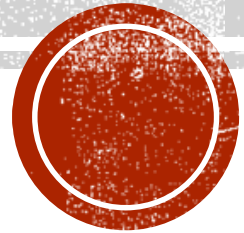
ENVIRONMENTAL POLLUTION & REMEDIATION



ENVIRONMENT

"The **sum total of all surroundings** of a living organism, including natural forces and other living things, which provide conditions for development and growth as well as of danger and damage."

POLLUTION

"Environmental pollution is "the **contamination** of the physical and biological components of the earth/atmosphere system to such an extent that normal **environmental processes** are adversely **affected**".

WHAT IS WASTE?

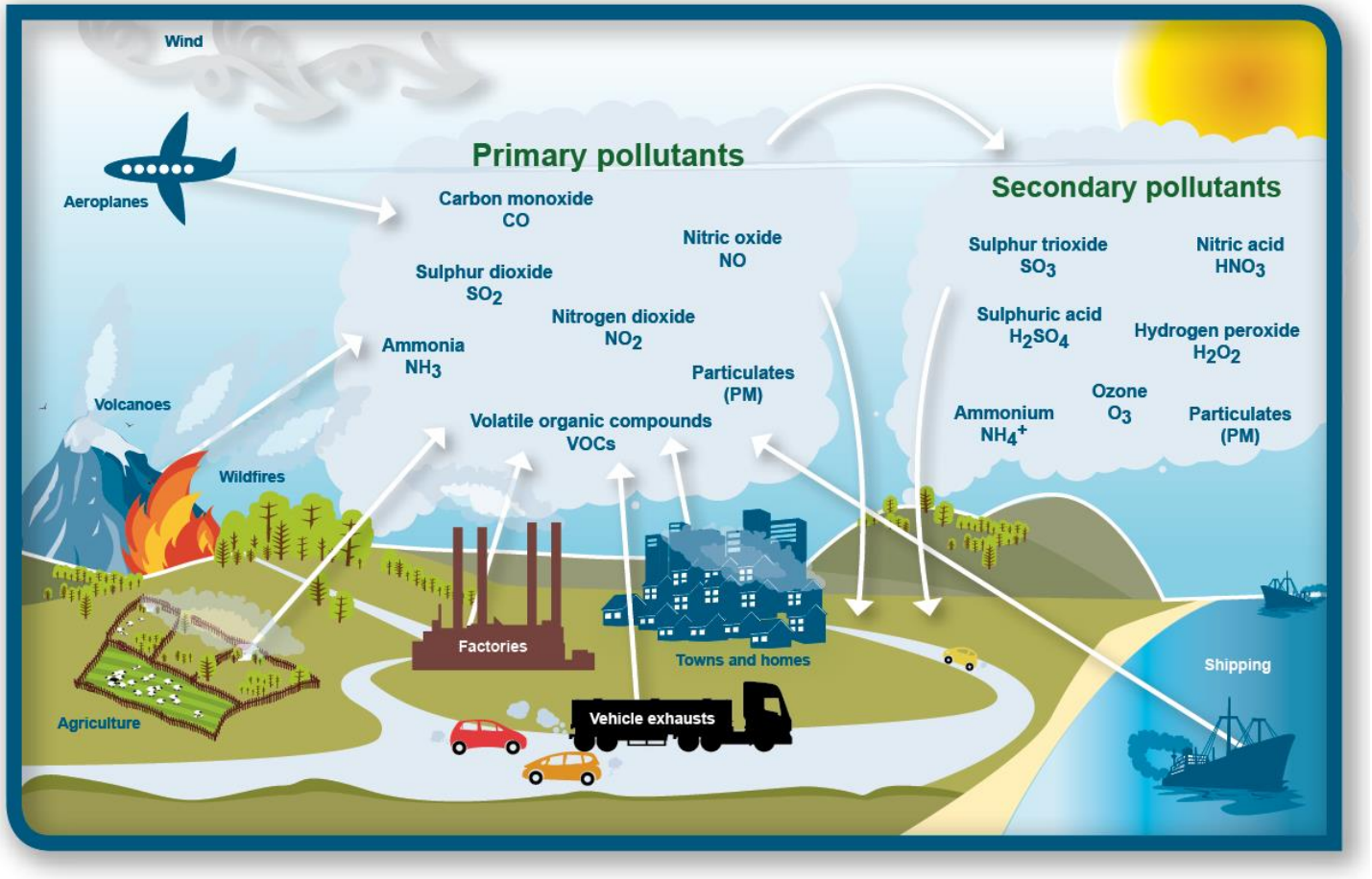
Resource Conservation and Recovery Act (RCRA) defintion:

- Industry – Anything that is not your **product**
- Wastewater treatment – **Everything** that comes out of a wastewater treatment plant

TYPES OF POLLUTION

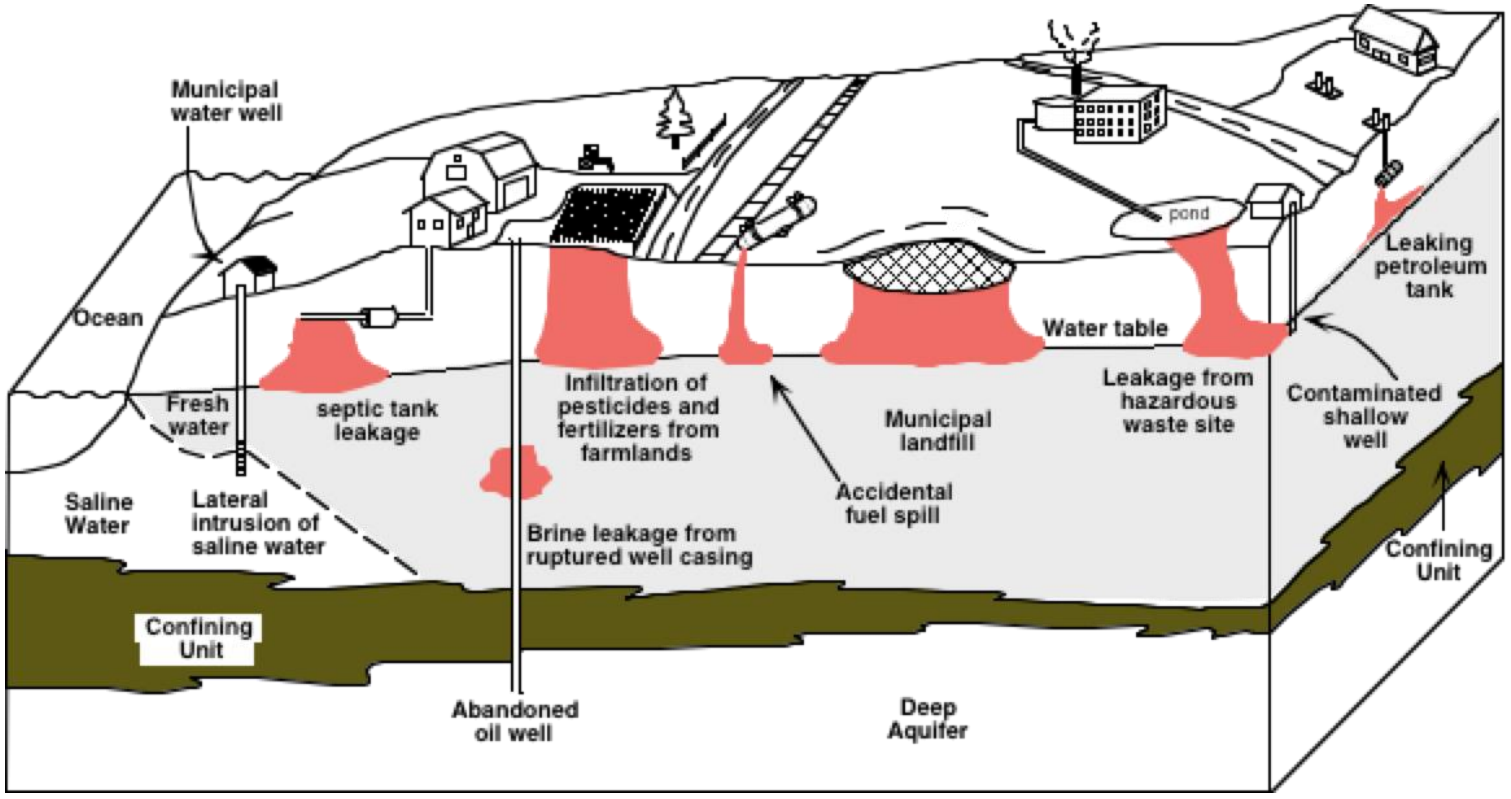
- Air Pollution – Particulates, sulfur dioxide, nitrogen dioxide, ozone, volatile organic compounds, radioactive
- Water Pollution – pesticides, heavy metals, chemical wastes,
- Soil Contamination – hydrocarbons, solvents and heavy metals
- Other types of pollution – noise, light, thermal etc

SOURCES OF AIR POLLUTION



- Human activity
- Industrial activity
- Other plant and animal activity

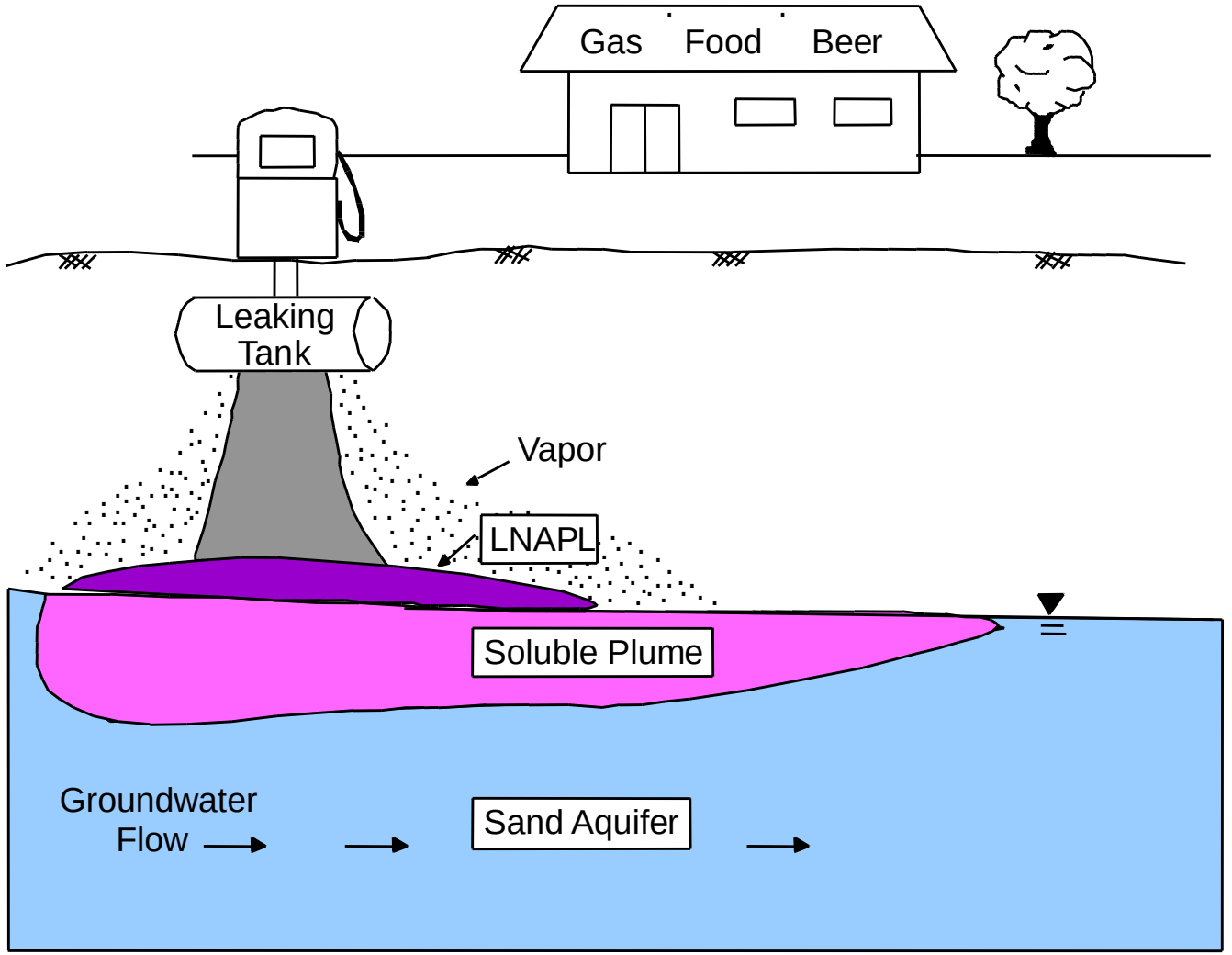
SOURCES OF SOIL & WATER POLLUTION



- Industrial spills and leaks
- Surface impoundments
- Storage tanks and pipes
- Landfills
- Burial areas and dumps
- Injection wells

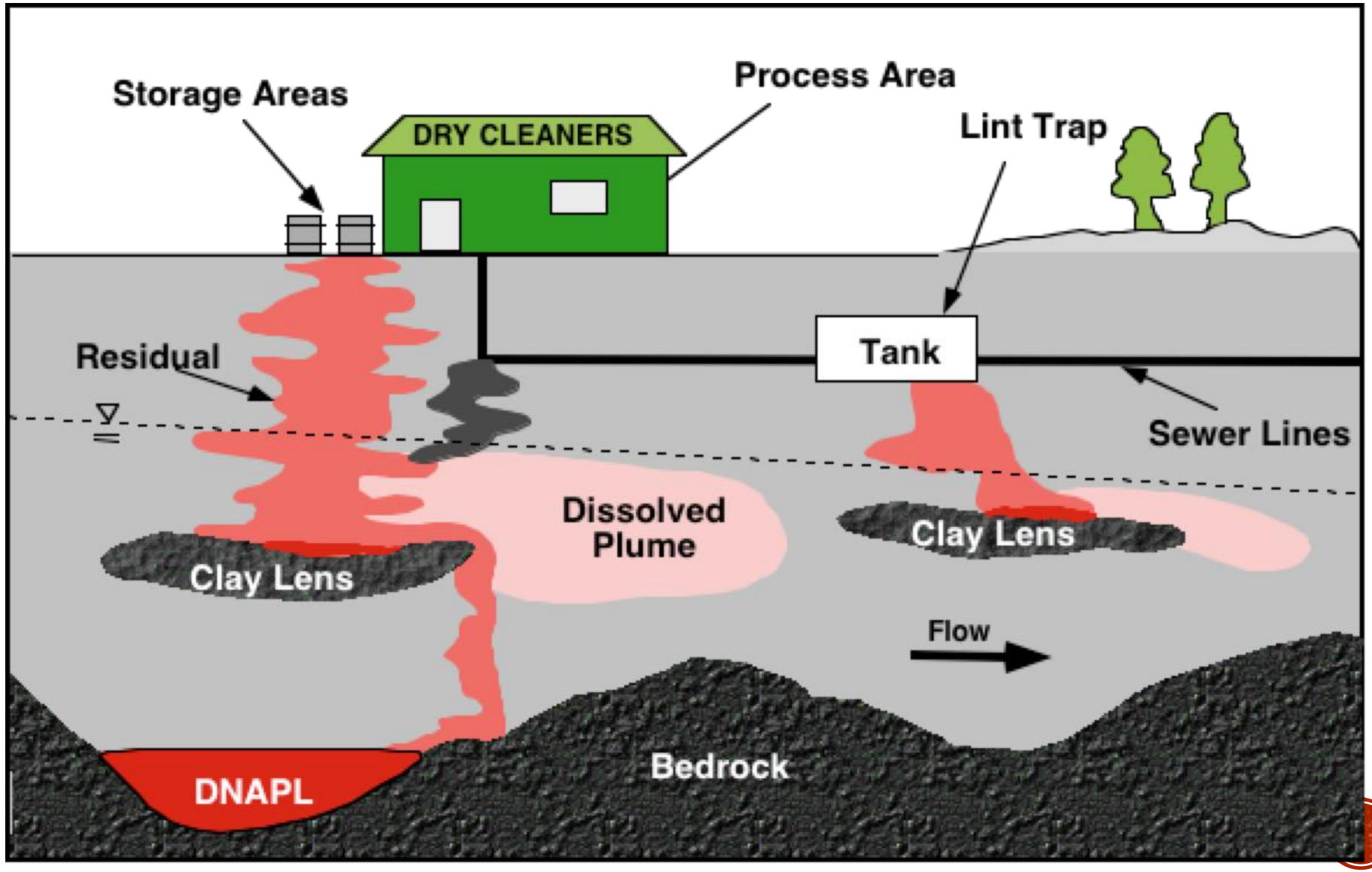
TYPICAL FUEL SPILL

Light Non-Aqueous Phase Liquid (LNAPL)



ROUTES OF DNAPL MIGRATION

Dense Non-Aqueous Phase Liquid (DNAPL)



Cleanup Continues from 2010 Oil Spill

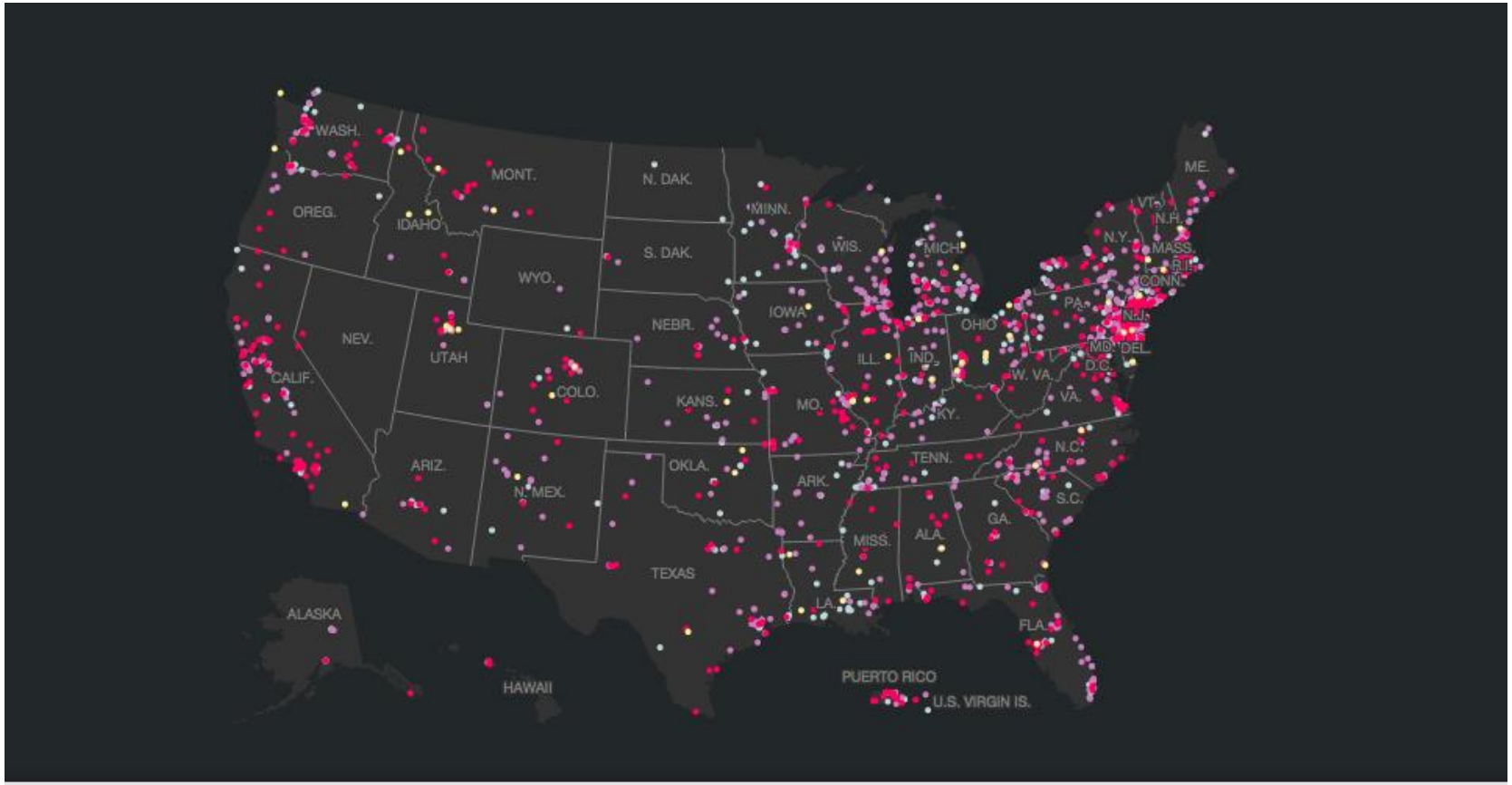
The Environmental Protection Agency has ordered Enbridge Inc. to do further cleanup of three sites along the Kalamazoo River contaminated by a 2010 spill of more than a million gallons of oil. One of those sites, at Morrow Lake, is within a mile of a Superfund site.

SOURCE: InsideClimate News research

PAUL HORN / InsideClimate News

SUPERFUND SITES

- http://www.nationalgeographic.com/superfund/



Proposed

Sites have been studied, and cleanup plans proposed.

Active

Cleanup facilities have not yet been completed.

Construction Completed

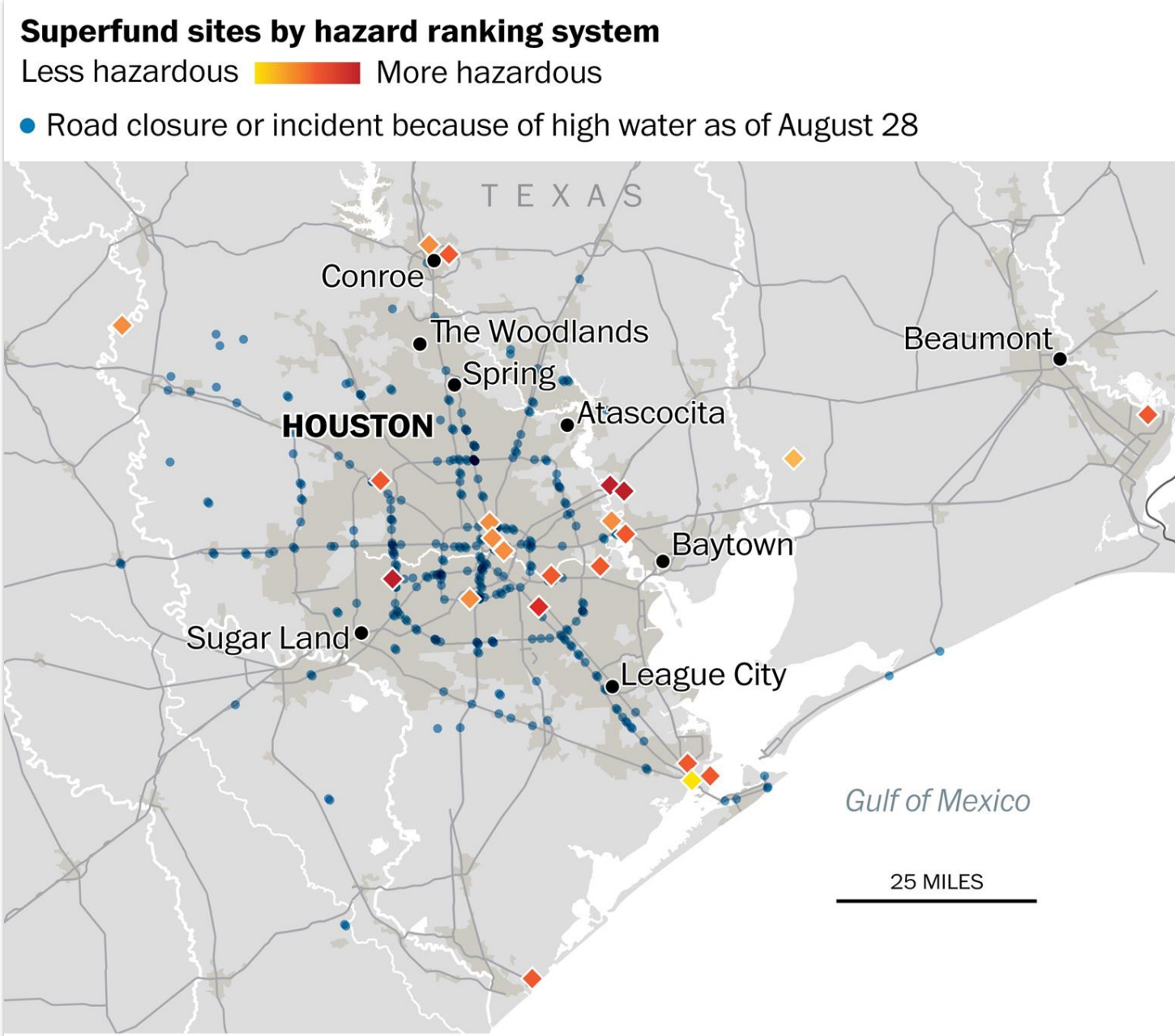
All the facilities necessary for cleanup have been built. They may need to be operated and maintained indefinitely.

Deleted

All cleanup efforts have been completed and the site removed from the National Priorities List.

Superfund Sites

"A Superfund site is any land in the United States that has been contaminated by hazardous waste and identified by the EPA as a candidate for cleanup because it poses a risk to human health and/or the environment. These sites are placed on the National Priorities List (NPL)." - ToxMap



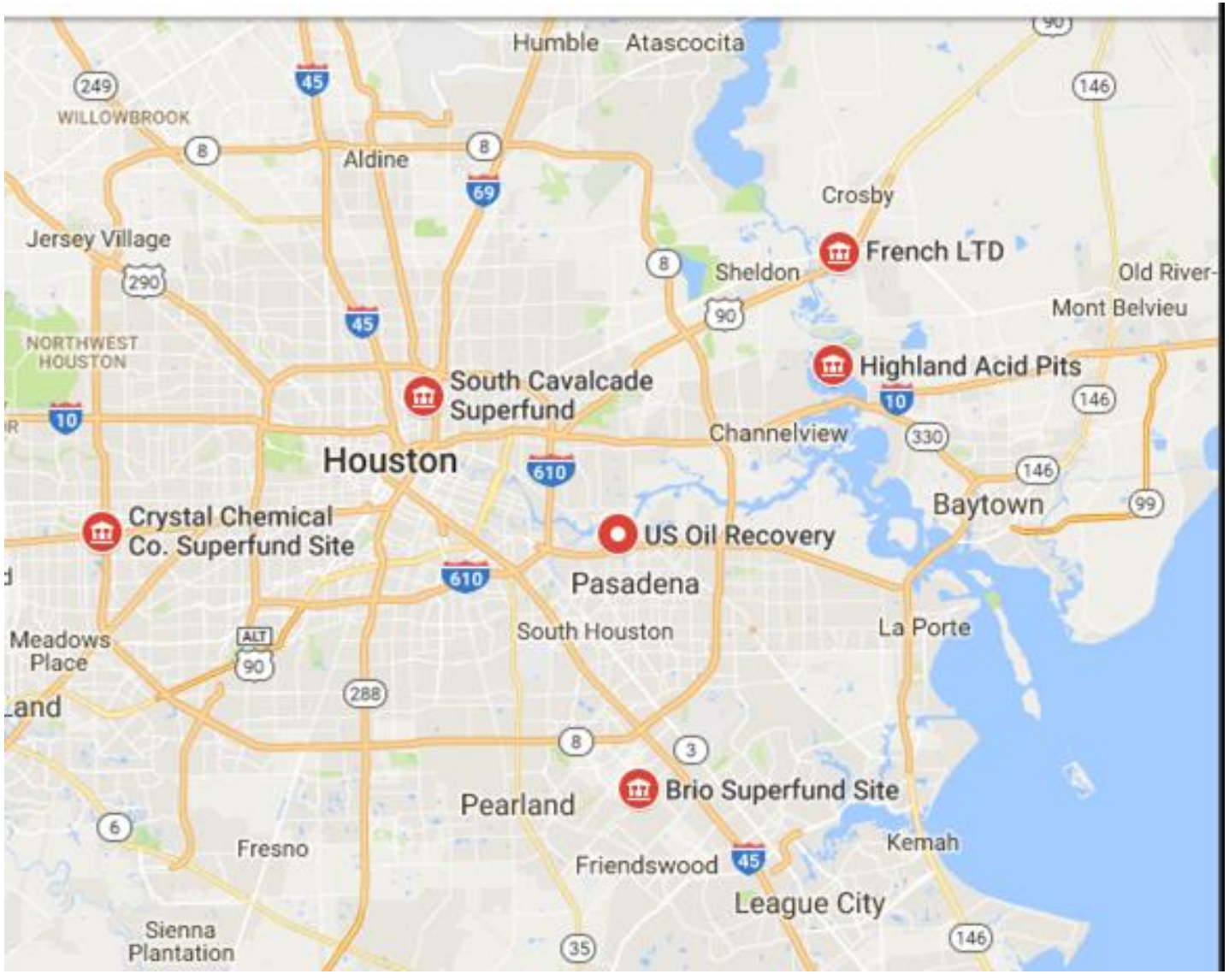
Sources: EPA Superfund Enterprise Management System Public User Database via National Institutes of Health. Data as of August 24. Traffic data via Houston Transtar.

DENISE LU AND AARON WILLIAMS/THE WASHINGTON POST

Superfund Sites

National Priorities List (NPL) entries

- Brio Superfund Site
- Crystal Chemical Co. Superfund Site
- South Cavalcade Superfund
- French LTD
- Highland Acid its
- US Oil Recovery




unbelt Rentals
Cheddar's Casual Café
Rd
Crystal Chemical
Co. Superfund Site
Energy Services
Sam Houston Tollway (Toll road)
W Sam Houston Pkwy S
Hunto

CRYSTAL CHEMICAL CO.

The 6.8-acre Crystal Chemical Co. site is located in southwest Houston, Texas.

Between 1979 and 1981, Crystal Chemical manufactured arsenic-, phenolic- and amine-based herbicides on site.

Although the site is not in a flood-prone area, it is located in the 100-year floodplain. In 1976, the area was subject to repeated flooding, which carried arsenic-contaminated wastewaters off site.

These activities and events contaminated soil and groundwater with arsenic. Following cleanup, operation and maintenance activities are ongoing.


Ivy St
Ivy St
UPS
En-Fab
7700 Schalker Drive
American
Corrugated Box Co
Saxon Fleet Services Inc
Cherry St
Houston Sou
Mill Distributi
Porter St
Cavalcade St
Schalke
Cavalcade St

CAVALCADE SUPERFUND

The 66-acre South Cavalcade site is located in Houston, Texas

.

A coal tar distillation plant also operated on site from 1944 to 1962.

These activities contaminated soil and groundwater with volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs) and metal salts such as arsenic, chromium, copper, lead, and zinc.

SUPERFUND CLEANUP TECHNOLOGIES

Technology	Estimated Energy Annual Average ($kWh*10^3$)	Total Estimated Energy Use in 2008-2030 ($kWh*10^3$)
Pump & Treat	489,607	11,260,969
Thermal Desorption	92,919	2,137,126
Multi-Phase Extraction	18,679	429,625
Air Sparging	10,156	233,599
Soil Vapor Extraction	6,734	154,890
Technology Total	*618,095*	*14,216,209*

HOW DO WE REMEDIATE CONTAMINATED SITES?

REMEDIATION TECHNIQUES

- In-situ – Remediation is done on the contaminated site

- Ex-situ – Remediation is done after the soil is excavated or the water is pumped

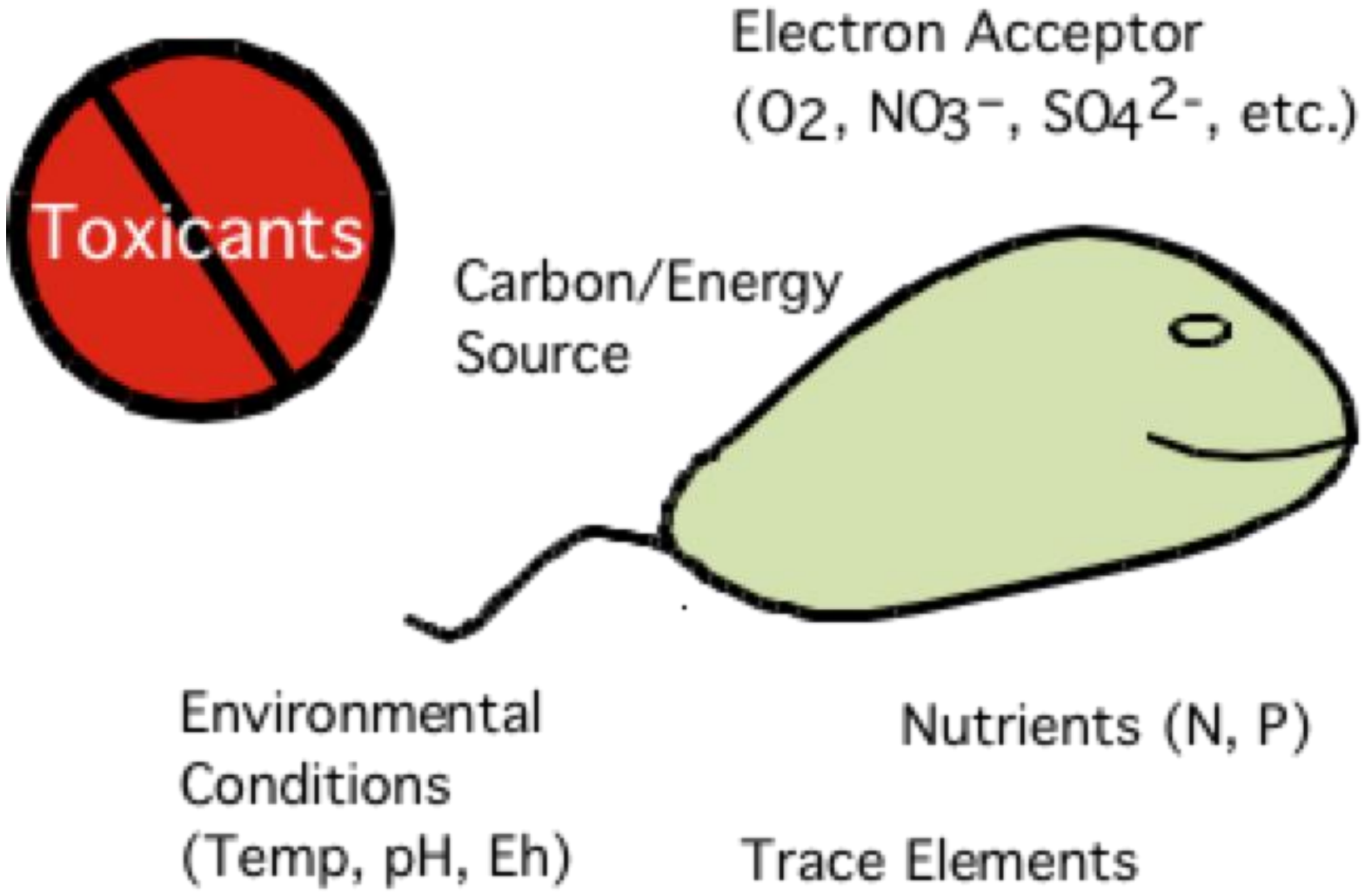
TYPES OF REMEDIATION

- Physical/Chemical
  - Air stripping
  - Oxidation
  - Soil vapor extraction
  - Solidification/Stabilization
  - Permeable Reactive Barriers

BIOREMEDIATION

Using bacteria to break down harmful chemical compounds

Typically done by aerobic bacteria (uses oxygen)



BIOREMEDIATION TYPES

- Natural attenuation – only monitoring
- Biostimulation – add nutrients, oxygen, bacteria is already there
- Bioaugmentation – add bacteria and oxygen
- Phytoremediation – Using plants to remove pollutants

BIOREMEDIATION BACKGROUND

- Natural Attenuation is **Not fast enough, Not complete enough, Not frequently occurring enough** to be broadly used for some compounds, especially chlorinated solvents
- The current trend is to stimulate/enhance a site's indigenous subsurface microorganisms by the addition of nutrients and electron donor
- In some cases, bioaugmentation is necessary when metabolic capabilities are not naturally present.

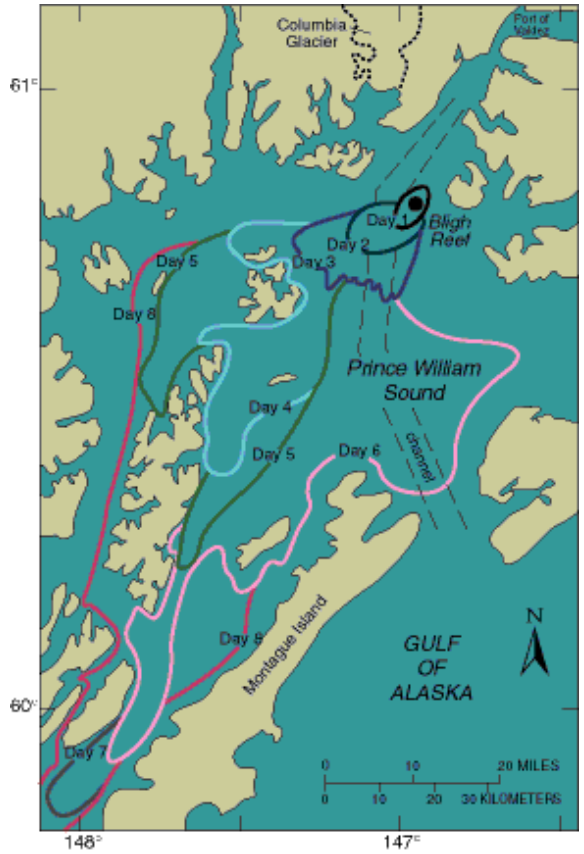
PHASES OF REMEDIATION

- Phase 1 – Site information assessment
  - What is the site like?
  - What is the contaminant we are dealing with?
- Phase II – Testing program
  - Figure out the extent of contamination and understand how to best deal with it
- Phase III – Detailed testing program
  - Based on results from Phase II
  - Figure out a remedial action plan (RAP) if it poses risk to human health
  - RAP depends on the type of site

EXXON-VALDEZ OIL SPILL

1989 EXXON VALDEZ OIL SPILL

- March 24th, 1989
- Prince William's Sound, Gulf of Alaska
  - Shallow
  - Reef
  - Island barriers
    - No roads connection
    - Inaccessible
- Largely unused area, but was a popular shipping lane.



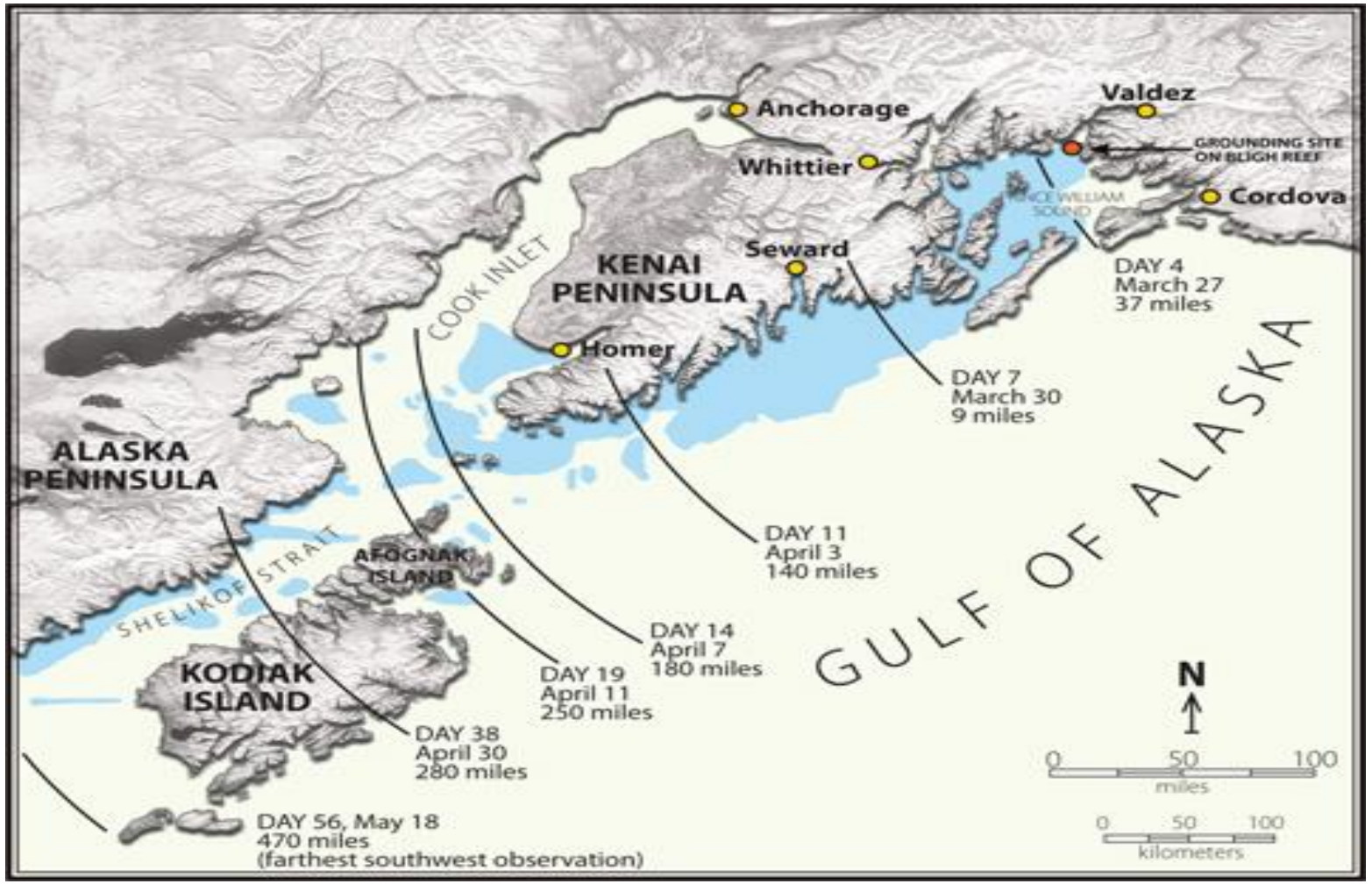
THE ACCIDENT

- The *Exxon Valdez,* an oil tanker en route from Valdez, Alaska to Los Angeles, California, ran aground on Bligh Reef.
- The tanker was outside it's normal shipping lanes in an attempt to avoid ice.
- Within six hours of the grounding, approximately 10.9 million gallons spilled into the ocean of its 53 million gallon cargo.

THE ACCIDENT…

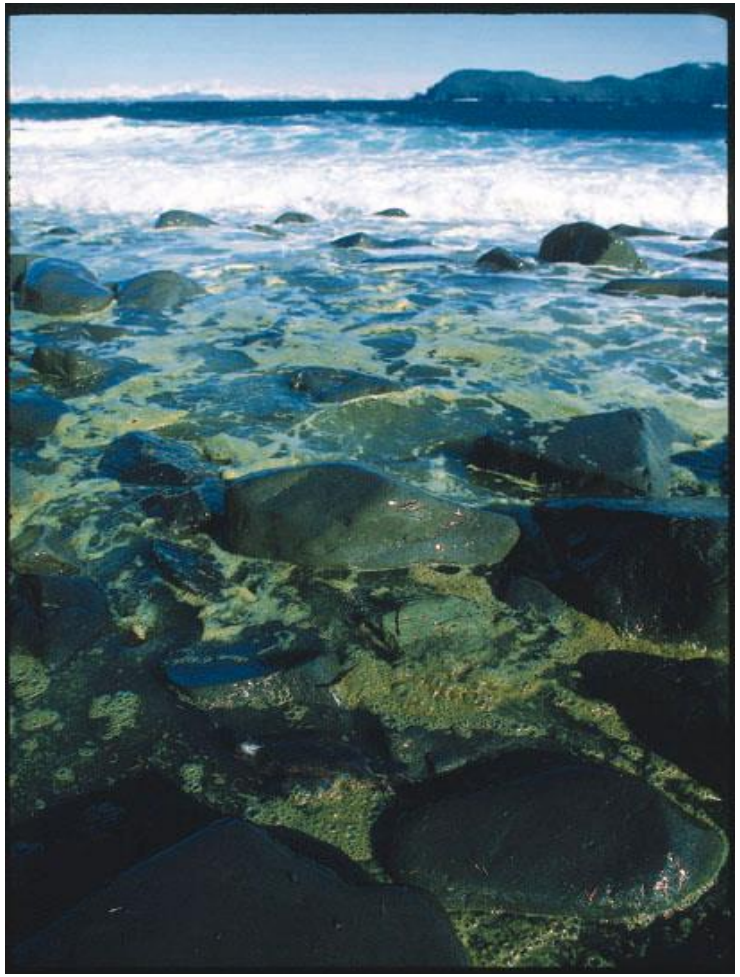
- **Poor Clean up response**
- The first three days after the *Exxon Valdez* oil spill , no clean up was initialized by Exxon although there was nearly ideal weather for oil recovery.
- Reasons:
  - Equipment wasn't ready for booming or skimming.
  - Exxon was concerned about offloading the remaining oil from the ship.
  - Boats and crews were ready to work but oil-containment and recovery equipment was not available. For several days, oil continued to pour out of the tanker
- Local Fishermen, began the clean up initiative prior to Exxon involvement.

THE ACCIDENT…



THE ACCIDENT…

- Three days after the spill, much of the oil was converted by wind-driven mixing of the oil and sea water into an emulsion (mousse)
  - Couldn't burn
  - Difficult to remove from the surface of the sea or from shoreline.
- Not until 3 weeks after the spill, the White House federalized the cleanup effort.



THE CLEANUP

- METHODS:
  - On The Water: Boom, Burning, Dispersants, Skimming
  - On The Beach: Bioremediation, Chemical Cleaning, Hot Water and High Pressure, Manual Treatment, Mechanical Treatment

ON THE WATER…

- BOOM
  - Used as a barrier, deflector, absorbent and corral for collected oil.
  - During the EVOS, a crew of 6 cleaned 1,000 feet of boom a day

ON THE WATER…

- SKIMMING
  - Over 260 skimmers were purchased.
  - At any given time at least 50 were being used.
  - Principal of skimmers: oil floats on surface of water and skimmers are designed to take oil off top of water, separate it from most of water that is also collected and hold it in a storage tank.

ON THE WATER…

- BURNING
  - Igniting volatile gases in oil to be reduced to tarry residue.
  - However, massive detrimental environmental effects
  - Burning was not used because oil was to far spread when clean up started.

ON THE WATER…

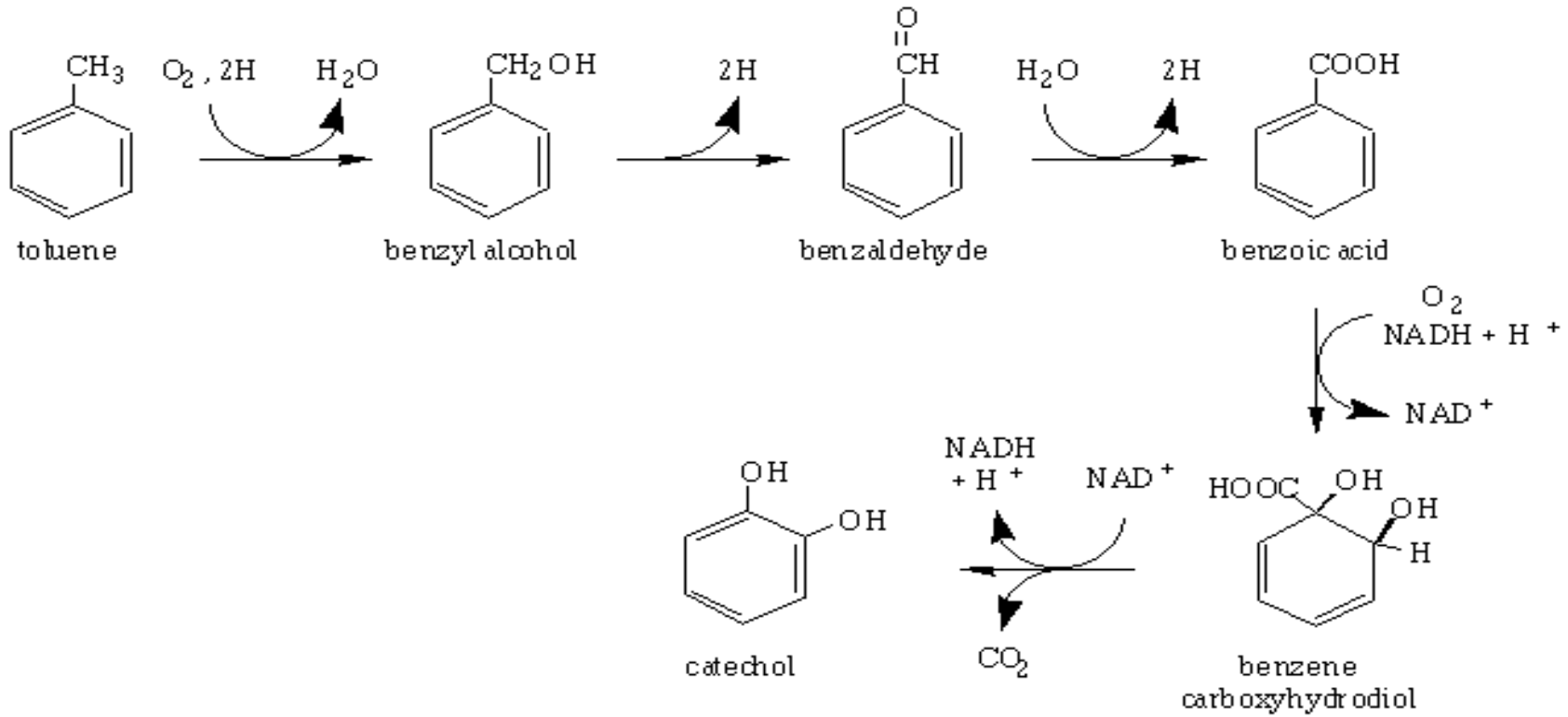
- DISPERSANTS
  - Chemicals that break-up oil into smaller and smaller concentrations.
  - Was ineffective to EVOS because of the time it took for Exxon to get approval or use.
  - By the time they got approval, it was too late and ineffective because purpose of dispersants is to prevent oil from reaching the shoreline. By this time, it had already done so.

ON THE BEACH…

- BIOREMEDIATION
  - Application of fertilizers to increase the number of oil-eating microbes. *Psuedomonas aeruginosa* was used for the bioremediation, but was the progress was slow.
  - To promote the acceleration of microbe production nitrogen and phosphorus was added to the shorelines.
  - First application July 1989. By the end of the summer, up to 110 miles of beaches had been treated with bioremediation.
  - Very effective method.

ON THE BEACH…

- BIOREMEDIATION CONT..



Oxidation of toluene to catechol by *Psuedomonas aeruginosa.*

ON THE BEACH…

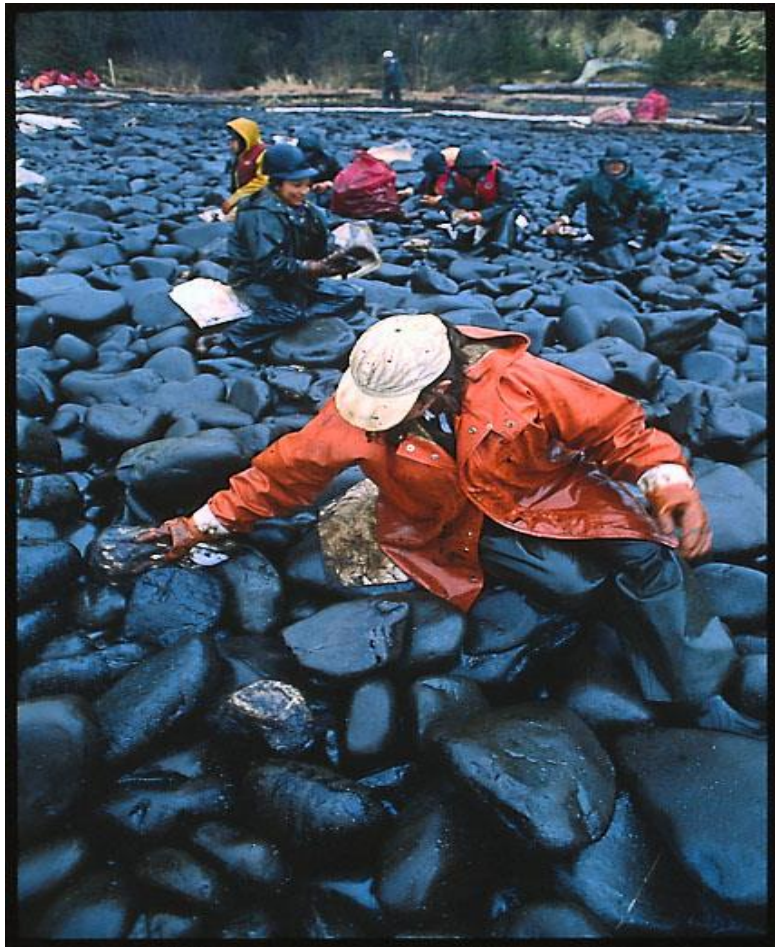
- CHEMICAL CLEANERS
  - Chemical produced by Exxon: Corexit 9580A (kerosene with the aromatics taken out)
  - COREXIT 9580A is used on shorelines in fresh or salt water. It is effective on all types of oil including heavily weathered and emulsified oil containing up to 50 percent water.
  - However, Corexit was not effective enough considering its environmental effects to move beyond testing. Not enough information regarding its toxicity was available at the time.

ON THE BEACH…

- Hot Water & High Pressure
  - Cleanup crews can blast oil off beaches into the water where it can be skimmed off.
  - Full scale hot water washing became the standard shoreline treatment of EVOS oiled beaches
  - Created controversy because it is extremely harsh on beaches - it cooks all life leaving a dead shoreline.
  - Very debated cleanup method - 150 miles of beaches were washed, but was argued it did more harm than good.

ON THE BEACH…

- MANUAL TREATMENT
  - Use of shovels, rakes, absorbents, and hand to clean beach segments of pooled oil, oily fine-grained sediment, and oily debris.
  - Used on beaches where oiling was light.



ON THE BEACH…

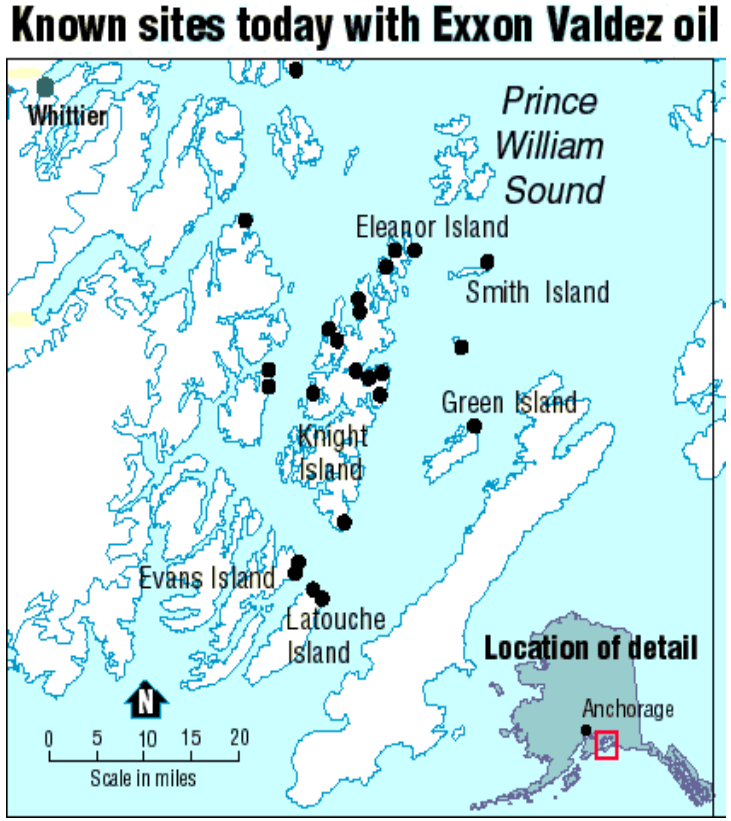
- MECHANICAL TREATMENT
  - Tractors, backhoes, front-end loaders, and other machines were used to remove oil from beaches.
  - Used in 1990 and limited amount in 1991.

13% settled in subtidal sediment
6% recovered from beaches during cleanup
2% weathered on intertidal shoreline
1% remained in water column

CONSEQUENCES

Table 5. Fate of the Exxon-Valdez Oil Source: Reference 7

Process	March 1989	June 1989	June 1992
Evaporation and photolysis	10%	18%	20%
Dispersion (water column)	4%	28%	38%
Floating	84%	0%	0%
Beached	0%	48%	34%
Skimmed	2%	6%	8%



* 50% biodegraded on beaches & in water column
13% settled in subtidal sediment
6% recovered from beaches during cleanup
2% weathered on intertidal shoreline
1% remained in water column

CONSEQUENCES . . .

- Ecological – Immediate
  - Oiling of fur or feathers
    - loss of insulating capacity and
      - death
        - hypothermia, smothering, drowning, and ingestion of toxic hydrocabons.
  - Mortalities – a few days after
    - 250,000–500,000 seabirds
    - 2,800–5,000 sea otters
    - approximately 12 river otters
    - 300 harbour seals
    - 250 bald eagles
    - 22 orcas
    - and billions of salmon and herring eggs

CONSEQUENCES . . .

- Ecological – Long term
  - Deeply penetrated oil continues to visibly leach from a few beaches, as on Smith Island.
  - Bivalves, such as mussels, are still contaminated by oil due to their ability to contain hydrocarbons in their tissues
    - Has a great effect on the animals which each them (sea otters, birds, etc)

CONSEQUENCES . . .

- Species Recovery status as of 2002

Recovery Unknown	Not Recovering	Recovering	Recovered
Cutthroat Trout	**Common Loon**	Clams	**Archaeological Sites**
Dolly Varden	Cormorants	**Killer Whales**	Bald Eagle
Kittlitz's	Harbor Seal	Marbled Murrelet	**Black Oystercatcher**
Murrelet	Harlequin Duck	Mussels	**Common Murre**
Rockfish	**Pacific Herring**	Sea Otter	**Pink Salmon**
	Pigeon Guillemot	Sediments	River Otter
		Tidal Communities	**Sockeye Salmon**
		Wilderness Areas	

***As time passes it becomes more difficult to separate natural changes from oil-spill impacts…

CONSEQUENCES…

- Major Legal Changes
  - Oil Pollution Act of 1990, which established a five-cent per barrel tax on oil to create a $1 billion per spill cleanup fund.
  - Ship Escort and Response Vessel System (SERVS)
    - Two vessels escort the tanker for 60 miles to the ocean entrance to PWS , at least one ship is equipped: oil skimmers, containment boom, oil dispersants, and oil storage tanks.
  - Marine Spill Response Corporation (MSRC)
    - 5 regional spill centers each equipped to handle a spill of 200K barrels.
  - Double-hulled tankers
  - Total spill cost for Exxon = $2.1 billion in clean up costs, 300 million dollars to business in PWS affected by spill, $1 billion in state and federal settlement fees (used for environmental studies)