

# **Understanding the Conceptual Site Model for Vapor Intrusion Into Buildings**

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**Geosyntec**   
consultants

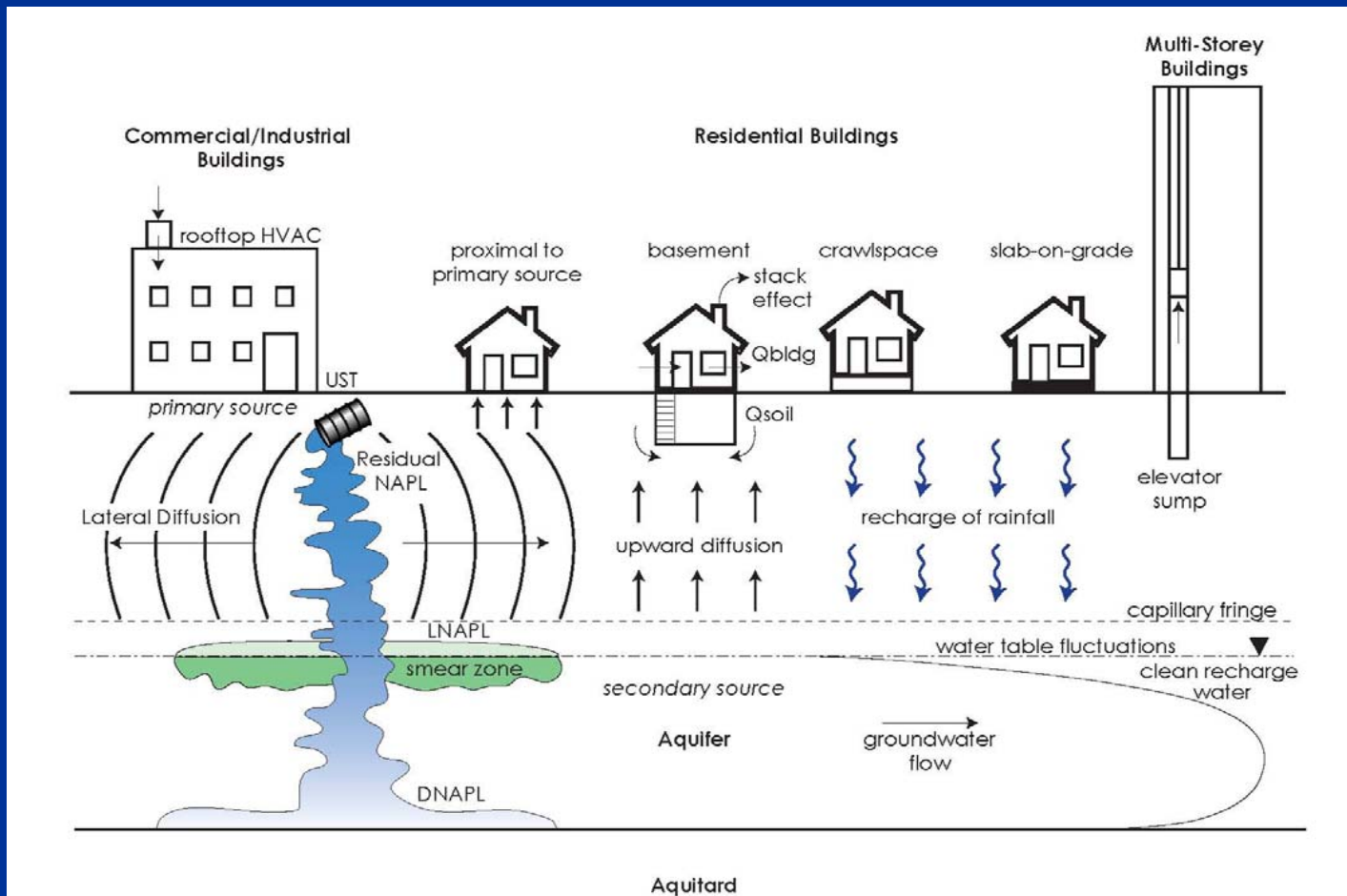
# Objectives

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- Introduce the key components of a vapor intrusion (VI) conceptual site model (CSM)
- Provide an overview of VI fate and transport processes
- Present modeling analysis to illustrate the effect of different CSM on the VI pathway

# The Vapor Intrusion Pathway

The VI pathway considers the migration of chemicals from subsurface sources into buildings



# Conceptual Site Model

- Simplified description of a complex real-world system
- Useful for site investigation planning and data interpretation
- Framework to assess potential exposure to site contaminants

## CSM Components

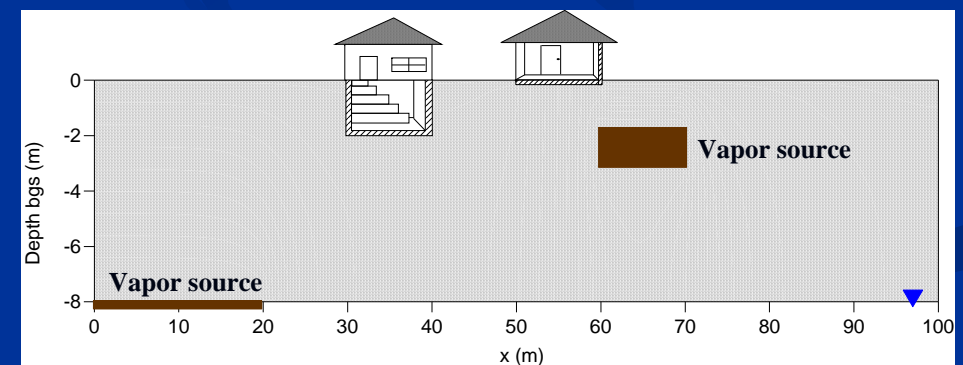
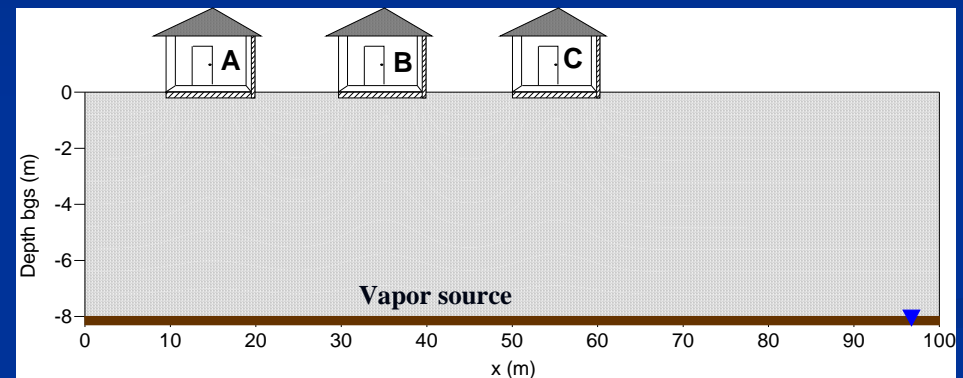


# CSM - Source



## Source Considerations

- Position
- Size
- Composition
- Concentration

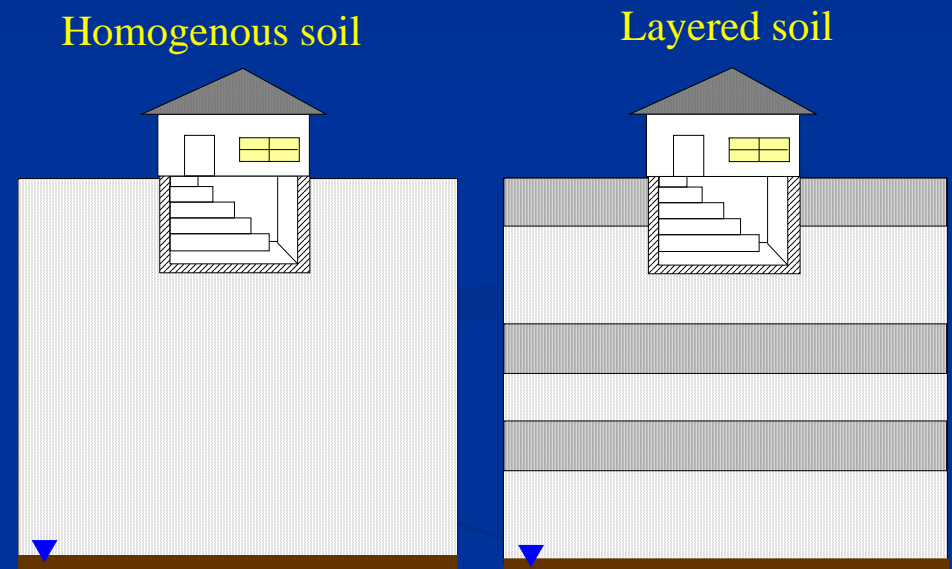


# CSM - Pathway



## Pathway Considerations

- Site Lithology
  - Homogeneous
  - Diffusive barriers
- Groundwater capillary fringe effects
- Biodegradation
- Pressure effects



# CSM - Receptors

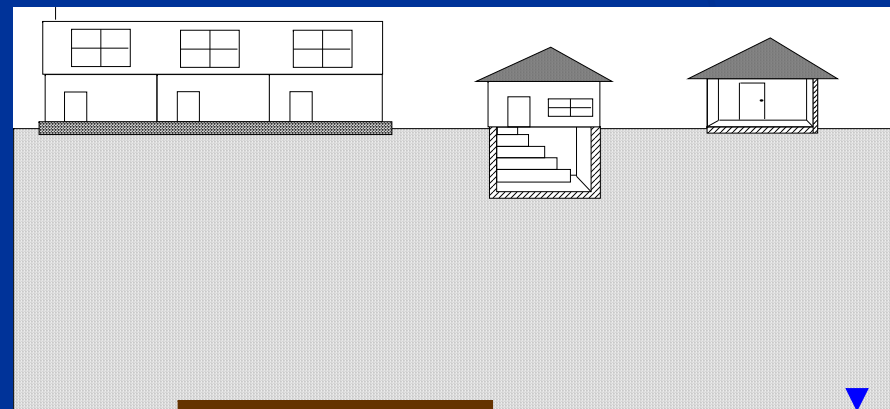


## Receptor Considerations

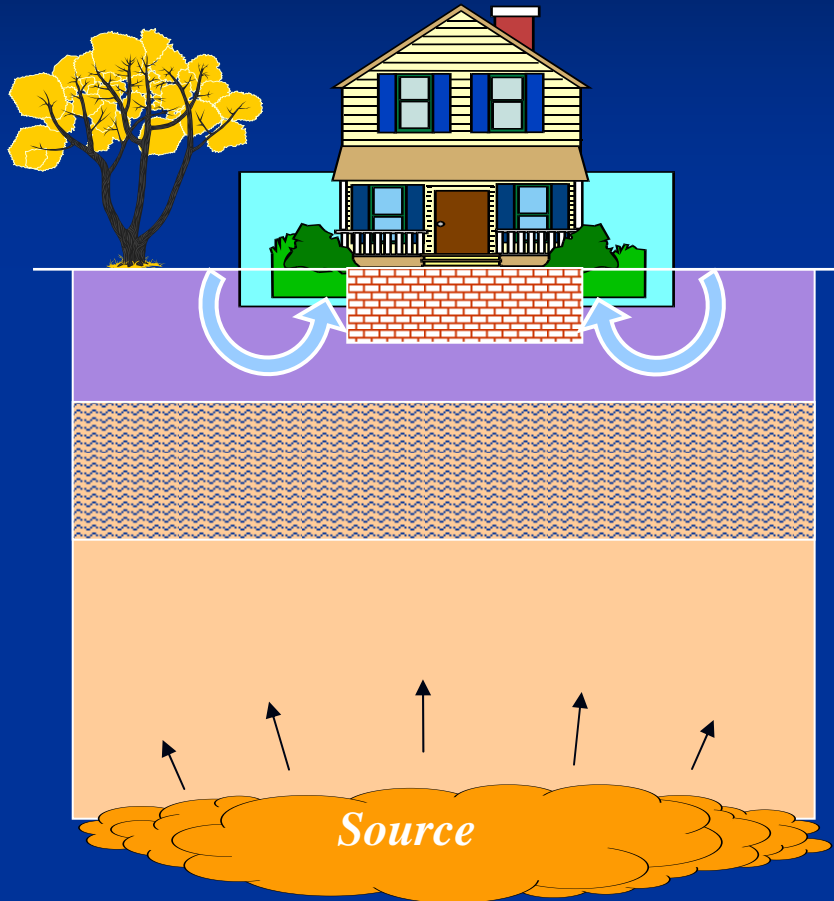
- Building Use
- Occupancy
- Building Construction
- Ventilation Rate

Industrial/commercial

Residential



# Vapor Fate & Transport Mechanisms



Mixing in Building

Advection

Biodegradation

Diffusion

Partitioning

# Vapor Intrusion for Different CSMs

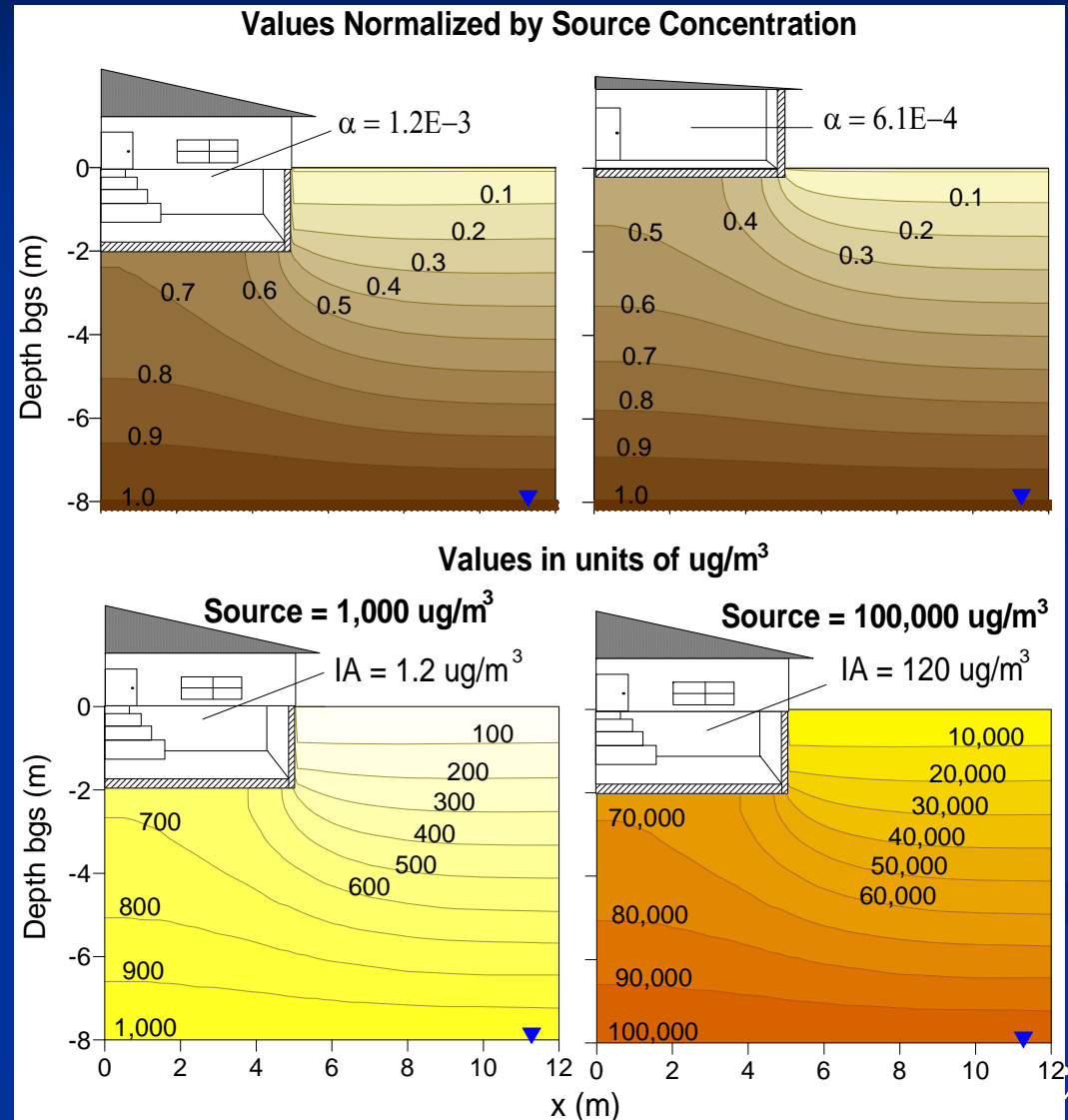
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- Simulations with Abreu and Johnson 3D Model used to evaluate the effect of various site conditions on the VI pathway
  - Foundation type
  - Source location (depth and lateral separation)
  - Lithology
  - Transient transport
  - Biodegradation

# Presentation of Results

- Vertical cross-sections through center of building showing:
  - Normalized soil gas concentration distribution
  - VI attenuation factor
- Concentrations normalized to the source-zone vapor concentration

*For recalcitrant compounds, normalized concentrations are independent of source concentration*



# Attenuation Factor, $\alpha$

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- Attenuation factor,  $\alpha$ , often used to characterize significance of VI Pathway:

$$\alpha = C_{\text{indoor}} / C_{\text{source}}$$

- As  $\alpha$  values decrease (approach zero):
  - Indoor air concentrations are reduced (more attenuation)
  - Vapor intrusion pathway is less significant
- Risk is proportional to  $\alpha$

# Source Depth and Building Type

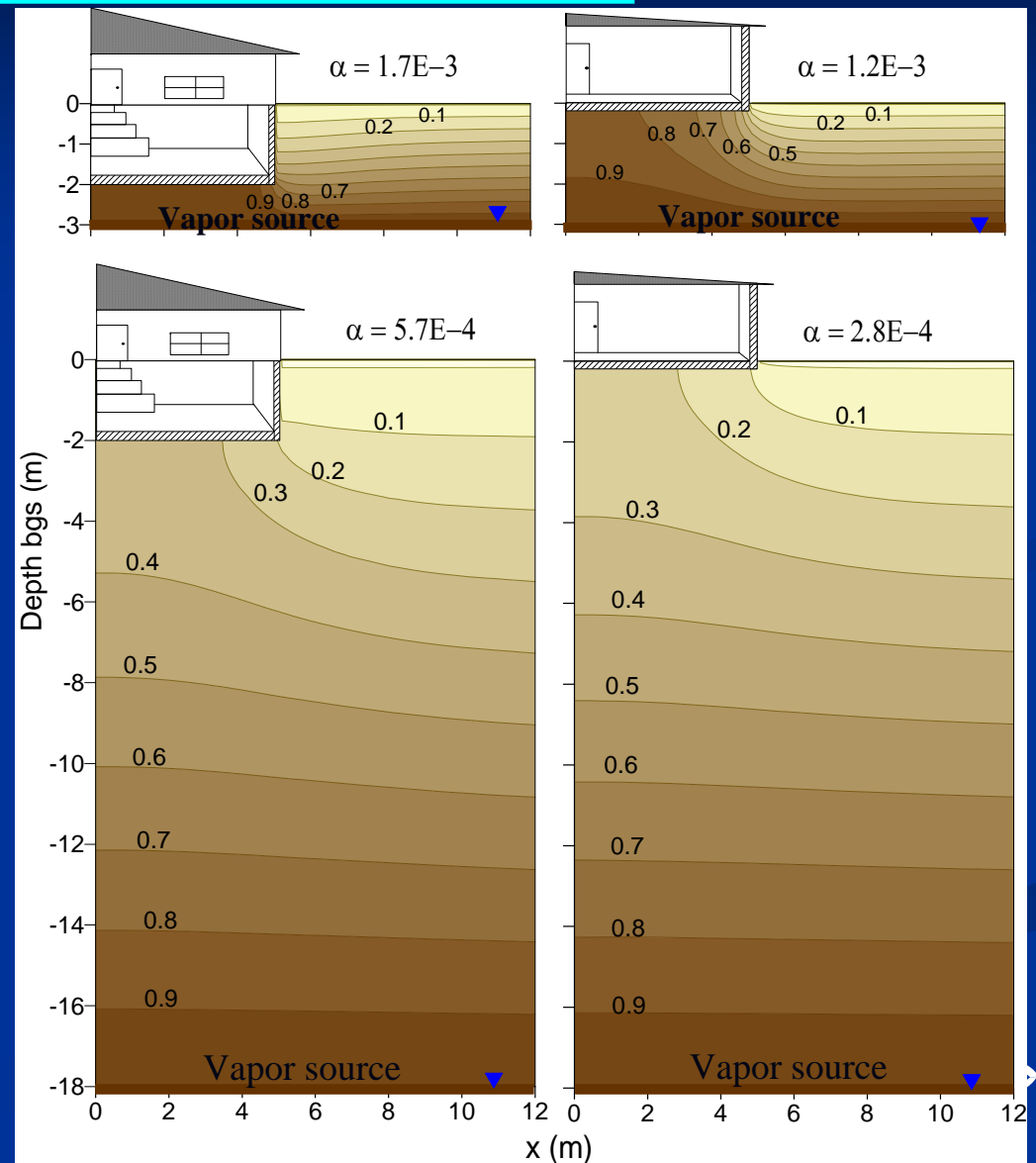
- Increased source depth results in decrease in  $\alpha$ 
  - Not a proportional relationship
- Attenuation factors for buildings with basements are slightly higher than slab-on-grade construction

## Model Assumptions:

Recalcitrant VOC

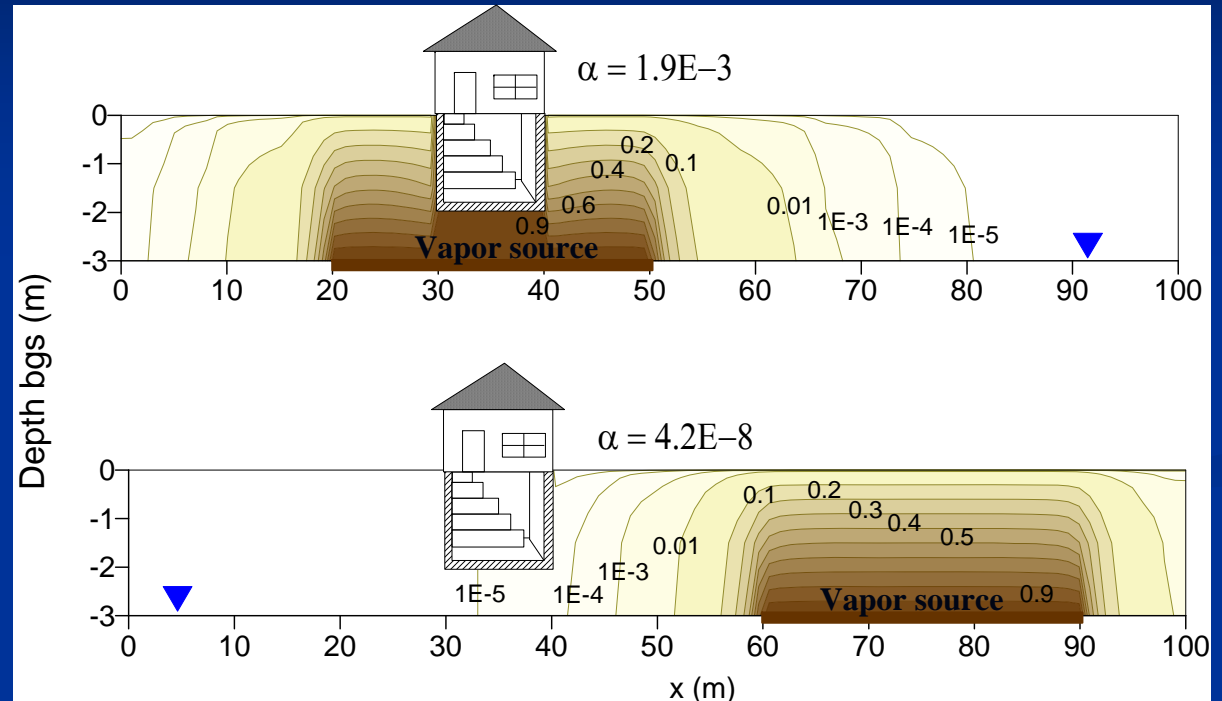
Homogeneous sand

Building under-pressurized 5 Pa



# Source Lateral Distance – Shallow GW

- A 20 m lateral distance separation results in decrease in  $\alpha$  by five orders of magnitude



## Model Assumptions:

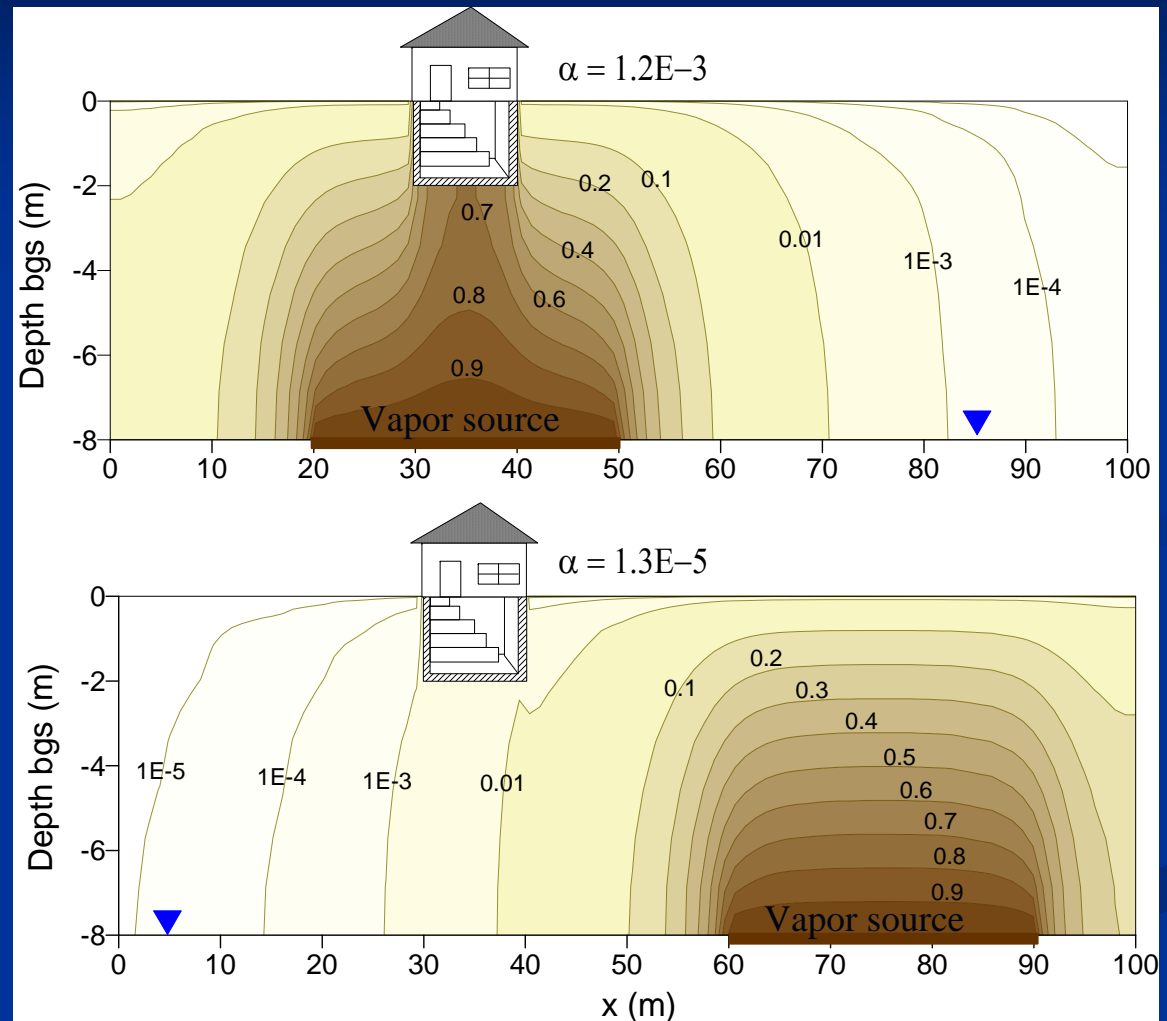
Recalcitrant VOC

Homogeneous sand

Building under-pressurized 5 Pa

# Source Lateral Distance – Deep GW

- A 20 m lateral distance separation results in decrease in  $\alpha$  by two orders of magnitude



## Model Assumptions:

Recalcitrant VOC

Homogeneous sand

Building under-pressurized 5 Pa

# Source Depth & Lateral Distance

## Key findings:

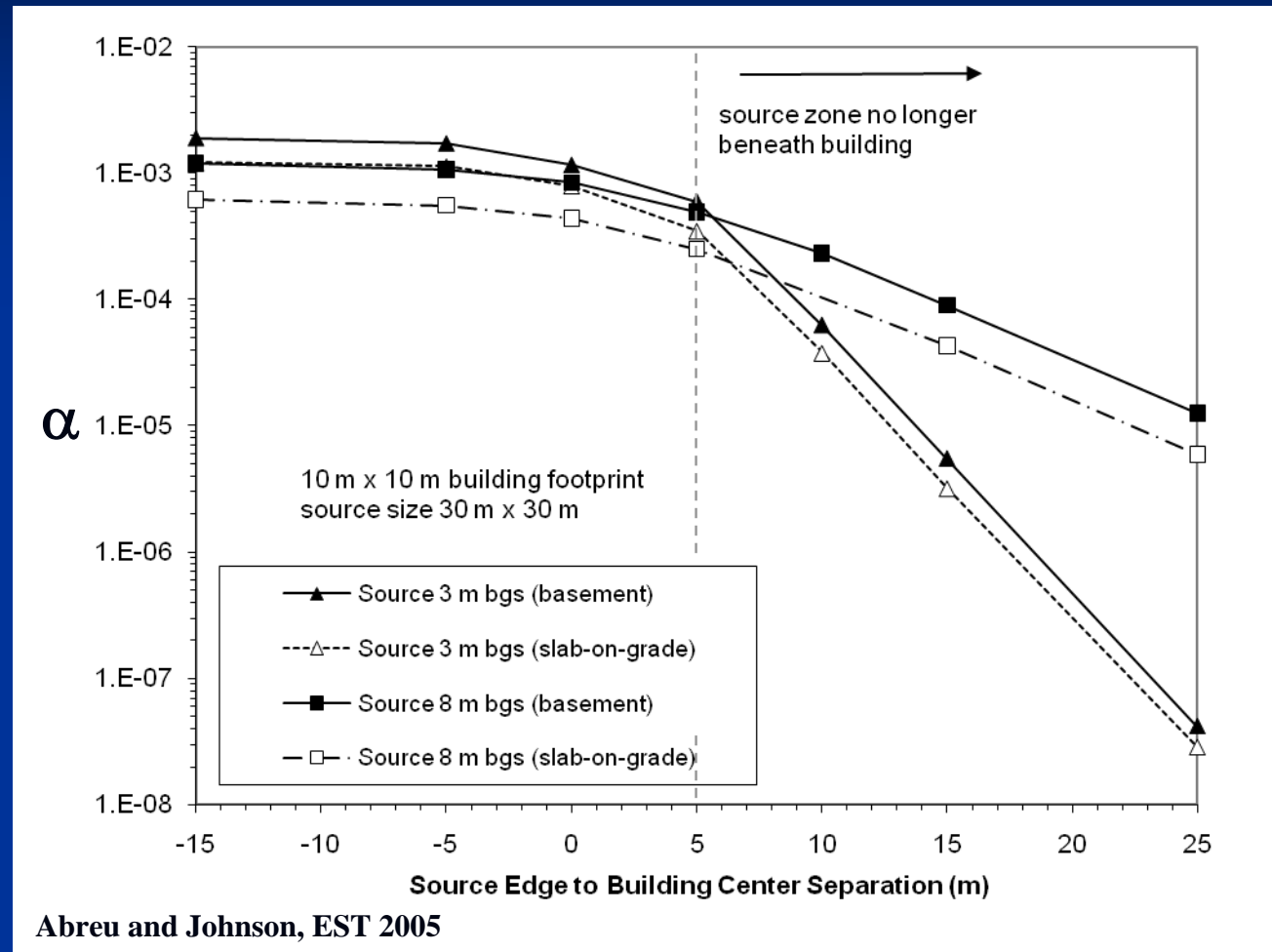
- Building construction has limited impact
- Source depth has limited effect when building above source area
- Effect of lateral distance separation is more significant for shallow source scenarios

## Model Assumptions:

Recalcitrant VOC

Homogeneous sand

Building under-pressurized 5 Pa



# Layered Lithology

- Moist, fine-grained soils may act as diffusive barrier
  - Higher concentration below
  - Lower concentration above

$Q_s$  are calculated by the model

Model Assumptions:

Recalcitrant VOC

Building under-pressurized 5 Pa

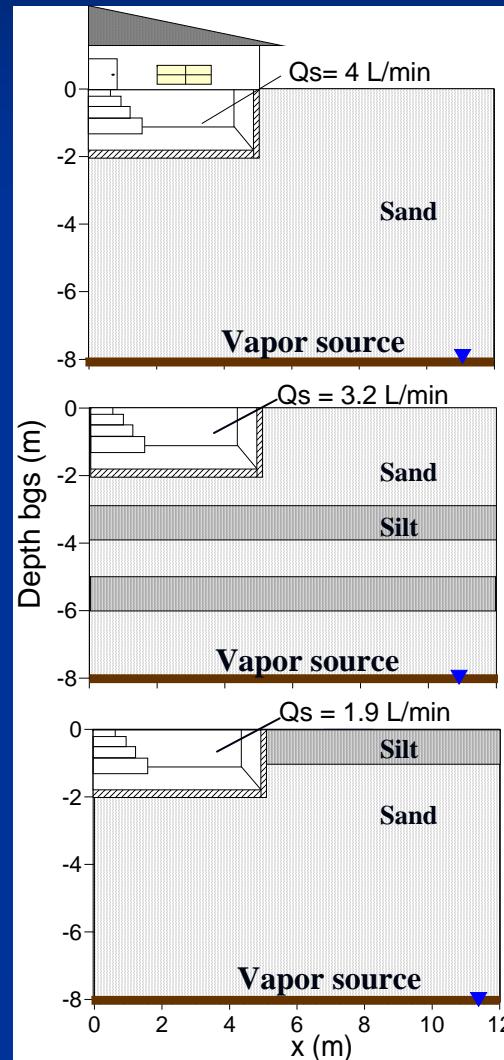


Sand:  $S_w = 20\%$ ;  $k = 1E-11 \text{ m}^2$

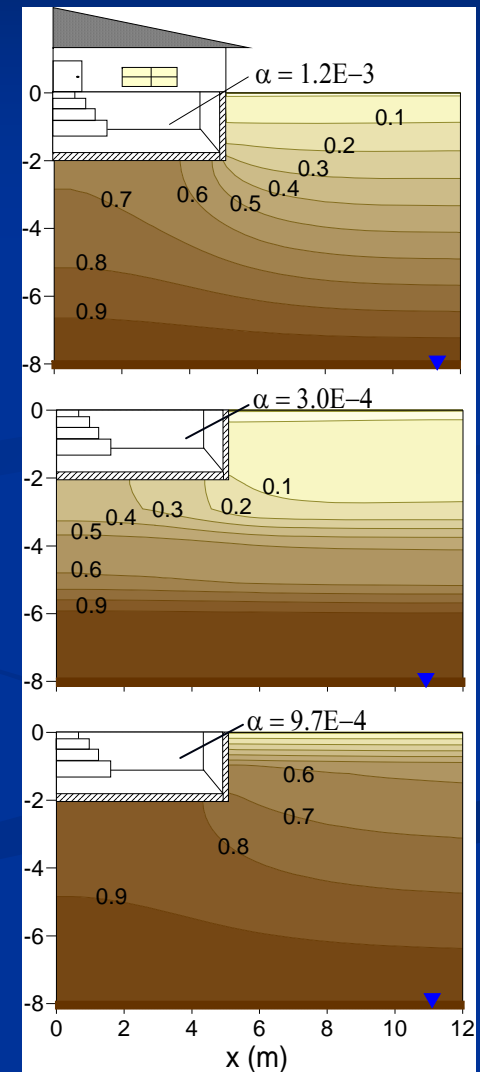


Silt;  $S_w = 60\%$ ;  $k = 1E-13 \text{ m}^2$

CSM



Results




# Layered Lithology & Lateral Source

- High moisture content layer on ground surface increases the Vapor lateral migration
- High moisture content layer right above the vapor source significantly decrease vapor migration

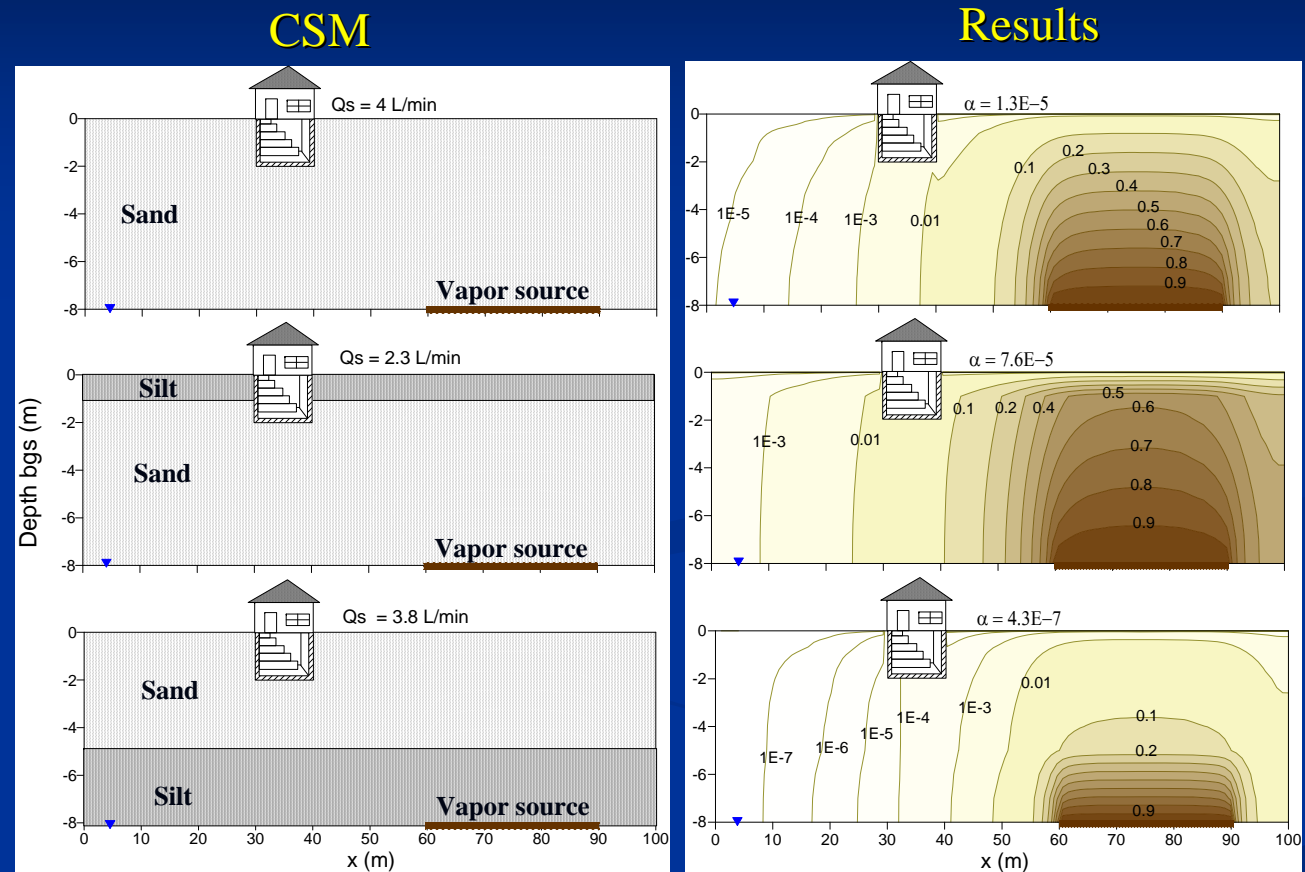
## Model Assumptions:

Recalcitrant VOC

Building under-pressurized 5 Pa

 Sand:  $S_w = 20\%$ ;  $k = 1E-11 \text{ m}^2$

 Silt:  $S_w = 60\%$ ;  $k = 1E-13 \text{ m}^2$



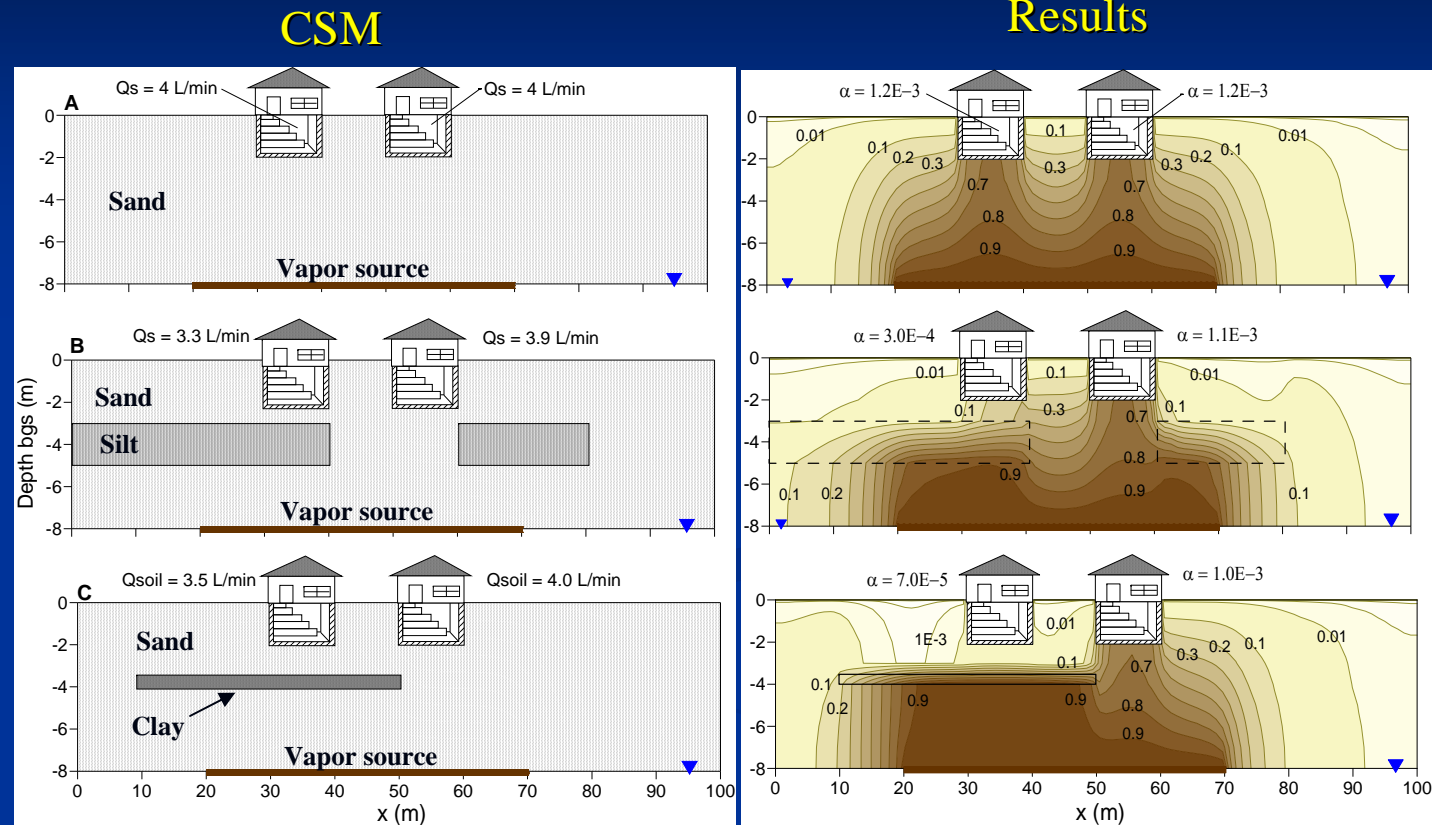
Qs are calculated by the model

# Heterogeneous Lithology

- Note that these simulations consider large soil heterogeneities (e.g., varying from dry to damp/wet soils)
- Smaller-scale heterogeneities may not be significant

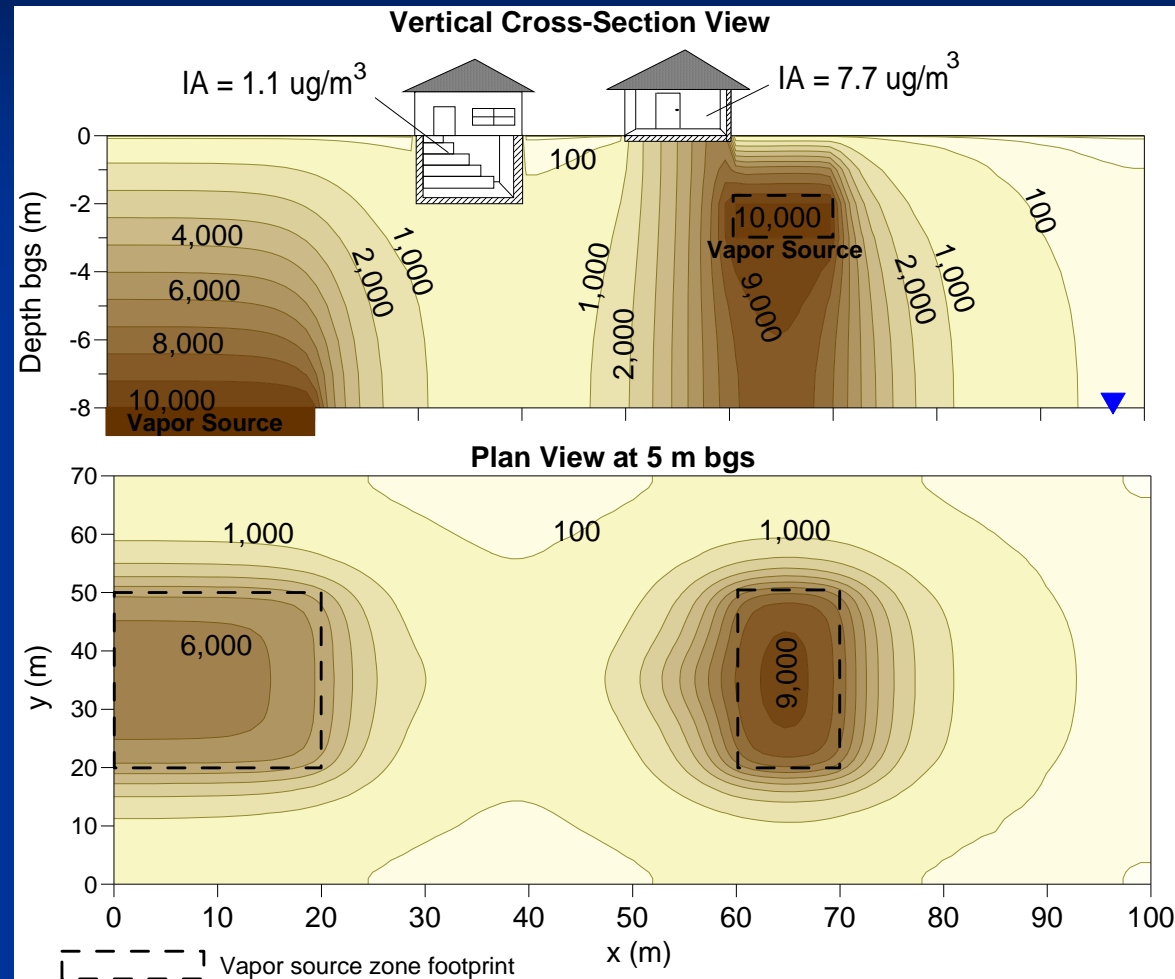
Model Assumptions:  
 Recalcitrant VOC  
 Building under-pressurized 5 Pa

- Sand:  $S_w = 20\%$ ;  $k = 1E-11 \text{ m}^2$
- Silt:  $S_w = 60\%$ ;  $k = 1E-13 \text{ m}^2$
- Clay:  $S_w = 95\%$ ;  $k = 1E-13 \text{ m}^2$



$Q_s$  are calculated by the model

# Multiple Sources



## Model Assumptions:

Recalcitrant VOC

Homogeneous sand

Building under-pressurized 5 Pa

# Transient Transport

## Time Since Source Release

- The transient concentration profile is affected by
  - Source depth & lateral distance
  - Soil moisture & foc
  - Contaminant (koc)
  - Source depletion or increased concentration with time

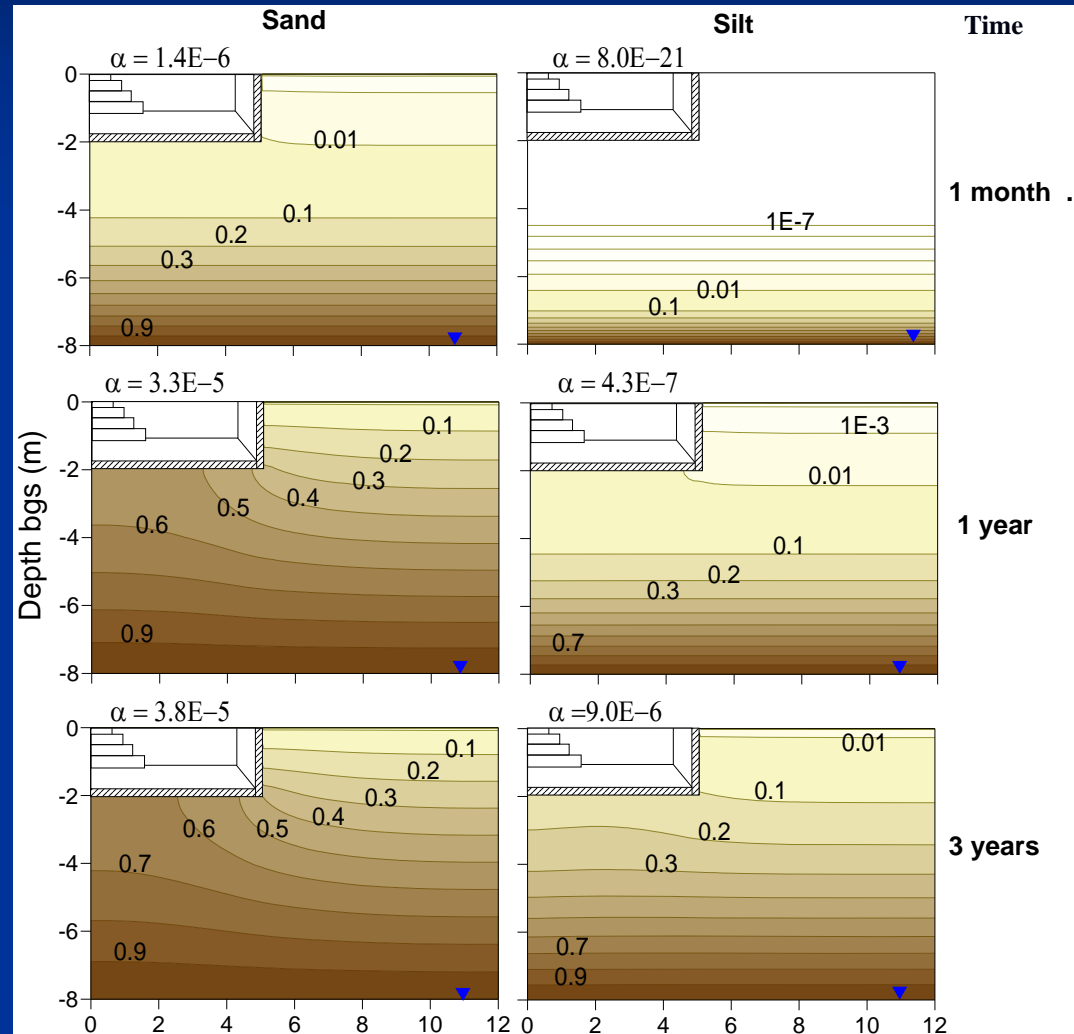
### Model Assumptions:

Recalcitrant VOC

Building at atmospheric pressure

Steady source (does not deplete or increase concentration)

foc = 0.001, koc = 62



# Soil Heterogeneities, Multiple Sources and Transient Transport

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- These conditions can have a significant impact on soil gas concentration profiles that may result in soil gas distribution quite different from commonly assumed homogeneous soils and steady state conditions
- May result in spatial and temporal variability of soil gas
- CSM should represent site conditions

# Aerobic Biodegradation

## Effect of Vapor Source Depth

- Results suggest that there is a critical depth beyond which VI is of little concern for degradable compounds
- This critical depth will be a function of source concentration and degradation rate

### Model Assumptions:

Homogeneous sand

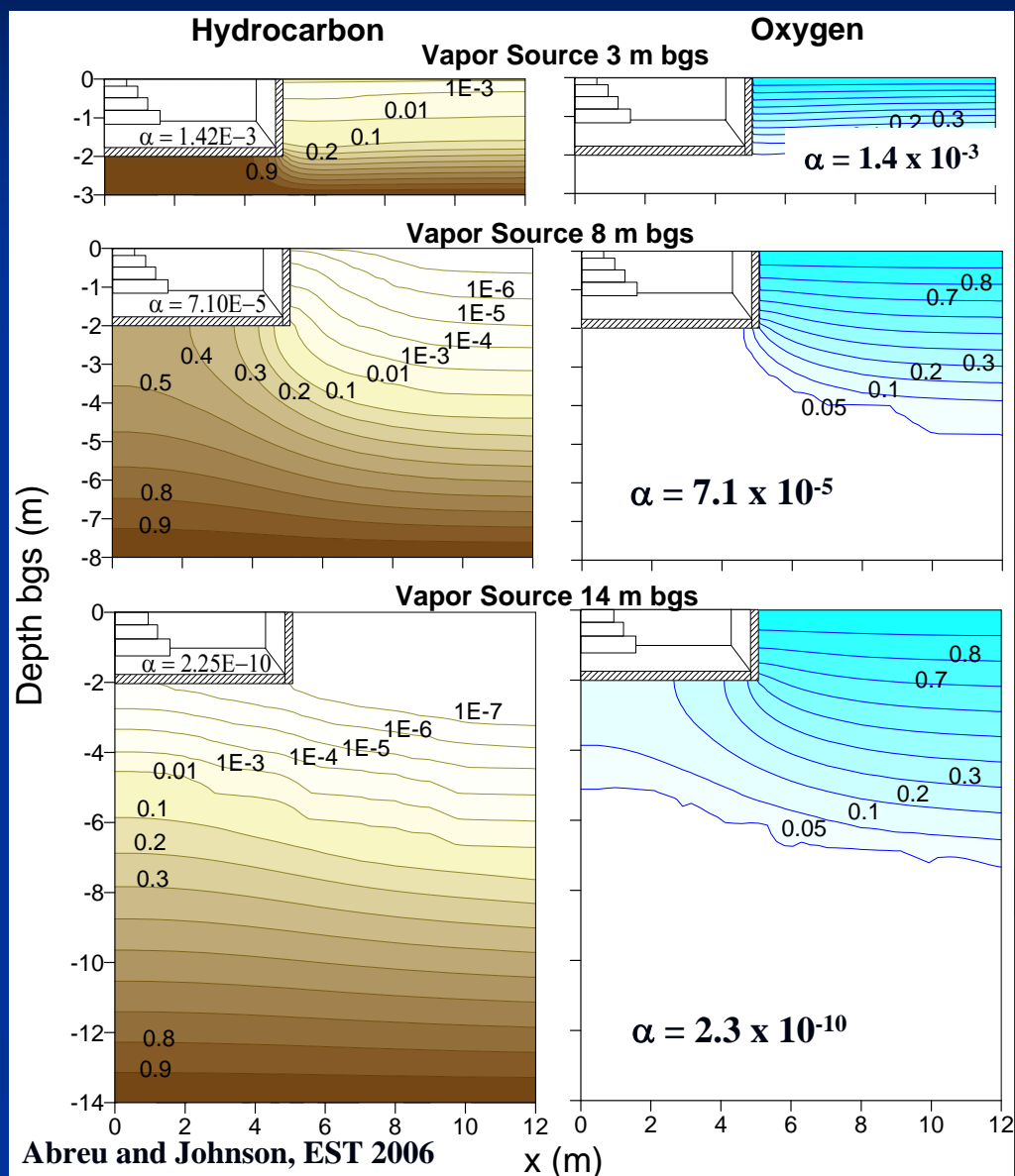
Basement scenario

Building under-pressurized 5 Pa

Benzene source

$C_{vs} = 200 \text{ mg/L}$  (NAPL source)

$\lambda = 0.18 \text{ h}^{-1}$



# Aerobic Biodegradation

## Effect of Source Vapor Concentration

- Results suggest that there is a source vapor concentration below which VI is of little concern for degradable compounds

### Model Assumptions:

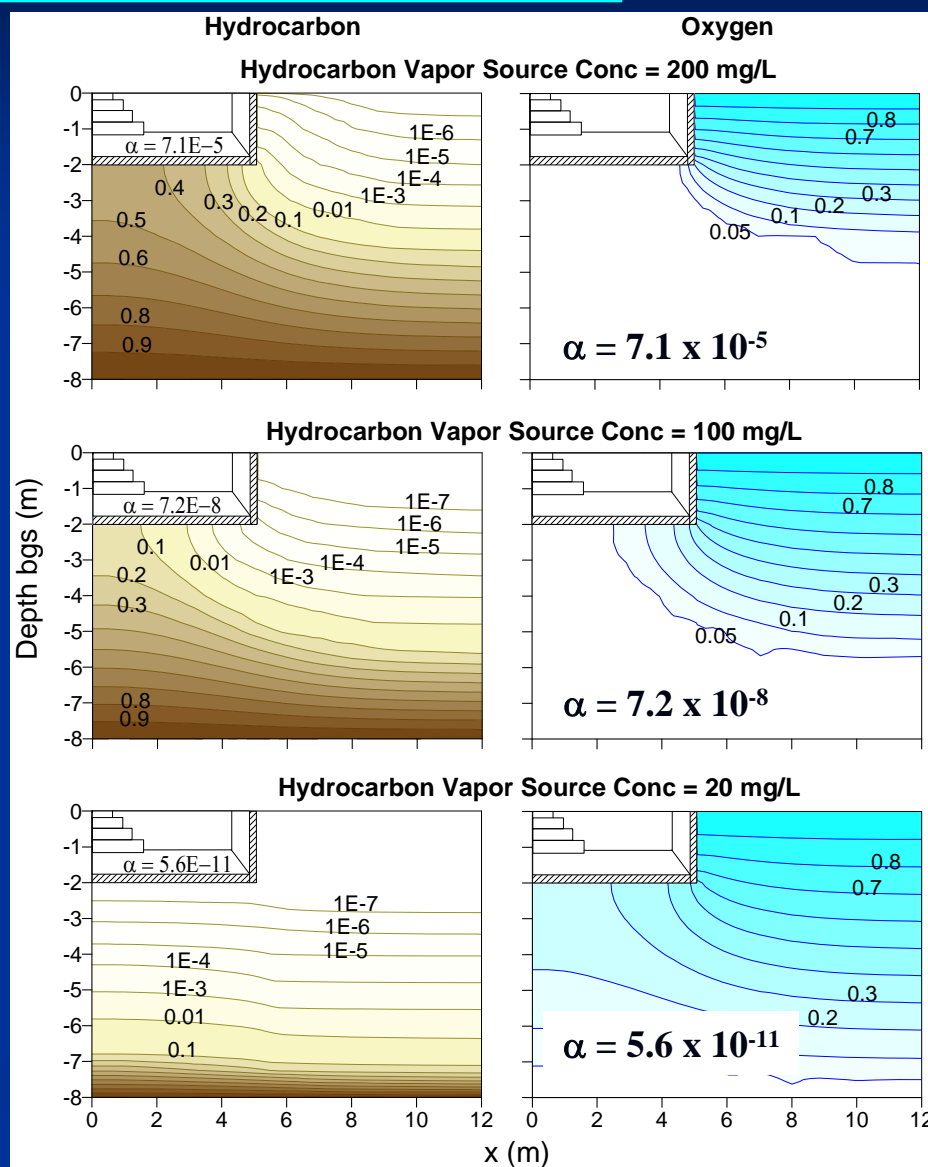
Homogeneous sand

Basement scenario

Building under-pressurized 5 Pa

Benzene source

$\lambda = 0.18 \text{ h}^{-1}$



# Aerobic Biodegradation

## Effect of Vapor Source Concentration and Depth

Biodegradation is likely to have a significant effect on  $\alpha$  for non-NAPL sources

The effect is more pronounced for deeper sources

For NAPL sources, effect of biodegradation on  $\alpha$  may be minimal due to oxygen depletion

### Model Assumptions:

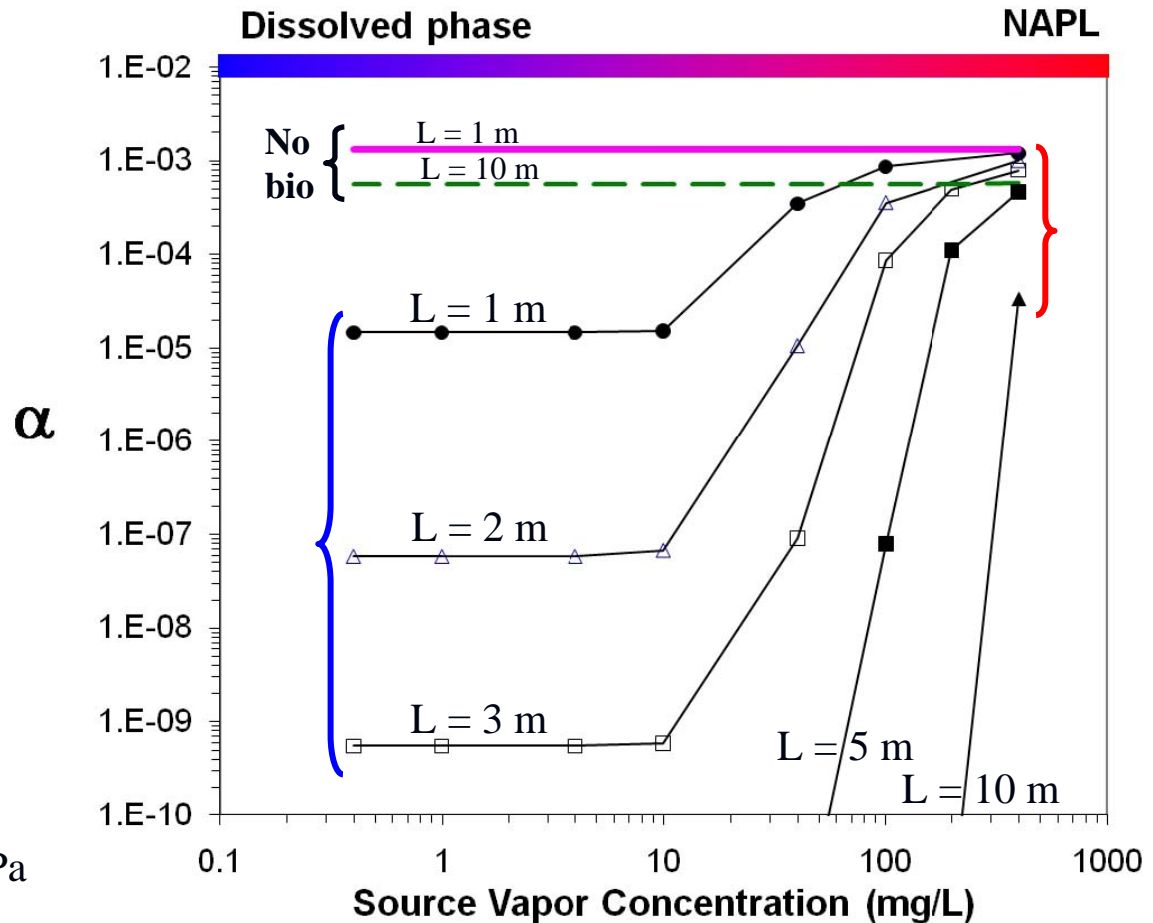
Homogeneous sand

Basement scenario

Building under-pressurized 5 Pa

Benzene source

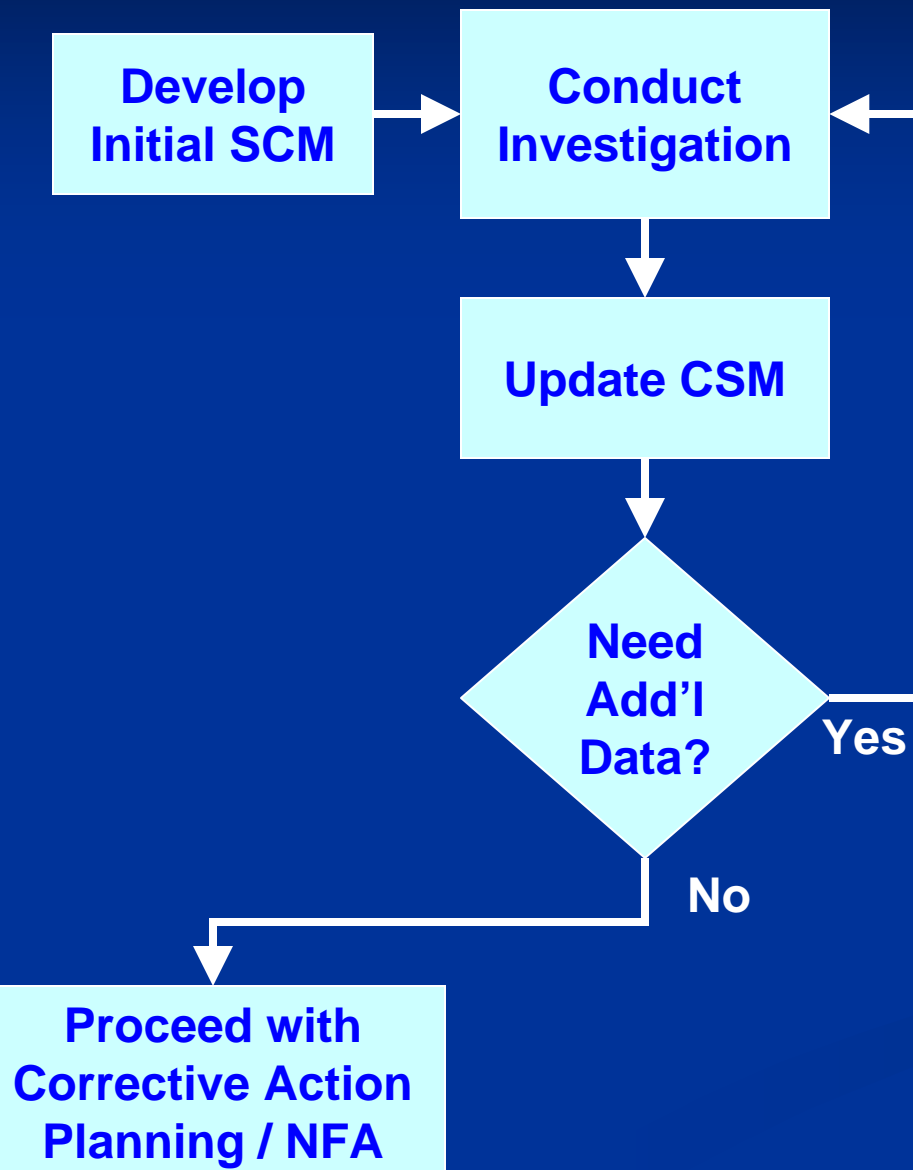
**L:** source-foundation distance



$\lambda = 0.79 \text{ h}^{-1}$

Abreu et al., GWMR 2009

# Use of CSM to Guide Investigation



- Site-specific conditions should be used to plan investigation
- Collect site characterization data in addition to soil gas samples for analysis to refine CSM
- If data are not consistent with CSM:
  - Update CSM and/or
  - Confirm data quality

# Conclusions

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## Why bother with a CSM?

### ■ Planning & Interpretation

- Organize and interpret existing data
- Rank data importance
- Identify data needs and data gaps
- Minimize schedule and budget

### ■ Communication

- “Pictures are worth 1,000 words”