# Assessing Variability in Petroleum Vapor Intrusion with PVIScreen

Jim Weaver
(US EPA, retired)

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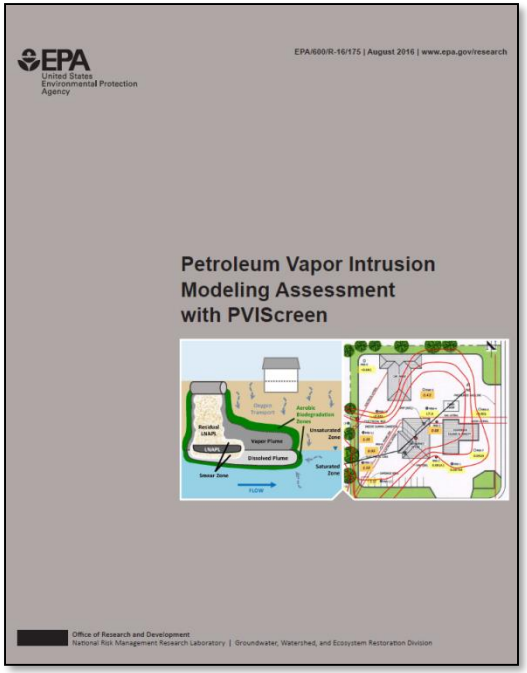
# Outline

- Characteristics of Environmental Models
- Vapor Intrusion and Petroleum Vapor Intrusion
- PVIScreen model
- Excerpts from examples
  - PVI indicated versus not indicated
- Secrets of PVIScreen
- Summary
- Availability



# Why vapor intrusion and models?

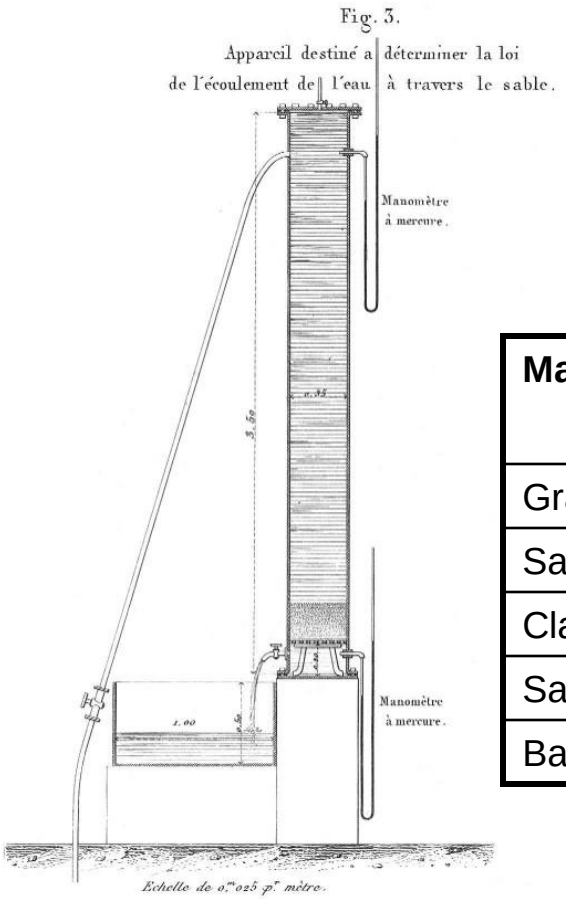
- Technical Challenges
  - ambient air contamination, internal sources/sinks, temporal changes
- Social
  - RP or homeowner reluctance to sample
- In some cases—redeveloping a site—no building exists for testing, so models are relied upon

# Vapor Intrusion and Models

- Series of articles in the Denver Post in 2000
  - The vapor intrusion model (Johnson-Ettinger) over-predicted indoor air concentrations sometimes and under-predicted indoor air concentrations sometimes
  - Model used with defaults and very few site specific values

# Example: Darcy's Law

- Darcy flux q = -K dh/dl
  - Relationship from Darcy's sand tank experiments
  - Empirical coefficient, the hydraulic conductivity (K), from experiment: measuring the flow (q)

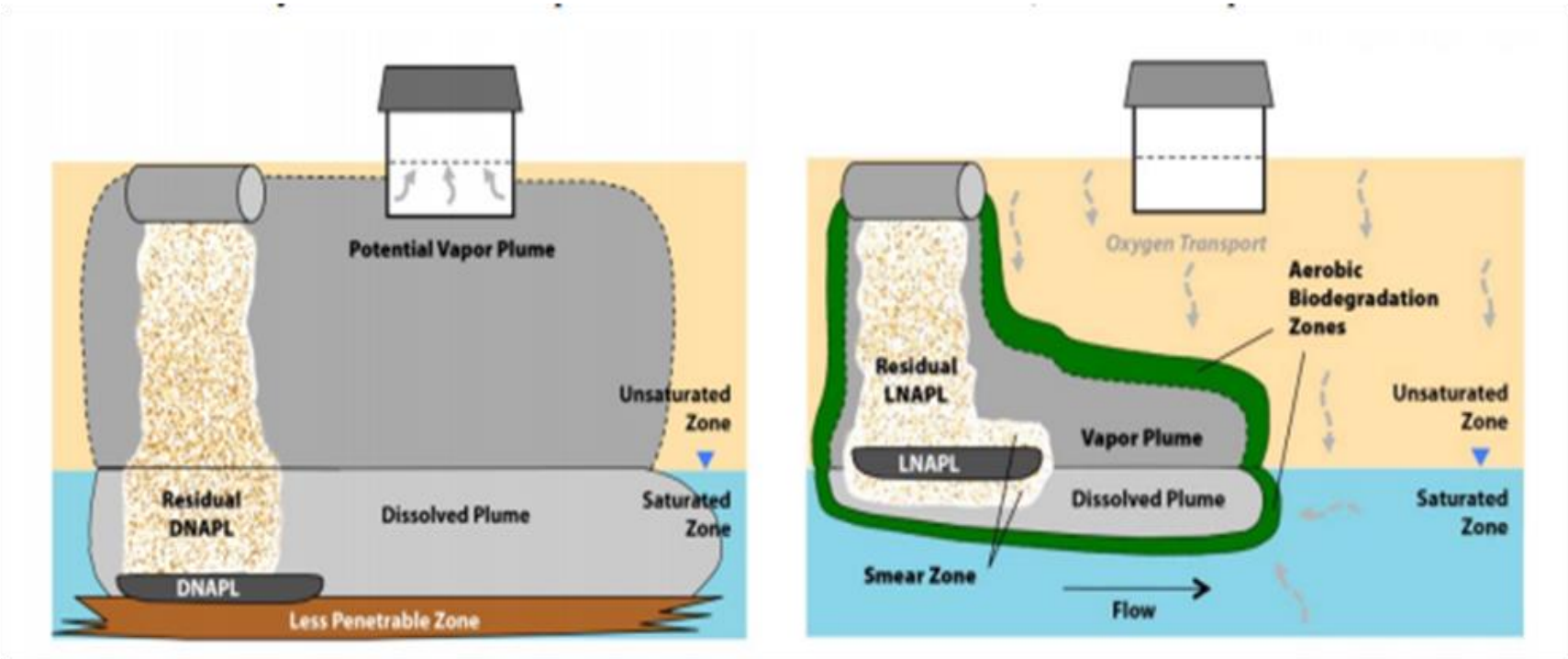



| Material | Value (m/d) |
|---|---|
| Gravel | $10^{2}$ to $10^{4}$ |
| Sand | $10^{-1}$ to $10^{3}$ |
| Clay | $10^{-8}$ to $10^{-3}$ |
| Sandstone | $10^{-5}$ to 10 |
| Basalt | $10^{-6}$ to $10^{-2}$ |

# Limits to Predictability

- Note the work of N. Oreskes on ideal applications for models:
  - Weather forecasting
    - Forecast *given* and *received* with uncertainties

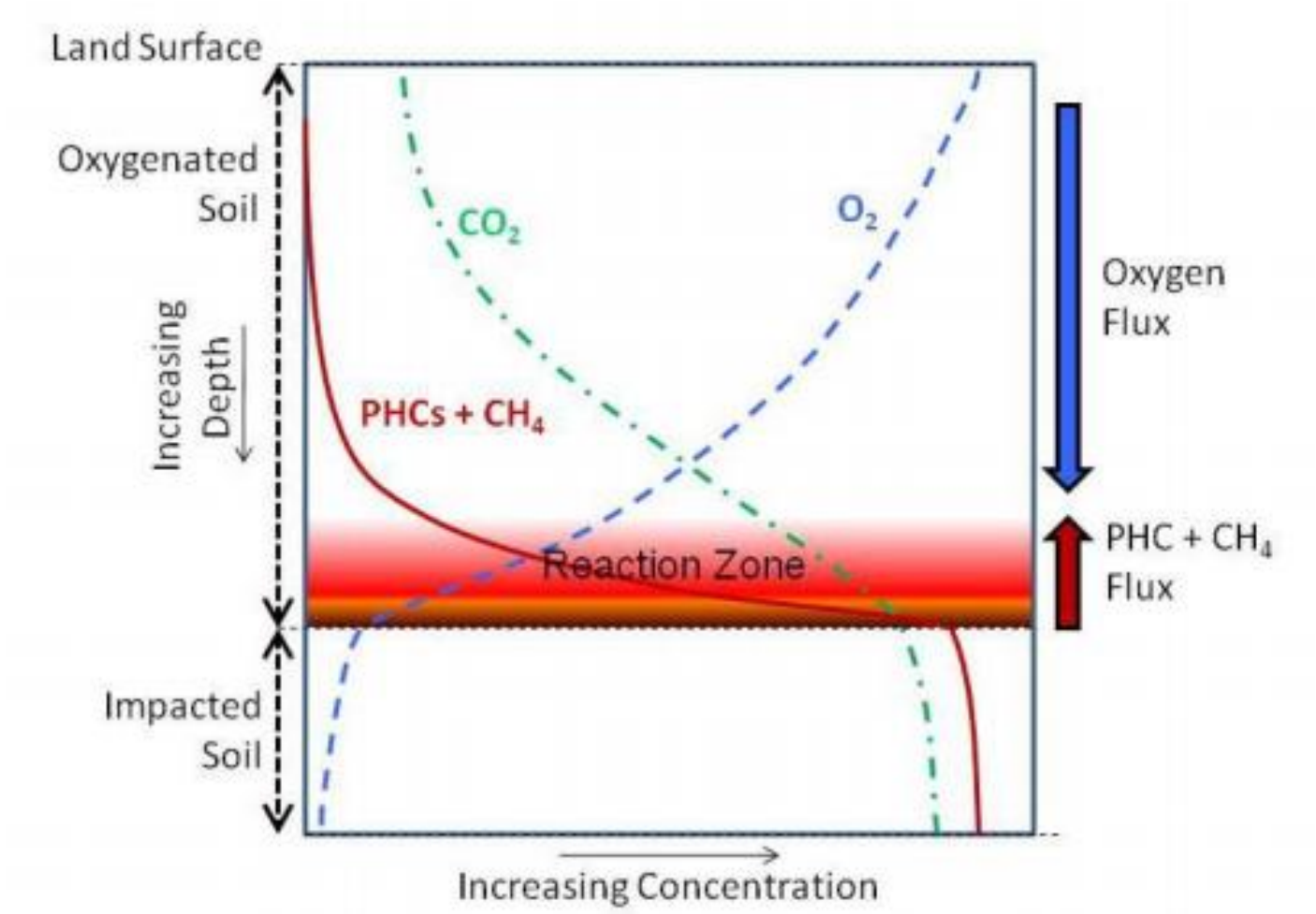
- Oreskes, Naomi, 2003, The role of quantitative models in science, in Models in Ecosystem Science, C.D. Canham and W.K. Lauenroth, eds. Princeton University Press, 13-31



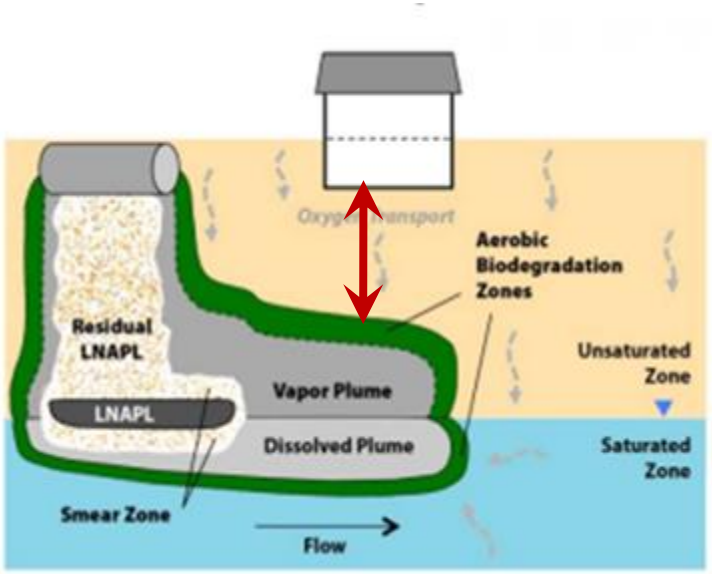

Chlorinated Solvent (left) petroleum (right) are distinguished by prospects for biodegradation

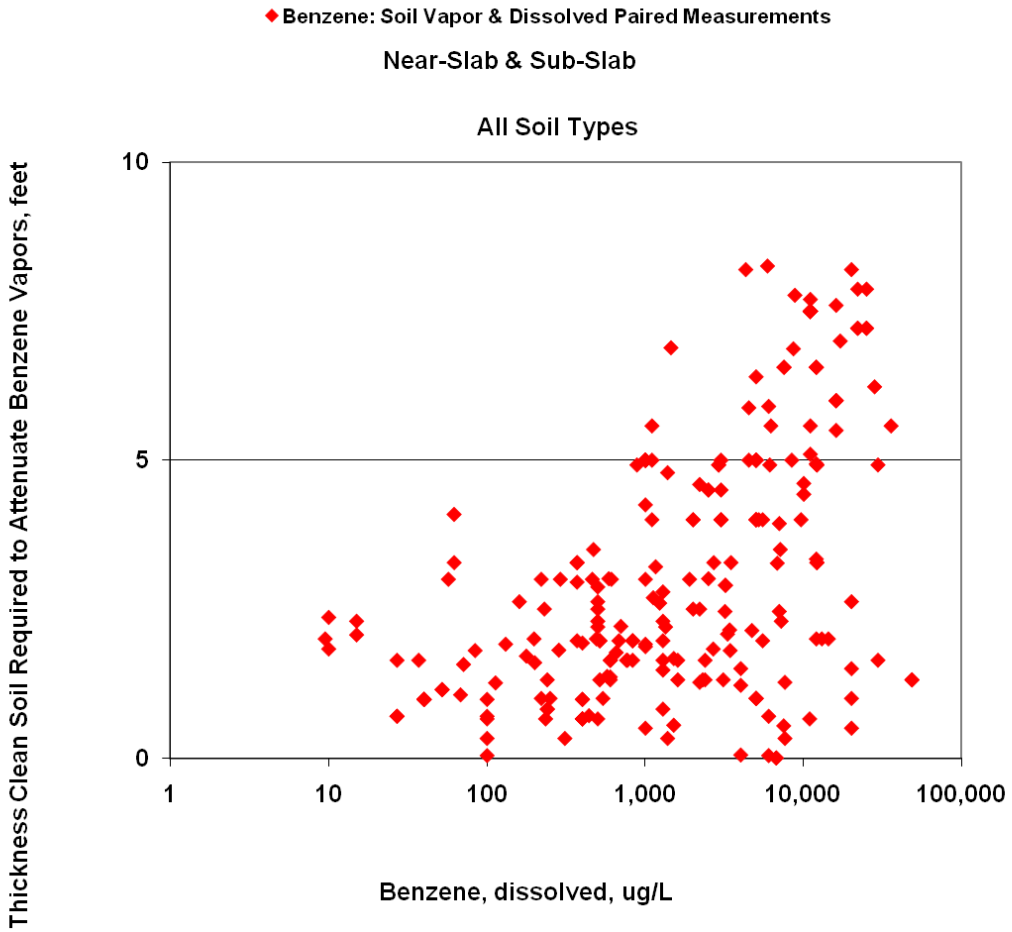
U.S. EPA, 2012, Petroleum Hydrocarbons And Chlorinated Hydrocarbons Differ In Their Potential For Vapor Intrusion, U.S. Environmental Protection Agency, Washington, DC., March.

# Petroleum Vapor Intrusion and biodegradation:

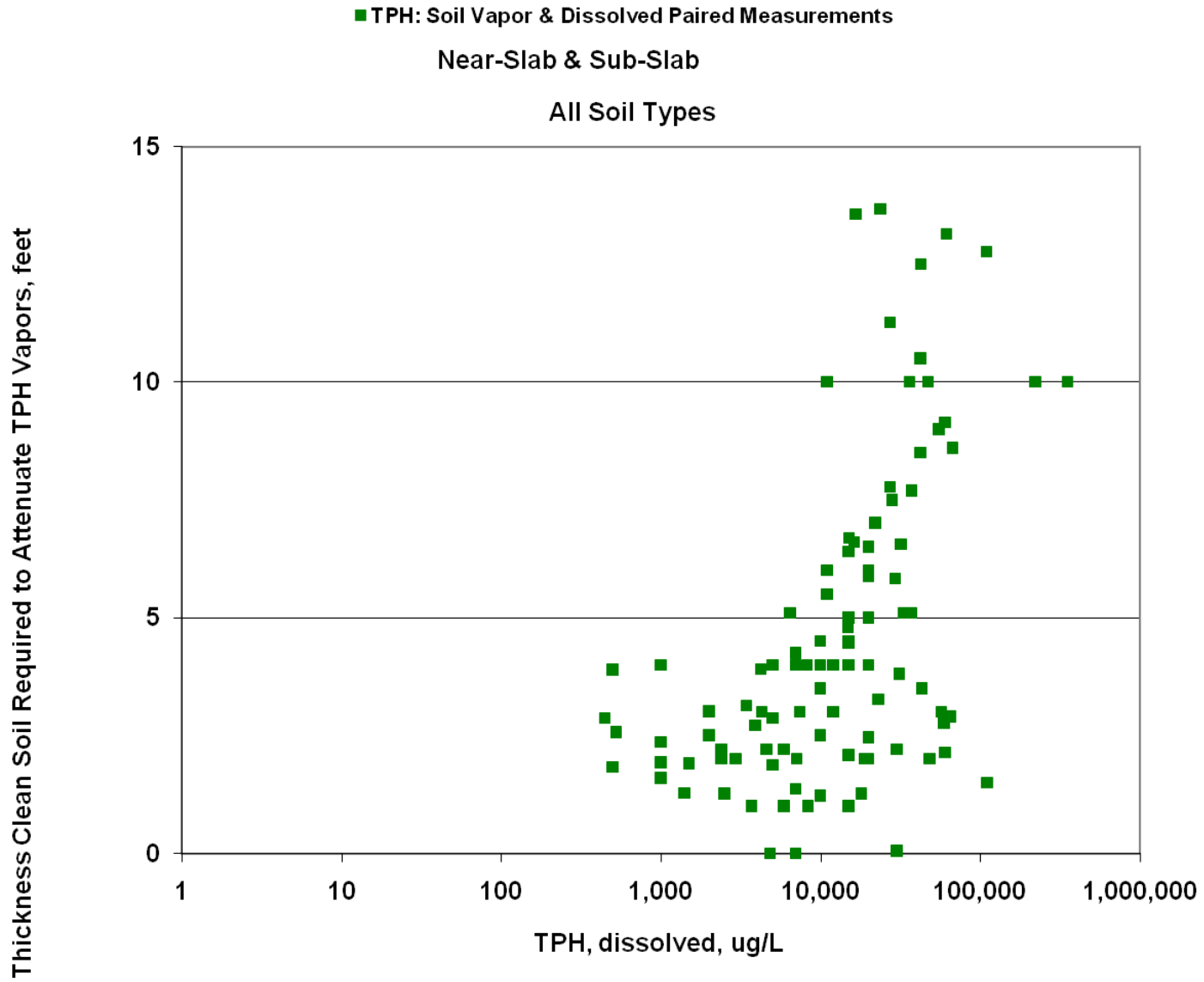


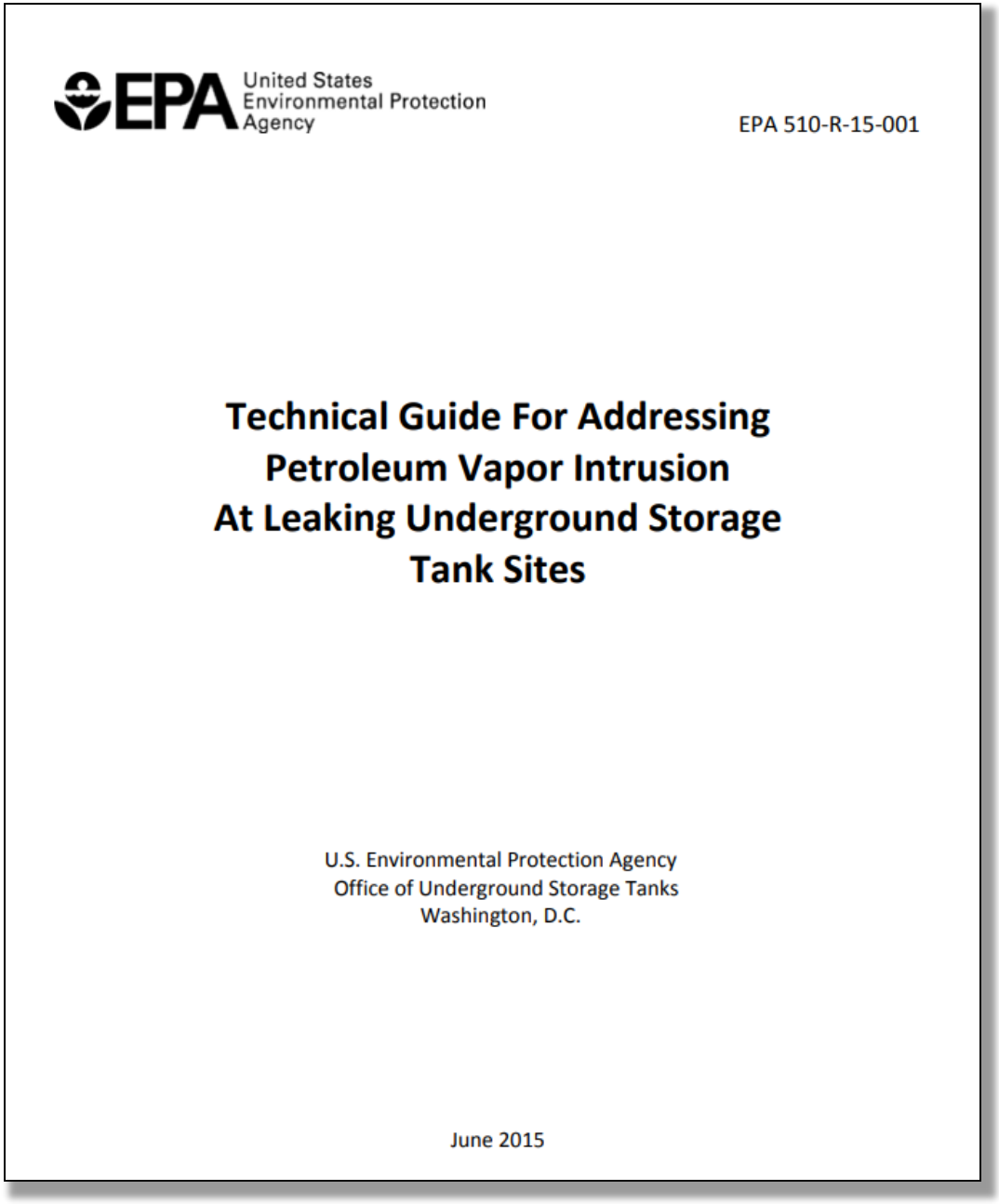
# PVIScreen rests on a foundation of field data:




Robin V. Davis, 2009, Update on Recent Studies and Proposed Screening Criteria for the Vapor-Intrusion Pathway, LUSTLine Bulletin 61, pp 11-14.


TPH: Soil Vapor & Dissolved Paired Measurements
Near-Slab & Sub-Slab
All Soil Types
Thickness Clean Soil Required to Attenuate TPH Vapors, feet
15
10
5
0
1
10
100
1,000
10,000
100,000
1,000,000
TPH, dissolved, ug/L


EPA United States Environmental Protection Agency
EPA 510-R-15-001
Technical Guide For Addressing Petroleum Vapor Intrusion At Leaking Underground Storage Tank Sites
U.S. Environmental Protection Agency
Office of Underground Storage Tanks
Washington, D.C.
June 2015

Site assessment flow chart from OUST guide on PVI

Model Use:

- NOT without mitigating immediate threats
- NOT without site characterization
- As a line of evidence for related to determination of vertical separation distance*

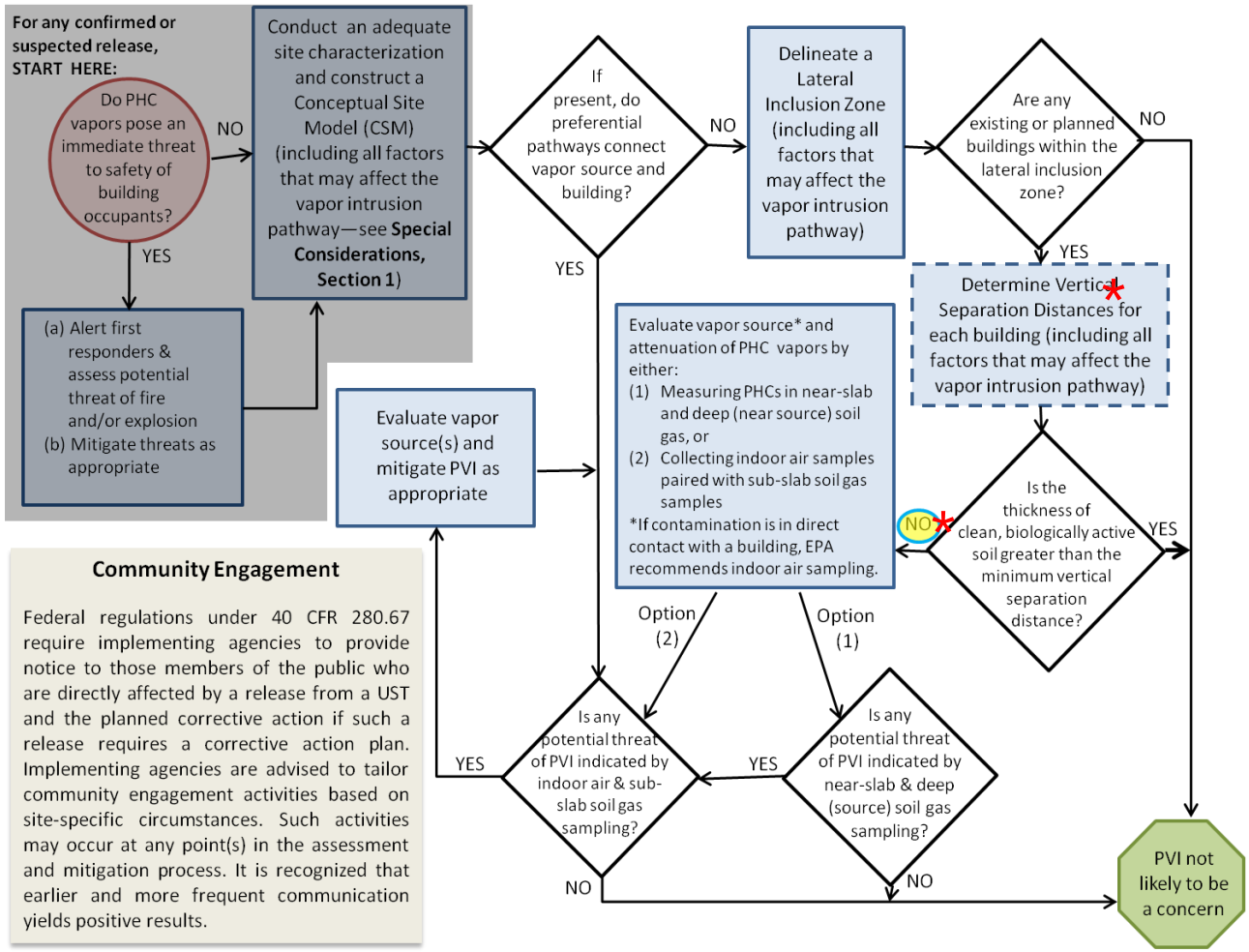


**Table 3. Recommended Vertical Separation Distance Between Contamination And Building Basement Floor, Foundation, Or Crawlspace Surface.**

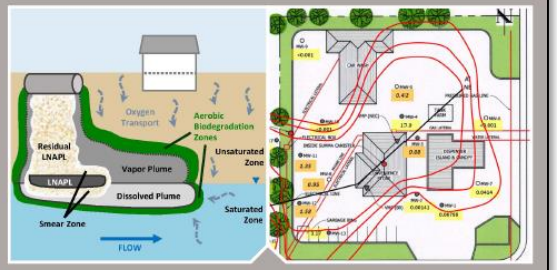
| Media | Benzene | TPH | Vertical Separation Distance (feet)* |
|---|---|---|---|
| Soil (mg/Kg) | ≤10 | ≤ 100 (unweathered gasoline), or ≤ 250 (weathered gasoline, diesel) | 6 |
| | >10 (LNAPL) | > 100 (unweathered gasoline) >250 (weathered gasoline, diesel) | 15 |
| Groundwater (mg/L) | ≤5 | ≤30 | 6 |
| | >5 (LNAPL) | >30 (LNAPL) | 15 |

Consider PVIScreen usage in marginal cases as a second line of evidence

EPA
United States
Environmental Protection
Agency

EPA/600/R-16/175 | August 2016 | www.epa.gov/research

# Petroleum Vapor Intrusion Modeling Assessment with PVIScreen




Office of Research and Development
National Risk Management Research Laboratory | Groundwater, Watershed, and Ecosystem Restoration Division

EPA/600/R-16/175
August 2016

# Petroleum Vapor Intrusion Modeling Assessment with PVIScreen

James W. Weaver
United States Environmental Protection Agency
Office of Research and Development
National Risk Management Research Laboratory
Groundwater, Watershed, and Ecosystem Restoration Division
Ada, Oklahoma 74820

Robin V. Davis
Utah Department of Environmental Quality
Salt Lake City, Utah 84116

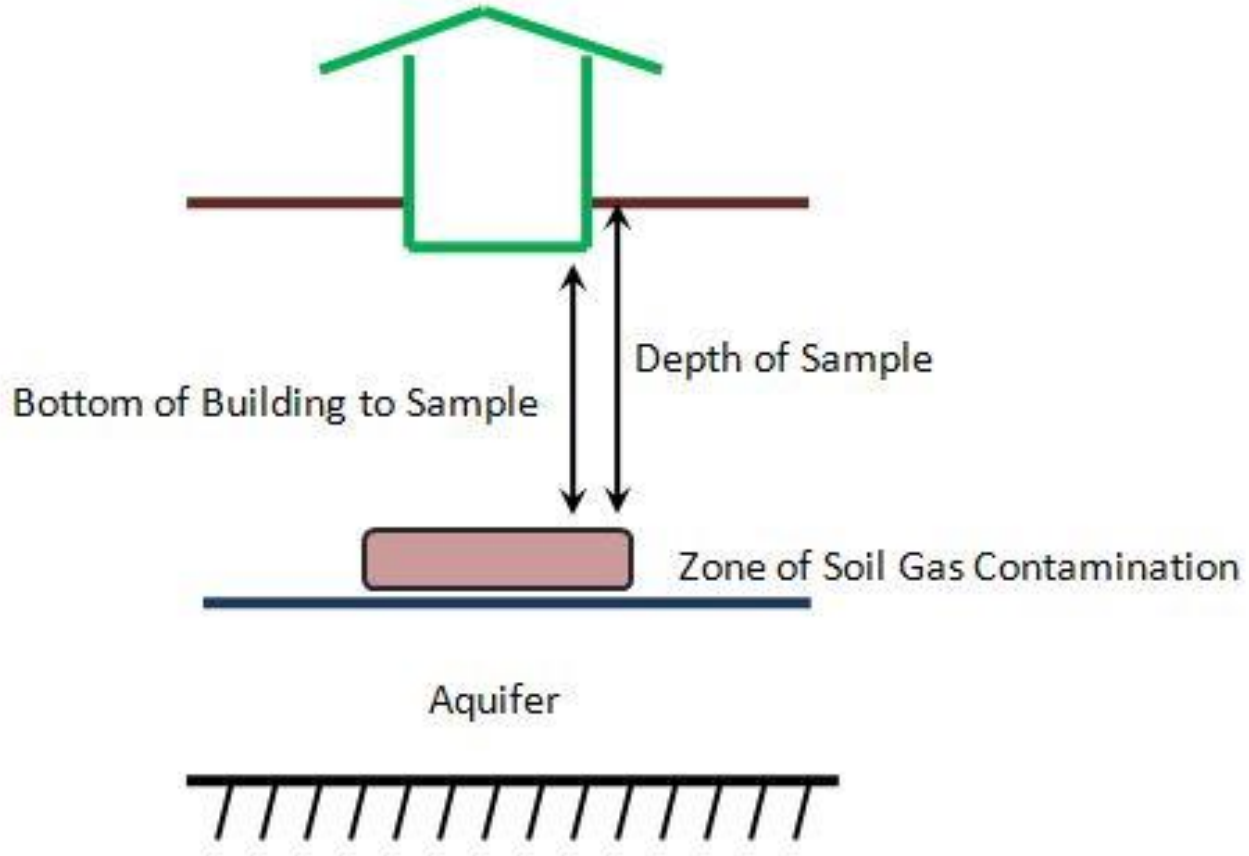
Office of Research and Development
National Risk Management Research Laboratory | Groundwater, Watershed, and Ecosystem Restoration Division

http://www.epa.gov/land-research/pviscreen

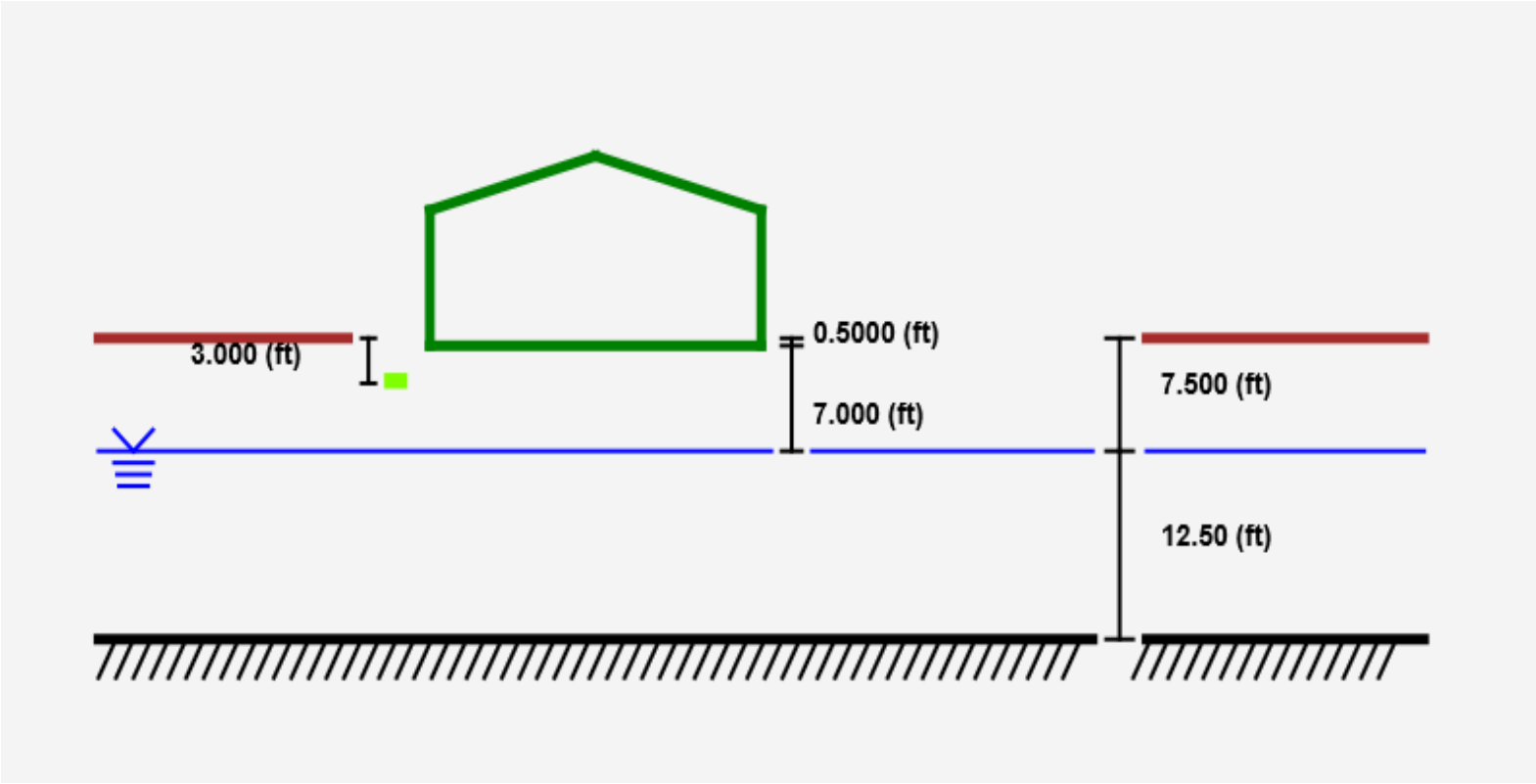
# PVIScreen

- PVIScreen includes:
  - BioVapor equations, recoded in Java for speed
  - Automated Monte Carlo uncertainty analysis
    - the native way the code is used
  - Soil gas or ground water source
  - Comparison to screening levels
  - Flexible and customizable unit choices
  - Automated Report
- Primary focus:
  - To add line of evidence for site assessment and closure decisions
  - To make uncertainty analysis practical by giving a prediction and estimate of its uncertainty

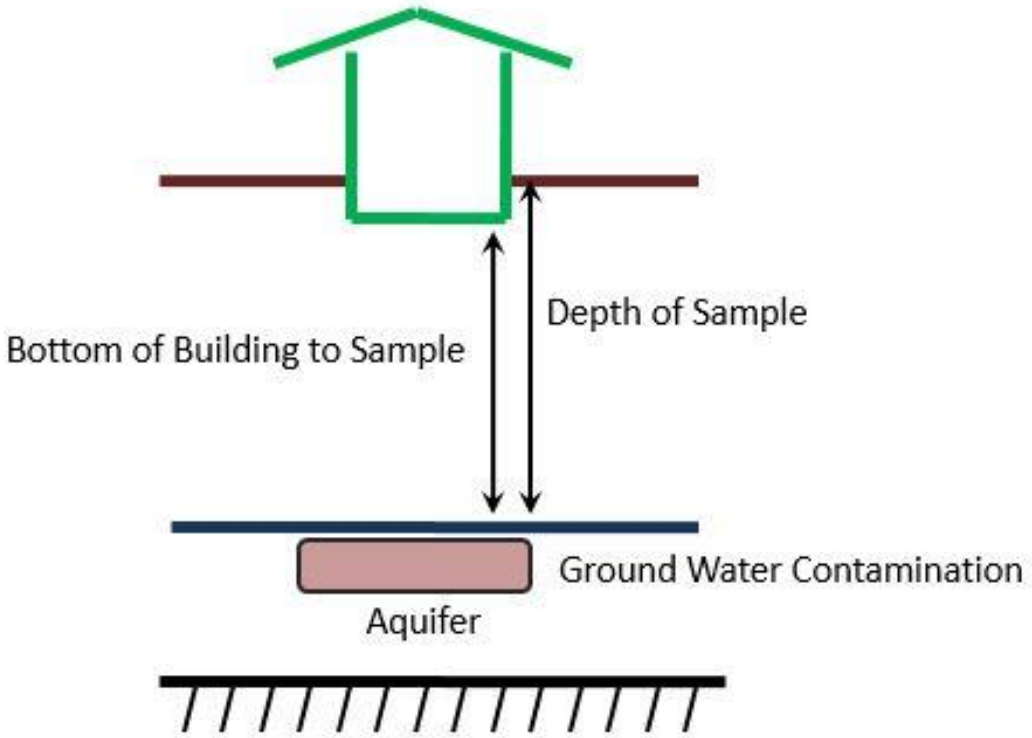
# PVIScreen Sources:  Soil Gas Data



# PVIScreen generates schematic



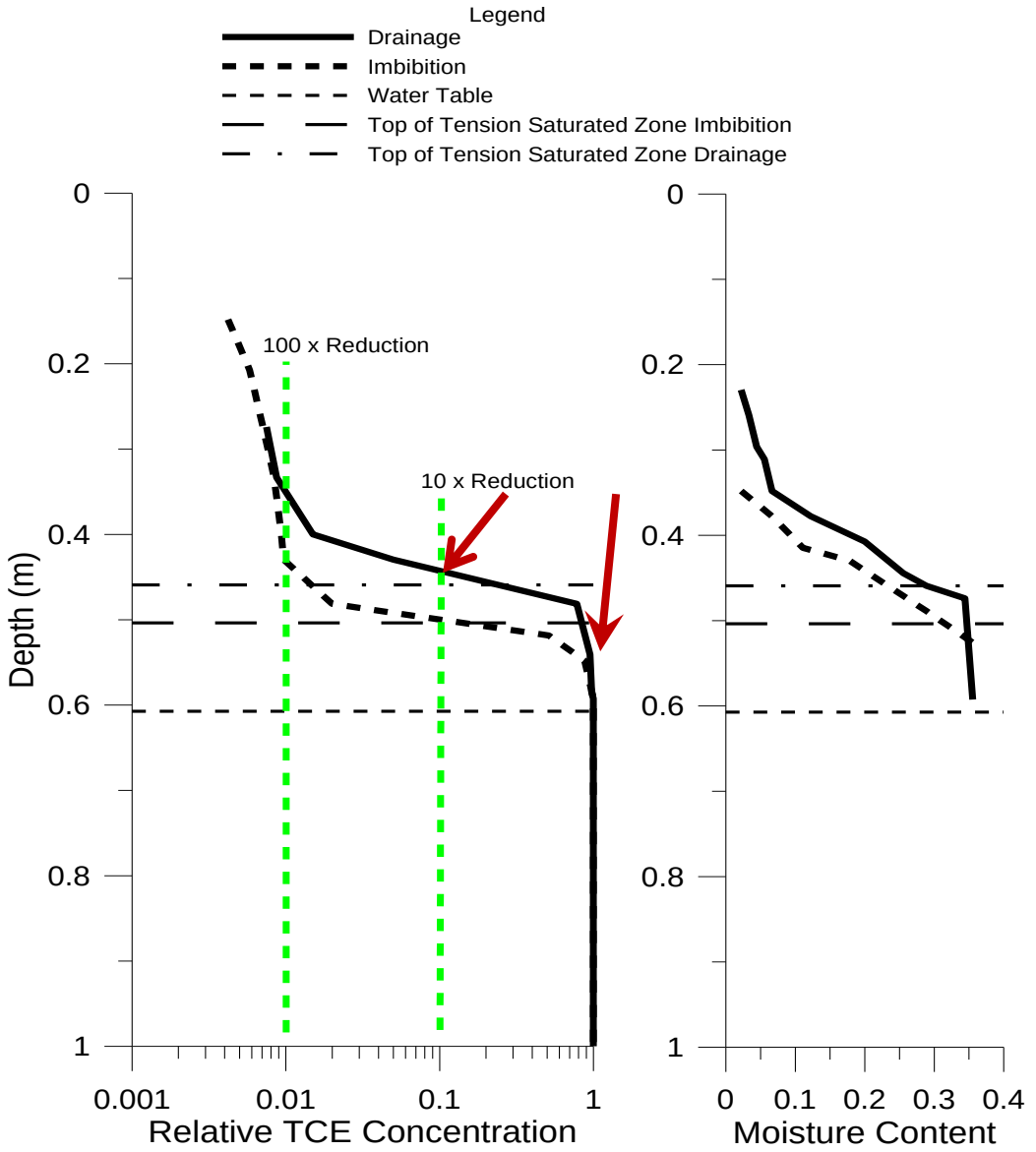
# PVIScreen Sources:  Ground Water Data



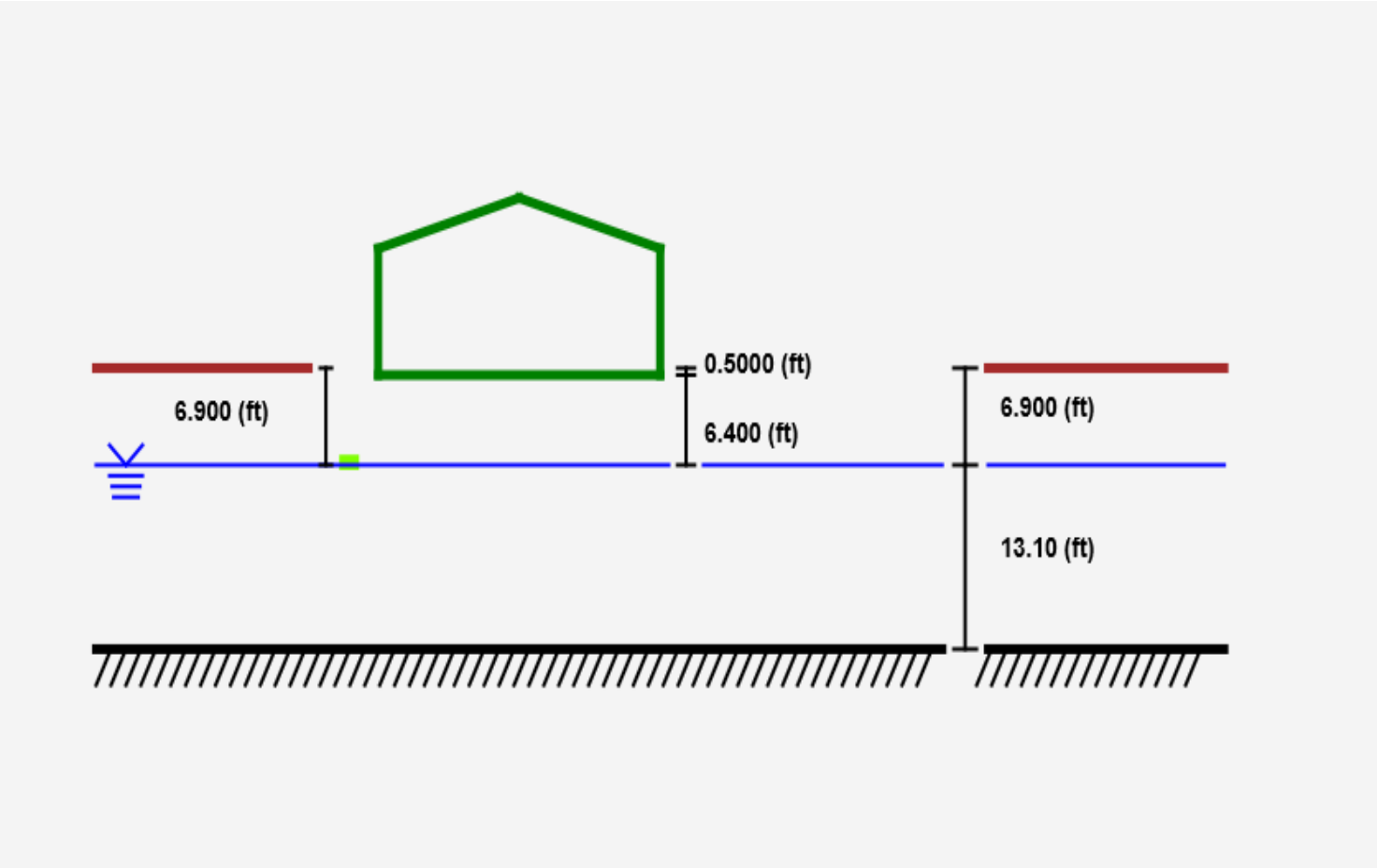
# Concentration relationships in the capillary fringe: from one data set*

- Concentration reduction by ~1/10 through the capillary fringe

*McCarthy, K.A. and Johnson, R.L., 1993, Transport of volatile organic compounds across the capillary fringe, Water Resources Research, 29(6) 1675-1683.



# Schematic showing ground water source



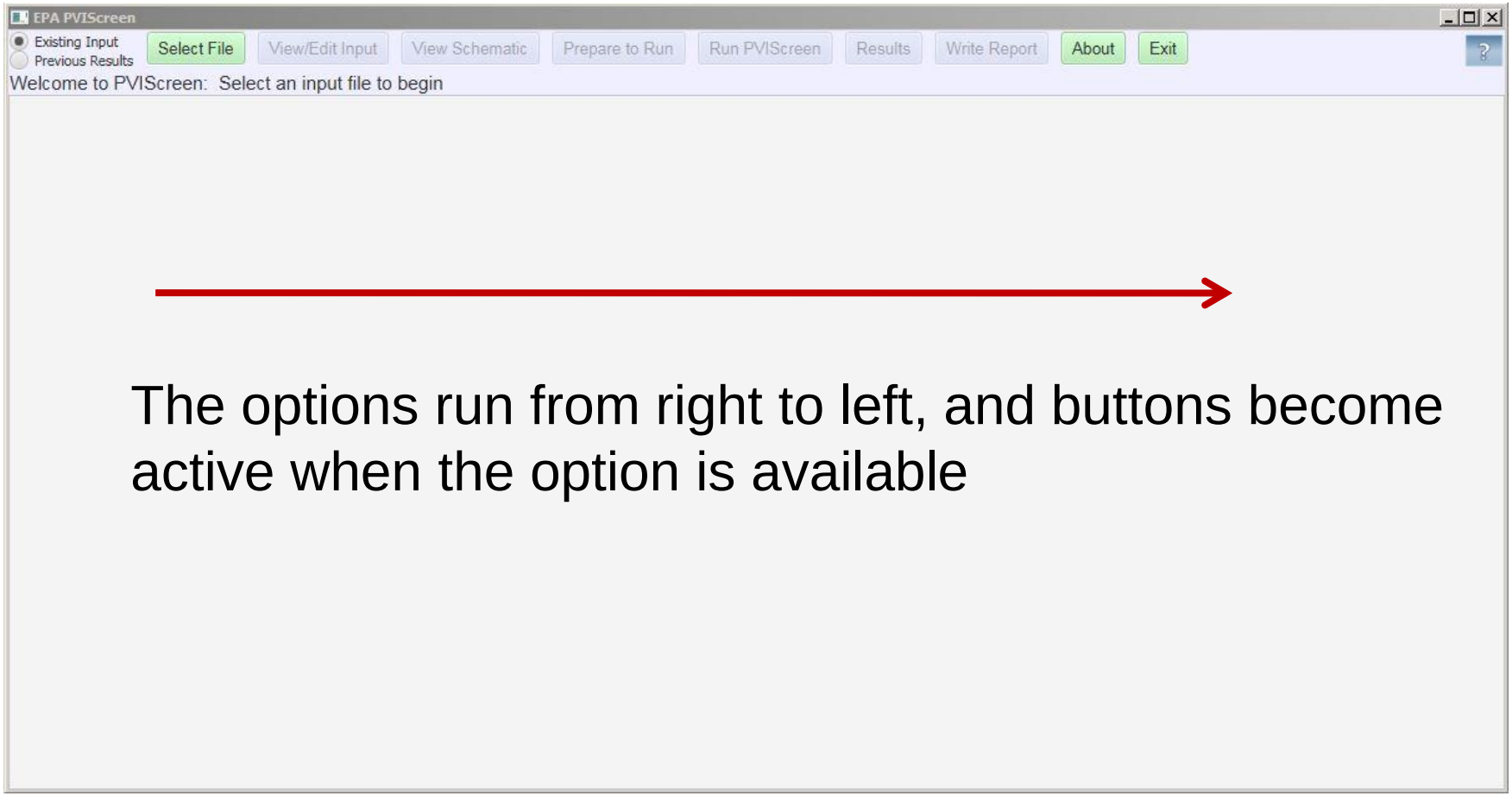
# Perils of Ground Water as the Source for PVIScreen

- Does the ground water concentration represent the capillary fringe?
- Borehole dilution and screen length?

# How does it work?

- PVIScreen is written in Java
- The interface:  JavaFX
- All inputs and outputs saved in text files:
  - File extensions managed by User Interface:
    - Input:  *ProblemName*.pvi
    - Output: ProblemName-DateTime.PVIScreen.Result.csv
    - Input and output files are ASCII text files in comma-separated value format—direct editing not advised.
- Runs from Windows Directory (double click)

# PVIScreen Interface:



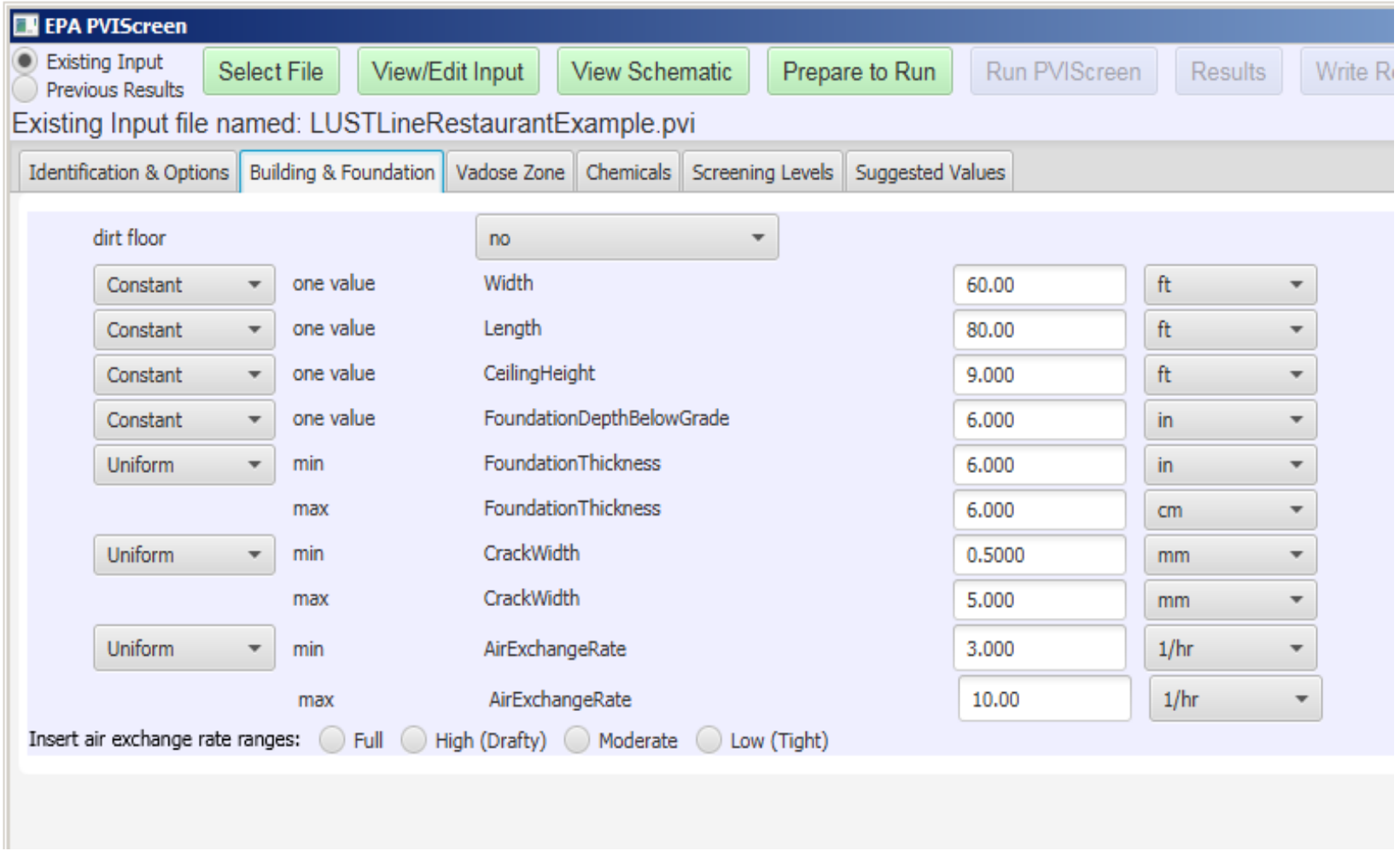

The options run from right to left, and buttons become active when the option is available

Approach to uncertainty:  allow parameters to be treated as uncertain, *but incorporate all known parameter values*

- GUI allows
  - Constant
  - min to max range

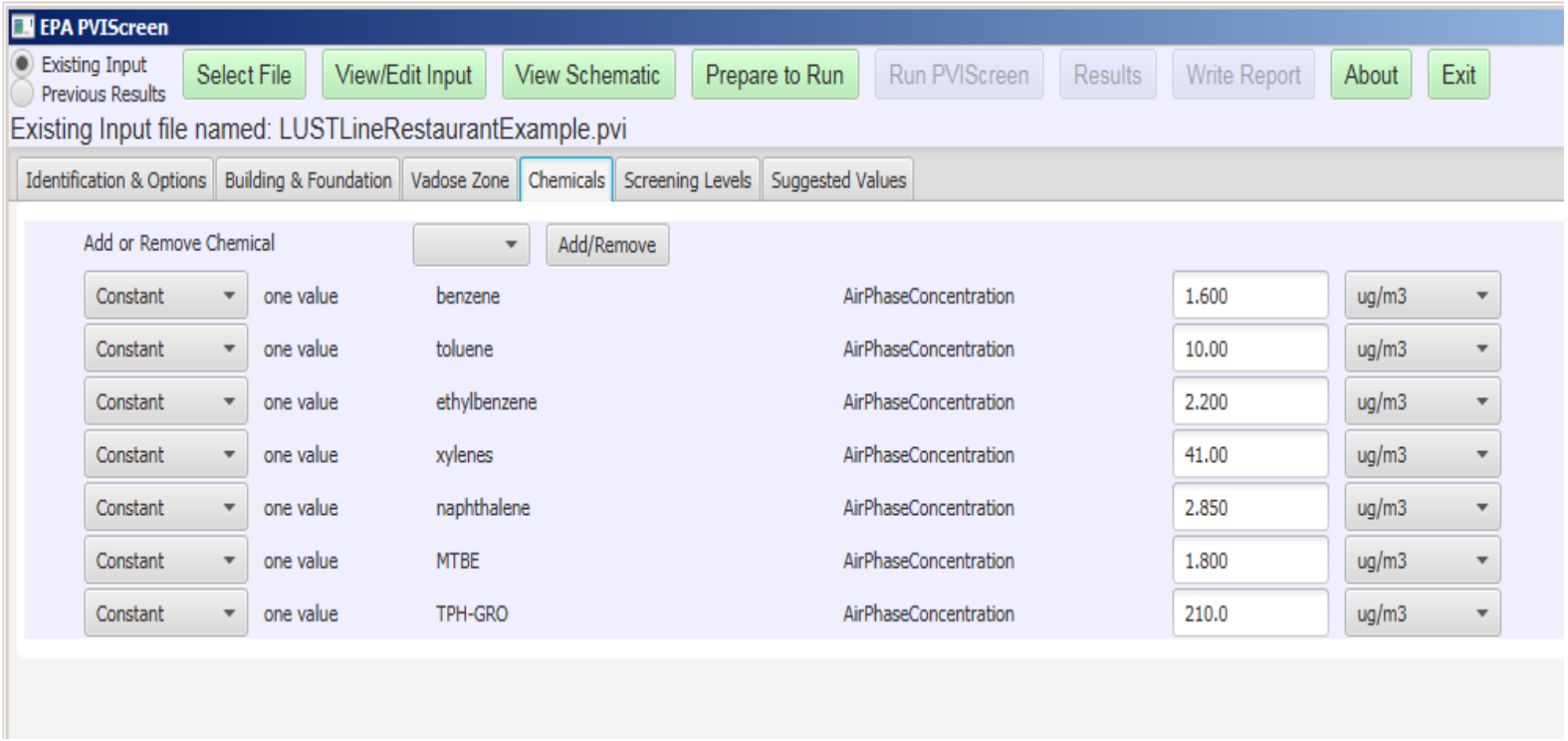

- Command line also allows empirical and parametric distributions
  - (not included in GUI or today's presentation)

# Example inputs: constants or ranges

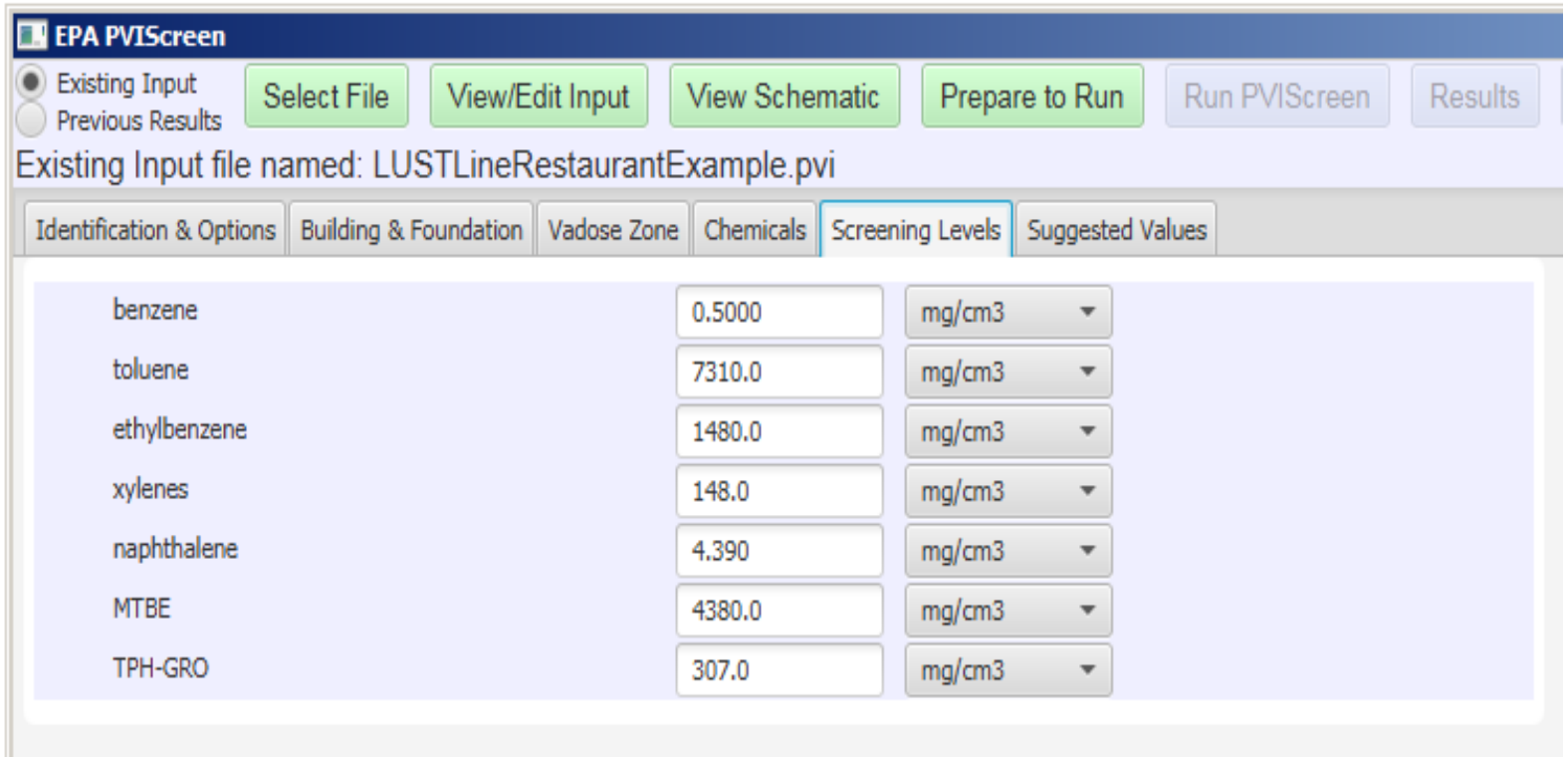


# Inputs of multiple constituents

- all oxygen should NOT go to degrade only benzene,
- Include TPH or petroleum fractions



# Input of Screening Levels:

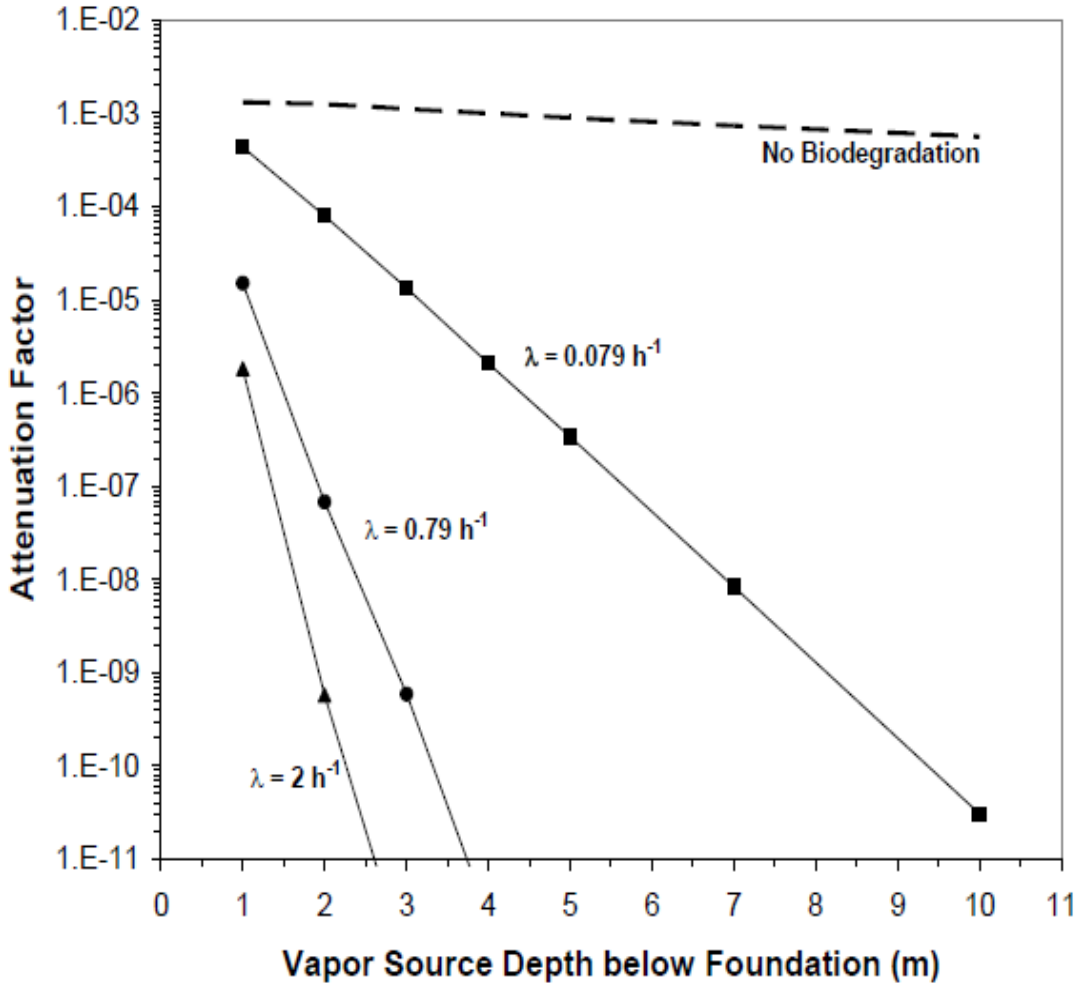



State-specific or EPA RSL

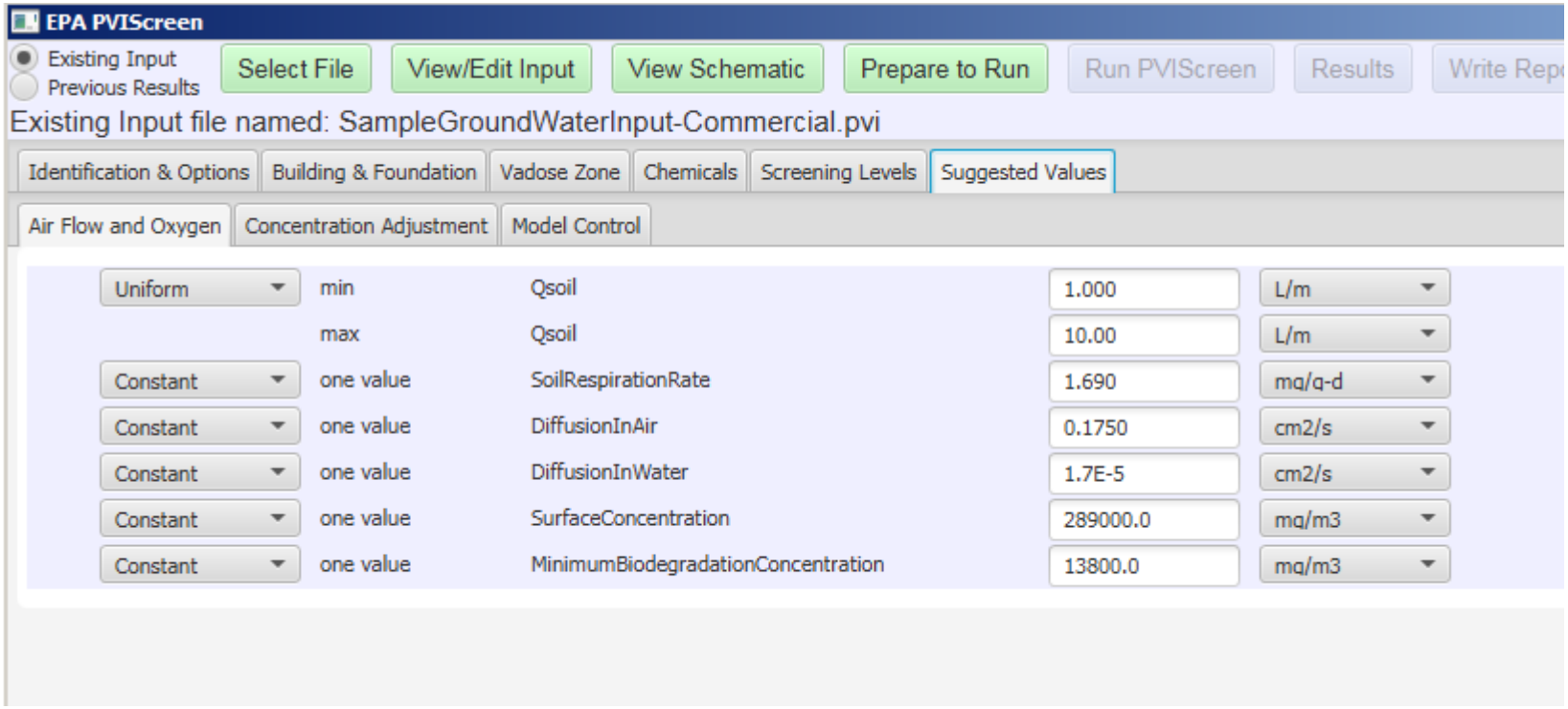
https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables

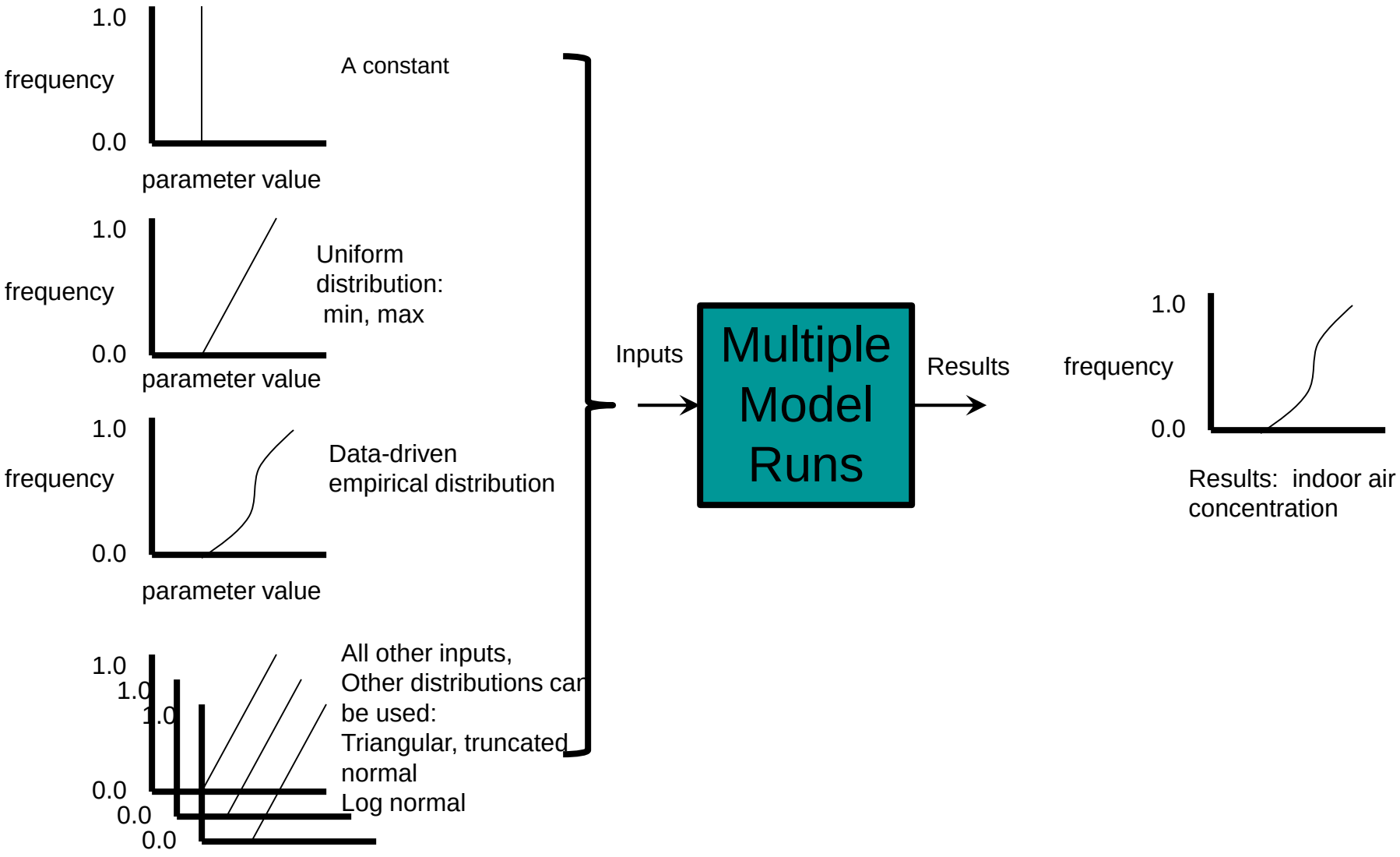
Factors controlling biodegradation are uncertain, variable

- Hydrocarbon degradation rates vary by factor of 100
- How does this impact PVI?

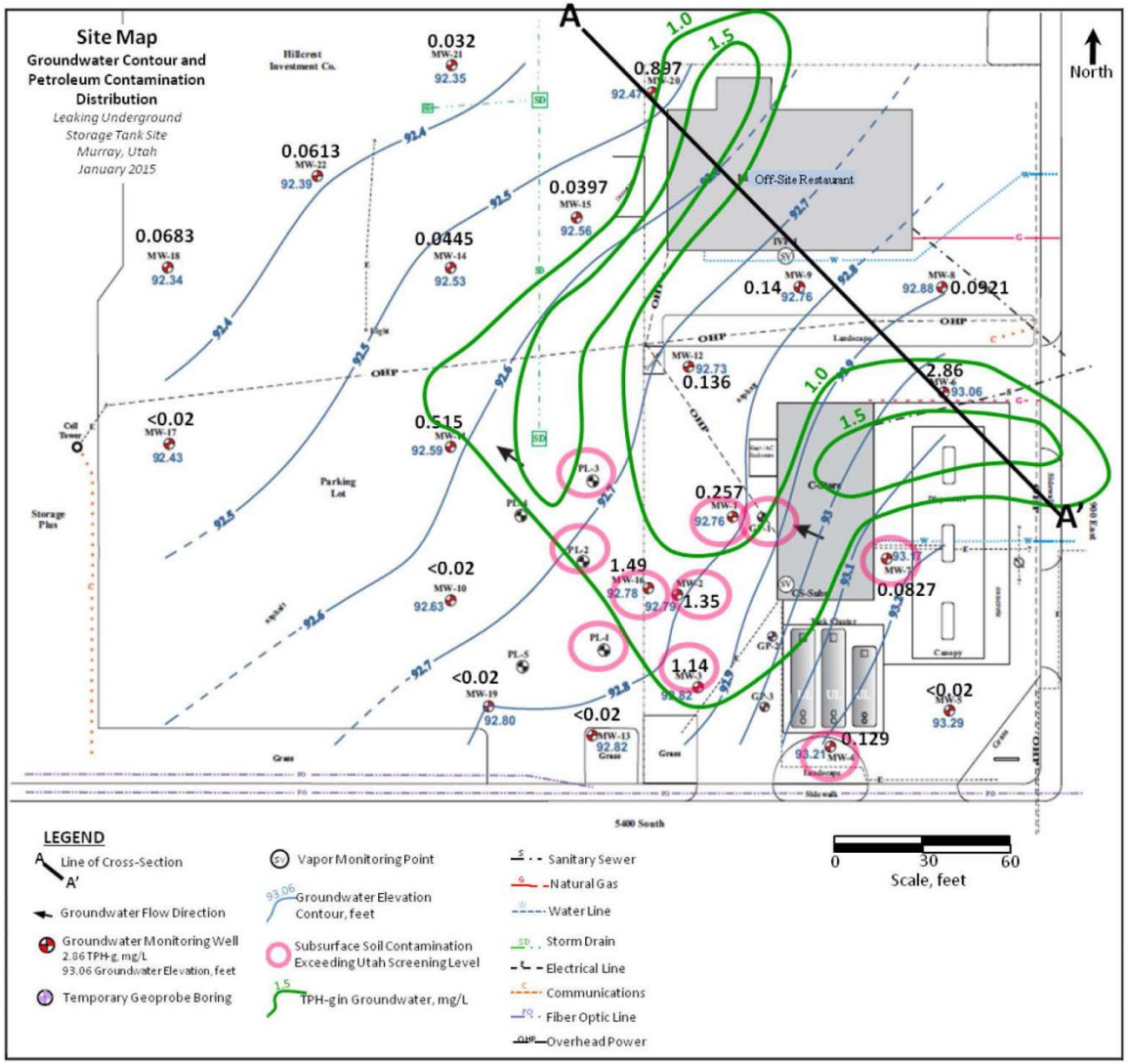


# “Suggested” Values

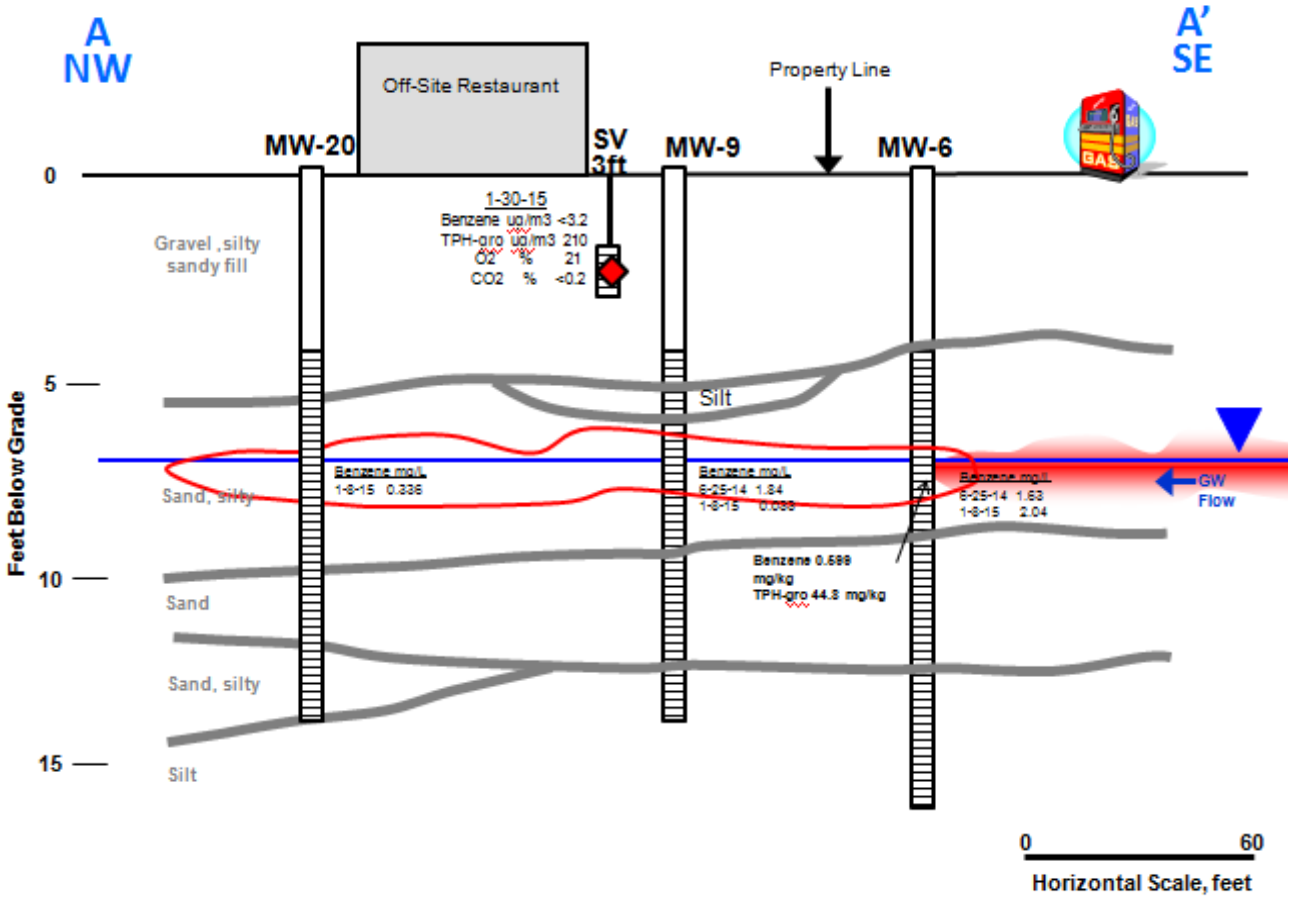



1.0
frequency
0.0
parameter value
A constant
1.0
frequency
0.0
parameter value
Uniform distribution: min, max
1.0
frequency
0.0
parameter value
Data-driven empirical distribution
1.0
1.0
1.0
0.0
0.0
0.0
All other inputs, Other distributions can be used: Triangular, truncated normal Log normal
Inputs
Multiple Model Runs
Results
1.0
frequency
0.0
Results: indoor air concentration

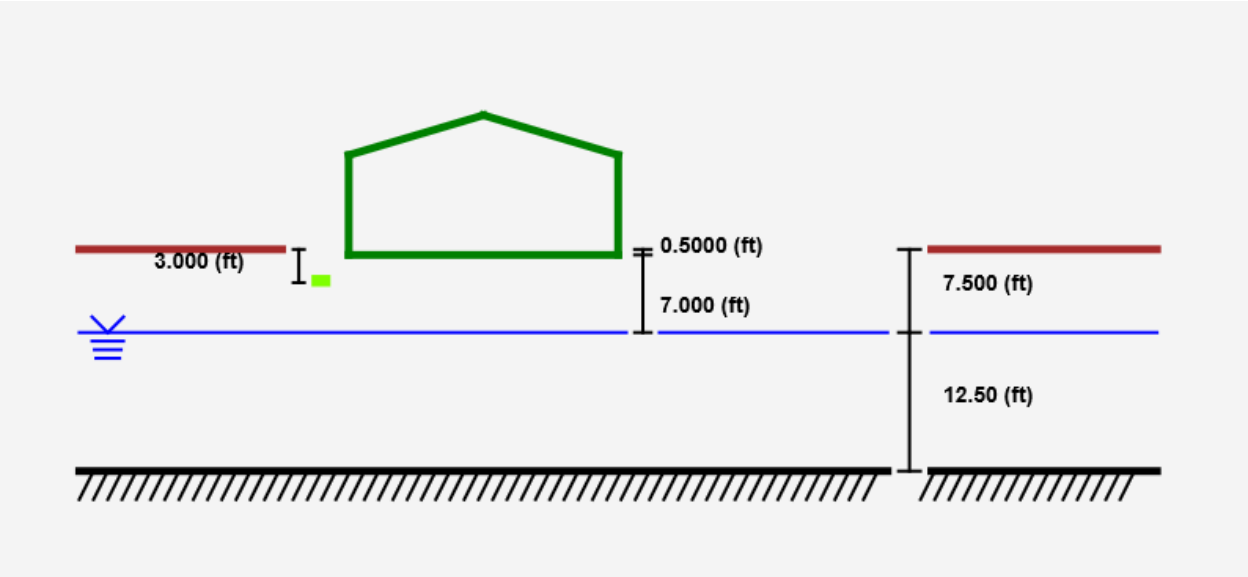
# Soil gas input data example from a site in Utah:

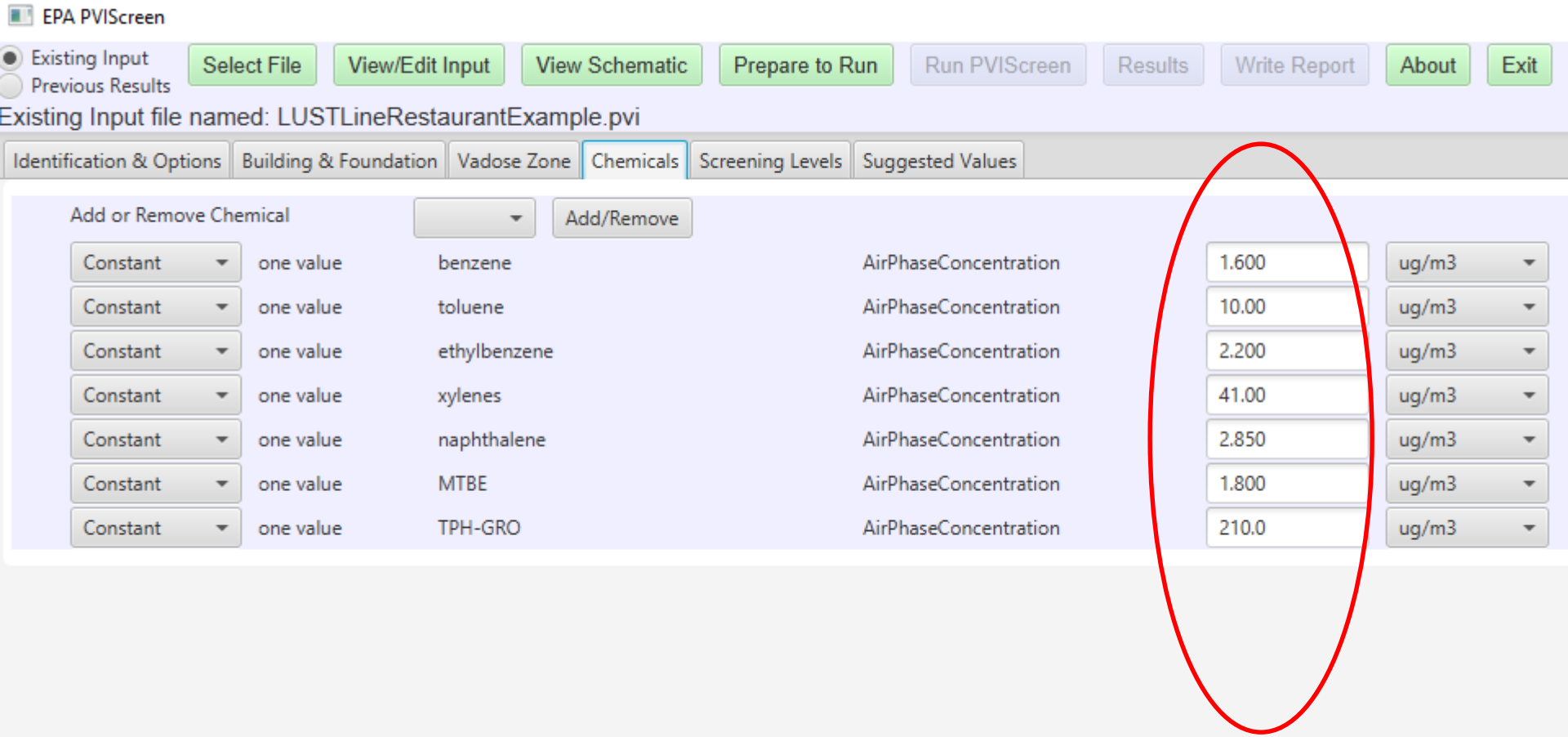


# Impacts to Off-Site Restaurant? PVIScreen 'driven' by soil gas data at 3' below the surface

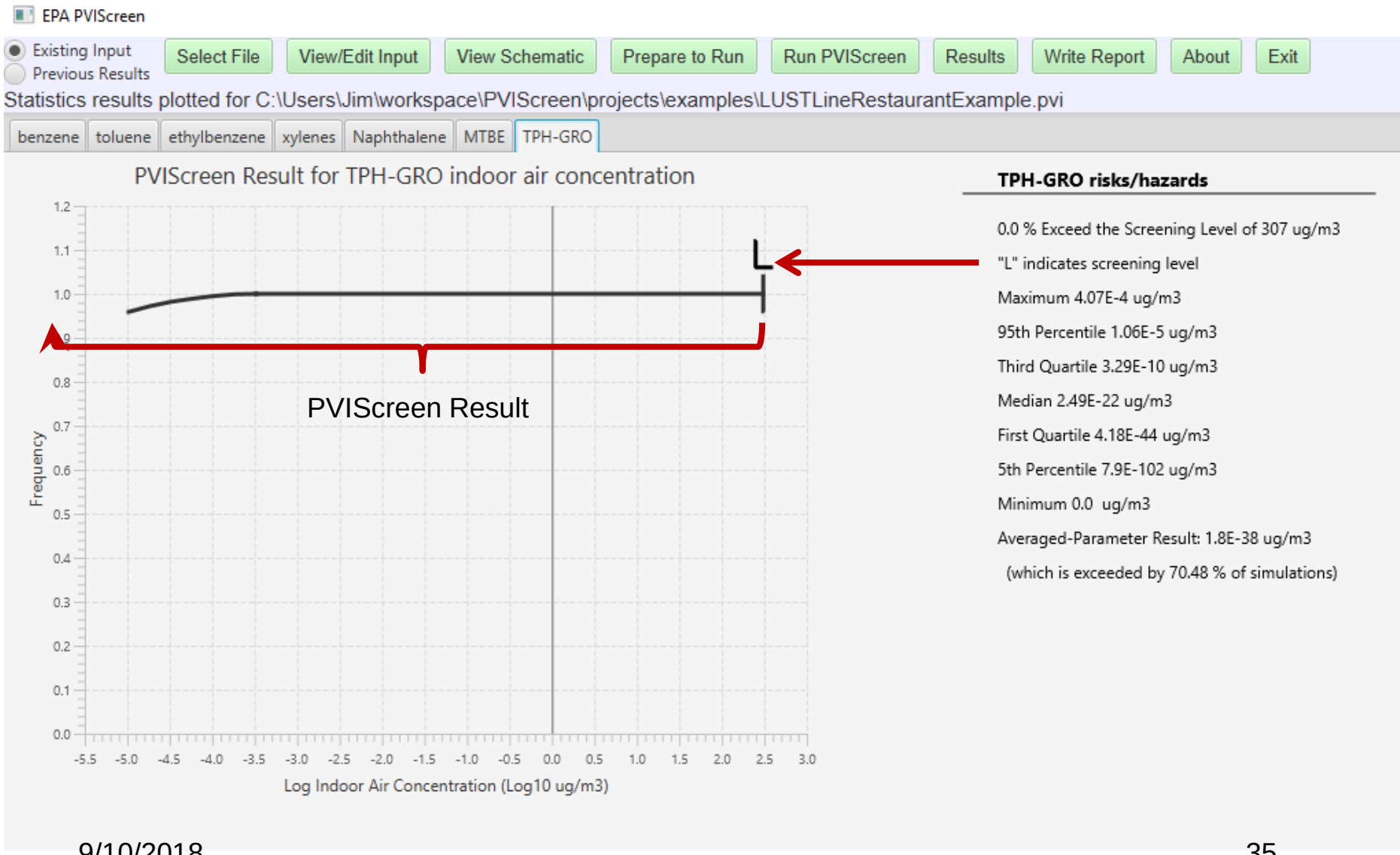


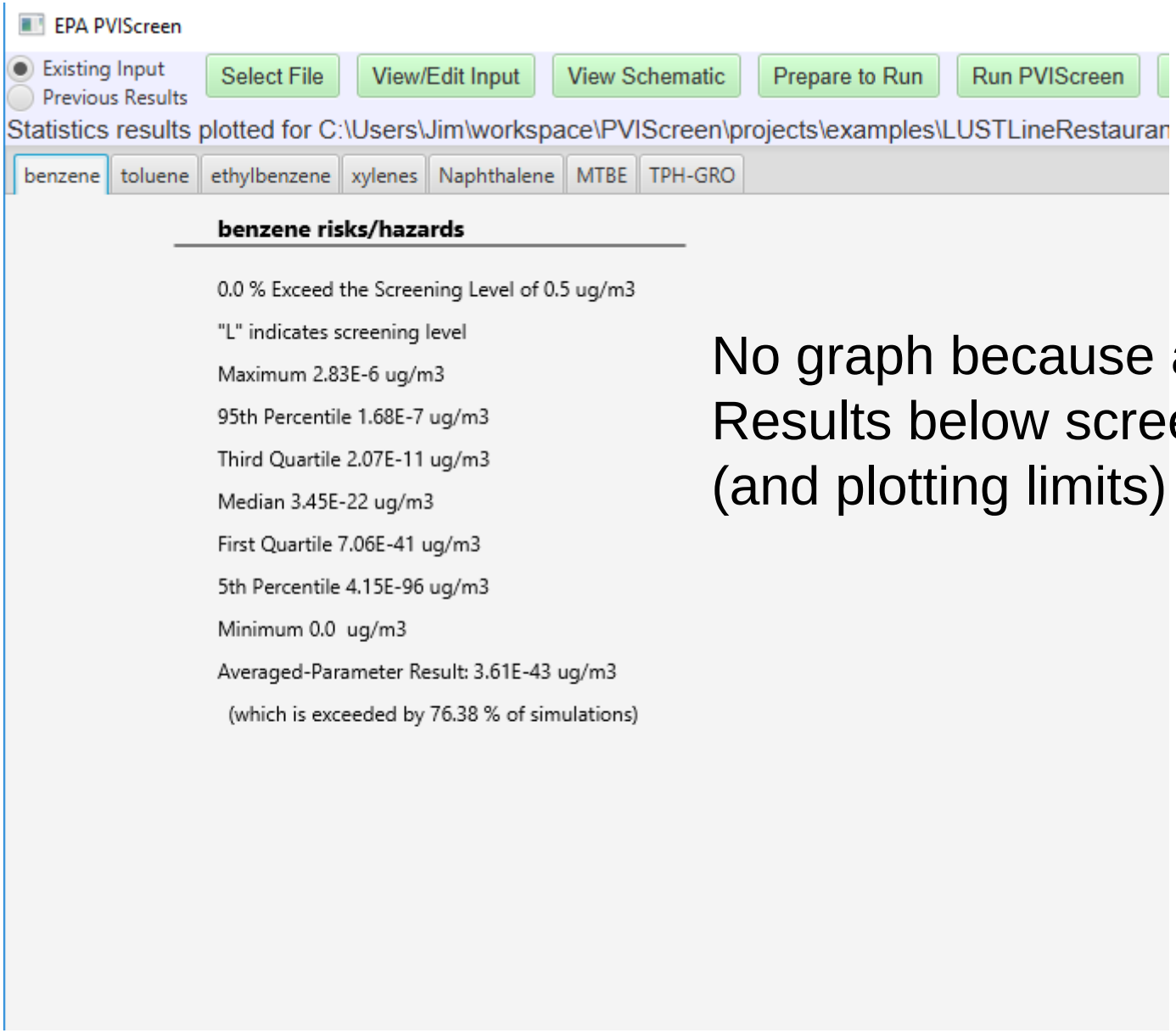
# PVIScreen generates schematic



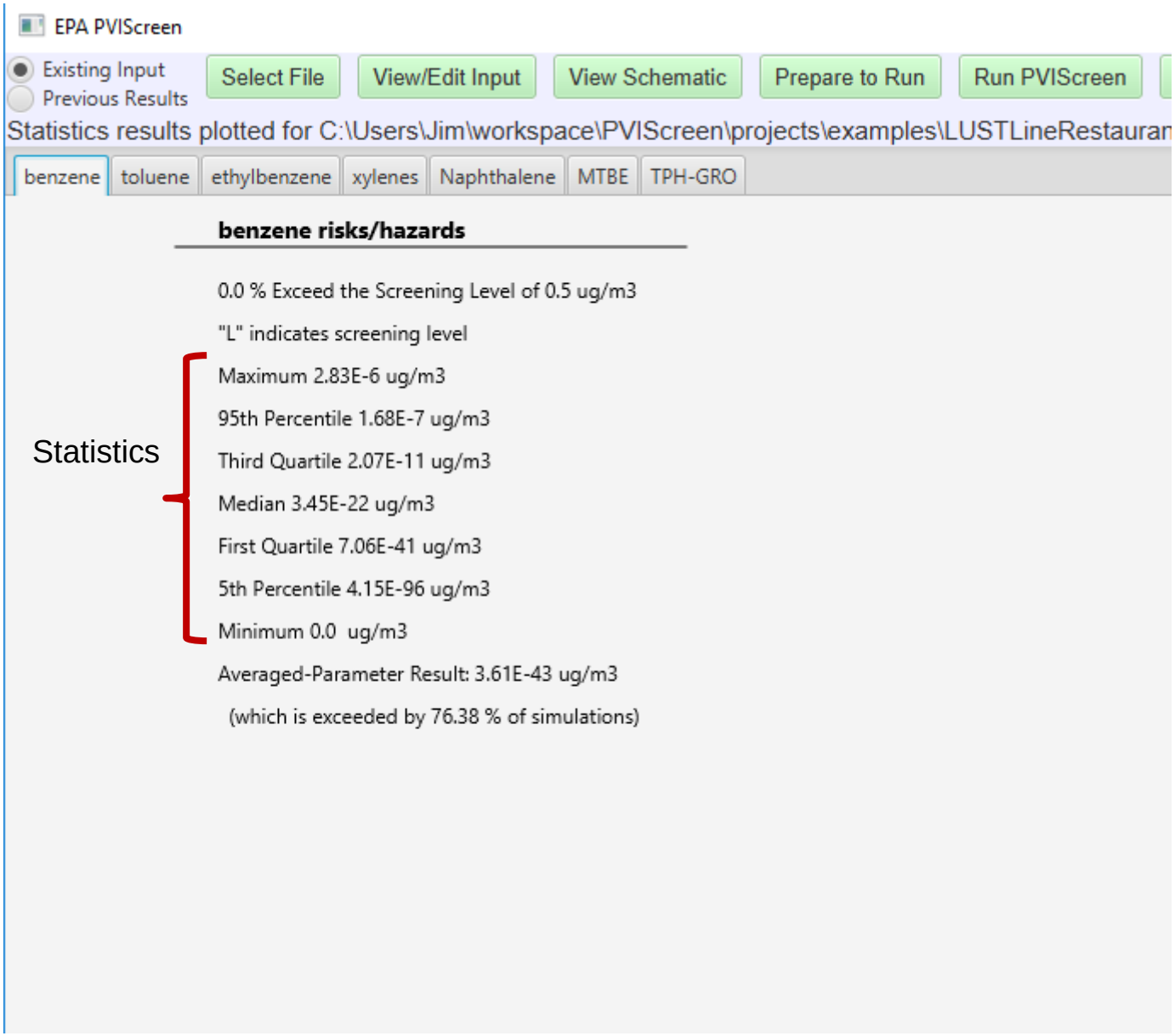

EPA PVIScreen
Existing Input
Previous Results
Select File
View/Edit Input
View Schematic
Prepare to Run
Run PVIScreen
Results
Write Report
About
Exit
Existing Input file named: LUSTLineRestaurantExample.pvi
Identification & Options
Building & Foundation
Vadose Zone
Chemicals
Screening Levels
Suggested Values
Add or Remove Chemical
Add/Remove
Constant one value benzene AirPhaseConcentration 1.600 ug/m3
Constant one value toluene AirPhaseConcentration 10.00 ug/m3
Constant one value ethylbenzene AirPhaseConcentration 2.200 ug/m3
Constant one value xylenes AirPhaseConcentration 41.00 ug/m3
Constant one value naphthalene AirPhaseConcentration 2.850 ug/m3
Constant one value MTBE AirPhaseConcentration 1.800 ug/m3
Constant one value TPH-GRO AirPhaseConcentration 210.0 ug/m3

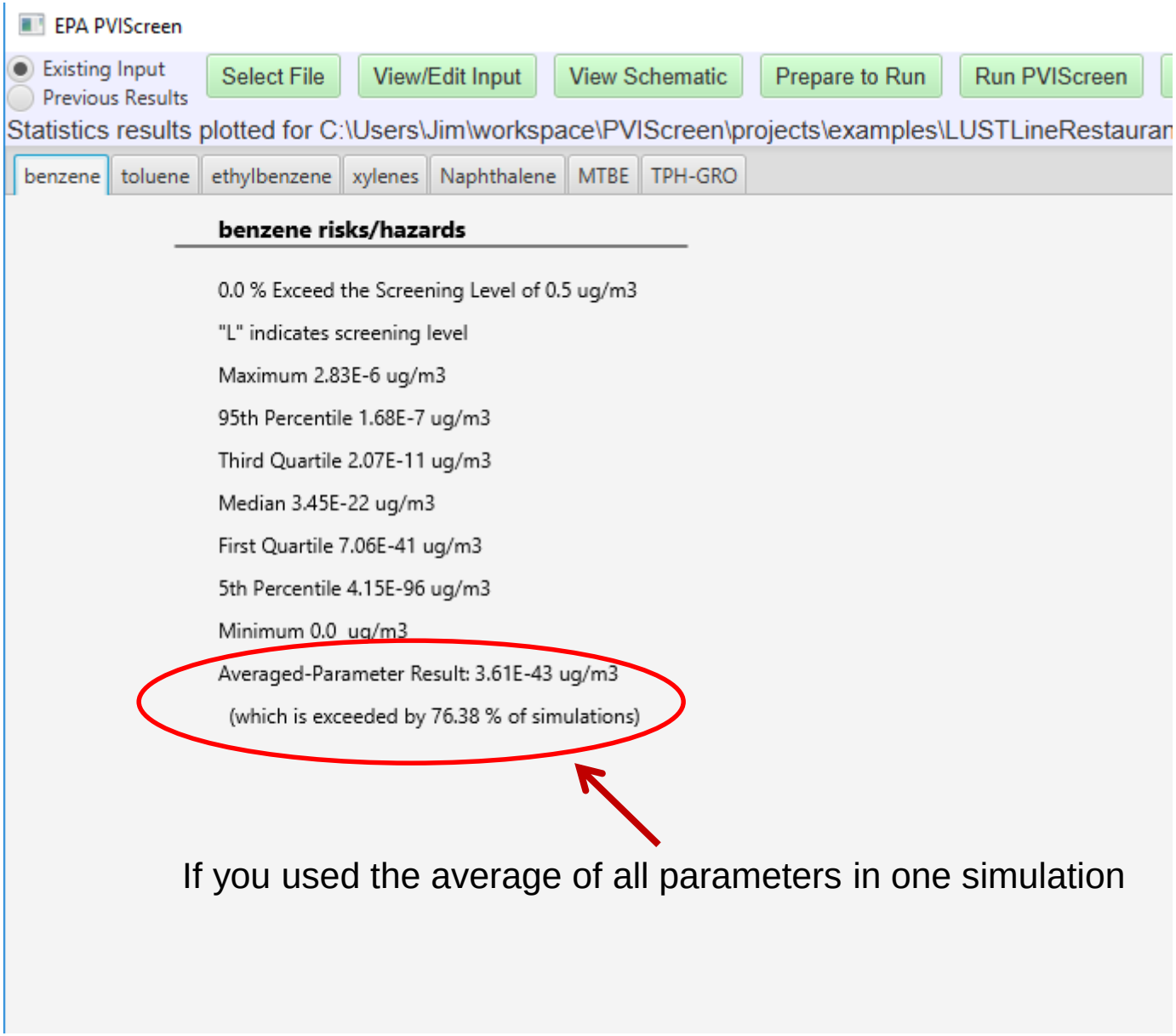
# Results: PVIScreen model runs indicate no impact





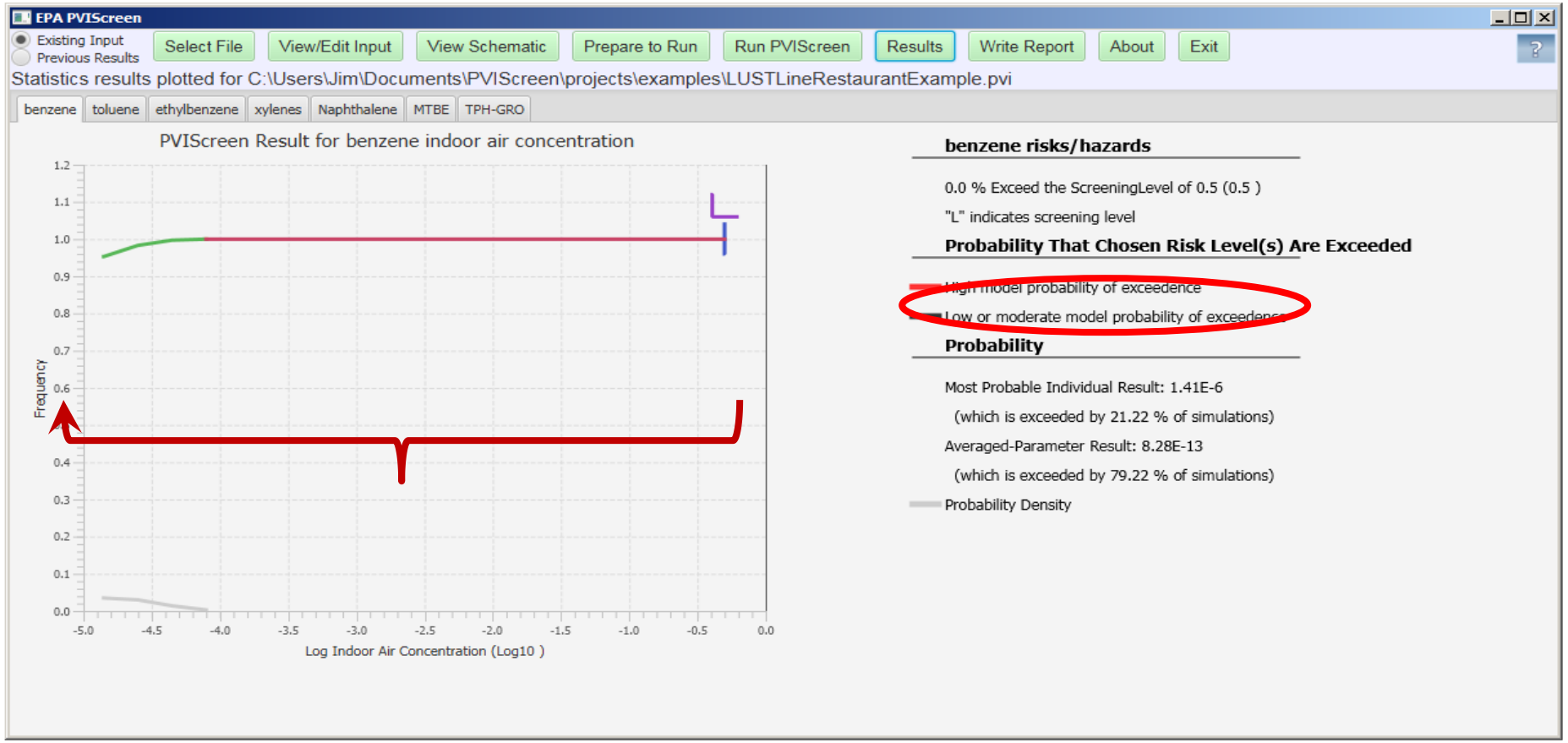

No graph because all
Results below screening leve
(and plotting limits)


EPA PVIScreen
Existing Input
Previous Results
Select File
View/Edit Input
View Schematic
Prepare to Run
Run PVIScreen
Statistics results plotted for C:\Users\Jim\workspace\PVIScreen\projects\examples\LUSTLineRestauran
benzene
toluene
ethylbenzene
xylenes
Naphthalene
MTBE
TPH-GRO
benzene risks/hazards
0.0 % Exceed the Screening Level of 0.5 ug/m3
"L" indicates screening level
Statistics
Maximum 2.83E-6 ug/m3
95th Percentile 1.68E-7 ug/m3
Third Quartile 2.07E-11 ug/m3
Median 3.45E-22 ug/m3
First Quartile 7.06E-41 ug/m3
5th Percentile 4.15E-96 ug/m3
Minimum 0.0 ug/m3
Averaged-Parameter Result: 3.61E-43 ug/m3
(which is exceeded by 76.38 % of simulations)

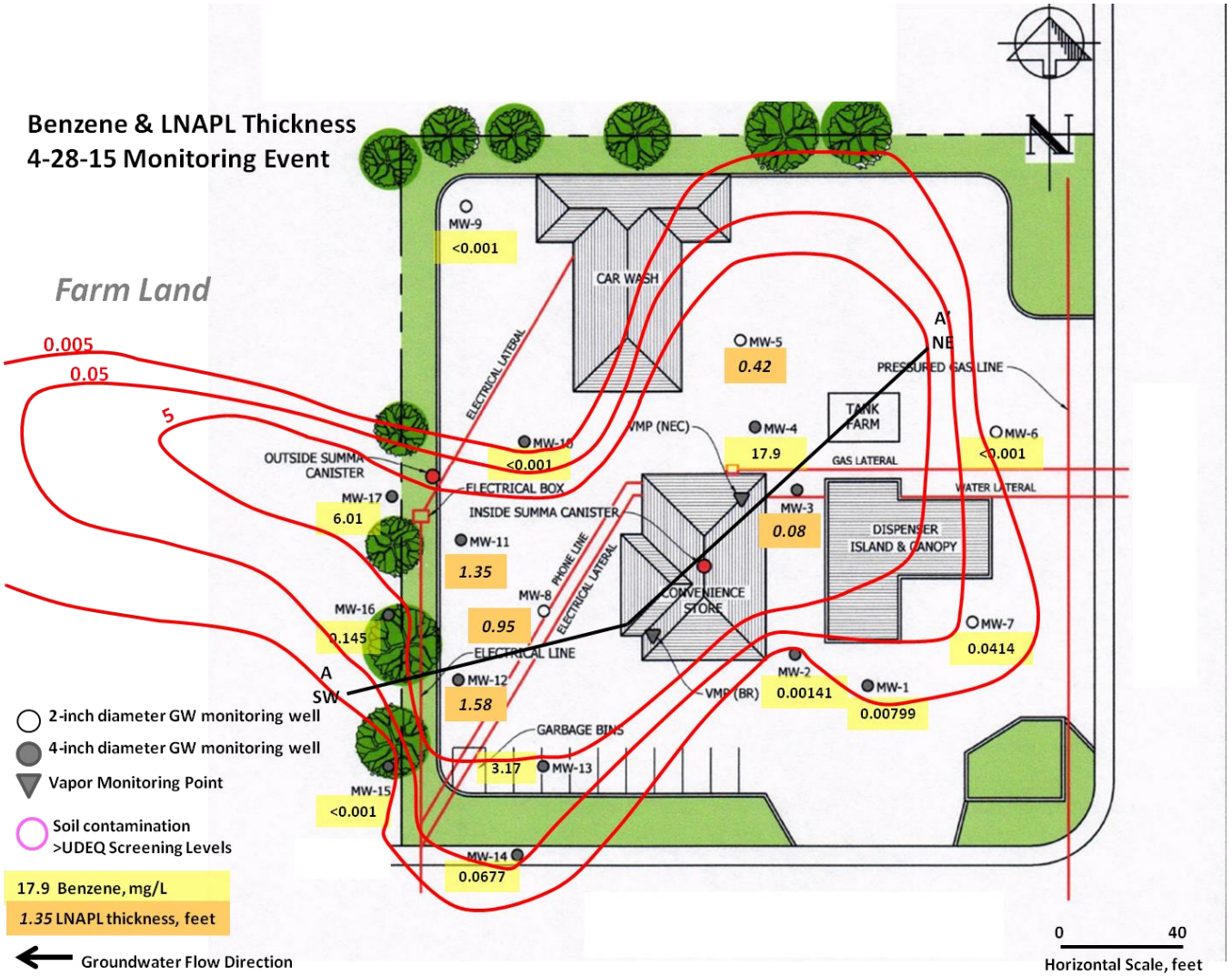


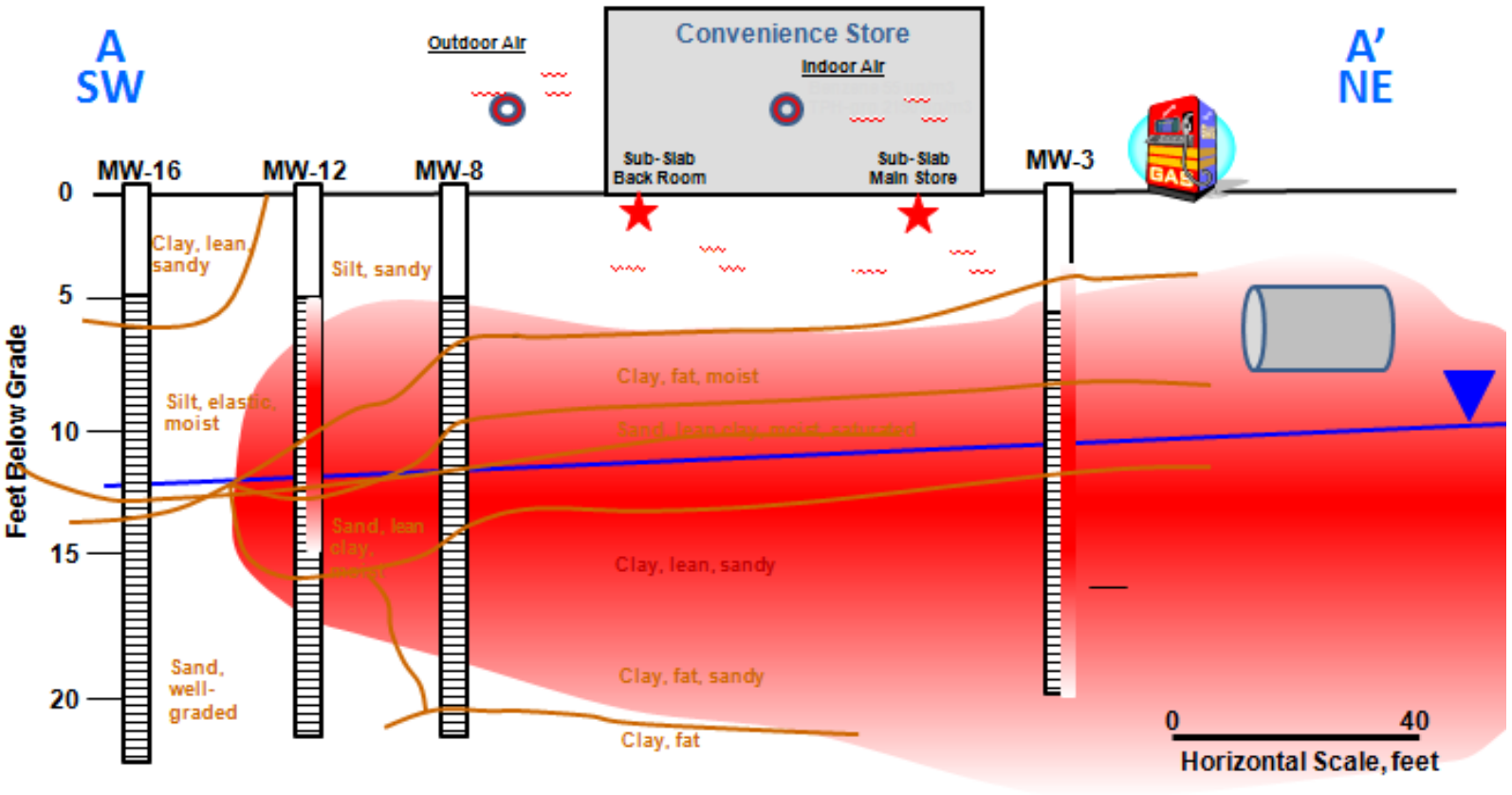

If you used the average of all parameters in one simulation

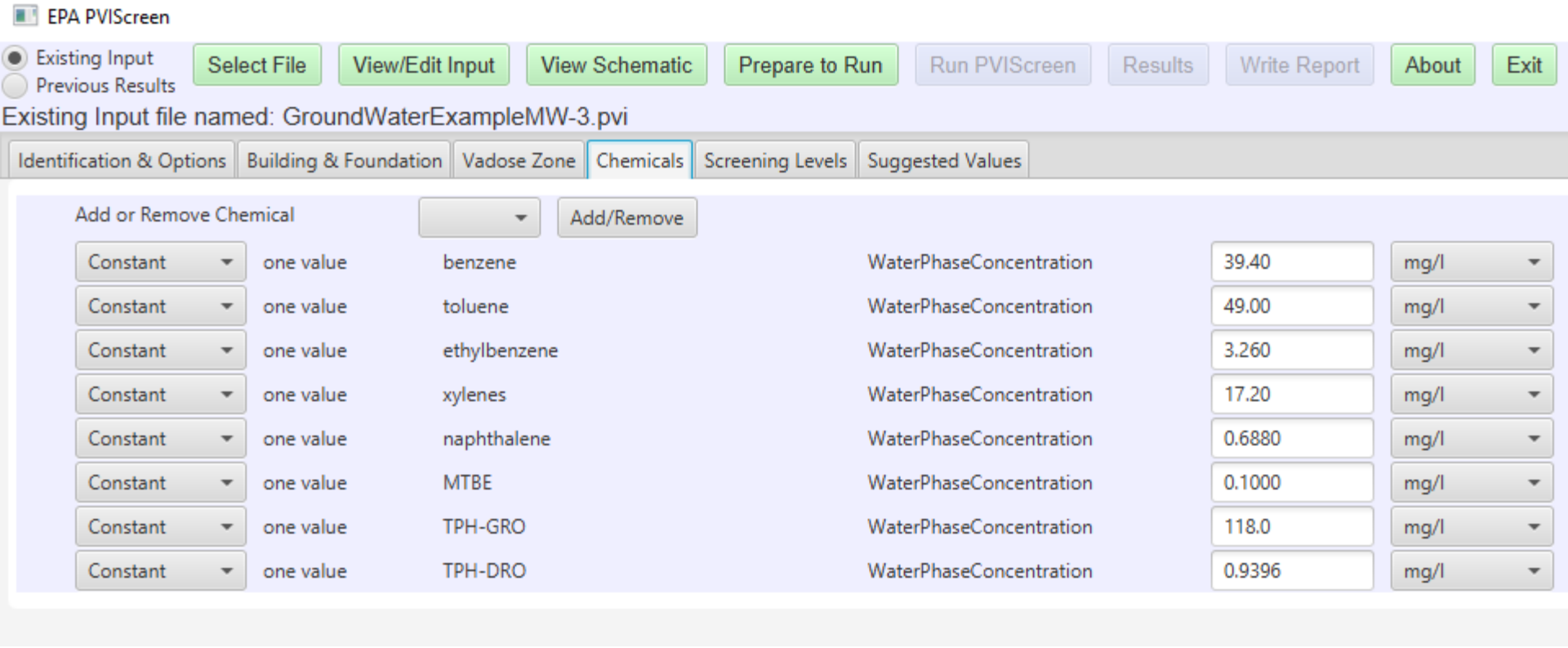
# Old style output:



# Example with impact indicated:




A
SW
A'
NE
Outdoor Air
Convenience Store
Indoor Air
Sub-Slab
Back Room
Sub-Slab
Main Store
MW-16
MW-12
MW-8
MW-3
GAS
0
5
10
15
20
Feet Below Grade
Clay, lean, sandy
Silt, sandy
Silt, elastic, moist
Clay, fat, moist
Sand, lean clay, moist, saturated
Sand, lean clay,
Clay, lean, sandy
Sand, well-graded
Clay, fat, sandy
Clay, fat
0
40
Horizontal Scale, feet


EPA PVIScreen
Existing Input
Previous Results
Select File
View/Edit Input
View Schematic
Prepare to Run
Run PVIScreen
Results
Write Report
About
Exit
Existing Input file named: GroundWaterExampleMW-3.pvi
Identification & Options
Building & Foundation
Vadose Zone
Chemicals
Screening Levels
Suggested Values
Add or Remove Chemical
Add/Remove
Constant one value benzene WaterPhaseConcentration 39.40 mg/l
Constant one value toluene WaterPhaseConcentration 49.00 mg/l
Constant one value ethylbenzene WaterPhaseConcentration 3.260 mg/l
Constant one value xylenes WaterPhaseConcentration 17.20 mg/l
Constant one value naphthalene WaterPhaseConcentration 0.6880 mg/l
Constant one value MTBE WaterPhaseConcentration 0.1000 mg/l
Constant one value TPH-GRO WaterPhaseConcentration 118.0 mg/l
Constant one value TPH-DRO WaterPhaseConcentration 0.9396 mg/l

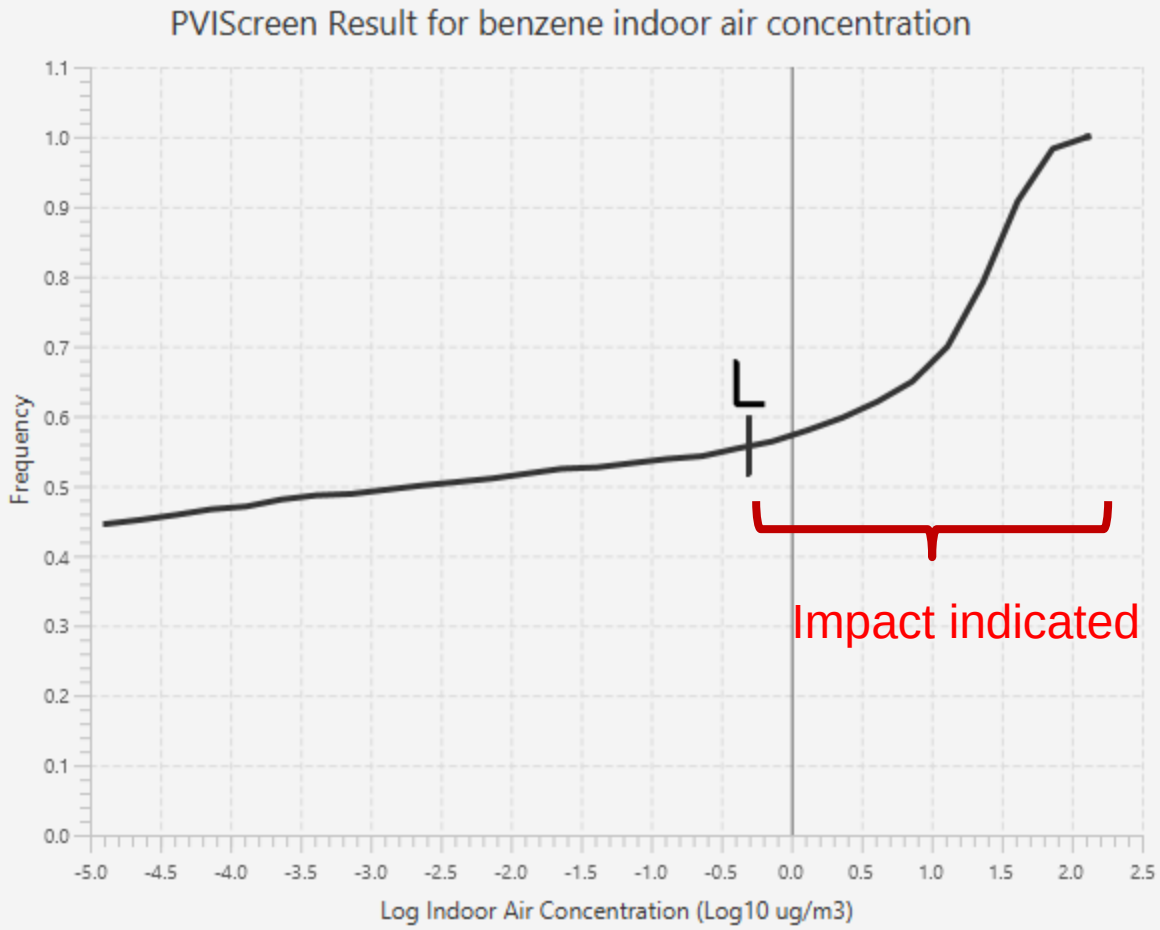
EPA PVIScreen

Existing Input
Previous Results

Select File | View/Edit Input | View Schematic | Prepare to Run | Run PVIScreen | Results | Write Report | About | Exit

Statistics results plotted for C:\Users\Jim\workspace\PVIScreen\projects\examples\GroundWaterExampleMW-3.pvi

benzene | toluene | ethylbenzene | xylenes | Naphthalene | MTBE | TPH-GRO | TPH-DRO




**benzene risks/hazards**

44.3% Exceed the Screening Level of 0.5 ug/m

"L" indicates screening level

Maximum 163.32 ug/m3

95th Percentile 68.57 ug/m3

Third Quartile 25.11 ug/m3

Median 2.77E-3 ug/m3

First Quartile 3.25E-20 ug/m3

5th Percentile 4.95E-89 ug/m3

Minimum 0.0 ug/m3

Averaged-Parameter Result: 1.15E-10 ug/m3

(which is exceeded by 64.93 % of simulation

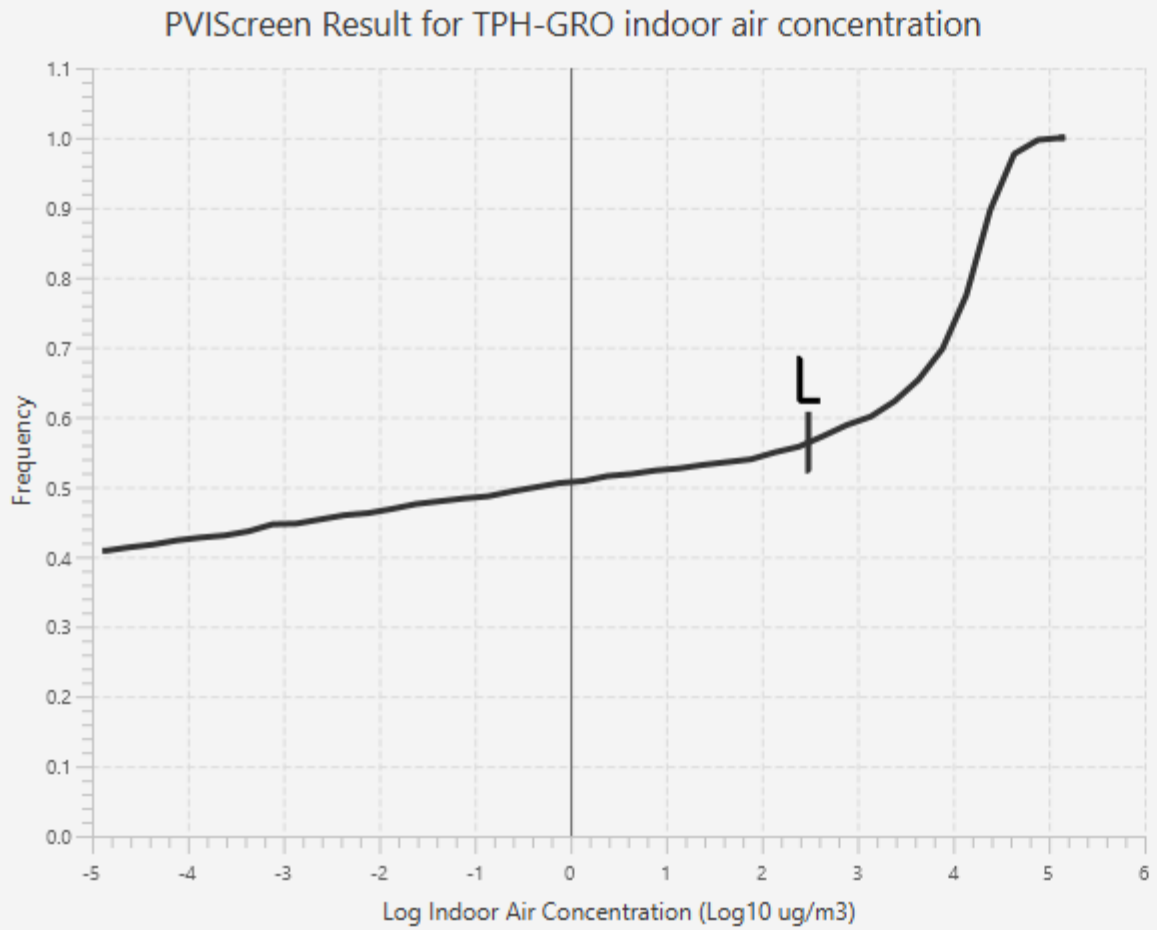
EPA PVIScreen

Existing Input
Previous Results

Select File | View/Edit Input | View Schematic | Prepare to Run | Run PVIScreen | Results | Write Report | About | Exit

Statistics results plotted for C:\Users\Jim\workspace\PVIScreen\projects\examples\GroundWaterExampleMW-3.pvi

benzene | toluene | ethylbenzene | xylenes | Naphthalene | MTBE | TPH-GRO | TPH-DRO




**TPH-GRO risks/hazards**

43.65% Exceed the Screening Level of 307 ug

"L" indicates screening level

Maximum 1.13E5 ug/m3

95th Percentile 4.8E4 ug/m3

Third Quartile 1.56E4 ug/m3

Median 0.57 ug/m3

First Quartile 3.36E-20 ug/m3

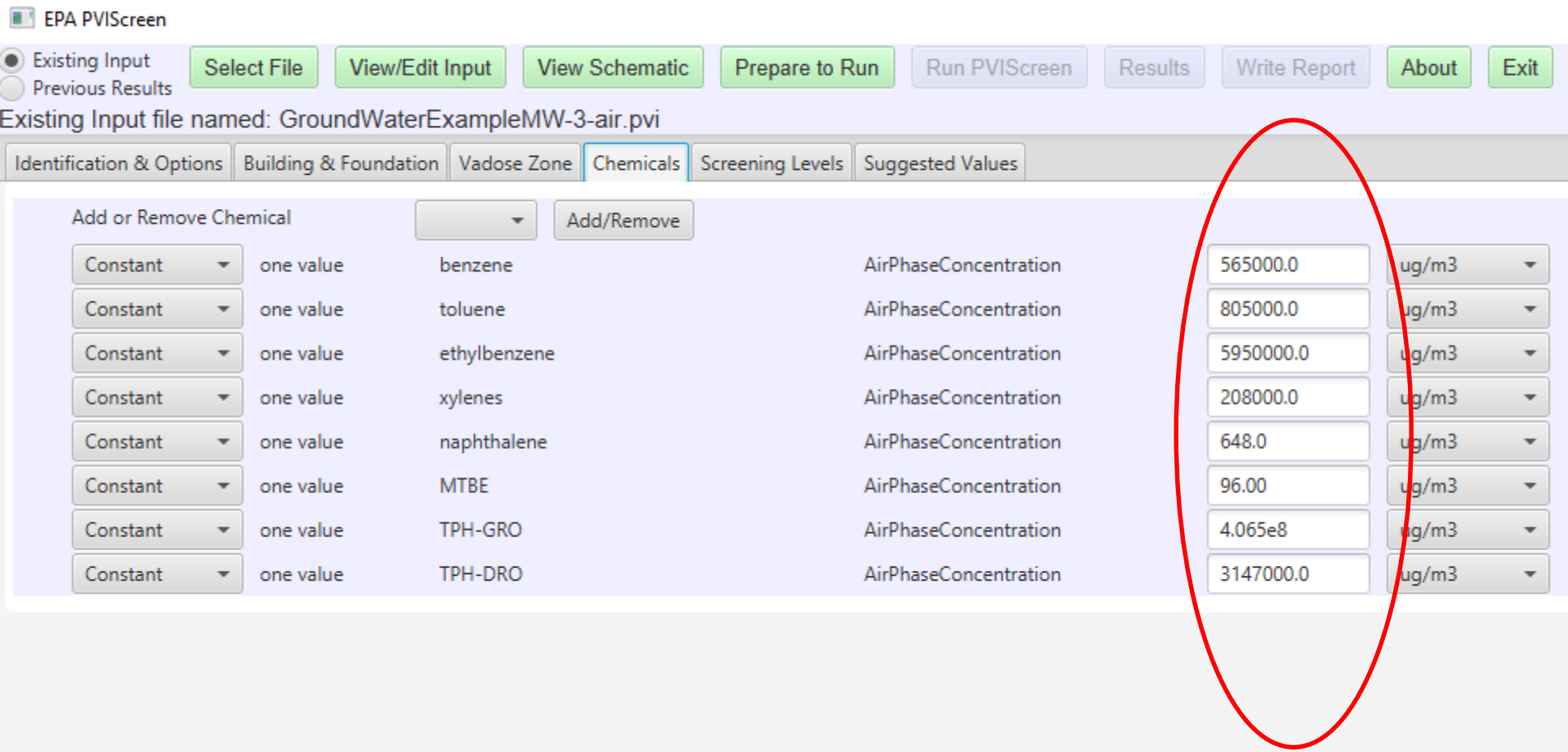
5th Percentile 1.42E-93 ug/m3

Minimum 0.0 ug/m3

Averaged-Parameter Result: 4.77E-7 ug/m3

(which is exceeded by 61.98 % of simulation

# Simulation with equilavent soil gas inputs



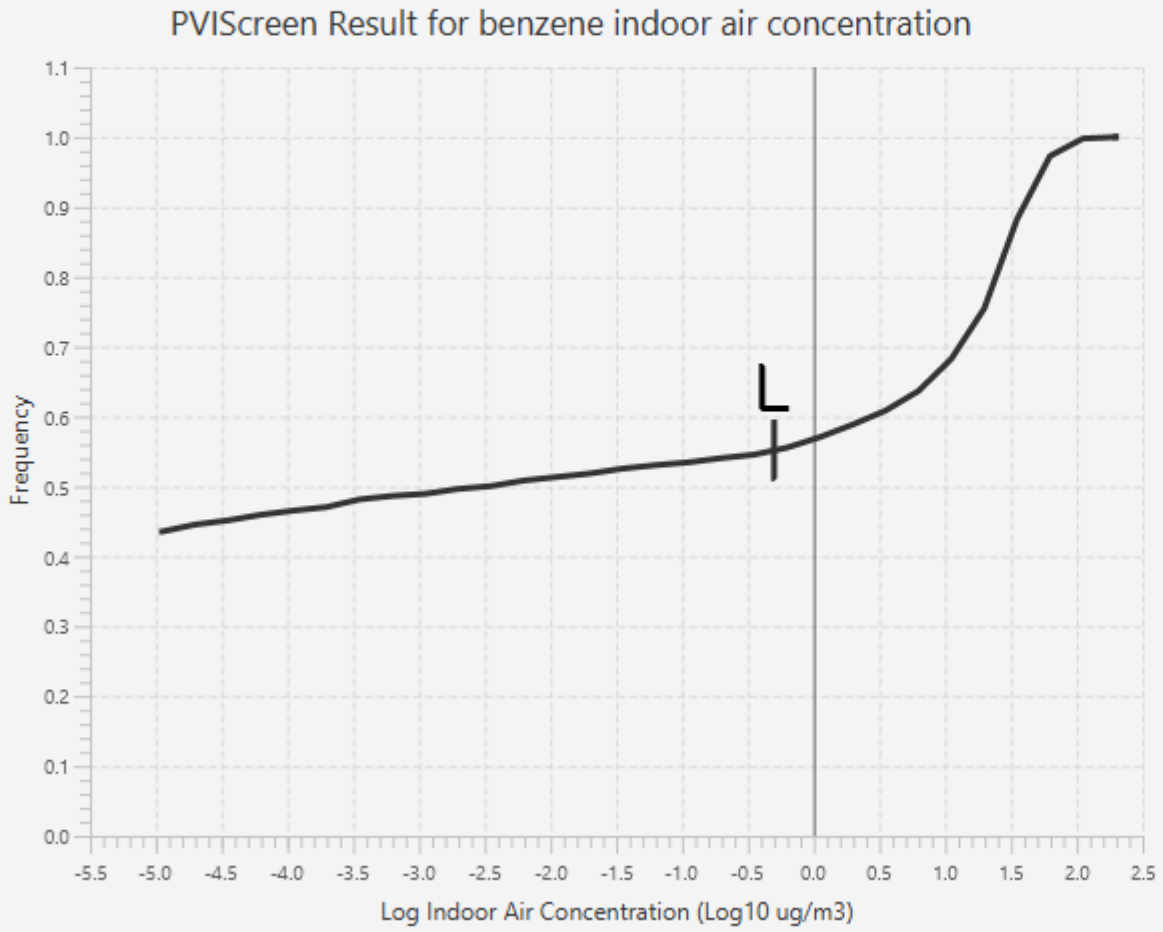
EPA PVIScreen

Existing Input
Previous Results

Select File | View/Edit Input | View Schematic | Prepare to Run | Run PVIScreen | Results | Write Report | About | Exit

Statistics results plotted for C:\Users\Jim\workspace\PVIScreen\projects\examples\GroundWaterExampleMW-3-air.pvi

benzene | toluene | ethylbenzene | xylenes | Naphthalene | MTBE | TPH-GRO | TPH-DRO




**benzene risks/hazards**

44.84% Exceed the Screening Level of 0.5 ug/

"L" indicates screening level

Maximum 164.81 ug/m3

95th Percentile 68.8 ug/m3

Third Quartile 25.86 ug/m3

Median 4.45E-3 ug/m3

First Quartile 5.62E-20 ug/m3

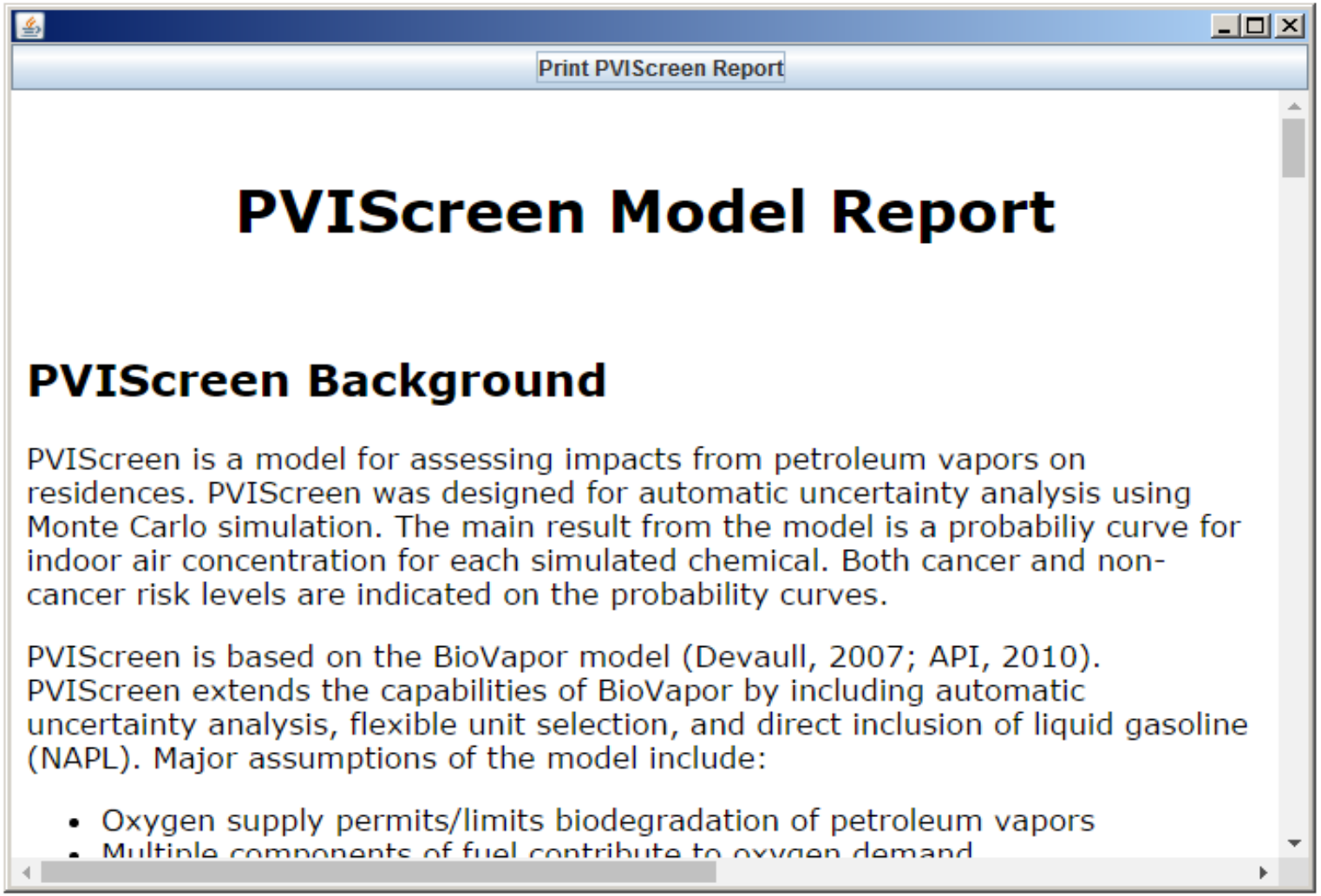
5th Percentile 8.37E-89 ug/m3

Minimum 0.0 ug/m3

Averaged-Parameter Result: 2.31E-10 ug/m3

(which is exceeded by 64.81 % of simulation

# Automated Report:



Model Output – all parameter values saved with results
Method to display parameter values which exceed risk levels is being developed


HP1010 | 1.7467179531079

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Control | Statistics | | | | | | | | |
| 2 | EPA-PetroleumVaporIntrusion | | | | | | | | | |
| 3 | Post-Processed Output: Statistics-Histograms-Cumulative Probabilities | | | | | | | | | |
| 4 | Input Data File: C:\Users\Jim\workspace\PVIScreen\RFG-25Ft-NYC2003-Leached-f1000-None-Fixed half foot.csv | | | | | | | | | |
| 5 | Output File Name: RFG 25Ft NYC2003 Leached f1000 half foot PVIScreen 2013-Sep-6 4h-59m-19.0s.csv | | | | | | | | | |
| 6 | Sorted Output File Name (this file): RFG 25Ft NYC2003 Leached f1000 half foot PVIScreen 2013-Sep-6 4h-59m-19.0s Statistics.csv | | | | | | | | | |
| 7 | | | | | | | | | | |
| 8 | | | | | | | | | | |
| 9 | Result | Heading | building AirExchangeRate | building MixingZ | building \ | building L | building D | building FoundationThicl | building CrackWic | building |
| 10 | Result | Unit/Cour | (1/s) | (cm) | (cm) | (cm) | (cm) | (cm) | (cm) | (cm3/s) |
| 1001 | Result | 653 | 4.96E-05 | 450.0480365 | 1000 | 1000 | 15 | 19.91185664 | 0.282173926 | 28.3 |
| 1002 | Result | 940 | 7.81E-05 | 452.0850911 | 1000 | 1000 | 15 | 14.06168026 | 0.113904141 | 96.7 |
| 1003 | Result | 688 | 2.79E-05 | 344.1029533 | 1000 | 1000 | 15 | 16.17564898 | 0.226845316 | 53.3 |
| 1004 | Result | 300 | 2.95E-05 | 385.8951733 | 1000 | 1000 | 15 | 18.97272857 | 0.416460407 | 42.0 |
| 1005 | Result | 133 | 6.97E-05 | 277.8792118 | 1000 | 1000 | 15 | 12.38464698 | 0.235393048 | 34.5 |
| 1006 | Result | 211 | 4.03E-05 | 411.0058471 | 1000 | 1000 | 15 | 19.81538962 | 0.273654733 | 18.6 |
| 1007 | Result | 180 | 1.19E-04 | 254.5569291 | 1000 | 1000 | 15 | 16.0461374 | 0.173825781 | 1 |
| 1008 | Result | 50 | 3.59E-05 | 476.6361125 | 1000 | 1000 | 15 | 17.24209519 | 0.229550274 | 18.9 |
| 1009 | Result | 307 | 3.44E-05 | 459.0581482 | 1000 | 1000 | 15 | 14.0713416 | 0.28272131 | 31.9 |
| 1010 | Result | 114 | 7.97E-05 | 269.9006984 | 1000 | 1000 | 15 | 18.11253617 | 0.258346466 | 125. |
| 1011 | | | | | | | | | | |
| 1012 | Simple Statistics: | | | | | | | | | |

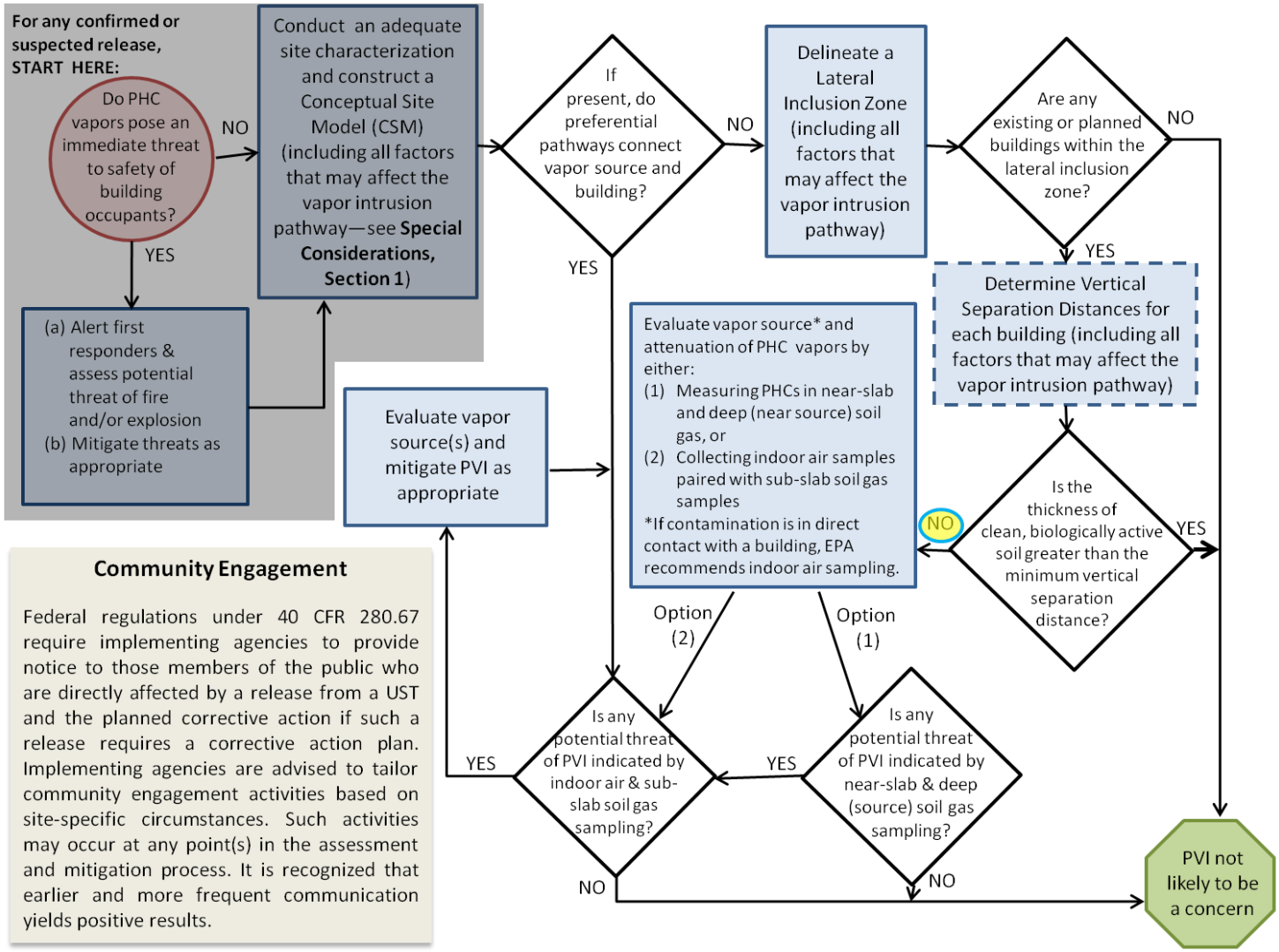
# Secrets of PVIScreen…

- *Java must be enabled.*
- *Always* start PVIScreen by opening an existing file (examples or templates).
  - Template files regenerate every time the model is run—save under different name.
  - Create project directories for each project.
  - All files are saved with date/time stamp (can pile up).
  - If results are not displayed, exit and restart PVIScreen.
- If you see an orange line across the screen..
  - Restart PVIScreen

# Secrets of PVIScreen…

- Use the correct template to begin.
- Concentrations needed to drive model.
- Biodegradation is always treated as being uncertain.
- When an impact is shown…
  - ~~Because of randomness, % will very with each simulation~~
  - If result has marginal exceedances (say <5%) consider refining ranges of parameters.
- DON'T only simulate benzene or BTEX.
  - you will probably never see an impact
  - because TPH needs to be included.

Results fit within PVI guidance framework --one line of evidence



# Summary

- Immediate threats must be handled first.
- Site characterization and development of a Conceptual Site Model next.
- Model use (including PVIScreen) should be embedded with site assessment.
- PVIScreen incorporates parameter. uncertainty into PVI modeling.
- Results can add a line of evidence to an assessment.

Available at http://www.epa.gov/land-research/pviscreen
(look for copy dated Sept 2018)

- EPA Contact: kremer.fran@epa.gov
- *The views expressed in this presentation are those of the author and do not necessarily represent the views or policies of the U.S. Environmental Protection Agency*