General Principles for Hydrocarbon Vapor Intrusion

G. Todd Ririe

BP

La Palma, CA

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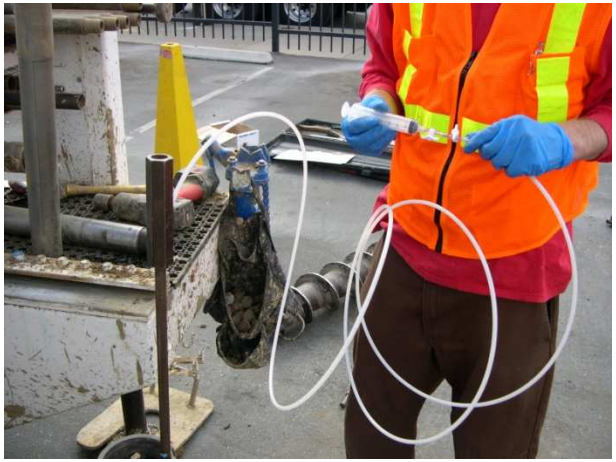


Petroleum Hydrocarbons And Chlorinated Hydrocarbons Differ In Their Potential For Vapor Intrusion

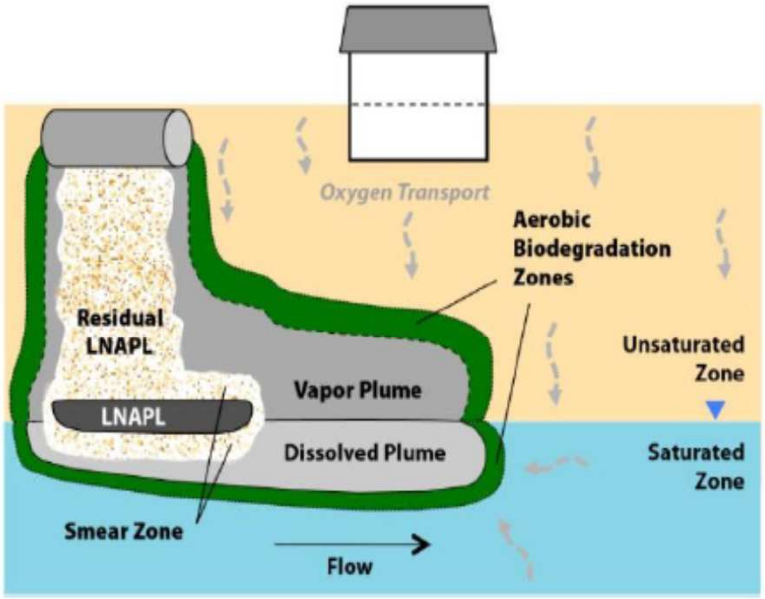


Figure 1. Typical petroleum hydrocarbon transport conceptual scenario

Aerobic biodegradation of PHCs along the perimeter of the vapor and dissolved plumes limits subsurface contaminant spreading. Effective oxygen transport (dashed arrows) maintains aerobic conditions in the biodegradation zone. Petroleum LNAPL (light nonaqueous phase liquid) collects at the groundwater surface (the water table, blue triangle).

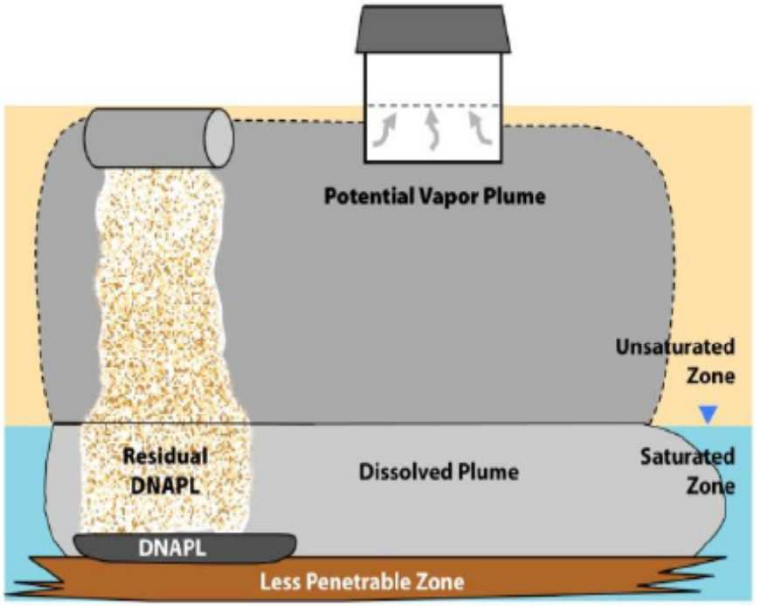
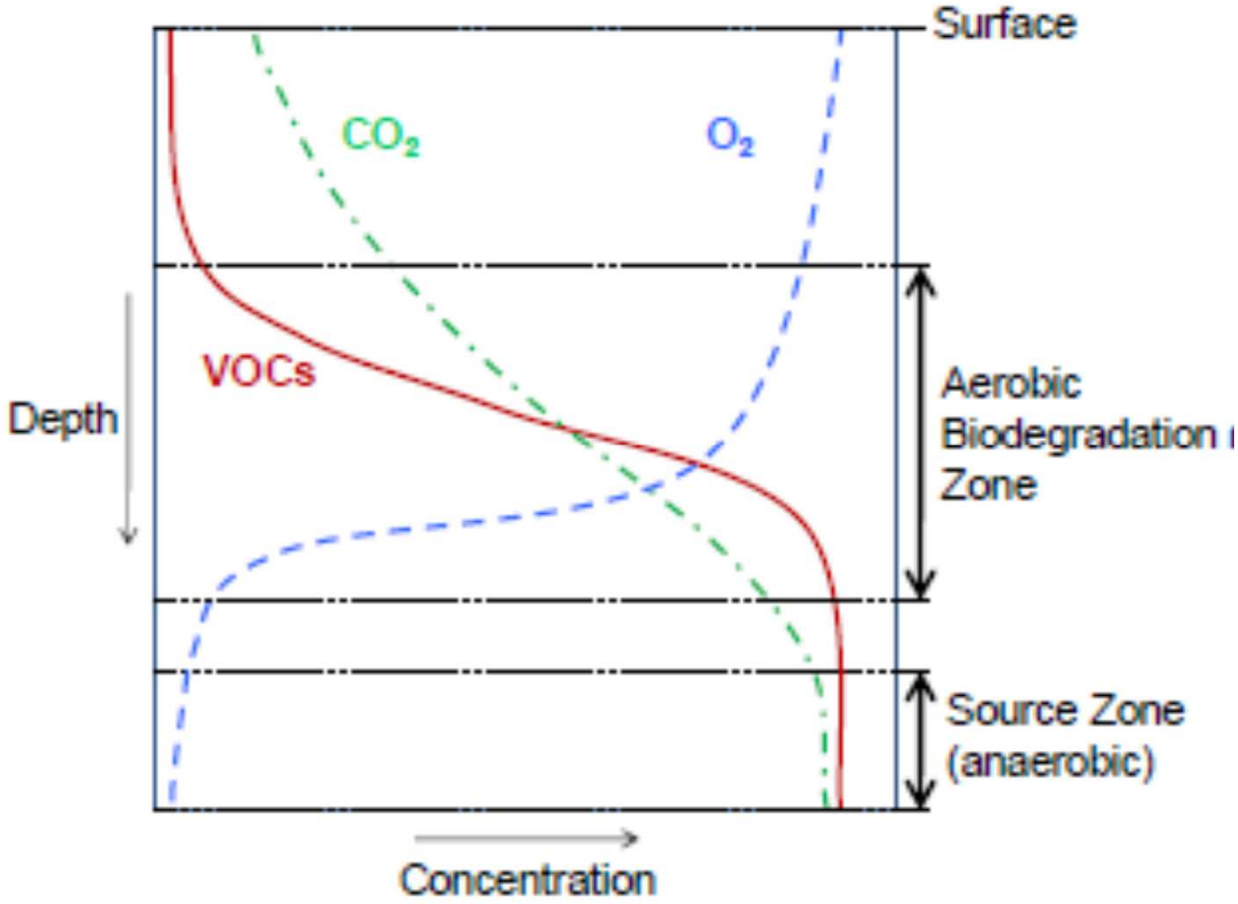


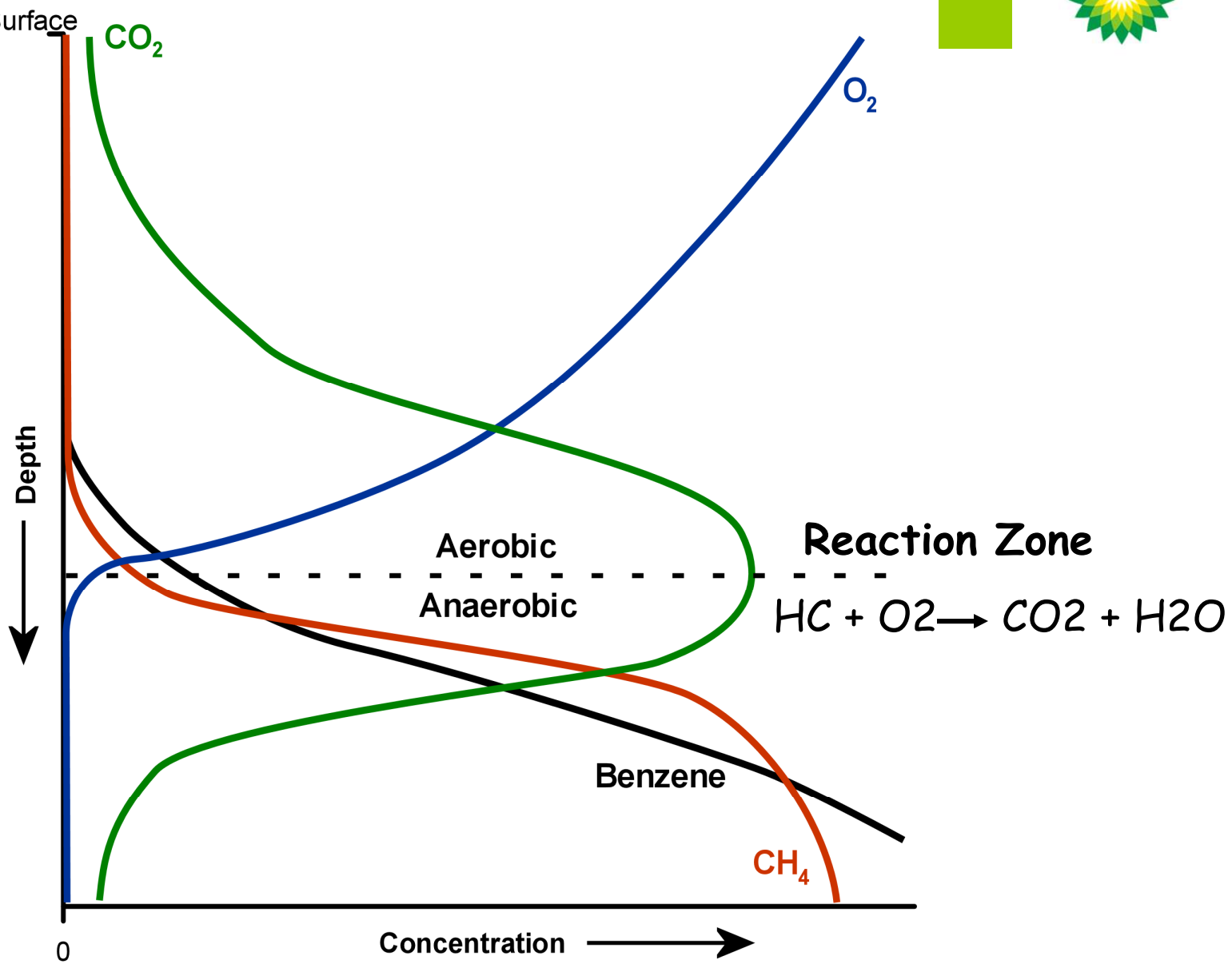
Figure 2. Typical chlorinated solvent transport conceptual scenario

Biodegradation of CHCs is anaerobic and usually slower than PHC biodegradation, so that the vapor and dissolved plumes often migrate farther than PHC plumes. CHC DNAPL (dense nonaqueous-phase liquid), if present, can sink below the water table, collecting in this case on a less penetrable layer.

Typical vertical concentration profile in the unsaturated zone for VOCs, CO_2, and O_2



Clean Soil Model for HC Vapors



Clean Soils vs Dirty Soils

CLEAN SOILS

- Have oxygen concentrations above 3%
- Have no residual petroleum hydrocarbons
- PID values will be below 100 ppm
- Usually have low methane and carbon dioxide values
- Non-detect or very low petroleum hydrocarbon vapors

DIRTY SOILS

Have low oxygen concentrations (at or near 0%)

Can have residual petroleum hydrocarbons

PID reading at or above 100 ppm

Usually have high methane and carbon dioxide values

Elevated petroleum hydrocarbon vapors

Importance of Biodegradation of Petroleum Hydrocarbons

Ground Water Monitoring&Remediation

Evidence for Instantaneous Oxygen-Limited Biodegradation of Petroleum Hydrocarbon Vapors in the Subsurface

by G.B. Davis, B.M. Patterson, and M.G. Trefry

Ground Water Monitoring & Remediation 29, no. 1/Winter 2009/pages 126–137

Oxygen versus Petroleum Hydrocarbon Plots

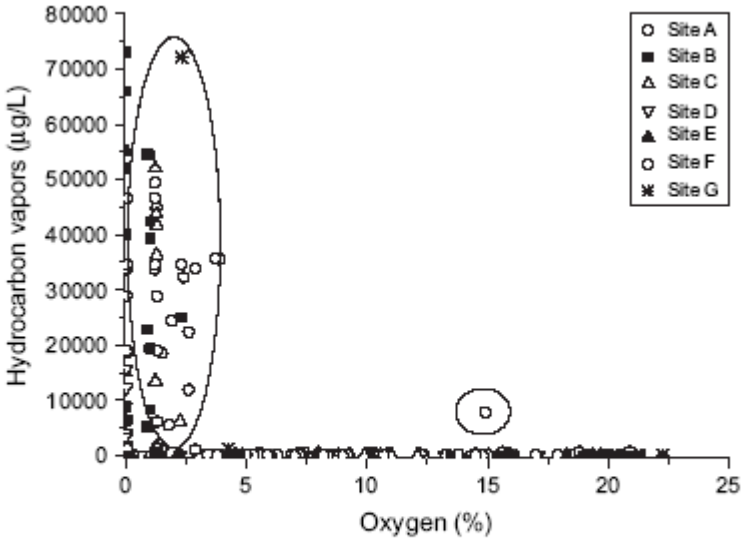


Figure 2. Total petroleum hydrocarbon vapor concentrations compared to oxygen concentrations for Sites A-G. Circled are data from sites where at the same sampling port both oxygen and hydrocarbon vapors were above detection levels.

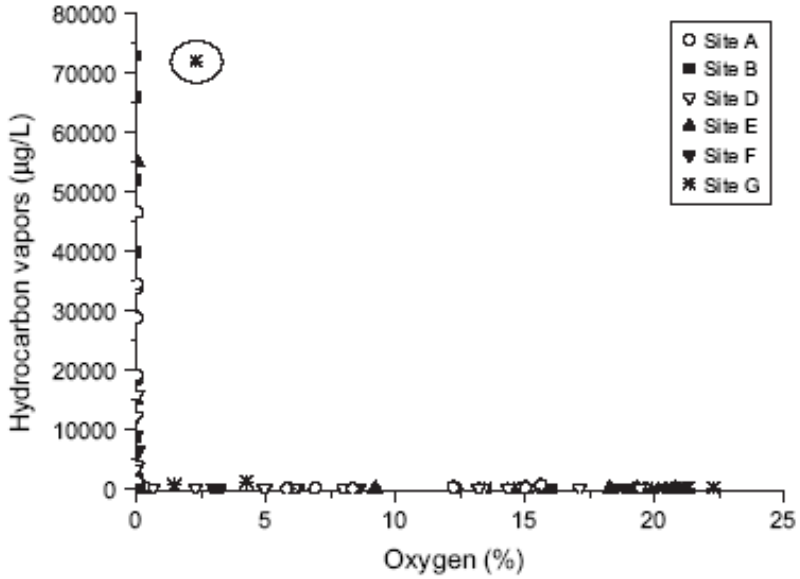


Figure 4. Total petroleum hydrocarbon vapor concentrations compared to oxygen concentrations; data from in situ oxygen and VOC probes for all available sites.

Manual collected O2 data: Leakage of O2 into syringe

In situ O2 data

From Davis et al., 2009

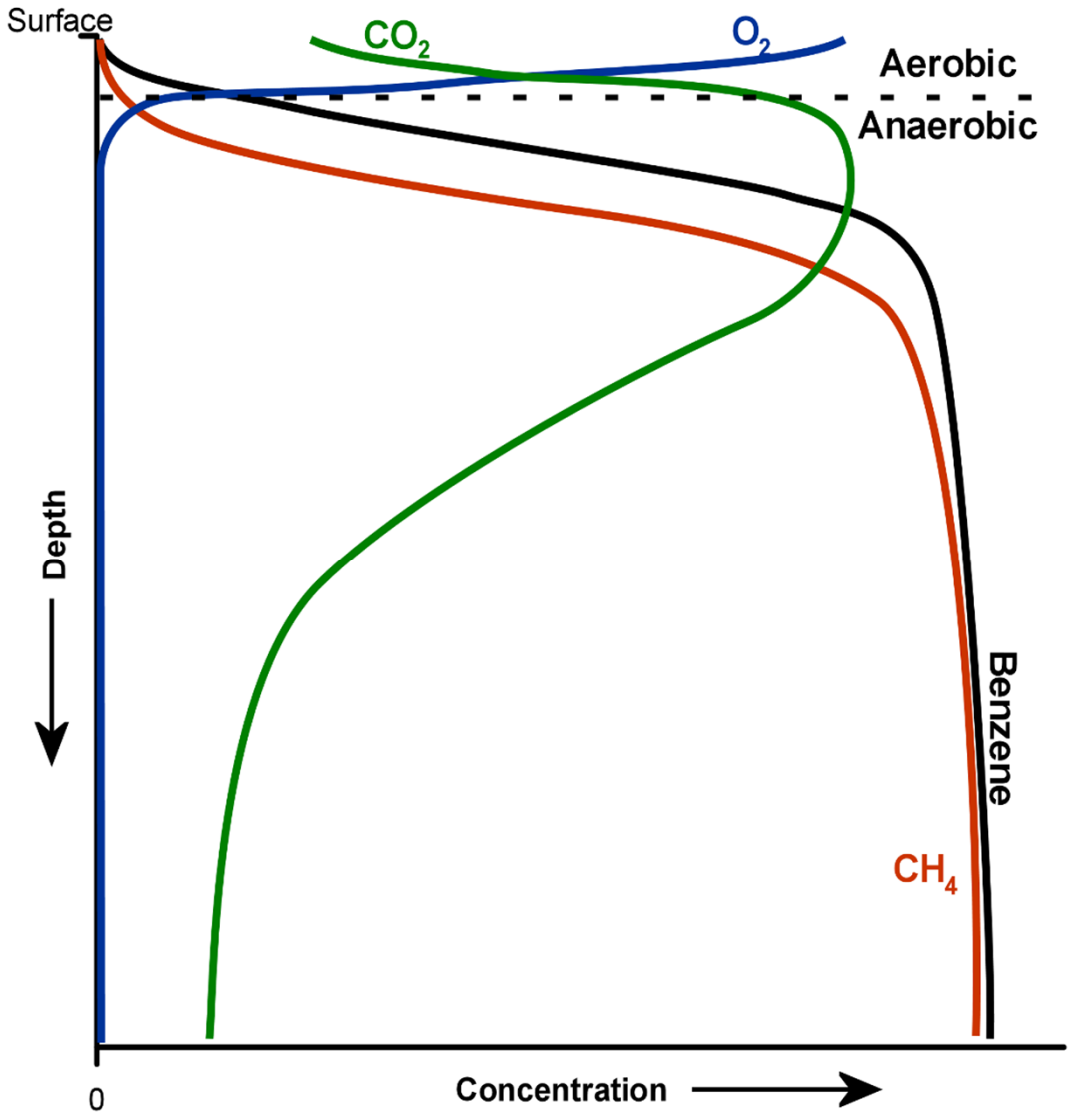
Is There Enough Oxygen?

- **Aerobic Biodegradation**
  - **Hydrocarbon to Oxygen use ratio: 1 : 3 (kg/kg)**
  - **Atmospheric air (21% Oxygen; 275 g/m3 oxygen) provides the capacity to degrade 92 g/m3 hydrocarbon vapors (92,000,000 ug/m3)**

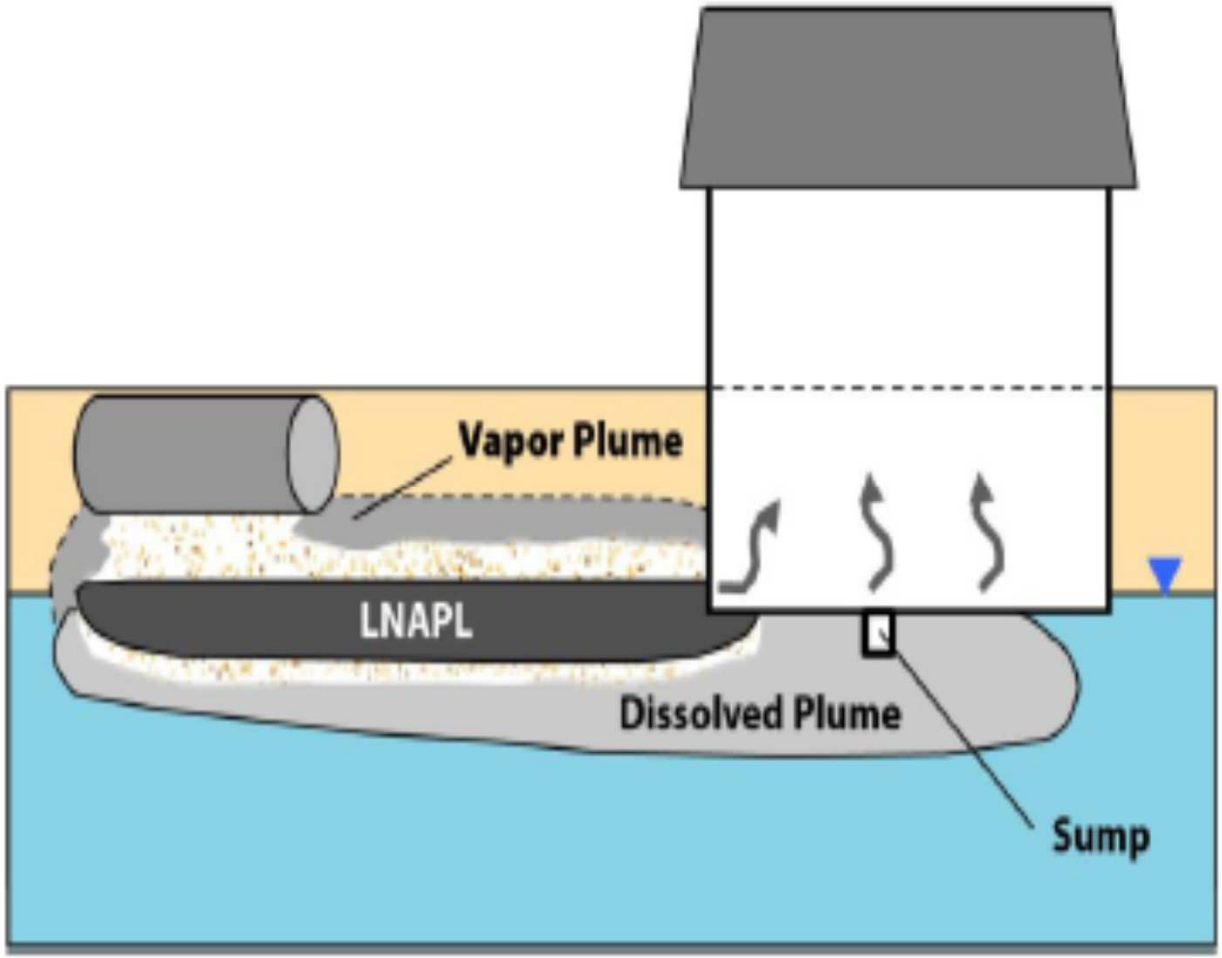
George DeVaull
george.devaull@shell.com

- **Oxygen below a Foundation: can it get there?**
  - **Through the foundation**
    - **Cracks; concrete does have permeability to air**
  - **Around the foundation edges (bonus)**
    - **Oxygen has been found in sufficiently high quantities under most buildings**
    - **Large buildings or buildings built over dirty soils can be areas of low oxygen concentration**

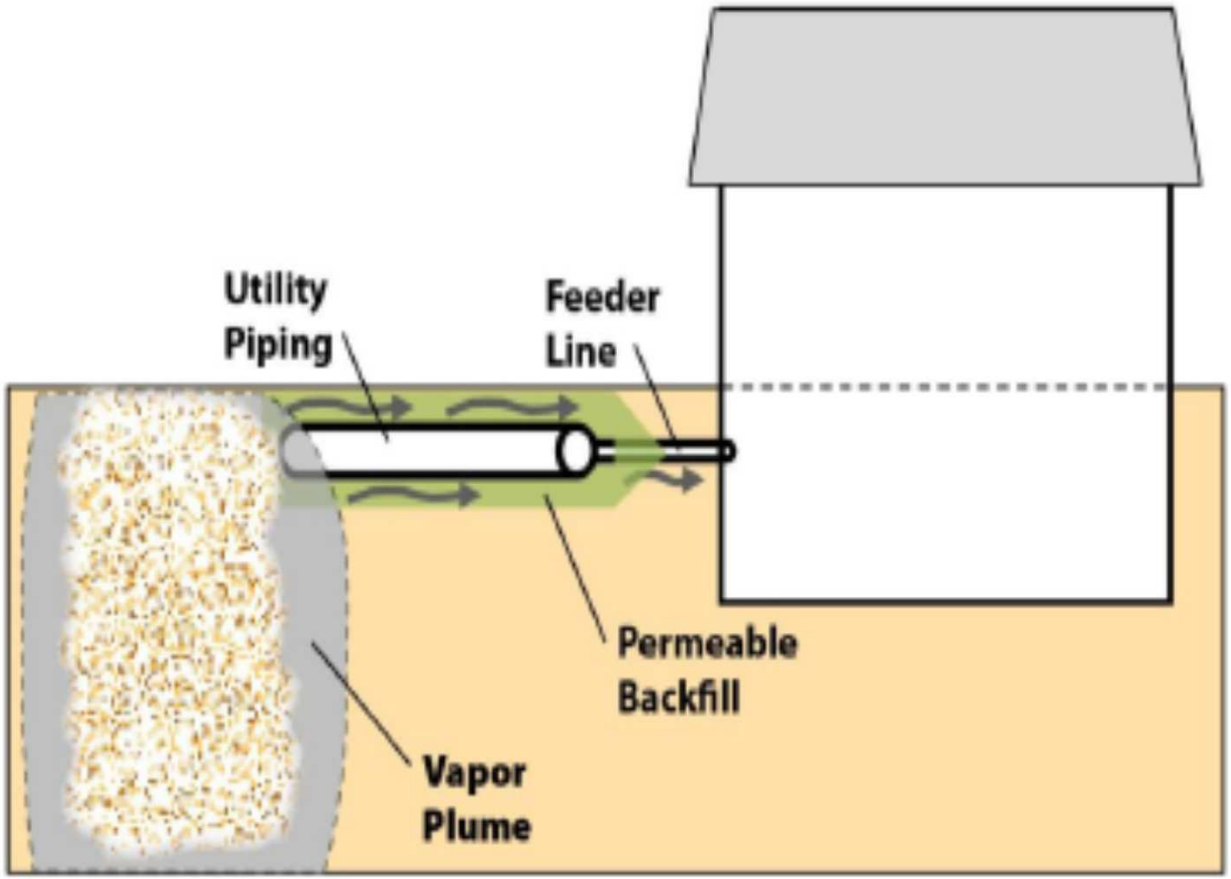
Dirty Soil Model for HC Vapors



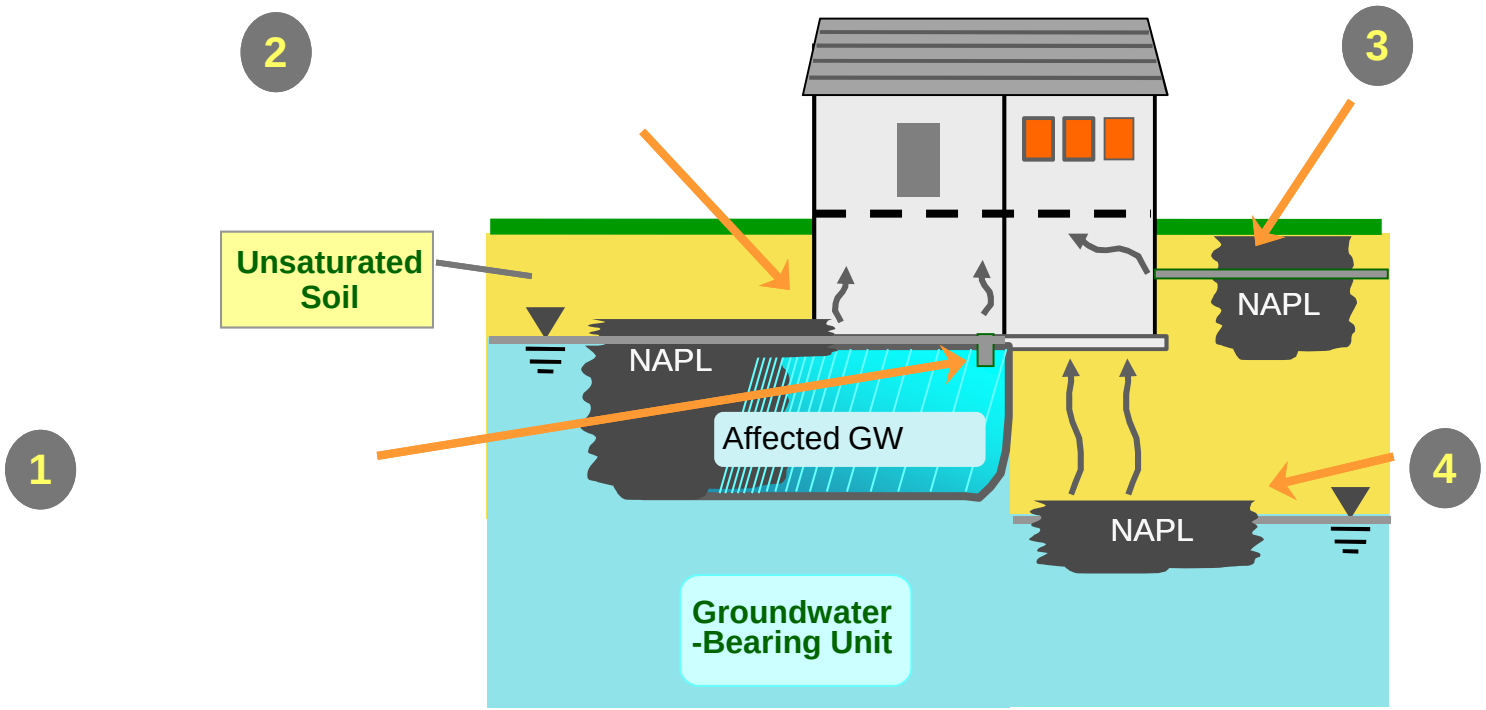
Vapor intrusion from direct building contact



Preferential transport through a utility trench



Petroleum Vapor Intrusion: Petroleum Industry Experience



KEY POINT:

- **For petroleum sites, vapor intrusion is generally associated with i) direct impacts or ii) NAPL sources, but not diffusion of vapors from dissolved plumes.**
- **Delineation of vapor sources is important for screening**