# Nevada Division of Environmental Protection

Bureau of Corrective Actions CEM Workshop for Remediation and Leaking Underground Storage Tank Cases

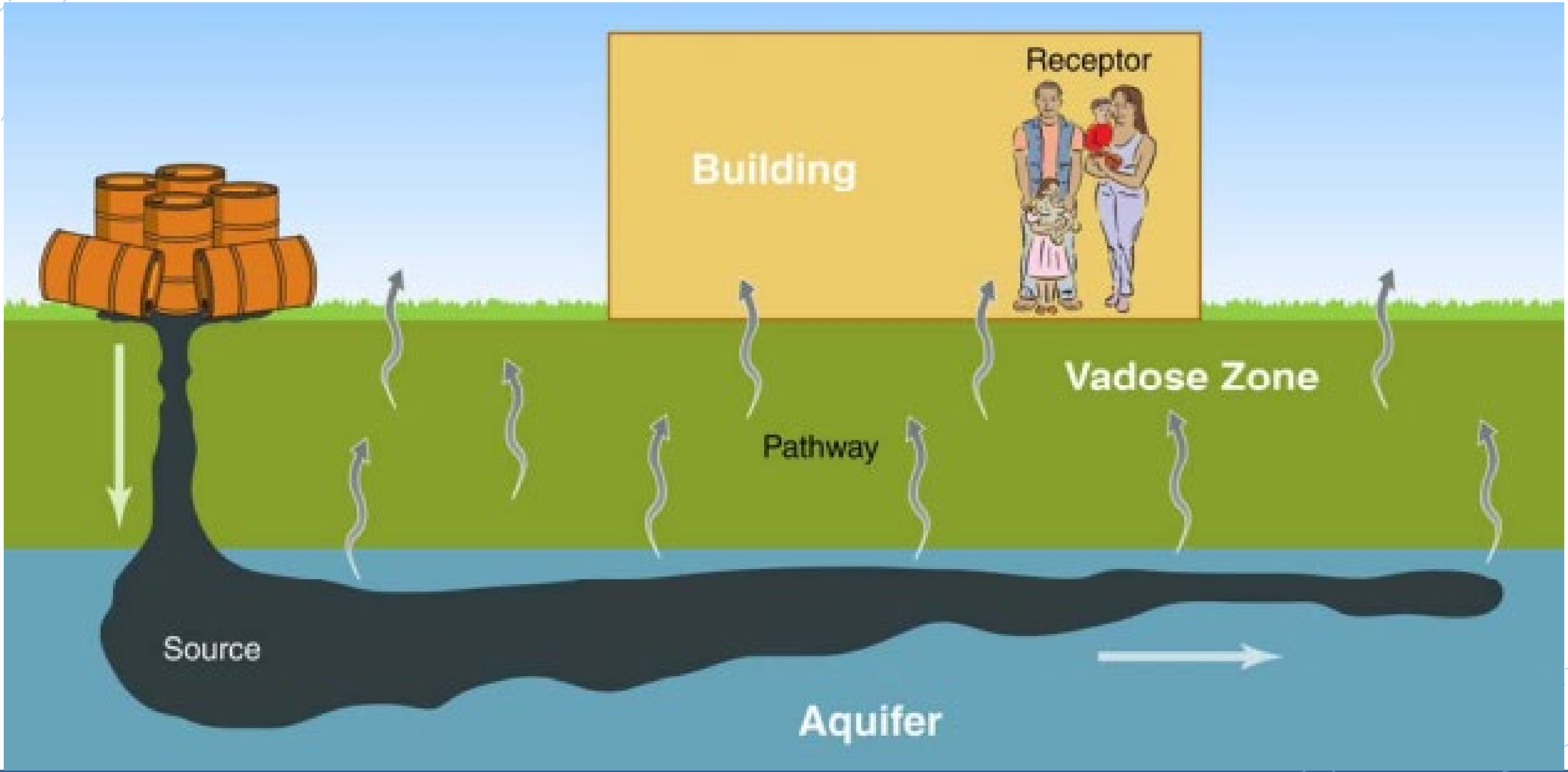
**April 22 and 24, 2025**

Presented by
**The NDEP Bureau of Corrective Actions**

Nevada Department of Conservation & Natural Resources

Nevada Division of Environmental Protection

# Vapor Intrusion 101



# Vapor Intrusion 101

## Resources

- https://www.epa.gov/vaporintrusion
- https://www.epa.gov/vaporintrusion/vapor-intrusion-screening-level-calculator
- https://www.epa.gov/vaporintrusion/epa-spreadsheet-modeling-subsurface-vapor-intrusion
- https://www.api.org/oil-and-natural-gas/environment/clean-water/ground-water/vapor-intrusion/biovapor
- https://itrcweb.org/
  - Under "Guidance Materials" choose "Search by Topic" and Vapor Intrusion from the drop-down menu. ITRC will be combining and updating VI guidance for release early 2026.

# Vapor Intrusion

## NDEP

- BCA does not regulate indoor air but can consider VI potential as a line of evidence when evaluating closure requests, can require mitigation be offered when air SSLs are exceeded, and can consider VI potential for setting cleanup goals.
- NDEP does not have action levels or reportable concentrations for soil vapor.
  - Verify results with soil and/or groundwater samples
- NDEP has not published official VI guidance but plans to do so in the next year.

# Vapor Intrusion

## Ultimate Goal: Prevent Indoor Air SSL Exceedances

| | Resident Air (µg/m$^3$) | Industrial Air (µg/m$^3$) |
|---|---|---|
| Benzene | 0.36 | 16 |
| PCE | 11 | 47 |
| TCE | 0.48 | 3.0 |

From the EPA RSL Tables as of April 2025

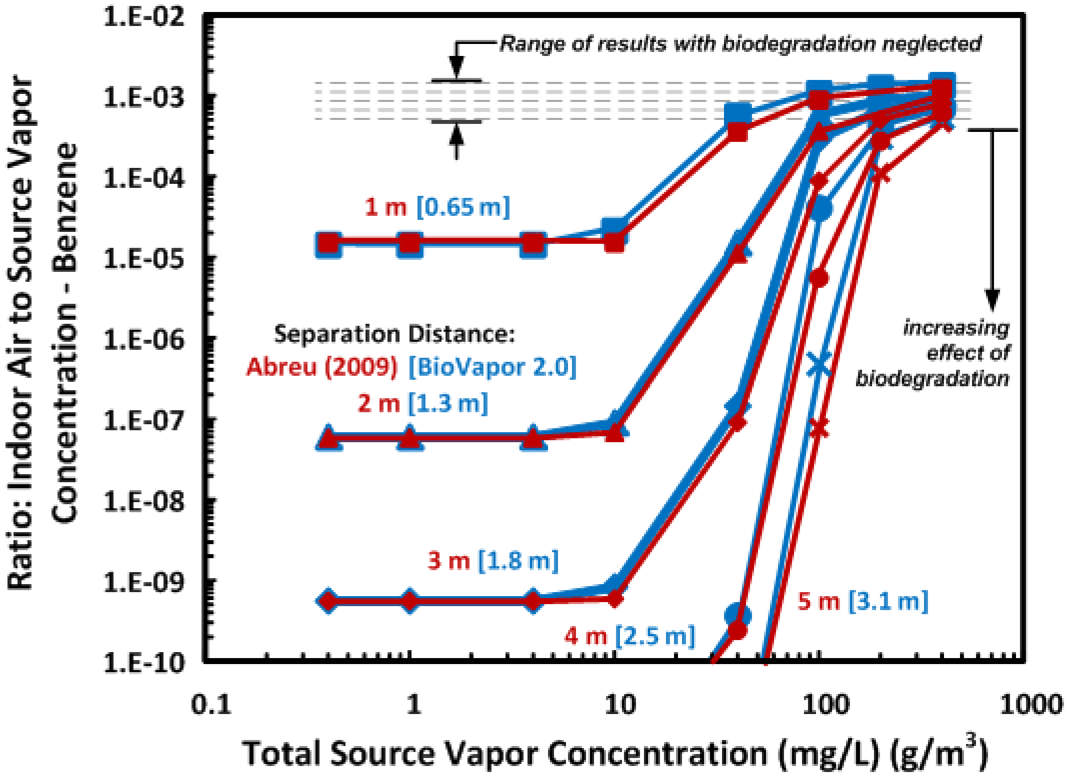
# Vapor Intrusion

## Methods to estimate indoor air concentrations or screen out sites

- Some states use screening distances:
  - Vertical
    - Typically 15 feet for LNAPL
    - 5 feet for dissolved phase petroleum products
    - 100 feet for chlorinated solvents
  - Horizontal
    - 30 feet is standard for many states
- Default attenuation factor
  - Often 0.003 – 0.01, based on sub-slab soil vapor concentrations
- NDEP does not use default attenuation factors or screening distances, but may consider using the above vertical distances for petroleum releases
- Modeling: VISL, Johnson & Ettinger, BioVapor

# Vapor Intrusion

## Petroleum VI vs chlorinated VI




BioVapor modeling indicates that at a depth of 1.8 meters (5.9 feet), an attenuation factor of 1E-09 is appropriate for benzene concentrations <10 mg/L (10,000,000 µg/m$^3$)

This scenario would result in an indoor air concentration of 0.01 µg/m$^3$, well below the Residential SSL of 0.36 µg/m$^3$.

# Vapor Intrusion

## Petroleum VI


NDEP does not require VI assessment for most PVI cases because:

- Most gas stations have plumes contained onsite and the exposure from nozzles is much higher than through pavement and foundations
- Most offsite dissolved phase plumes are deeper than 5 feet below ground surface

- May need to consider PVI if depth to water is <5 feet for dissolved phase or <15 feet for LNAPL

# Vapor Intrusion

## Chlorinated VI

- NDEP does not use default vertical screening distances for CVI
- Prefers use of Johnson & Ettinger Model or a similar risk assessment
- Existing guidance is for internal case officer use but is dated due to updated indoor air SSLs. Also is based on a higher risk of $1 \times 10^{-4}$

Groundwater Temperature = 15 degrees C

| *PCE | Depth to Groundwater (ft bgs) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Soil Texture | 5 | 10 | 15 | 20 | 25 | 30 | 40 | 50 | Units |
| Sand | 70 | 85 | 100 | 115 | 130 | 145 | 180 | 210 | µg/L |
| Loamy sand | 180 | 200 | 220 | 240 | 250 | 270 | 310 | 340 | µg/L |
| Sandy loam | 500 | 520 | 550 | 570 | 600 | 620 | 690 | 720 | µg/L |
| Loam | 780 | 820 | 860 | 900 | 930 | 970 | 1,050 | 1,130 | µg/L |

| TCE | Depth to Groundwater (ft bgs) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Soil Texture | 5 | 10 | 15 | 20 | 25 | 30 | 40 | 50 | Units |
| Sand | 8 | 9 | 11 | 12 | 14 | 16 | 19 | 22 | µg/L |
| Loamy sand | 19 | 21 | 23 | 25 | 27 | 29 | 32 | 36 | µg/L |
| Sandy loam | 52 | 54 | 57 | 59 | 62 | 64 | 69 | 75 | µg/L |
| Loam | 80 | 84 | 88 | 92 | 96 | 101 | 109 | 117 | µg/L |

# Vapor Intrusion

## Using the Johnson & Ettinger Model

RESET TO D

Use English / Metric Converter

**Model Input** Site Name/Run Number: Example, Run 1

*Note:*
*-Yellow highlighted cells indicate parameters that typically are changed or must be inputted by the user.*
*-Dotted outline cells indicate default values that may be changed with justification.*
*-Toxicity values are taken from Regional Screening Level tables. These tables are updated semi-annually and may not reflect the most current toxicity information.*

| Source Characteristics: | Units | Symbol | Value | Default | Potential Span | CV |
|---|---|---|---|---|---|---|
| Source medium | | Source | Groundwater | | | |
| Groundwater concentration | (ug/L) | Cmedium | Groundwater | | NA | |
| Depth below grade to water table | (m) | Ls | Exterior Soil Gas | | Vary - 50 | NA |
| Average groundwater temperature | (°C) | Ts | Sub-slab Soil Gas | 25 | 3 - 25 | |
| Calc: Source vapor concentration | (ug/m3) | Cs | 361919 | | | |
| Calc: % of pure component saturated vapor concentration | (%) | %Sat | 0.219% | | | |

| Chemical: R | Units | Symbol | Value | Default | Potential Span | CV |
|---|---|---|---|---|---|---|
| Chemical Name | | Chem | Tetrachloroethylene | | | |
| CAS No. | | CAS | 127-18-4 | | | |

| Toxicity Factors | Units | Symbol | Value | Default | Potential Span | CV |
|---|---|---|---|---|---|---|
| Unit risk factor | $(ug/m^3)^{-1}$ | IUR | 2.60E-07 | 2.60E-07 | NA | NA |
| Mutagenic compound | | Mut | No | NA | NA | NA |
| Reference concentration | $(mg/m^3)$ | RfC | 4.00E-02 | 4.00E-02 | NA | NA |

The model can be run using groundwater, exterior soil gas, or sub-slab soil gas data.

Using groundwater data is common because many sites have years of quarterly groundwater data.

Select chemical and the toxicity values will load automatically

# Vapor Intrusion

## Using the Johnson & Ettinger Model

**Building Characteristics:**

Select Building Assumptions

- (selected) Use ratio for Qsoil/Qbuilding (recommended if no site specific data available)
- Specify Qsoil and Qbuilding separately; calculate ratio

Click to change assumptions

| | Units | Symbol | Value | Default | Potential Span | CV | Flag | Comment |
|---|---|---|---|---|---|---|---|---|
| Building setting | | Bldg_Setting | Residential | Residential | | | | |
| Foundation type | | Found_Type | Slab-on-grade | Slab-on-grade | | | | |
| Depth below grade to base of foundation | (m) | Lb | 0.10 | 0.10 | 0.1 - 2.44 | NA | | |
| Foundation thickness | (m) | Lf | 0.10 | 0.10 | 0.1 - 0.25 | NA | | |
| Fraction of foundation area with cracks | (-) | eta | 0.001 | 0.001 | 0.00019-0.0019 | 1.00 | | |
| Enclosed space floor area | (m2) | Abf | 150.00 | 150.00 | 80 - 200 | NA | | |
| Enclosed space mixing height | (m) | Hb | 2.44 | 2.44 | 2.13 - 3.05 | NA | | |
| Indoor air exchange rate | (1 / hr) | ach | 0.45 | 0.45 | .15-1.26 | NA | | |
| Qsoil/Qbuilding | (-) | Qsoil_Qb | 0.0030 | 0.0030 | 0.0001 - 0.05 | 1.24 | | |
| Calc: Building ventilation rate | (m3/hr) | Qb | 164.70 | 164.70 | NA | 0.30 | | |
| Calc: Average vapor flow rate into building | (m3/hr) | Qsoil | 0.49 | 0.49 | NA | NA | | |

Use defaults for generic building unless different site-specific values are known

# Vapor Intrusion

## Using the Johnson & Ettinger Model

**Model Input** — Site Name/Run Number: Example, Run 1

Chemical Name: Tetrachloroethylene — CAS No. 127-18-4

Depth below grade to water table: 4.50 meters

| Vadose zone characteristics: | Units | Symbol | Value | Default | Potential Span | CV | Flag |
|---|---|---|---|---|---|---|---|
| Stratum A (Top of soil profile): R | | | | | | | |
| Stratum A SCS soil type | | SCS_A | Silt | | | | |
| Stratum A thickness (from surface) | (m) | hSA | 4.50 | | | | |
| Stratum A total porosity | (-) | nSA | 0.489 | 0.489 | NA | 0.20 | |
| Stratum A water-filled porosity | (-) | nwSA | 0.167 | 0.167 | 0.05 - 0.28 | 0.25 | |
| Stratum A bulk density | (g/cm³) | rhoSA | 1.350 | 1.350 | NA | 0.05 | |
| Stratum B (Soil layer below Stratum A): | | | | | | | |
| Stratum B SCS soil type | | SCS_B | Not Present | | | | |
| Stratum B thickness | (m) | hSB | 0.00 | | | | |
| Stratum B total porosity | (-) | nSB | | | NA | NA | |
| Stratum B water-filled porosity | (-) | nwSB | | | NA | NA | |
| Stratum B bulk density | (g/cm³) | rhoSB | | | NA | NA | |
| Stratum C (Soil layer below Stratum B): | | | | | | | |
| Stratum C SCS soil type | | SCS_C | Not Present | | | | |
| Stratum C thickness | (m) | hSC | 0.00 | | | | |
| Stratum C total porosity | (-) | nSC | | | NA | NA | |
| Stratum C water-filled porosity | (-) | nwSC | | | NA | NA | |
| Stratum C bulk density | (g/cm³) | rhoSC | | | NA | NA | |
| Stratum directly above the water table | | | | | | | |
| Stratum A, B, or C | | src_soil | Stratum A | | | | |
| Height of capillary fringe | (m) | hcz | 1.630 | 1.630 | NA | NA | |
| Capillary zone total porosity | (-) | ncz | 0.489 | 0.489 | NA | 0.20 | |
| Capillary zone water filled porosity | (-) | nwcz | 0.382 | 0.382 | NA | 0.24 | |

Can select up to 3 soil stratums, specifying soil type for each

# Vapor Intrusion

## Using the Johnson & Ettinger Model

| Exposure Parameters: R | Units | Symbol | Value | Default | Potential Span | CV |
|---|---|---|---|---|---|---|
| **Target risk for carcinogens** | (-) | Target_CR | 1.00E-06 | 1.00E-06 | NA | NA |
| **Target hazard quotient for non-carcinogen:** | (-) | Target_HQ | 1 | 1 | NA | NA |
| Exposure Scenario | | Scenario | Residential | Residential | | |
| Averaging time for carcinogens | (yrs) | ATc | 70 | 70 | NA | NA |
| Averaging time for non-carcinogens | (yrs) | ATnc | 26 | 26 | NA | NA |
| Exposure duration | (yrs) | ED | 26 | 26 | NA | NA |
| Exposure frequency | (days/yr) | EF | 350 | 350 | NA | NA |
| Exposure time | (hrs/24 hrs) | ET | 24 | 24 | NA | NA |
| Mutagenic mode-of-action factor | (yrs) | MMOAF | 72 | 72 | NA | NA |

Default cancer risk is $1 \times 10^{-6}$ and hazard index is 1, but these can be changed

# Vapor Intrusion

## Using the Johnson & Ettinger Model

**Range** is based on the re...
values, as reported in the li...

**Model Output** Site Name/Run Number: Example, Run 1

Chemical Name: Tetrachloroethylene CAS No. 127-18-4

| Source to Indoor Air Attenuation Factor | Units | Symbol | Value | Range | Default | Default Range |
|---|---|---|---|---|---|---|
| Groundwater to indoor air attenuation coefficient | (-) | alpha | 2.5E-05 | 2.0E-05 - 2.5E-05 | 2.5E-05 | 2.0E-05 - 2.5E-05 |
| **Predicted Indoor Air Concentration** | **Units** | **Symbol** | **Value** | **Range** | **Default** | **Default Range** |
| Indoor air concentration due to vapor intrusion | (ug/m3) | Cia | 9.1E+00 | 7.3E+00 - 9.1E+00 | 9.1E+00 | 7.3E+00 - 9.1E+00 |
| | (ppbv) | | 1.3E+00 | 1.1E+00 - 1.3E+00 | 1.3E+00 | 1.1E+00 - 1.3E+00 |
| **Predicted Vapor Conc. Beneath Foundation** | **Units** | **Symbol** | **Value** | **Range** | **Default** | **Default Range** |
| Subslab vapor concentration | (ug/m3) | Css | 3.0E+03 | 1.8E+02 - 7.3E+04 | 3.0E+03 | 7.3E+04 - 9.1E+04 |
| | (ppbv) | | 4.5E+02 | 2.7E+01 - 1.1E+04 | 4.5E+02 | 1.1E+04 - 1.3E+04 |

For this scenario, the predicted indoor air concentration is 9.1 µg/m$^3$, below the SSL of 11 µg/m$^3$.

Nevada Department of CONSERVATION & NATURAL RESOURCES

NEVADA DIVISION OF ENVIRONMENTAL PROTECTION

# Vapor Intrusion

## Using the Johnson & Ettinger Model

**Model Output** Site Name/Run Number: Example, Run 1

Chemical Name: Tetrachloroethylene CAS No. 127-18-4

| Risk Calculations | Units | Symbol | Value | Range | Default | Range |
|---|---|---|---|---|---|---|
| **Risk-Based Target Screening Levels** Scenario: Residential | | | | | | |
| Target risk for carcinogens | (-) | Target_CR | 1E-06 | - | 1E-06 | - |
| Target hazard quotient for noncarcinogens | (-) | Target_HQ | 1 | - | 1 | - |
| **Target indoor air concentration** | (ug/m3) | Target_IA | 1.08E+01 | - | 1.08E+01 | - |
| | (ppbv) | | 1.59E+00 | - | 1.59E+00 | - |
| **Target groundwater concentration** | (ug/L) | Target_GW | 5.95E+02 | [illegible]E+02 - 7.4E+0[illegible] | 5.95E+02 | [illegible] |
| **Incremental Risk Estimates** | | | | | | |
| **Incremental cancer risk from vapor intrusion** | (-) | Cancer_Risk | 8.40E-07 | [illegible].8E-07 - 8.5E-0[illegible] | 8.40E-07 | 6.8E-07 - 8.5E-07 |
| **Hazard quotient from vapor intrusion** | (-) | HQ | 2.17E-01 | 1.8E-01 - 2.2E-01 | 2.17E-01 | 1.8E-01 - 2.2E-01 |

The predicted cancer risk is $8.4 \times 10^{-7}$ and hazard index is 0.217, below the respective screening levels of $1.0 \times 10^{-6}$ and 1.0. The target groundwater concentration is 595 µg/L.

# Vapor Intrusion

## Modeling vs Indoor Air Sampling

Modeling can be a useful line of evidence and may be used in lieu of indoor air sampling in some scenarios:

- The plume is currently under a vacant lot
- The plume is migrating towards buildings of interest but hasn't reached them yet
- Property owners won't allow access
- Properties have other VOC sources that can influence results

# Vapor Intrusion

## Modeling – Communication to NDEP

- Explain selection of each input parameter
  - Can use defaults or model recommended when site-specific data are lacking
- Describe assumptions and assess variability in available data
- Use conservative values (highest current or recent concentrations, coarsest soil type, etc.) to identify worst case scenario.
- Compare predicted indoor air concentrations to current SSLs for Residential and Industrial sites.

# Vapor Intrusion

## Indoor Air Sampling

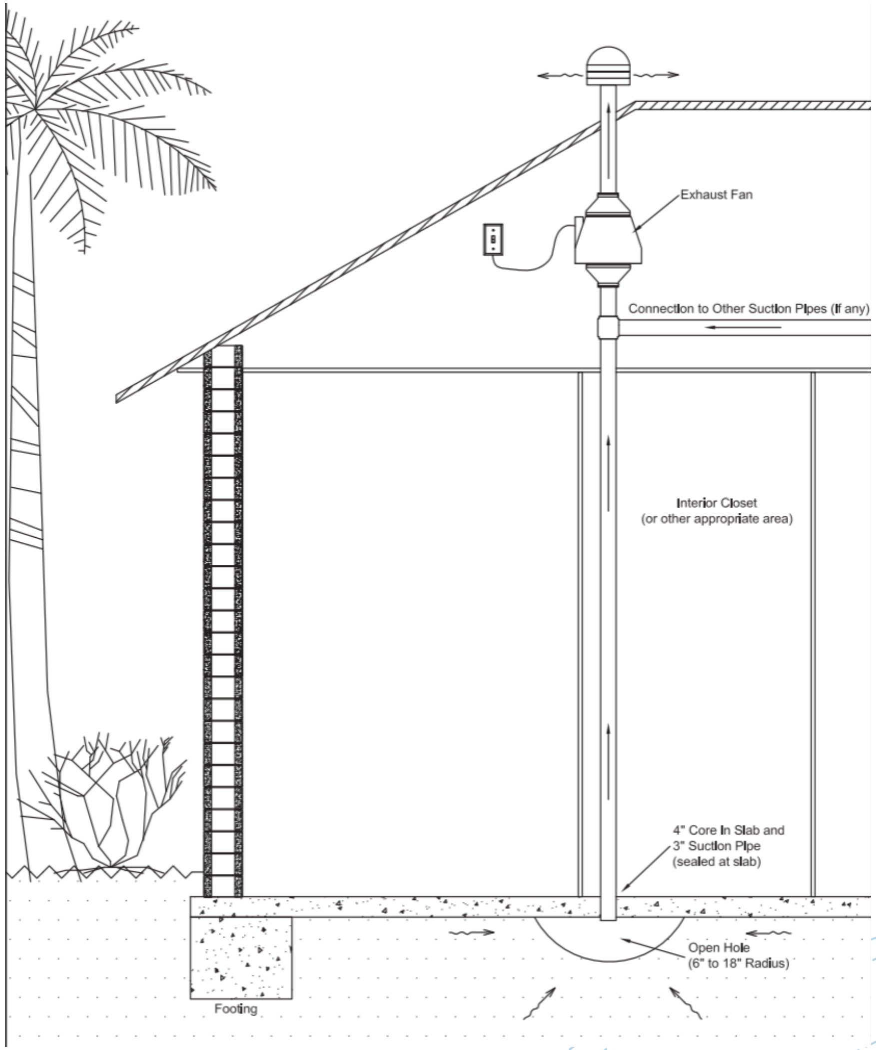
- Requires outreach to property owners and access agreements
- Pre-sampling survey to identify background influence

# Vapor Intrusion

## Mitigation

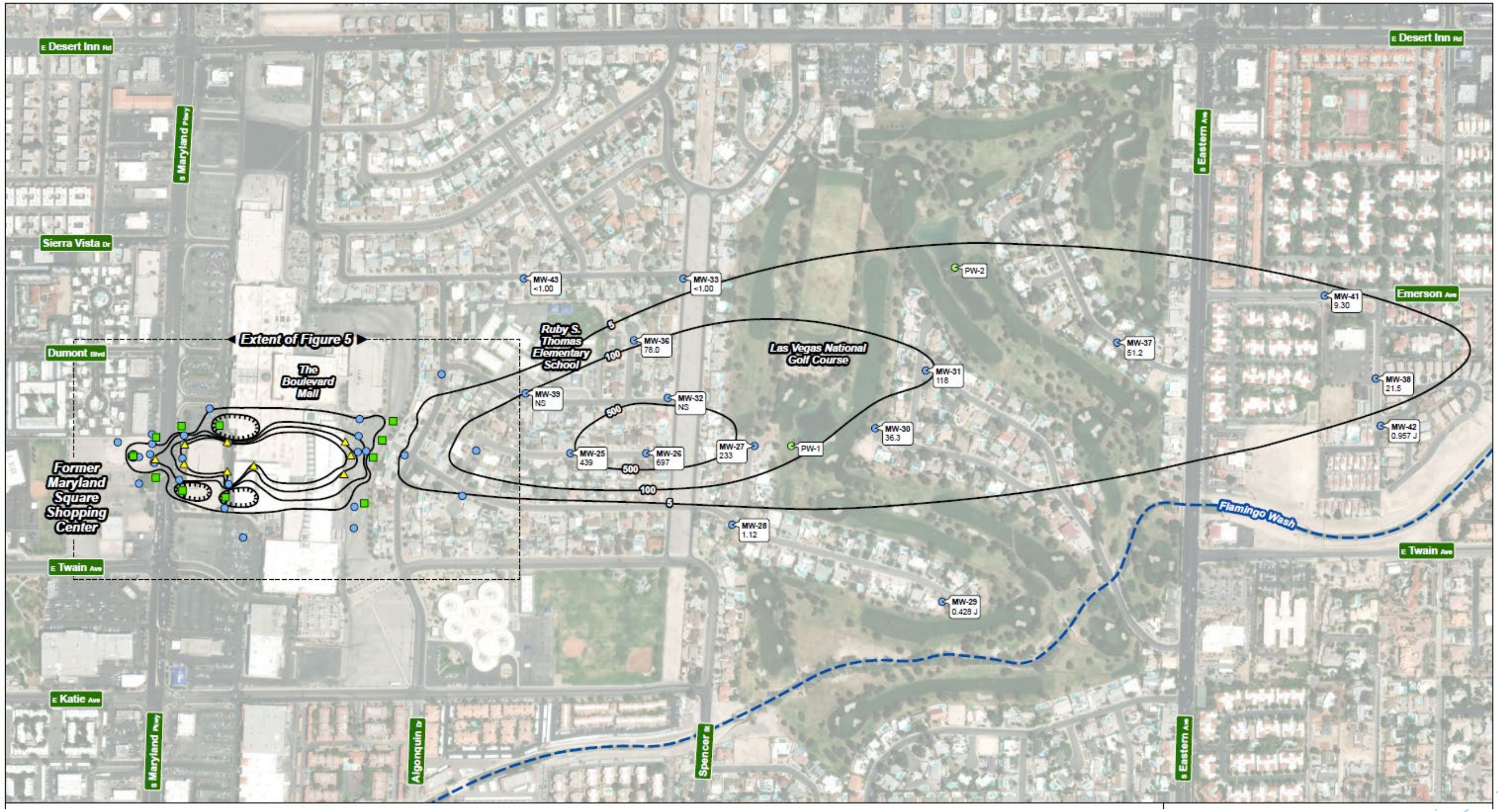
Sub-slab depressurization system is typical

- Voluntary on part of property owner
- Paid for by party responsible for contaminant release

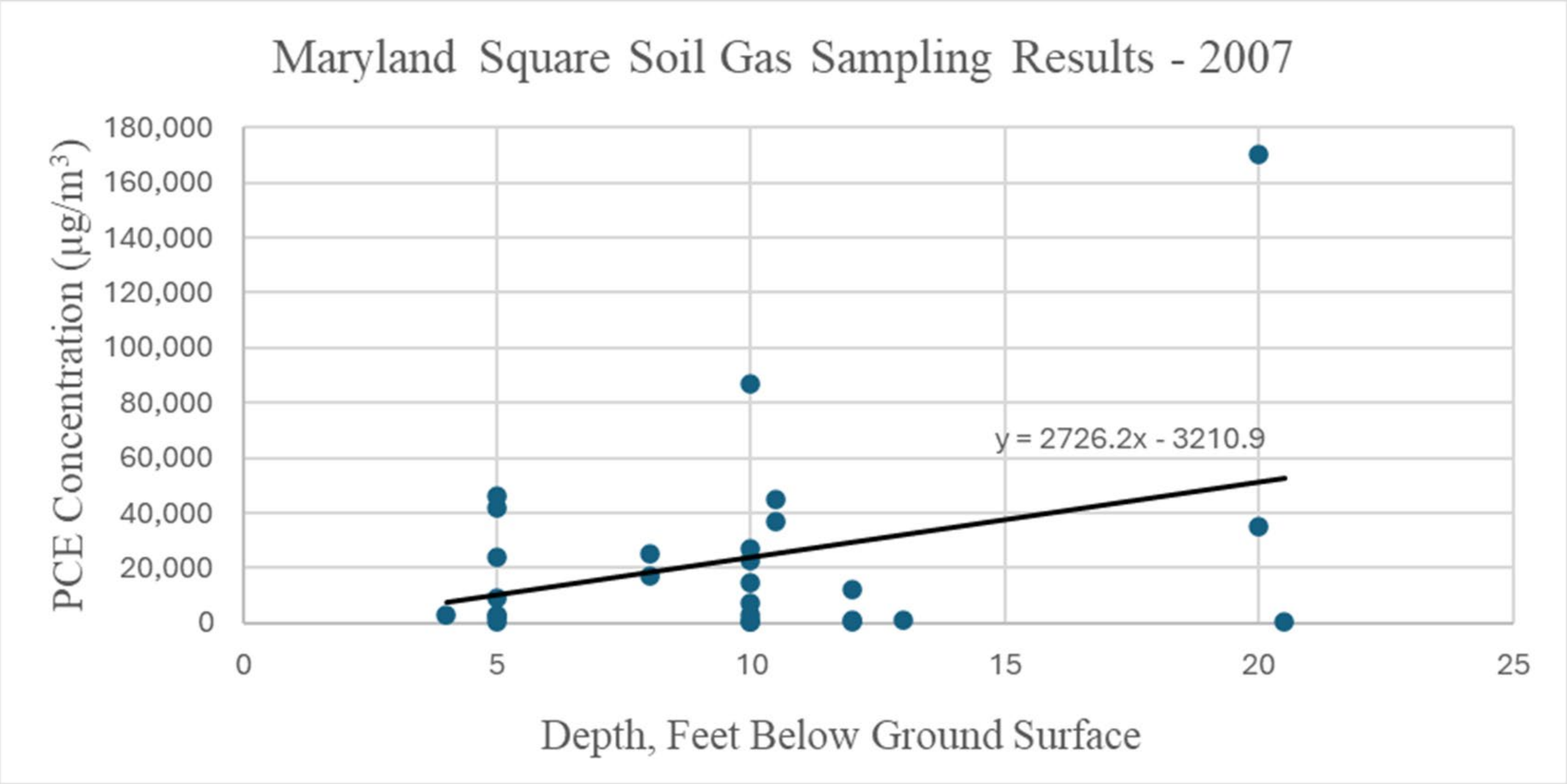


# Vapor Intrusion

## Maryland Square Case Study



# Vapor Intrusion
## Maryland Square Case Study

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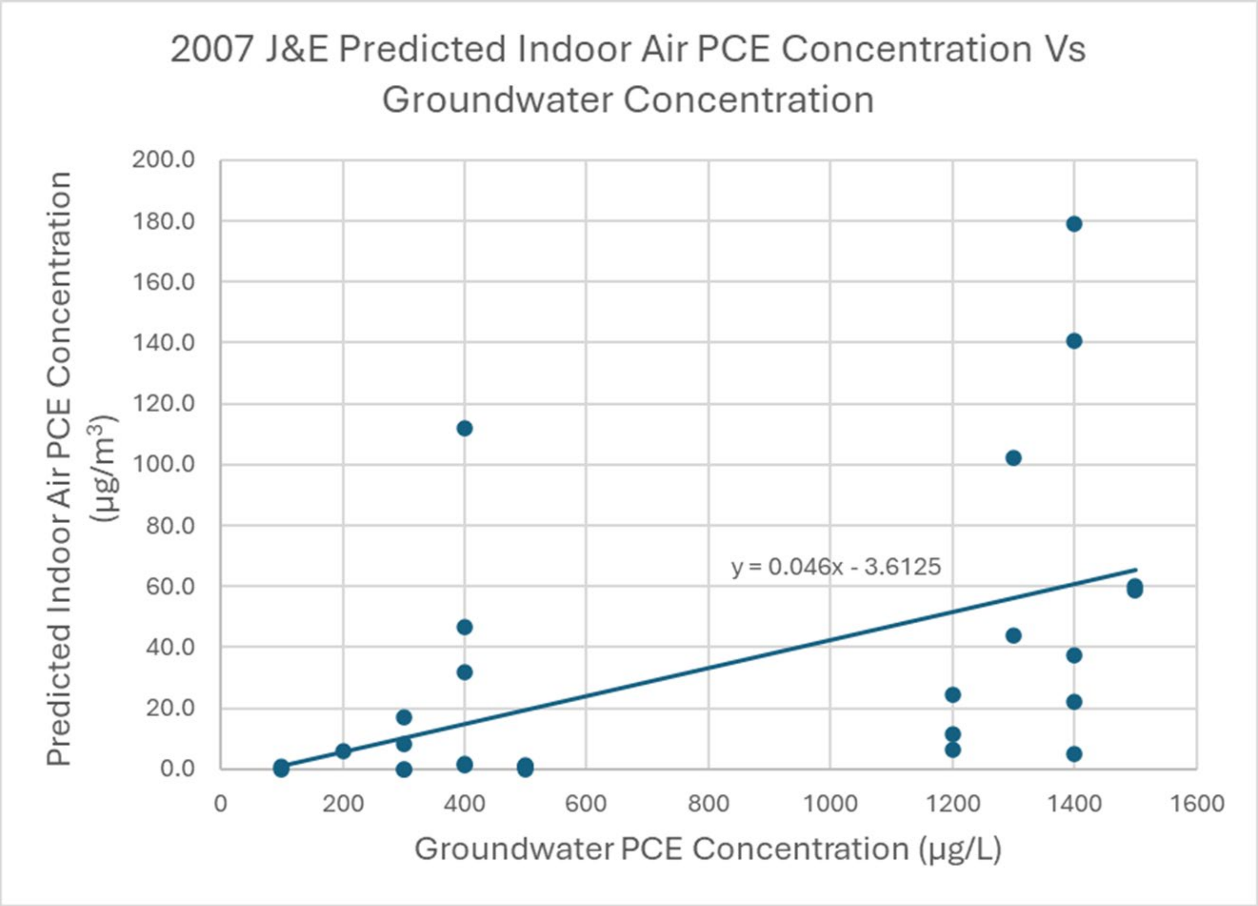
# Vapor Intrusion

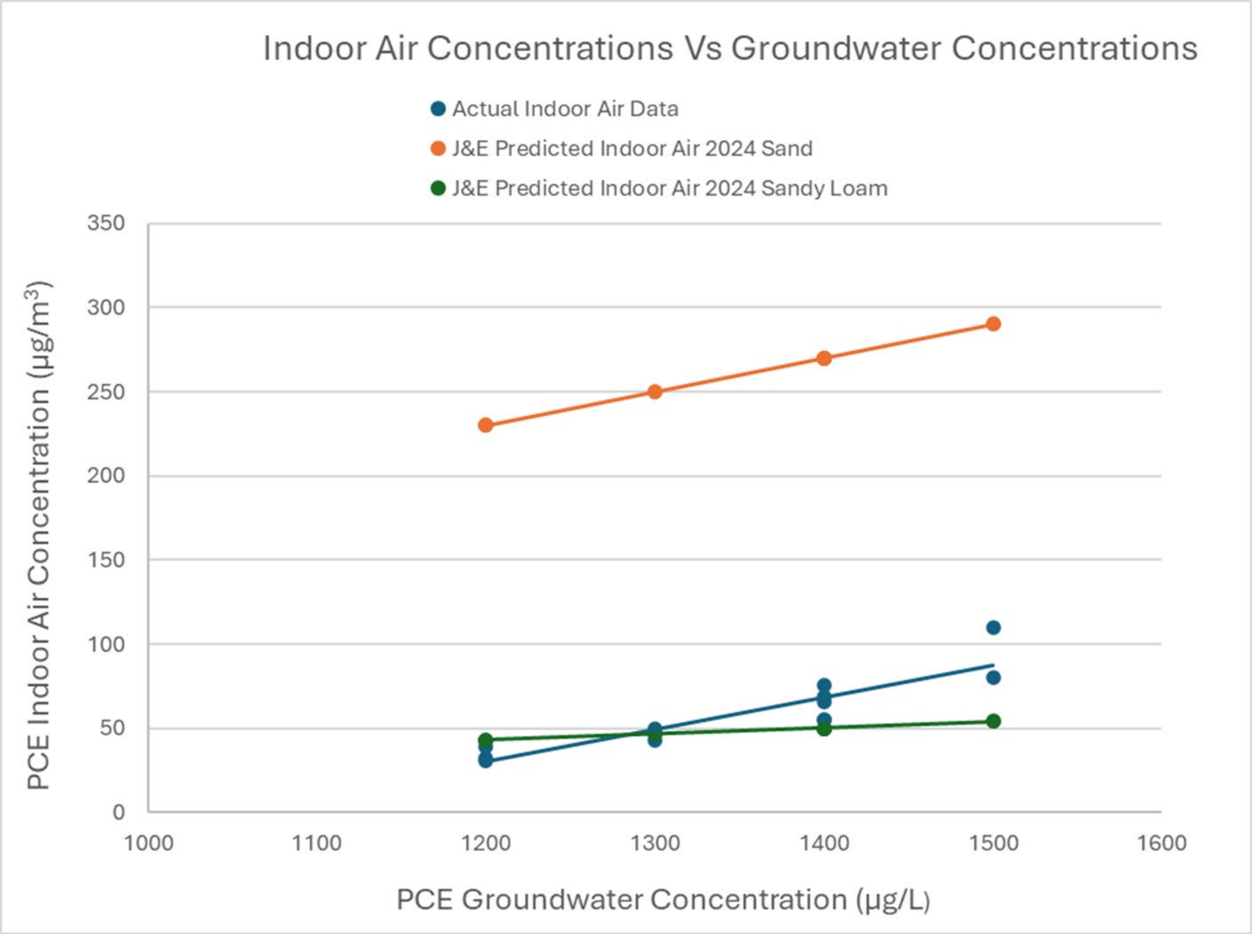
## Maryland Square Case Study

| Sample ID | Depth (feet bgs) | Soil Vapor PCE ($\mu g/m^3$) | J&E Modeling Predicted Indoor Air PCE ($\mu g/m^3$) |
|---|---|---|---|
| SVB-01-05 | 5 | 2,500 | 6.1 |
| SVB-02-04 | 4 | 3,000 | 8.1 |
| SVB-03-05 | 5 | 46,000 | 112.1 |
| SVB-03-12 | 12 | 800 | 1.1 |
| SVB-04-05 | 5 | 400 | 1.0 |
| SVB-04-12 | 12 | 1,000 | 1.4 |
| SVB-05-08 | 8 | 25,000 | 46.8 |

# Vapor Intrusion
## Maryland Square Case Study



# Vapor Intrusion
## Maryland Square Case Study



# Vapor Intrusion
## Maryland Square Case Study

- Indoor air sampling offered annually to households above plume with PCE concentrations >100 µg/L
- SSDS offered to households with indoor air PCE >9.4 $\mu g/m^3$
- ~14 houses have active SSDSs
- Ongoing remediation in the source area

# Vapor Intrusion
## Summary

- Assessment not required for most petroleum sites due to biodegradation in vadose zone. May need to be considered for sites with depth to groundwater <5 feet for dissolved phase, <15 feet for LNAPL or with very high soil vapor concentrations (>10,000,000 µg/m3).
- No default screening distances or attenuation factors for chlorinated solvents. Use Johnson & Ettinger or similar to estimate indoor air concentrations given soil gas or groundwater data, temperature, and soil type.

# Thank You! Questions?

Contact information:

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