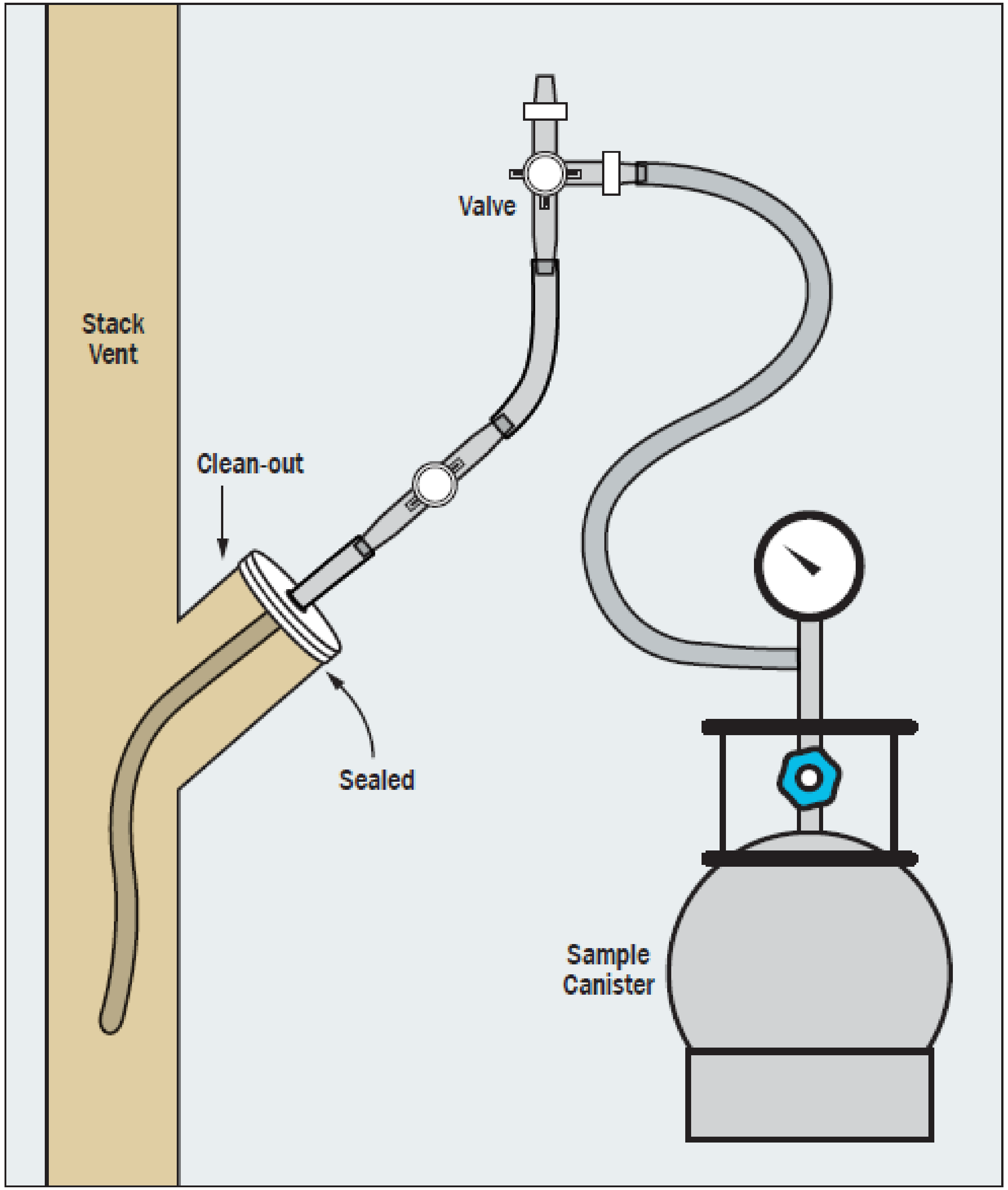
Current method used in state-funded investigations.

Not in RR-649



Manhole Passive Sampling





Plumbing Cleanout Sampling - Evacuated canister

Recommended in RR-649.
May not be current best practice.

Source: RR-649

Photo courtesy of Beacon Environmental

Plumbing Cleanout Sampling – Passive Sorbent

Method being evaluated for state-funded investigations.

Not in RR-649

Passive Sorbent Soil Gas Sampling:

Screening for a Release from the Sewer Pipe

NR-700 Rule Series Investigations

- “One Clean-up Program”
- Self-implementing with required steps (detailed guidance documents)
- Responsible Parties (causers & possessors) – WI Admin. Code requires investigation of all pathways including conduits
- RR-649 published in June 2021
- 2,700 Open Cases (about 885 with trichloroethene (TCE))
- 28,000 Closed cases (estimated 1,600 with TCE)
- 1,000s of properties with chlorinated solvent use never reported

Conduit Sample Type and Setting* (6/2019 – 5/2024)

Sample Type	Sanitary Sewer MH	Cleanout	Sump	Floor Drain	Plumbing	Storm Sewer MH
Canister	219	69	37	7	11	25
Beacon Passive	70		8			
Waterloo Membrane Sampler (WMS) Passive	24		7		4	
Gas Chromatograph	69	3		1	4	
Total	382	72	52	8	19	25

* May not include all data

Conduit Sampling Statistics (6/2019 – 5/2024)

Year	2019	2020	2021	2022	2023	2024
# Samples	46	49	51	78	269	59

Statistic	#
Consulting Firms	33
Dry Cleaners	34
Manufacturing	33
Petroleum	2
Landfills	1
Total Sites	70

Manufacturing = basic industries, foundries, machine shops, metal fabricators, platers, and similar.

Interior Plumbing and Sump Statistics - Vapor

Statistic	No. Locations	No. Samples	Det Freq (%)*	10^{th} (µg/m^3)	Median (µg/m^3)	90^{th} (µg/m^3)	Maximum (µg/m^3)
CO, FD, P Source	43	57	68	0.2	2.3	1,506	58,400
CO, FD, P Off-Source	22	42	76	0.6	16	230	410
Sumps	45	53	68	0.2	10.7	1111	3,700

Detection limit used for statistics if not detected.

CO = cleanout   FD = floor drain   P = other plumbing   TCE unless noted   * = % of samples

Interior Plumbing and Sump Statistics - Vapor

Statistic	No. Locations	No. Samples	Det Freq (%)*	10th (µg/m³)	Median (µg/m³)	90th (µg/m³)	Maximum (µg/m³)
CO, FD, P Source	43	57	68	0.2	2.3	1,506	58,400 7,320,000
CO, FD, P Off-Source	22	42	76	0.6	16	230	410 77
Sumps	45	53	68	0.2	10.7	1111	3,700 98,300

Detection Limit used for statistics if not detected

PCE aka "perc"

CO = cleanout FD = floor drain P = other plumbing TCE unless noted * = % of samples

Sanitary Sewer Manhole Statistics - Vapor

Statistic	No. Locations	No. Samples	Det Freq. (%)*	10th (µg/m³)	Median (µg/m³)	90th (µg/m³)	Maximum (µg/m³)
SA Up-flow MH (all)	57	88	58	0.3	1.3	26	484
SA Down-flow D	60	73	55	0.3	1.6	51.7	1,240
SA Down-flow D PCE	60	73	70	0.4	12	764.2	33,000
SA Down-flow M/L	137	210	79	0.3	15.3	564	7,660

SA = sanitary MH = manhole D = dry cleaner M = manufacturing L = landfill
TCE unless noted * = % of samples

Historical Dry Cleaner Effluent Data

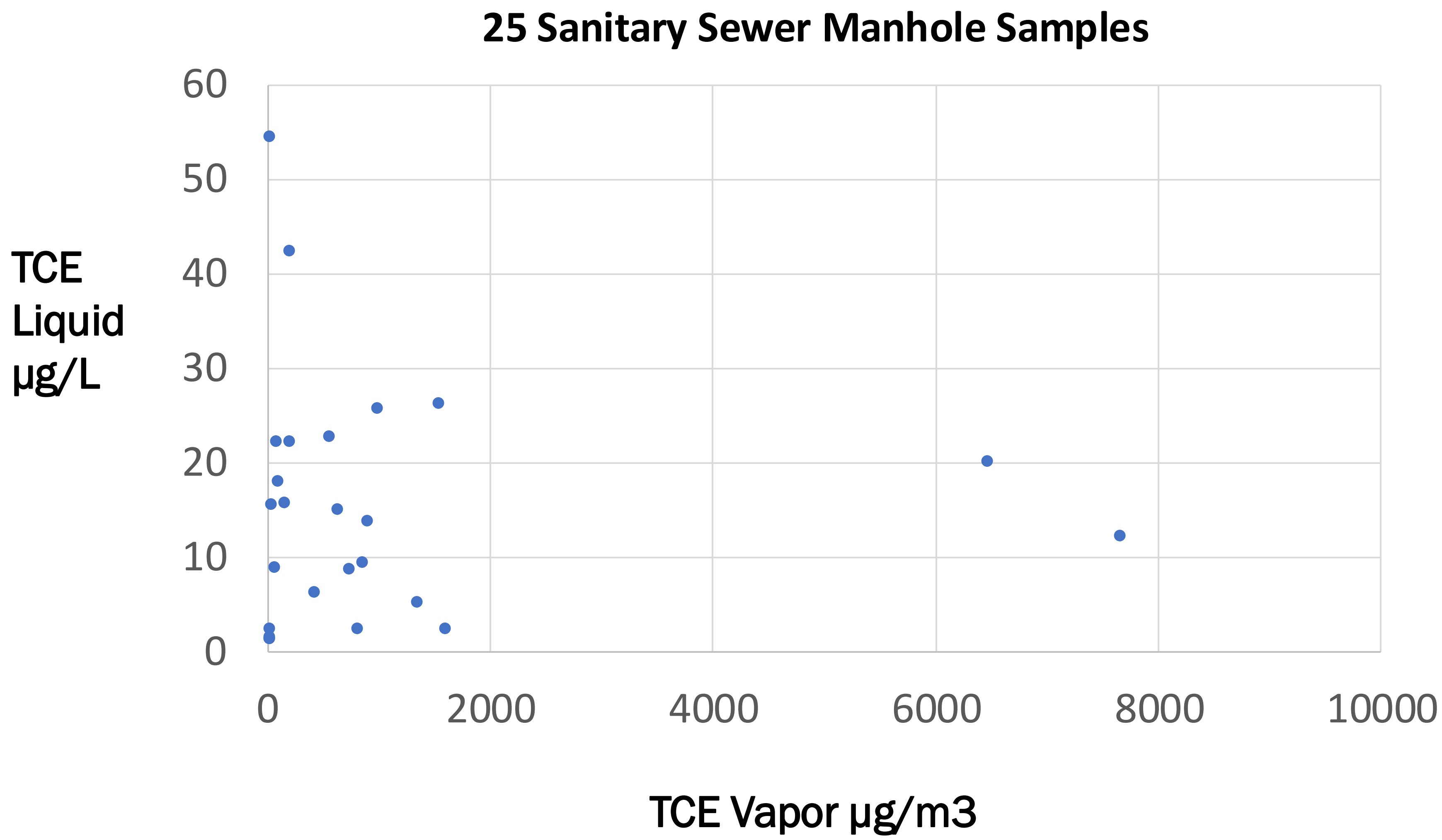
(ppb or µg/L)

Dry Cleaners Sampling Results from Condensate Liquid

CLEANER	CITY	DATE	RESULT in ppb	UNIT
Busy Bee	Lodi	9/11/90	60,699	Reclaimer
Turlock Cleaners	Turlock	4/29/91	62,755	Cooker
Snow White	Turlock	1/26/89	140	Reclaimer
			56	Cooker
Durite Cleaners	Turlock	1/30/89	15,000	Sniffer & Reclaimer II
			150,000	Reclaimer I
Brite Cleaners	Turlock	5/11/89	66,000	Reclaimer
Southgate Norge	Sacramento	3/20/91	247,000	Sniffer & Reclaimer
Tillet Cleaners	Roseville	4/11/89	74,000	Reclaimer
Merced Laundry	Merced	11/29/88	130,000	Sniffer
Modesto Steam	Modesto	4/30/91	1,119,300	Reclaimer
			139,087	Cooker
			8,120	Chiller
			53,618	Recalimer
		Median	64,000	
		Average	151,800	

Source: Drycleaners a Major Source of PCE in Groundwater, 1992, California Water Control Board

Liquid vs Vapor Concentrations



24 other samples (not shown) with <0.76 µg/L liquid had vapor concentrations averaging 106 µg/m^3 and a maximum of 960

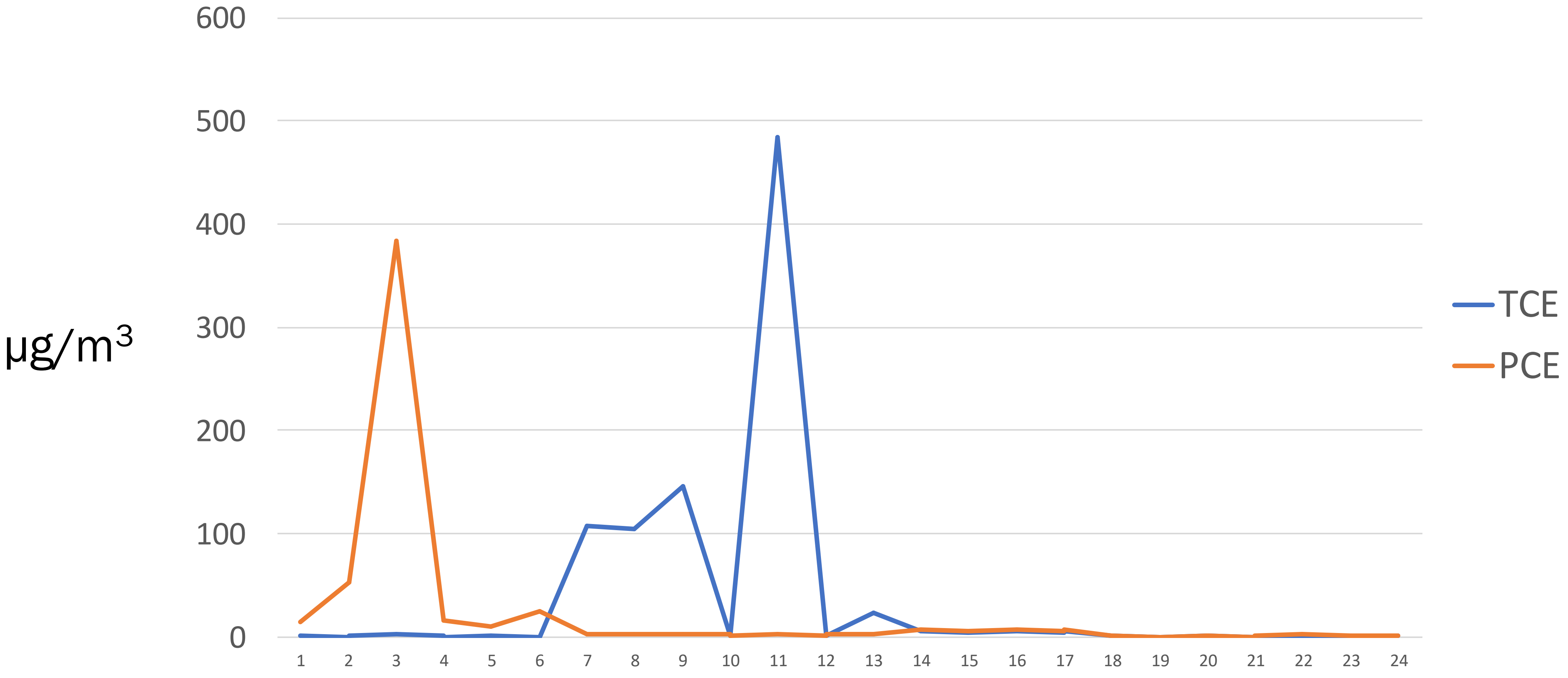
Short-term Concentration Variation (Passive/Canister)

P = passive sampler
C = canister
G = grab
J = J flag
< = not detected

All sanitary sewer MHs

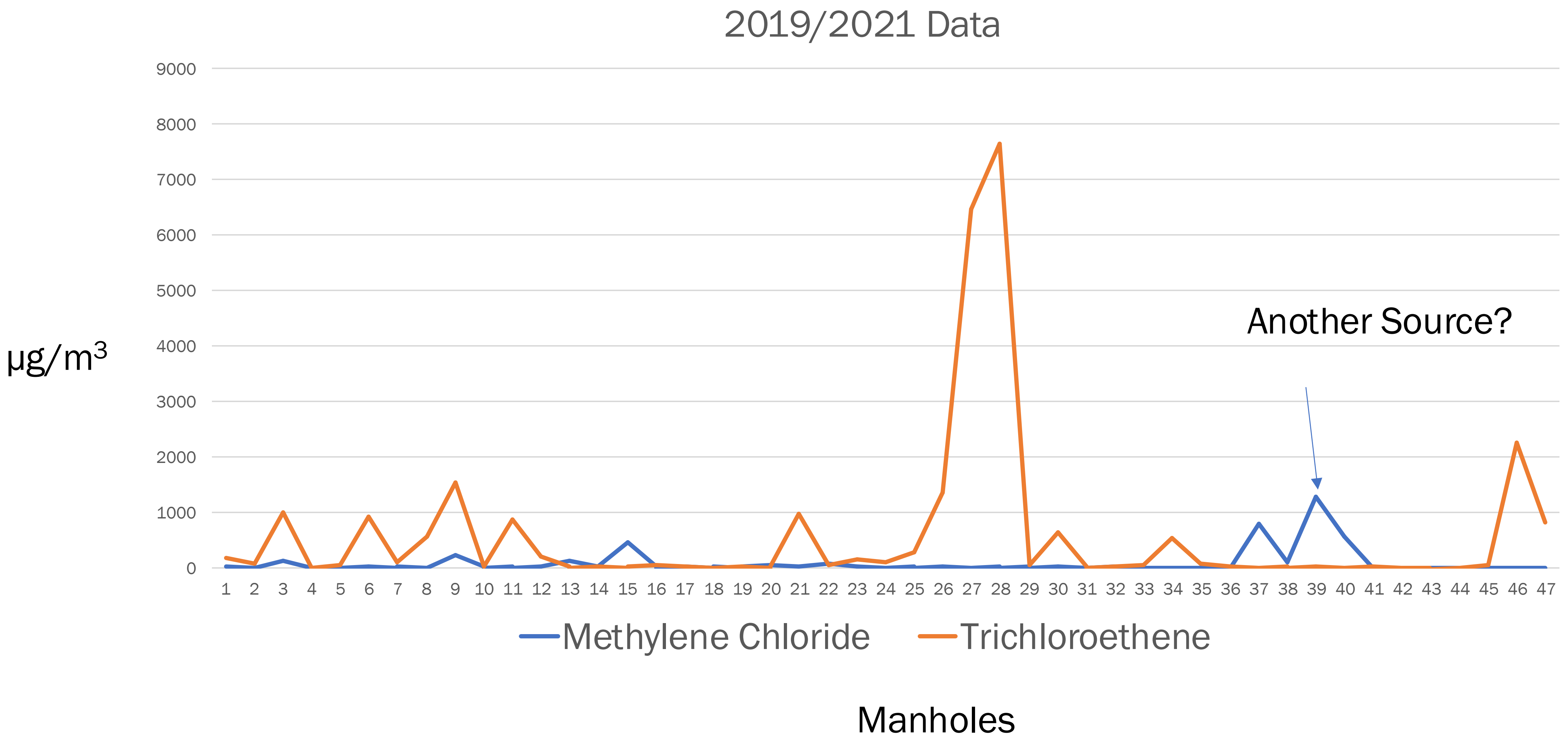
ID	Sample Type	Duration (Days)	Date/End Date	TCE µg/m3
86	P	6	11/22/22	2.68
86	C	G	11/16/22	0.64 J
87	P	6	11/22/22	8.24
87	C	G	11/16/22	0.46 J
88	P	6	11/22/22	4.59
88	C	G	11/16/22	<0.45
89	P	6	11/22/22	0.065 J
89	C	G	11/16/22	0.46 J
111	C	G	1/26/23	<10.7
111	P	7	1/26/23	<31.9
112	C	G	1/26/23	<10.7
112	P	7	1/26/23	<31.9
245	P	7	11/3/23	230
245	C	G	10/27/23	110
248	P	7	11/3/23	300
248	C	G	10/26/23	130

Storm Sewer Manholes - Vapor



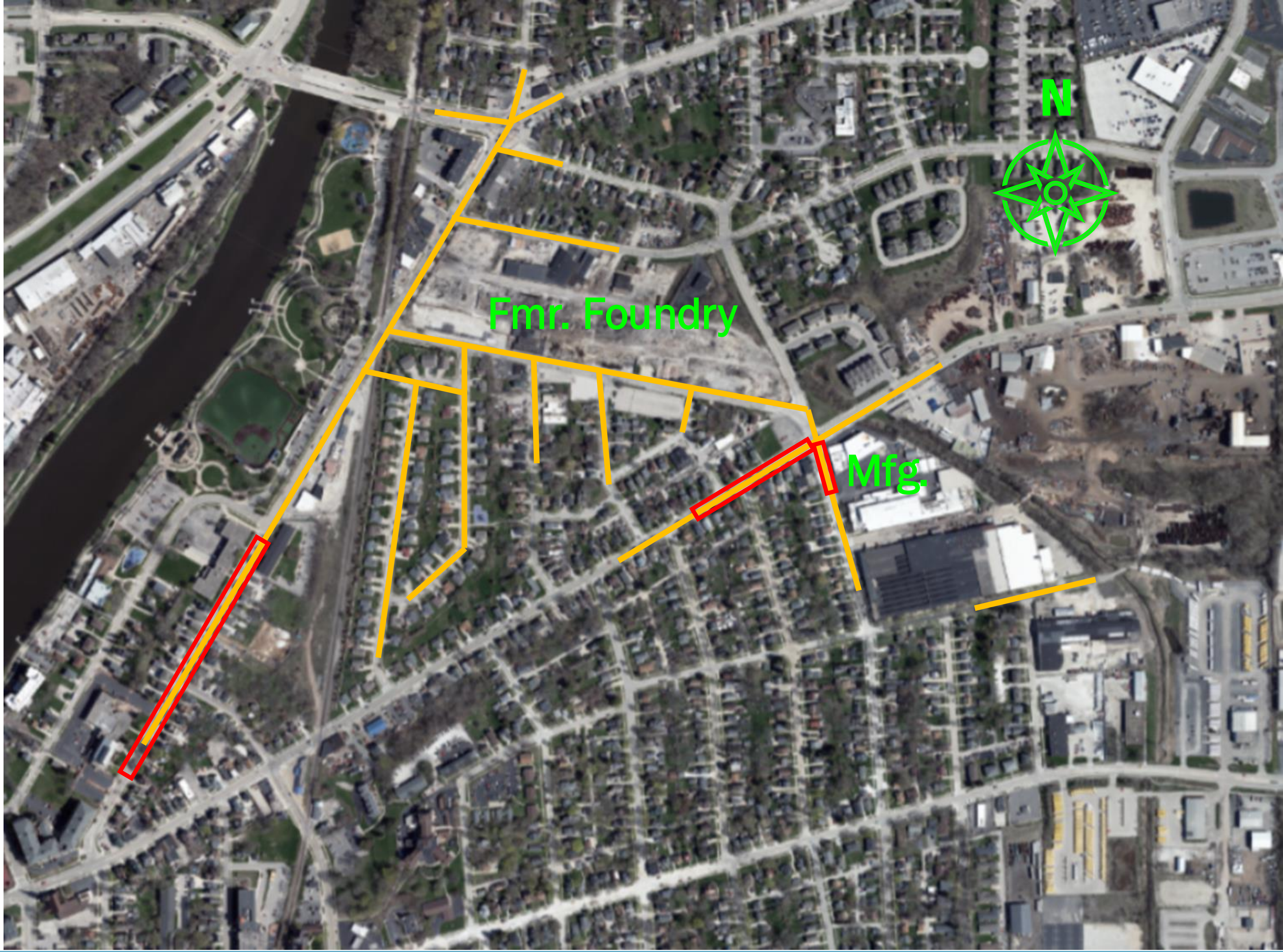
Manholes 1-3 Two Dry Cleaner Sites; Manholes 4-24 Six Manf. Sites)

Other Compounds



Site A Investigation

State Funded Sewer Investigation (fall 2023)



Sanitary Sewer Manholes

Passive Soil Gas

Investigation Details

65 Manholes & Apt. Bldg. COs: TCE with Gas Chromatograph

13 MH WMS passive

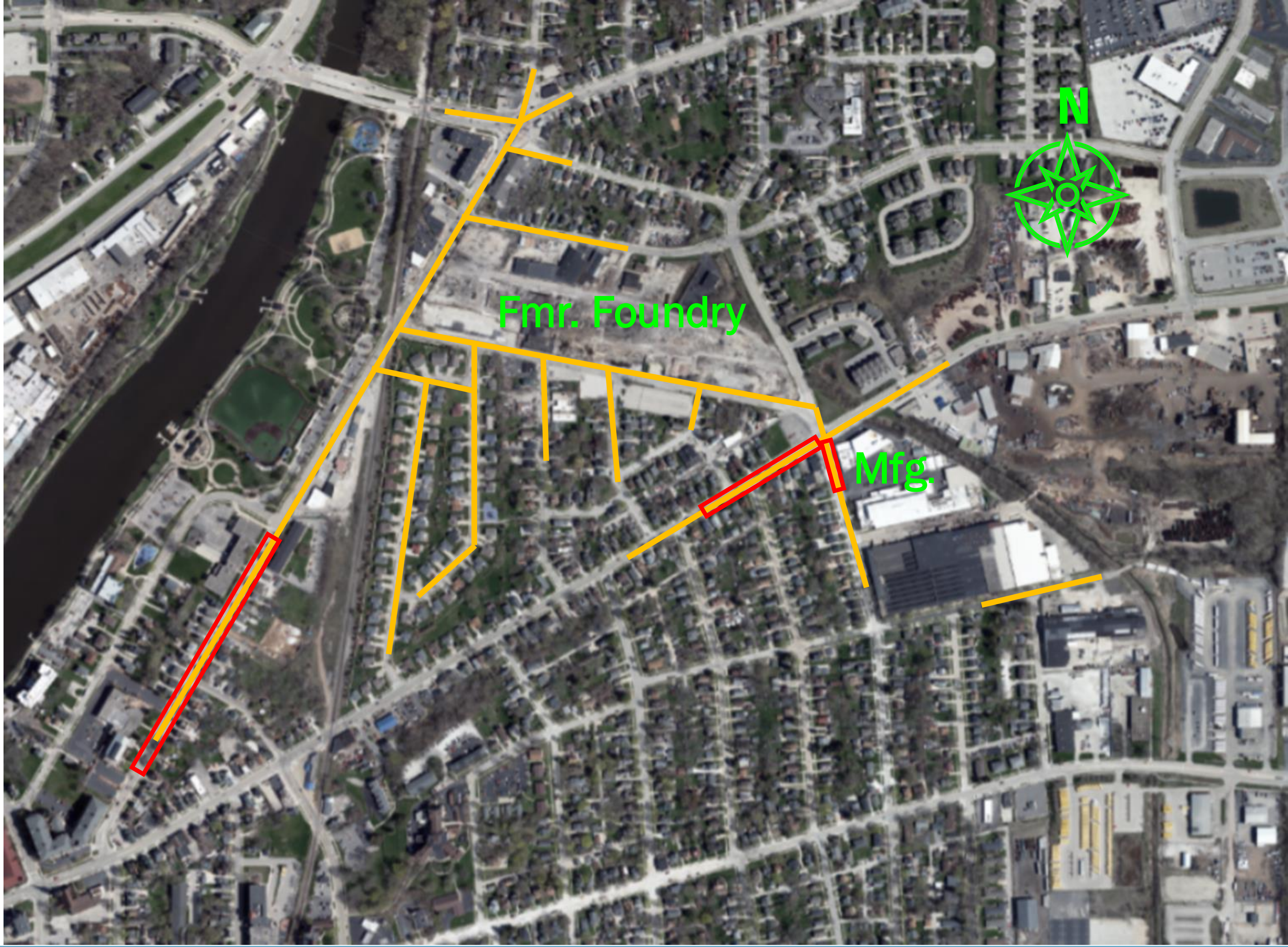
5 MH Beacon passive

7 Day duration

8 MH Liquid sample

30 Beacon passive soil gas samples (3’ deep)

11 Day duration



Passive & Grab Comparison Sanitary Sewer MHs

All TCE in µg/m3

NS = not sampled

Passive samplers 7-day duration

Grab sample collected on first day of passive sampling

Location ID	Beacon	WMS	Grab GC
196	<3	<1.9	1.2
197	86	200	47
200	NS	740	1.4
209	19.5	70	<1.0
213	NS	210	5.3
214	NS	520	3.8
215	NS	420	<1.0
216	941	450	1.4
218	NS	450	<1.0
222	NS	7	3.7
234	811	1,600	87
236	NS	1,300	92
237	NS	390	21

Site B Investigation

CVOC Air Concentrations
Sanitary Sewer Manholes (µg/m³)

	PCE	TCE
Beacon	22,600	1,240
WMS	33,000	350

PCE	TCE
42	6
230	50

PCE	TCE
4620	324

Former Dry Cleaner

PCE	TCE
765	155

Laterals

Sanitary Sewer Main & Flow

Not To Scale

PCE	TCE
545	53
990	45

PCE	TCE
12	1

PCE	TCE
714	83

Manhole

N

- 11-day duration, passive
- Residential Sanitary Sewer Gas Screening Level = 1,400 PCE, 70 TCE

State Funded Sewer Sampling Costs (2023)

Site #	1	2	3	4	5	6	7	8
# MHs	3	5	3	2	5	7	61	7
$/MH	4499	2434	1400	1250	1793	1045	975	2000

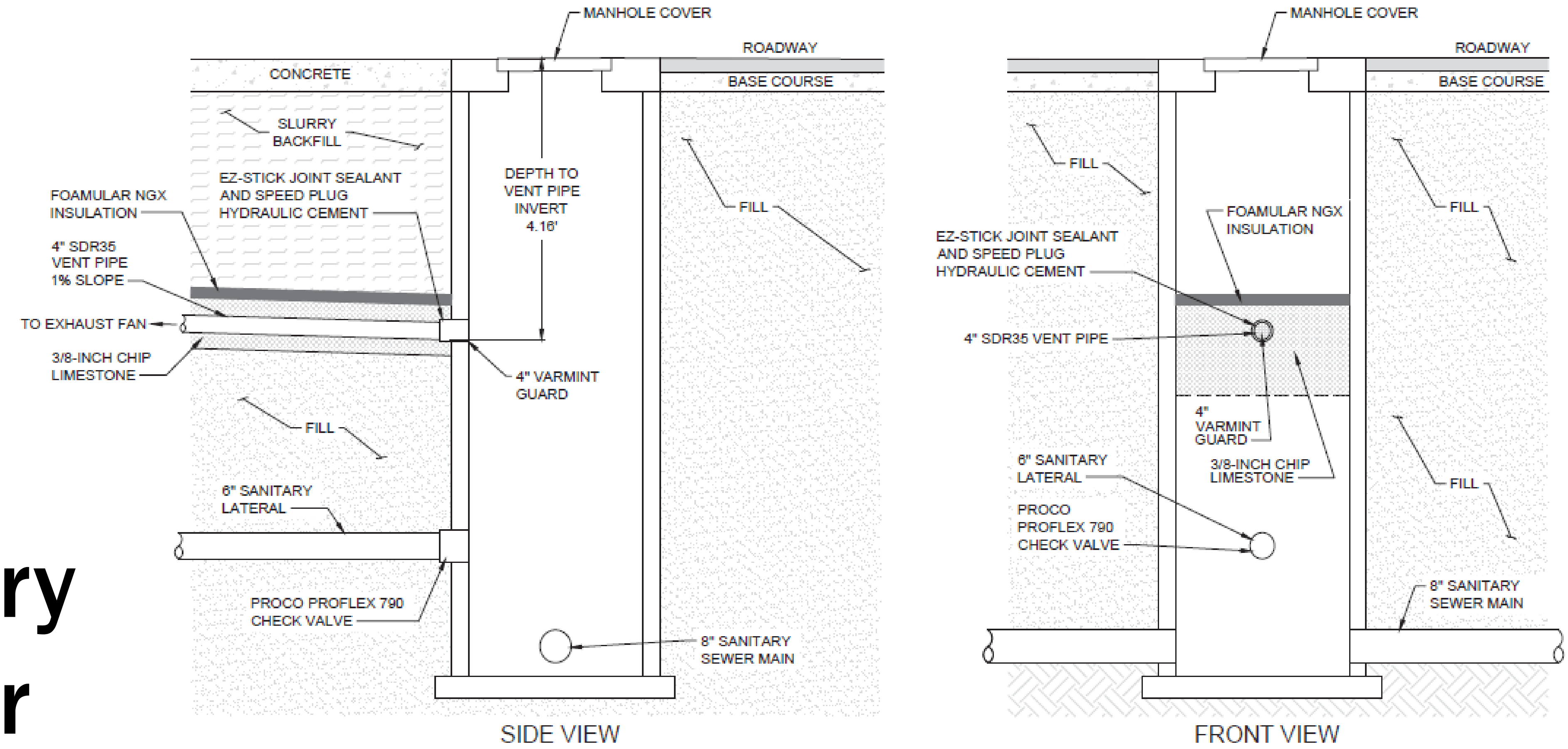
All passive sampling except site 7 which was grab sampling at 61 MHs and passive sampling at 13 MHs

* Includes all costs: samplers, professional services, permits, traffic control, reporting, travel

Conduit Mitigation Options

- Address Plumbing Deficiencies: dried out p-traps, wax rings
- One-way valves
- Seal sumps
- Line, replace, or re-locate conduits
- Gas trap siphons
- Ventilate sumps, indoor plumbing, sewer manholes

Sanitary Sewer Manhole Ventilation



1 / A-3 DETAIL
MH-5175 MANHOLE CONNECTION
NTS

ENGINEER:
Geosyntec consultants

130 STONE RD WEST
GUELPH, ON
N1G 3Z2

Takeaways

- Conduit sampling has increased substantially in Wisconsin following publication of RR-649.
  - Percentage of chlorinated sites where conduit vapor samples collected is still small.

- Unsealed sumps and other conduits in both manufacturing and dry cleaner source buildings often have significant TCE and PCE concentrations and pose a potential risk to indoor air.

Takeaways

- The limited paired vapor sampling of sanitary sewer main and connected building plumbing collected to date are insufficient to draw conclusions regarding vapor attenuation from sewer mains.

- Contaminated groundwater penetration is a major risk factor.

- Longer duration passive sorbent sampling within sewer mains provides more representative results than grab samples.

Takeaways

- Sanitary sewers downflow from manufacturing properties have often had vapor concentrations exceeding the screening criterion for TCE, sometimes extending thousands of feet. Investigations are increasingly moving into buildings connected to those sewers and found concentrations over 400 µg/m^3 in building plumbing cleanouts.

- Development of best practices are needed for sampling, mitigating, and maintaining protections over the long-term.

- Nationwide sharing of data from conduits and incorporation into a single data base would assist development of more robust screening criteria.

References

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