

# Role of Hydrogeology in Professional Environmental Projects

A photograph of a large, layered rock formation, possibly a dam or a natural cliff face, with a blue sky above and green vegetation at the base. The rock is reddish-brown and shows distinct horizontal strata. The sky is a clear, bright blue. The foreground is filled with green grass and some small plants.

## Use of Hydrogeology in Professional Environmental Projects

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United States Environmental Protection  
Agency



- Introductions
- Geology, Hydrogeology, Hydrology
- Hydrogeology projects
  - Solvent Savers
  - Tucson International Airport
  - Other GW Remediation
- Conclusions
- Discussions

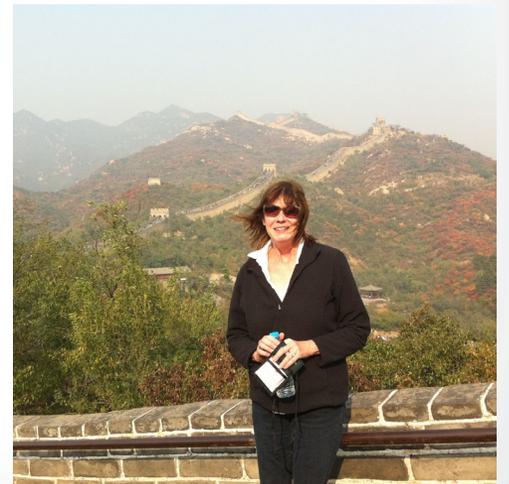


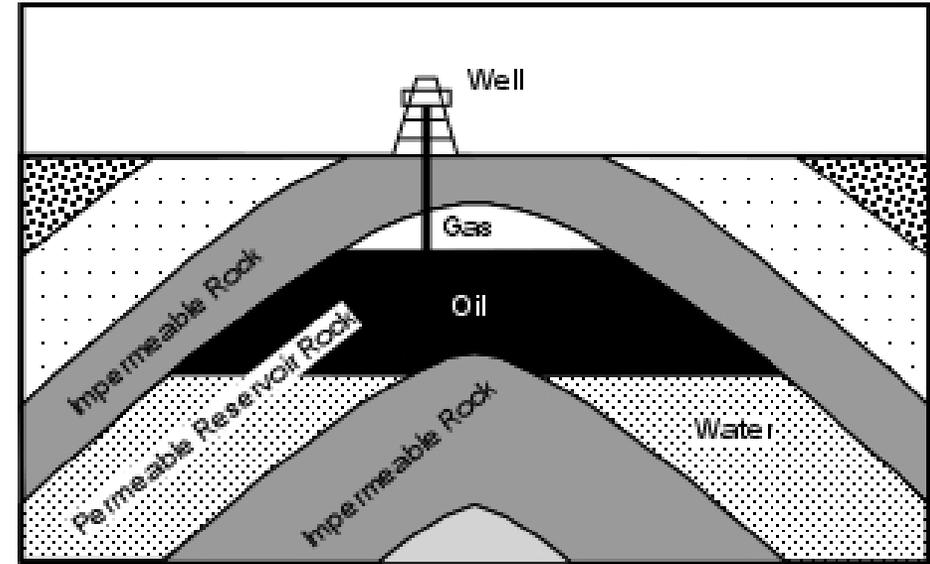
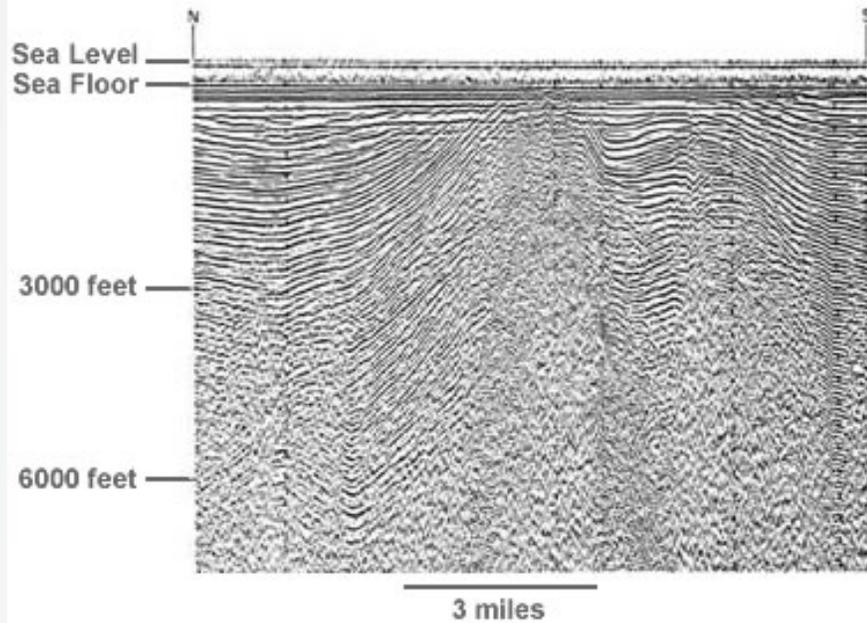
## **Disclaimer**

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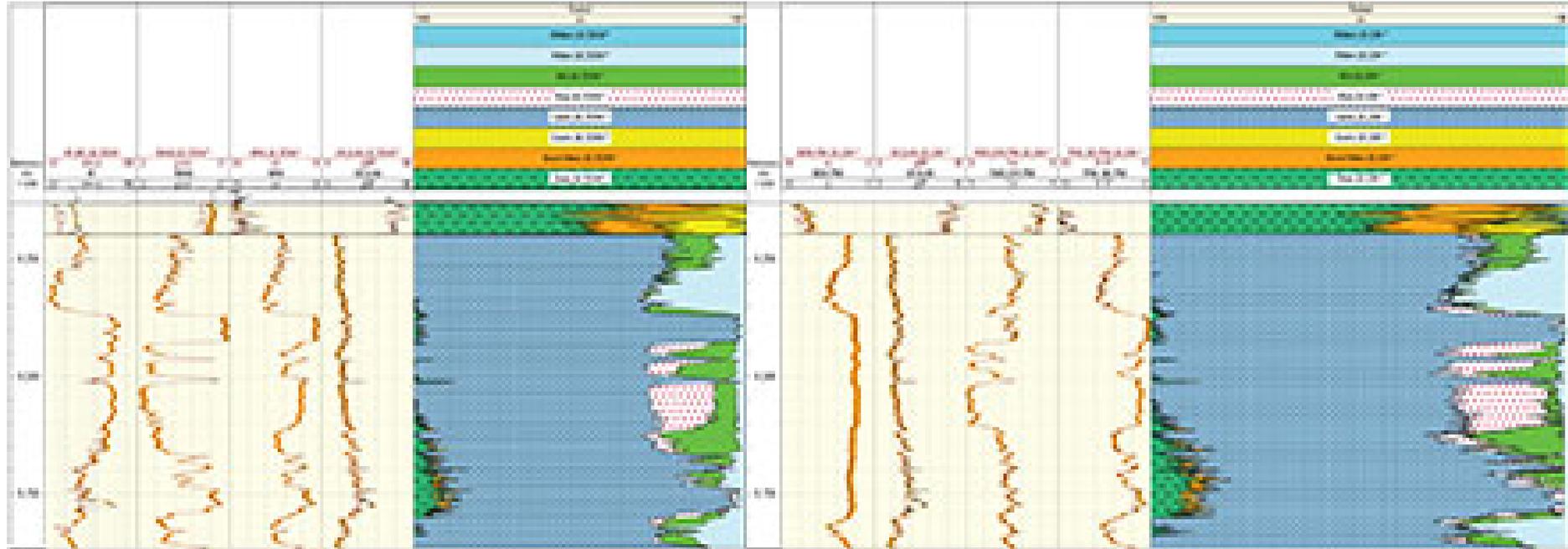
- Michelle Simon
  - BS Chemical Engineering, University of Notre Dame
  - MS Chemical Engineering, Colorado School of Mines
  - PhD Environmental Science, Minor Chemical Engineering, University of Arizona
- Worked in Oil Industry for 10 years
- Went to US EPA in 1990 – Vadose Zone and Groundwater
- Worked on Superfund Site Cleanup until 2010
- Then worked on Stormwater Run-off
- And Surface Water - Groundwater Interaction





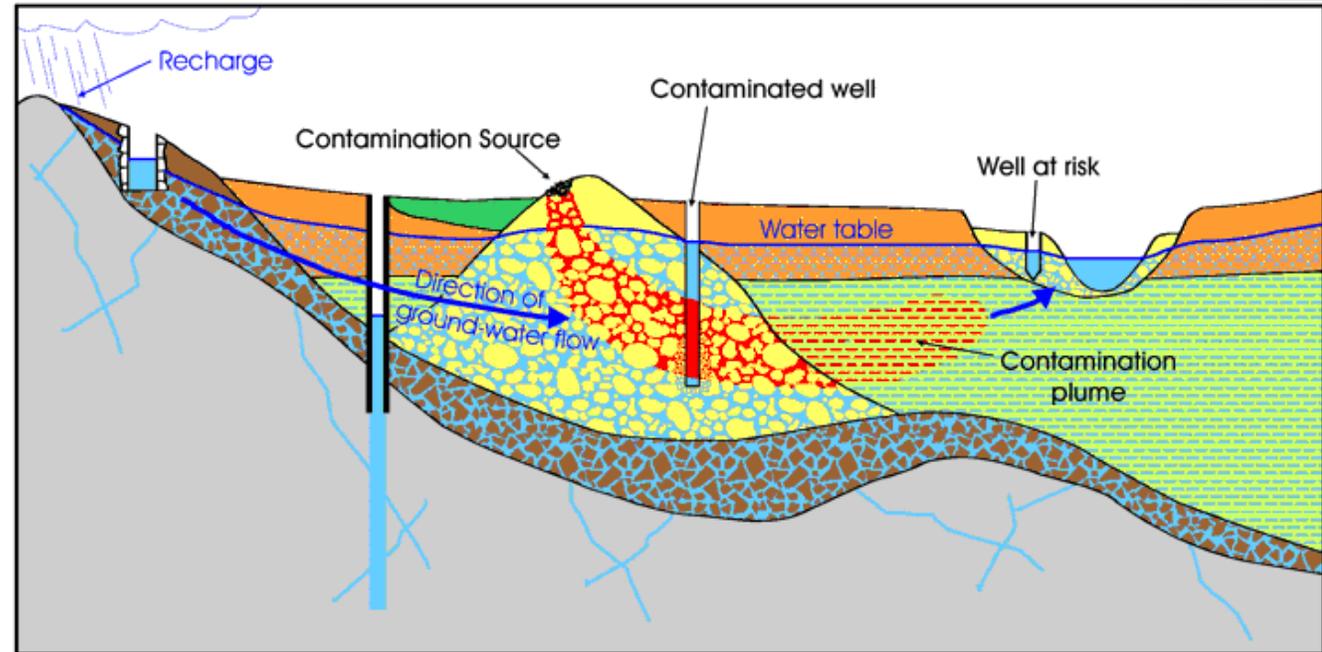
Oil companies need to use geological evaluation techniques to find oil and gas reservoirs, evaluate the transmissivity of reservoir, and calculate the amount of fluid present to determine the economics of recovery

# Formation Evaluation



Oil companies developed seismic techniques as well as electronic formation evaluation methods to find water versus oil, oil versus gas. Hydrogeologists can use the same techniques.

- USEPA Superfund Contaminated Site Remediation – 70 sites
- Same techniques
  - Evaluate formation
    - Transmissivity/conductivity
    - Size
    - Mass of contaminant in place
    - Recoverability
  - Decide Clean-up Goals
  - Remediation strategies



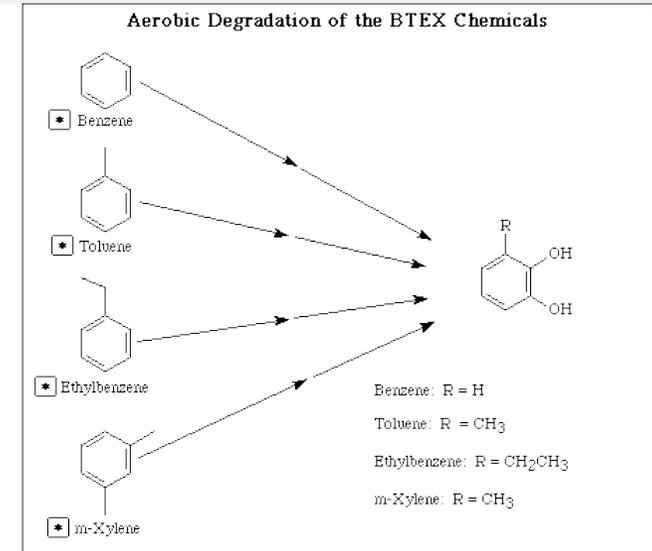


## Contaminated Sites Compounds

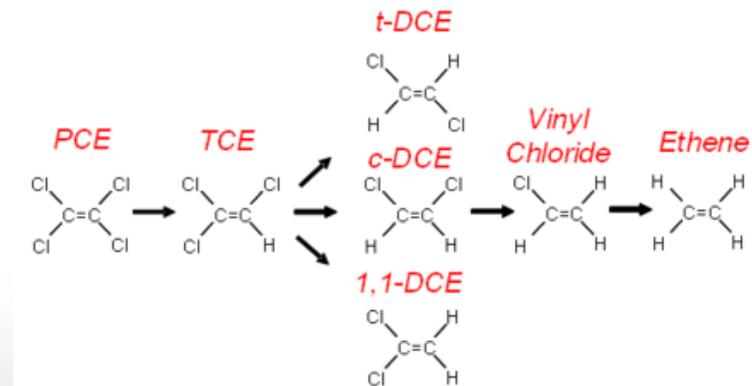
- Specialized in Volatile Organic Contaminated Sites
- Non-chlorinated – BTEX (Benzene, Toluene, Ethyl-benzene, Xylene)
  - Fuels – gasoline, Jet Propulsion Fuel 4
  - MTBE (Methyl *tert*-butyl ether)
- Chlorinated – PCE, TCE, DCE, VC, ethene, ethane

## Destruction\Removal\Containment

- Non-chlorinated
  - Aerobic Bioaugmentation
  - Biosparging
  - Airsparging
  
- Chlorinated
  - Anaerobic Bioaugmentation
  - Soil Vapor Extraction
  - In Situ Oxidation



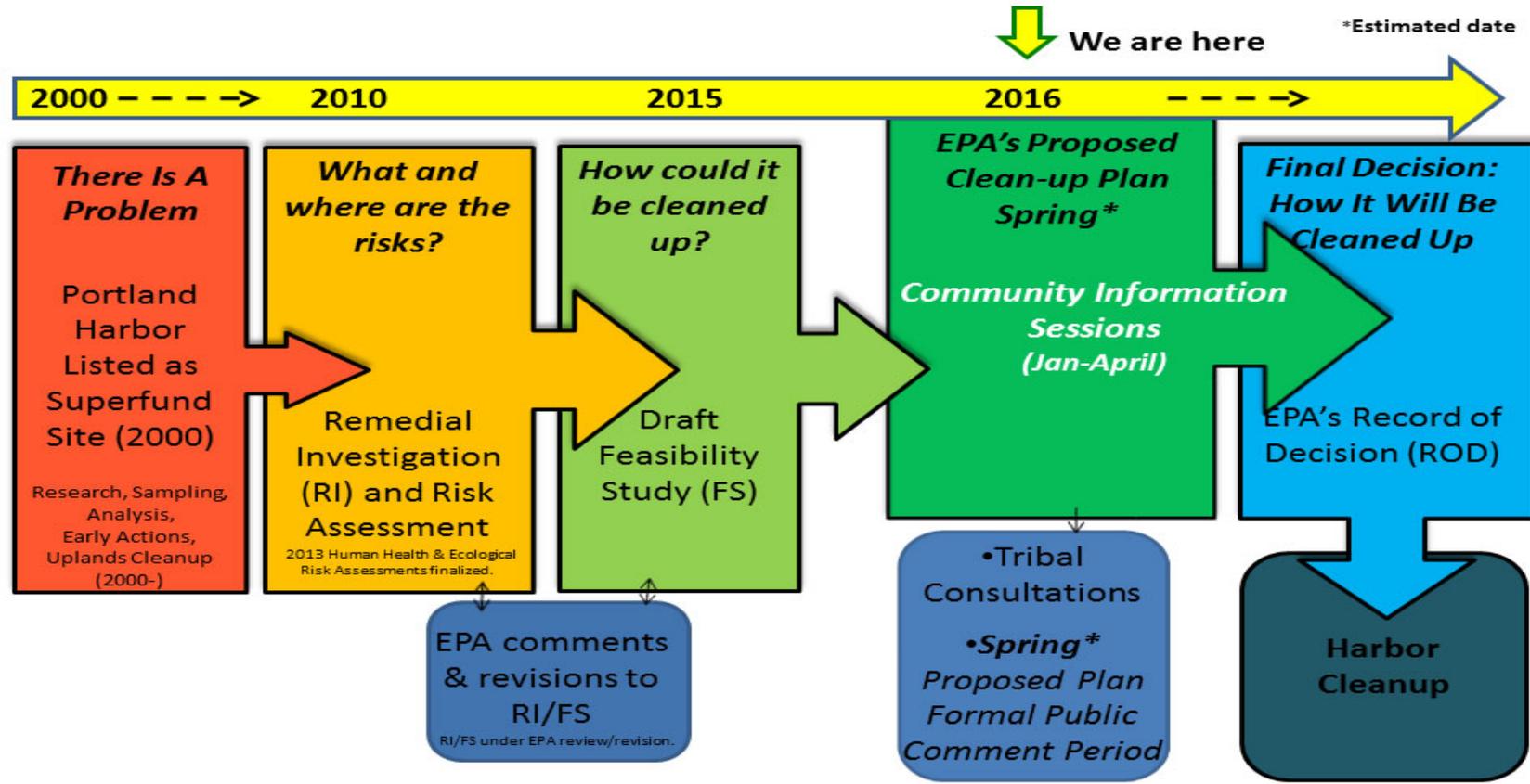
→ Reductive Dechlorination





# Superfund Process

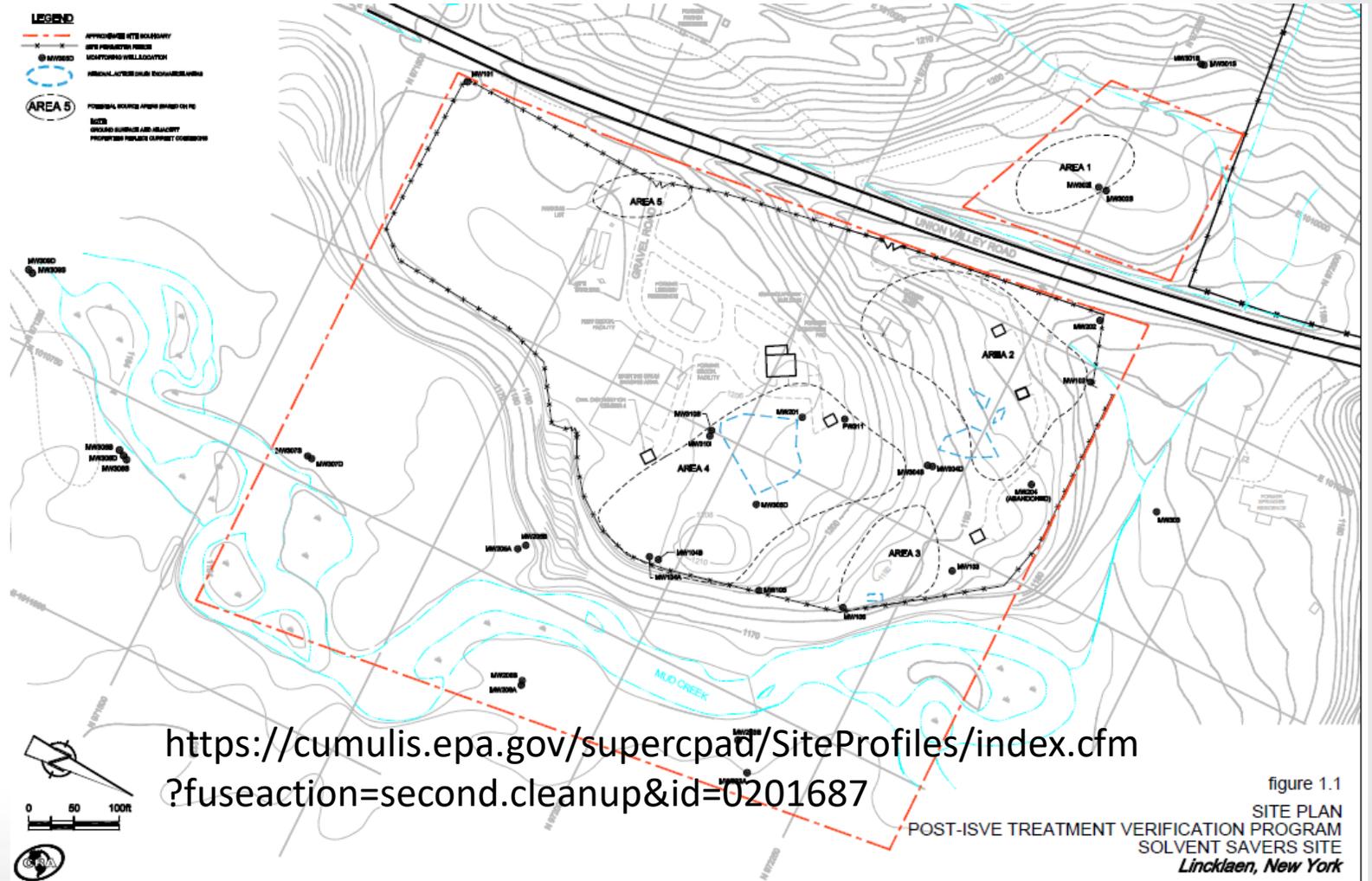
## Key Milestones





# Site Investigation

## New York State Solvent Recycling Facility





# Install Wells

## New York State Solvent Recycling Facility

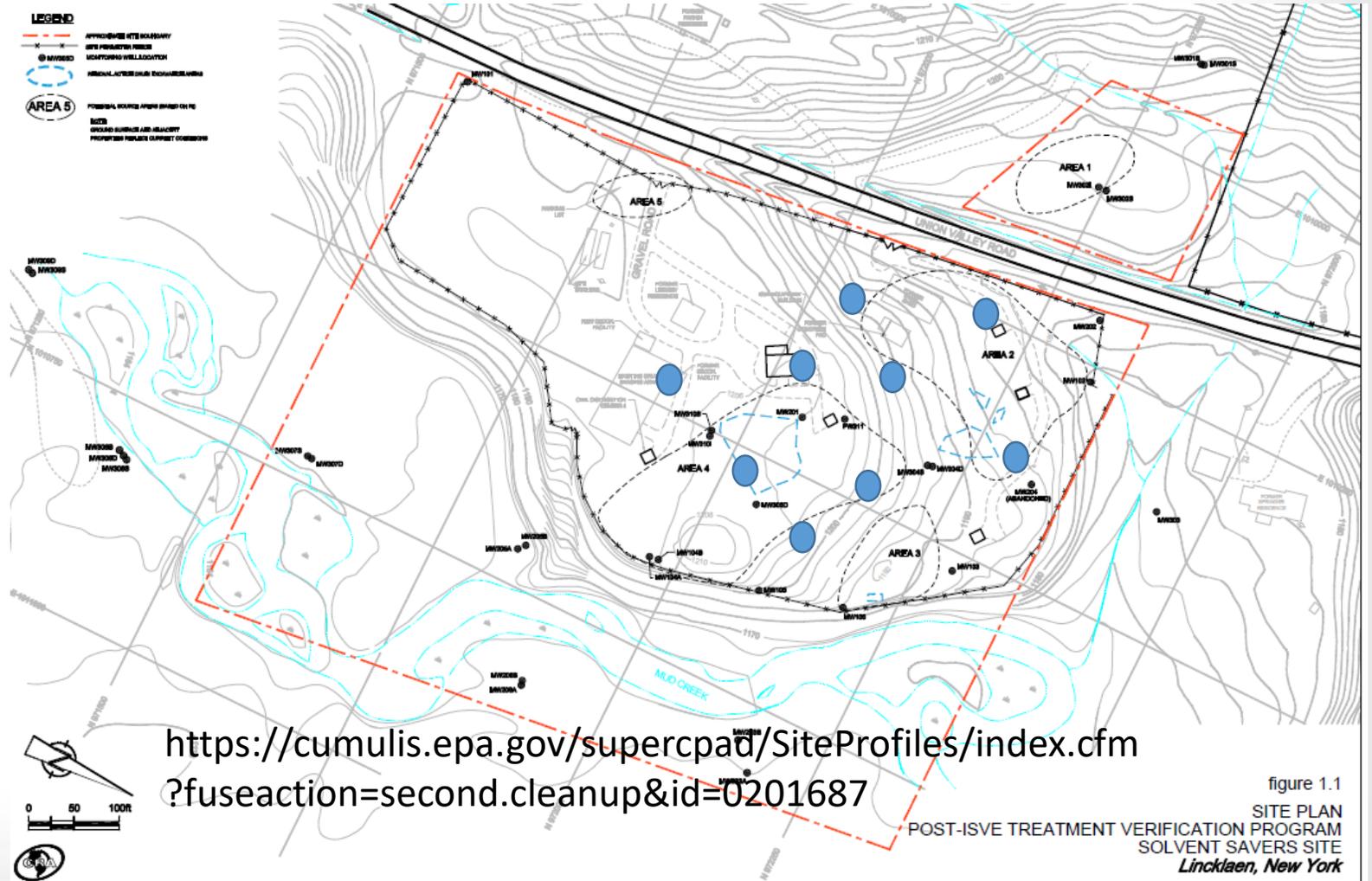


figure 1.1  
SITE PLAN  
POST-ISVE TREATMENT VERIFICATION PROGRAM  
SOLVENT SAVERS SITE  
Lincolden, New York



# Characterize Geology

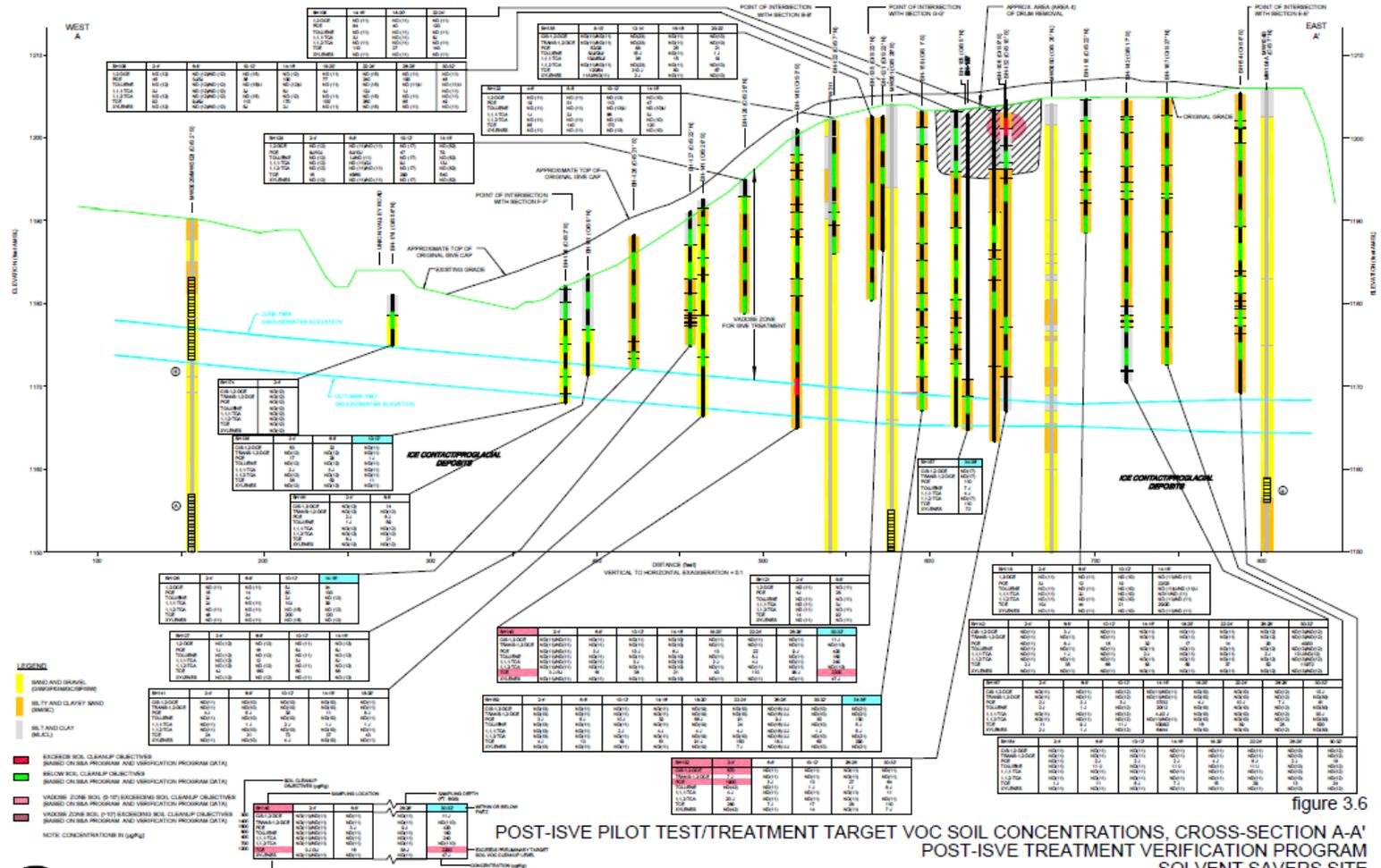
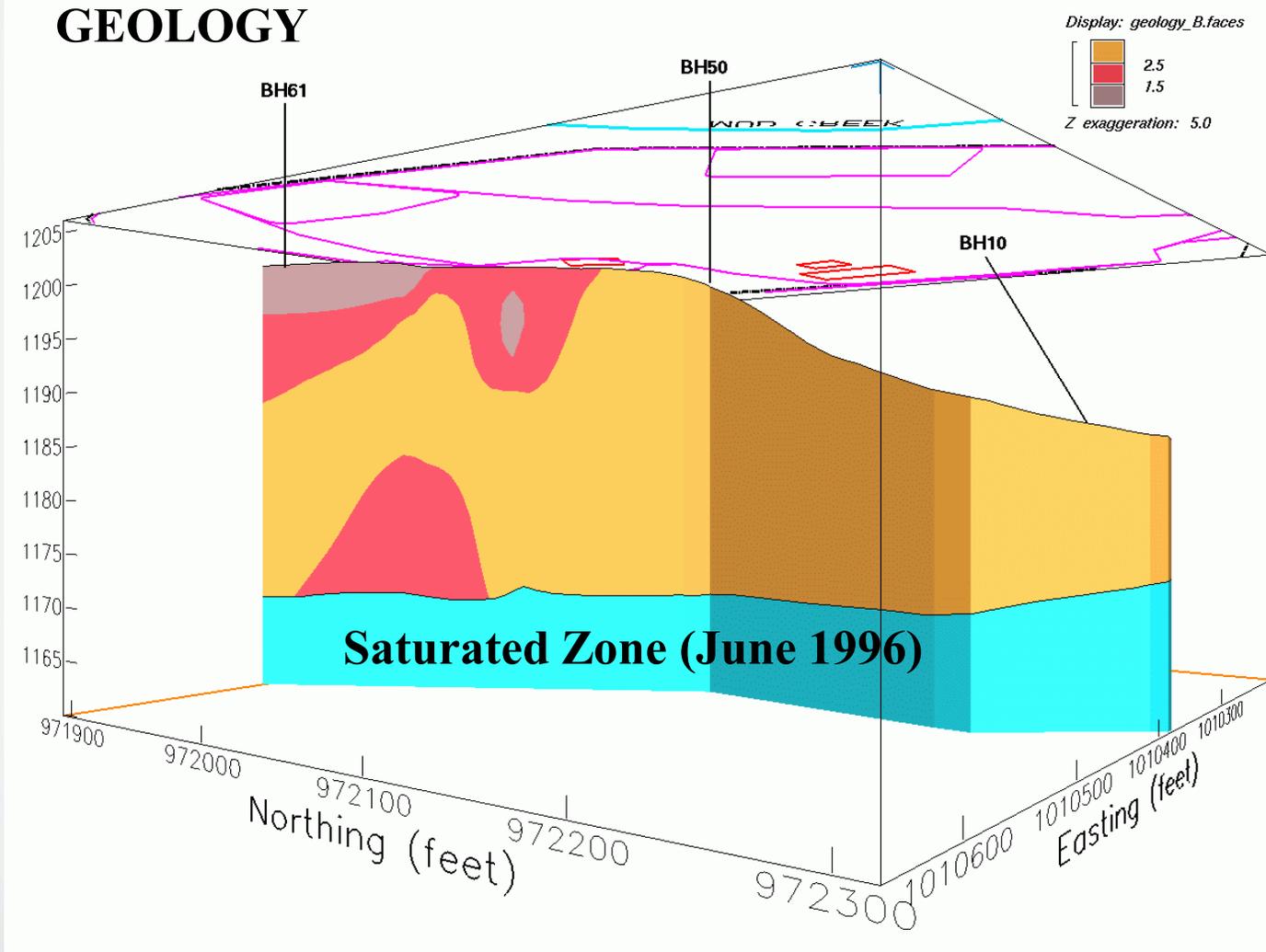


figure 3.6



# Calculate Vadose Zone Characteristics

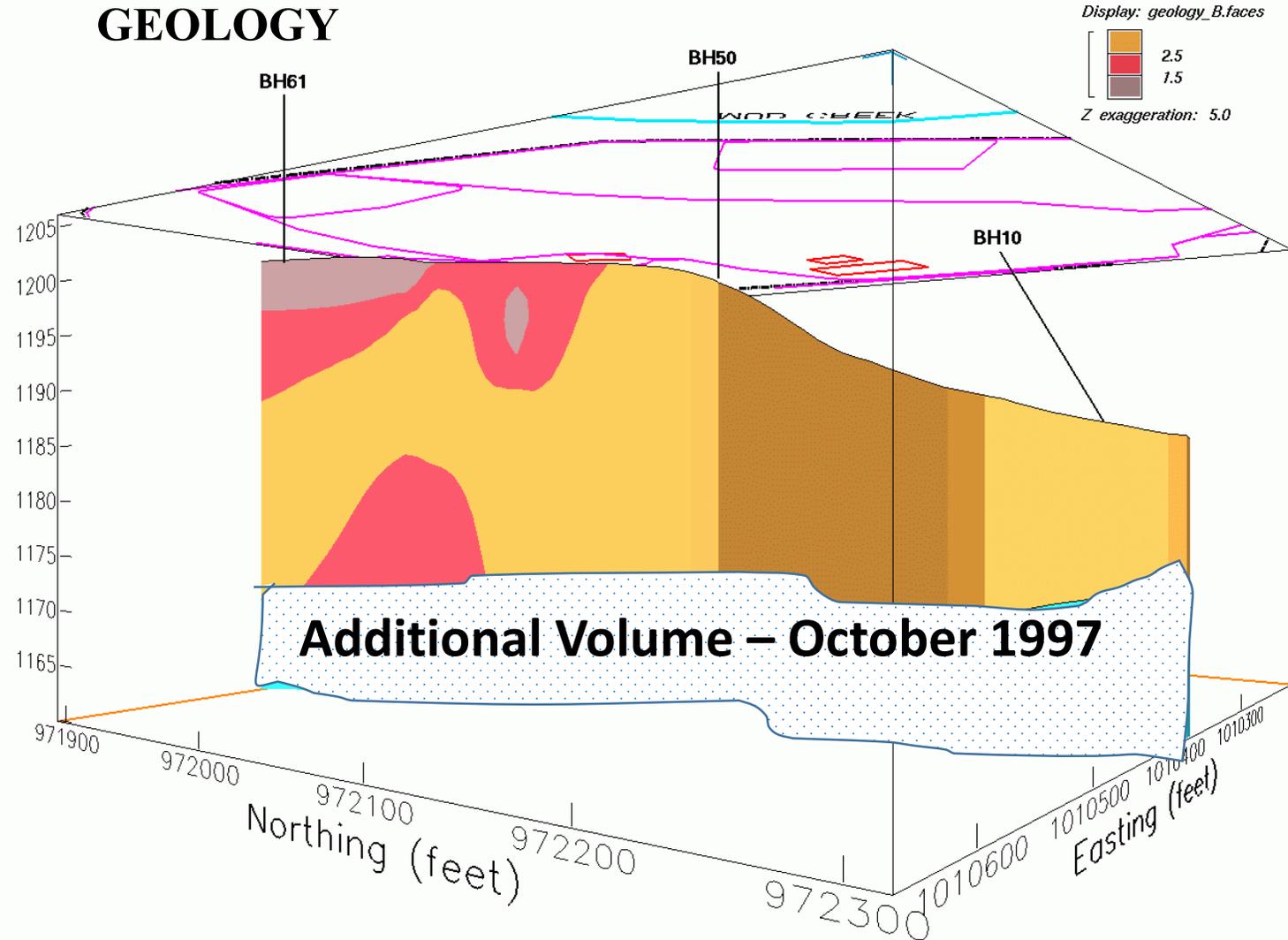


## Calculate Vadose Zone Volume

- Conductivity
- Extent
- Porosity
- Depth to Water



# Calculate Vadose Zone Characteristics



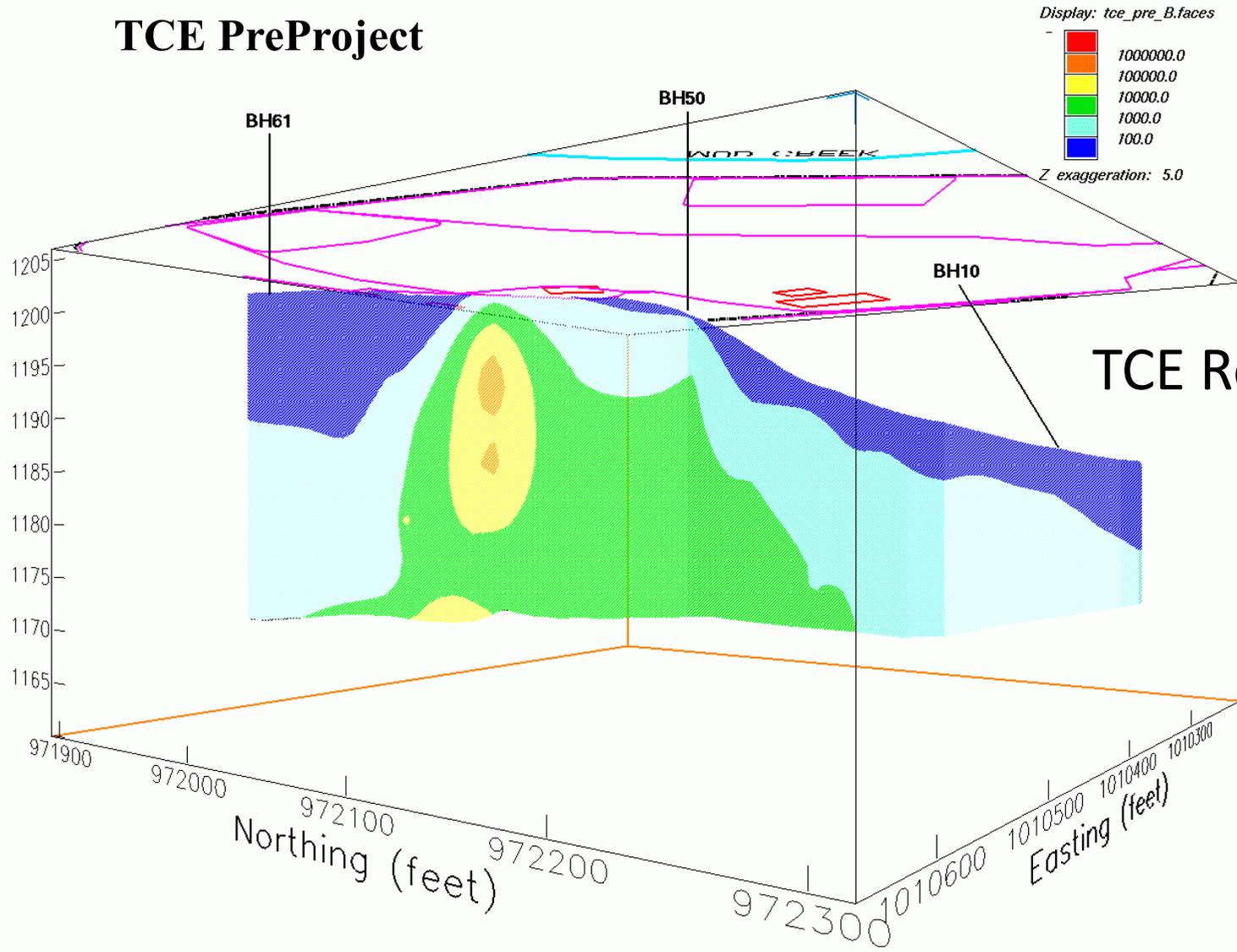
Which can change with time

- Water Level dropped



# Calculated Contaminant Mass in Place

## TCE PreProject



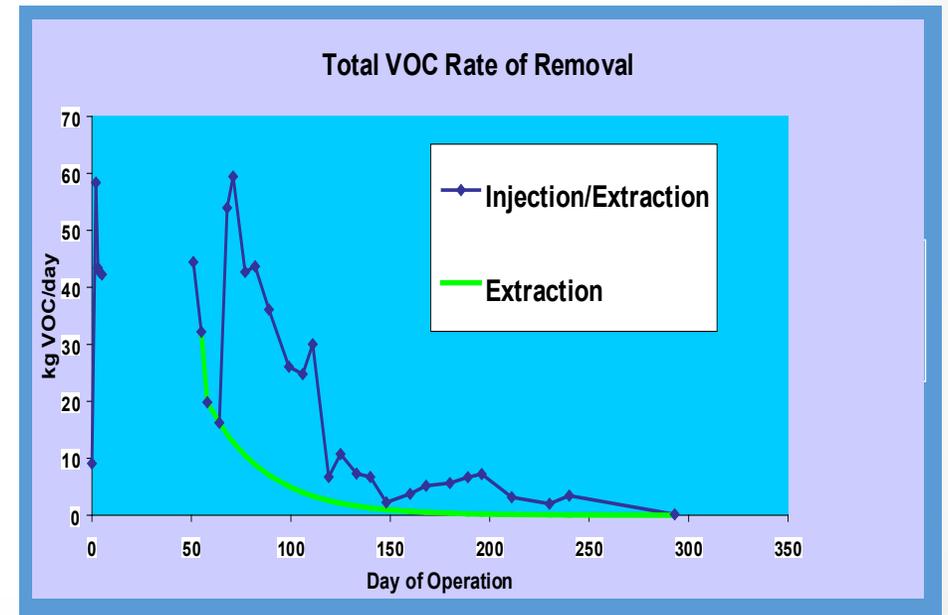
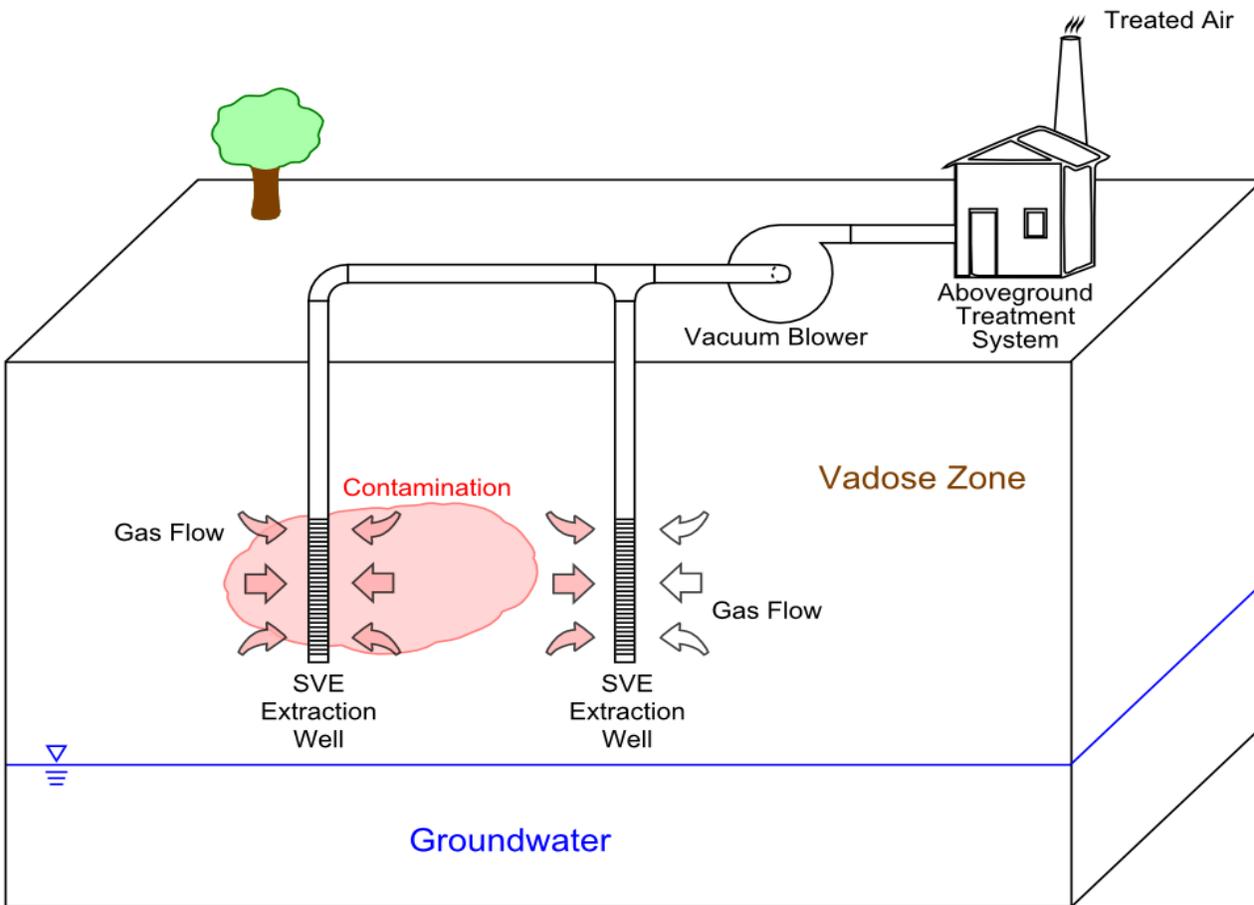
TCE Representative Concentrations

X Subvolumes

= TCE Initial Mass in Place

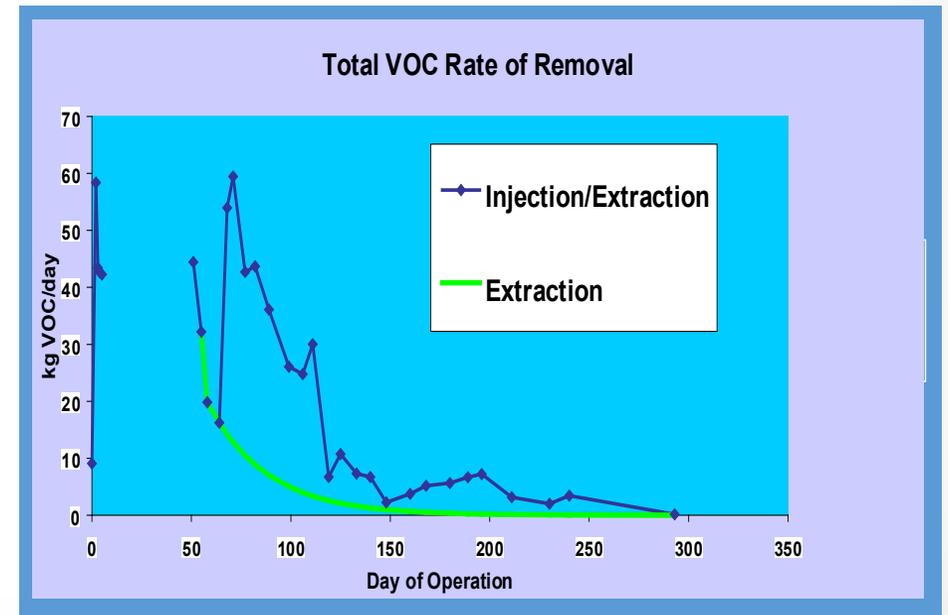
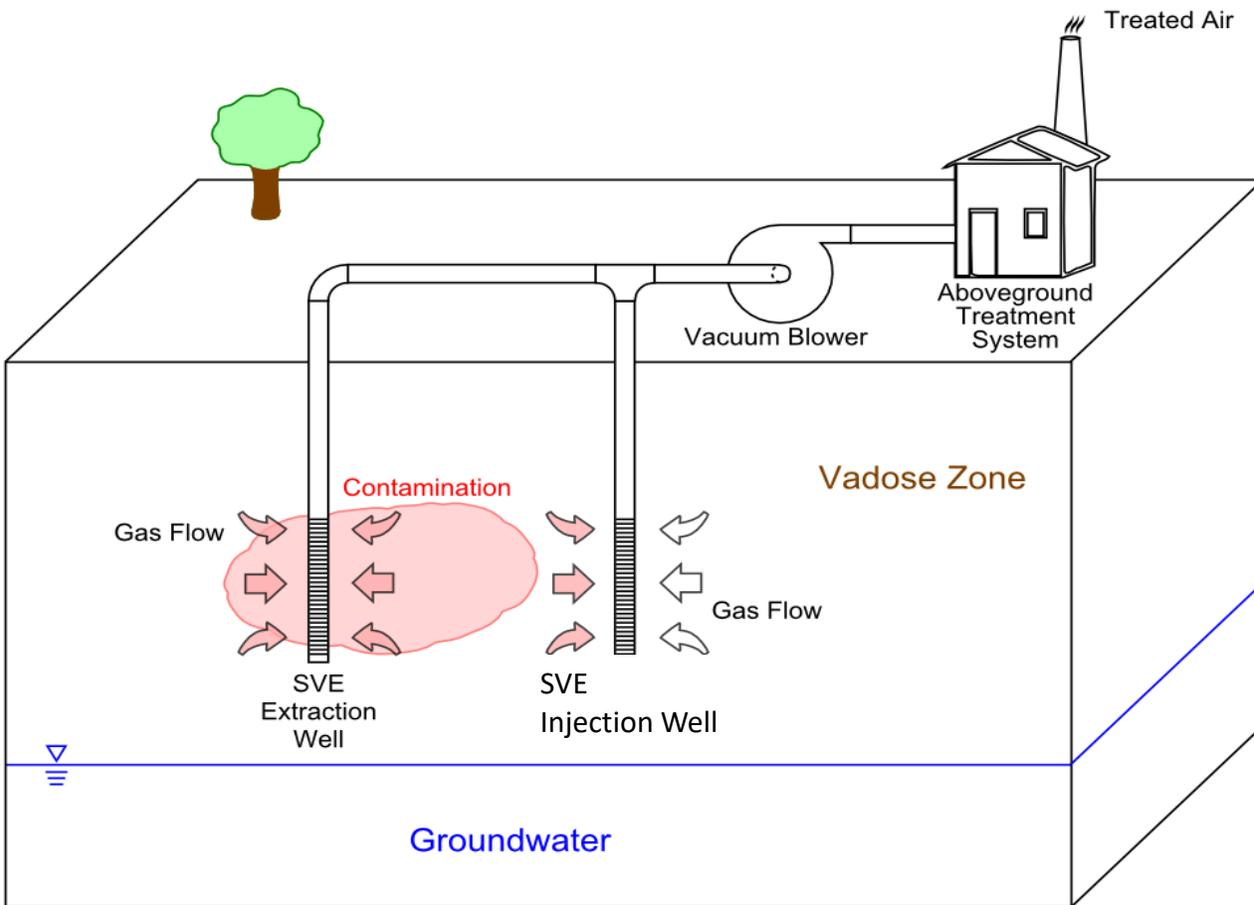
# VOC Remediation Soil Vapor Extraction

Removes VOCs before they get to the groundwater



# VOC Remediation Soil Vapor Extraction

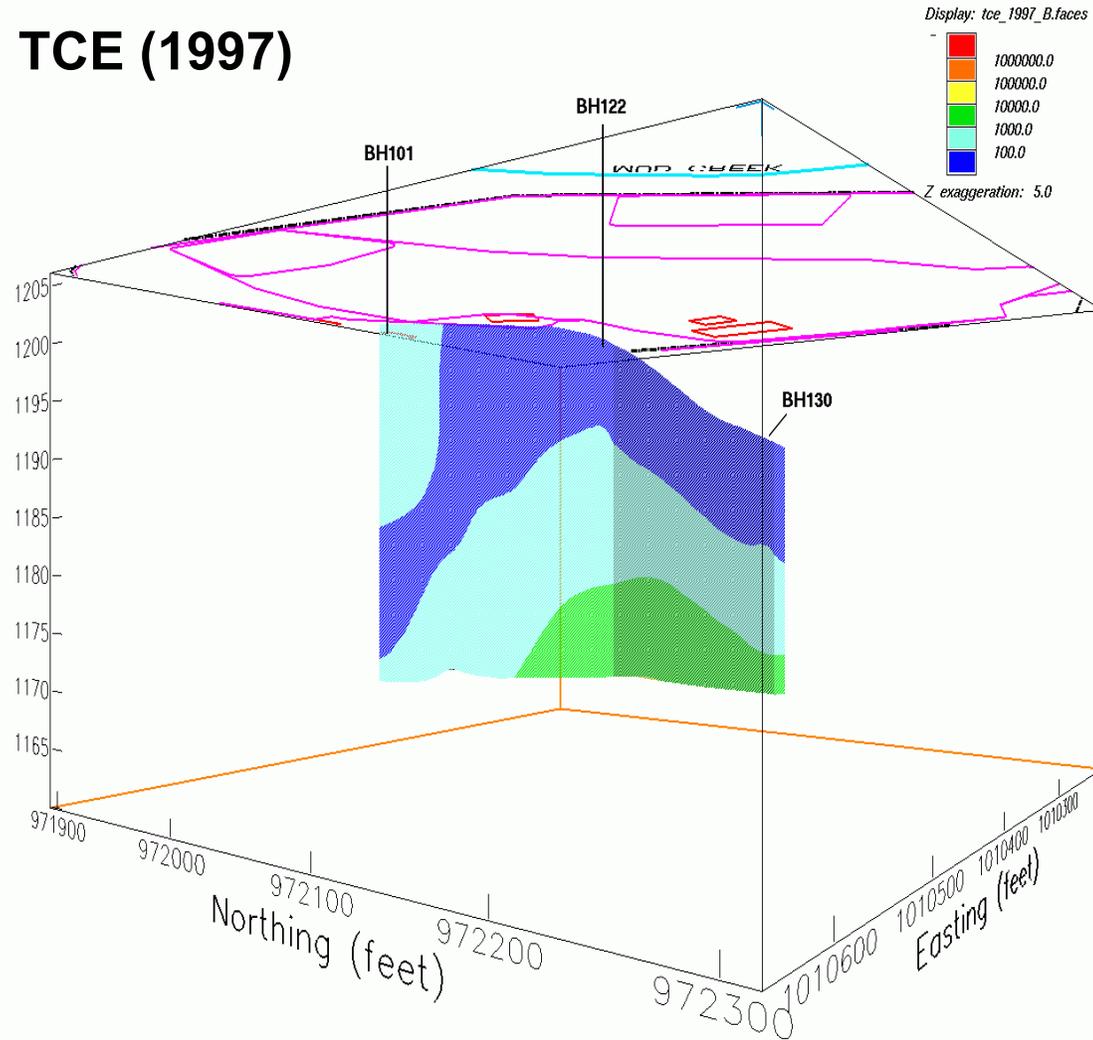
Removes VOCs before they get to the groundwater



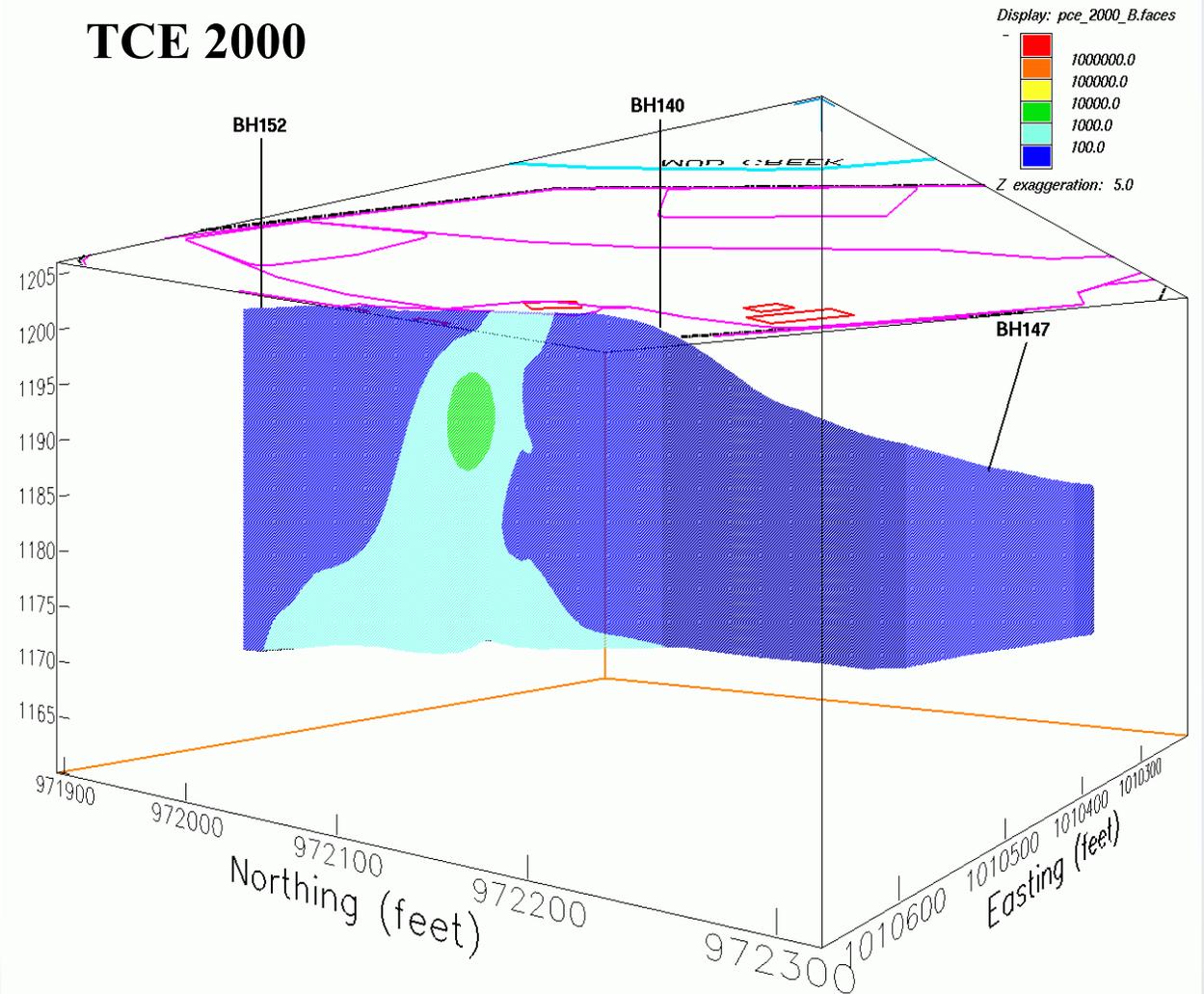


# VOC Contaminant Removal with Time

## TCE (1997)



## TCE 2000

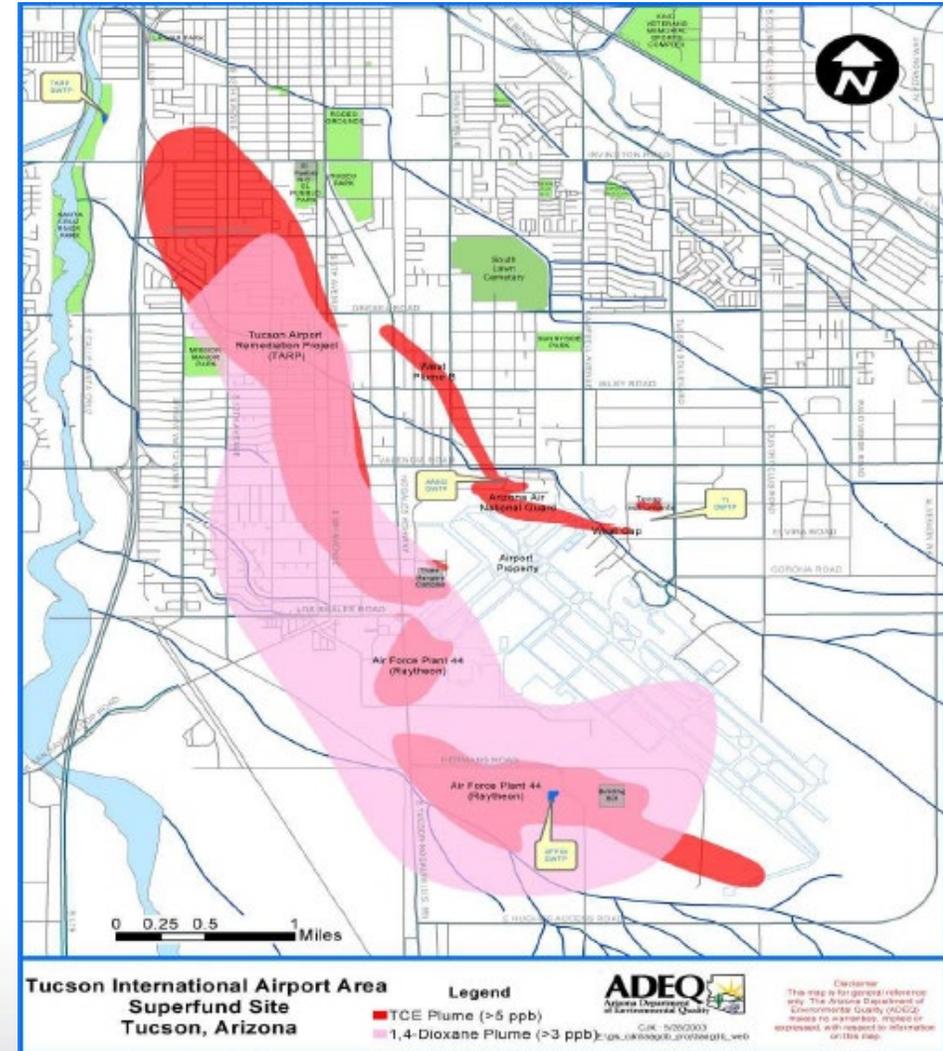


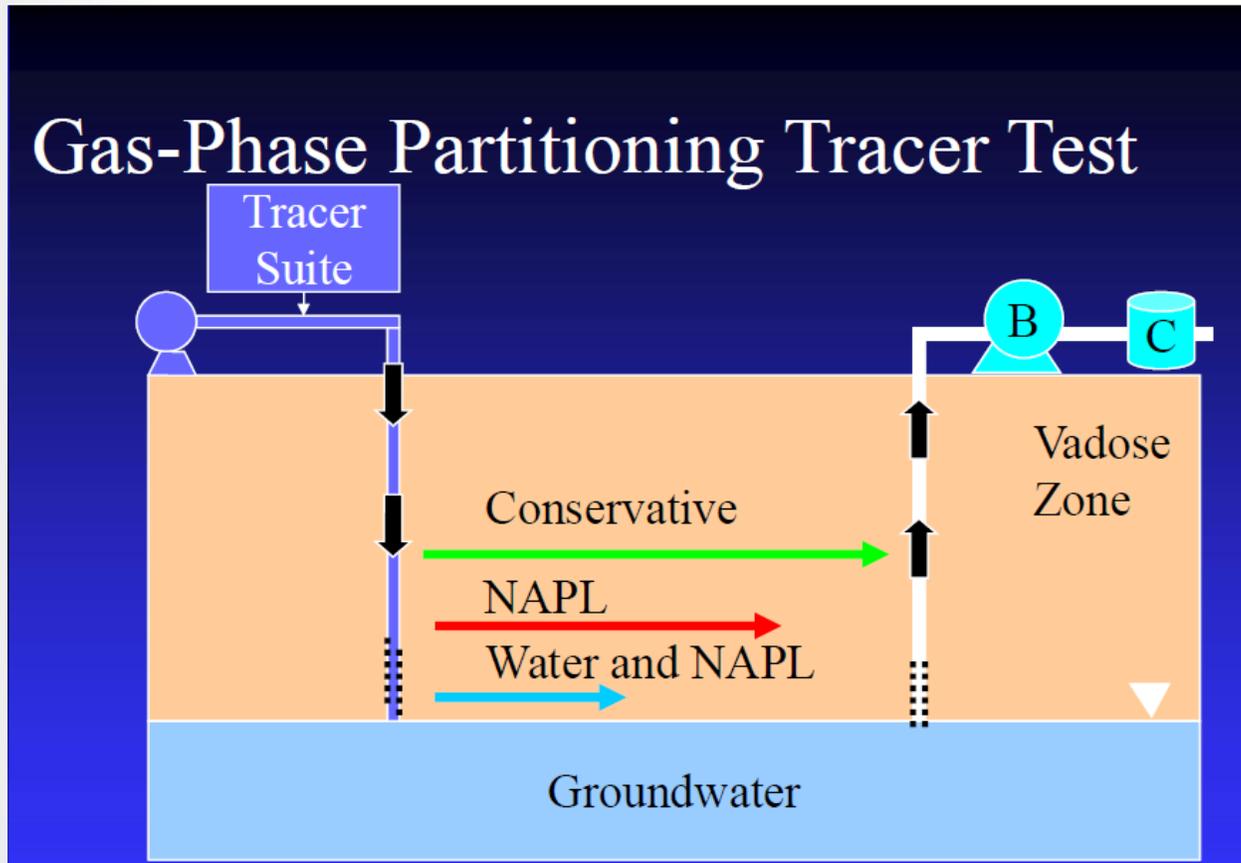


# But when do you stop remediating?

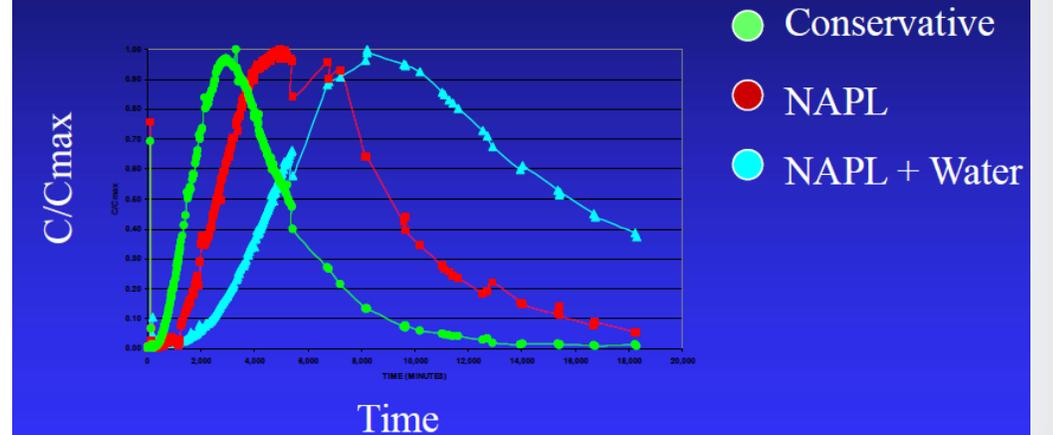
Vadose Zone Clean-up goals depend on infiltrating water's impact on underlying groundwater

Another project





## Tracer Breakthrough Curve

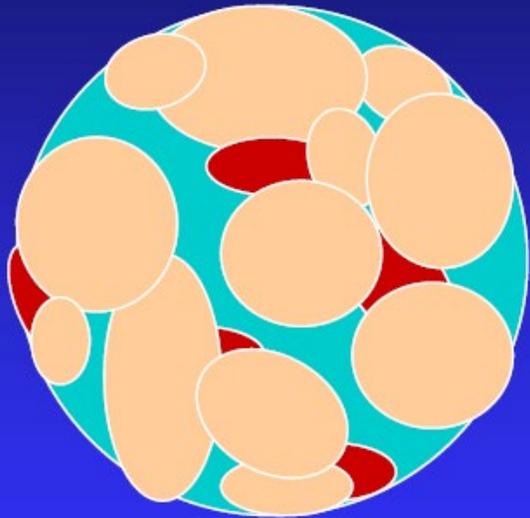


Simon, M. A. and Mark L. Brusseau (2007). "Analysis of a Gas-Phase Partitioning Tracer Test Conducted in an Unsaturated Fractured Clay Formation" *Journal of Contaminant Hydrology* 90(2007) 146-158.

# Partitioning Tracer

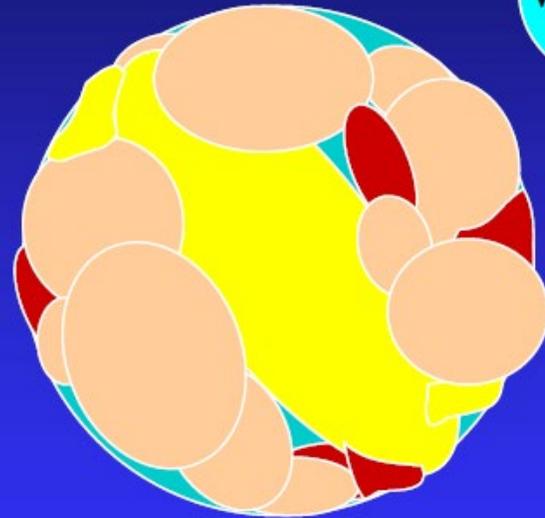
## Pore Scale

Saturated



$$S_w + S_n = 1$$

Unsaturated



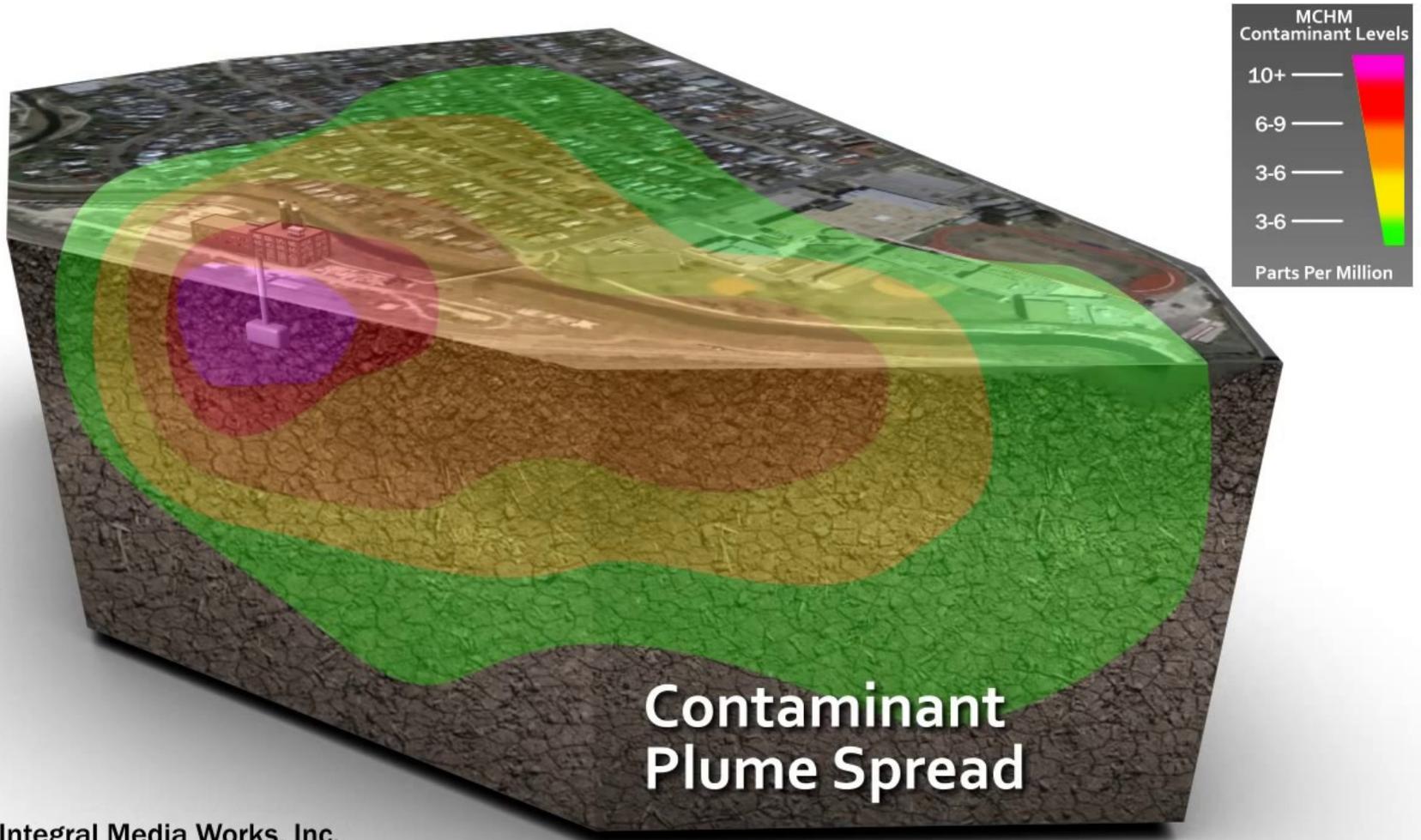
$$S_g + S_w + S_n = 1$$

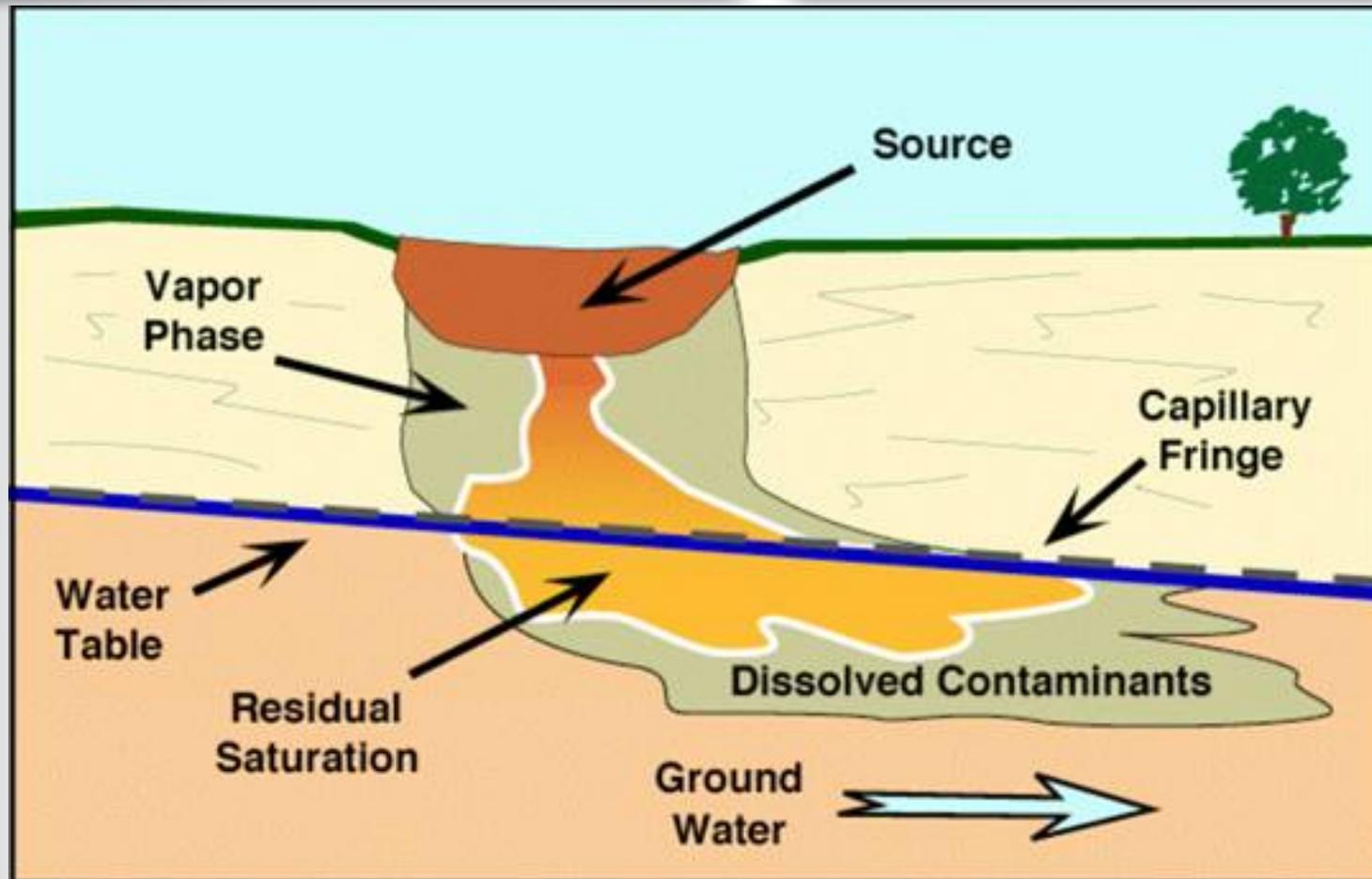


Assessing remaining  
contaminant mass in  
the vadose zone

**Simon, M. A.** and Mark L. Brusseau, (2006)  
"Method for Measuring Air-Immiscible Liquid  
Partition Coefficients" *Journal of Environmental  
Engineering –ASCE* **132**:140-144.

# Contaminant Groundwater Movement





## Infiltrating Water Hydrology

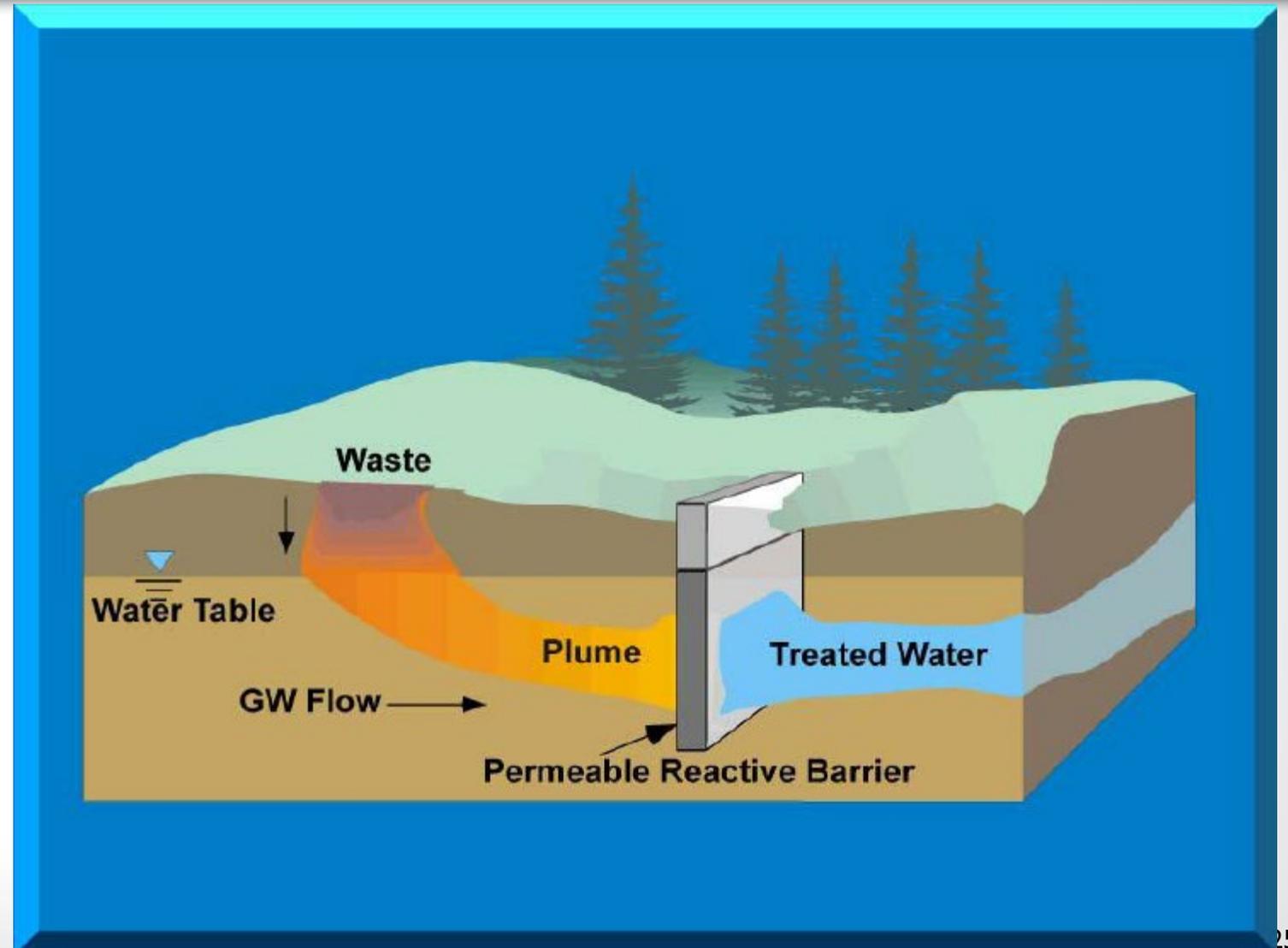
- Richards Equation
- Green and Ampt
- Horton
- Others

## Water carries contaminants

- Dissolved/Advection
- Diffusion

## Reactive Barriers

[https://www.google.com/search?q=reactive+barrier+figures&tbm=isch&source=iu&ictx=1&fir=tC\\_kNR2uLBtgrM%253A%252ChpMoJRsvjMKuM%252C\\_&usg=\\_\\_Bhyj1owDbOWQG7ZkOgyZBFoYgg0%3D&sa=X&ved=0ahUKEwjeiKqNw-HXAhVPct8KHW8QAwcQ9QEITzAH#imgrc=tC\\_kNR2uLBtgrM](https://www.google.com/search?q=reactive+barrier+figures&tbm=isch&source=iu&ictx=1&fir=tC_kNR2uLBtgrM%253A%252ChpMoJRsvjMKuM%252C_&usg=__Bhyj1owDbOWQG7ZkOgyZBFoYgg0%3D&sa=X&ved=0ahUKEwjeiKqNw-HXAhVPct8KHW8QAwcQ9QEITzAH#imgrc=tC_kNR2uLBtgrM)



# In Situ Destruction

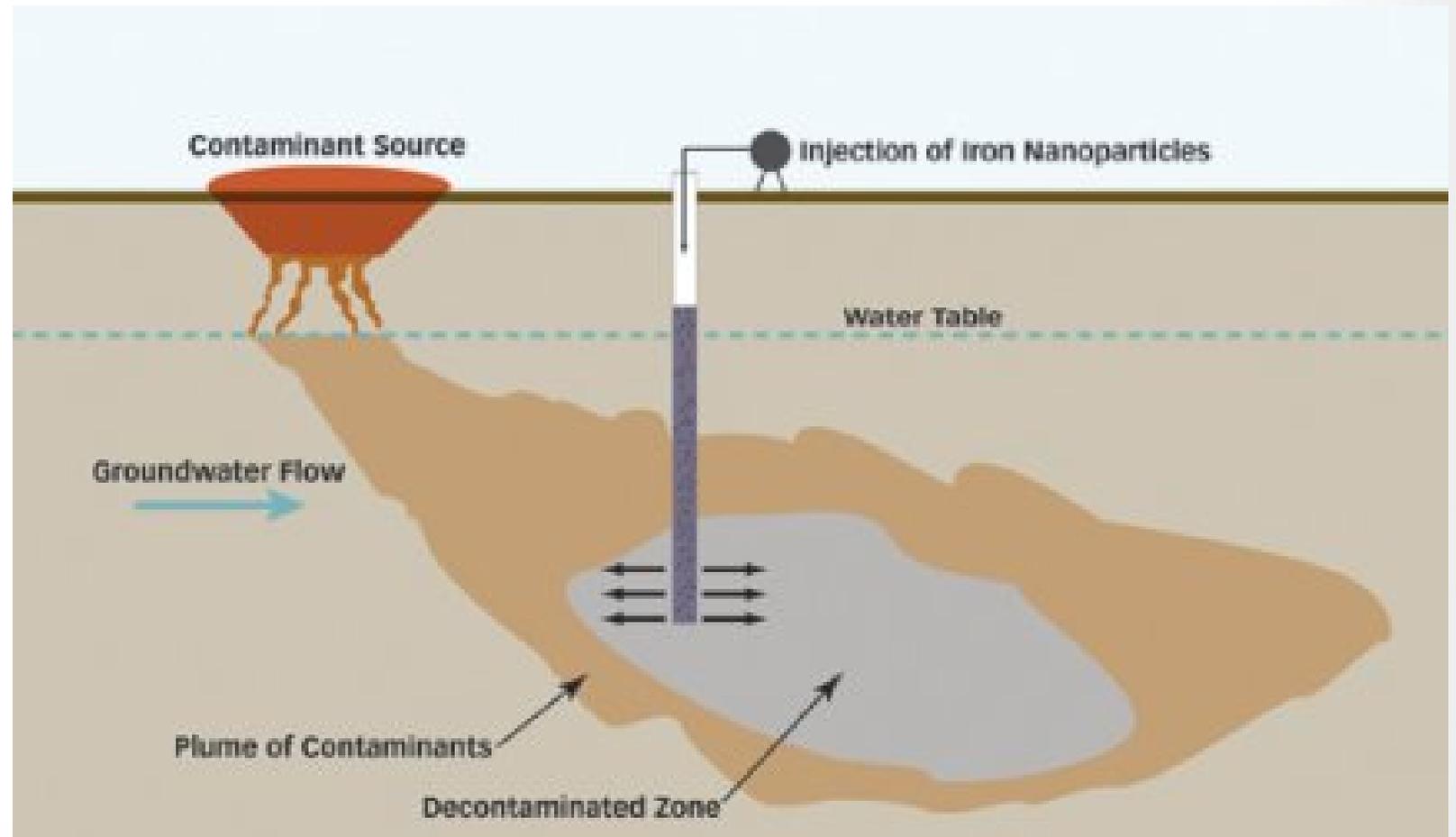
Inject

Bioremediation

- Oxygen
- Nutrients

Chemical Oxidation

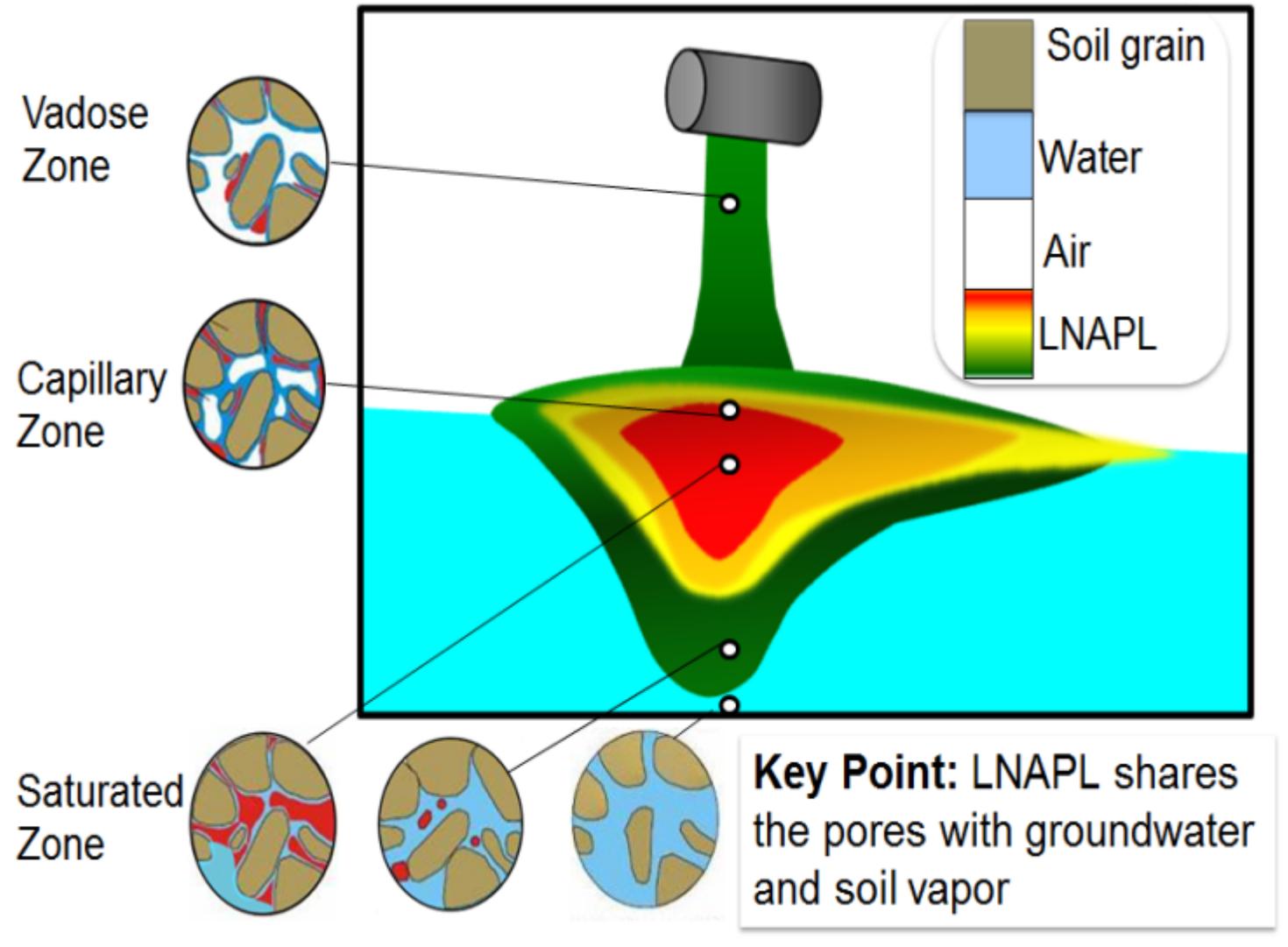
- Zero Valent Iron
- Permanganate
- Peroxide



# LNAPLs in the subsurface

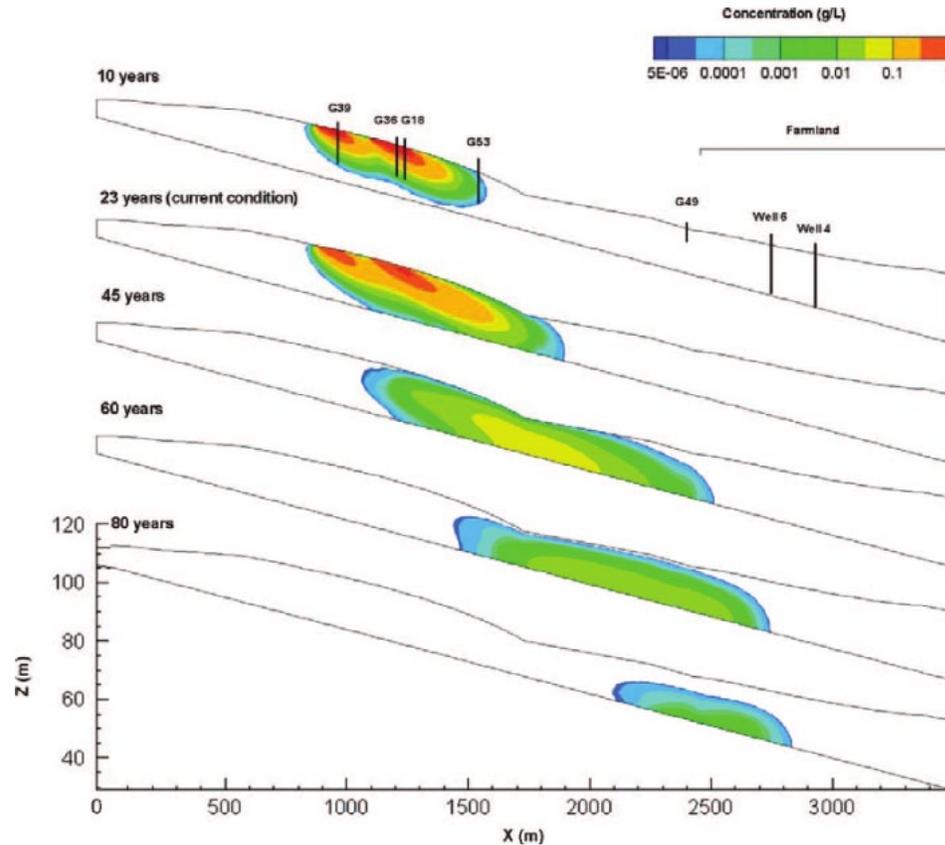
LNAPL – Light Non-Aqueous Phase Liquid

<https://www.google.com/search?q=lnapl+figures&tbm=isch&tbo=u&source=univ&sa=X&ved=0ahUKEwjK68CiyuHXAhVMMd8KHSFvBT0Q7AkIVw&biw=1280&bih=918#imgdii=p6xYhUOqol4dDM:&imgsrc=PBOhil7Kri5sfM:>





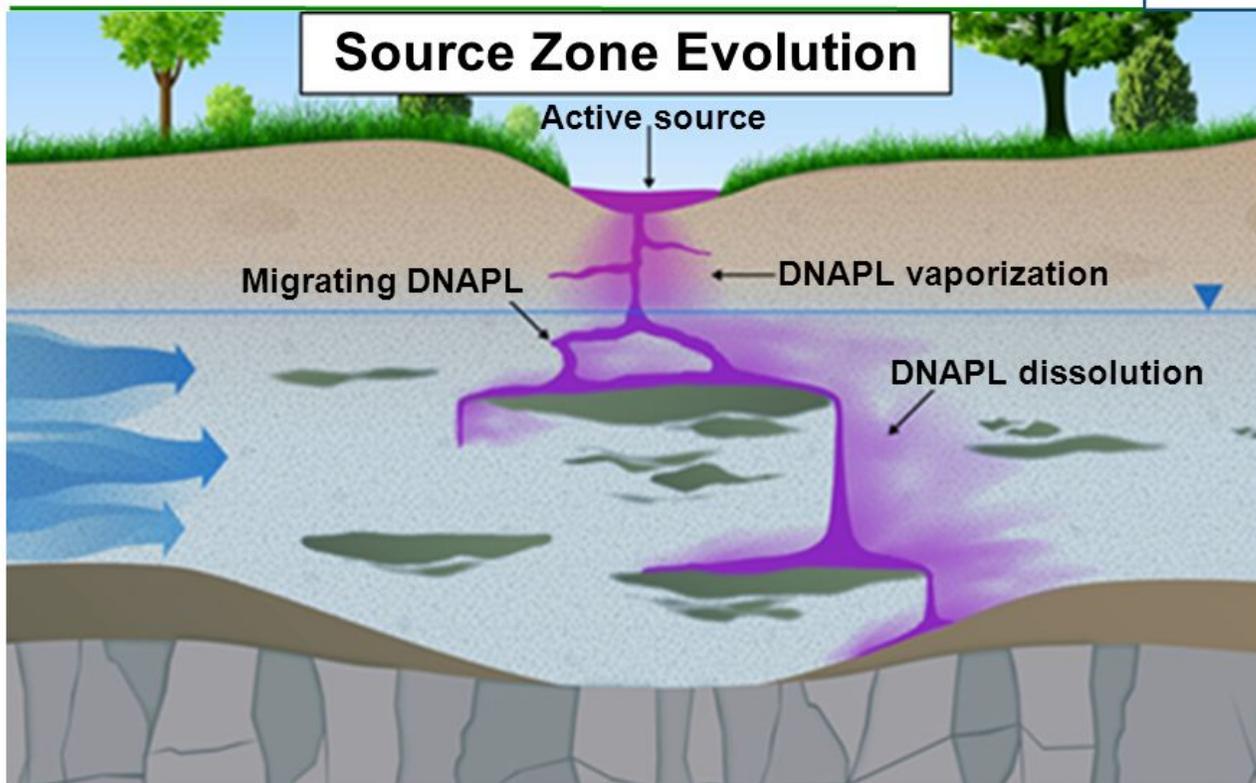
# LNAPL in the Subsurface with Time



<https://www.google.com/search?q=lnapl+figures&tbm=isch&tbo=u&source=univ&sa=X&ved=0ahUKEwjK68CiyuHXAhVMMd8KHSFvBT0Q7AkIVw&biw=1280&bih=918#imgsrc=Q9S7pGqFlucFEM:>

32

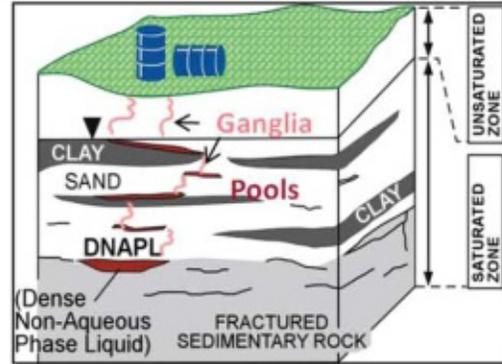
## DNAPL Life Cycle – Classical Model



Kueper et al., 2013

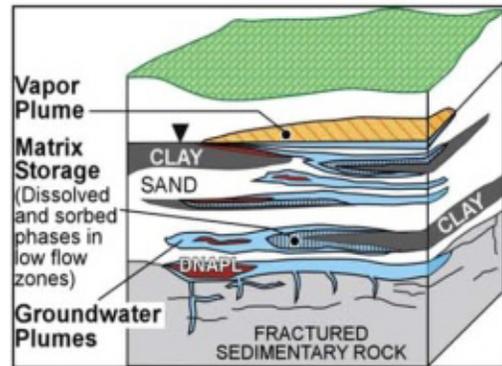
DNAPL – Dense  
Non-Aqueous  
Phase Liquid

# DNAPLS in the Subsurface with time



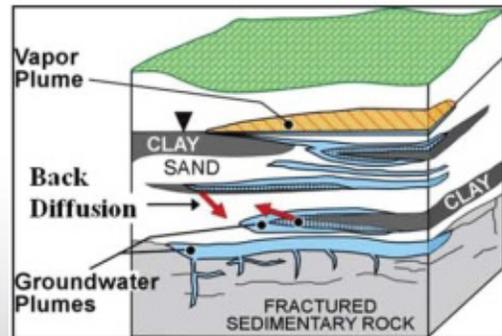
## EARLY SOURCES

Relatively low Pool Fraction  
 Ganglia prevalent, pools at interfaces  
 Nascent vapor / groundwater plumes  
 Little matrix diffusion  
 VOCs in DNAPL and sorbed phases  
 VOCs primarily in transmissive zones



## MATURE SOURCES

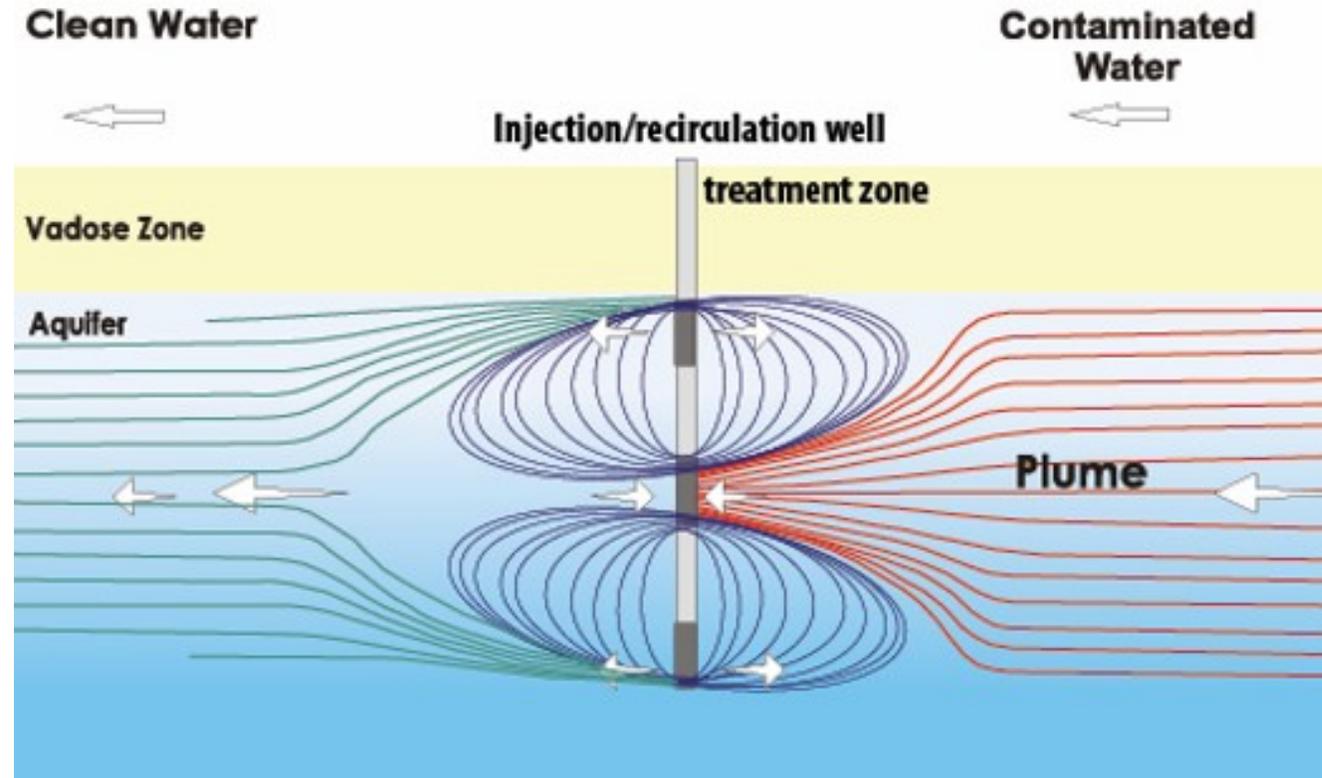
Pool Fraction increases  
 Ganglia preferentially depleted  
 Pools partly depleted, leaving ganglia  
 Mass discharge plateaus  
 Matrix diffusion in source and plume



## AGED/TREATED SOURCES

Little to no DNAPL remains  
 Mass discharge greatly reduced  
 Low VOCs in transmissive zones  
 Back diffusion / desorption continue

# Injection\Extraction



# GW Pump and Treat

Key:

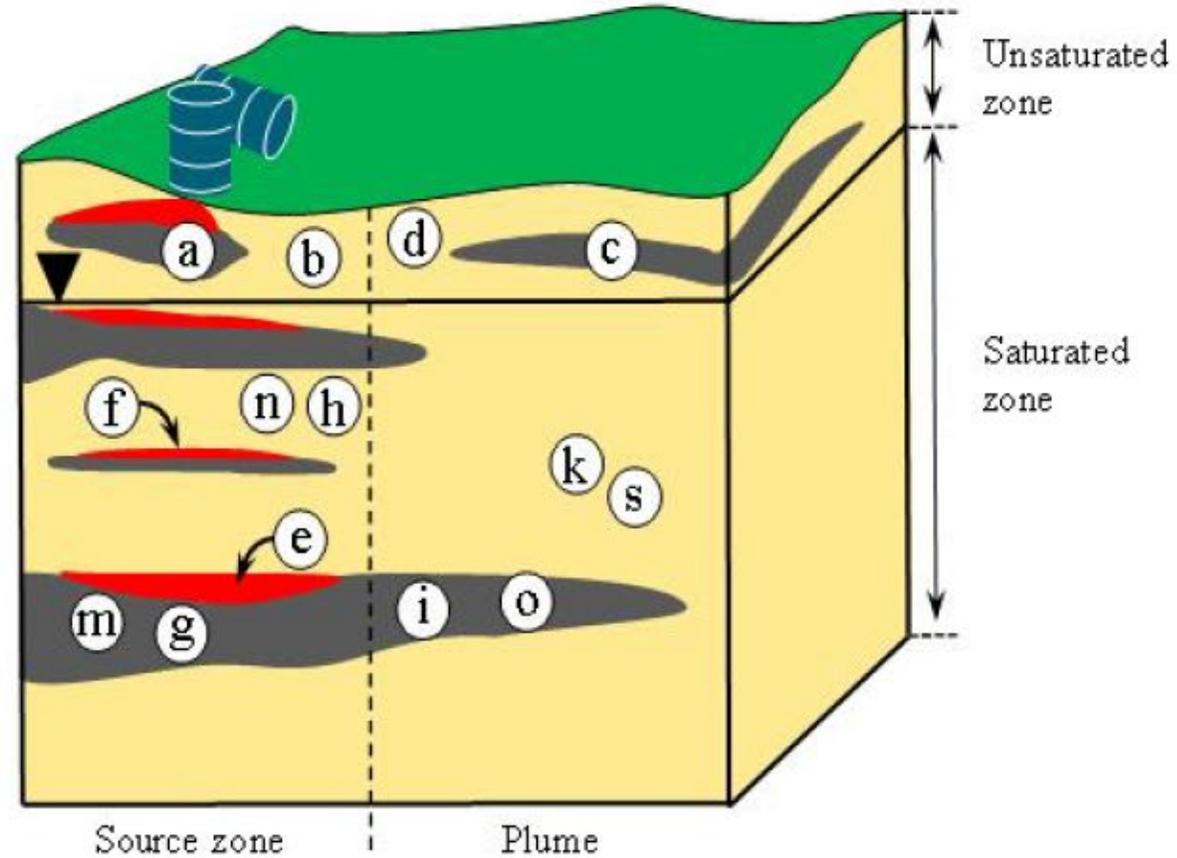
sand

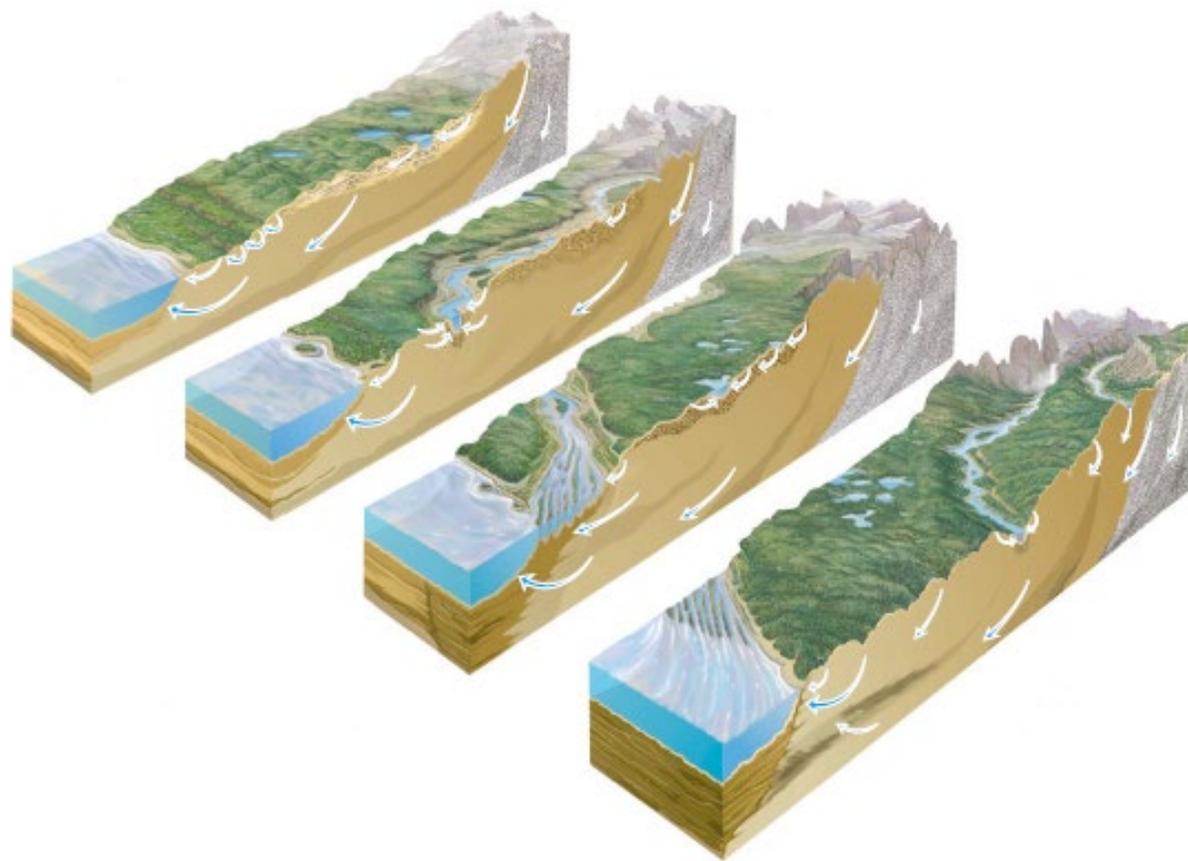


clay



DNAPL





- A knowledge of the subsurface is important to many fields
- The success of removal of fluids can be greatly impacted by subsurface characteristics
- The subsurface is
  - Complex
  - Heterogenous
  - Hidden



# Questions



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