# RCRA Corrective Action Training Program: Getting to YES!

## *Strategies for Meeting the 2020 Vision*

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# Module 8

# Remediation Technologies

# Module Overview

- Common remediation technologies
- Remediation considerations for non-aqueous phase liquids
- Green remediation

# Technology Spectrum

| Emerging Technologies | Innovative Technologies | Established Technologies | Presumptive Remedies |
|---|---|---|---|
| *Less Proven* | ← | → | *More Proven* |

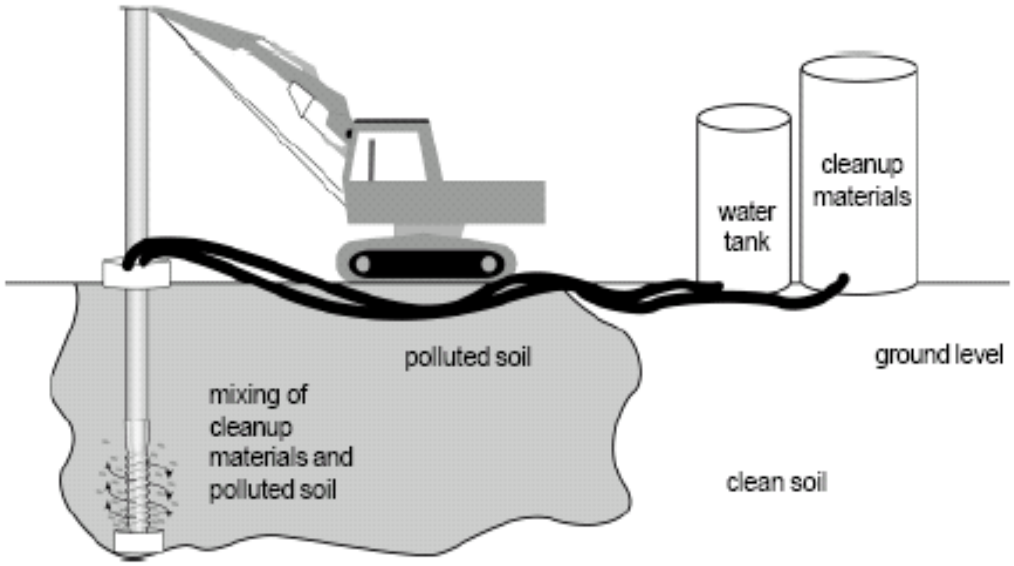
# Common Soil Remediation Technologies

- Excavation and e*x situ tr*eatment/ disposal
- Solidification/stabilization
- Soil vapor extraction

# Soil Excavation

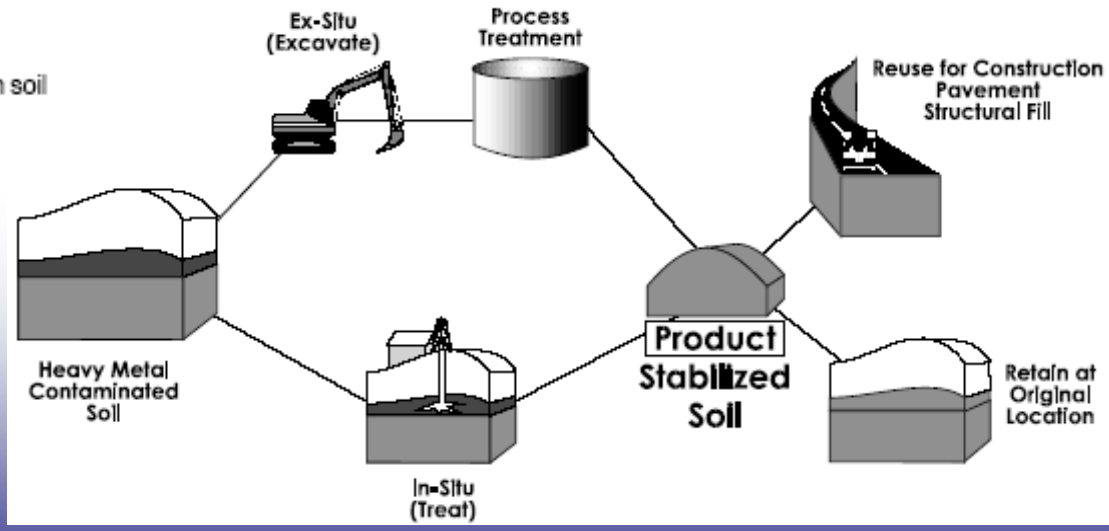
- Removes contaminated soil and commingled materials (waste, sludge, and debris) for management.
- Excavated soil can be treated by various *ex situ* technologies.
- On site placement of treated soil may be an option.

# Solidification/Stabilization

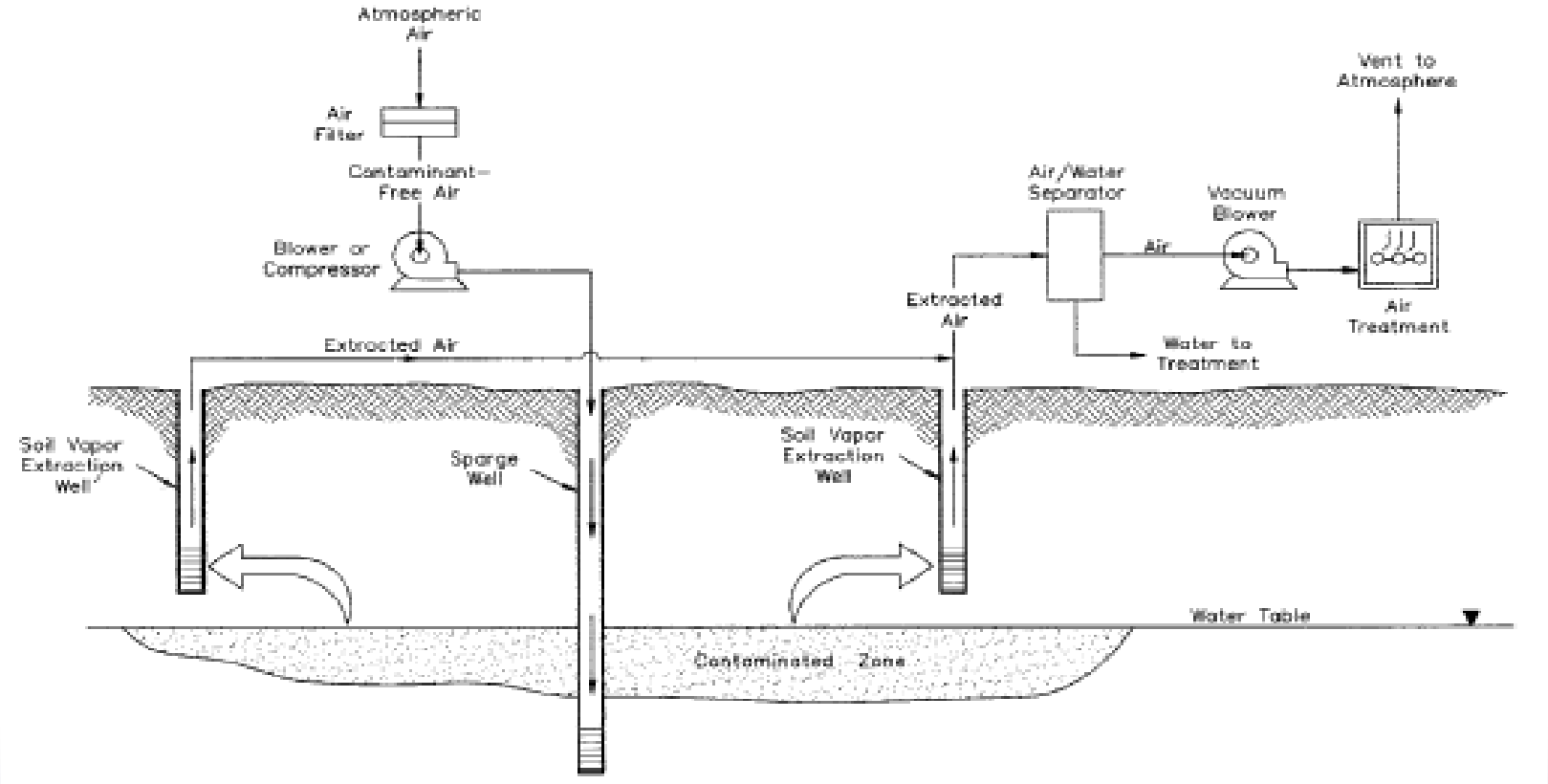



Typical Auger/Caisson and Reagent/Injector Head Systems

In situ/ Ex situ heavy metal stabilization process



# Soil Vapor Extraction




**EPA. 1997. Analysis of Selected Enhancements for Soil Vapor Extraction. EPA-552-R-97-007. September.**

# Remediation Approaches to Contaminated Sediments

- Dredging and excavation
- In-situ capping
- Monitored Natural Recovery (MNR)
- In-situ treatment
- Institutional controls (e.g., fish advisories or fishing bans)

http://www.epa.gov/superfund/health/conmedia/sediment/ssrc.htm

# Common Groundwater Remediation Technologies

*Ex-Situ* Technologies/Approaches

- Pump & Treat
- Multi-Phase Extraction
- Air Stripping
- Carbon Adsorption

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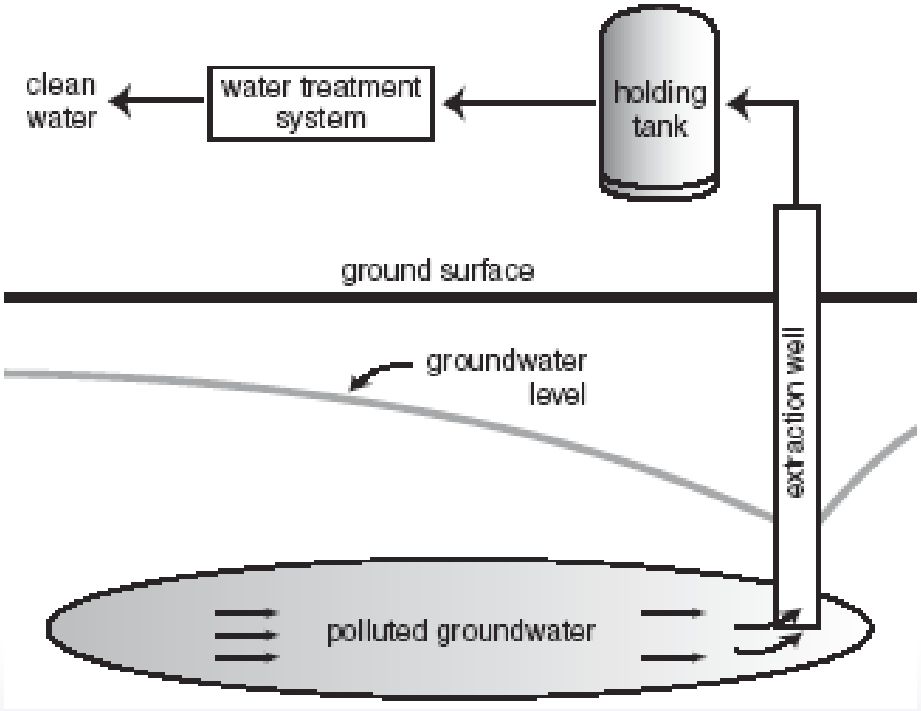
# Common Groundwater Remediation Technologies

*In-Situ* Technologies/Approaches

- Air Sparging
- Bioremediation
- Chemical Oxidation
- Permeable Reactive Barrier
- Monitored Natural Attenuation

# Groundwater Extraction (Pump and Treat)

- Can be effective in controlling contaminant migration and reducing contaminant mass.
- Recovery wells may be drilled vertically or horizontally or trenched (interceptor trench).



# Vertical Recovery Wells

# Horizontal Recovery Wells

# Plume Control Design

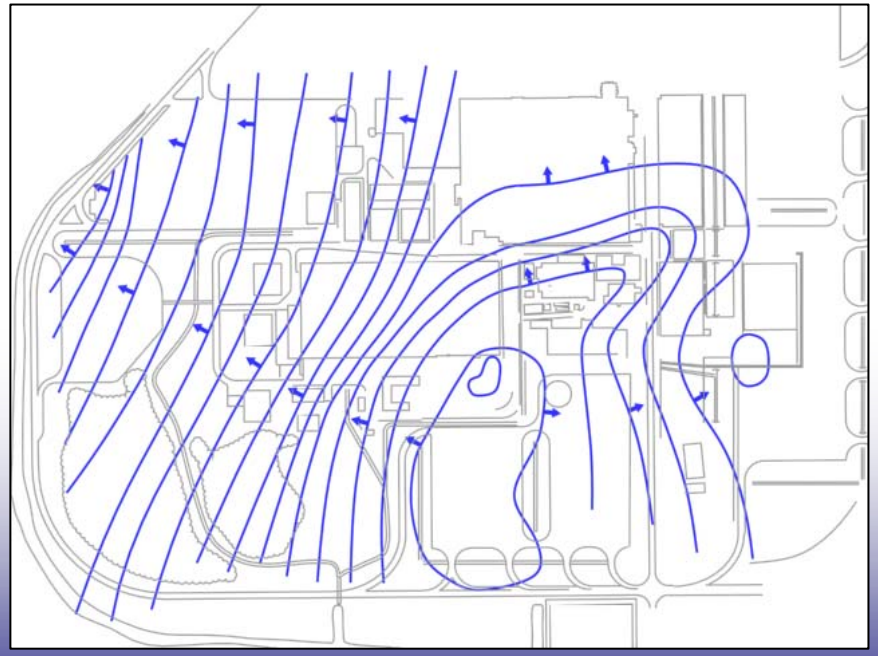
**Legend**

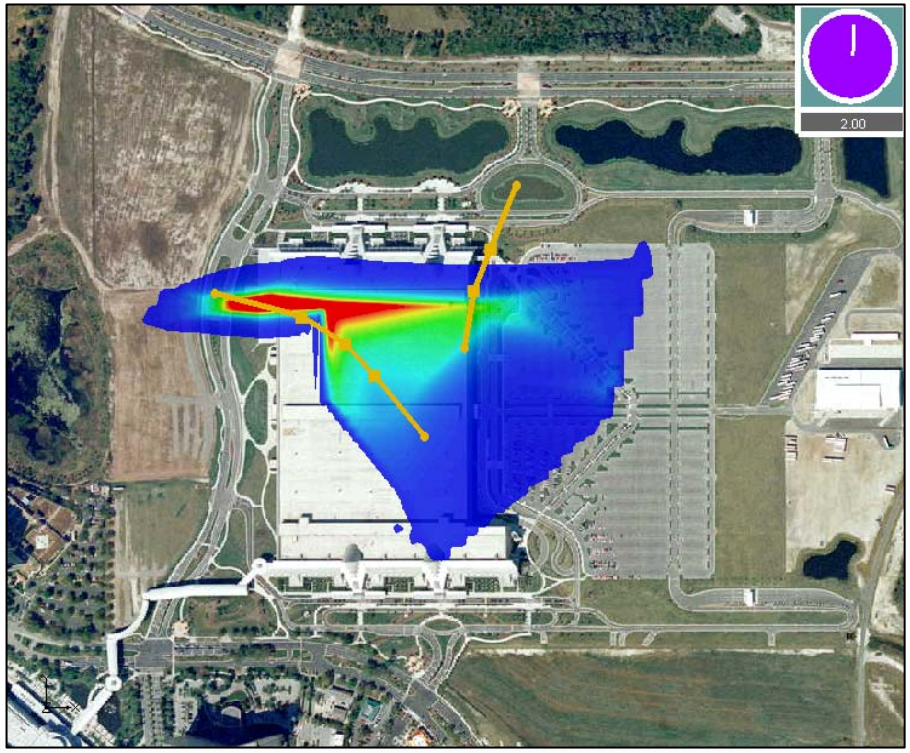
**GW Contour**

**Plume**

**Horizontal Wells**

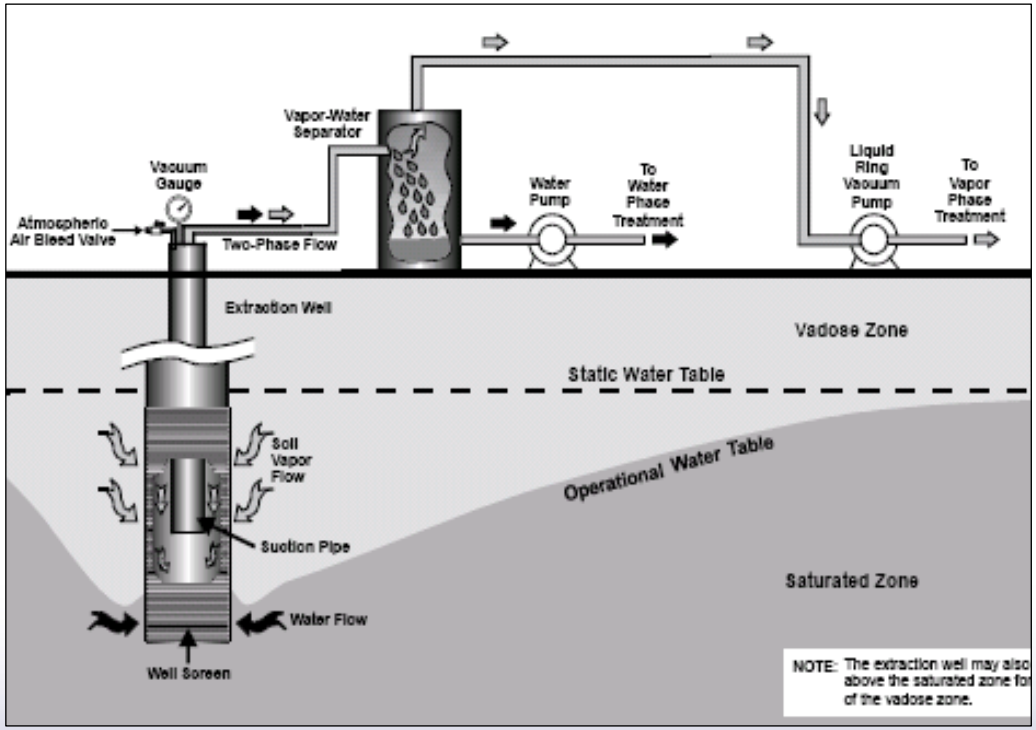
**Capture Zone**





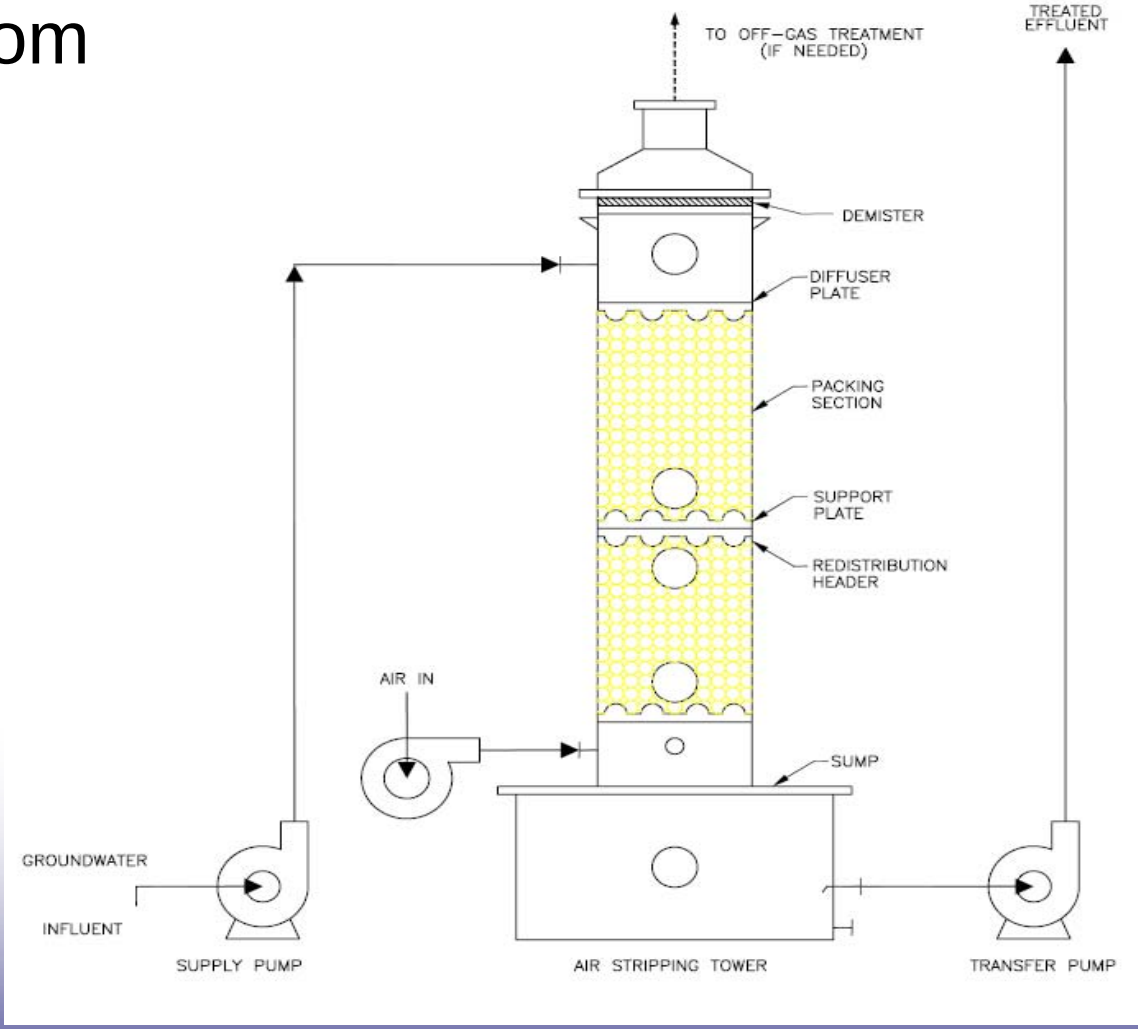
# Multi-Phase Extraction

- Vacuum applied to well to extract groundwater and vapor simultaneously
- Water table lowered around well, exposing previously saturated zone to vacuum extraction



# Air Stripping

- Transfers VOCs from treated water to ambient air
- Fouling may be problem at some sites

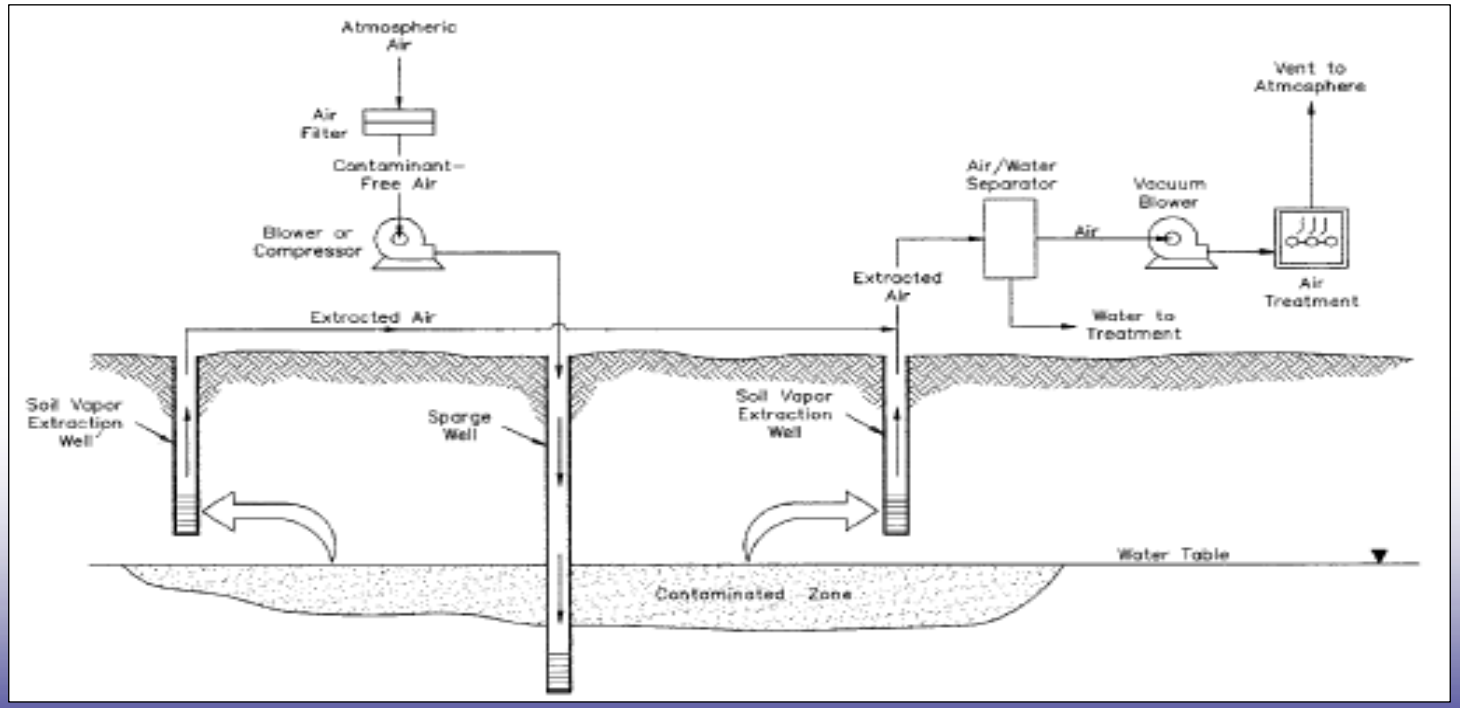


# Granular Activated Carbon (GAC)

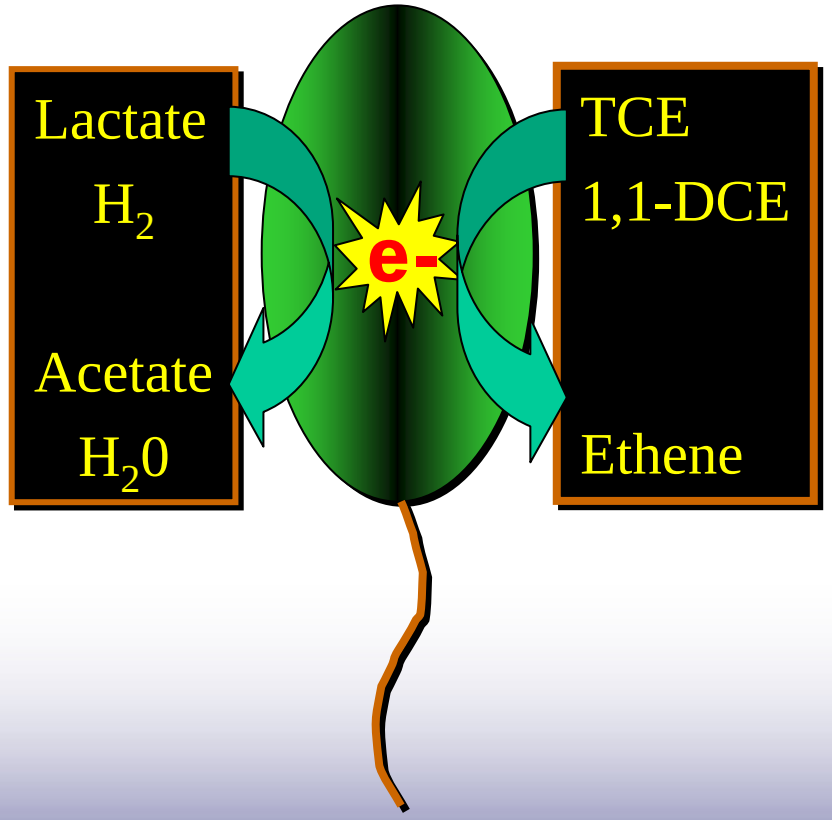
- Removes low contaminant concentrations in groundwater and off-gas streams
- GAC may be regenerated on site or off site

# Air Sparging

- Air injected into aquifer
- Transfers dissolved and adsorbed VOCs into vapor phase
- Dependent on soil permeability
- Relatively inexpensive



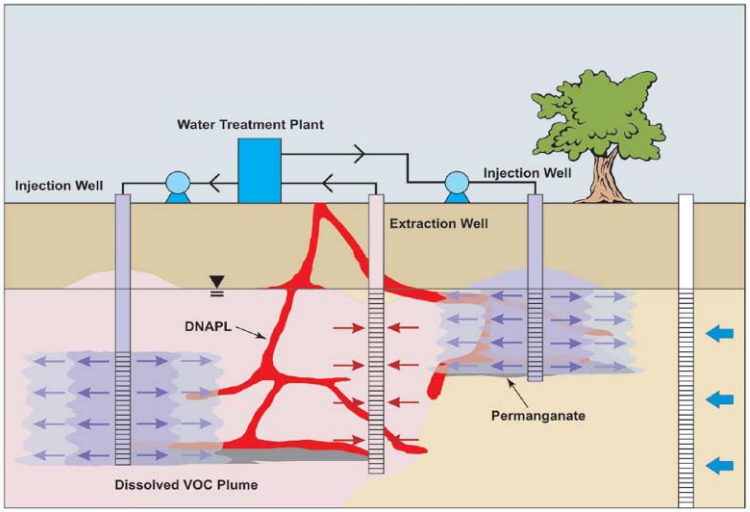
# Bioremediation




Source: Dr. Eric Petrovskis

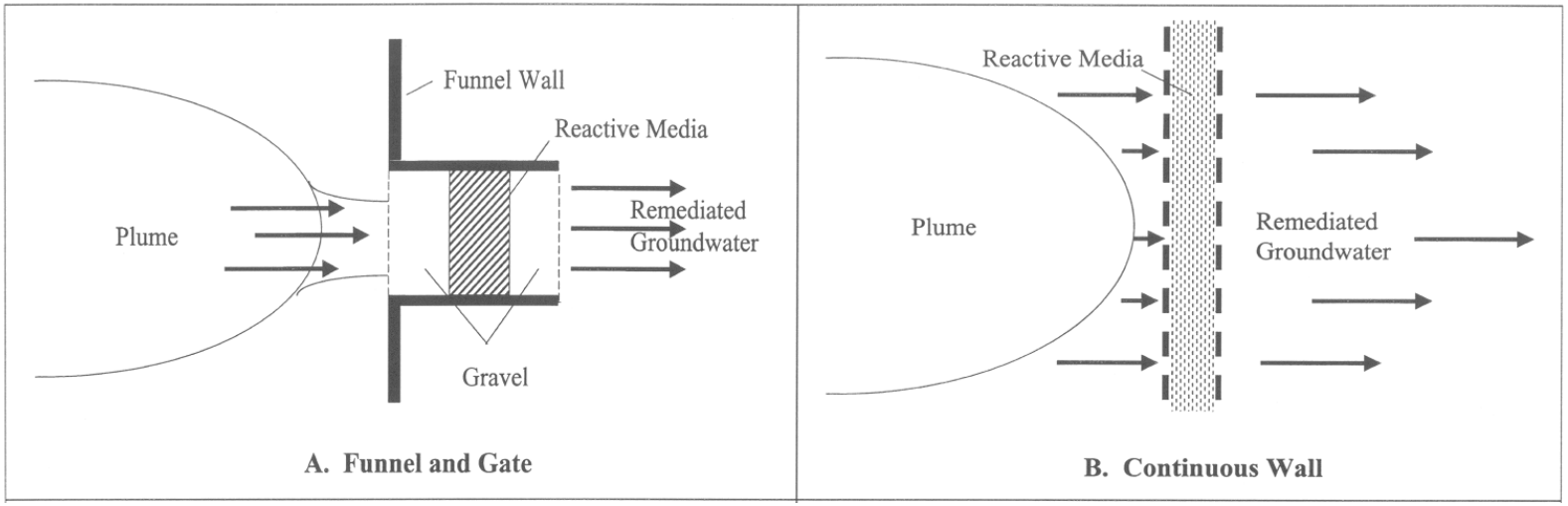
- Biostimulation is the injection of amendments
- Bioaugmentation is the injection of bacteria
- Unique applications for chlorinated solvents (TCE, 1,1,1-TCA, 1,1-DCE)

# Chemical Oxidation



- Chemical oxidants destroy range of VOCs, SVOCs, PAHs, PCBs, pesticides
- Ozone, permanganate, hydrogen peroxide/iron (Fenton's reagent), persulfate
- Applied through injection or injection/recovery

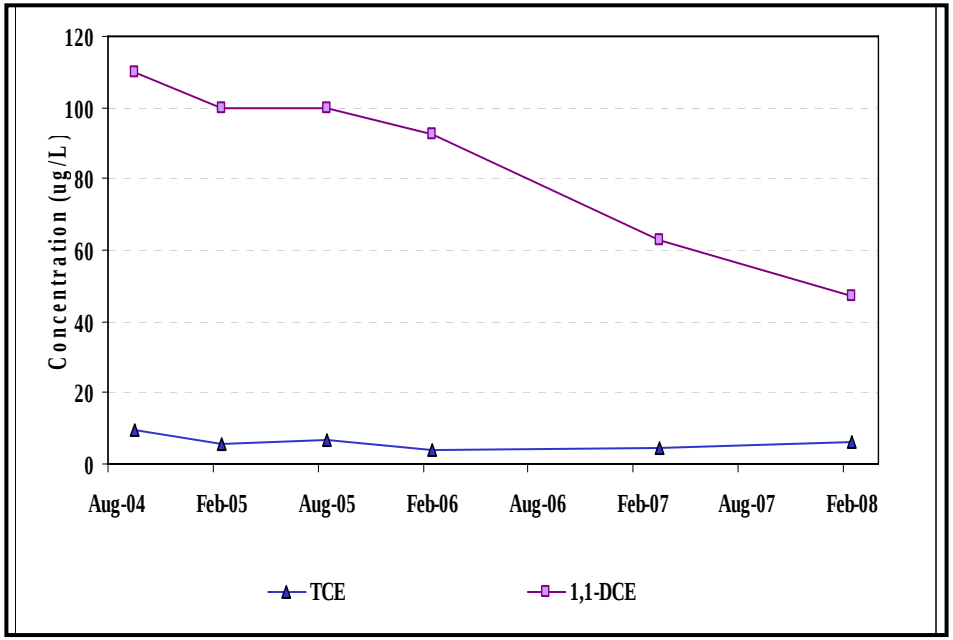
# Permeable Reactive Barriers




- Passive *in situ* technology that treats a variety of contaminants.
- Zero-valent iron is common reactive medium but other materials also used.
- Mineral precipitation over time may reduce system effectiveness.

# Monitored Natural Attenuation

- MNA relies on naturally occurring processes
  - Biodegradation and abiotic degradation
  - Volatilization
  - Sorption and chemical stabilization
  - Dispersion and dilution

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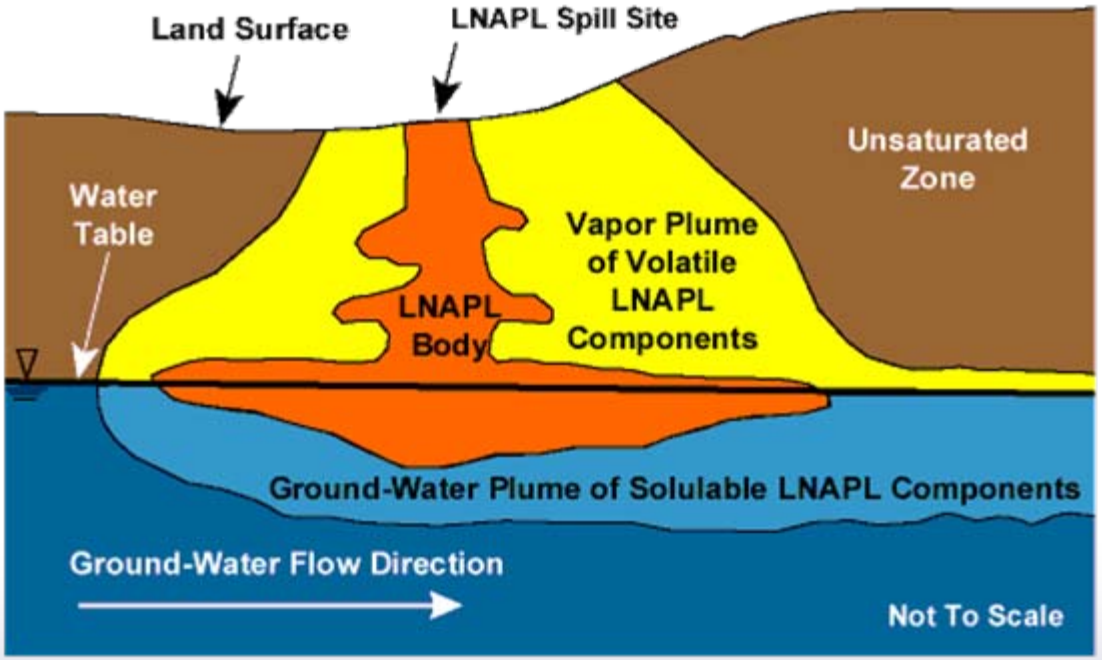
# Non-aqueous Phase Liquids (NAPLs)

- NAPLs do not mix with water; form separate phase
- Present special challenges for groundwater remediation
- Light- and dense- NAPLs (LNAPLs and DNAPLs) can be mixed at a site
- NAPL remedies should be protective but realistic

# LNAPLs

- Fuels, lubricants, and petroleum-based chemical feed stocks
- “Float” on the aquifer (like an iceberg)
- Continuous source of groundwater contamination
- Difficult to characterize and remediate

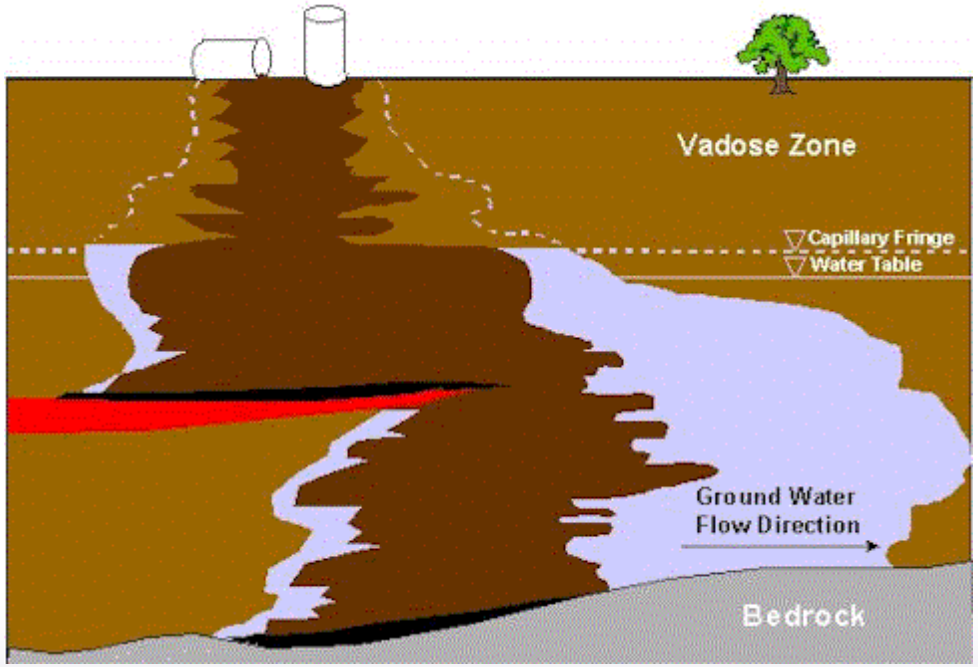


# LNAPL Remediation

- Traditional approaches:
  - P&T
  - Recovery trenches/drains
  - SVE
  - Containment
  - Excavation
- Emerging approaches (*in situ*):
  - Thermal treatment
  - Chemical oxidation
  - Surfactant/co-solvent flushing
  - Bioremediation

# DNAPLs

- Primarily chlorinated solvents and PAHs
- Sink in aquifer
- Continuous source of groundwater contamination
- Extremely difficult to characterize and remediate



# DNAPL Remediation

- Traditional approaches:
  - P&T (for containment of dissolved)
  - Containment
  - Excavation
- Emerging approaches (*in situ*):
  - Thermal treatment
  - Chemical oxidation
  - Surfactant/co-solvent flushing
  - Bioremediation

# DNAPL Remediation Challenges

- Traditional regulatory approaches
- Determining DNAPL mass and distribution difficult and costly
- Uncertainties of long-term remedial effectiveness and costs – no reliable metrics
- Limited availability of performance and costs for aggressive technologies

# DNAPL Realities

- Even 99% DNAPL removal can leave a significant groundwater contamination source
- Few DNAPL sites will be cleaned up to MCLs with current technologies
- No cook book – different cleanup levels are appropriate based on site-specific factors and risks
- Focus on managing risks based on reasonably anticipated land use

# DNAPL Excavation

# Green Remediation

- Green Remediation is the practice of considering **all** environmental effects of remedy **implementation** and incorporating options to maximize the **net environmental benefit** of cleanup actions.
- Strategies:
  - Efficient use of energy and resources
  - Reduce negative impacts to the environment
  - Minimize pollution at its source
  - Reduce waste

# Green Remediation Practices

- Energy requirements
  - Use renewable energy
  - Maximize efficiency of remediation equipment
- Air emissions
  - Use clean fuels
  - Reduce releases of toxic pollutants, greenhouse gases, and dust
- Water requirements
  - Reduce fresh water consumption; maximize water reclamation/reuse
  - Reduce surface water quality impacts

(cont.)

# Green Remediation Practices

- Land & ecosystem impacts
  - Inventory ecological species, land contours, and drainage patterns
  - Relocate sensitive or threatened species
- Waste generation
  - Reuse uncontaminated excavated soil
  - Recycle waste & scrap materials
- Long-term stewardship
  - Install renewable or passive energy systems for long-term site controls
  - Construct remediation structures to complement site redevelopment

# Green Remediation Case Study

- Objective was to recover hydrocarbons from groundwater at RCRA site
- Strategy was to use renewable energy systems – solar & wind energy
- Use 6 wind turbines to operate compressors for hydraulic skimming pumps & to generate electricity to power 9 submersible pumps and fluid-gathering system
- Use 6 photovoltaic panels to power recovery wells & submersible pumps
- Recycle recovered petroleum product at adjacent oil refinery

# Summary

- Remediation technologies support RCRA CA progress
- Resources and tools are available to support Project Managers
- Remember to focus on technologies that will support appropriate, protective & sustainable actions for current and reasonably anticipated uses