Vapor Intrusion (VI)

Regulatory Status
Assessment Challenges
Mitigation Options

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EPAZ Gatekeeper Regulatory Roundup
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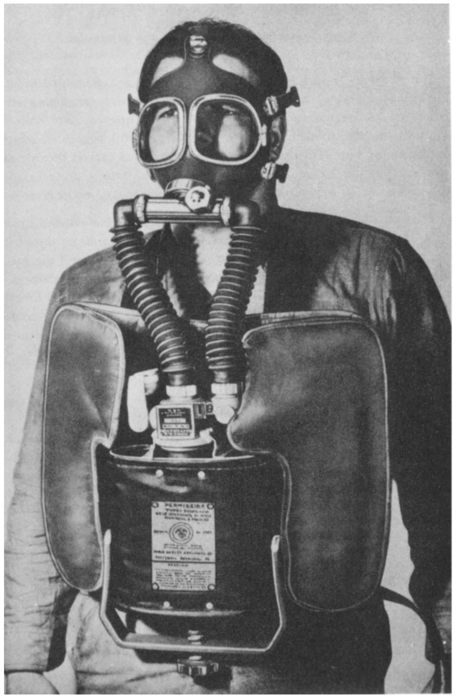
Topics

- Why is VI so Problematic?
- Overview of Federal and State VI Guidance
- Assessment Challenges and Solutions
- Mitigation Options

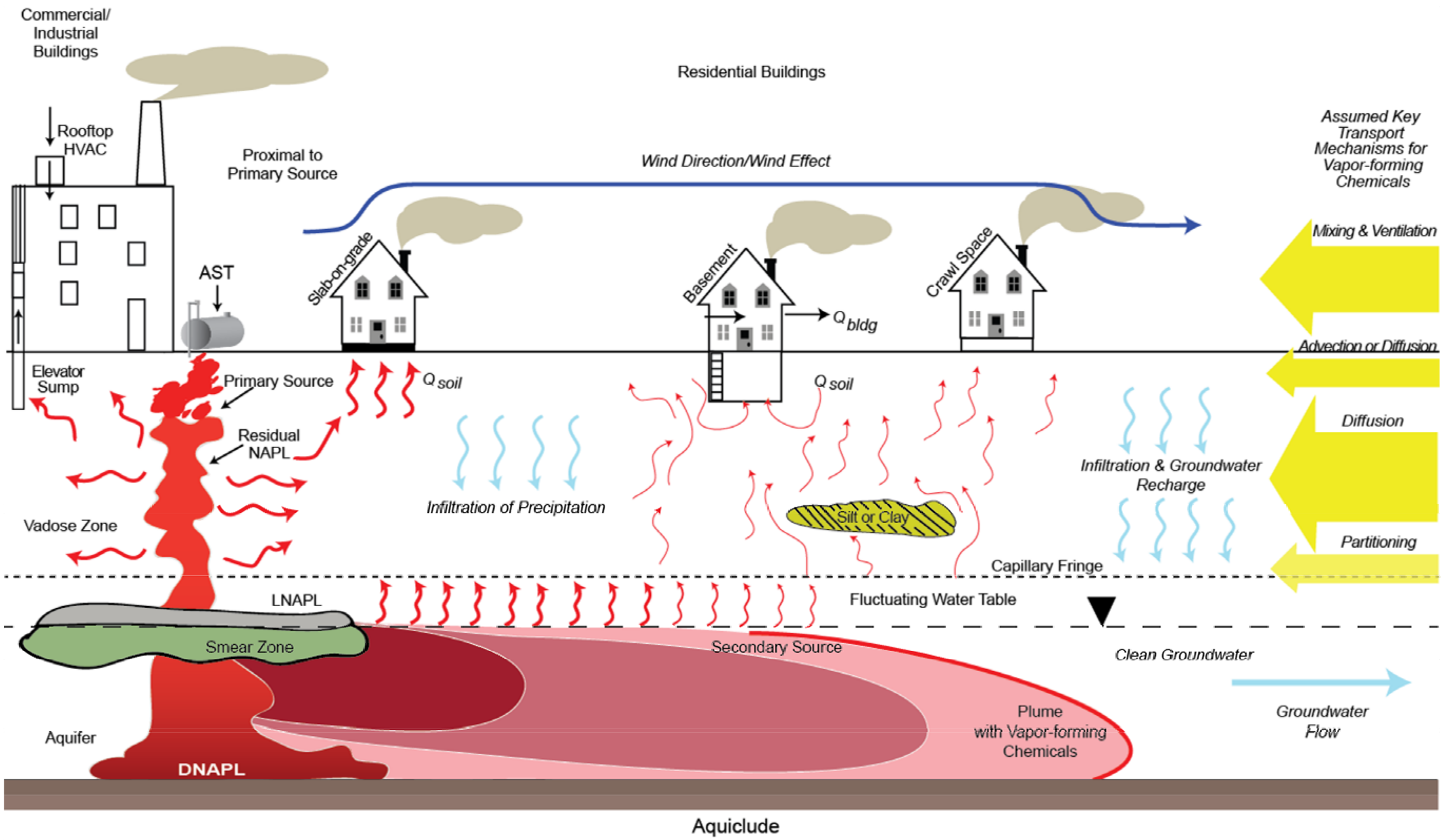
Why is VI so Problematic?

- Volatile organic chemicals (VOCs) of concern are common
  - Chlorinated solvents and petroleum hydrocarbons
- Human health risk through inhalation exposures
  - 20,000 liters/day vs 2 liters/day water ingestion
- Long term chronic exposure
  - People spend most of their lives indoors
- Not practicable to provide alternative air



Why is VI so Problematic?

- Technically complex and challenging



Additional Challenges

- Historically inconsistent interpretation and application of guidance.
- Low risk-based target concentrations of VOCs in soil and groundwater.
- Not so low background contributions to indoor air (household products).
- Sensitive subject for many stakeholders.
- Short-term action levels for TCE.

Legal Implications

- Leads to Re-opening of Closed Sites
- Real Estate Transactions are Complicated
  - ASTM E-2600-10 / ASTM E1527 (includes VI eval)
- Toxic Tort Suits
  - Bodily injury
  - Property devaluation
- Risk Communication is Difficult

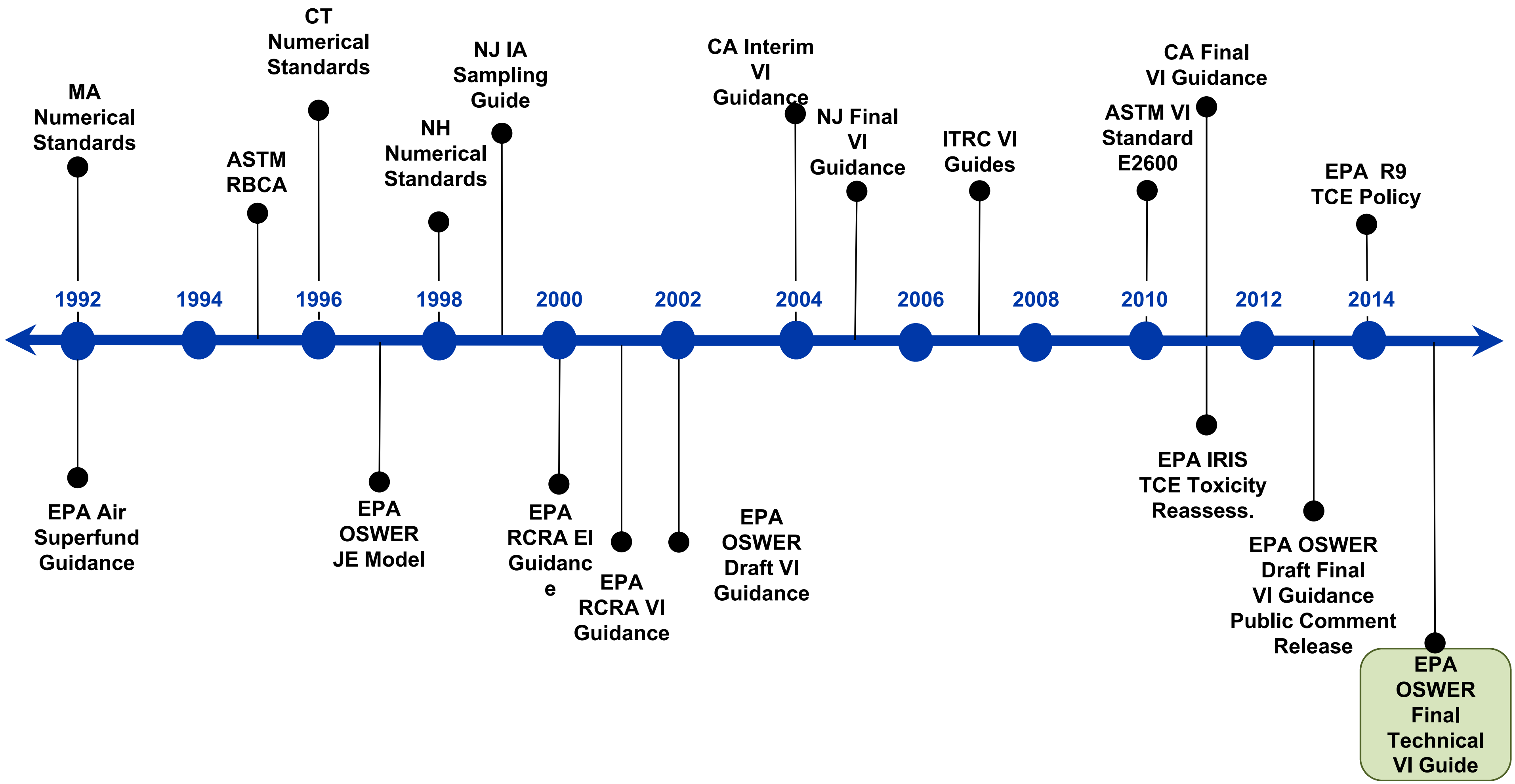
Status of Federal and State VI Guidance

Historic (?) Moving Target

Timeline of TCE Toxicity Assessment

- 1985 – EPA posts TCE health assessment in IRIS
- 1989 – Withdrawn from IRIS
- 2001 – Draft EPA TCE health assessment for review
- 2006 – NRC review report
- 2009 – Revised draft EPA TCE toxicity review
- 2011 – EPA posts revised TCE health assessment in IRIS
  - Identified non-cancer effects (including developmental effects)
  - Controversy regarding developmental effects
  - Significant implications for VI assessment and mitigation
- 2014 – EPA R9 Interim Policy
- 2015 – EPA Final Technical VI Guidance

Vapor Intrusion Guidance Timeline



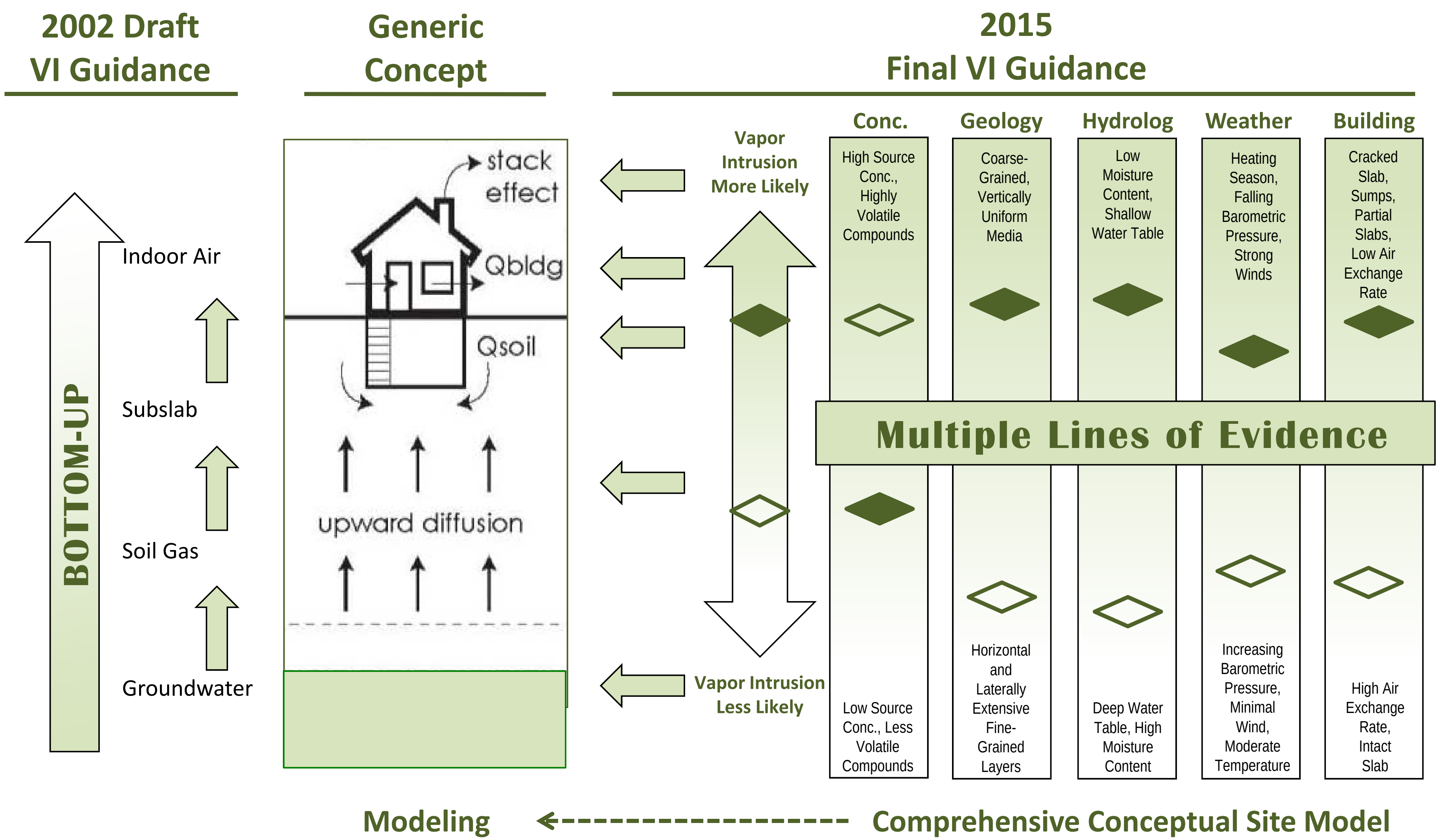
Final USEPA VI Guidance (2015) – Key Recommendations & Implications

- Multiple Lines of Evidence
- Vapor intrusion “lateral inclusion” zone
- Preferential pathways
- VI Pathway Sampling
  - Soil vapor
  - Sub-slab soil vapor
  - Indoor air
- Background Sources

Final USEPA VI Guidance (2015) – Key Recommendations & Implications

- Generic Attenuation Factors
- Risk-Based Screening Levels
- Short Term TCE Exposures
- Non-Residential Settings
- Petroleum Hydrocarbons

Multiple Lines of Evidence



Final USEPA VI Guidance (2015) – Preferential Pathways

- Significant preferential vapor migration routes
- May result in higher than anticipated impacts in overlying buildings (or in buildings not directly over contamination)

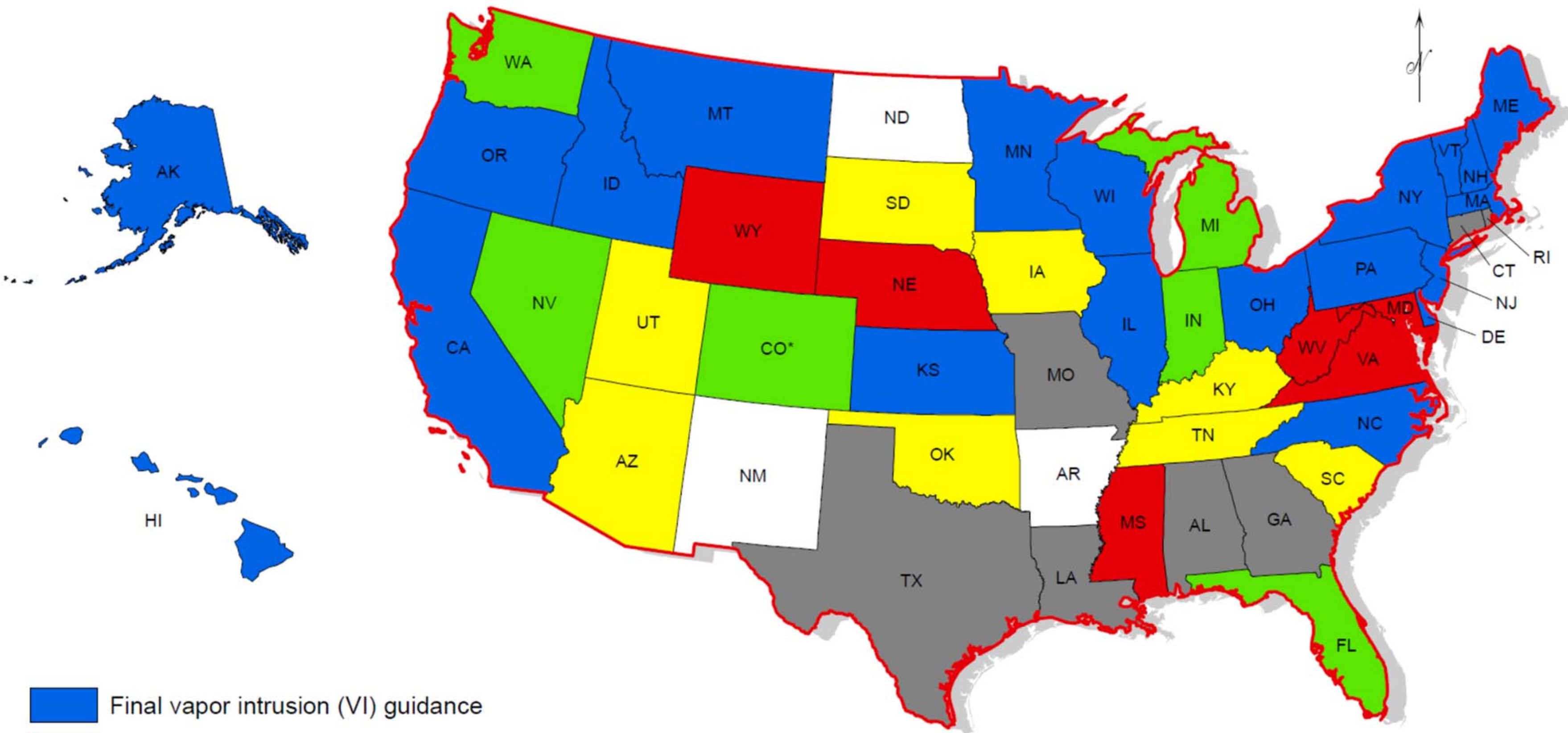
Final USEPA VI Guidance (2015) – VI Pathway Sampling

- Soil vapor: Valid and useful line of evidence. EPA recommends sampling multiple locations and depth intervals.

- Sub-slab: EPA recommends multiple sub-slab vapor samples per building and measurement of sub-slab to building pressure differential

- Indoor air: EPA recommends multiple sampling rounds to address temporal variability.

Status of State VI Guidance/Rule



- Final vapor intrusion (VI) guidance
- Draft VI guidance (NV and FL internal drafts)
- VI pathway included in risk-based regulations but limited or no VI guidance
- VI addressed through voluntary cleanup program guidance or fact sheets
- Petroleum VI guidance through leaking UST program
- No VI or PVI regulations or guidance

VI Assessment Challenges

Alligator Wrestling?

How Do We Assess the VI Pathway?

General Approach

- Groundwater sampling
- Soil gas sampling
- Sub-slab sampling
- Indoor air sampling
- Compare to screening levels

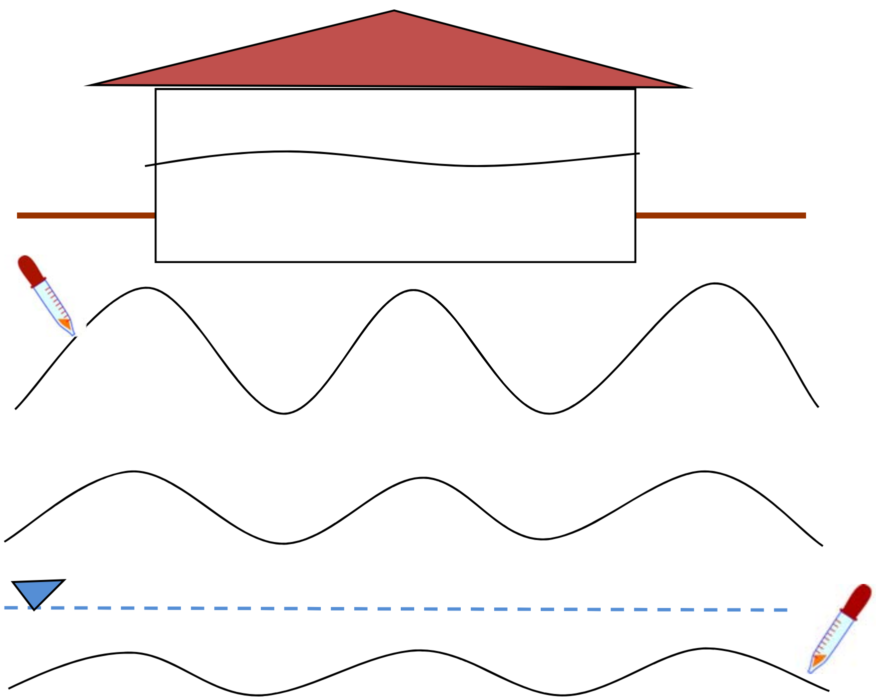
Geosyntec Advantages

- Develop a conceptual model
- Select appropriate lines of evidence
- Develop site-specific screening levels
- Negotiate regulatory approval
- Provide robust documentation

Spatial & Temporal Variability

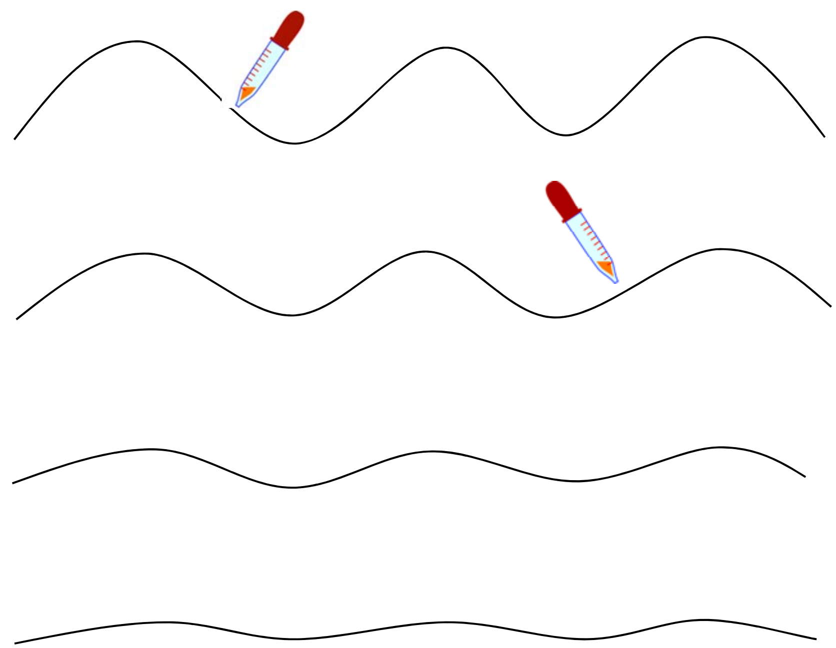
- Variability is inherent in all media along the VI pathway.

Spatial Variability



Integrate over space (volume)

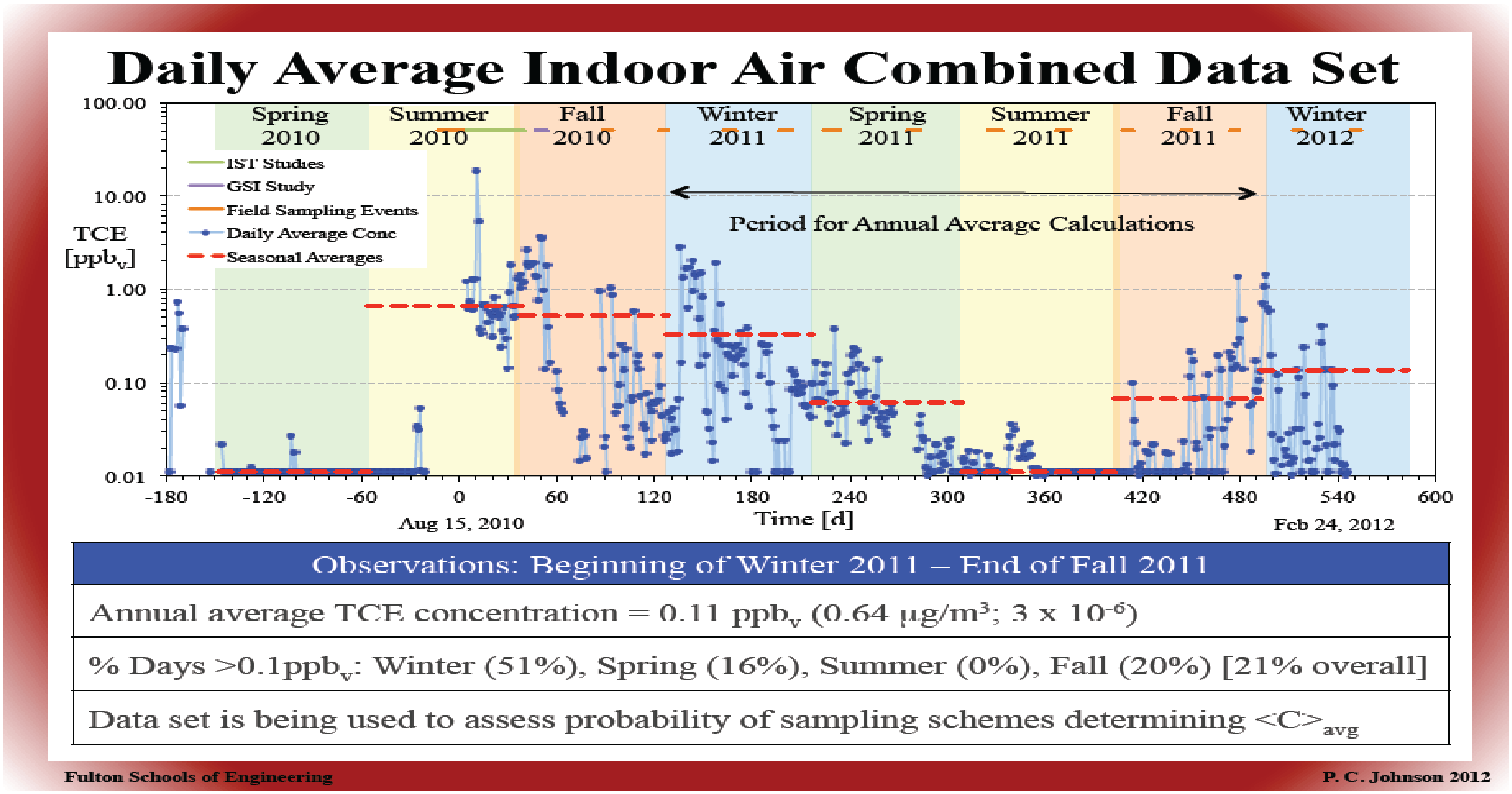
Temporal Variability



Integrate over time

Observed Temporal Variability in Indoor Air

Continuous monitoring results (24-hour average) for house over a TCE Plume.
Hill AFB, Utah (Johnson et al, 2012)



How many samples do we need to estimate the long term mean?

How long a sample duration do we need to minimize risk of missing peaks that dominate average exposure?

Do we need continuous monitoring?

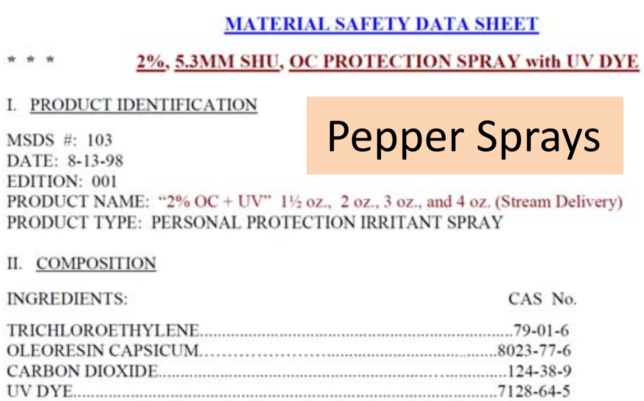
Background Sources of VOCs

Indoor air testing, preferred by EPA, is not a panacea

- Confounded by background sources of chemicals, e.g., consumer products
- TCE found in…

Gun Cleaners

Degreasers



MATERIAL SAFETY DATA SHEET

* * * 2%, 5.3MM SHU, OC PROTECTION SPRAY with UV DYE

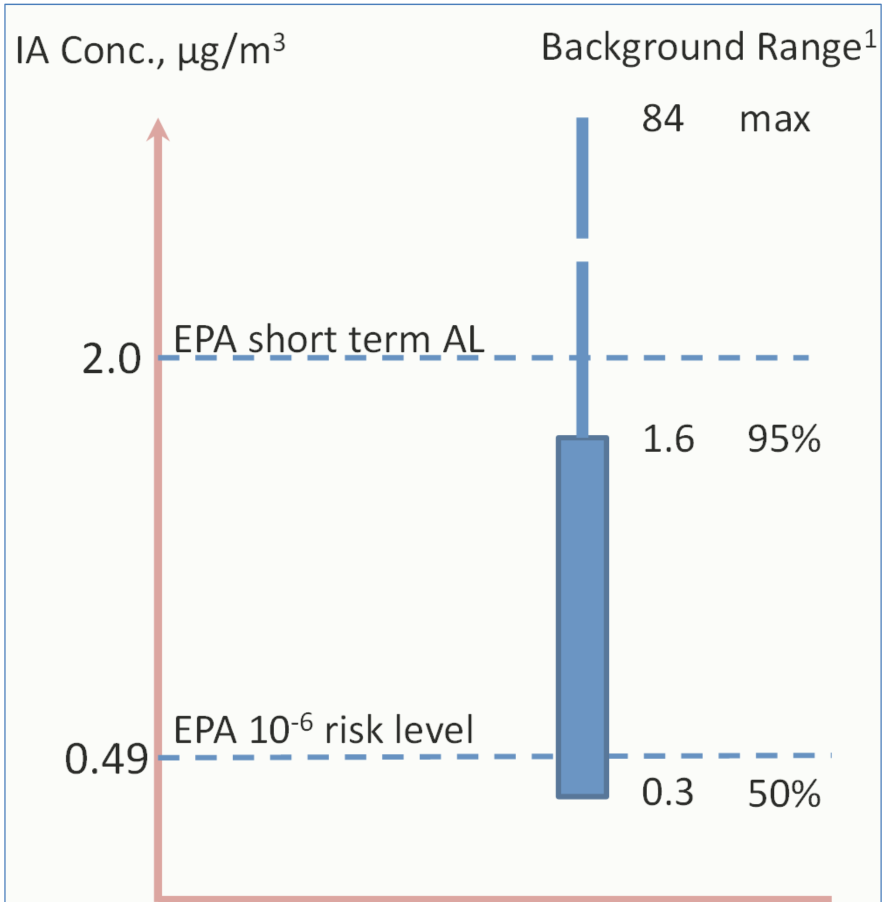
I. PRODUCT IDENTIFICATION

MSDS #: 103
DATE: 8-13-98
EDITION: 001
PRODUCT NAME: "2% OC + UV" 1½ oz., 2 oz., 3 oz., and 4 oz. (Stream Delivery)
PRODUCT TYPE: PERSONAL PROTECTION IRRITANT SPRAY

II. COMPOSITION

INGREDIENTS:	CAS No.
TRICHLOROETHYLENE	79-01-6
OLEORESIN CAPSICUM	8023-77-6
CARBON DIOXIDE	124-38-9
UV DYE	7128-64-5

Pepper Sprays



Background levels in the same range as IA screening levels

[1] Dawson & McAlary, 2009

Challenges → Innovative Solutions

- Temporal Variability
  - Long-Term Passive Sampling
  - Real-Time Monitoring
  - Mass-Flux Monitoring, Building Pressure Cycling
- Spatial Variability
  - High Volume Sampling
  - Multi-Increment® Sampling
- Background Sources
  - Comparison to Typical Indoor Air Data
  - Compound-Ratio Analysis
  - Portable Mass Spectrometers
  - Building Pressure Cycling
- Preferential Pathways
  - Pneumatic Testing and Leakance Analysis
  - Mass-Flux Monitoring

Passive Sampling

ATD Tubes

3M OVM 3500

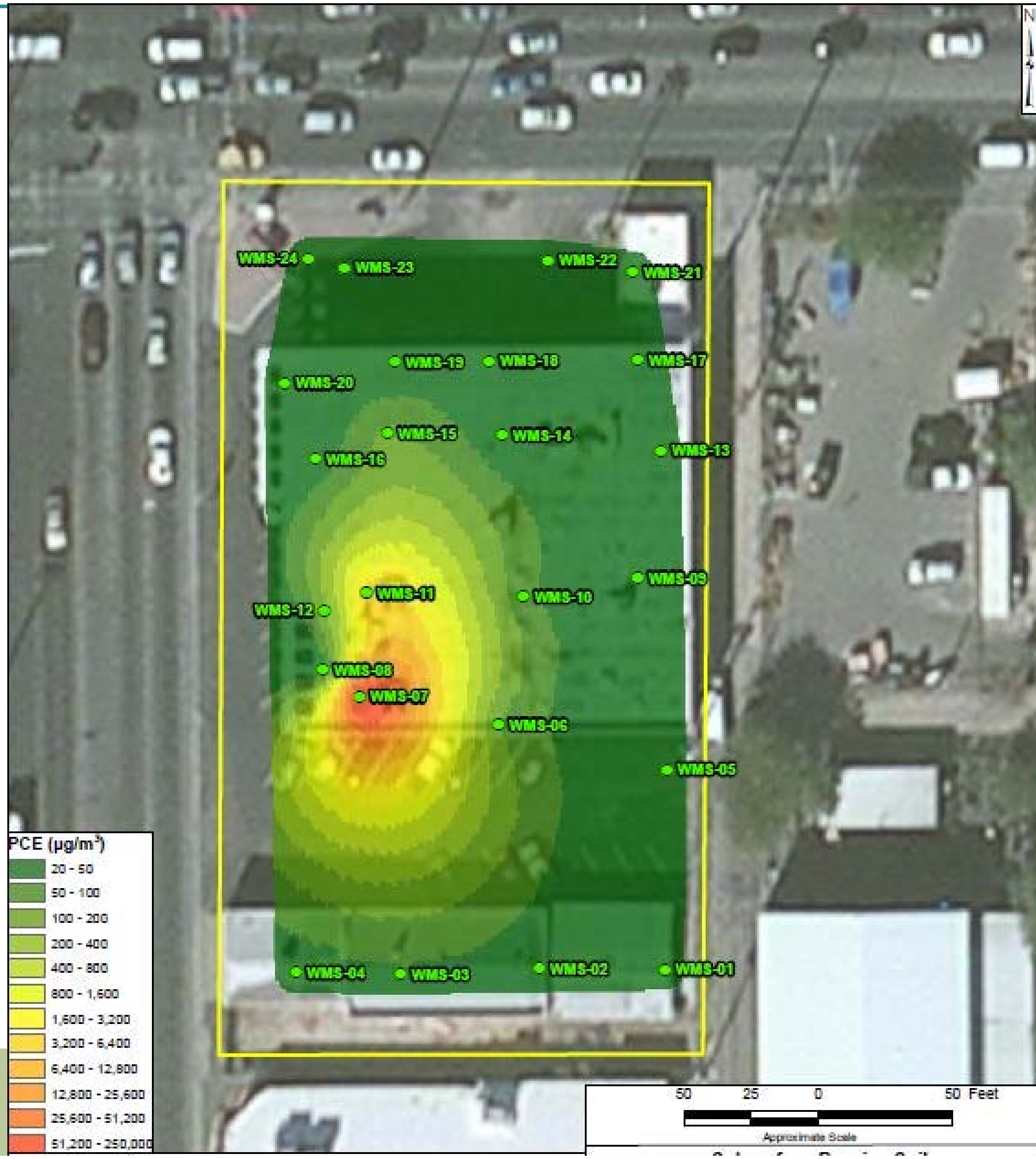
- More cost effective
- Longer term sampling duration
- Greater range of compounds

SKC Ultra II

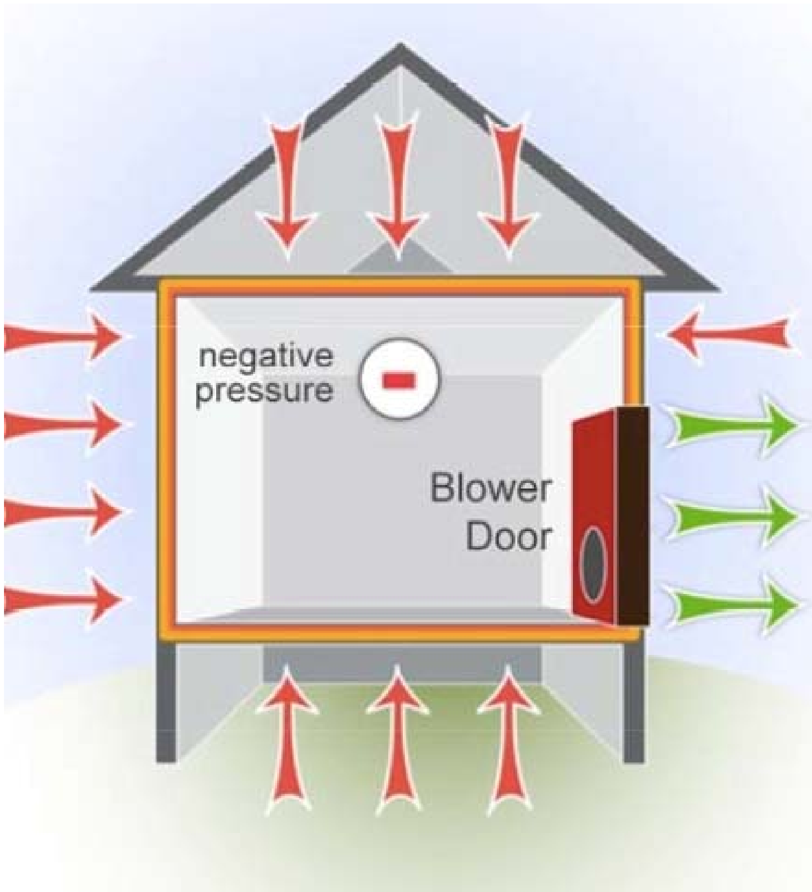
Radiello™

Waterloo Membrane Sampler™

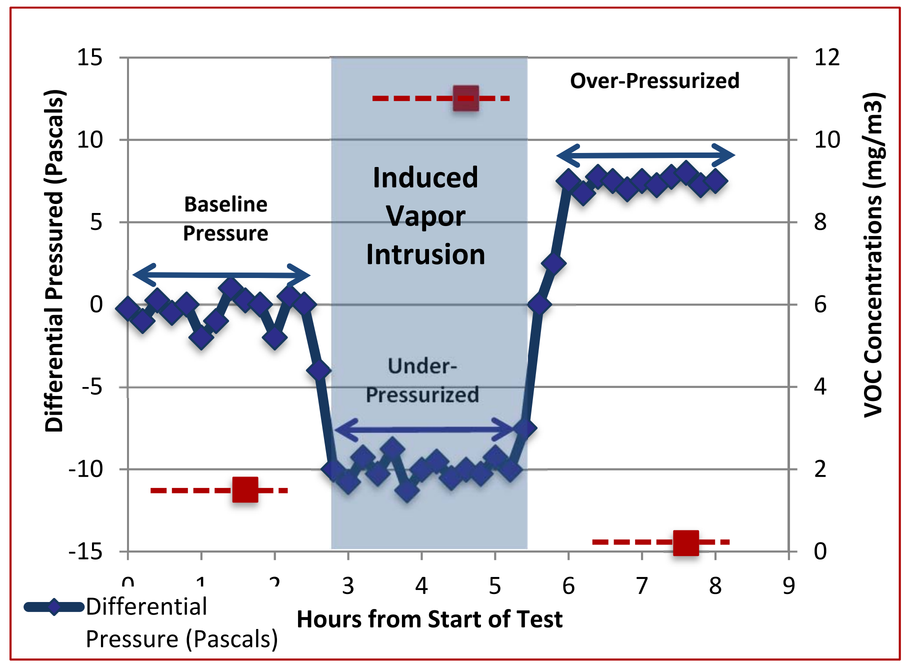
Passive Sampling



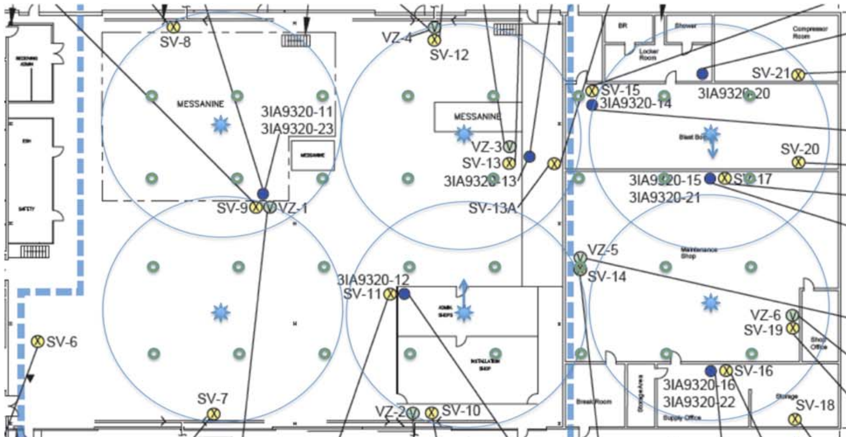
Building Pressure Cycling

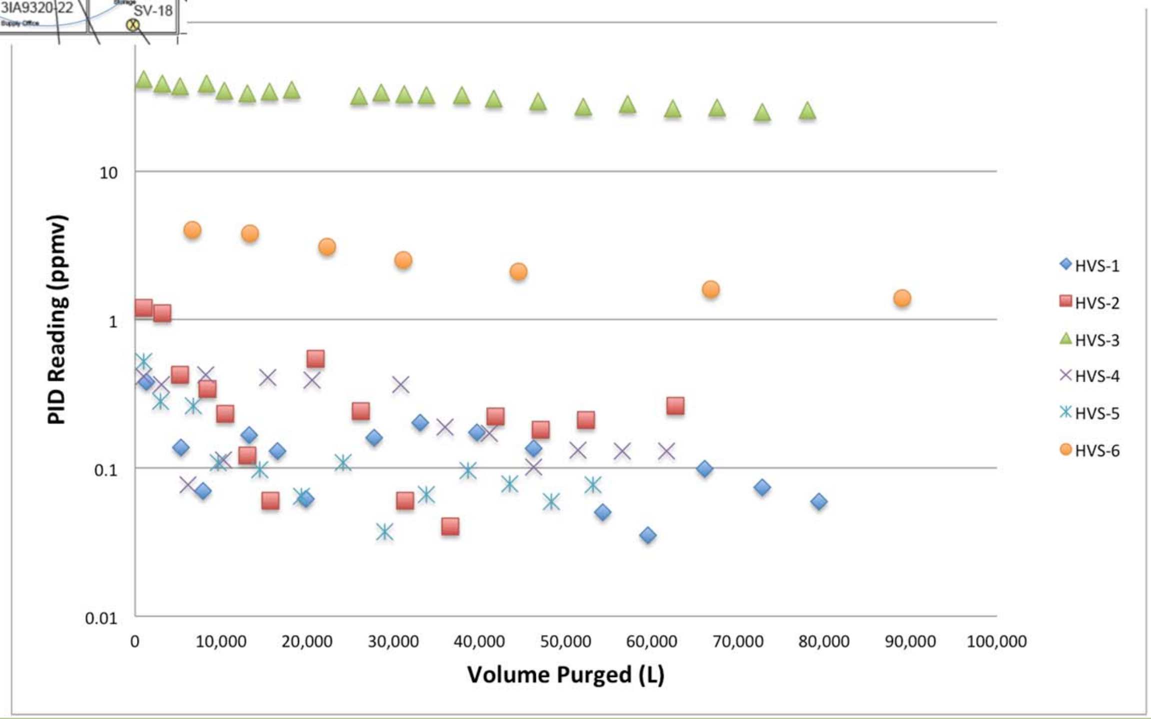


- Negative pressure: induces vapor intrusion
- Positive pressure: inhibits vapor intrusion
- For large commercial buildings, HVAC system can be adjusted to create pressure and vacuum conditions.



High Volume Sampling

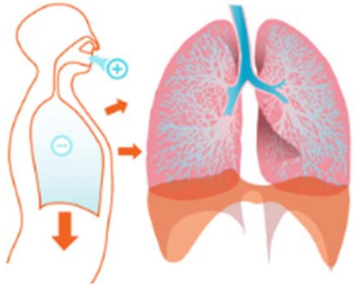




High Volume Sampling – Representative Volume

Inhalation = 20,000 L/day x 365 d/yr x 30 yr

= 219,000,000 L



Ventilation = 300,000 L x 12/day x 365 d/yr x 30 yr

= 39,000,000,000 L

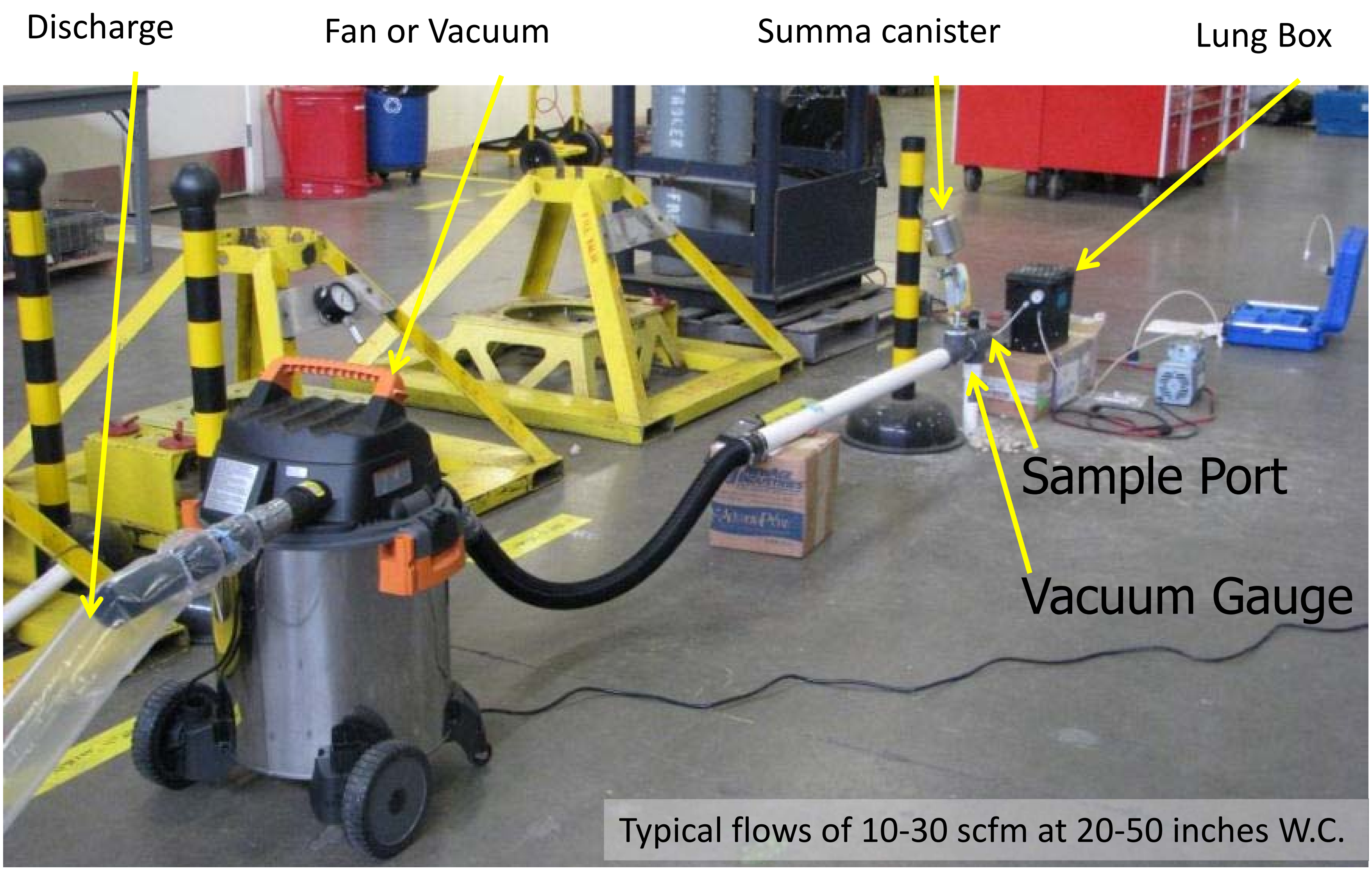
Is a 1 to 6L Summa canister sample "representative"?

What sample volume is the most representative?

High Volume Sampling – Sub-Slab Spatial Variability

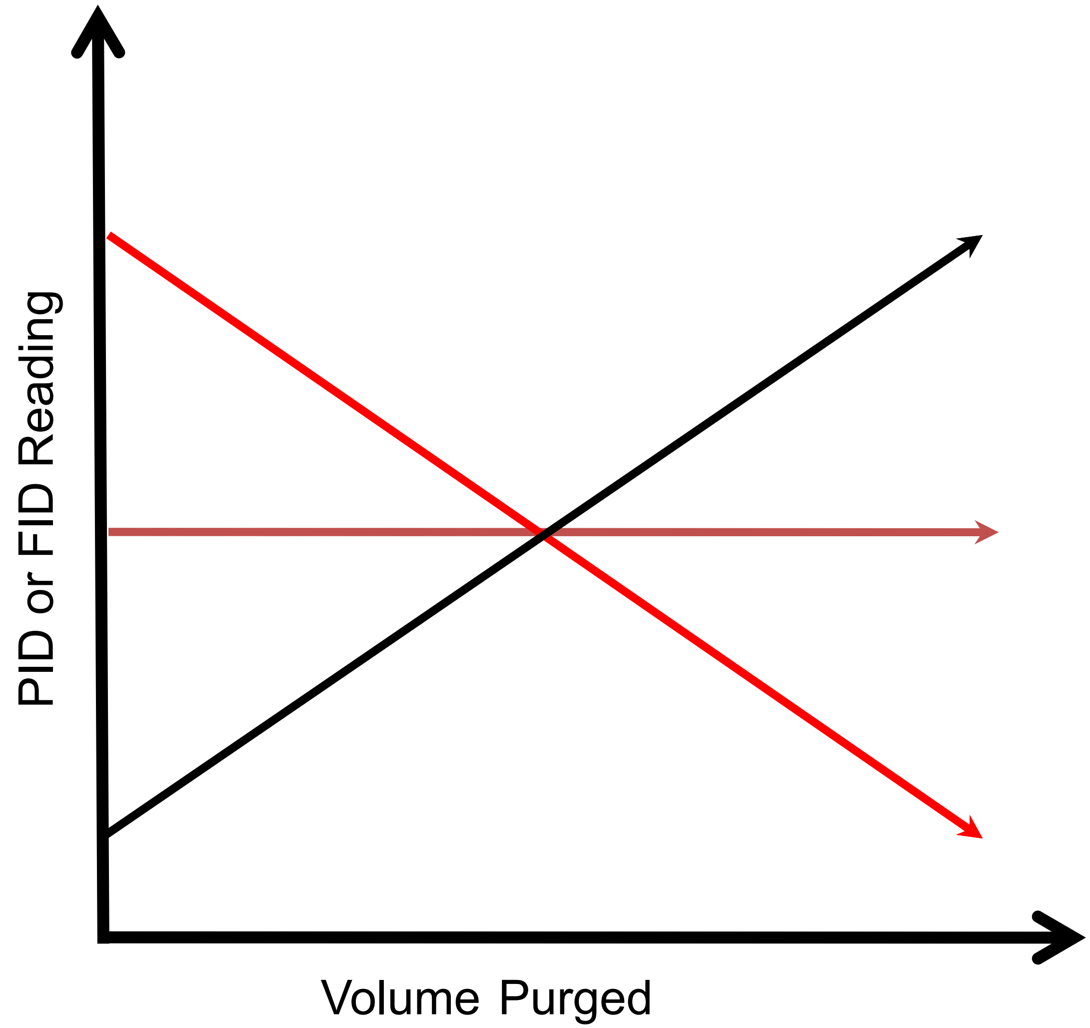
How many sub-slab samples is enough?

High Volume Sampling – Testing Apparatus

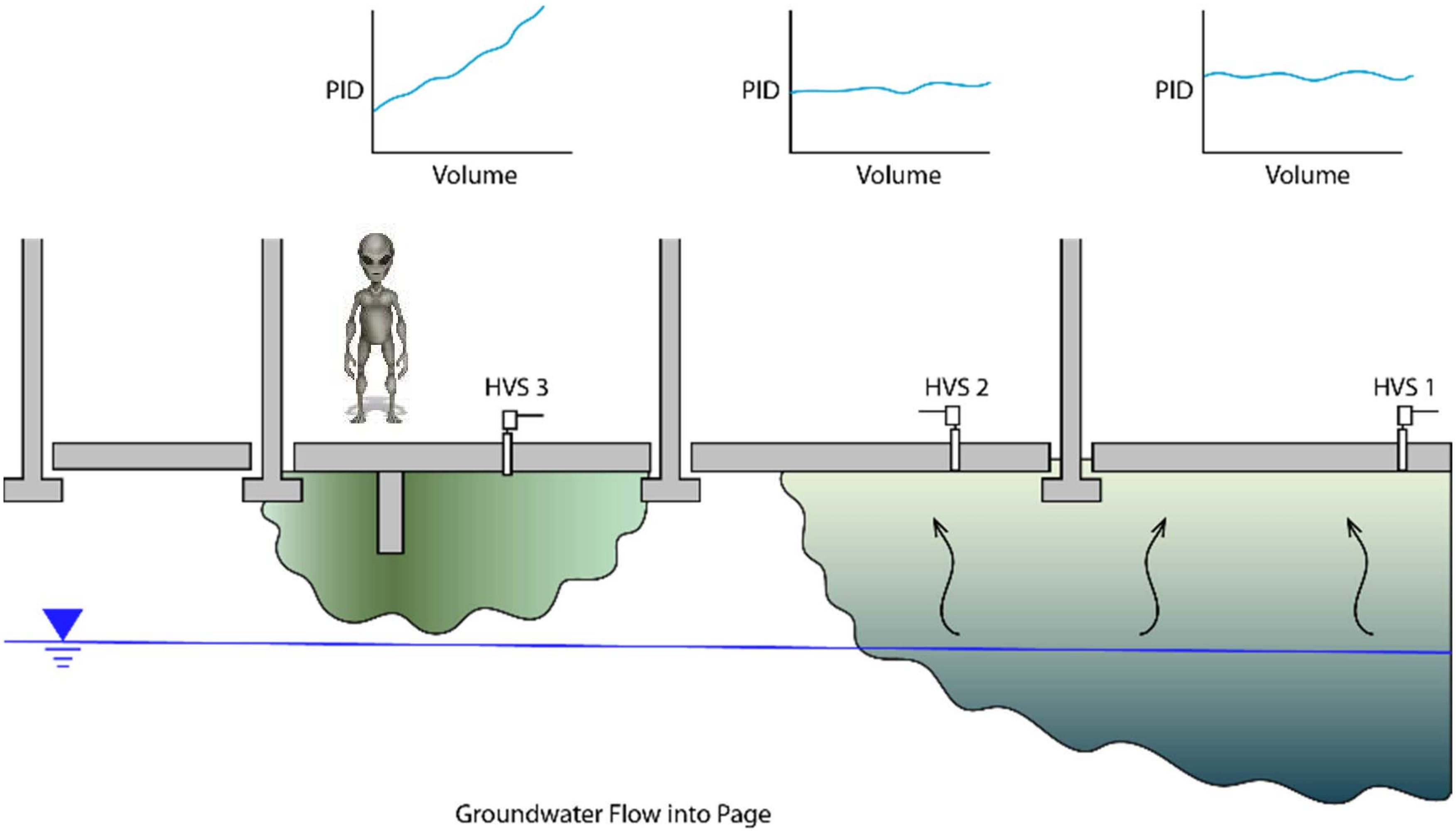


High Volume Sampling – Field Data Analysis

Each trend implies a different CSM



High Volume Sampling – Generalized CSMs



High Volume Sampling – Additional Benefit

Cycle the fan on and off a few times and in just a few minutes, you've got "pump-test" data

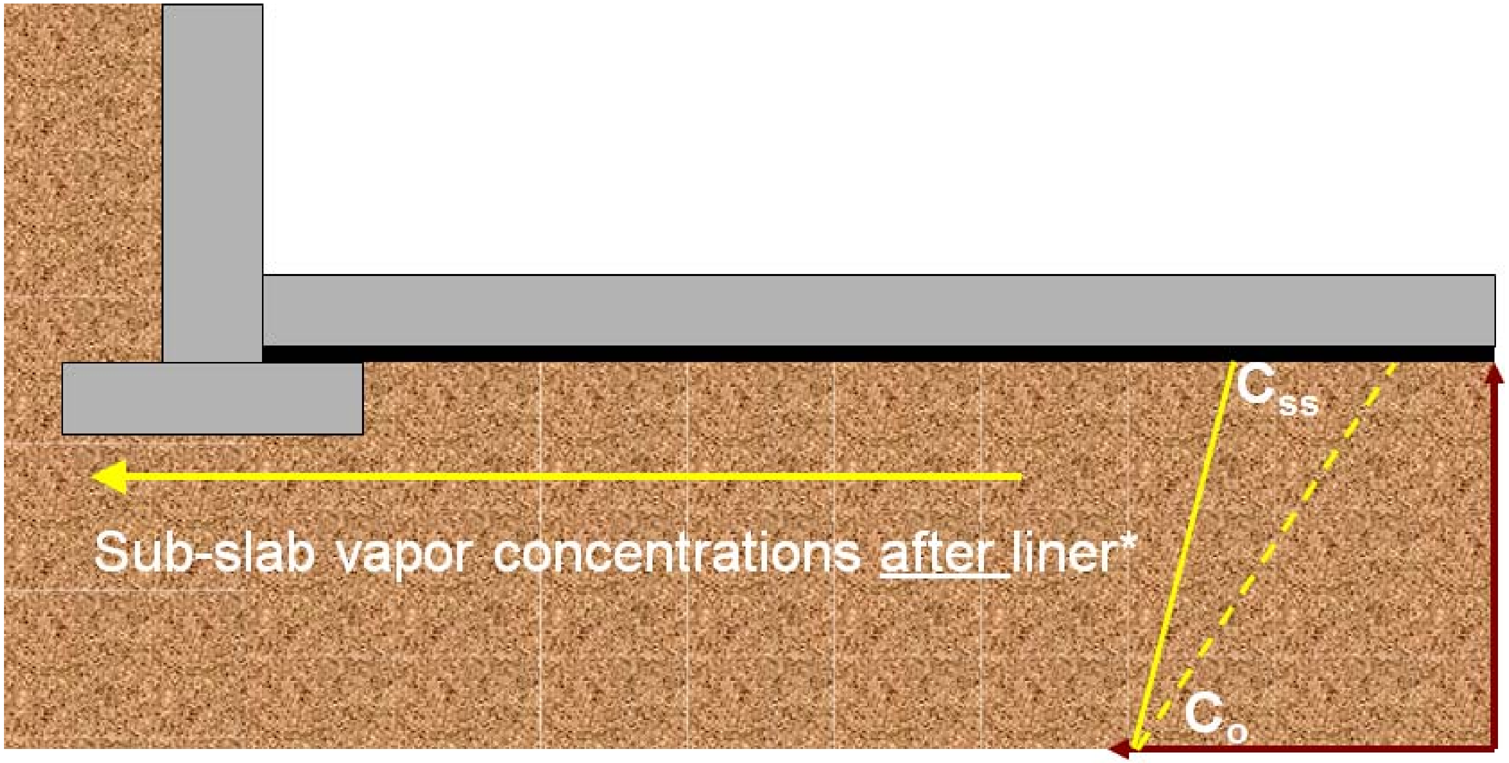
Mitigation Options

Mitigation Options

- **Relocation** (temporary or permanent) 
- **Engineering Controls** (typically temporary)
  - Building Ventilation (minutes - hours)
  - HVAC System Modifications (hours – days)
  - Indoor Air Filtration (hours – weeks)
- **Engineering Controls** (long term)
  - Passive Vapor Barriers (via membranes and seals)
  - Active Sub-Slab Venting or Depressurization
  - Active Aerated Flooring (new construction)
- **Institutional Controls**
  - New construction or building occupancy
  - Intrinsically Safe Building Design

Barrier Concept

- Vapors must diffuse or flow laterally to prevent intrusion through barrier
- Install of an active/passive system in conjunction with barrier is typical approach
- Barrier you select depends on what you are mitigating (e.g. VOCs, methane)



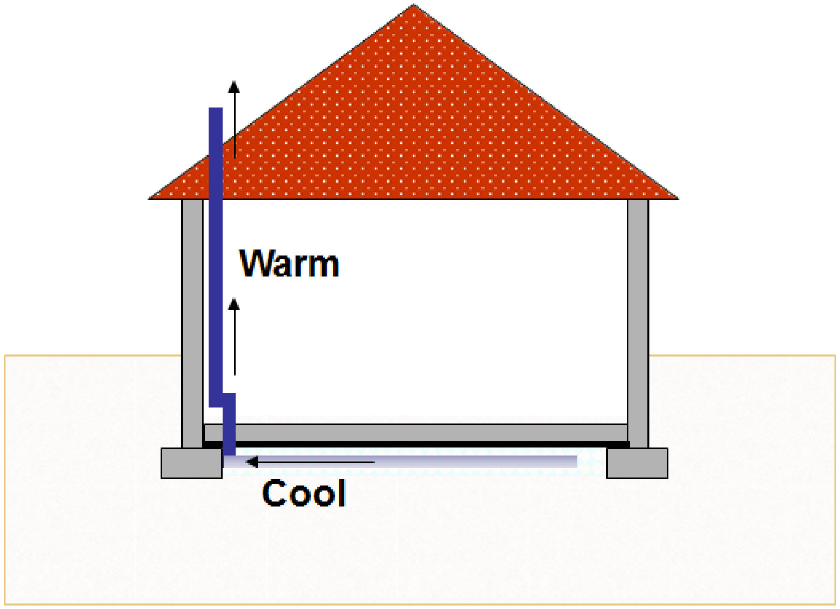
Passive Systems

Includes:

- Sealing floor slab (filling cracks, gaps around piping)
- Pouring concrete over unfinished areas
- Installing vapor barriers, geomembrane or strong plastic
- Installing a venting layer beneath building to promote vapor movement to outdoor ventilation

Approach:

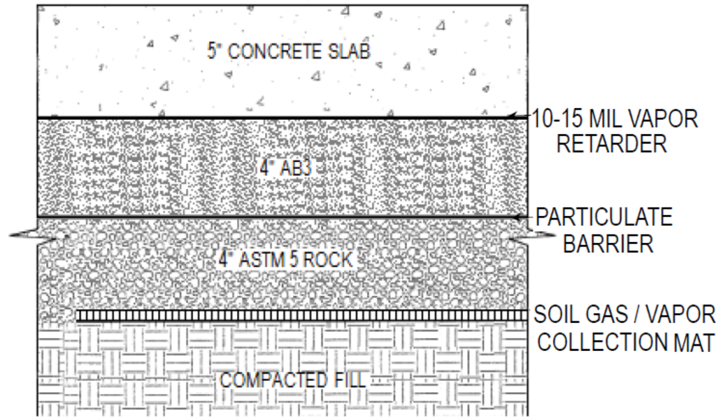
- Relies on diffusion along permeable "venting" layers and/or advection due to thermal gradients and wind
- Typ. 3" riser every 1,500 SF and/or 4" riser every 4,000 SF
- 10 to 50% as effective as active venting



Passive Systems

Pros:

- No grid power, low energy penalty on the building
- Convertible to an active system
- Typically results in lower construction costs
- Perception of lower O&M Cost

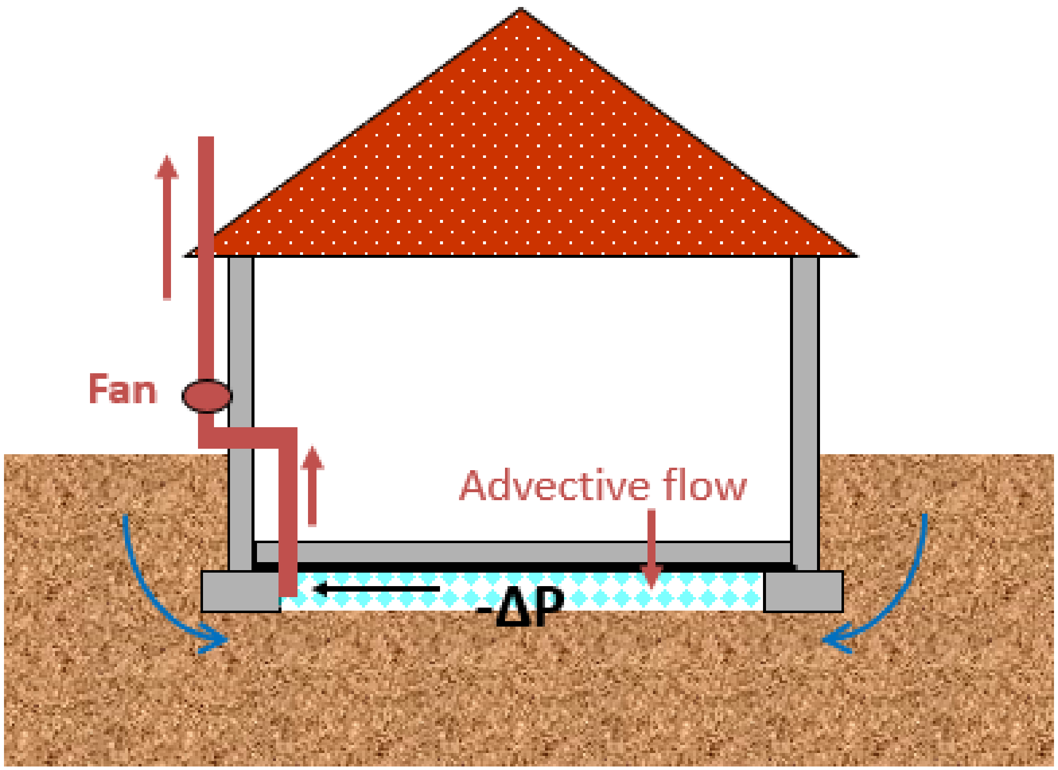


Cons:

- Relies on wind/sun (potentially inconsistent vacuum or dilution)
- Typically results in over-design to meet needs for higher risk VI sites
- Potentially more sampling requirements
- Potential for “dead spots” within building with reduced venting

Active Sub-Slab Depressurization (SSD)

- Most common technology
- Permeable venting layer or perforate pipes placed under vacuum
- Layer creates pressure barrier between source and receptors
- Keeps sub-surface air from flowing through a building slab or sub surface membrane.
- Negative pressure pulls air flow soil and building



Active Sub-Slab Depressurization (SSD)

Pros

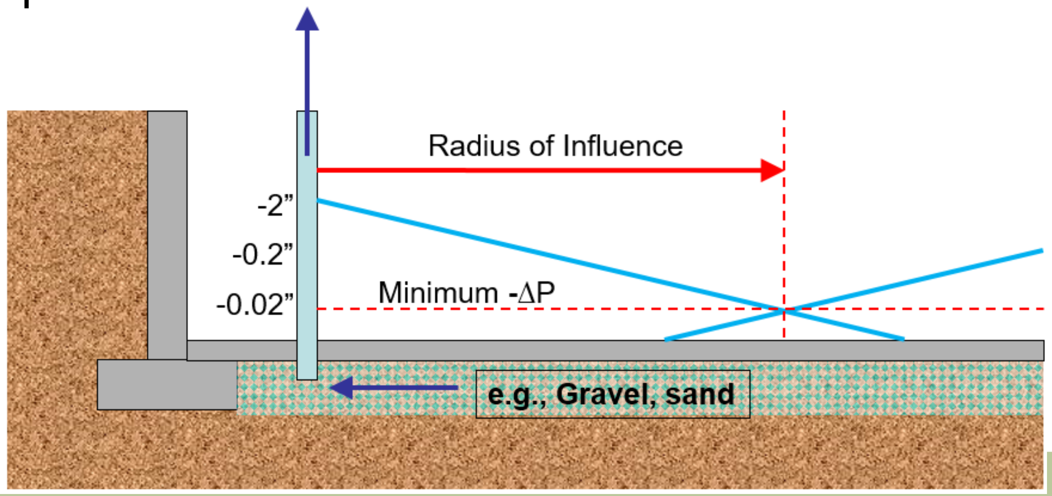
- Permeable venting layer under vacuum has proven record of success
- Cost effective in areas with immediate access to needed gravel

Cons

- Energy consumption
- Typically higher $/SF cost than passive system

In comparison to aerated systems

- Negative pressure decreases exponentially with distance from piping/vapor mat
- Multiple suction points often needed to meet min -ΔP



Active Sub-Slab Ventilation

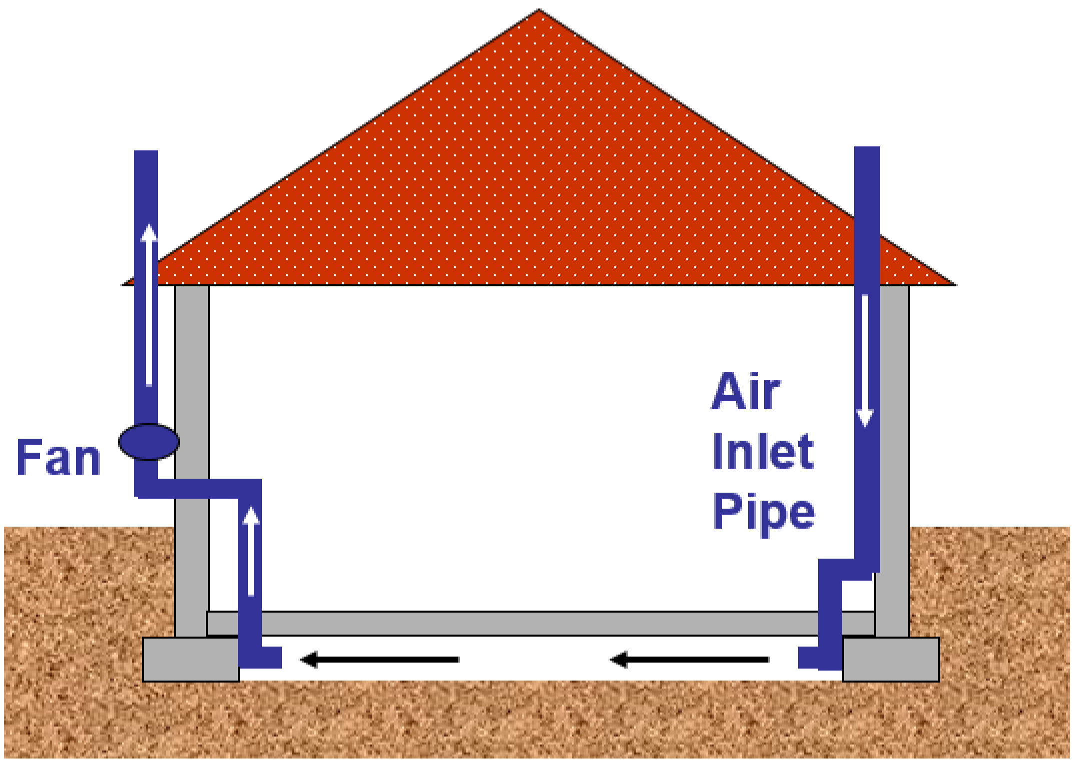
- Air sweeps area under floor to remove VOC mass and dilute concentrations
- Low resistance of void space increases air flow and exchange rate

Pros:

- Passive air flow due to wind ~10x greater through void space than gravel

Cons:

- Relies on wind/sun (potentially inconsistent)
- Typically involves higher construction costs/SF for piping and potential increase in fan size



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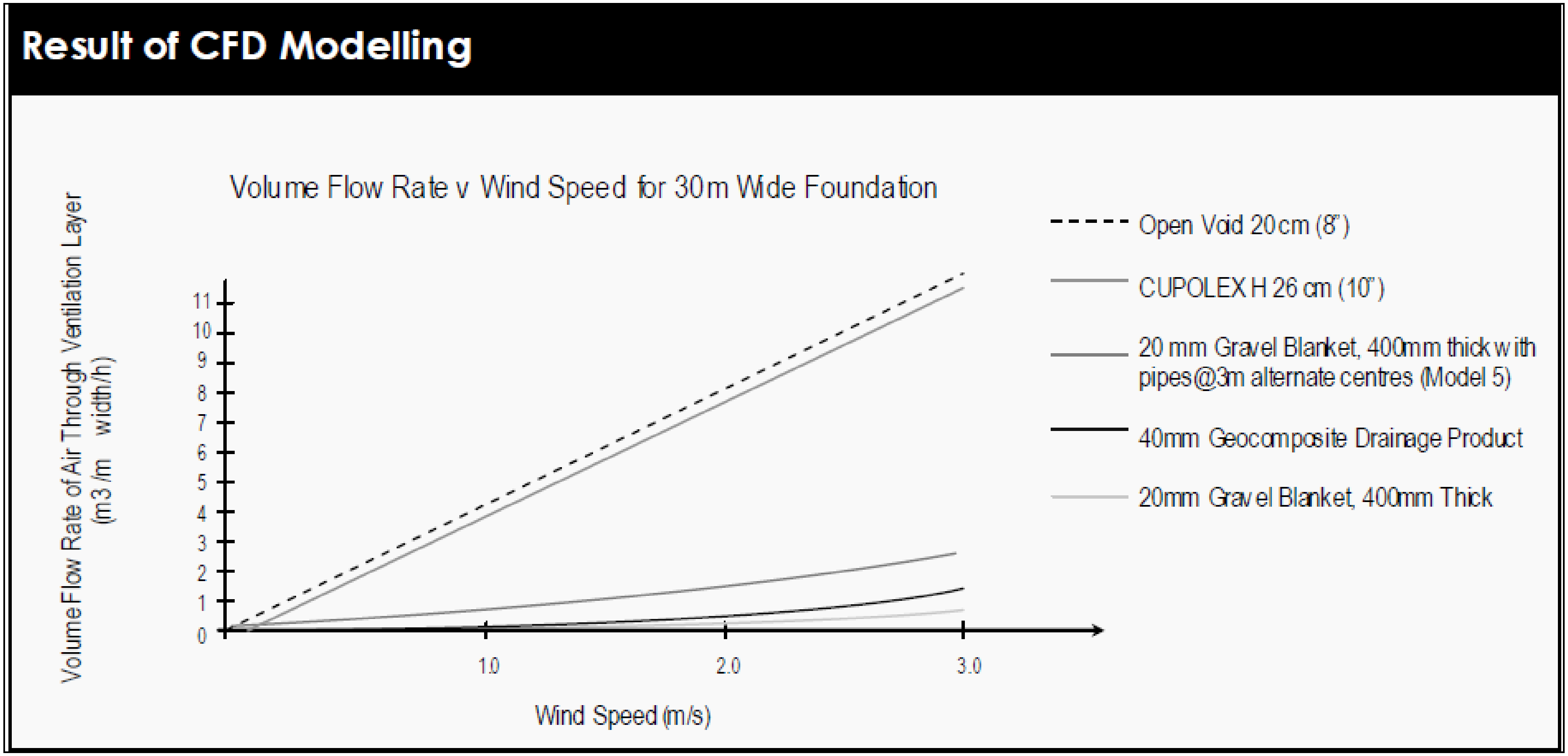
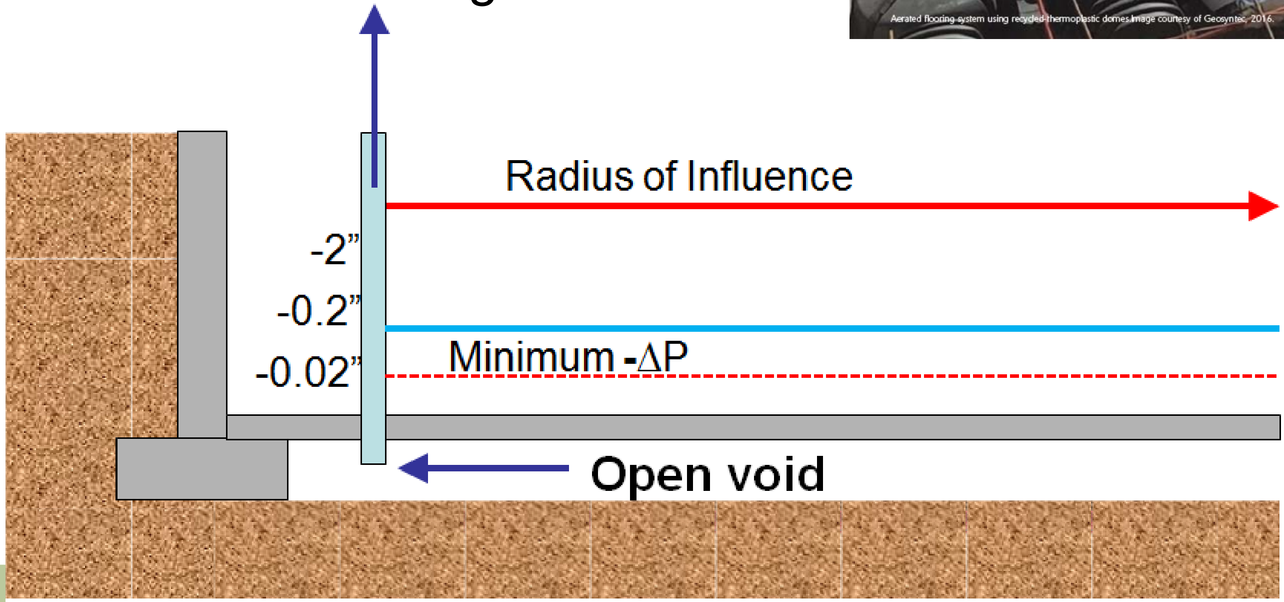


Active Aerated Flooring

- Uses plastic forms to create a continuous void below concrete slabs.
- Results in a vacuum field with limited effort
- Forms, vent pipes and reinforcement (e.g. welded wire mesh) can be installed in place.
- Separations in forms create grade beams in slab.



Active Aerated Flooring

- Only 4% of slab is in contact with sub-grade
- Concrete can be poured over the forms.
- Results in void below slab that can be vented for vapor intrusion control

Active Aerated Flooring

Pros

- More effective venting
- Lower cost for specific applications
- Green product
  - (1 pallet replaces 7 truck loads of gravel)
- Contributes to structural foundation
  - (Dome shape creates an orthogonal grid of arches, concrete under compression instead of tension)
- Allows for easy post-construction utility chase

Courtesy Pontarolo Engineering, Cupolex®

Cons

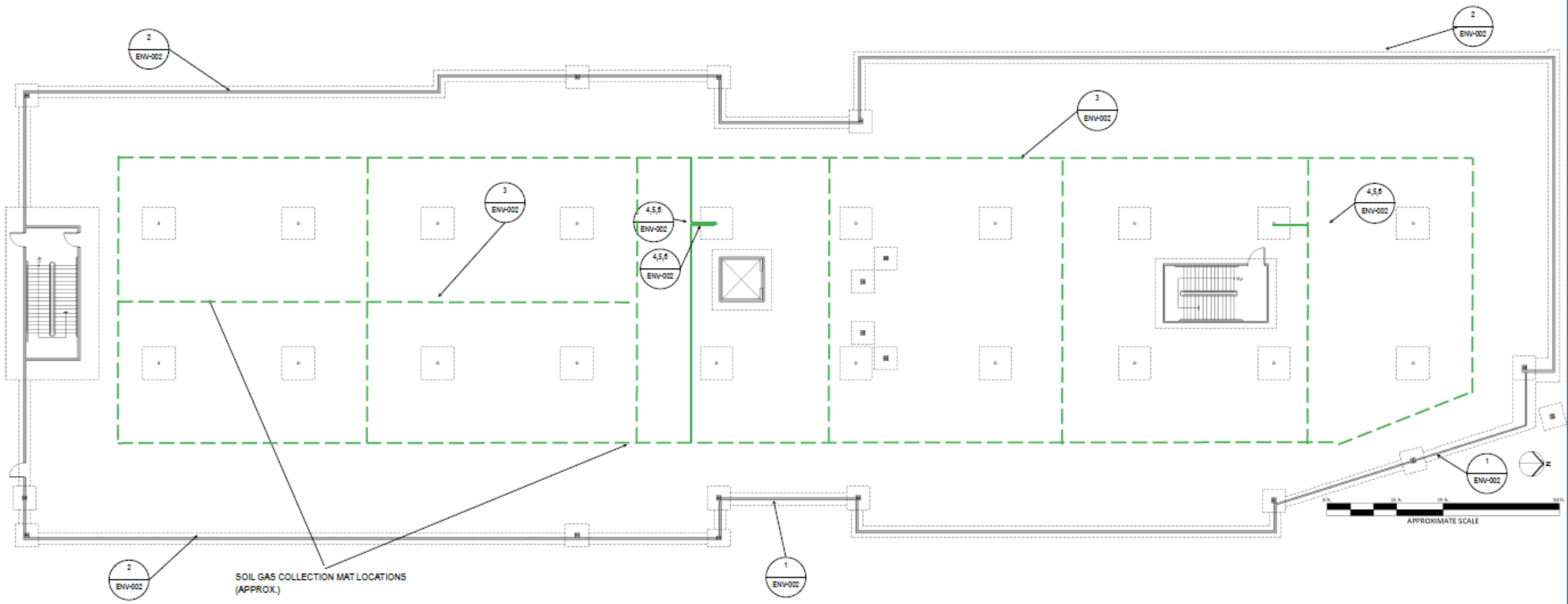
- New to US market
- Potential higher cost for smaller footprint applications

New Construction (Tempe, AZ)

New Construction

Vapor Mitigation System Installation Completion
Rio Salado Pkwy, Tempe, AZ

Example Vapor Mitigation System Layout

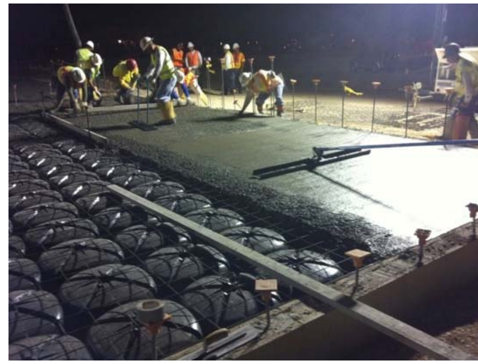


Challenges

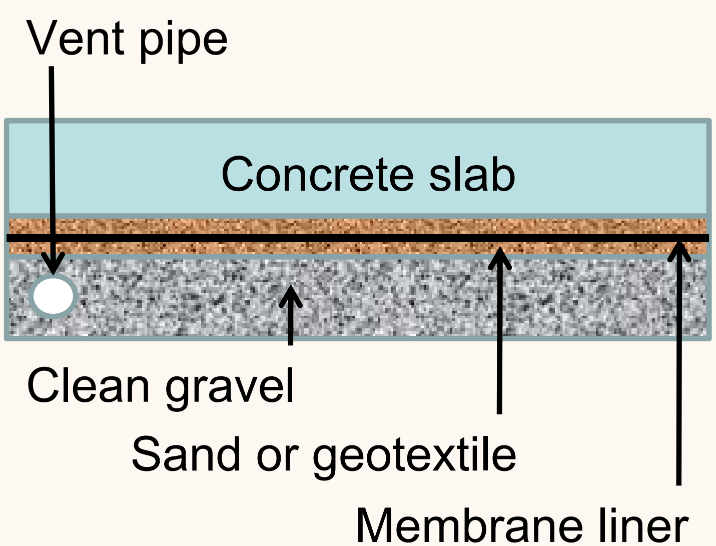
- Accelerated time frame/window for install
- Coordination with utility, concrete and construction companies
- Oversight/evaluation of work performed by others

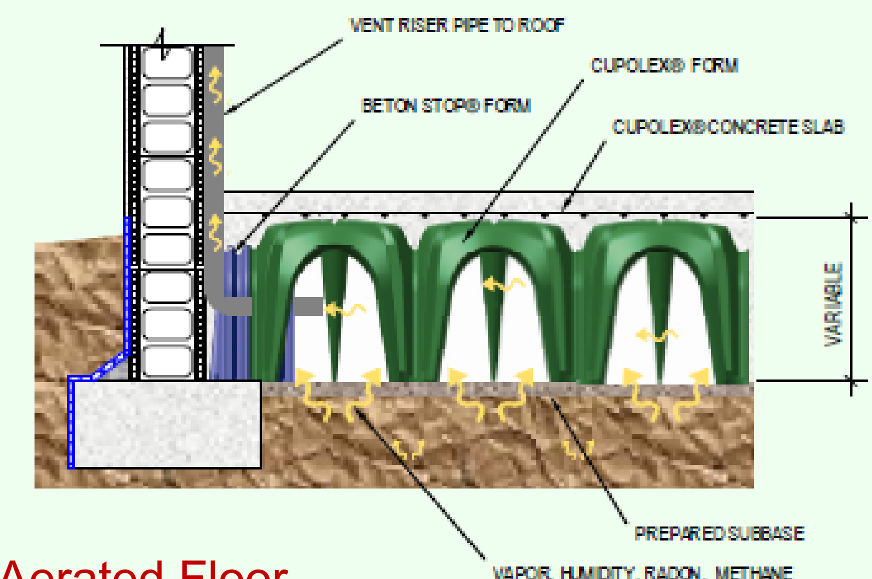
Options for New Buildings

- More options available:
- Passive barriers (~$2-6/SF)
- SSD systems (~$3-6/SF)
- Aerated floors (~$2-4/SF)



SSD System





Aerated Floor

Courtesy Cupolex®

Conclusions

- Several technologies can reduce indoor air concentrations or cut off vapor intrusion (VI) pathways.
- The appropriate technology depends on vapor source, pathway, building and evaluation air contaminant concentrations.
- Construction cost is the typical driver for mitigation option implementation
  - Areas with limited access to gravel results in gravel systems being less effective
  - Larger footprint construction or site access can also drive selection
- Personal opinion, active systems are preferred, reduce risk and provide increased vacuum in comparison to gravel systems
- Depressurization systems are still the only proven long term mitigation
- Confirmatory sampling and long-term monitoring is key

Geosyntec's Vapor Intrusion Practice Experts

- Geosyntec's VI practitioners have been working in this field since its inception
  - Robbie Ettinger developed the J&E Model while working at Shell in the early 1990s.
  - Todd McAlary conducted one of the first large plume VI assessments in Massachusetts in the early 1990s.
  - Dave Folkes worked on the Redfield Site in Denver in the late 1990s.
  - Helen Dawson and Todd McAlary worked on the original EPA Draft VI Guidance in 2001 and 2002.
  - Helen Dawson was a VI technical lead at EPA until 2013. She was lead author on EPA's: 2002 VI guidance, VI Database report, Background Indoor Air report, and Vapor Intrusion Screening Level calculator.

Robbie Ettinger

Todd McAlary

Helen Dawson

Dave Folkes

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- Brian McNamara, P.E., is a Senior Engineer with Geosyntec Consultants' Phoenix office. He has more than 16 years of experience in environmental consulting, regulatory agency permitting, and manufacturing. Brian focuses on site investigation, remediation, and environmental compliance for a broad range of industries including power, aerospace, sand and gravel, metal processing, landfills, and general manufacturing facilities.
- He has led remediation and permitting projects at a variety of sites throughout the United States and American Samoa. Brian's experience and background provides clients with a unique perspective to effectively and expeditiously address regulatory requirements in a cost effective manner.

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- Mr. Pursoo is a Project Engineer with 10 years of experience providing environmental engineering investigation, process design, optimization, construction oversight and O&M management services. Mr. Pursoo is a 2006 West Virginia University civil engineering graduate who has split time on both the east and west coast for Geosyntec to assist with some of the company's most challenging wastewater treatment and remediation projects.
- Projects have been performed at an extensive range of facilities such as power plants, Superfund sites, landfills, sanitary treatment facilities, rail yards, bottling plants, manufacturing plants, aerospace facilities and residential and commercial locations.
- Mr. Pursoo has his Masters in Environmental Engineering from Marshall University and is a P.E. currently licensed in 3 states (AZ, NY, WV).