Multi-Dimensional Vapour Modeling for Assessing Vapour Risk at Hydrocarbon Contaminated Sites

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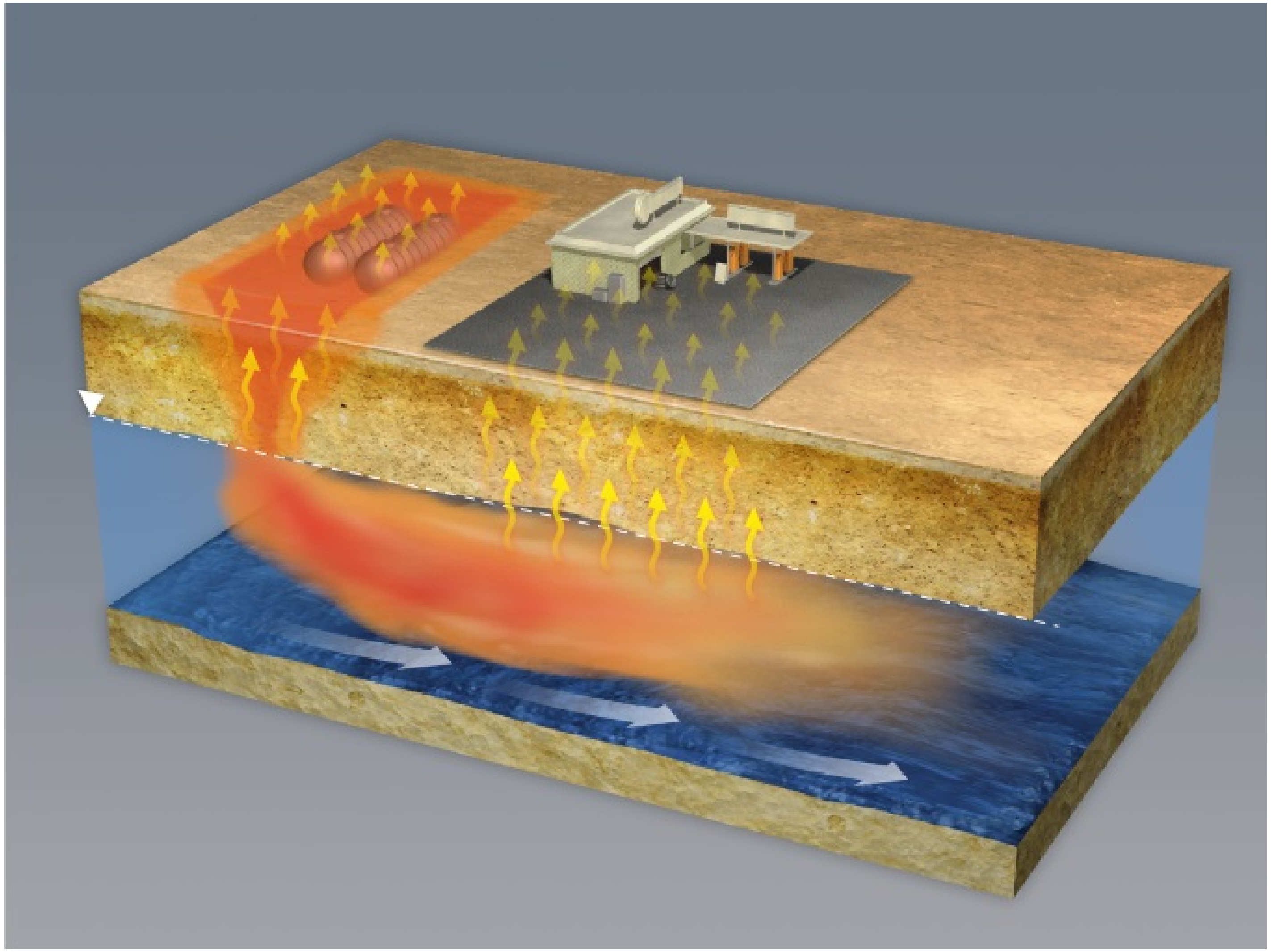
Outline

- Background
- Health effects of Vapour Intrusion
- Vapour Intrusion Models (VIM)
- Methodology
- Hypothesis
- Acknowledgement

Background

What is **Vapour Intrusion (VI)**?

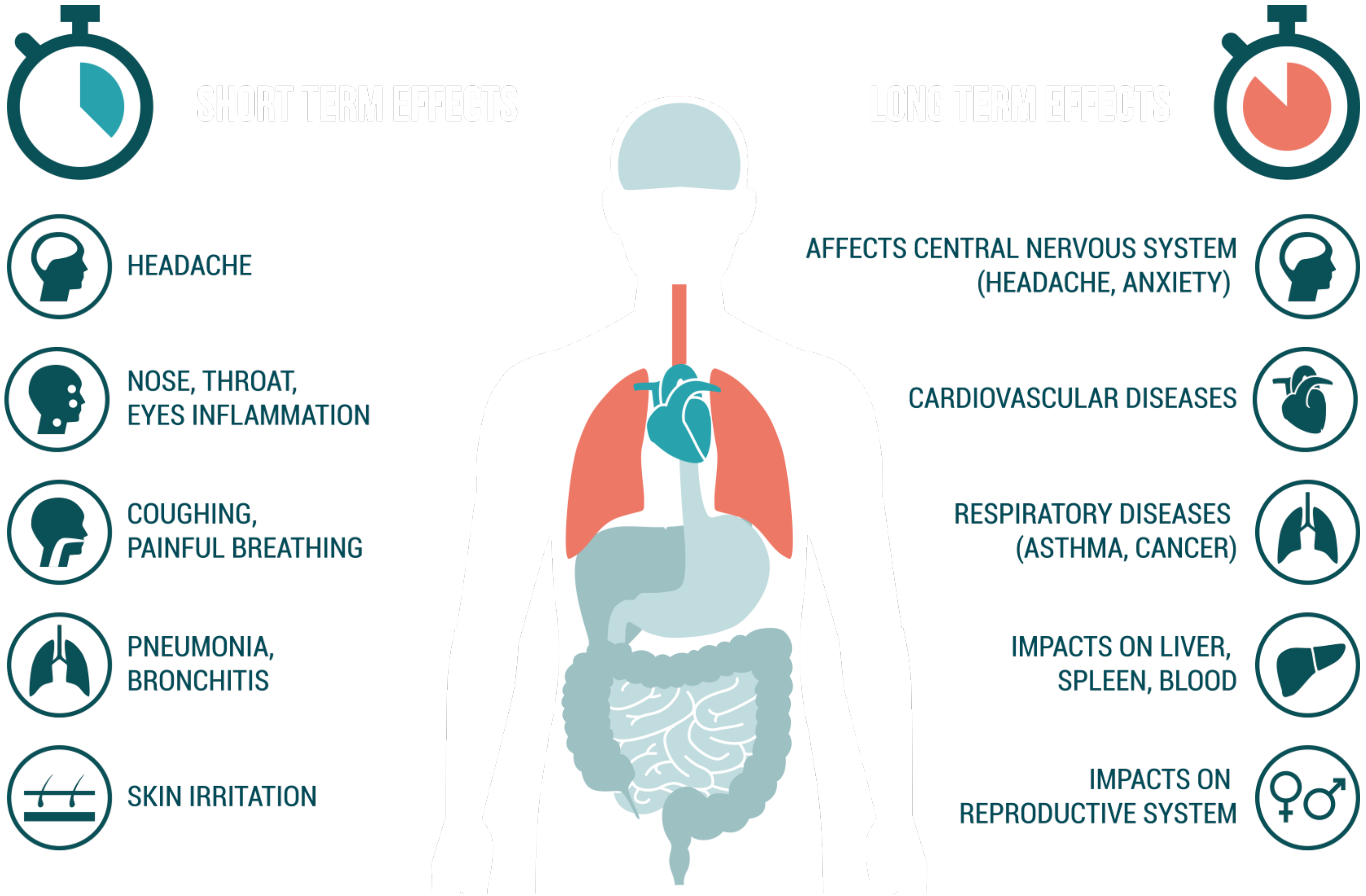
Migration of hazardous vapours from any subsurface vapour source, such as contaminated soil or groundwater, through the soil into an overlying building.



Source: www.rgenesis.com

Health Effects of VI

An average person inhales 20,000 litres of air per day!



Source: www.airthings.com/what-is-tvoc

Vapour Intrusion Models (VIM)

One Dimensional (1-D) Models

- considers vapour movement in vertical direction
- simple and easy to use

Two Dimensional (2-D) Models

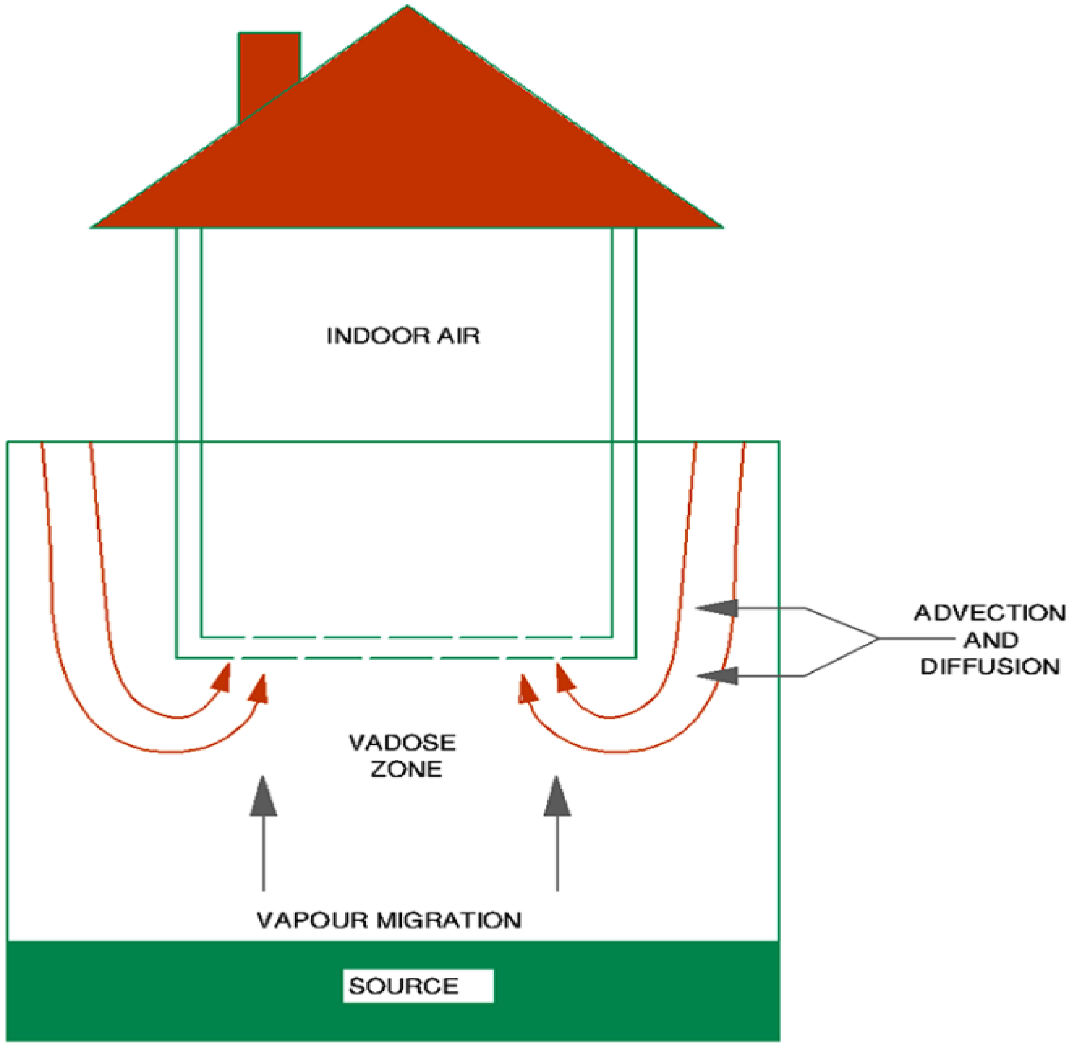
- Considers vapour movement in lateral and vertical directions
- Accurate than 1-D models; Less computational efforts than three dimensional models

Three Dimensional (3-D) Models

- Considers vapour movement in all three dimensions
- Capable to deal with complicated processes
- Requires significant computational effort

One dimensional (1-D) models

- Only vertical vapour flow is considered assuming infinite contaminant mass
- Simple and easy to use
- The most commonly used 1-D model is J&E model (Johnson & Ettinger, 1991)
- Considers diffusion as the main transport mechanism
- The advection is considered to affect only a small area around the building of interest



Conceptual Site Model for 1-D model (Johnson & Ettinger, 1991) cont.

- Contaminant transport primarily by molecular diffusion in the vadose zone described using Fick's law

$$E = A_B \frac{(C_{source} - C_{soil})}{L_T} . D_T^{eff}$$

- The effective diffusion coefficient depends on the porosities of the medium and is given by Millington and Quirk equation (1961)

$$D_{eff} = D_a \frac{\theta_a^{\frac{10}{3}}}{\theta_T^2} + \frac{D_w}{H} \frac{\theta_w}{\theta_T^2}$$

- The rate of molecular diffusion depends upon the contaminant concentration gradient and the effective diffusion coefficient

Limitations of 1-D model

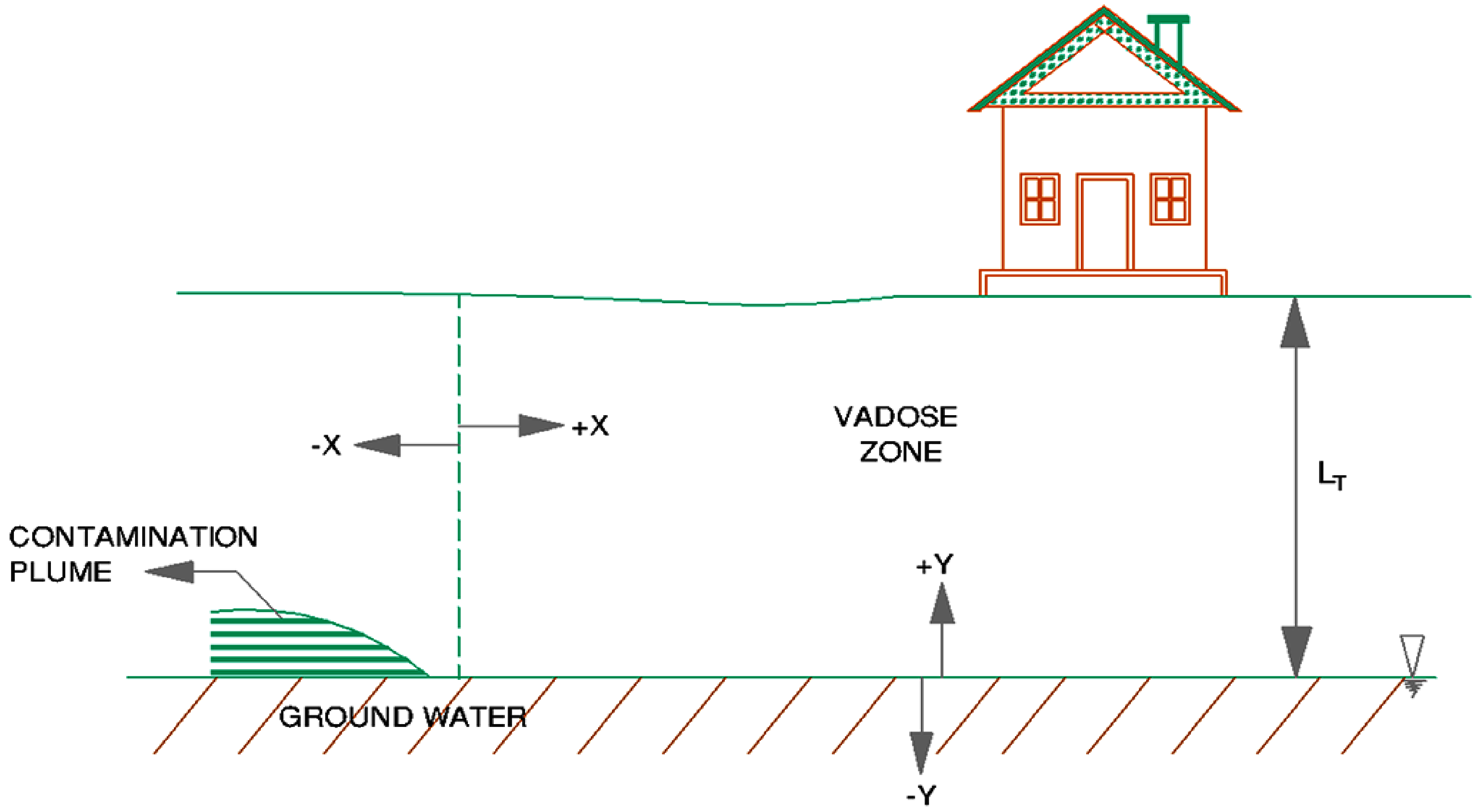
- Vapour movement is assumed to be only in vertical direction
- Simplifies the subsurface scenarios for ease of computation
- Limitations in addressing complicated soil and environmental factors
- Limits its use to a screening tool

Two Dimensional (2-D) models

- 2-D models calculate vapour flux at the ground surface as a function of lateral and vertical distance from the source
- As the dimensionality increases the difficulty in obtaining the solution also increases
- Transport mechanisms are simplified and boundary conditions are used to simplify the solution
- The governing equation for diffusion of contaminants becomes the Laplace equation (Lowell and Eklund, 2004)

$$D_{eff}\left(\frac{\partial^2 C}{\partial x^2} + \frac{\partial^2 C}{\partial y^2}\right)$$

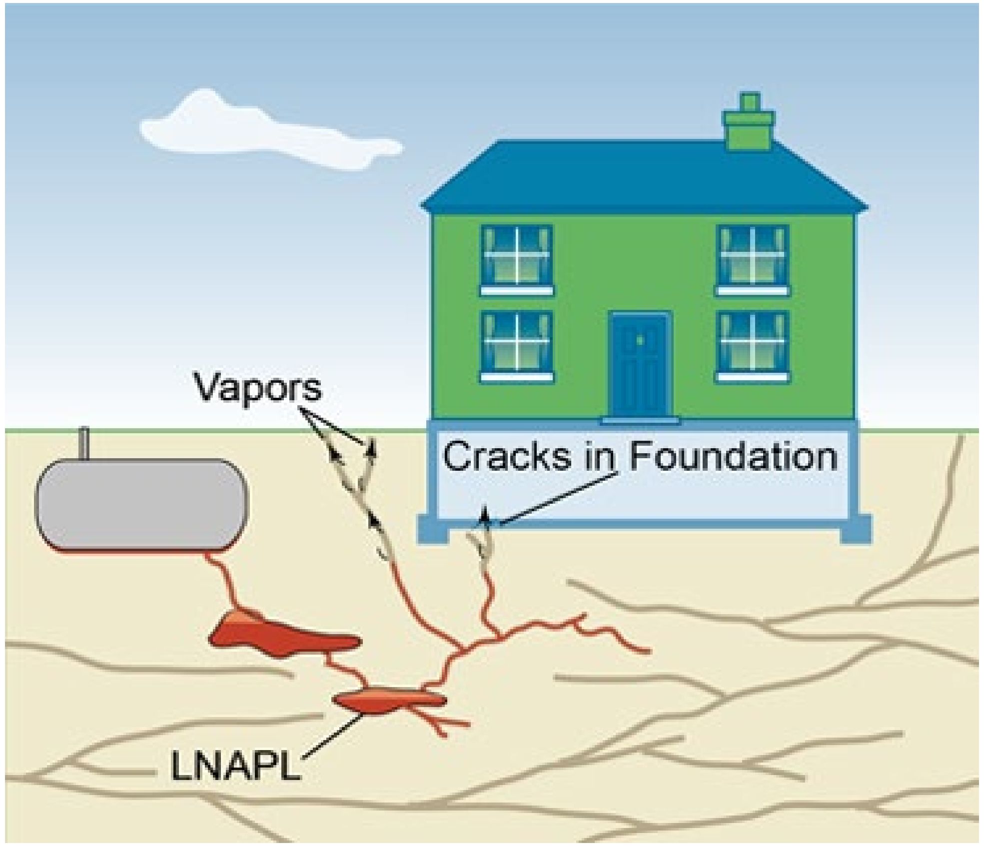
cont.



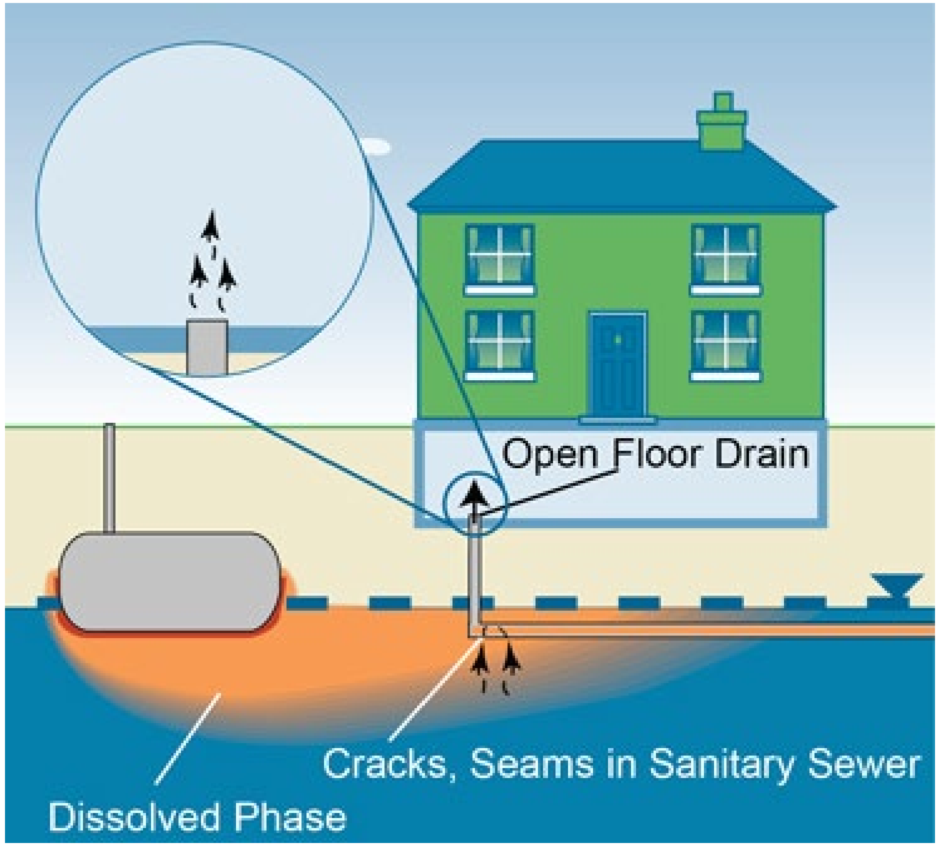
Conceptual Site model for 2-D modelling
(Lowell and Eklund, 2004)

$$E = D_{eff} \frac{\partial C\ (x, L_T)}{\partial y}$$

Preferential Pathways



Preferential Pathway - Natural



Preferential Pathway - Engineered

Image source: ITRC 2014

Preferential Pathways – Path of least resistance

Methodology

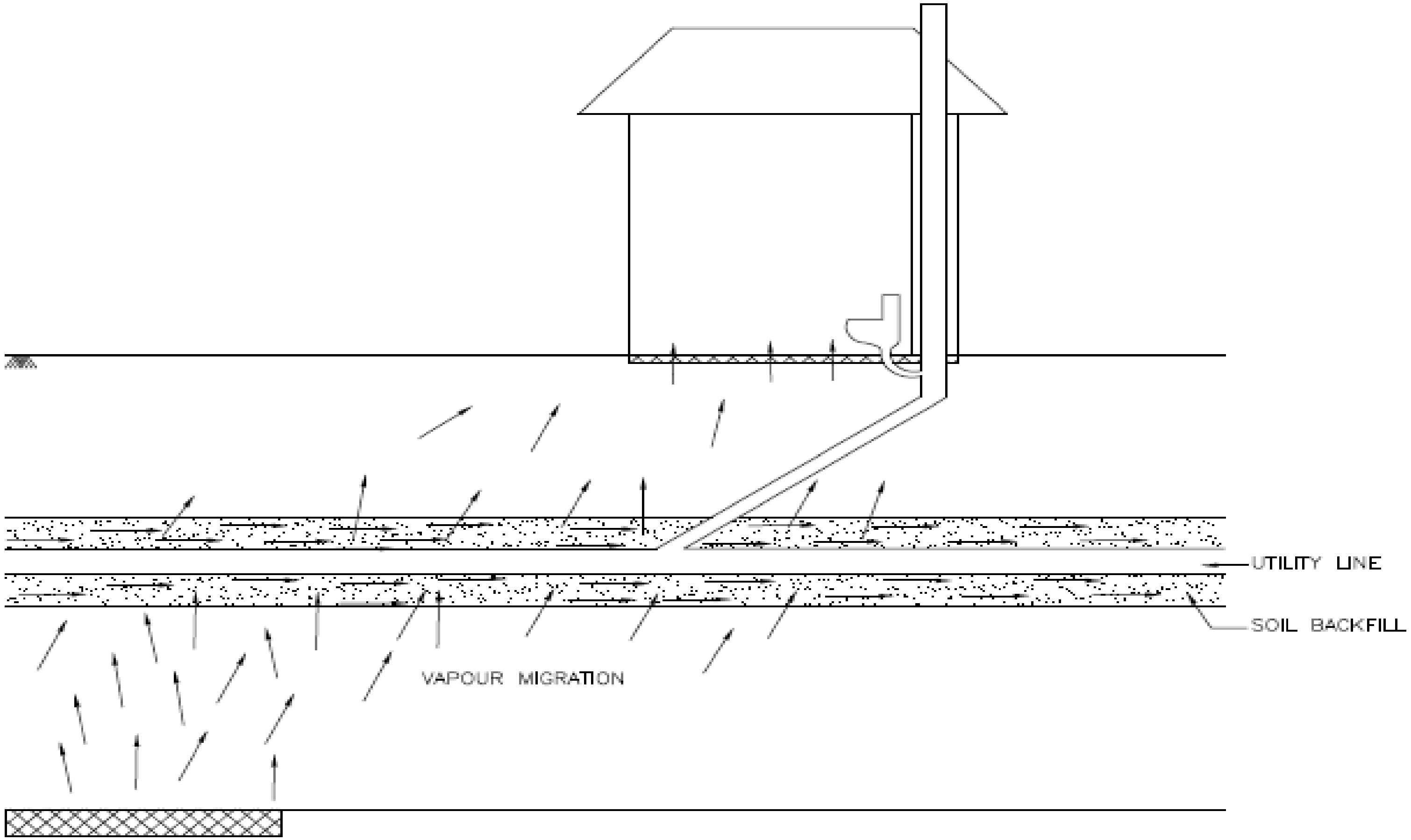
Model Assumptions

- The source is assumed to be infinite
- Model operates under steady state condition
- Subsurface is homogeneous
- Dominant mechanism of transport is diffusion
- Effect of biodegradation is not considered

Model Development

- A user-specified nodal mesh generation for each discrete layer
- Calculation of effective diffusion in the vadose zone soil and contaminant flux in the preferential pathways in each scenario
- Adjusting chemical and physical parameters at each nodal point
- Simulation of the fate of CHCs.

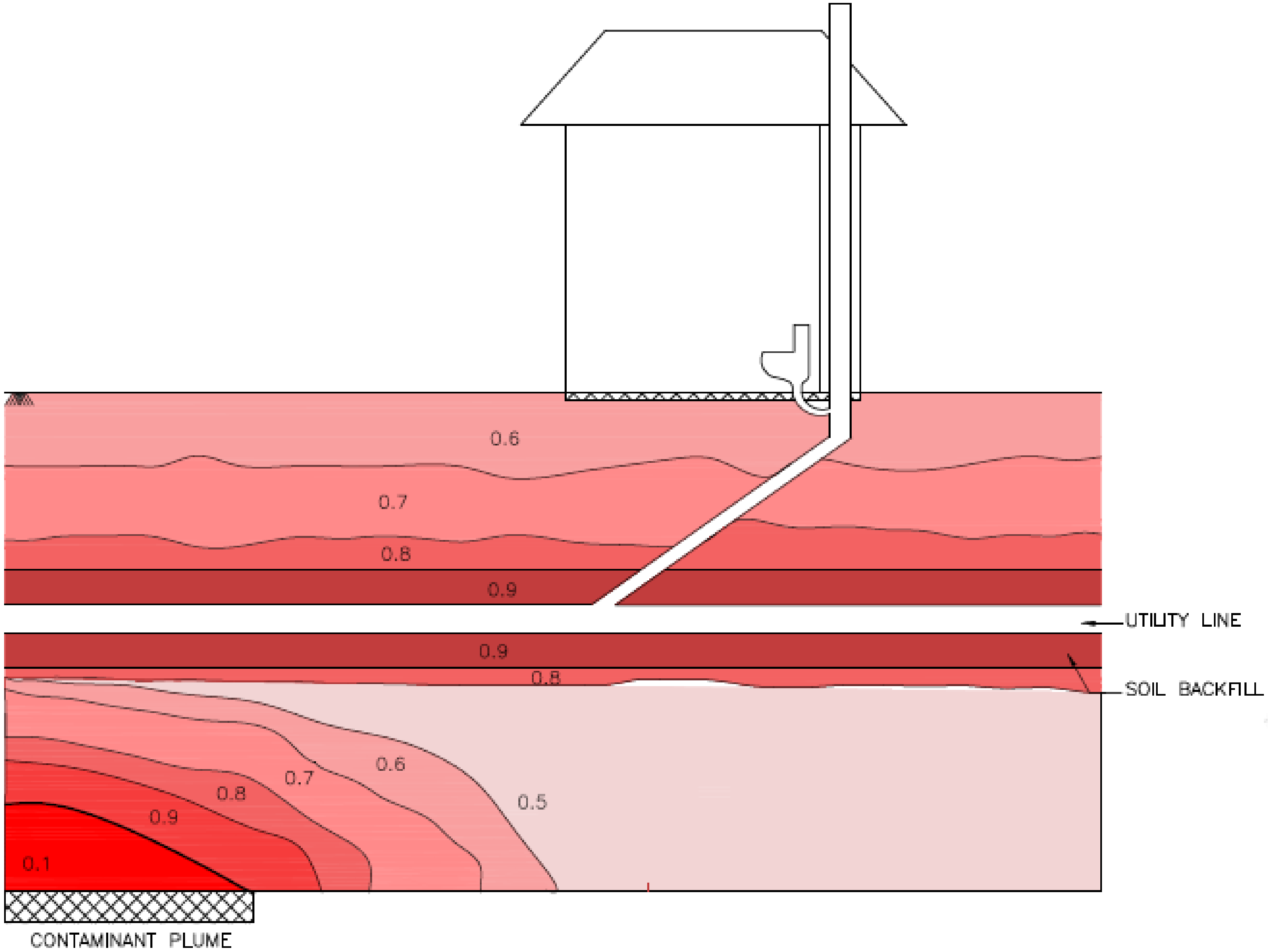
Conceptual Site Model (CSM)



$$E = -D_{eff}\frac{\partial C\,(x,L_T)}{\partial y}$$

The CSM considered is a sanitary sewer line running through vadose zone surrounded by sandy backfill soil acting as preferential pathway

Hypothesis



The soil gas concentration around the utility line increases as the rate of vapour transport increases due to high porosity of the backfill soil

THANK YOU

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