Groundwater Quality Issues and Remediation

Groundwater Resource Management

- Knowledge
- Contamination Sources
- Main Remediation

Knowledge

Contaminants

- identity
- sources
- chem./bio. Properties
- toxicity

Fate and Transport

- advection
- dispersion
- reaction
- persistence

Risk Evaluation

Contaminant Sources

Geological

- **fluoride**
- **selenium**

Animal Waste Management (biological and nutrients)

- **human (sewage management)**
- **livestock and domestic animals**
- **wildlife**

Contaminant Sources (cont.)

Agricultural Chemicals

- **nutrients (nitrogen and phosphorous)**
- **pesticides**

Resource Industries

- **mining**
- **petroleum**

Chemical Industry (producers and users)

Animal Waste

Bacterial and viral transmission

- human → human
- livestock → human (E. coli)

Nutrients

- nitrate
  - from land application of sewage and animal waste
  - from agricultural fertilizers

Factory Farms



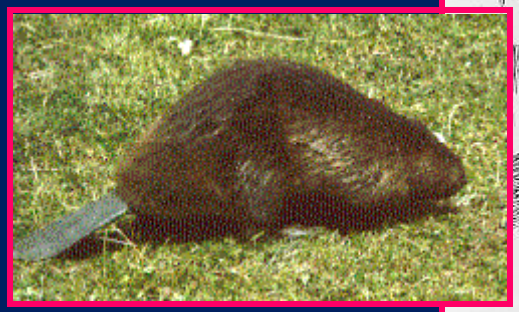


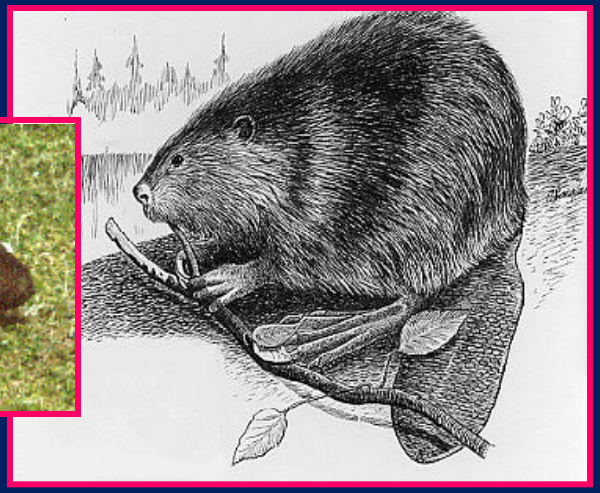


Greater concentration → greater risk

Wildlife





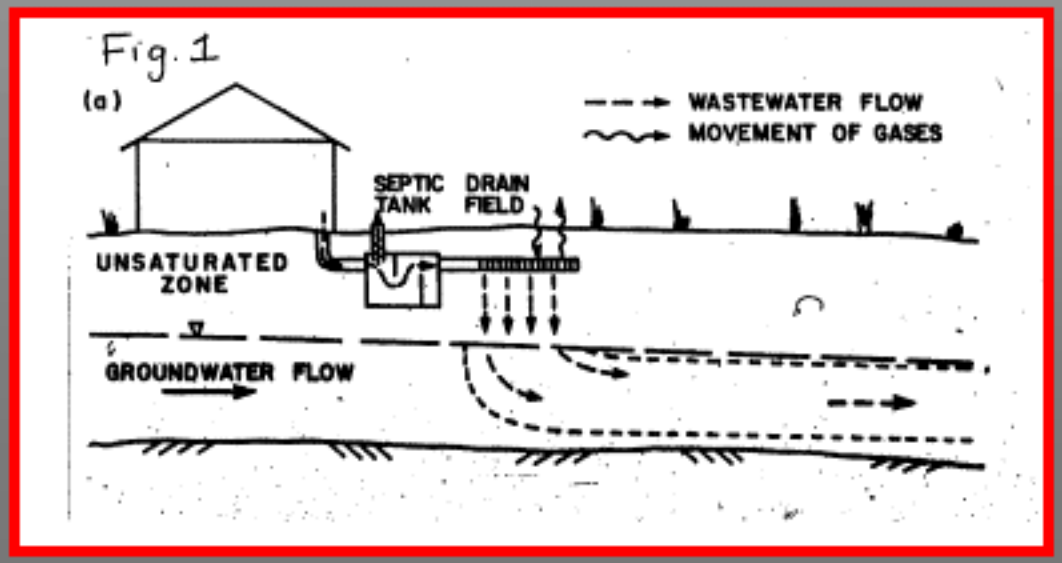


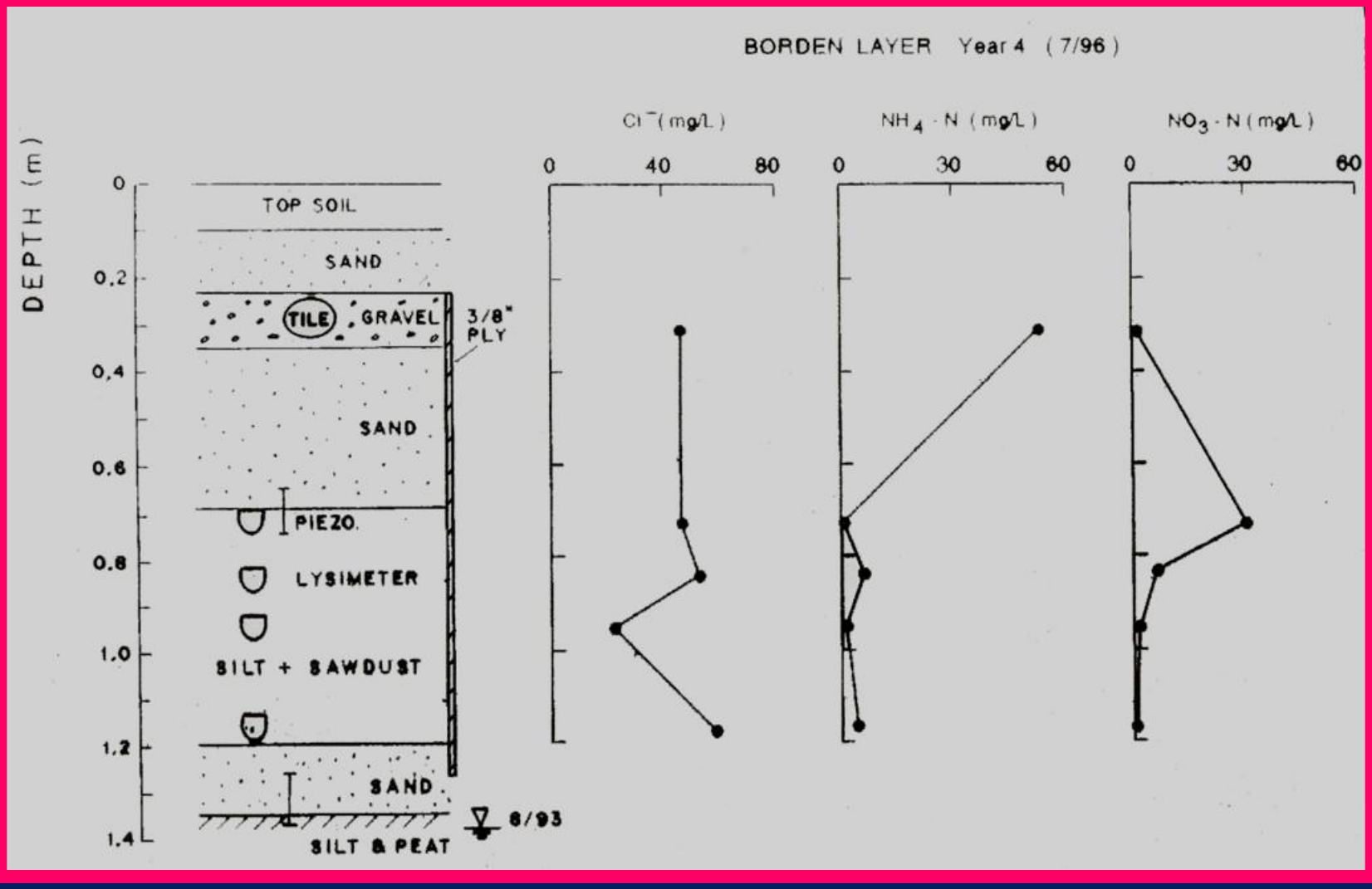


Giardia

Private Waste Disposal

- 70% of Canadians have centralized sewage collection and treatment
- 30% have private waste disposal systems




BORDEN LAYER Year 4 (7/96)
DEPTH (m)
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
TOP SOIL
SAND
TILE
GRAVEL
3/8" PLY
SAND
PIEZO.
LYSIMETER
SILT + SAWDUST
SAND
SILT & PEAT
6/93
Cl⁻ (mg/L)
0
40
80
NH4 - N (mg/L)
0
30
60
NO3 - N (mg/L)
0
30
60

Biological Contamination of Groundwater

- Limited mobility ~ 30 - 50 m

Precaution

- well location
- well construction (surface seals)
- shallow wells are susceptible

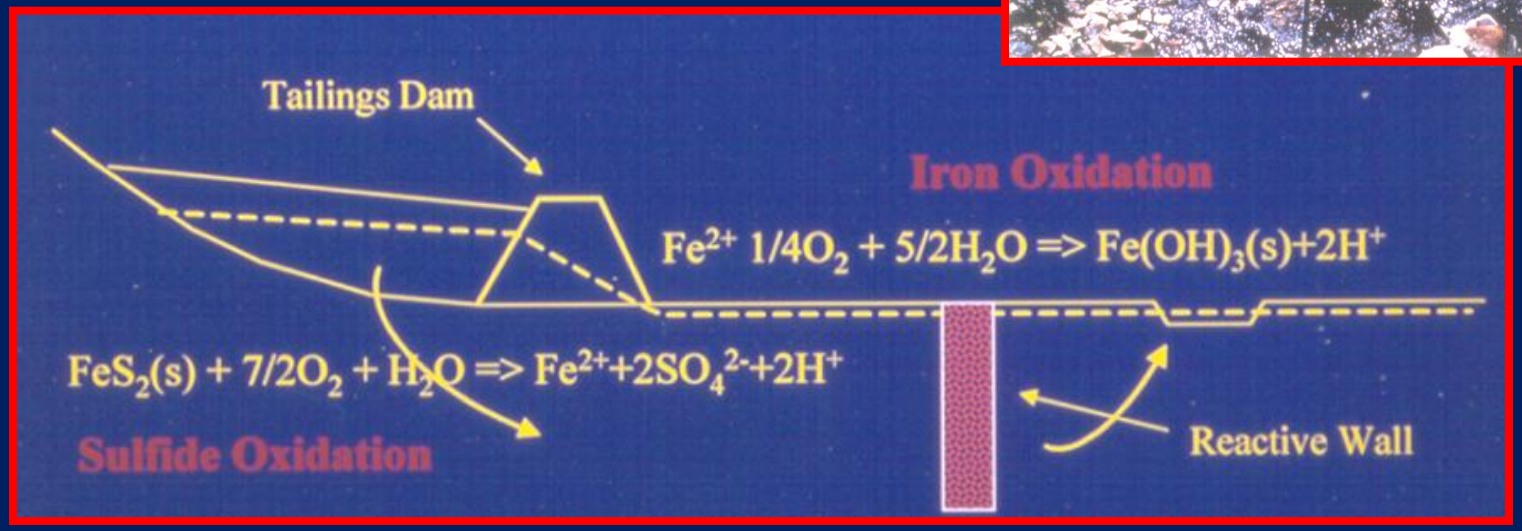
Mining

- Waste rock
- mine tailings
- acid mine drainage

(metals, pH, chemicals used in processing)






Tailings Dam
Iron Oxidation
Fe^{2+} $1/4O_2 + 5/2H_2O \Rightarrow Fe(OH)_3(s)+2H^+$
$FeS_2(s) + 7/2O_2 + H_2O \Rightarrow Fe^{2+}+2SO_4^{2-}+2H^+$
Sulfide Oxidation
Reactive Wall

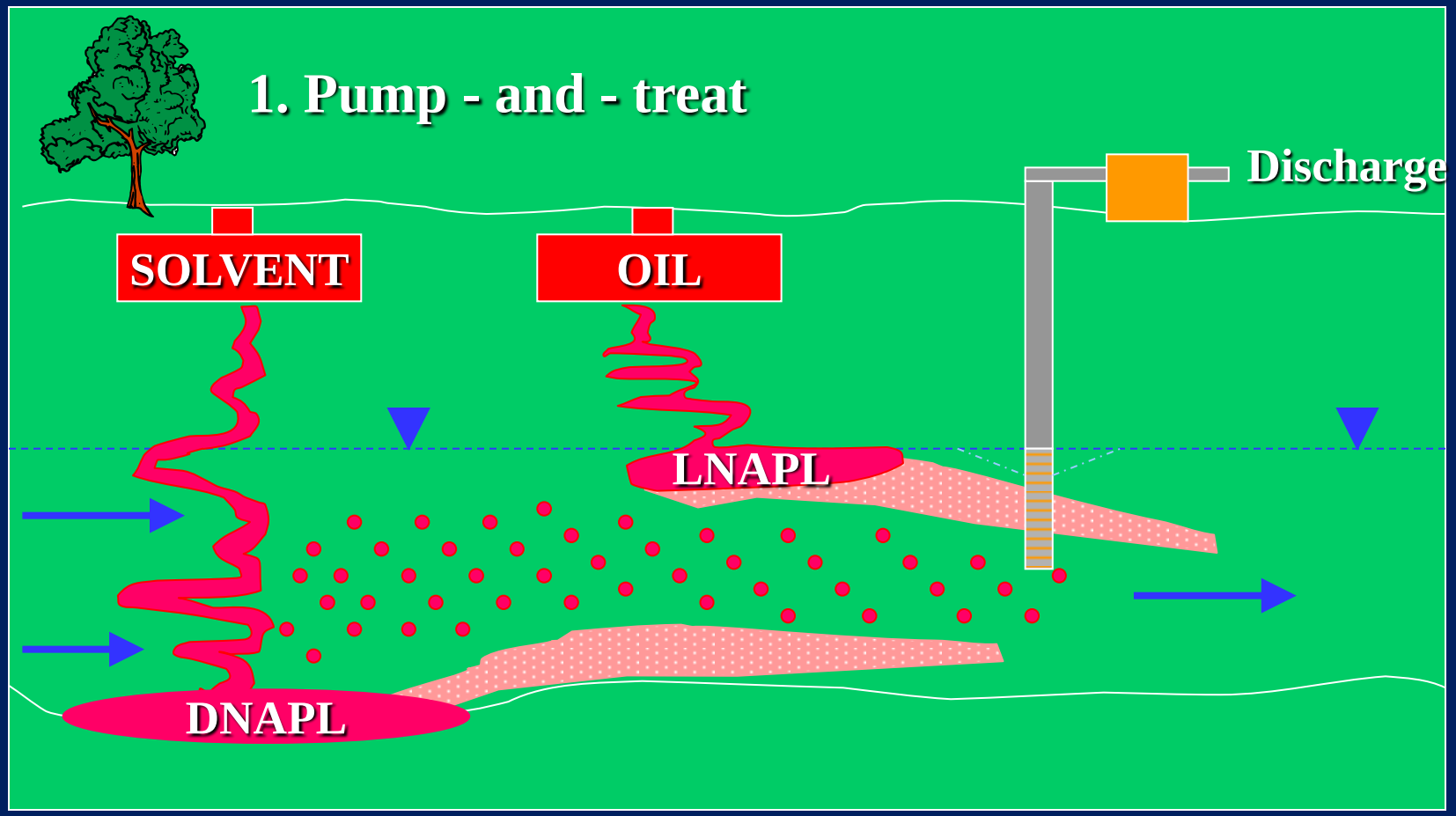
Petroleum Products

- Immiscible Fluid
- Slightly soluble
- Mixture of hydrocarbons
- Less dense than water
- (highly toxic - 5 ug/L)

Industrial Solvents (Chlorinated Solvents)

- Immiscible Fluid
- Slightly soluble
- Pure chemical
- More dense than water
- (highly toxic - 5 ug/L)

PLUMES FROM LNAPL AND DNAPL



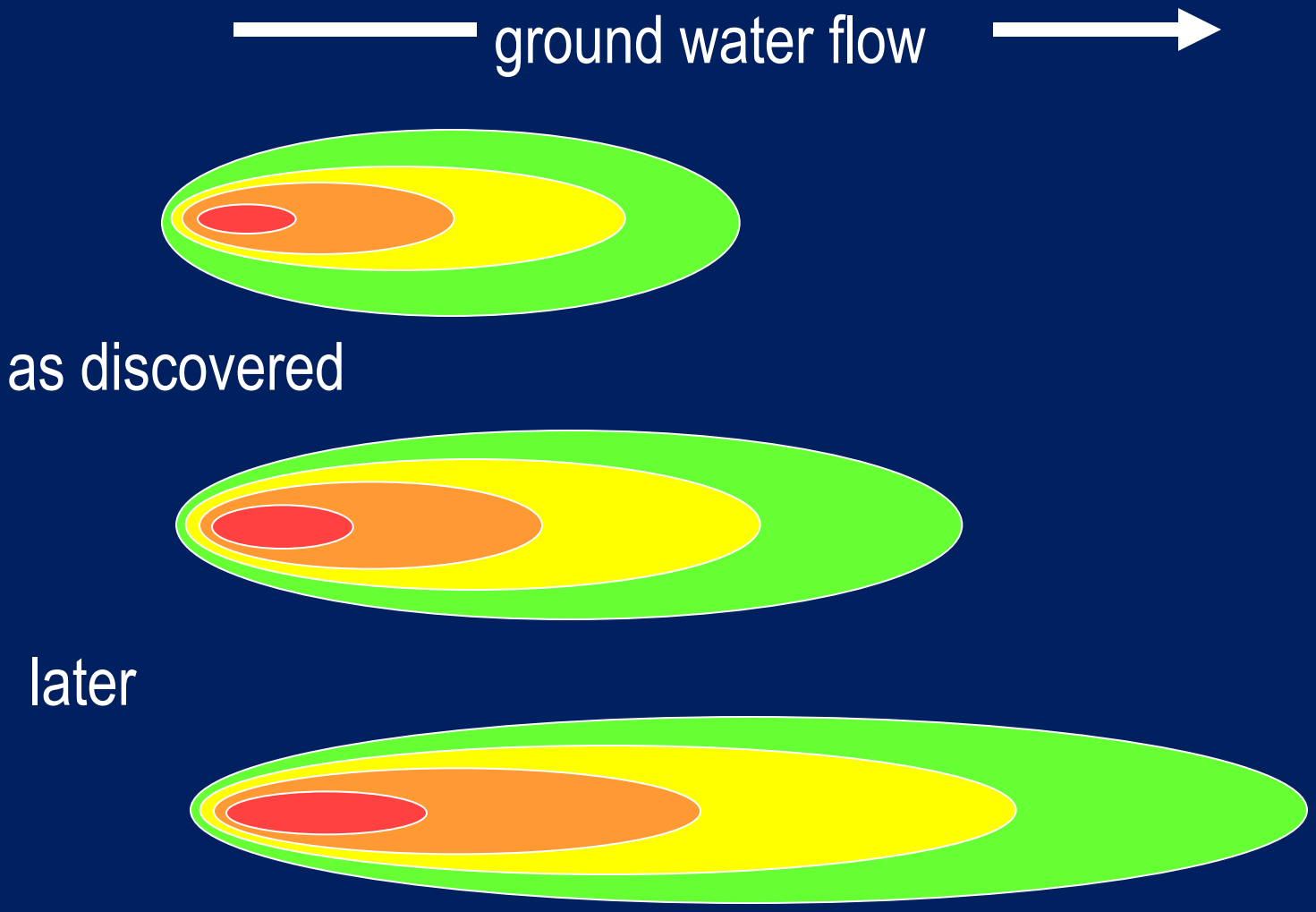
Long times **High costs**

Hazardous Waste Sites

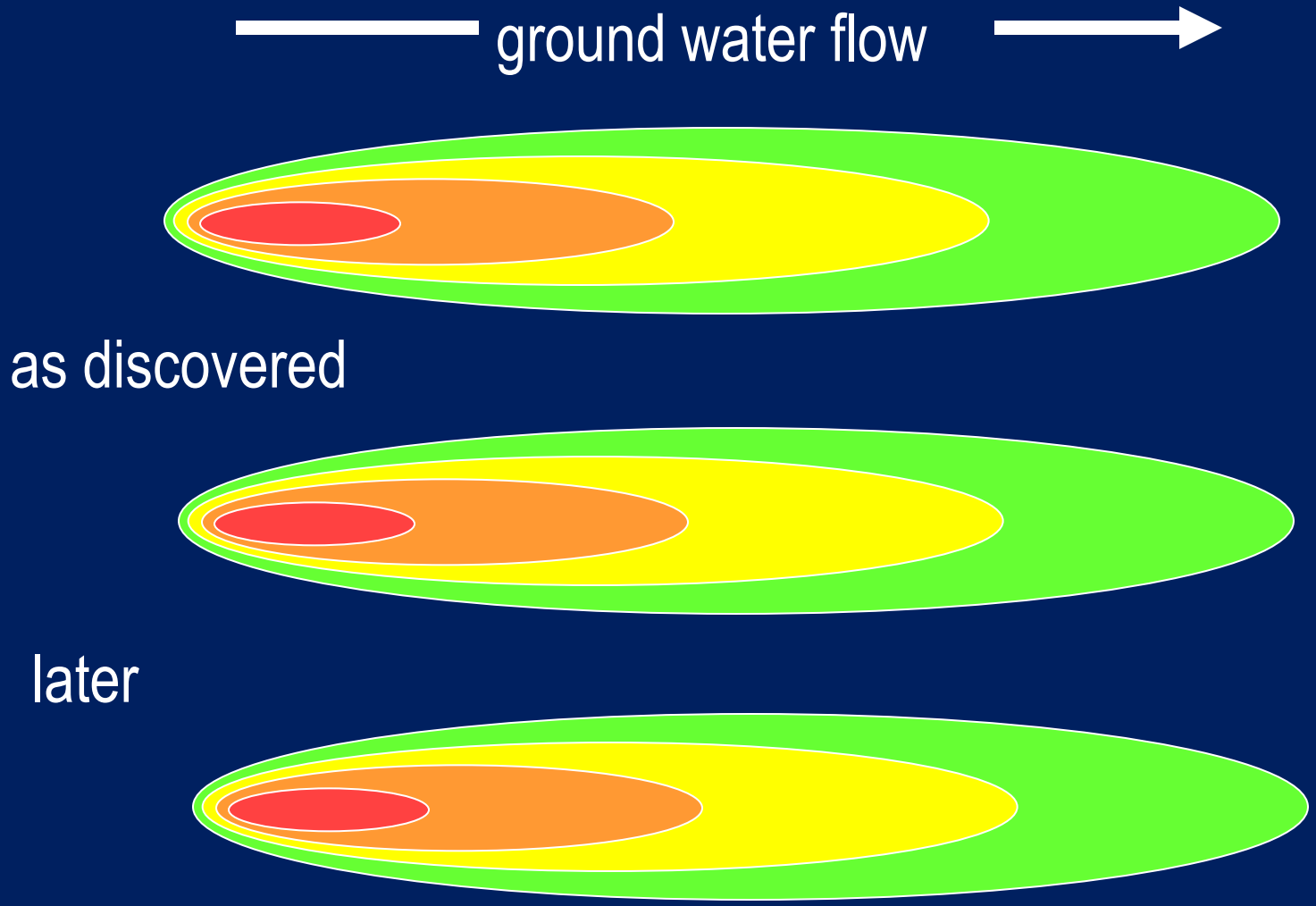
- **In the U.S.A.**
  - **»300,000 - 400,000 sites**
- **Globally -?-**

Patterns to Look for in the Life Cycle of Plumes

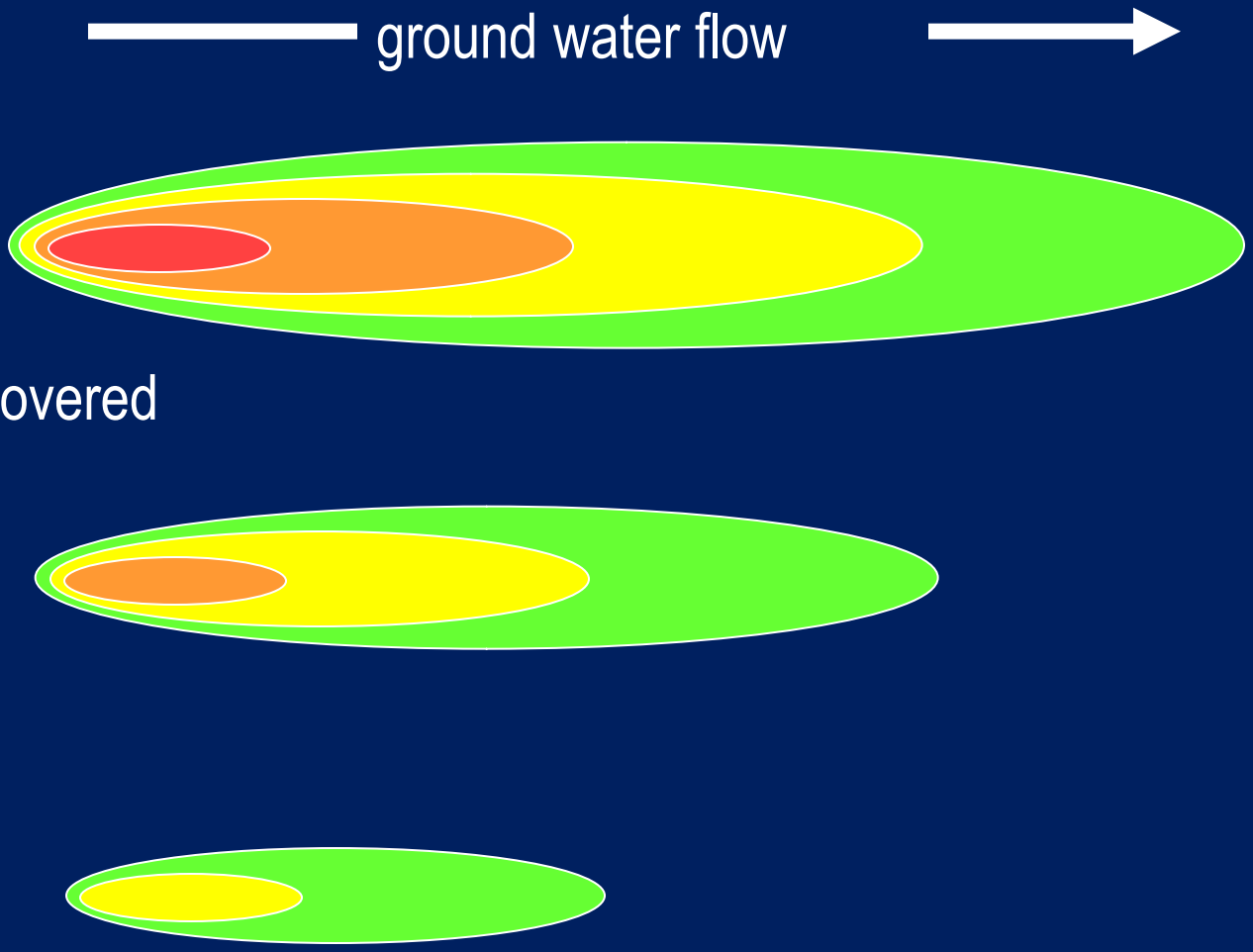
plume and source do not attenuate



plume attenuates, source does not



source and plume both attenuate



What is the Pattern of Behavior of the Plume over Time?		
Source Decay	**Plume Decay**	**Strategy**
Yes	**Yes**	**MNA**
No	**Yes**	**Risk Management**
No	**No**	**Active Remediation**

Remediation And Risk Management

- Following the evaluation of the data, development of the conceptual model and selection of the remediation guidelines, 2 options exist:
  - OPTION 1: Collect more data!
  - OPTION 2: In consultation with the client (and Regulator), determine the appropriate remediation and/or risk management measures

Remediation And Risk Management (Cont'd)

- **Remediation:** clean up the site to the appropriate guidelines
- **Risk Management:** install systems and/or barriers to prevent the existing contamination from migrating or from affecting the on-site receptors, without cleaning up the site
- Sometimes we do some of each at a site

Remediation Techniques

Soil Remediation

- Excavation and thermal treatment, biotreatment or landfill disposal
- Bio-aeration (landspreading/landfarming)
- Vapour extraction (with and without off-gas treatment)
- Dual phase vacuum extraction
- In situ electrical heating
- Bio-venting (air injection and circulation)

Groundwater Remediation

- Pumping & treat（treat and control）
- Barriers （physical –chemical-biological)
- Injection

- PRB
- ISCO
- MNA

Choosing a Remediation Technique

- What do you want to achieve?
  - Do you need site closure or just risk management?
  - What criteria do you need to reach?
- When does it have to be done?
  - Who or what is at risk?
  - Is the site available for long term access?
  - Are there external forces at play (land owners, media, regulators)?
  - Is the problem going to get worse if action is not taken promptly?

Choosing a Remediation Technique (Cont'd)

- How much can you spend on the project (and when can you spend the money)?
  - What is the budget this year? Next year?
  - Is long-term management (and long-term expense) acceptable?
- What conditions do you have to work with?
  - Land use and surface access?
  - Third party and stakeholder concerns?
  - Subsurface and weather conditions?

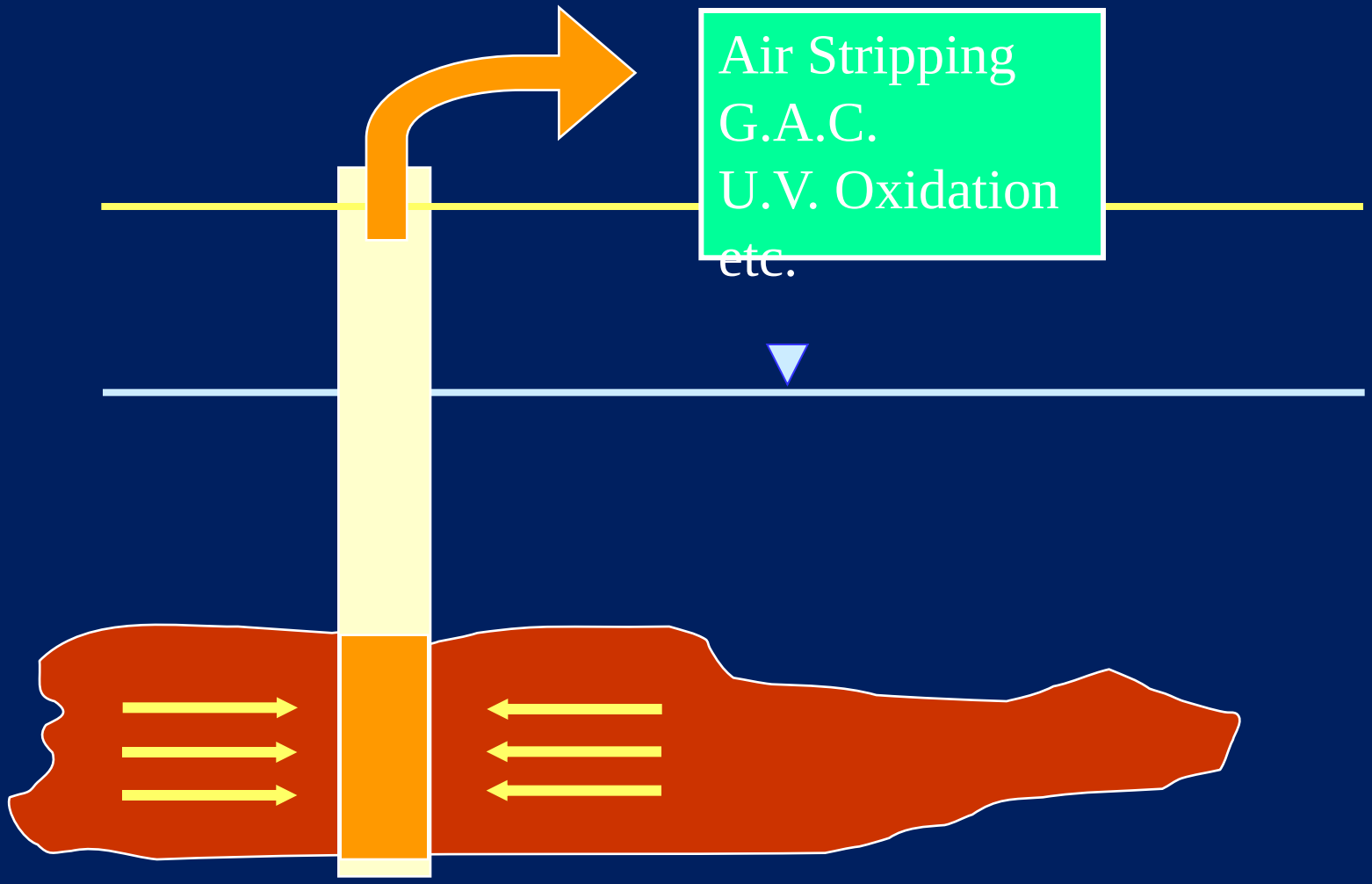
Examples of Some Remediation Techniques

Excavation and Soil Replacement





Pump-and-Treat



Excavation and Soil Replacement Pumping

- The reality is that digging up the contaminated soil and groundwater, disposing of it at a landfill and replacing it with clean engineered fill is usually the surest and fastest way to clean up a site

In Situ Technogies: In Situ Chemical Oxidation



In Situ Technogies: In Situ Chemical Oxidation





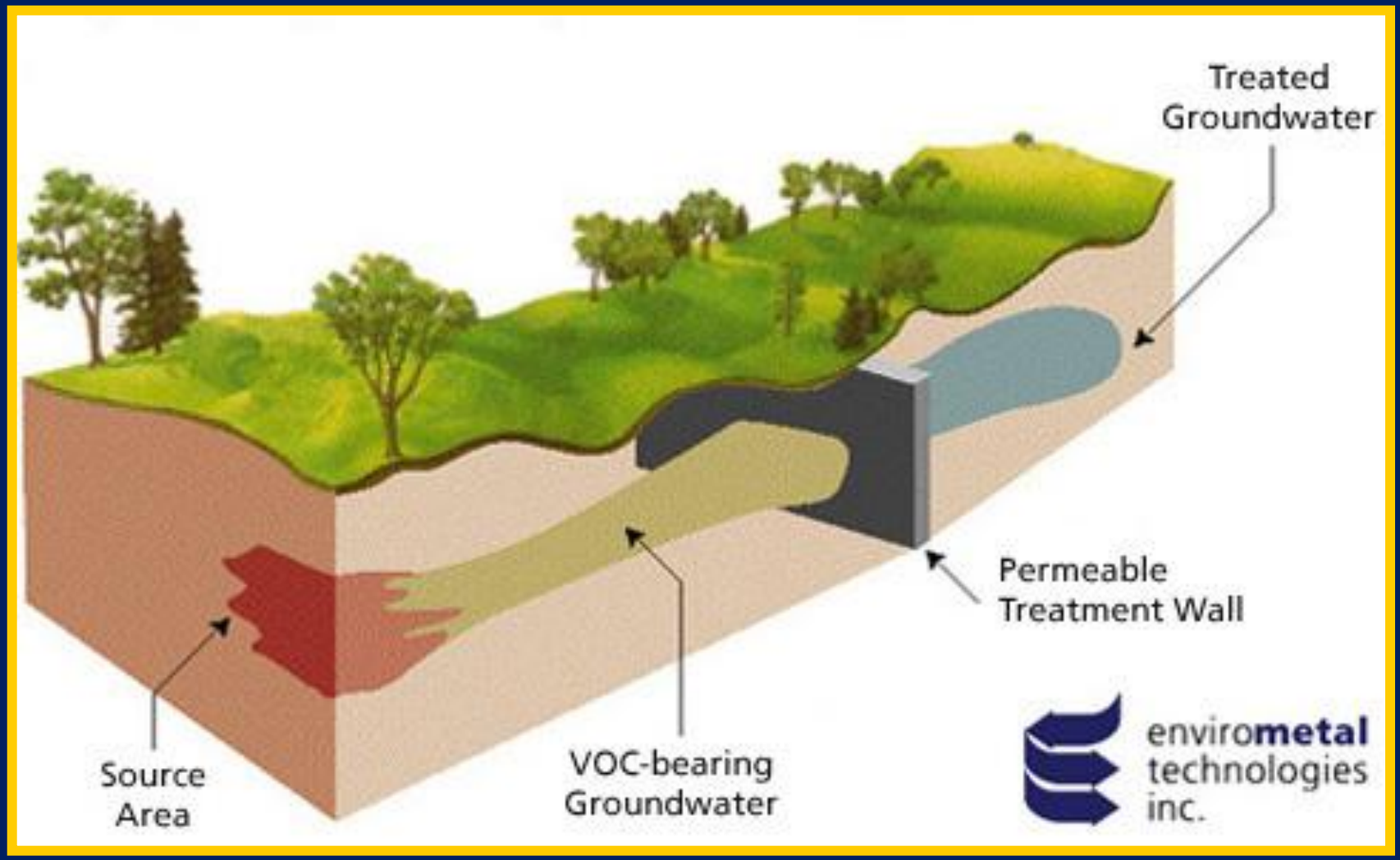
In Situ Technogies: In Situ Chemical Oxidation

- **Destroys contaminant in the subsurface, no need to excavate**
  - **chemicals used include hydrogen peroxide, potassium permanganate and others**

Advantages and Disadvantages of ISCO

- **Advantages**
  - Fast Treatment (weeks to months)
  - Temporary Facilities
  - Treatment to Low Levels (ND in some cases)
  - Effective on Some Hard-to-Treat Compounds
- **Disadvantages**
  - Requires Spending "Today's" Money to Get Fast Cleanup
  - Involves Handling Powerful Oxidants, and Carries Special Safety Requirements

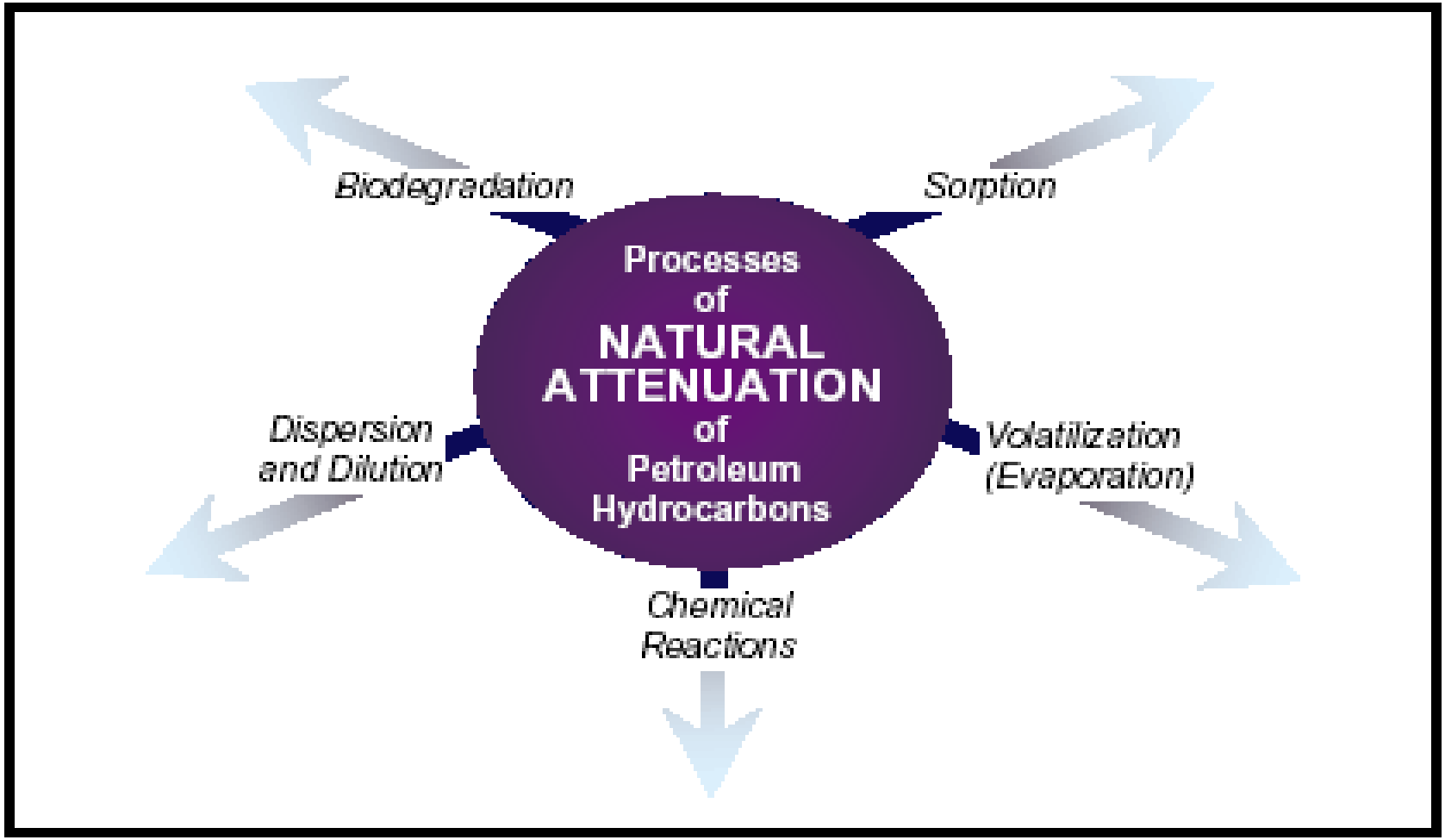
PRB Conceptualization



Potential Advantages

- Fully passive
- Low O and M
- Conserve water
- Conserve energy
- No above-ground structures
- Reuse land
- Disadvantages? ? ?

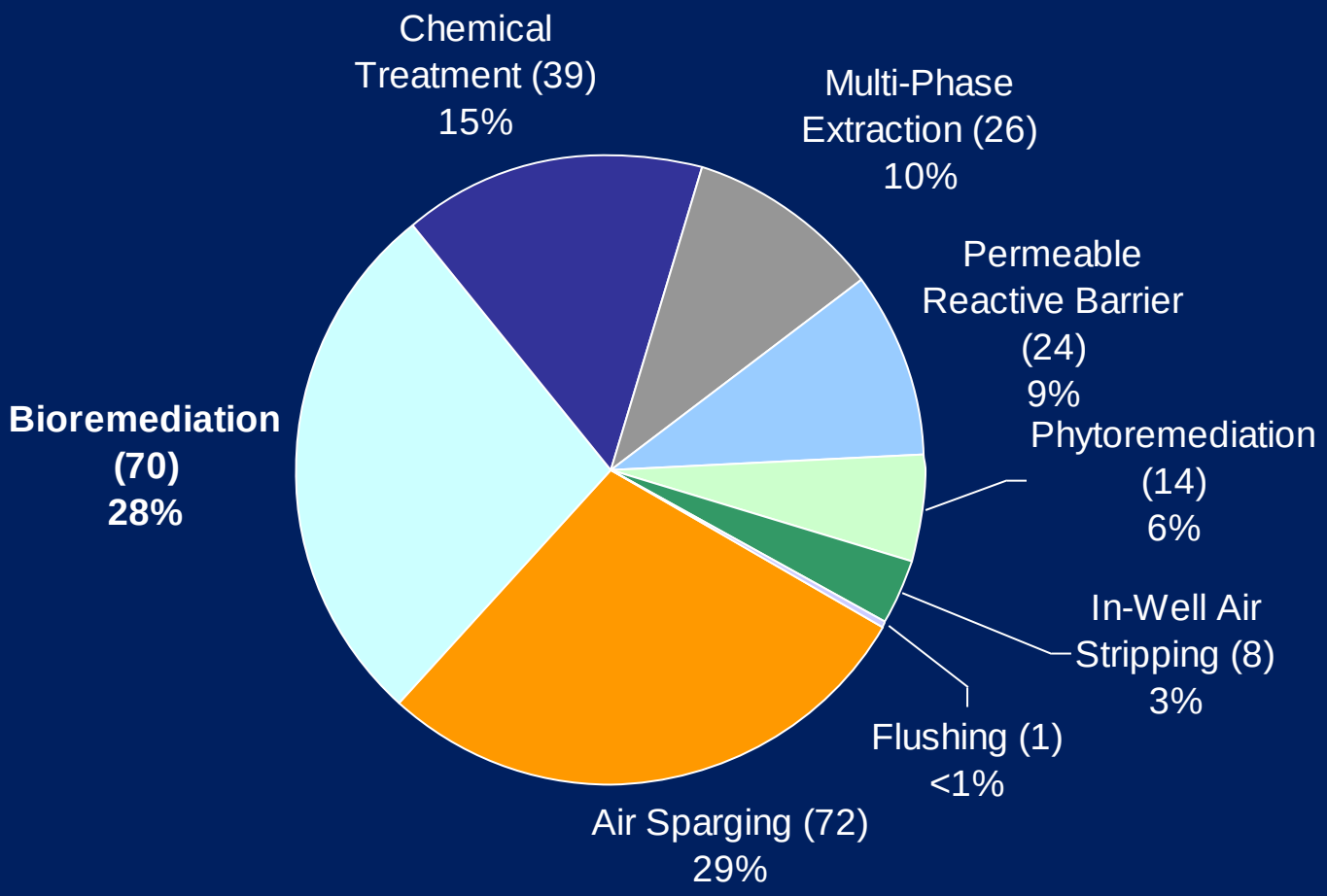
In Situ Technogies: MNA



In Situ Technogies: MNA

- Requires landowner and regulator buy-in
- The plume must be delineated
- There can be no immediate risk to receptors
- There must be an understanding of
  - what processes are causing the contaminant to break down,
  - how quickly it is happening,
  - what needs to be monitored to be sure it is progressing as intended
- This process can take many years or even decades

In Situ Groundwater Treatment Projects (FY 1982 - 2005)
Total Number of Projects = 254
EPA's Treatment Technologies for Site Cleanup: Annual Status Report - 12th Edition

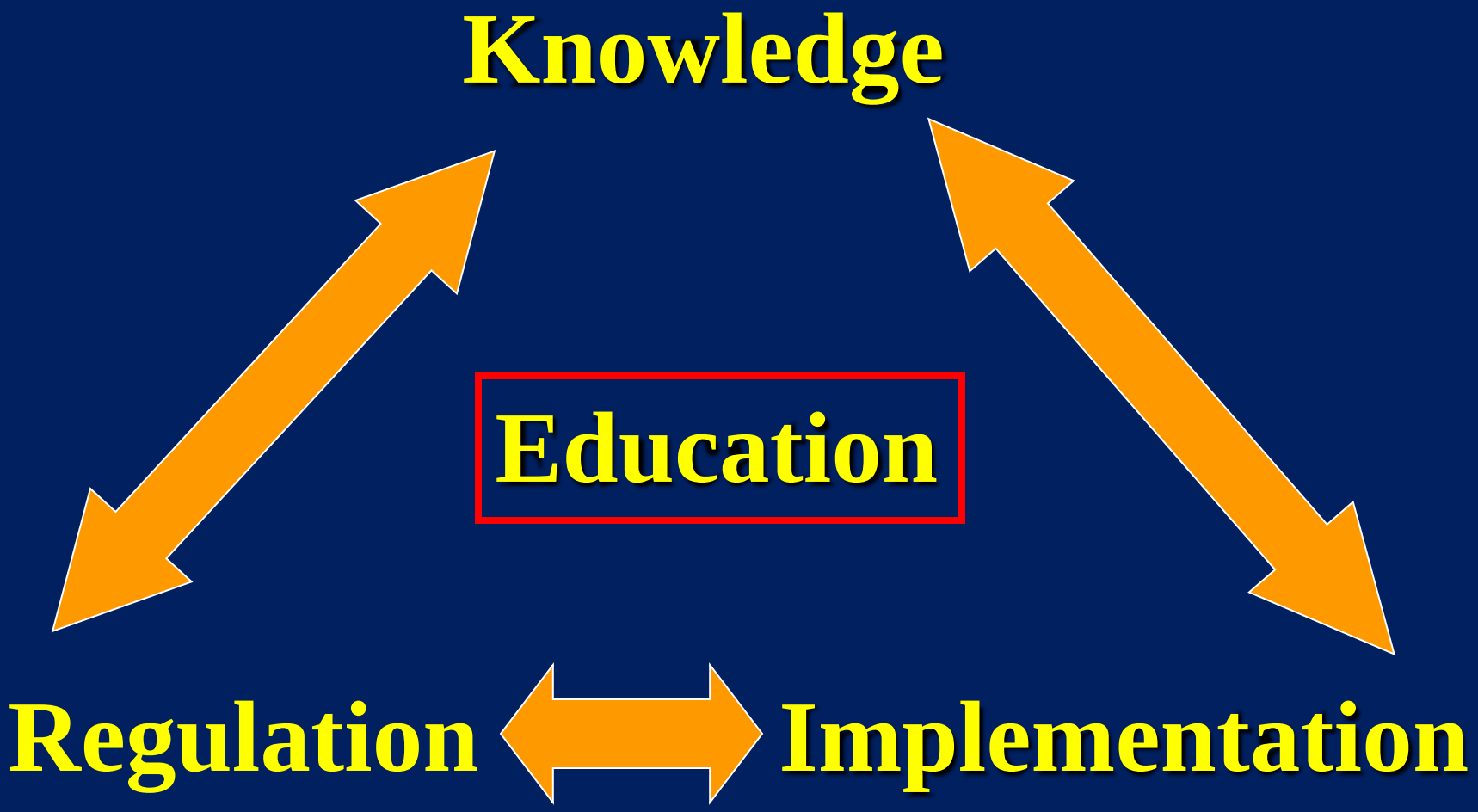


In Situ Groundwater Treatment Projects (ASR 12th Table 9)

Technology	ASR 11th Edition Number of New Projects Selected in FY 2000 – 2002*	ASR 12th Edition Number of New Projects Selected in FY 2002 – 2005**
Bioremediation	**21**	**26**
Chemical Treatment	15	17
Permeable Reactive Barrier	7	6
Air Sparging	10	6
Phytoremediation	3	5
Multi-Phase Extraction	4	5
In-Well Air Stripping	3	2
Flushing	2	0
Total	**65**	**67**

Status of In Situ Groundwater Treatment Projects by Technology (ASR 12th Table 10)

Technology	Predesign/ Design	Design Complete/Being Installed	Operational	Completed	Total
Air Sparging	9	5	38	20	72
Bioremediation	**29**	**4**	**27**	**10**	**70**
Chemical Treatment	19	2	9	9	39
Permeable Reactive Barrier	**6**	**1**	**15**	**2**	**24**
Multi-Phase Extraction	6	1	14	5	26
Phytoremediation	3	1	10	0	14
In-Well Air Stripping	1	1	6	0	8
Flushing	0	1	0	0	1
Total	**73**	**16**	**119**	**46**	**254**


Knowledge
Education
Regulation
Implementation