Contaminant Transport

Today's agenda

- Sources of contamination
- Contaminant transport
  - Advection
  - Diffusion
  - Dispersion

All water bodies are vulnerable to contamination.

→ Oceans, estuaries, lakes, rivers/streams, wetlands, groundwater

Major sources of contamination (mostly anthropogenic):

- Municipal
- Industrial
- Agricultural

Major types of contamination:

- ☠ Chemicals
- ☠ Nutrients
- ☠ Pathogens
- ☠ Sediment and debris
- ☠ Temperature - Brayton Point Power Station

Mount Hope Bay

Importance of Solute Transport in Groundwater:

- Contaminate drinking water – anthropogenic or natural
- Radioactive waste disposal - Yucca Mountain!
- Saltwater intrusion

Sources of Groundwater Contamination In the US:

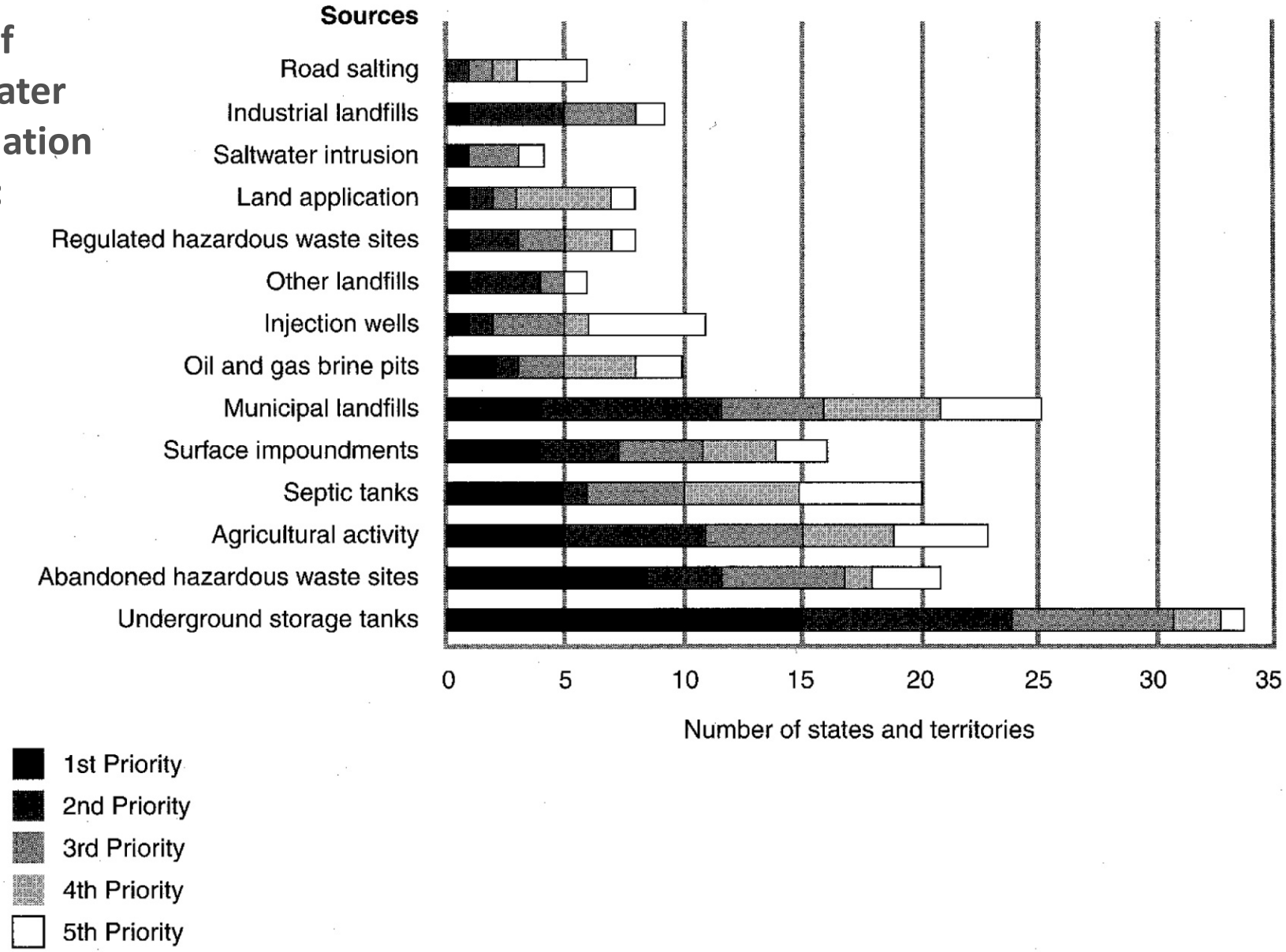
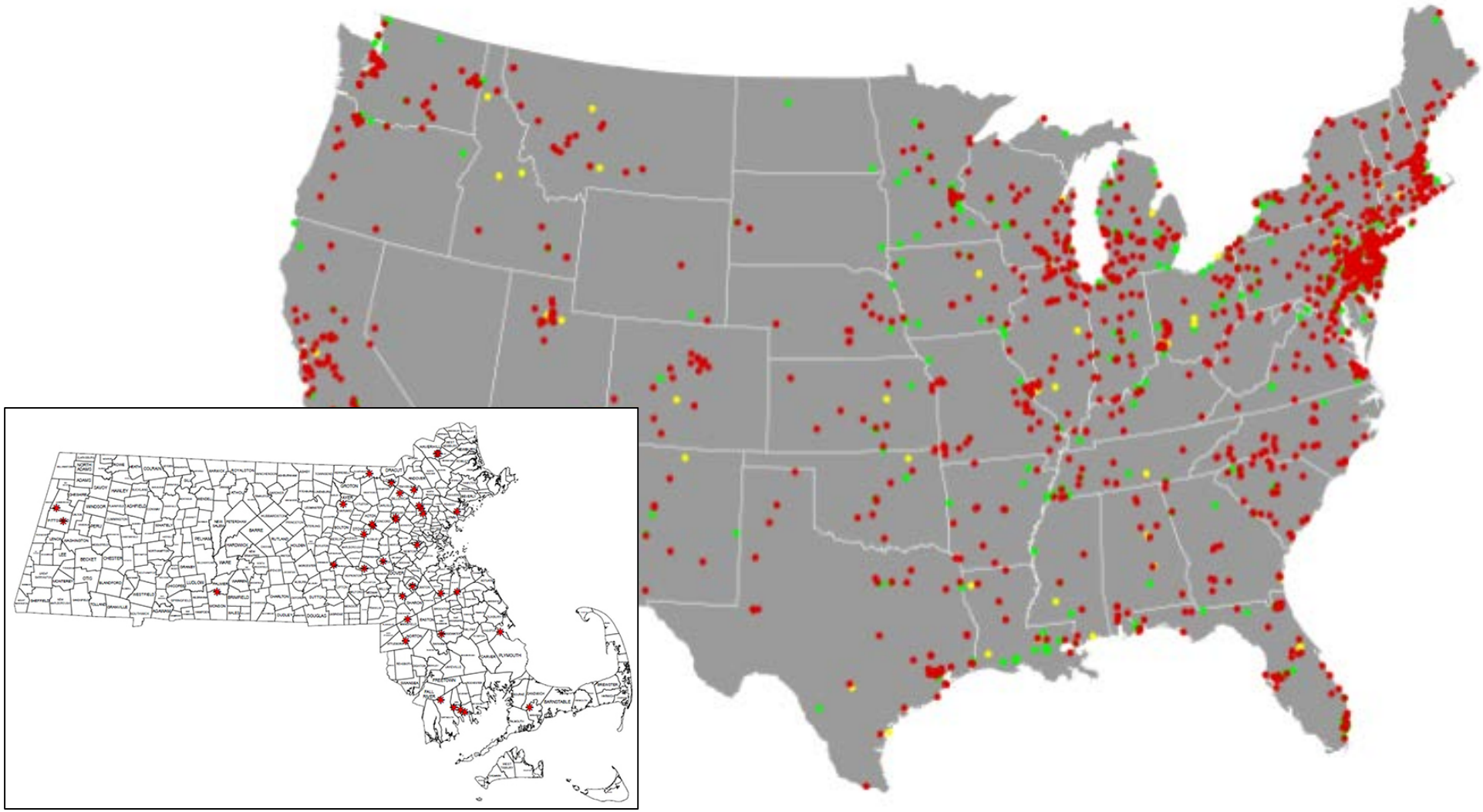


Figure 9.20 Sources of groundwater contamination ranked in terms of priority by states and territories of the United States.
(From EPA, 1990a.)

Superfund site locations



Source: Boston University

Drinking water standards

- **Dissolved compounds and elements** can be toxic and carcinogenic

- Some examples of EPA's *Maximum Contaminant Levels* (MCLs) for water supplies established under the Safe Drinking Water Act (note that these concentrations are very low! μg = PPM):

Trichloroethylene (TCE)	5 μg/L	(solvent, manufacturing)
Tetrachloroethylene (PCE)	5 μg/L	(textiles, dry cleaners)
Vinyl Chloride	2 μg/L	(manufacturing)
Benzene	5 μg/L	(solvent, manufacturing)
Carbon Tetrachloride	5 μg/L	(propellant, manufacturing)
Copper	1 mg/L	(natural, plumbing)
Lead	0.05 mg/L	(paint, plumbing)
Mercury	2 μg/L	(electrical products, batteries)

BTEX: Benzene, Toluene, Ethylbenzene, and Xylene. Four volatile organic compounds found in gasoline.

Contamination Clean-up:

"Superfund": The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) was enacted by Congress in 1980.

- Created a tax on the chemical and petroleum industries
- Provided Federal authority to respond directly to releases of hazardous substances (short-term removals and long-term remediation)
- $1.6 billion was collected over 5 years, going to a trust fund (Superfund) for cleaning up abandoned hazardous waste sites
- Provided for liability of parties responsible for release of hazardous waste (litigation – see *Erin Brockovich* and *A Civil Action*)
- Established a National Priorities List (NPL) of contaminated sites

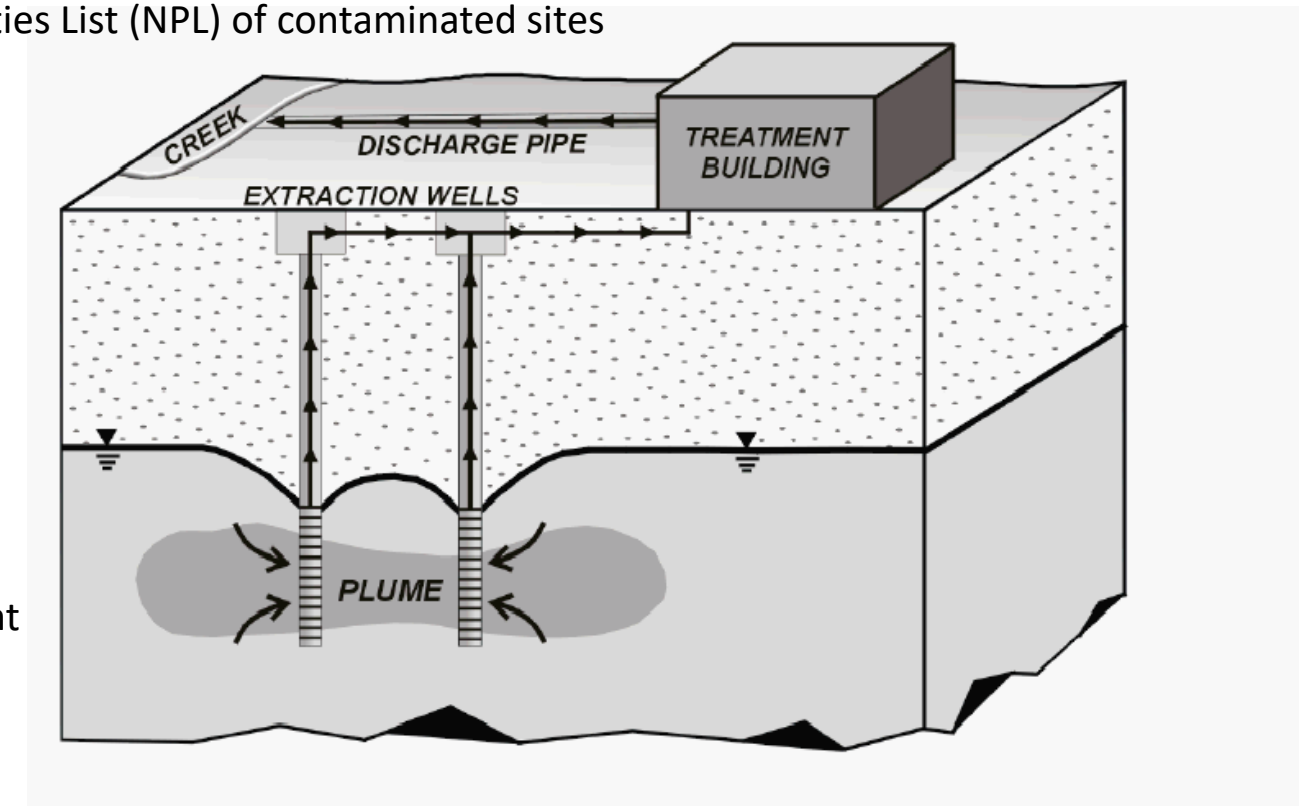
Types of Remediation (clean-up)

In –Situ (below ground, in place)

- Pump-and-treat
- Bioremediation
- Air sparging
- Soil-vapor extraction
- Natural attenuation

Ex-Situ (above ground)

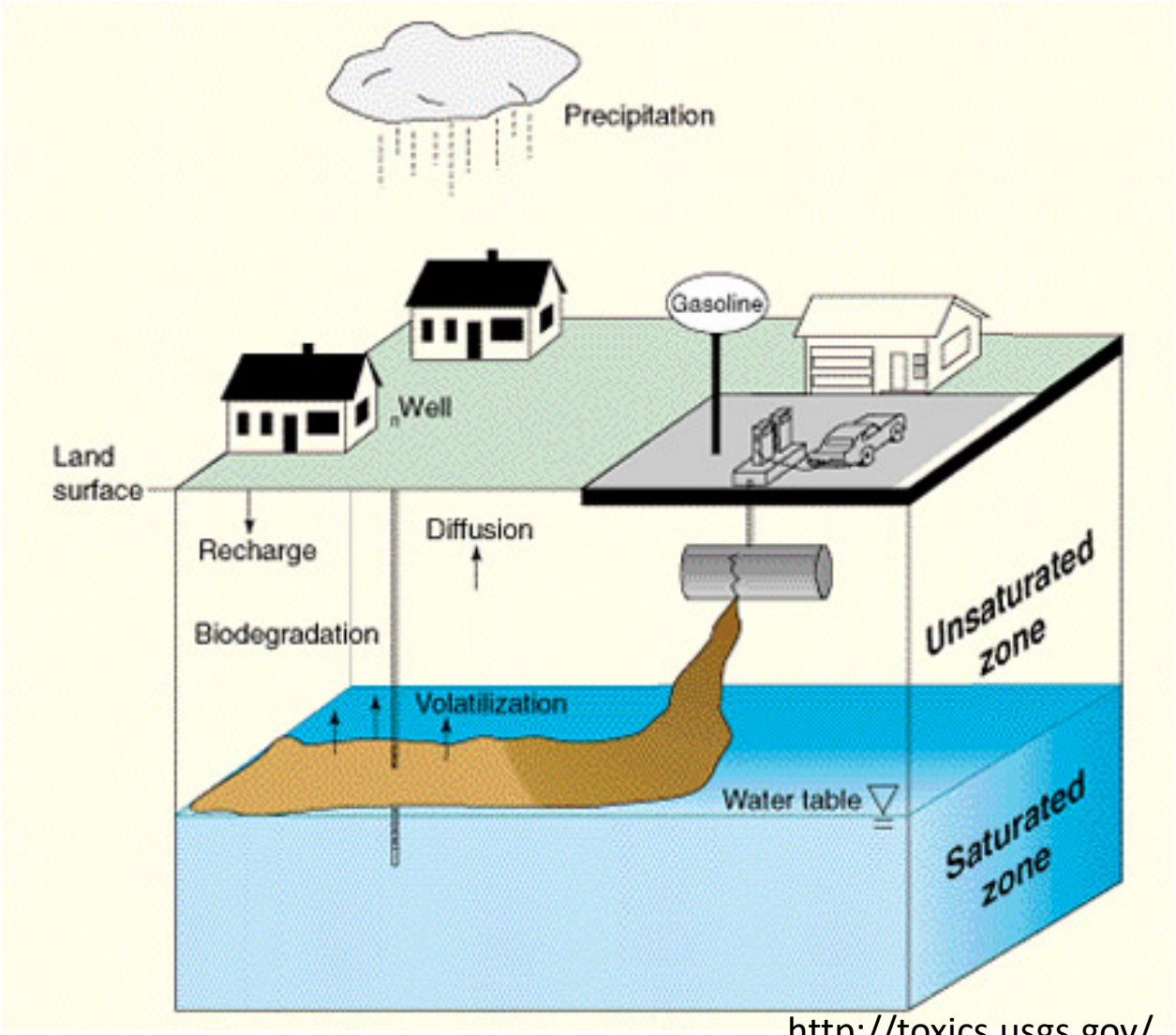
- Removal and disposal
- Removal and slurry treatment
- Removal and incineration



Immiscible compounds serve as a source of dissolved groundwater contamination.

NAPLs: Non-Aqueous Phase Liquids

LNAPL (lighter-than-water NAPL)



http://toxics.usgs.gov/

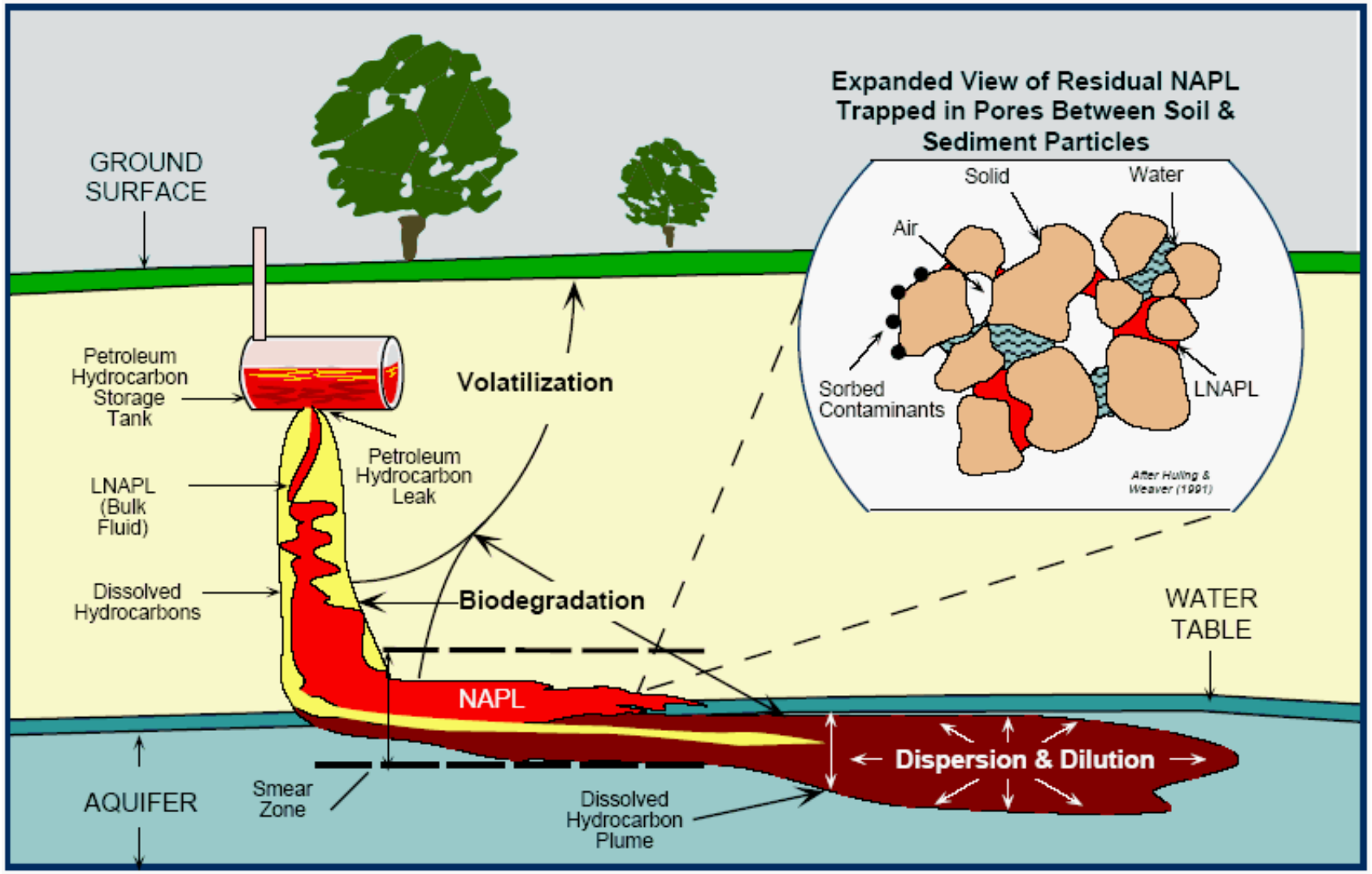
Immiscible compounds serve as a source of dissolved groundwater contamination.

NAPLs: Non-Aqueous Phase Liquids

LNAPL (lighter-than-water NAPL)

LNAPL (denser-than-water NAPL)

- Examples: gasoline (BTEX), diesel fuel
- Plume forms on surface of water table
- Migrates down water table gradient
- Must be skimmed



http://oceanworld.tamu.edu/resources/environment-book/groundwaterremediation.html

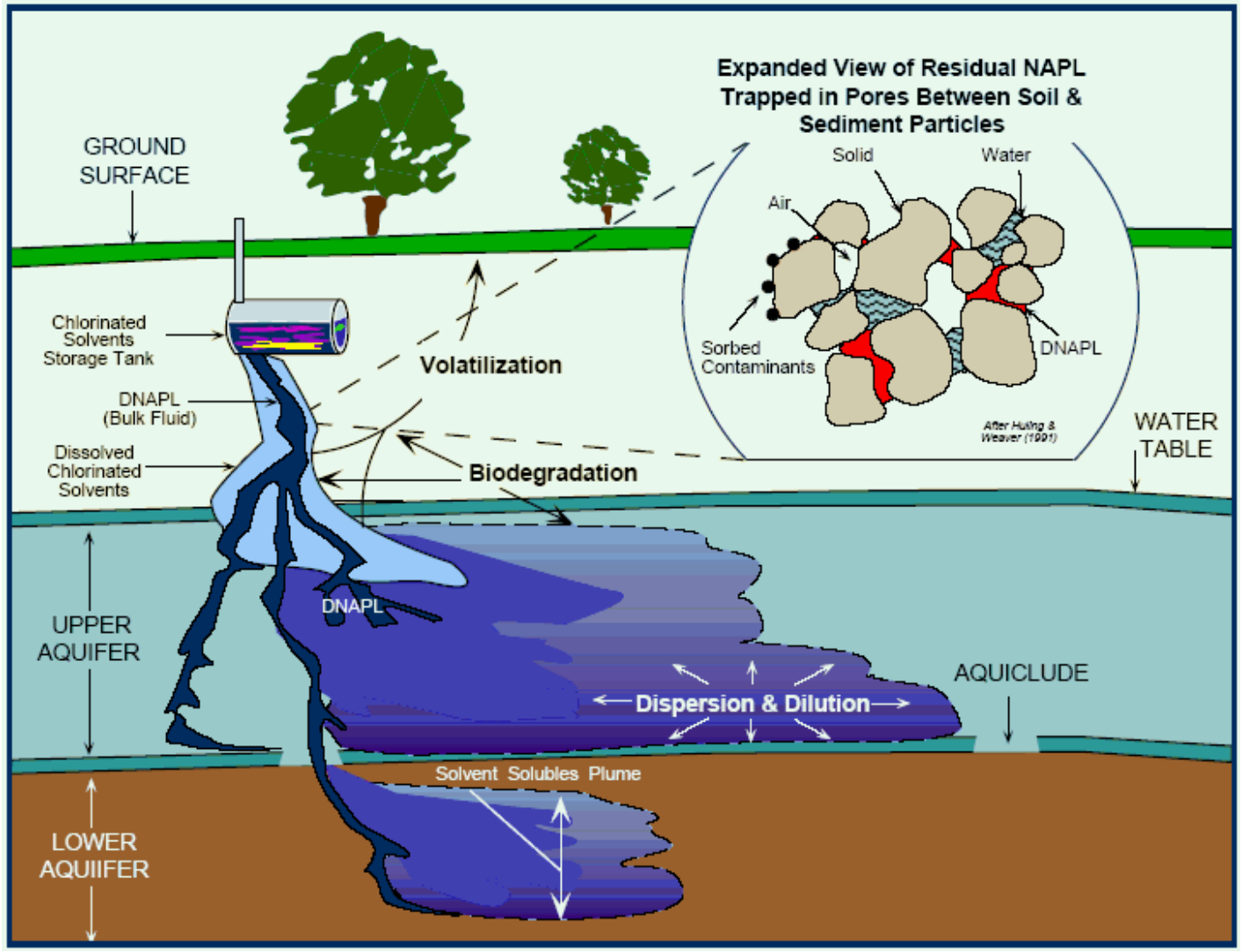
Immiscible compounds serve as a source of dissolved groundwater contamination.

NAPLs: Non-Aqueous Phase Liquids

DNAPL (denser-than-water NAPL)

DNAPL (denser-than-water NAPL)

- Examples: chlorinated hydrocarbons (TCE, TCA, Carbon Tetrachloride)
- Can sink to bottom of aquifer to form pool
- Can migrate down dip on aquifer bottom (**against hydraulic gradient**)
- Recovery difficult to impossible



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Immiscible compounds serve as a source of **dissolved** groundwater contamination.
NAPLs: Non-Aqueous Phase Liquids

The Problem:

- Easy to contaminate groundwater
- Low concentrations are hazardous
- Substances can migrate with flowing water
- Difficult to remove/remediate
- Exist as separate and **dissolved** phases

TopoDrive and ParticleFlow

http://water.usgs.gov/nrp/gwsoftware/tdpf/tdpf.html