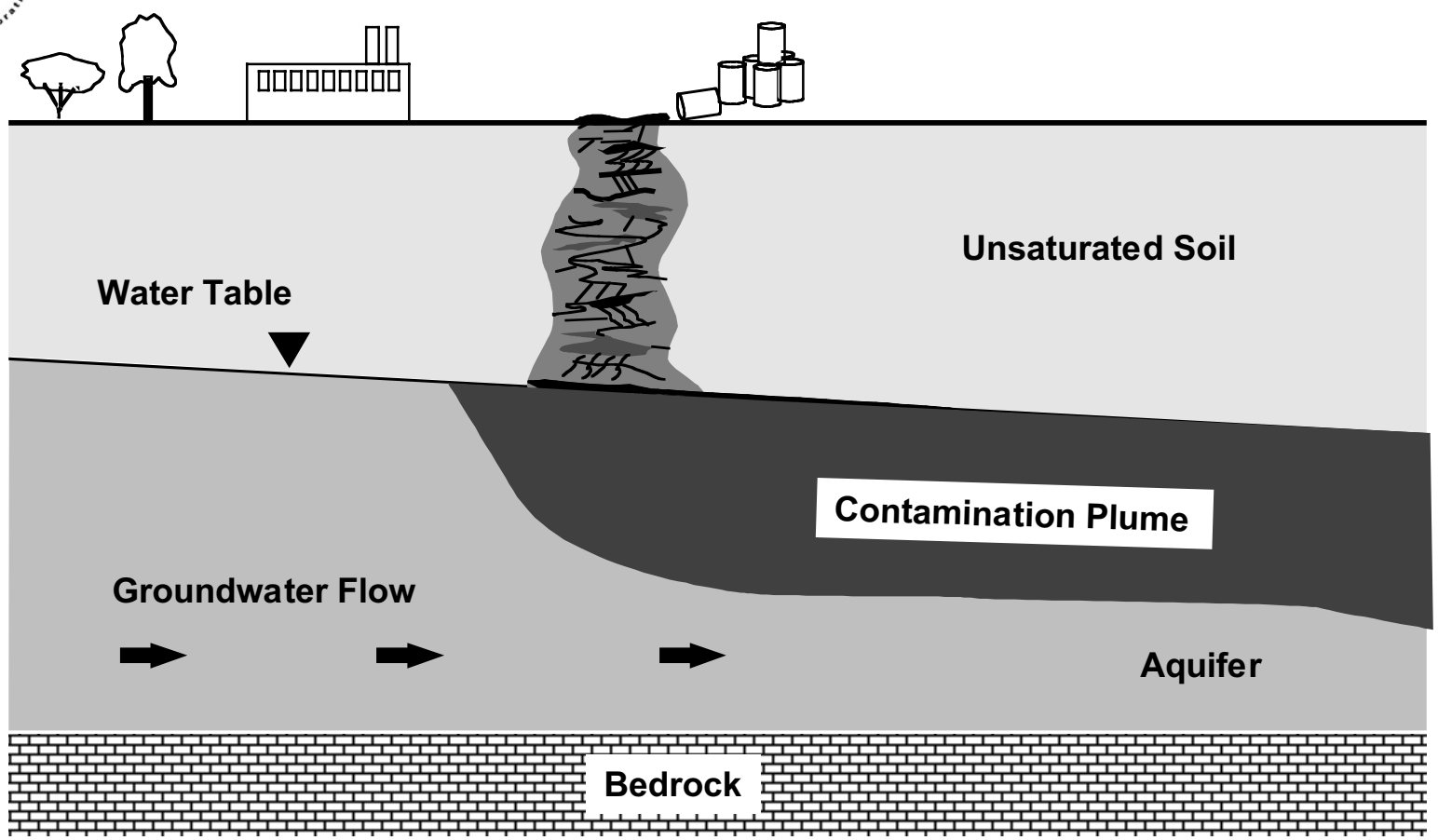
DON RAB/TRC
Training Workshop

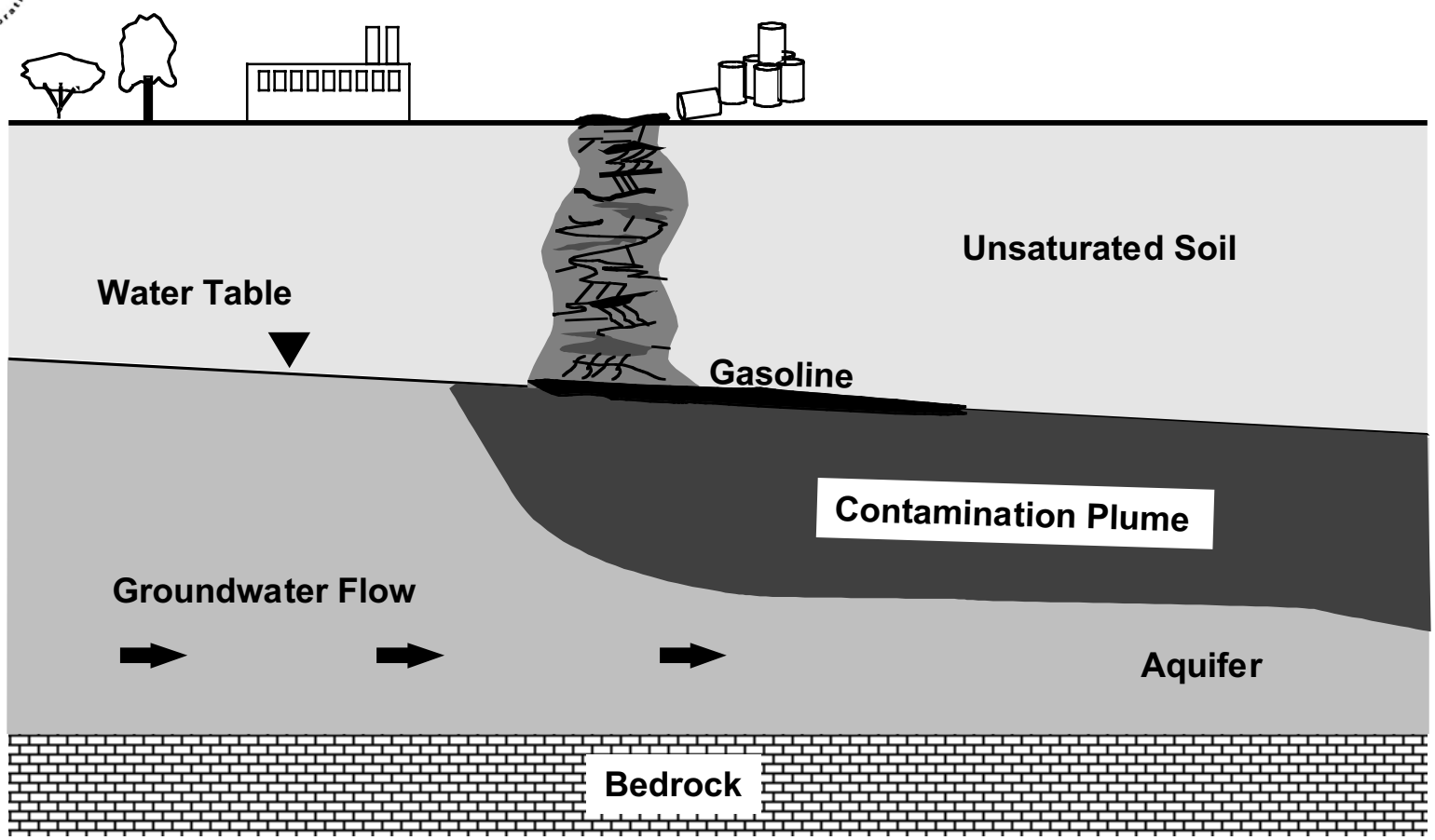
Geologic Limitations Of Remediation Technologies

Presenter:
Evan Nyer, Arcadis

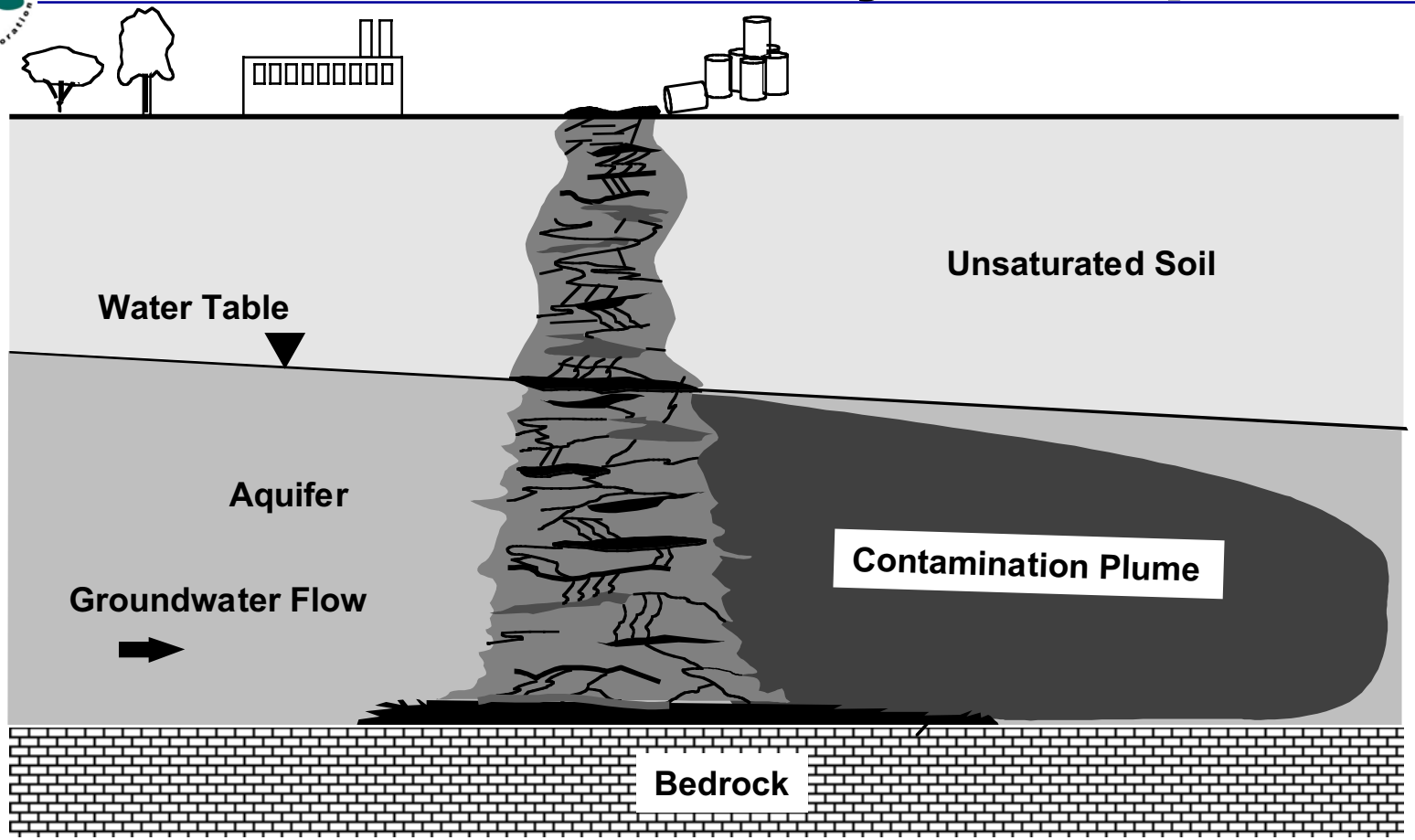
Contamination Plume in an Aquifer



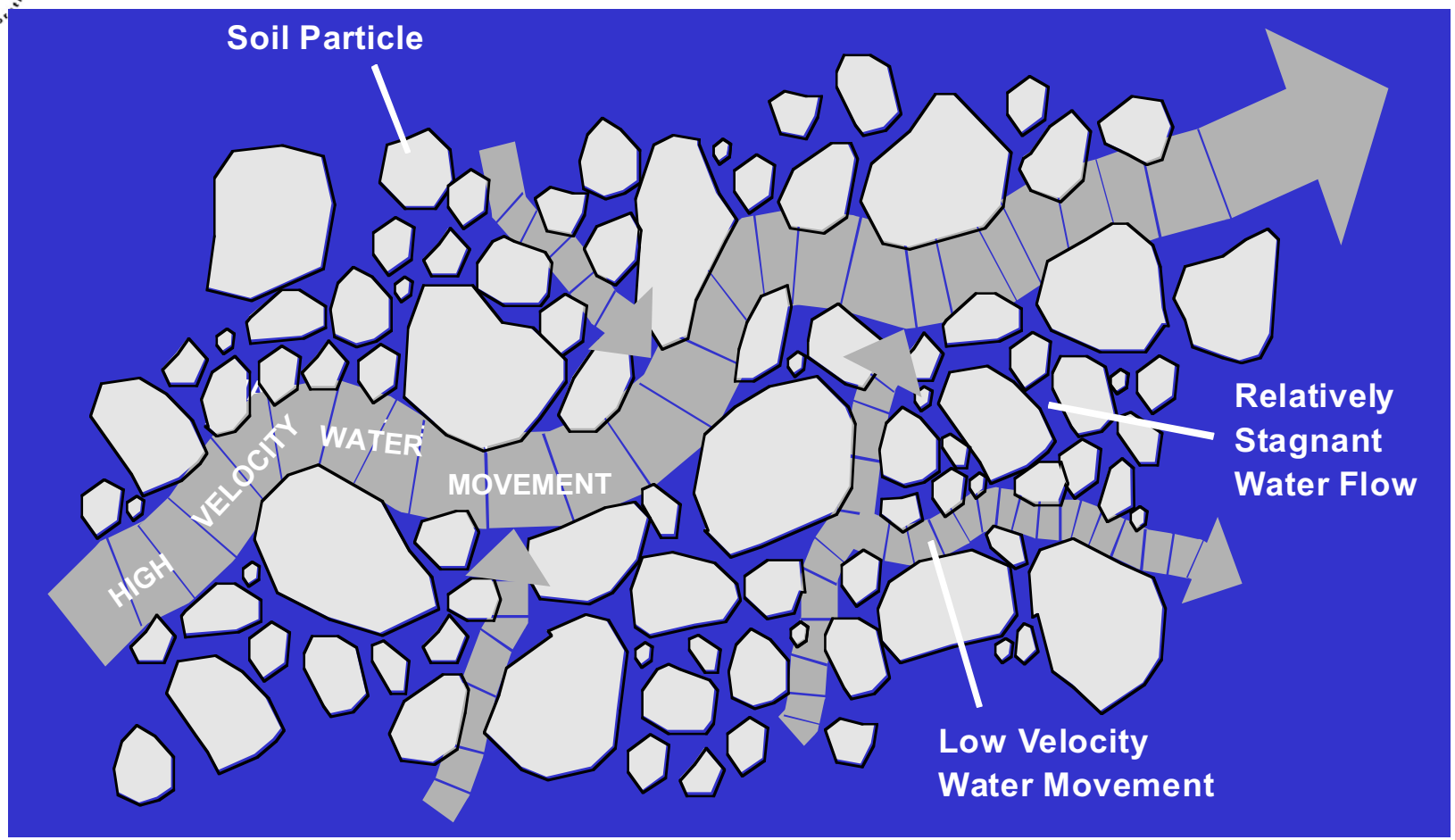
Contamination Plume Resulting From Gasoline Spill



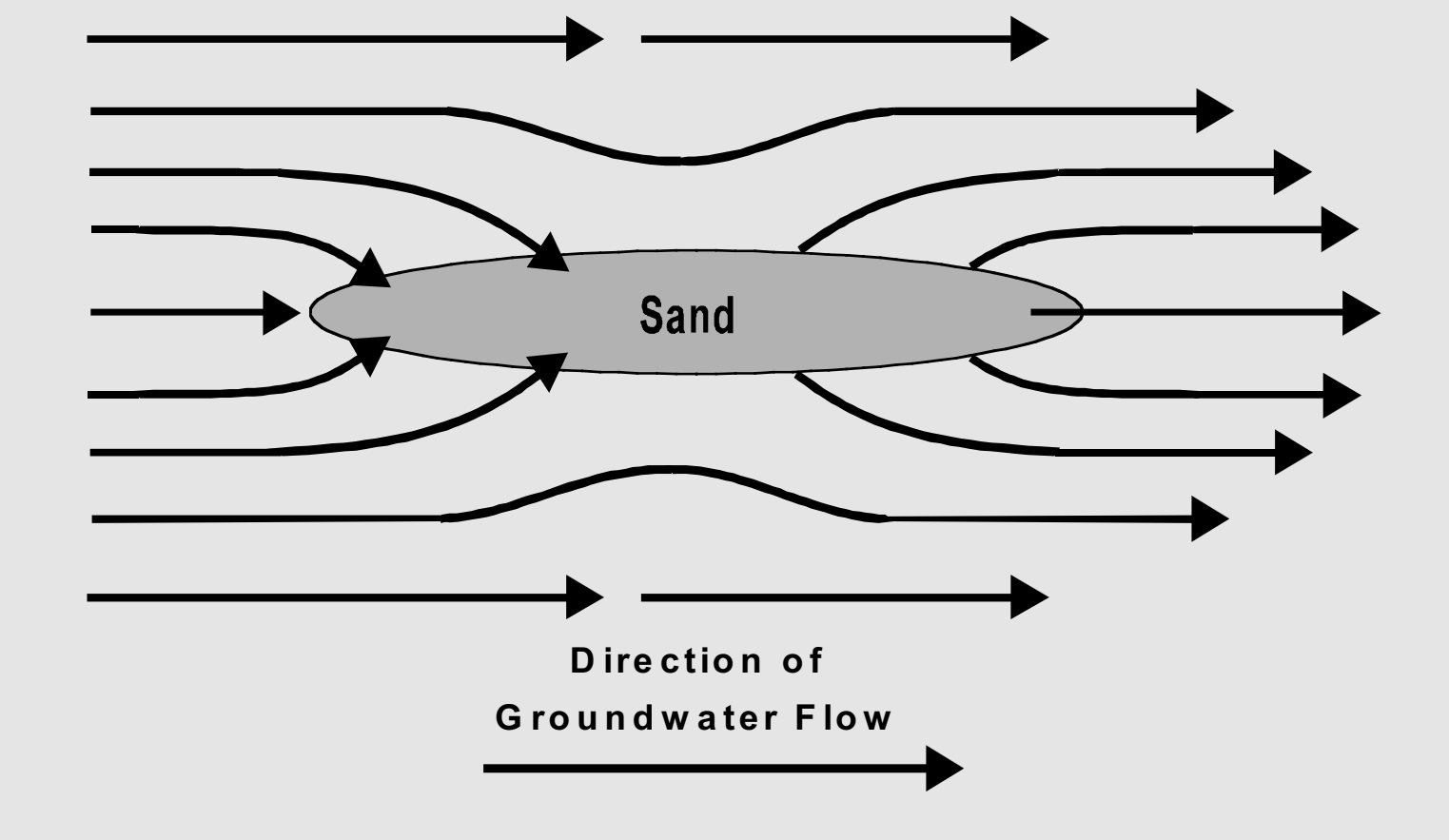
Contamination Plume Resulting From Trichloroethylene Spill



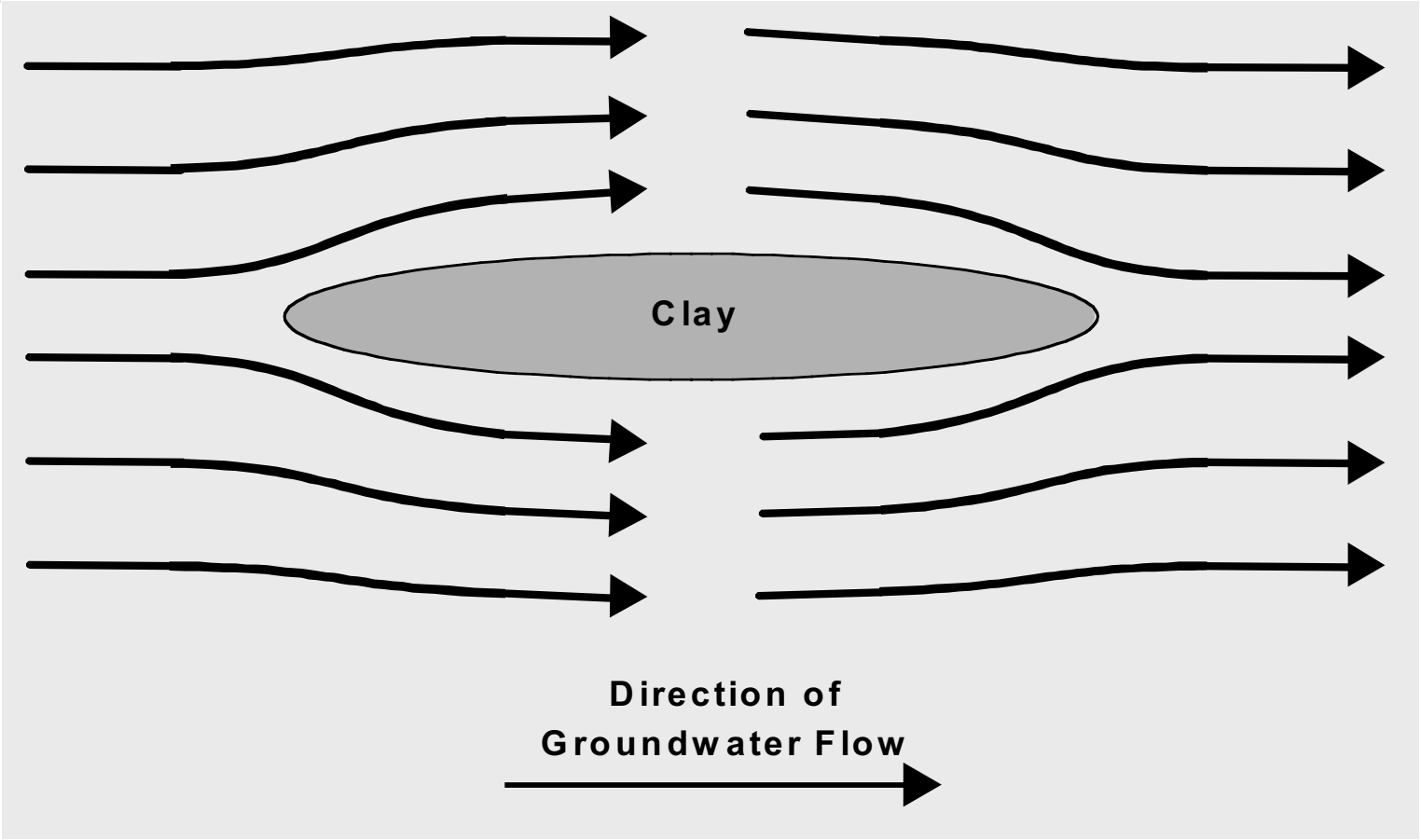
Water Flow Through Soil Microcosm



Groundwater Flow Pattern Resulting From a Sand Lens



Groundwater Flow Pattern Resulting From a Clay Lens



Water as a Carrier

- Disadvantages
  - Limited Speed of Water Movement
  - Chemical Properties of Compounds
  - Heterogeneous Geology
    - Sand and clay lenses
    - Micro lenses

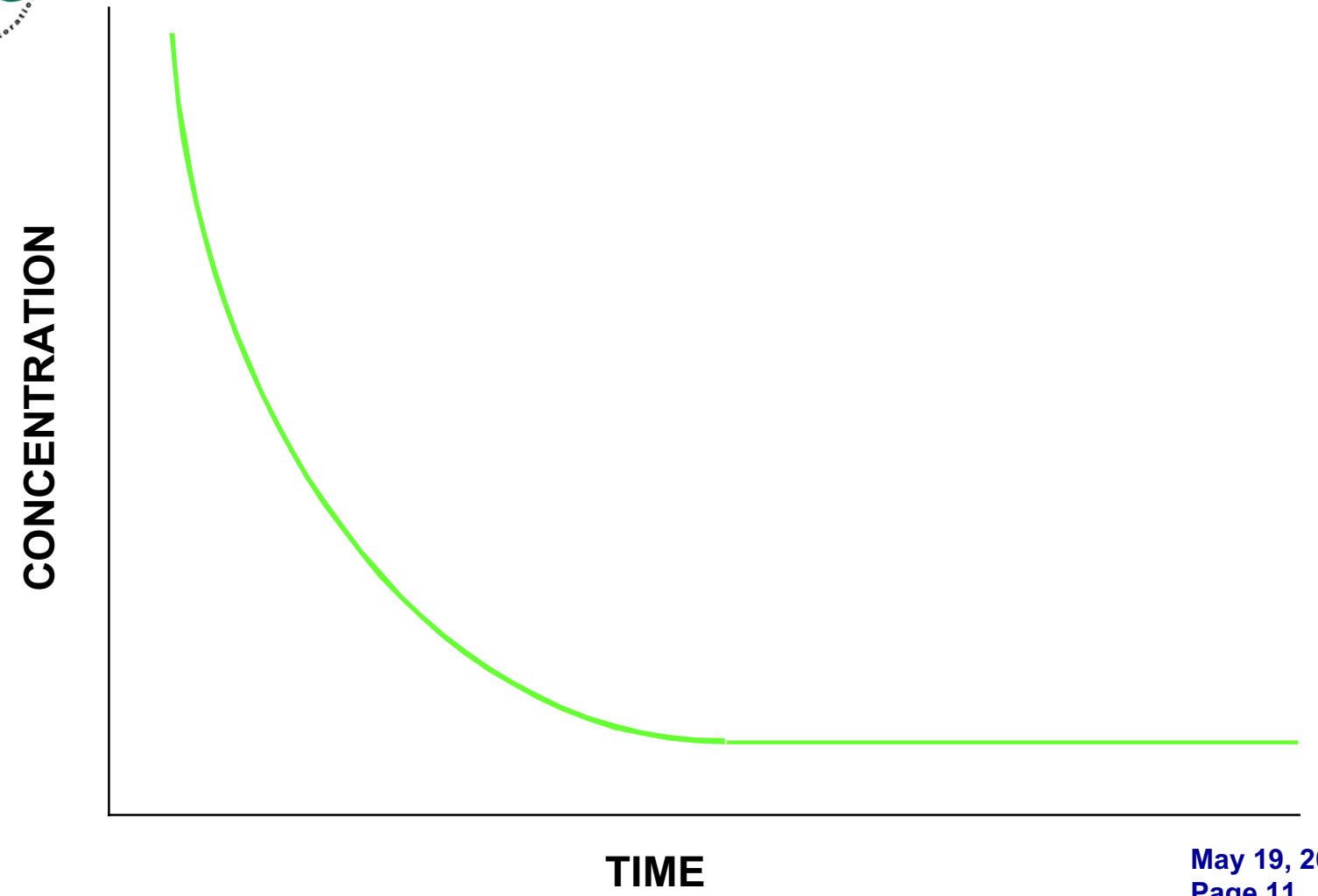
Advantages of Air as a Carrier

- Pore Volume Exchange
- Chemical Properties of Volatile
- Travel Through Smear Zone (Sparging)
- New Pathways in Aquifer
- 200 to 1 Pore Volume Exchange Rate
- 10,000 to 1 VOC Removal Advantage

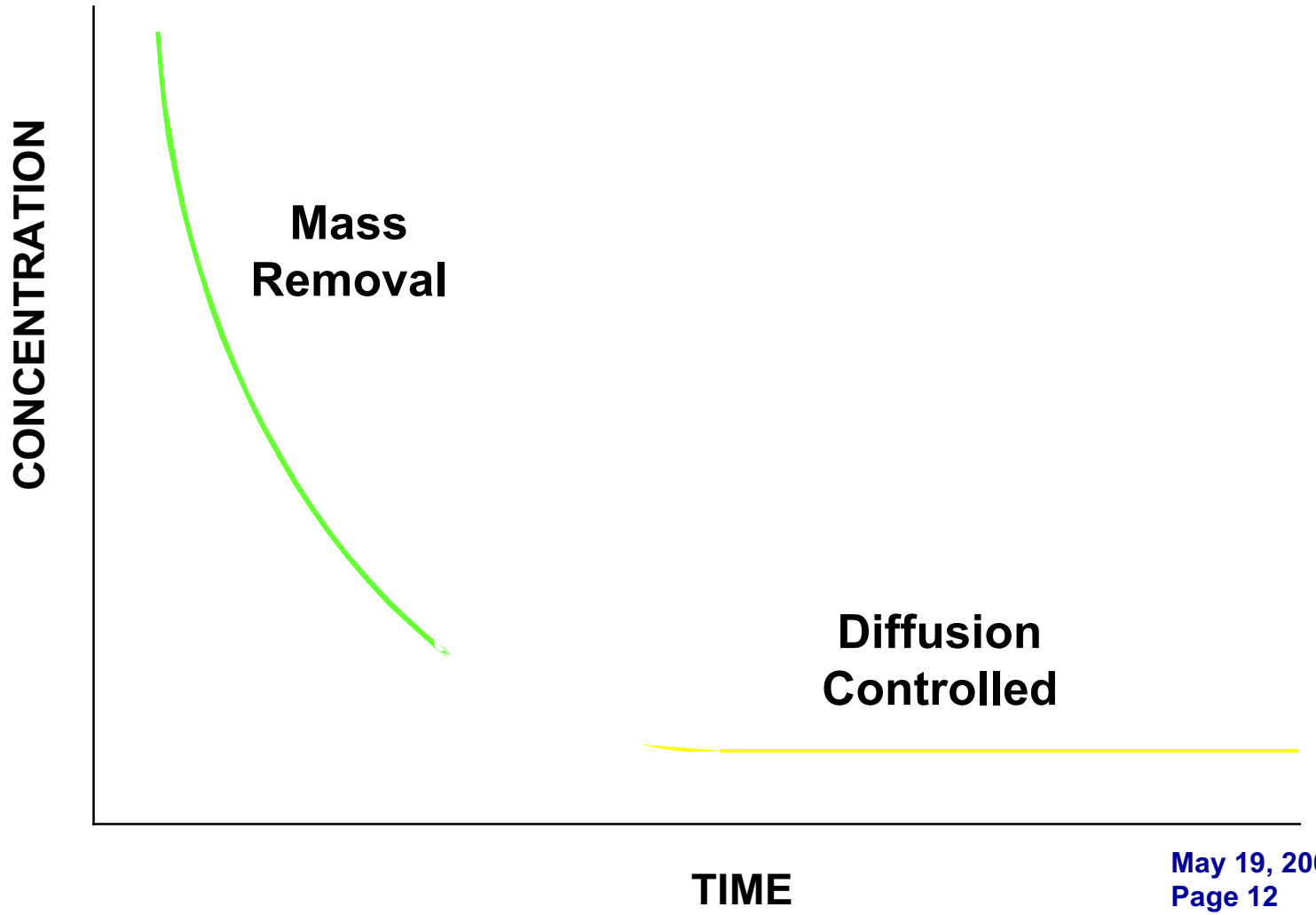
Disadvantages of Air as a Carrier

- Chemical Properties of Compounds
- Heterogeneous Geology

Life Cycle Concentration During Remediation



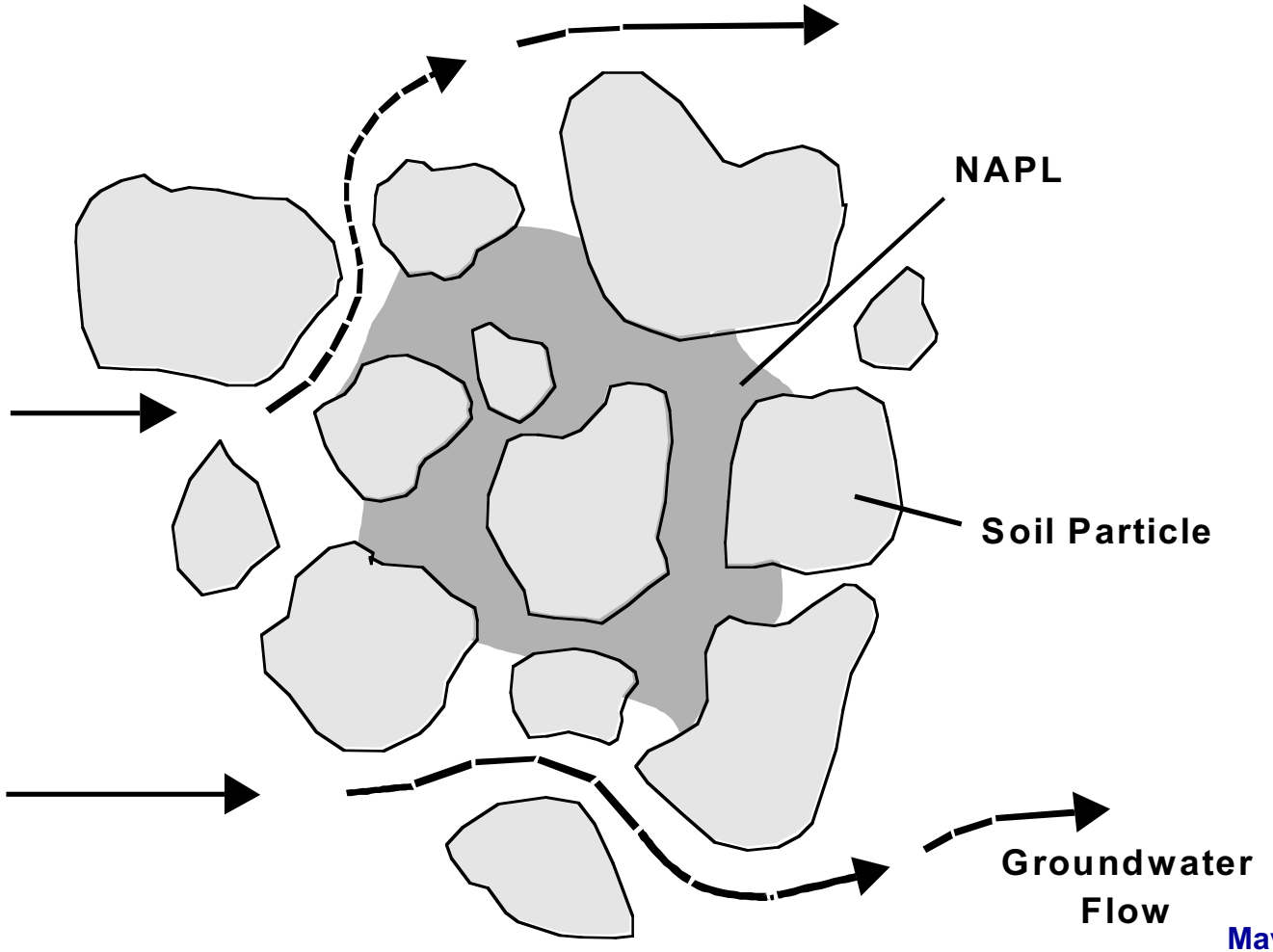
Life Cycle for In-situ Remediation



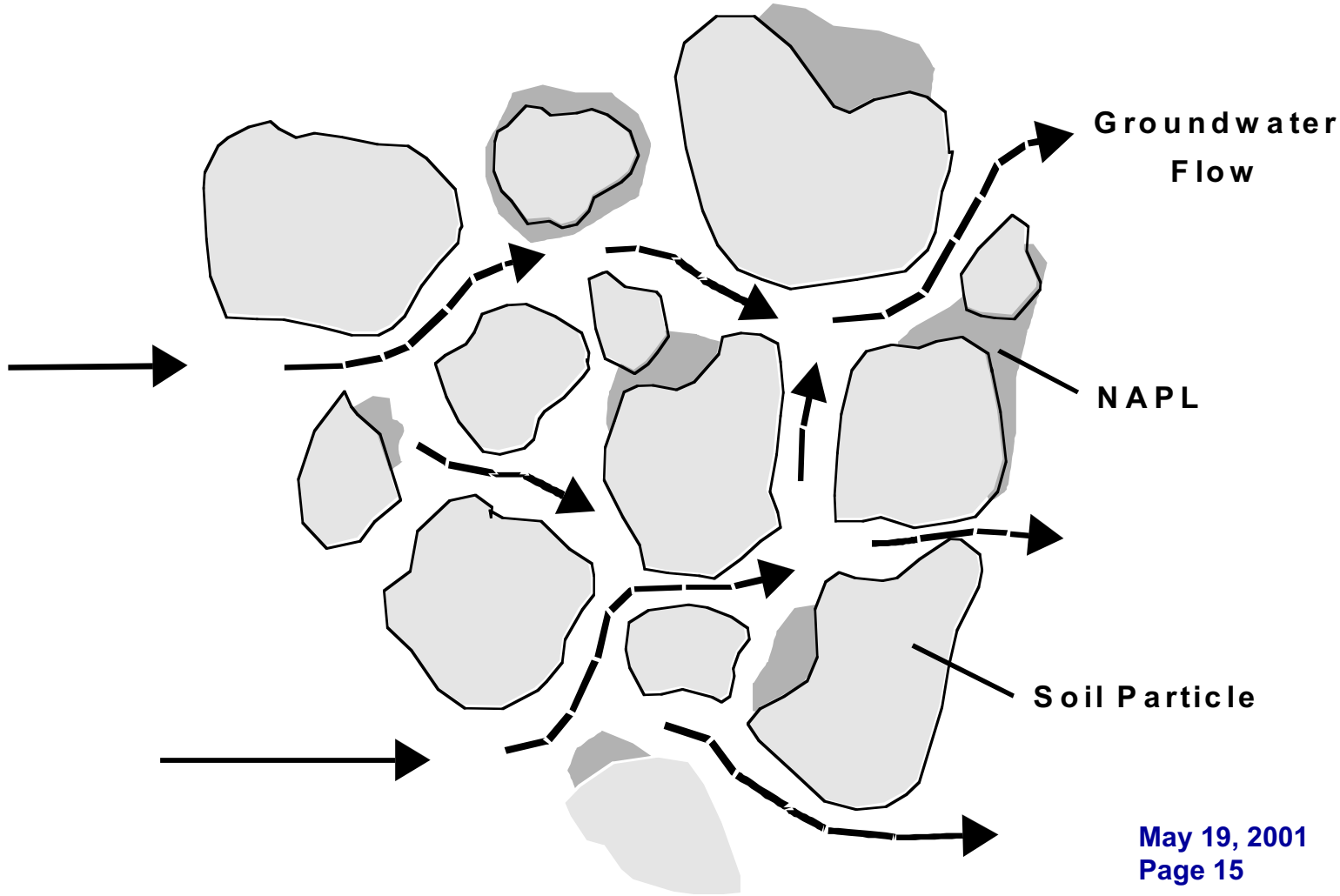
Non-Aqueous Phase Liquids

- LNAPL
- DNAPL

NAPL's Completely Filling In Pores



NAPLs Coating Soil Particles

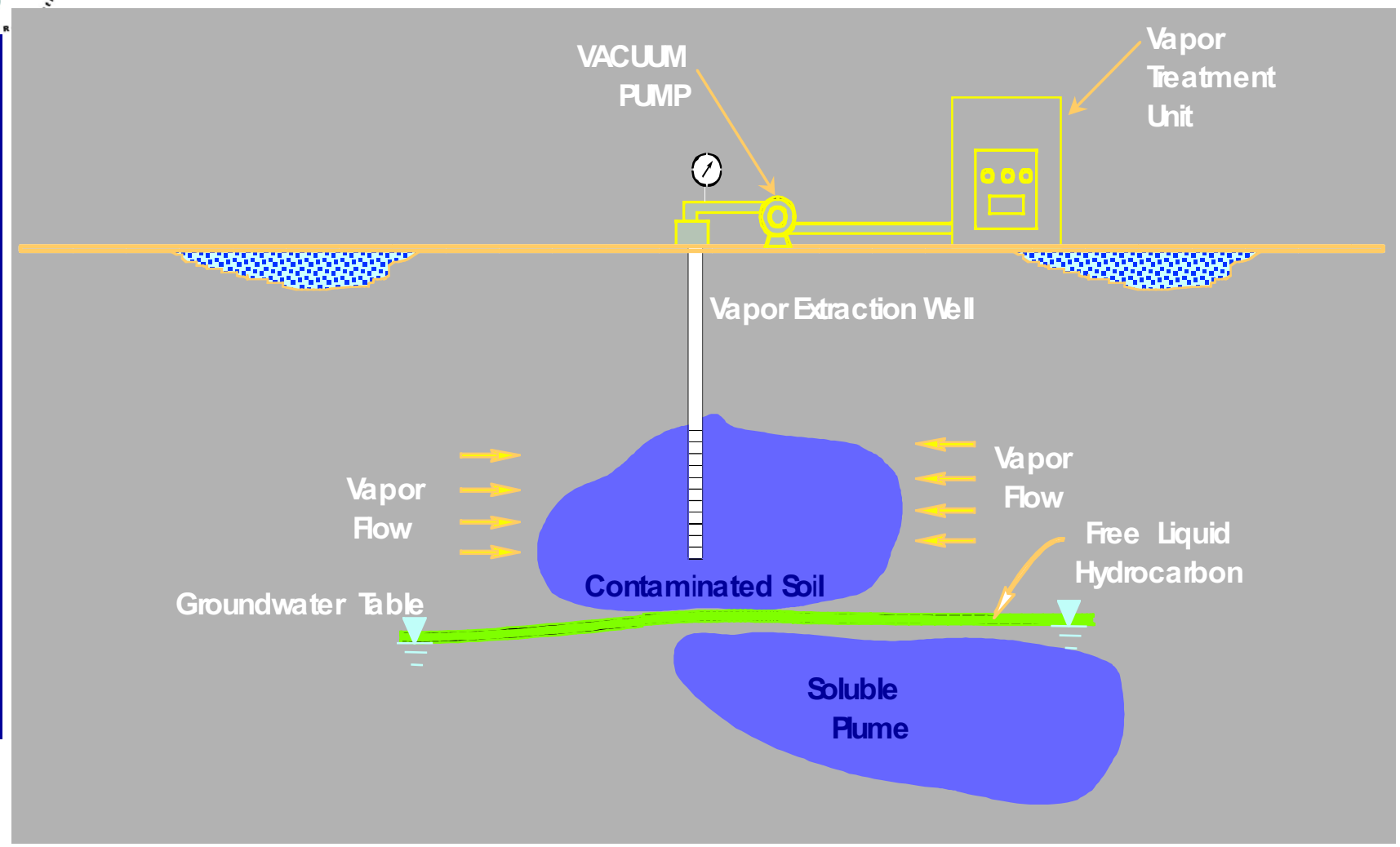


Mass Removal Technologies

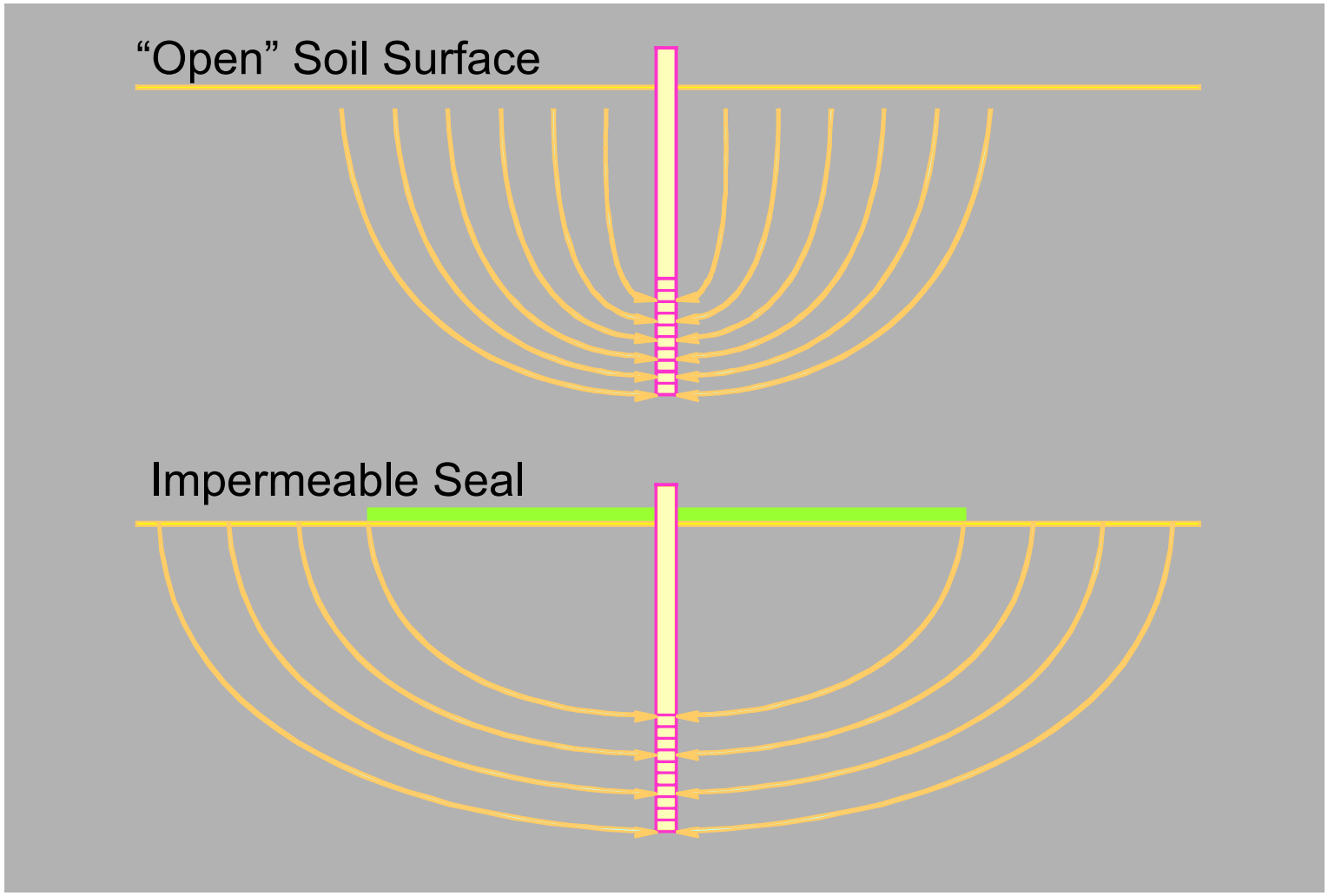
- Vapor Extraction
- Vacuum Enhanced Recovery
- Air Sparging

Vapor Extraction (VES)

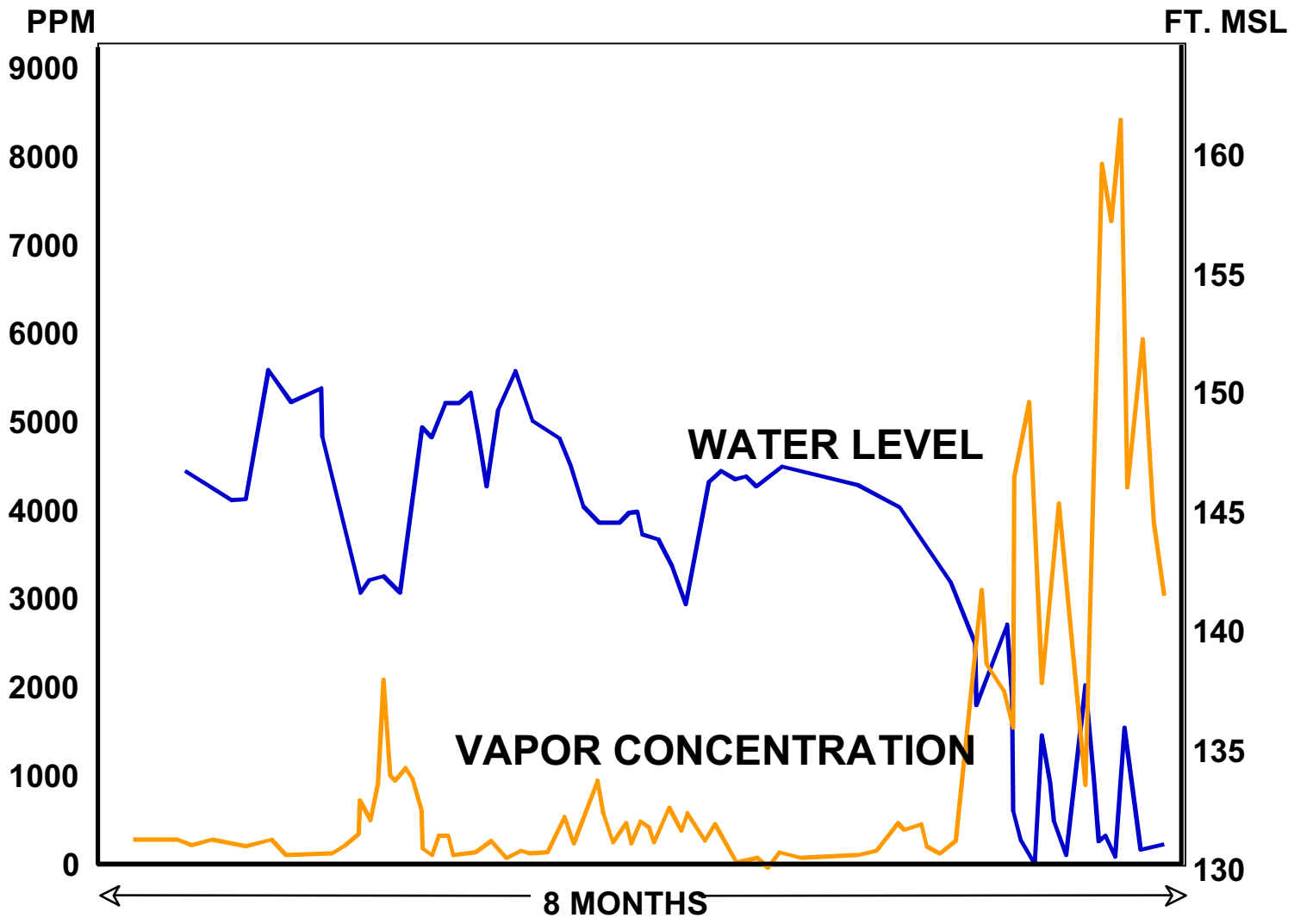
Basic VES System

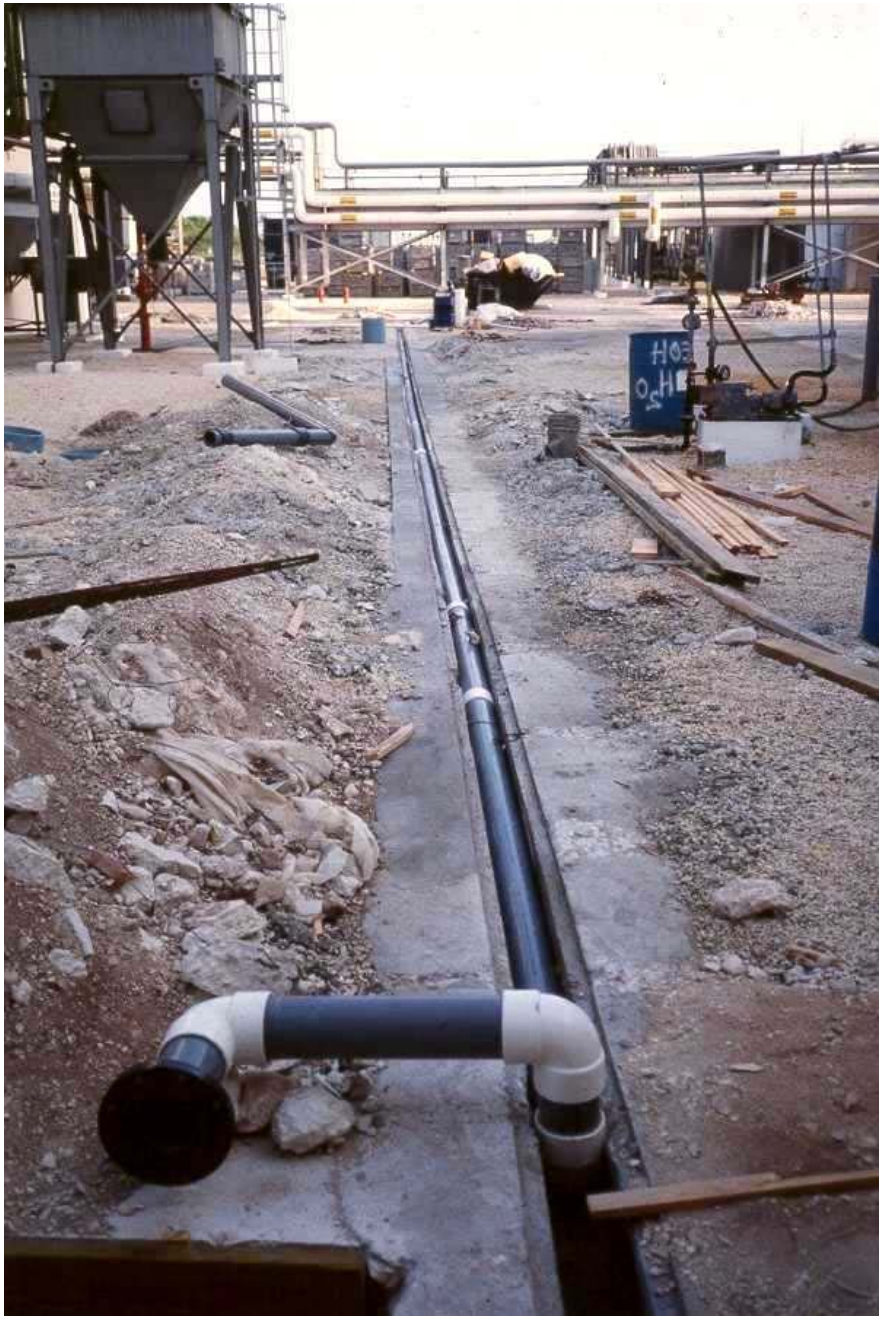


Effect of Surface Seal on Vapor Flowpath



Vapor Concentration vs. Water Levels

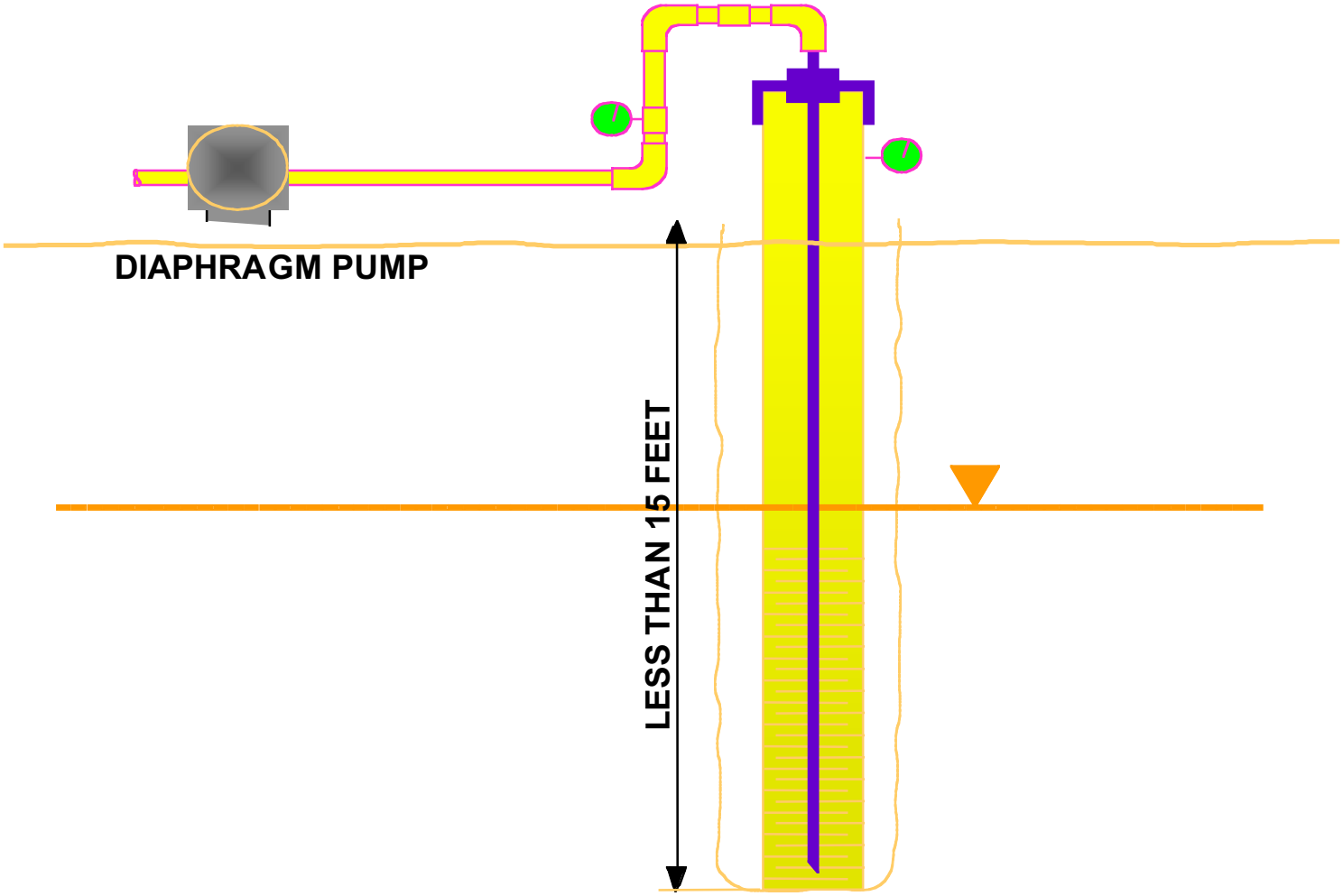




PLANT II OFFICE
CAUSTIC

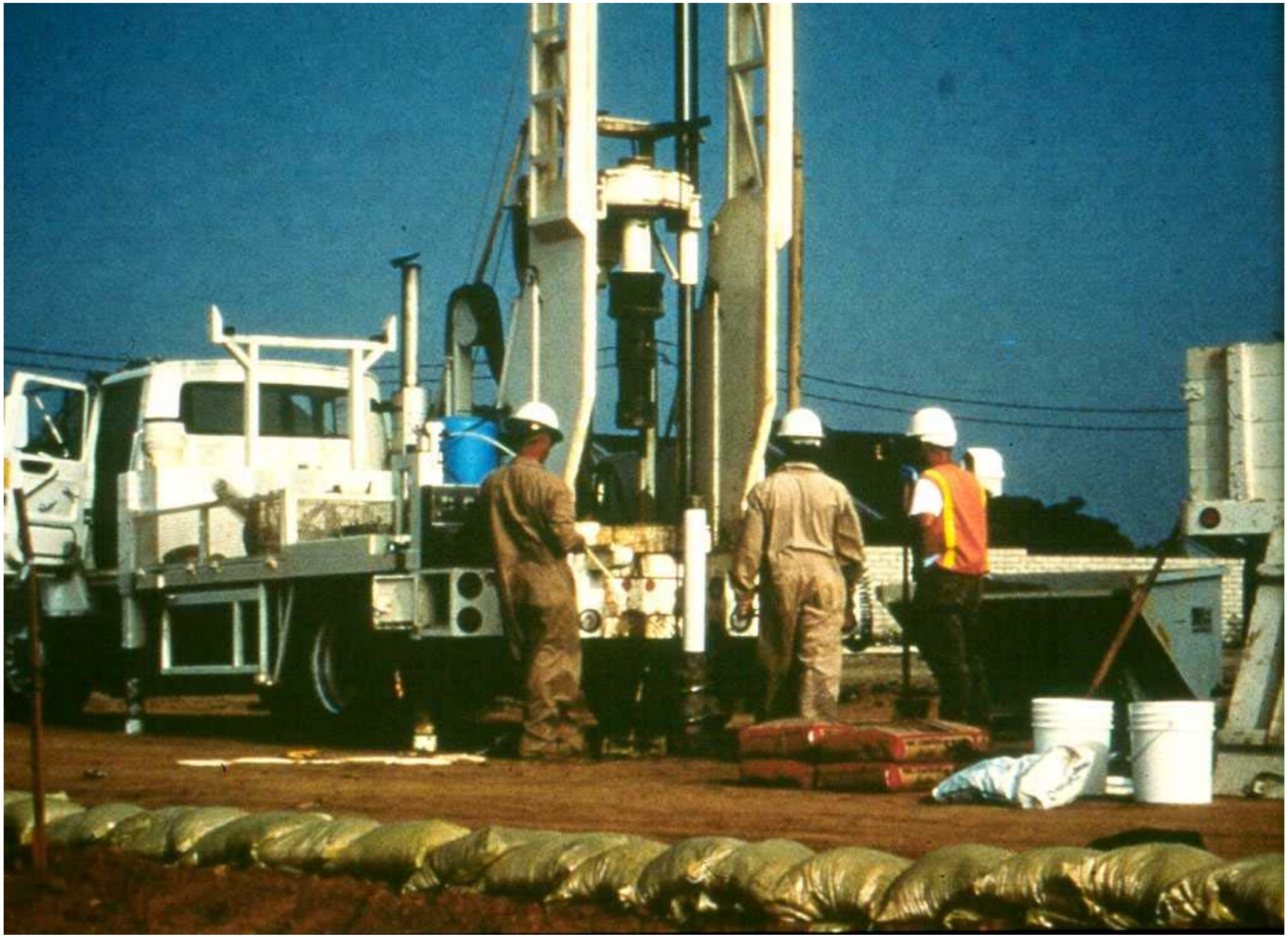
Vacuum-Enhanced Recovery (VER)

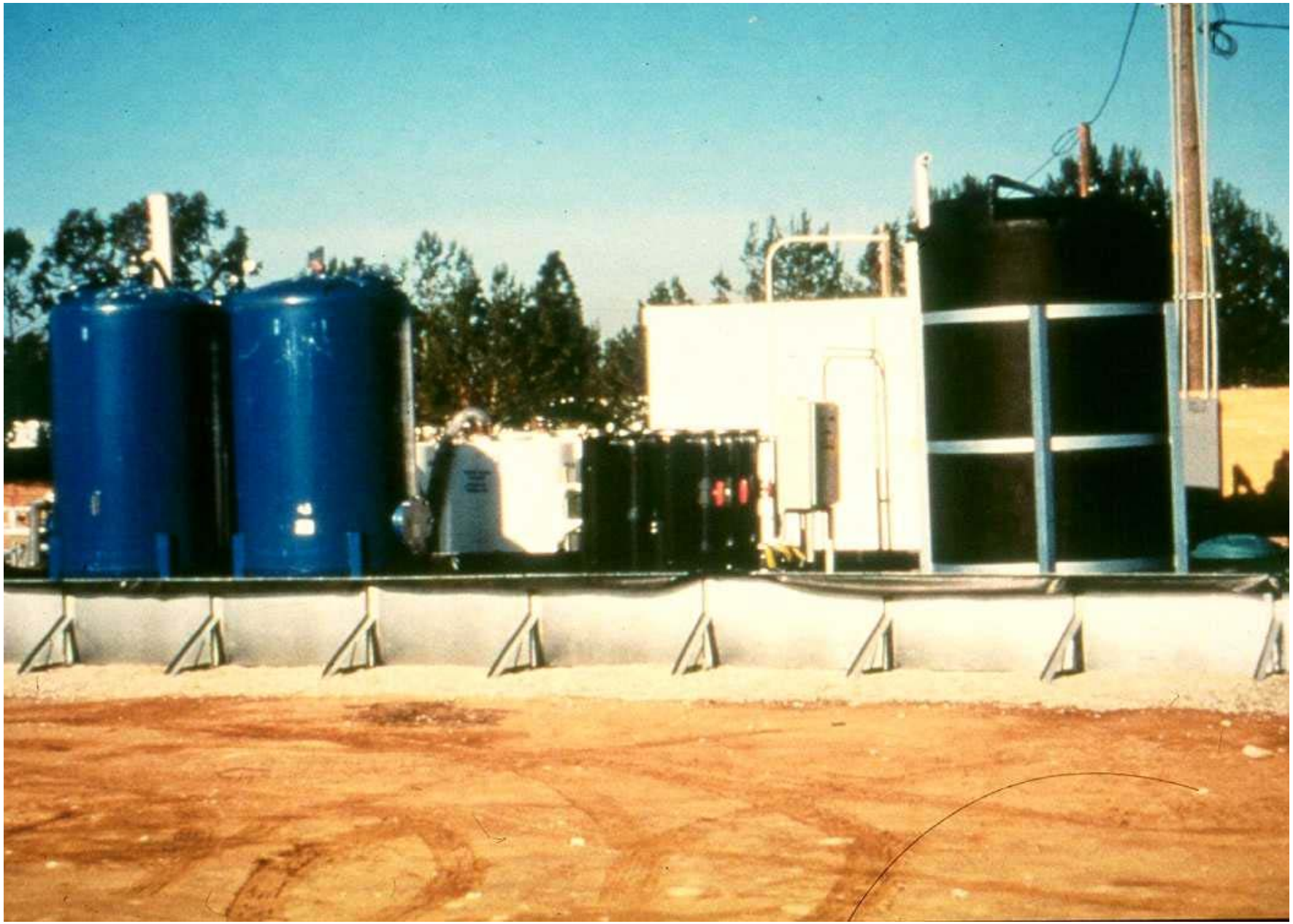
Schematic Showing The Configuration of a Single Pump Vacuum Enhanced Recovery System



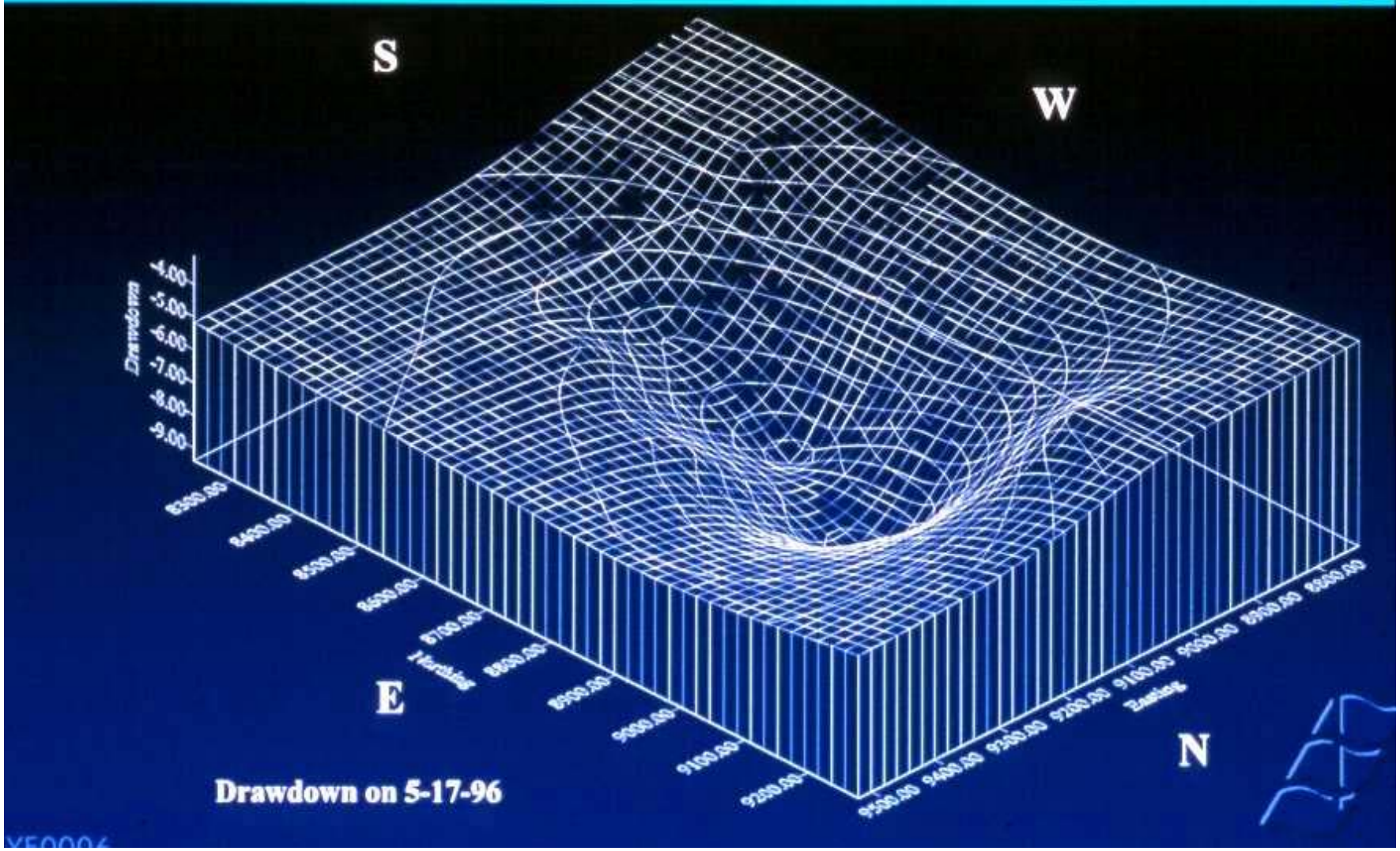
Industrial Redevelopment VER Case History

Site Plan
ORIGINAL
500 ug/L VOC
CONTOUR
N
TOP OF
EROSION
CONTROL
BERM
LEGEND:
EXTRACTION WELL
PIEZOMETER
80 FT
NYE0007

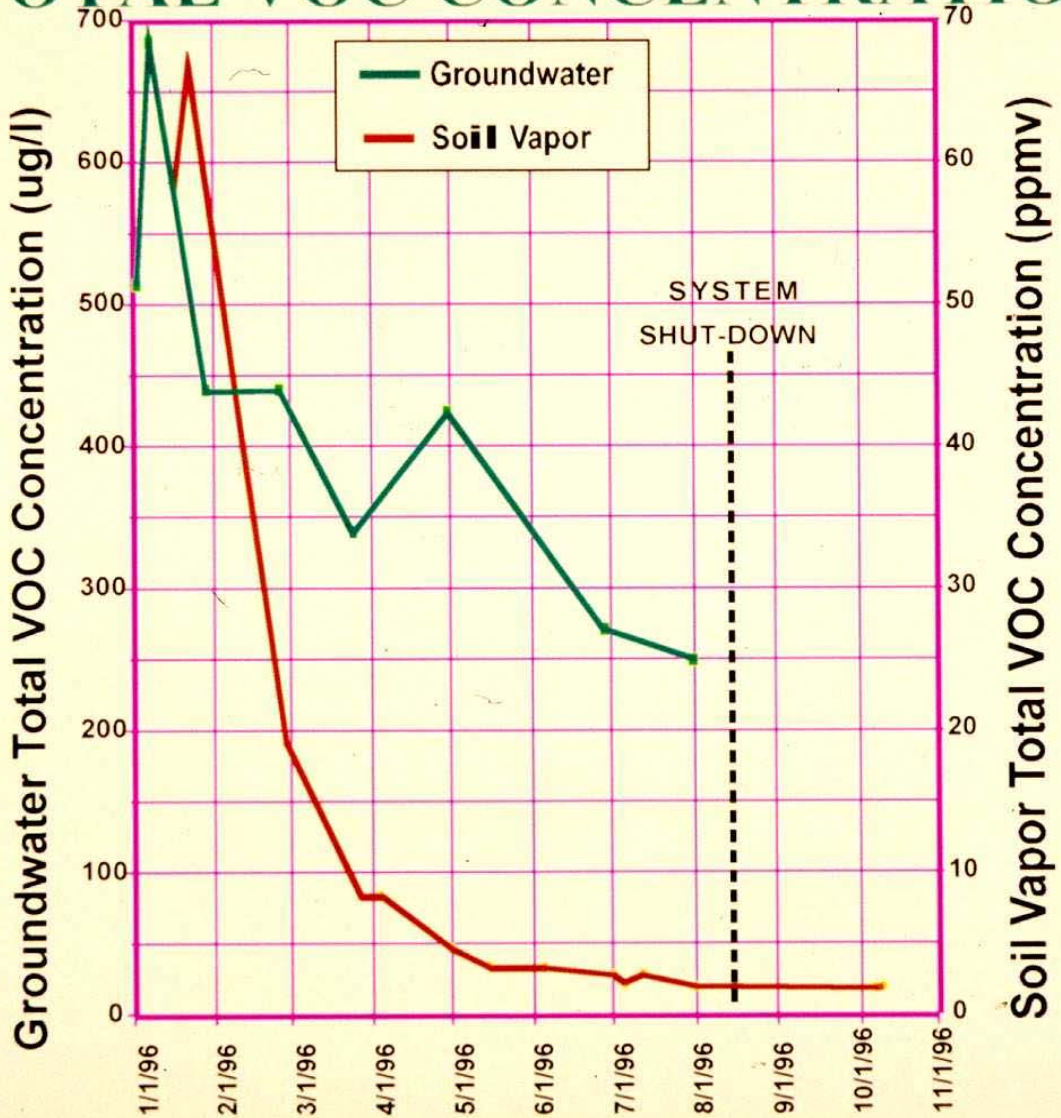




Groundwater Drawdown Contour Map



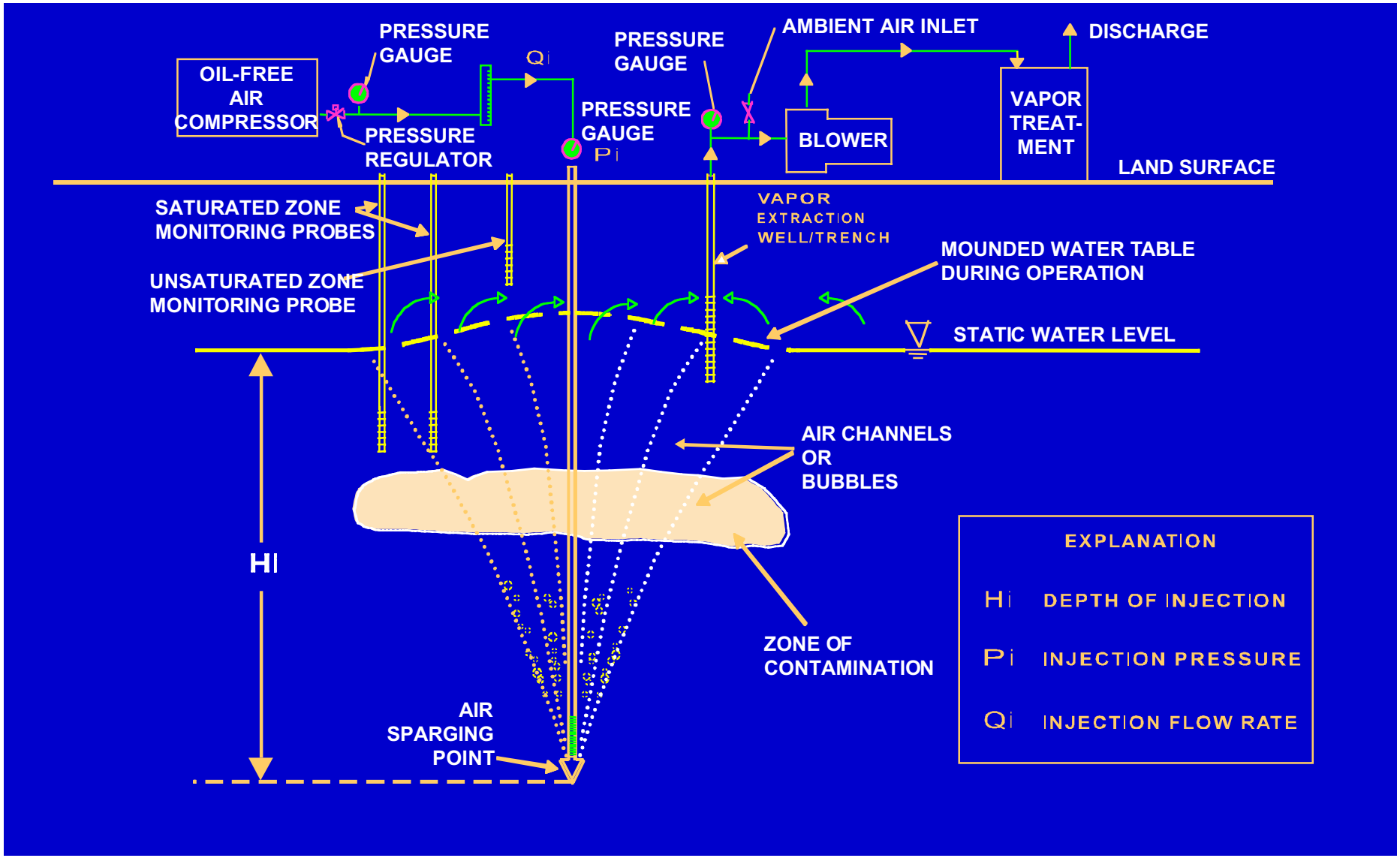
TOTAL VOC CONCENTRATION



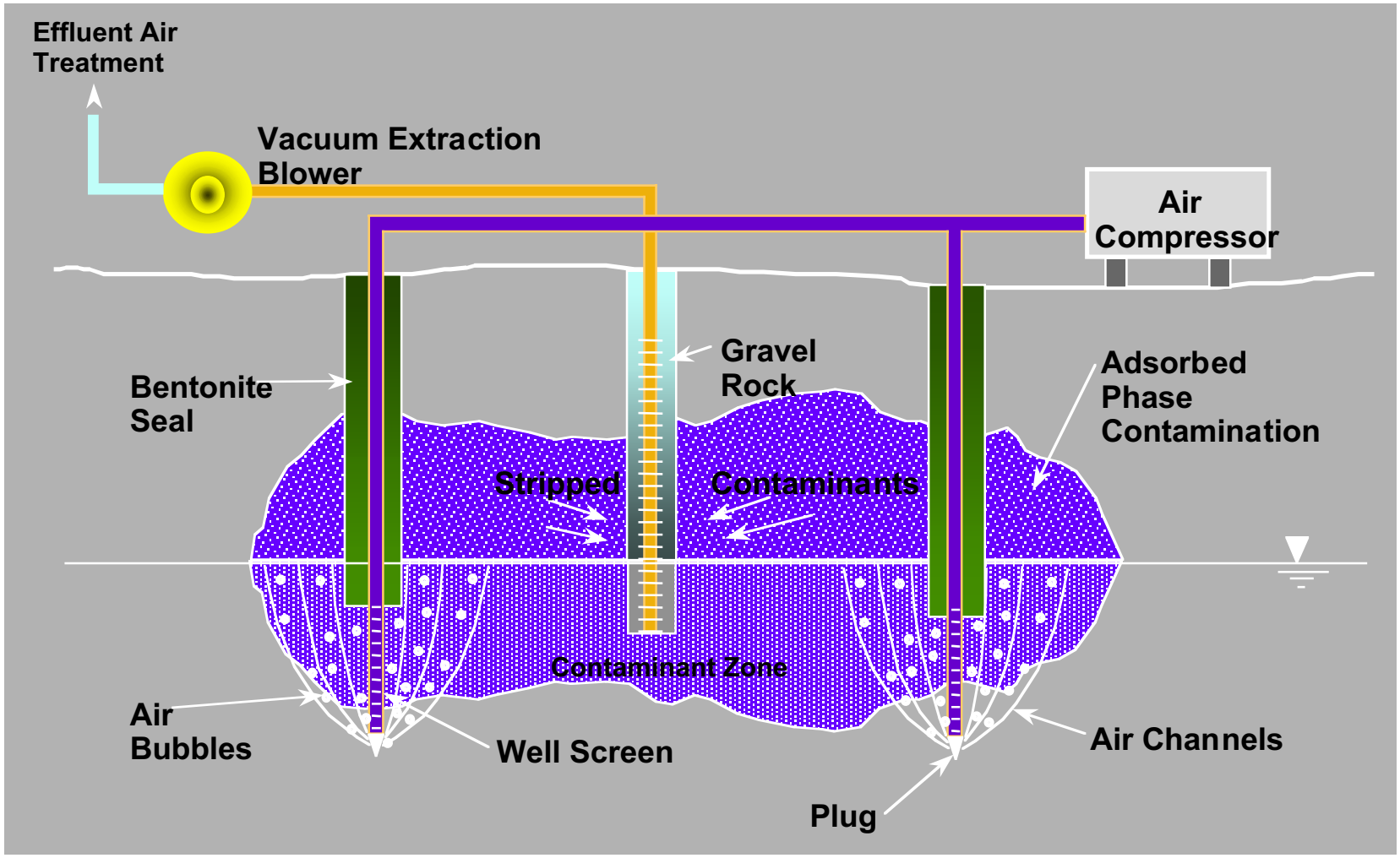
ARCADIS

STOP

Air Sparging Process Schematic

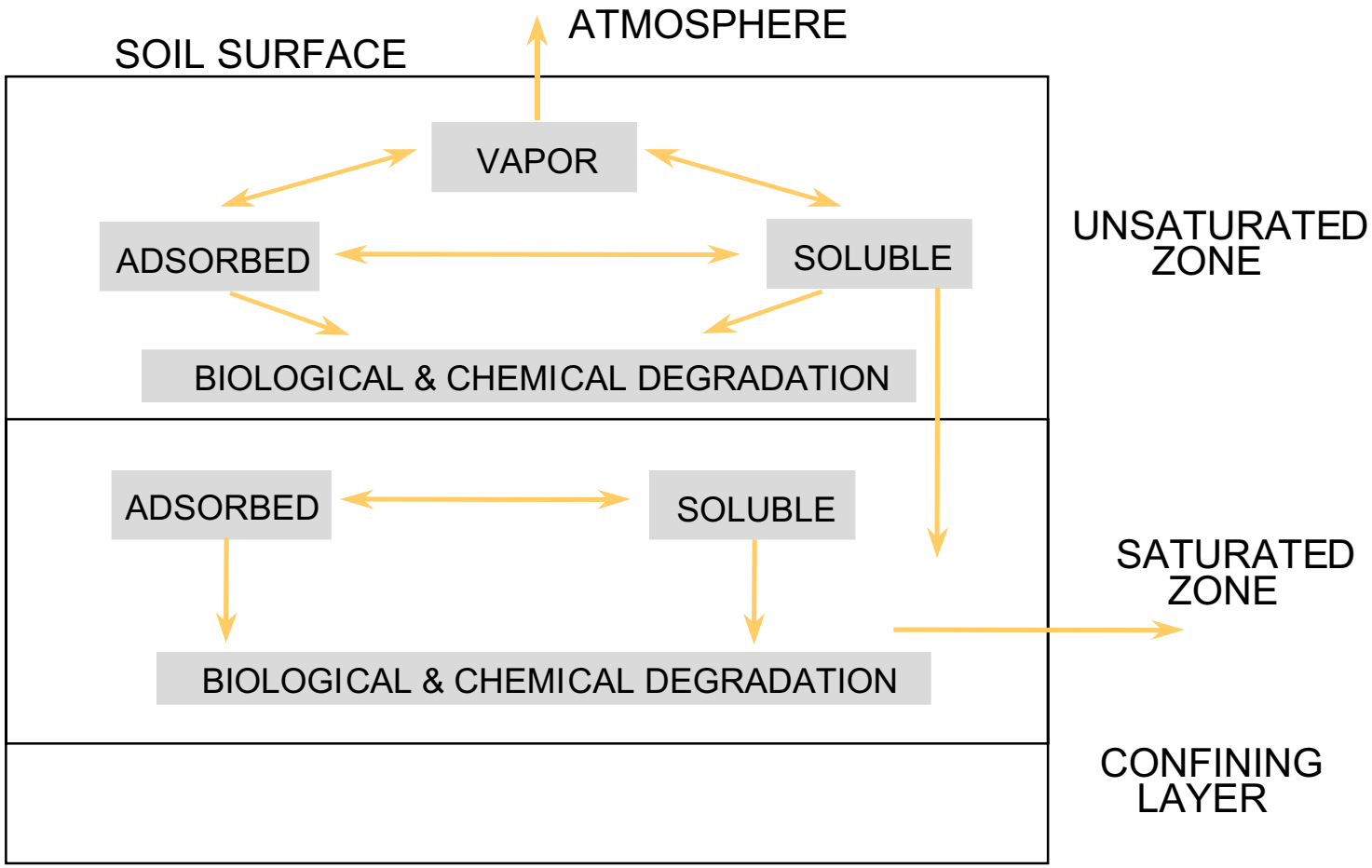


In-Situ Air Sparging Schematic



Monitored Natural Attenuation

Monitored Natural Attenuation



Latest Information from EPA

www.epa.gov/swerust1/directiv/d9200417.htm
or
Hot Line 800-424-9346 or 703-412-9810

Other Information Sources

- Natural Attenuation In Soil
  - www.lgst.com/matrix/section4/4_4.html
- Air Force Center for Environmental Excellence Site
  - www.afcee.brooks.af.mil/afceefrm.htm
  - www.afcee.brooks.af.mil/er/toolbox.htm
- Bioremediation Discussion Group
  - biogroup.gzea.com/

Other Information Sources (Cont.)

- U.S. EPA Bioremediation
  - www.epa.gov/ORD/WebPubs/biorem/
  - www.epa.gov/swerffrr/chlorine.htm
  - www.epa.gov/swerust1/directiv/9200_417.htm#other
  - www.epa.gov/ORD/WebPubs/biorem/D9200417.pdf
- Symposium on Natural Attenuation of Groundwater
  - burgundy.uwaterloo.ca/biol447new/epadocs/natural1.htm
- Remediation Technologies Screening Matrix and Reference Guide, Version 3.0
  - www.frtr.gov/matrix2/section3/tables3_2.html

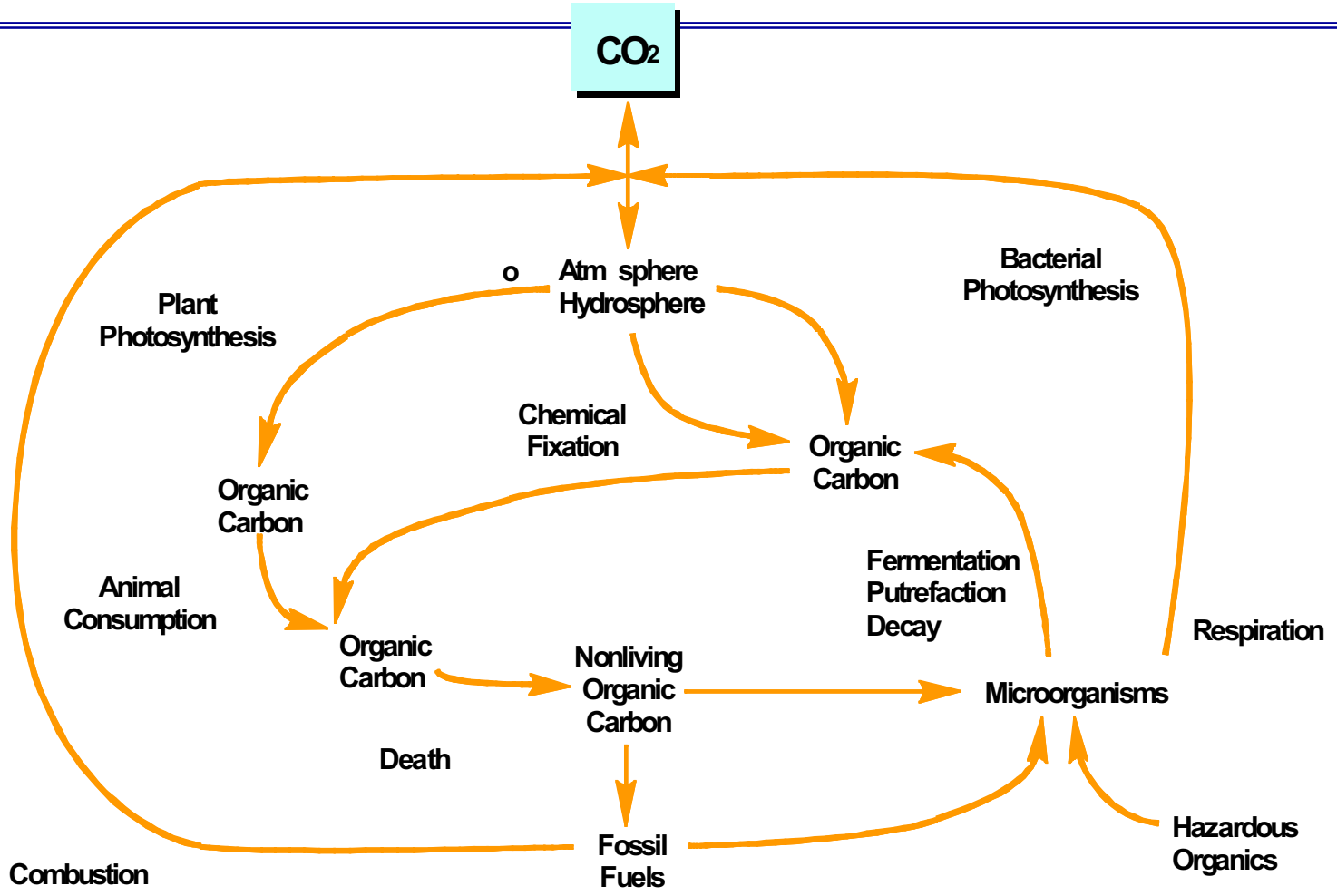
Definitions

- Anthropogenic - Manmade
- Aerobe - Organism that uses oxygen as an electron acceptor
- Anaerobe - Organism that uses molecules other than oxygen as electron acceptors
- Daughter products - Compounds that result from biodegradation of other compounds
- Cometabolism - Degradation of a non-growth substrate during degradation of a growth substrate

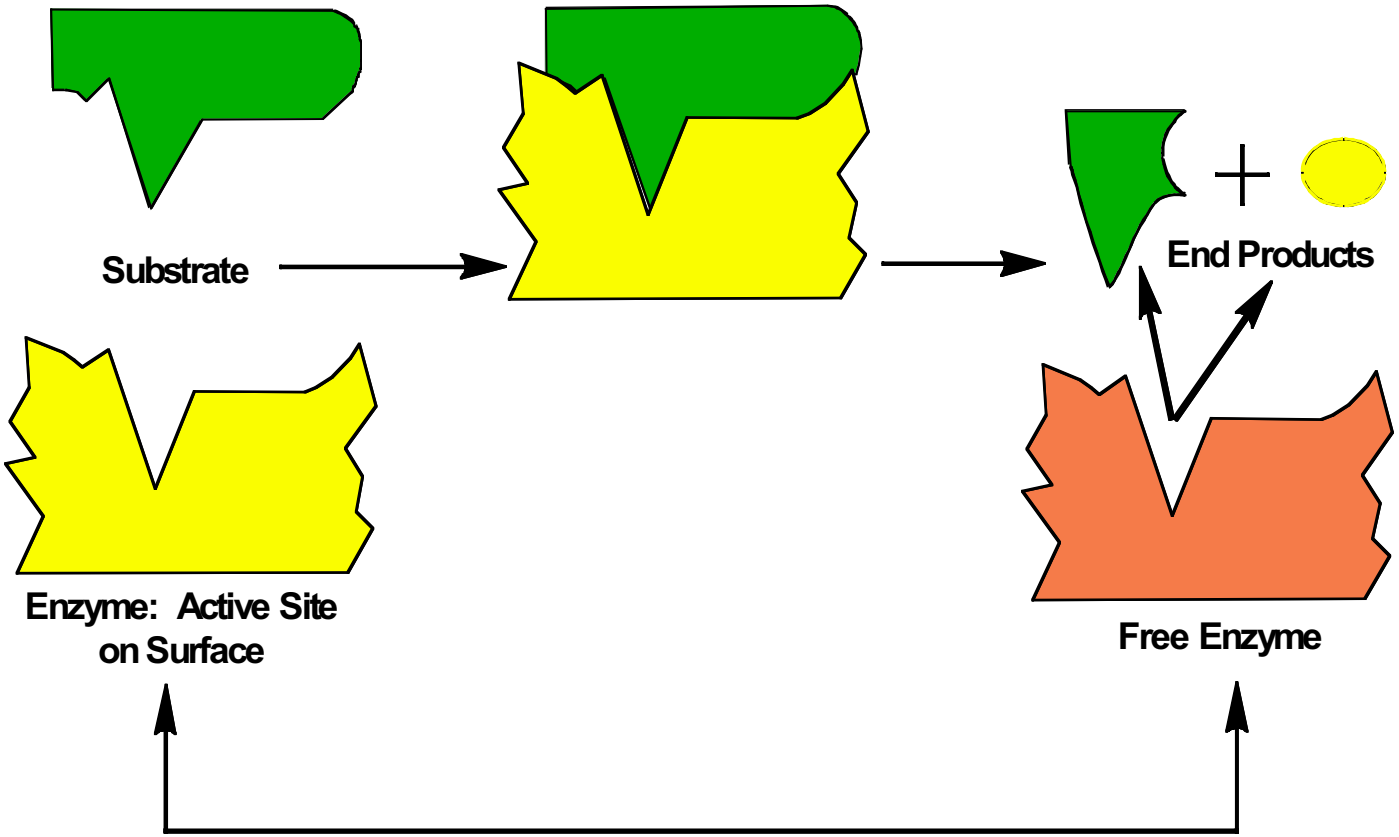
Definitions (Cont.)

- Biodegradation - Biological transformation of an organic chemical to another form
- Mineralization - Conversion to carbon dioxide, water, and inorganic products
- Persistent - Resistant to biodegradation under a specific set of conditions
- Recalcitrant - Inherent resistance to any degree of biodegradation
- Respiration - Process of coupling oxidation of organic compounds with reduction of inorganic compounds

Carbon Cycle

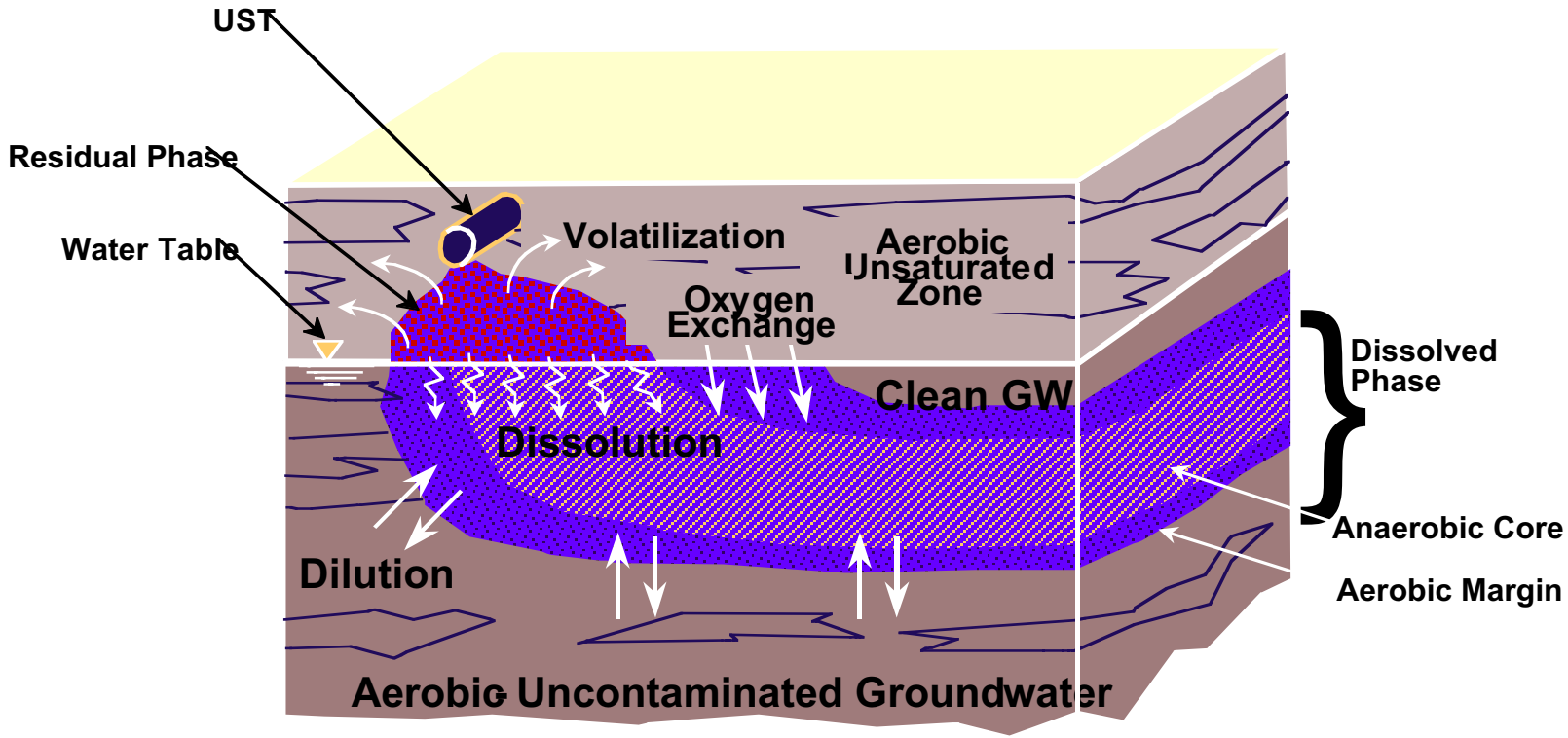


Enzymes as a Lock and Key



Natural Attenuation of Petroleum Hydrocarbons

Typical Hydrocarbon Plume Undergoing Natural Bioremediation



CROSS SECTION

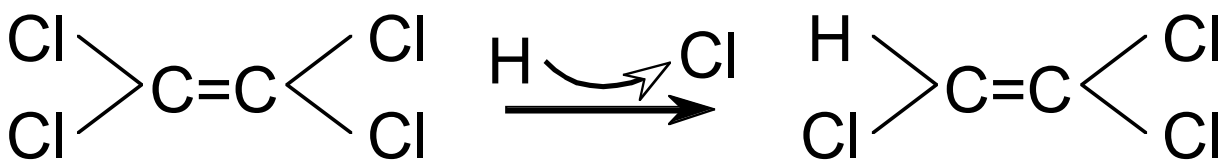
REDOX Versus Respiration Mechanism

Redox	Respiration	e Acceptor	By-Products
+ 200 mv	Aerobic	O_2	CO_2
	Denitrification	NO_3^{2-}	NO_2^-, N_2, NH_3
	Manganese Reduction	Mn^{4+}	Mn^{2+}
	Iron Reduction	Fe^{3+}	Fe^{2+}
	Sulfanogenesis	SO_4^{2-}	H_2S
- 400 mv	Methanogenesis	CO_2	CH_4

Natural Attenuation of Chlorinated Solvents

Reductive Dechlorination of Chlorinated Aliphatic Hydrocarbons

PCE Degrades to TCE



PCE **TCE**

Full Degradation

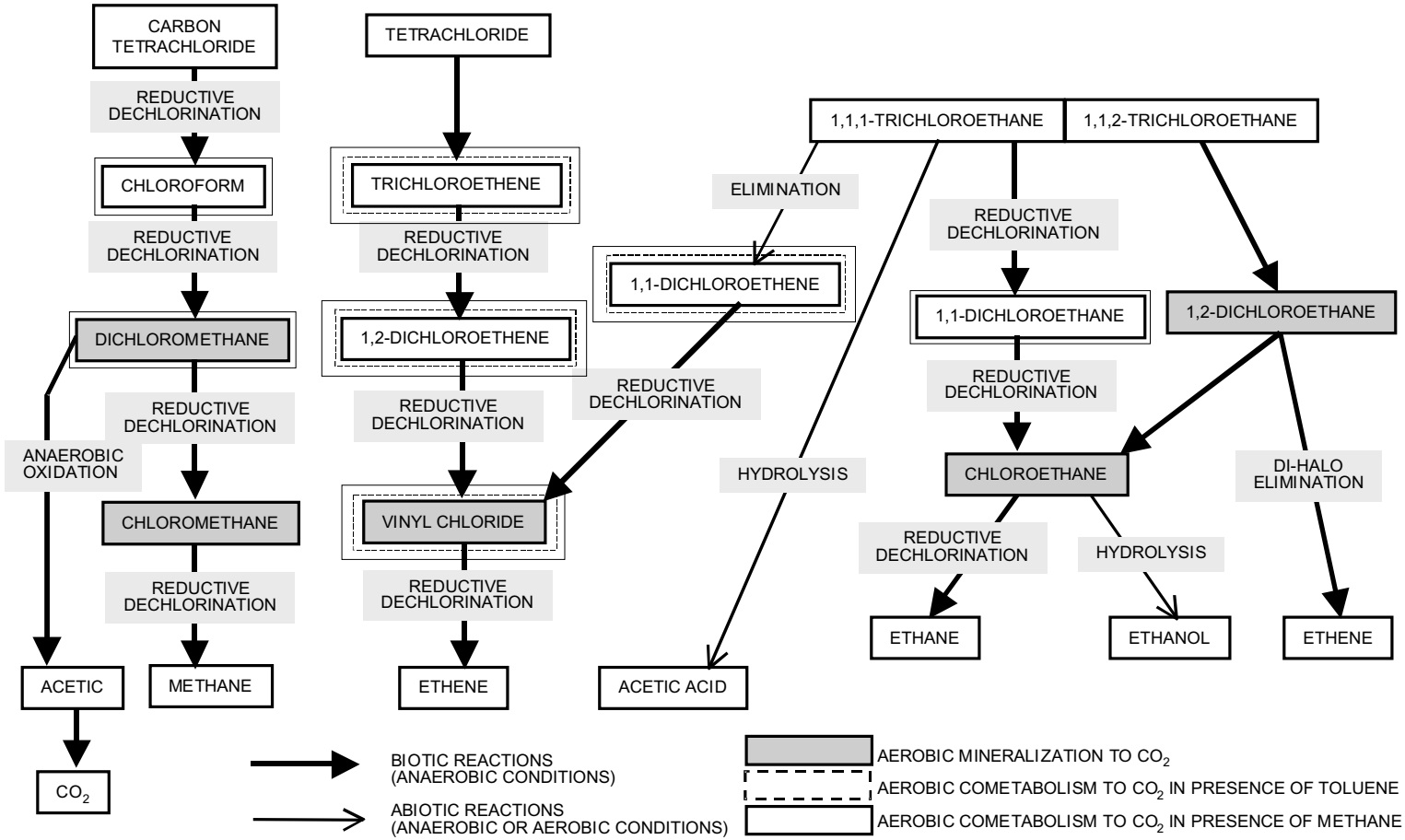
PCE → TCE → DCE → VC → ETHENE → ETHANE → CO_2

$CCl_2=CCl_2$ $CHCl=CCl_2$ $CHCl=CHCl$ $CH_2=CHCl$ $CH_2=CH_2$ C_2H_6 CO_2

Aerobic Degradation

- Cometabolism
  - Chlorinated solvent is neither electron acceptor nor primary substrate
  - Requires an enzyme or cofactor
  - Many chlorinated solvents, except PCE
  - Does not break solvent down completely

Common Degradation Pathways



SOURCE: ITRC 1999

Reactive Zone Remediation Technology

In-Situ Reactive Zones

"…the creation of a subsurface zone where migrating contaminants are intercepted and permanently immobilized or degraded into harmless end products."

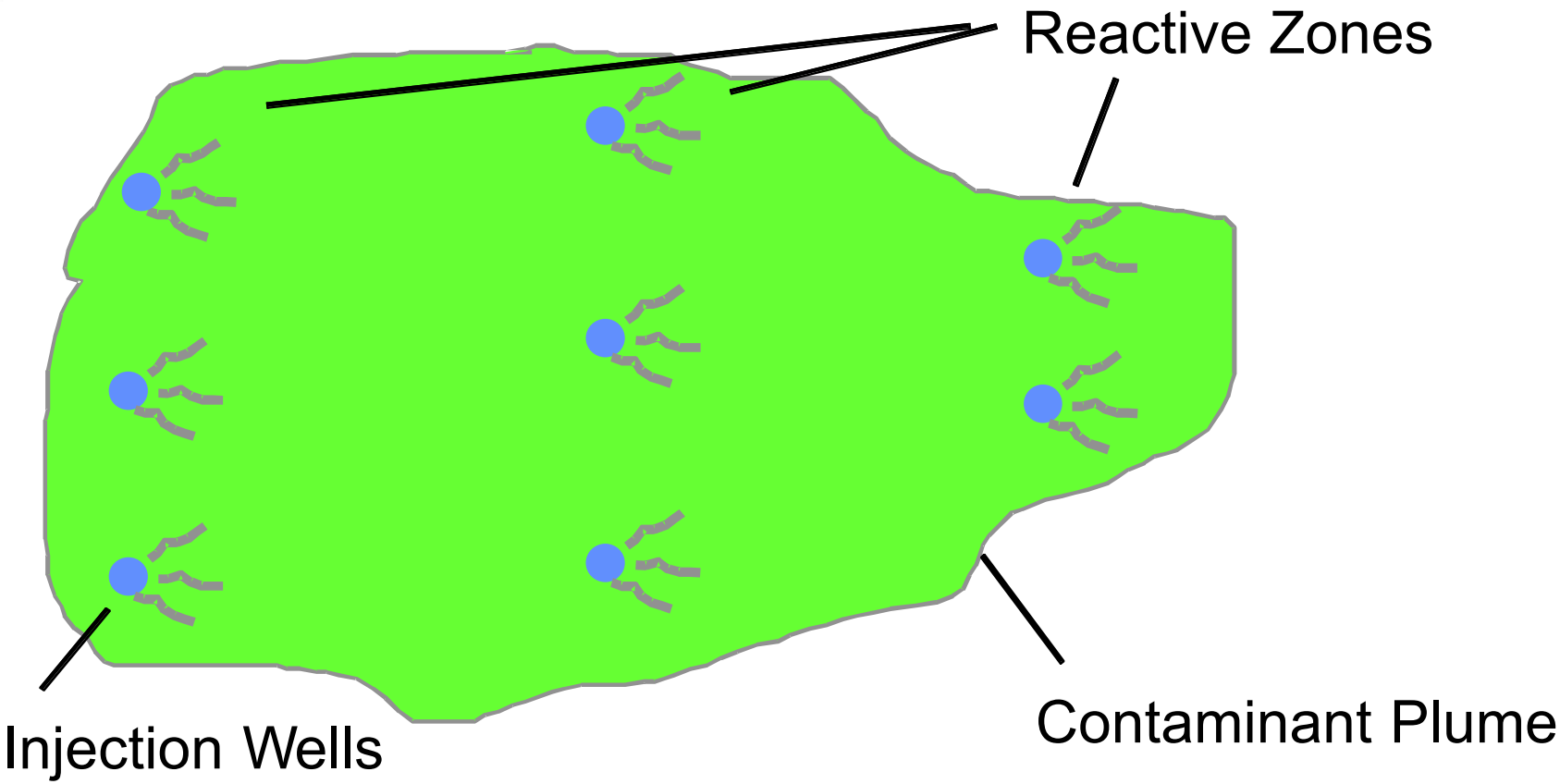
Primary Elements

- Creation of a Subsurface Zone
- Delivery of Reactive Reagents
- Migrating Contaminants Intercepted
- Permanently Immobilized or Degraded
- Harmless End Products

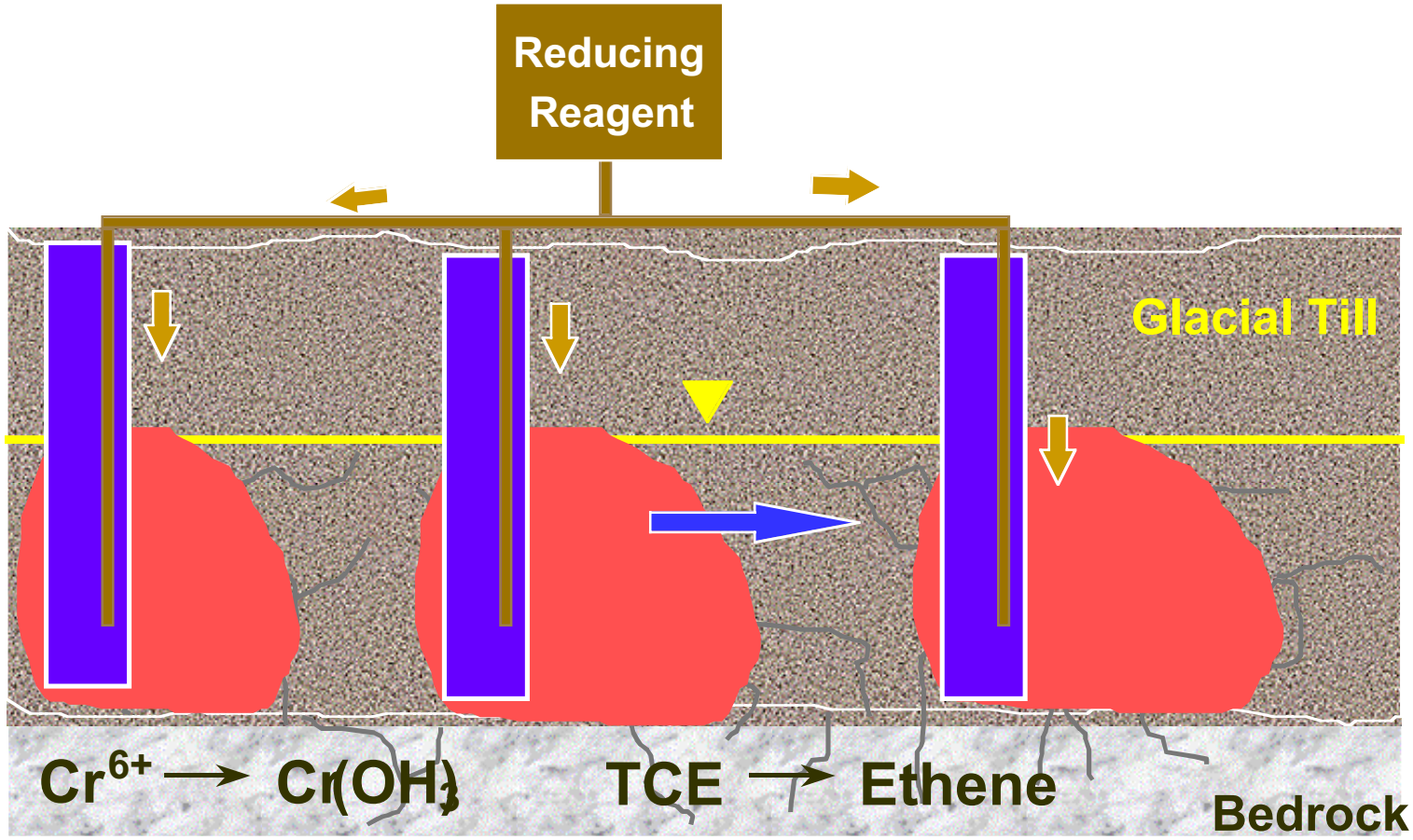
Required Elements

- Carbon Source
  - Natural, anthropogenic, supplemental
- Electron Acceptors
  - Nitrate, iron, manganese, sulfate, carbon dioxide
- Reducing Environment
  - Low redox (< -100 mV)
- Demonstrated Reduction End-Products

In-Situ Reactive Zone



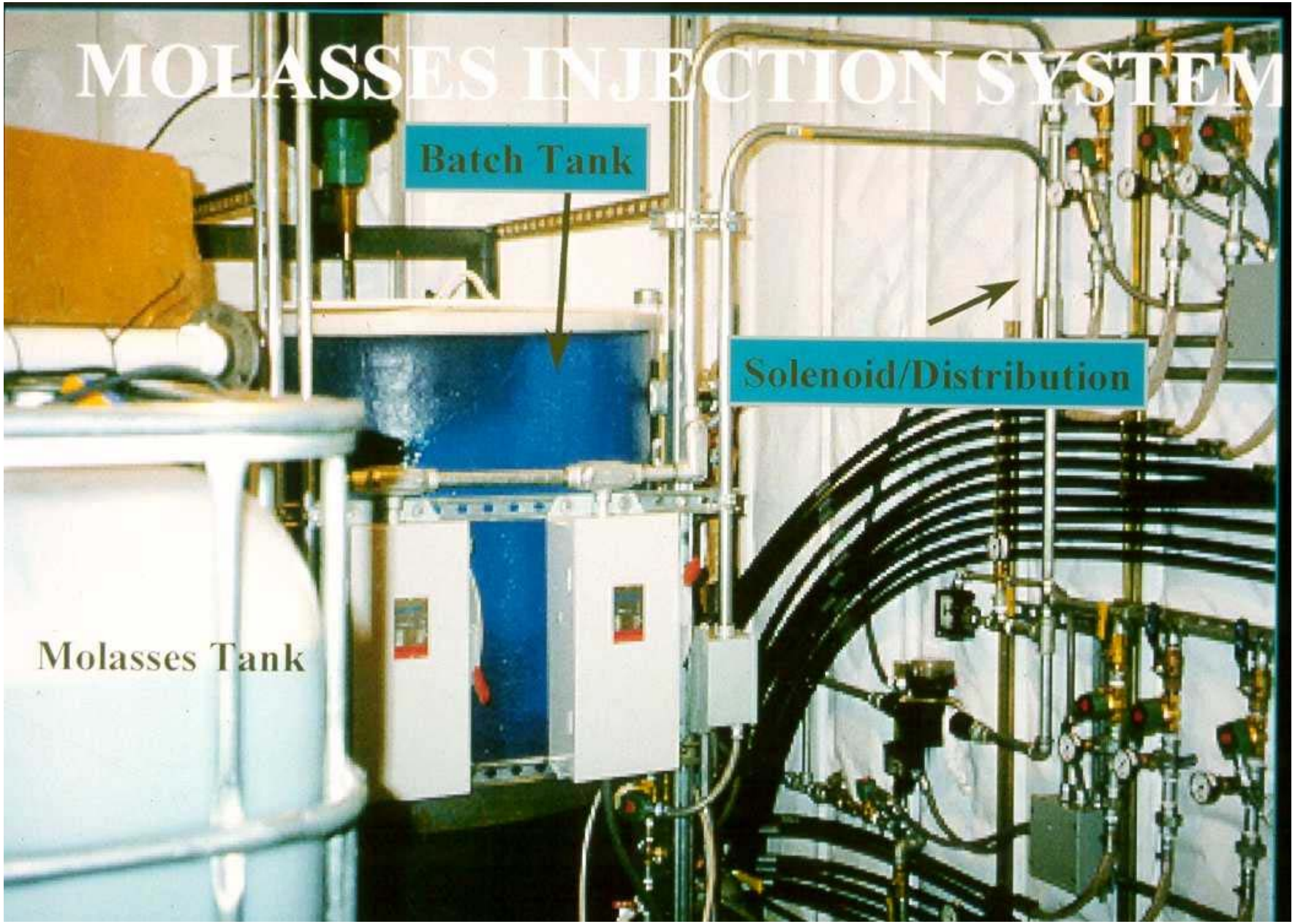
Reducing Reactive Zones

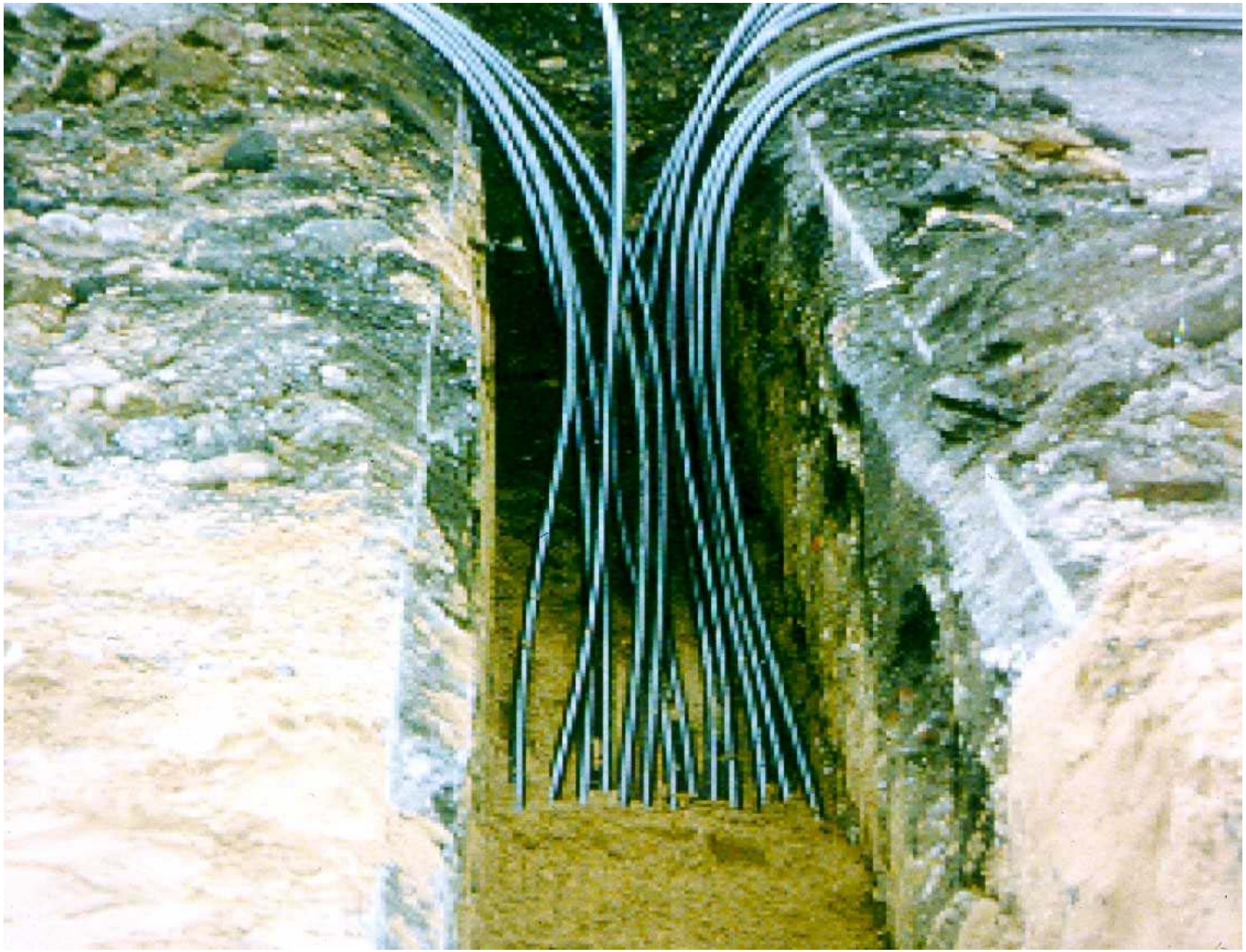


Region III Superfund Site Case History

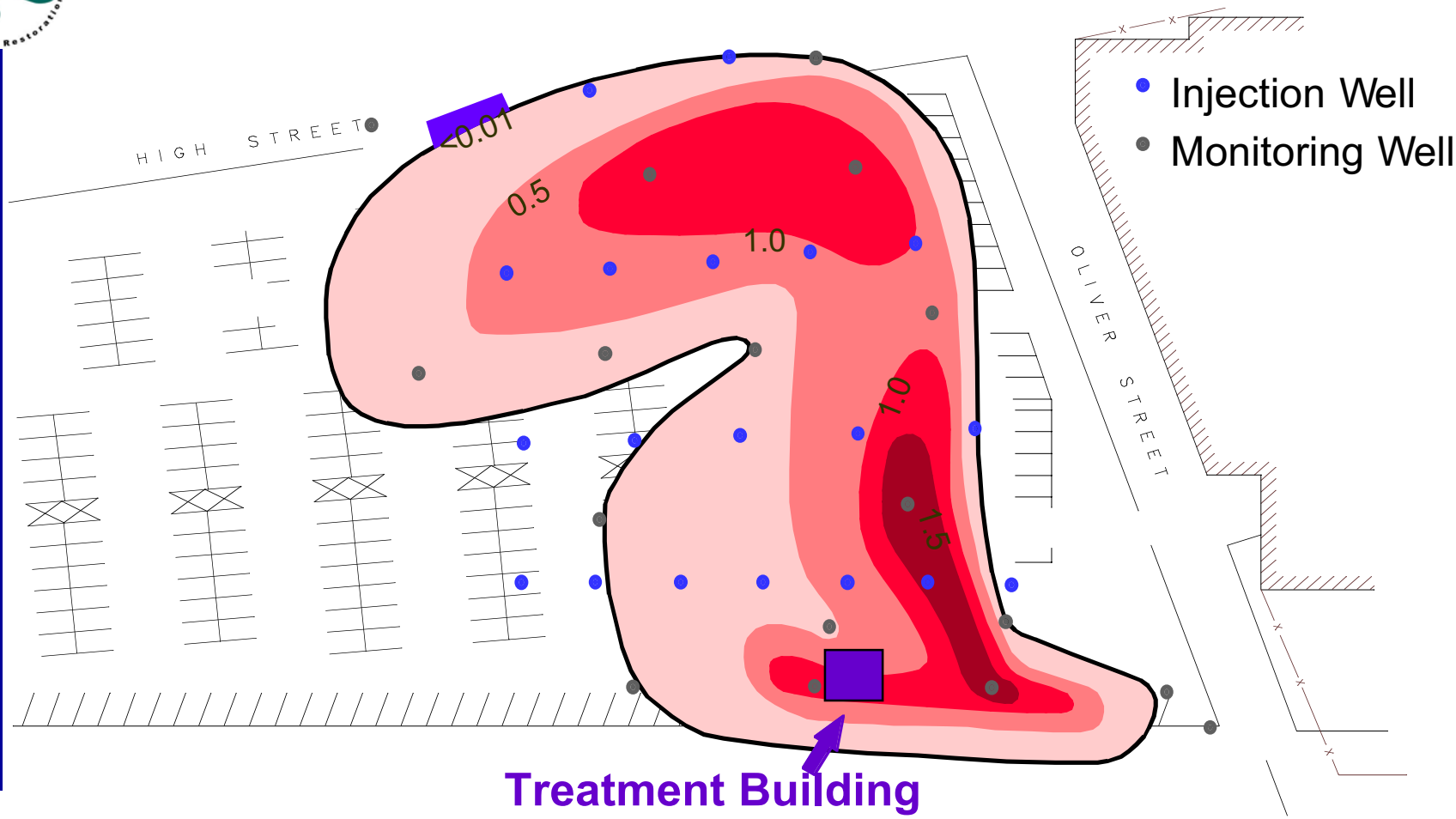
TREATMENT BUILDING

MOLASSES INJECTION SYSTEM

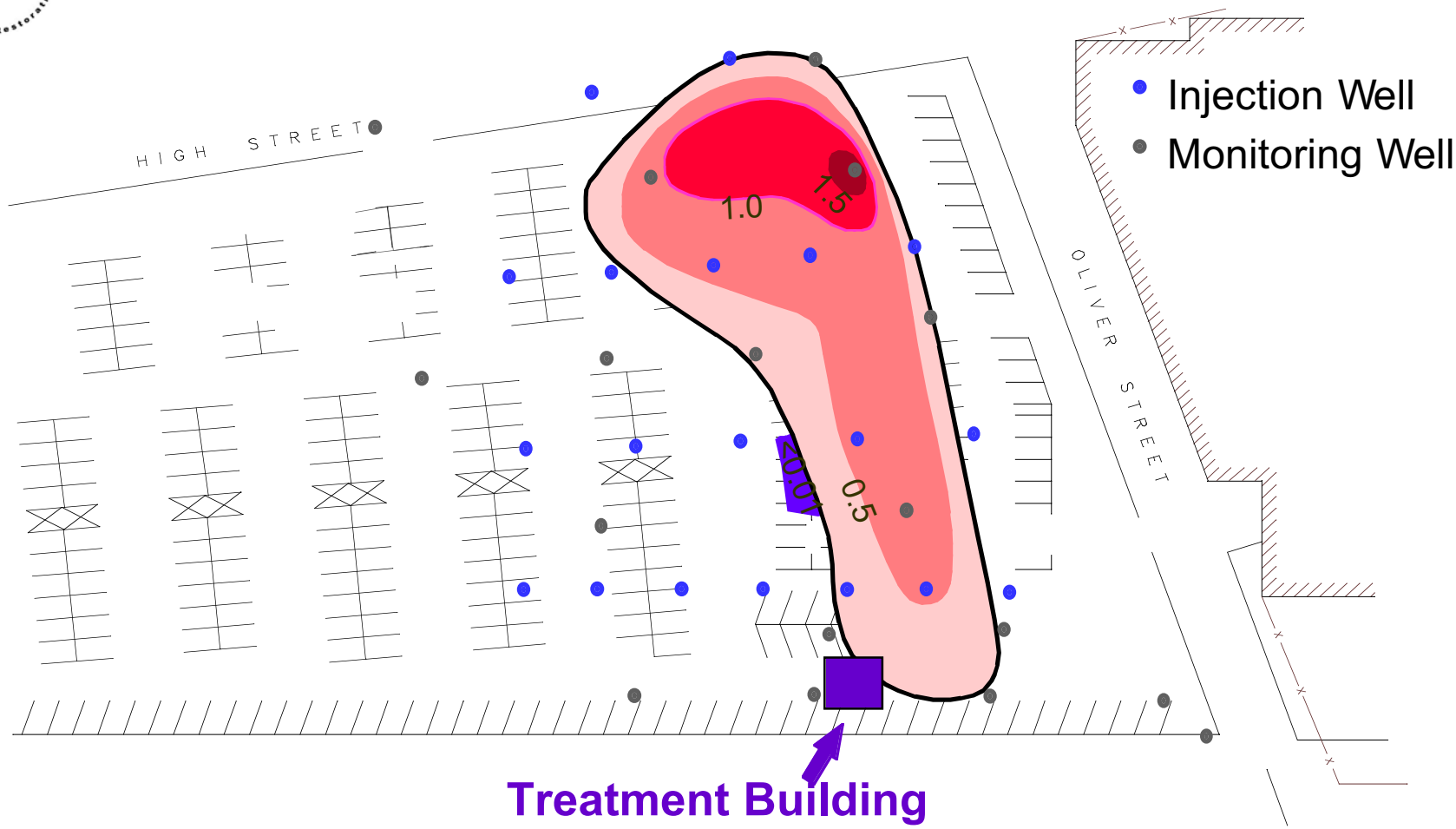




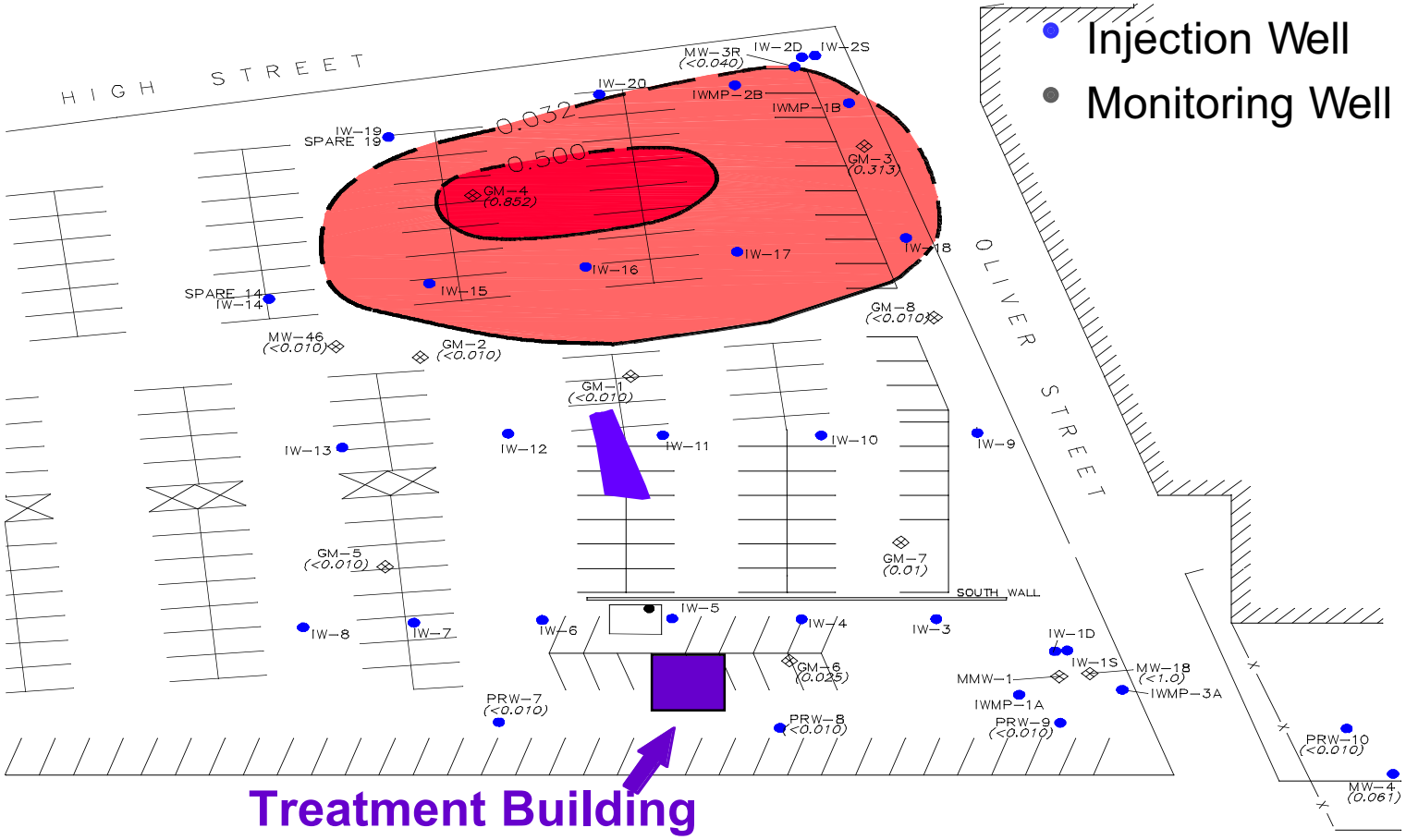
Cr6+ Plume January 1997



Cr6+ Plume November 1997

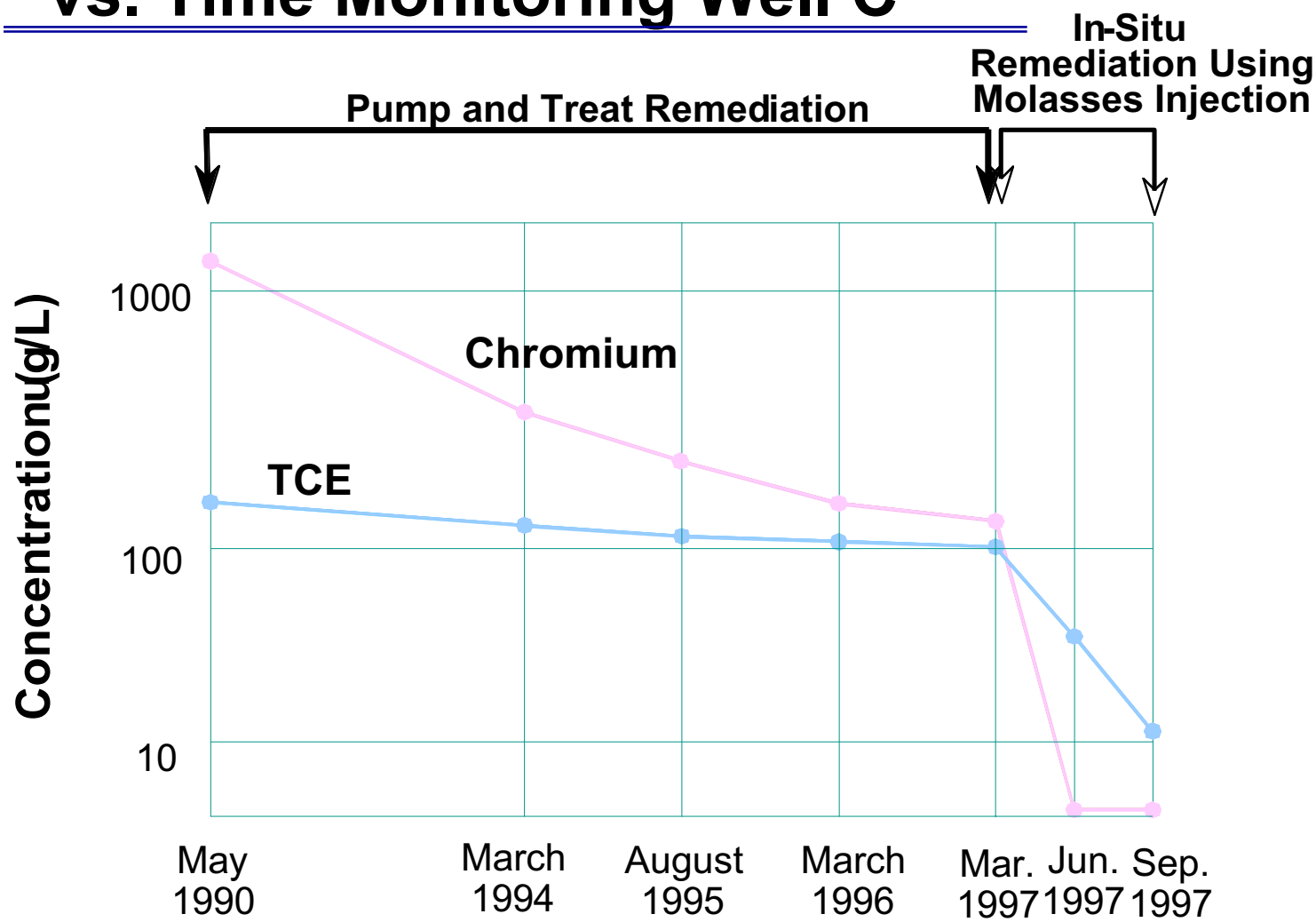


Cr6+ Plume July 1997



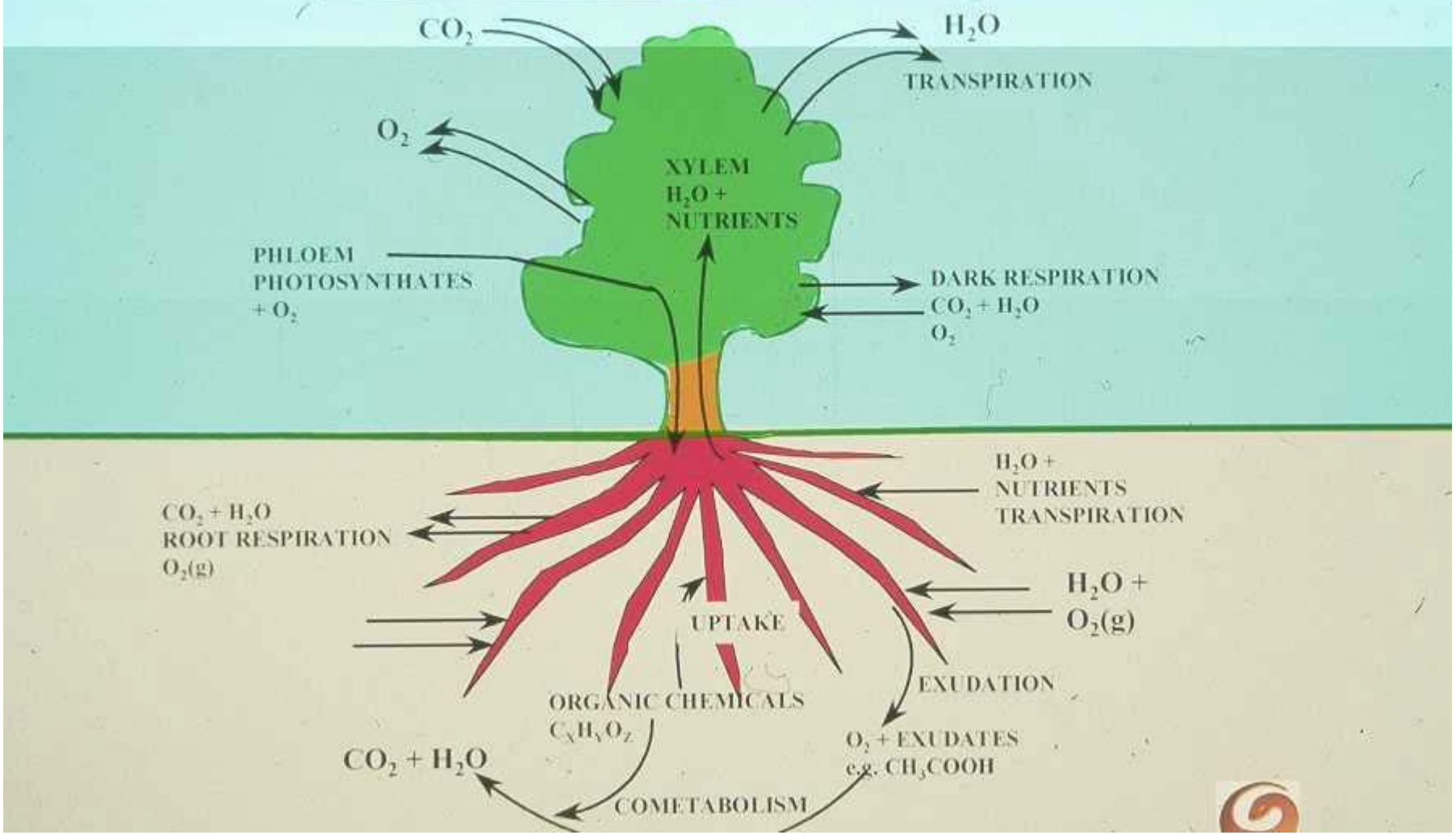
Remediation Technologies

TCE and Chromium Concentrations vs. Time Monitoring Well C



Phytoremediation

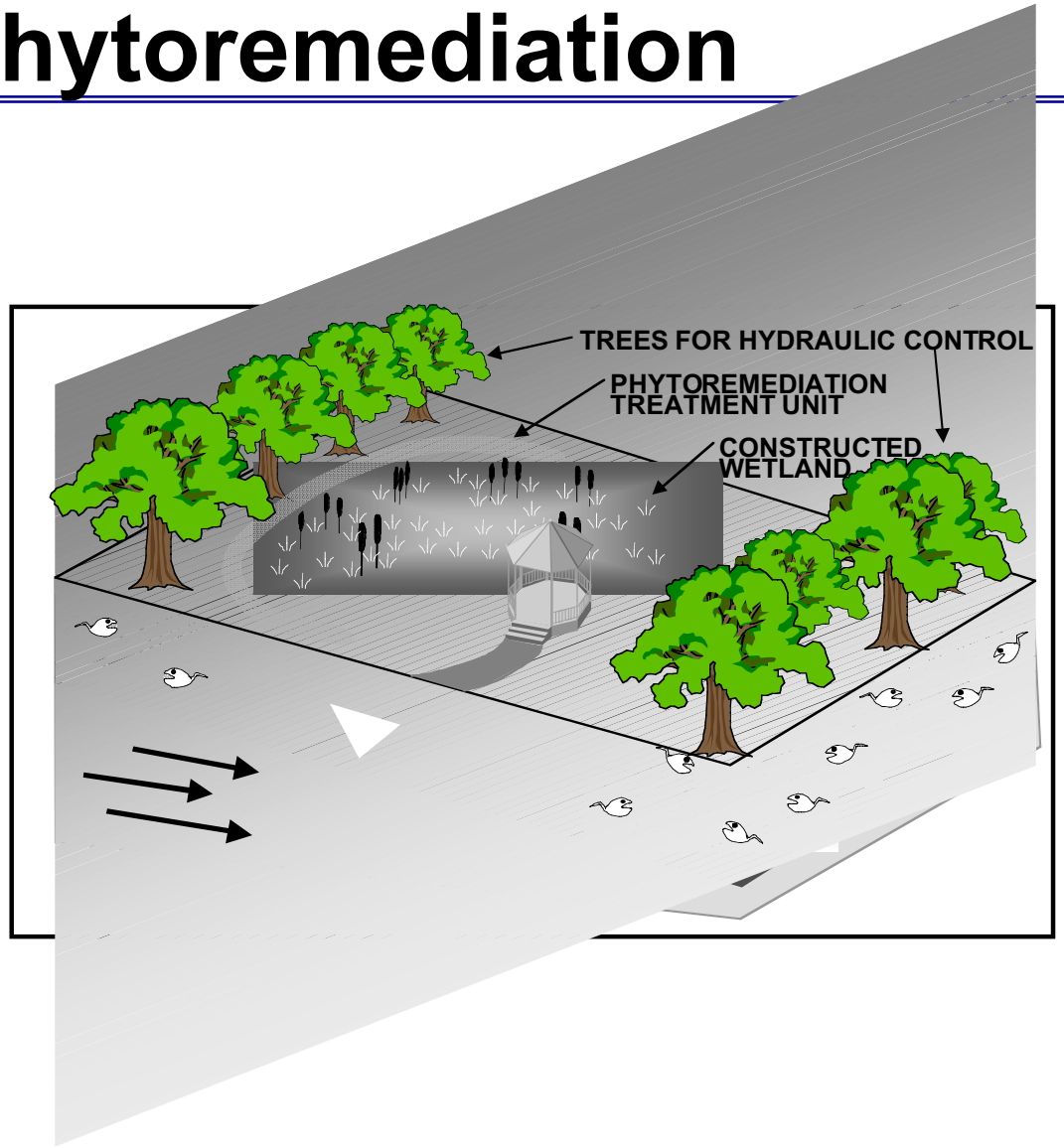
MASS FLOWS IN *POPULUS SPP*



Rhizosphere Enhancement Alabama Case History

- Alabama, Diesel Impacted UST Soils, Stockpiled
  - 1500 cubic yards
  - Soils were spread out to 2 ft depth
  - Baseline soil analysis method 8015-DRO
  - October 1995: Remediation objective <100 ppm TPH-DRO 8015
  - 23 Soil analysis - 1 ft depth
  - 16 of 23 > 100 ppm TPH-DRO
  - 23 of 23 > 54.6 ppm TPH-DRO
  - TPH-DRO Range 321 - 54.6 ppm

Rhizosphere Enhancement Alabama Case History (Cont.)

- October 1996: Method 8015 - DRO
- 23 Soil Analyses - 1 ft depth
- 0 of 23 Samples @ 1 ft > 100 ppm TPH-DRO
- 4 of 23 Samples @ 1 ft > 10 ppm TPH-DRO
- 19 of 23 Samples @ 1 ft < 10 ppm TPH-DRO
- 3 Samples of soils attached to roots 2.66 to 6.67 ppm TPH-DRO
- 1 Sample @ 2 ft - 70 ppm TPH-DRO
- 2 Samples @ 2 ft - 3-6 ppm TPH-DRO

The Future Applications of Phytoremediation