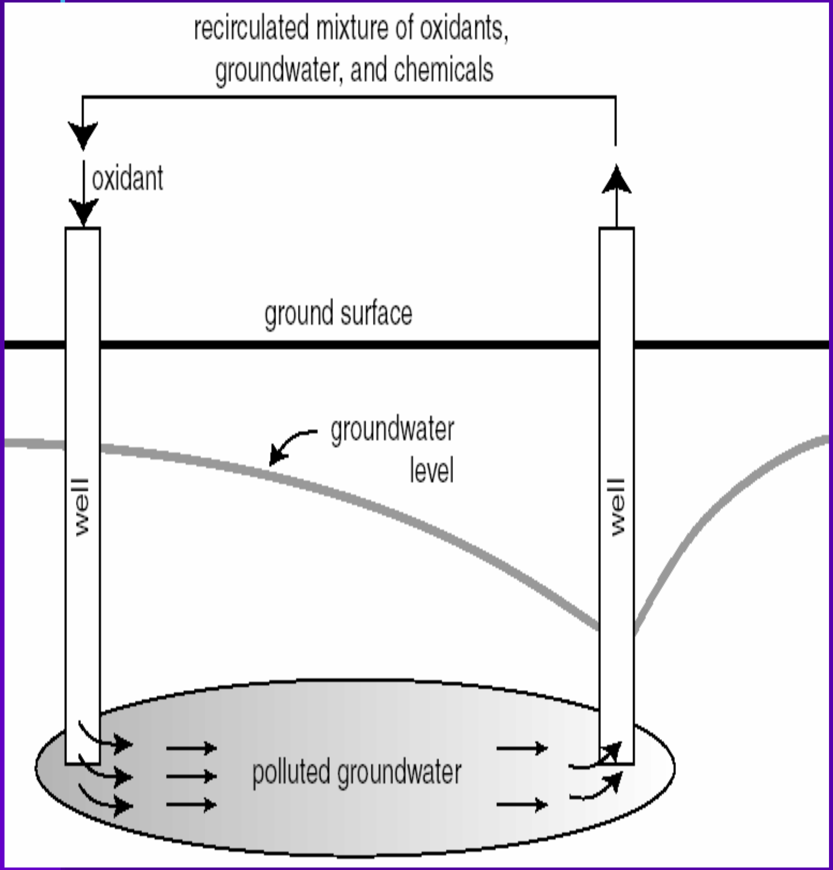
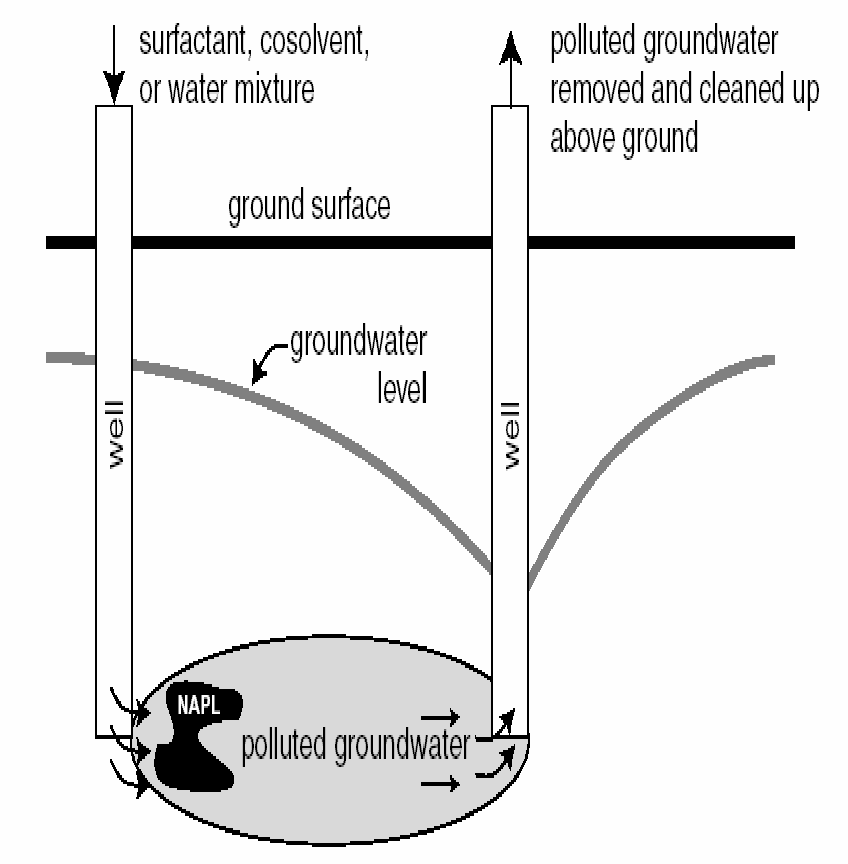
Delivery Methods for Optimizing in situ remediation with Treatment Amendments





Outline

- In situ Remediation – why the need?
- Trends
- Drivers for ISR
- Advantages/Benefits
- Amendment Delivery Assessment Tool
- ISR Verification

Technology Trends

- Principal Management Strategies:
  In-situ (always on-site)
  Ex-situ (either on- or off-site)
  Increasing use of innovative Remedial Technologies

- Growing preference for in-situ approaches and niche technologies for specialized chemicals which cannot be treated by other remediation technologies (e.g.: PCE/TCE, PCBs)

Canada

Key Remediation Market Drivers

- Principal market forces that drive remediation markets around the world, including in Canada (Industry Canada FCSW, 2006):
  - Regulations
  - Corporate liability
  - Property transaction liability
  - Economics
  - Damage to corporate reputation
  - Public stakeholder pressure

Growing need for Remedial Technologies that are …

- Faster
- Cheaper
- More effective (destruction vs. transfer)
- More sustainable (“small footprint”)
- In Situ (non-disruptive)

ITRC, US NSF, EPA, IC, SDTC, EU, Corp

But ...

Understanding of ISR using treatment amendments needs to be much improved, especially:

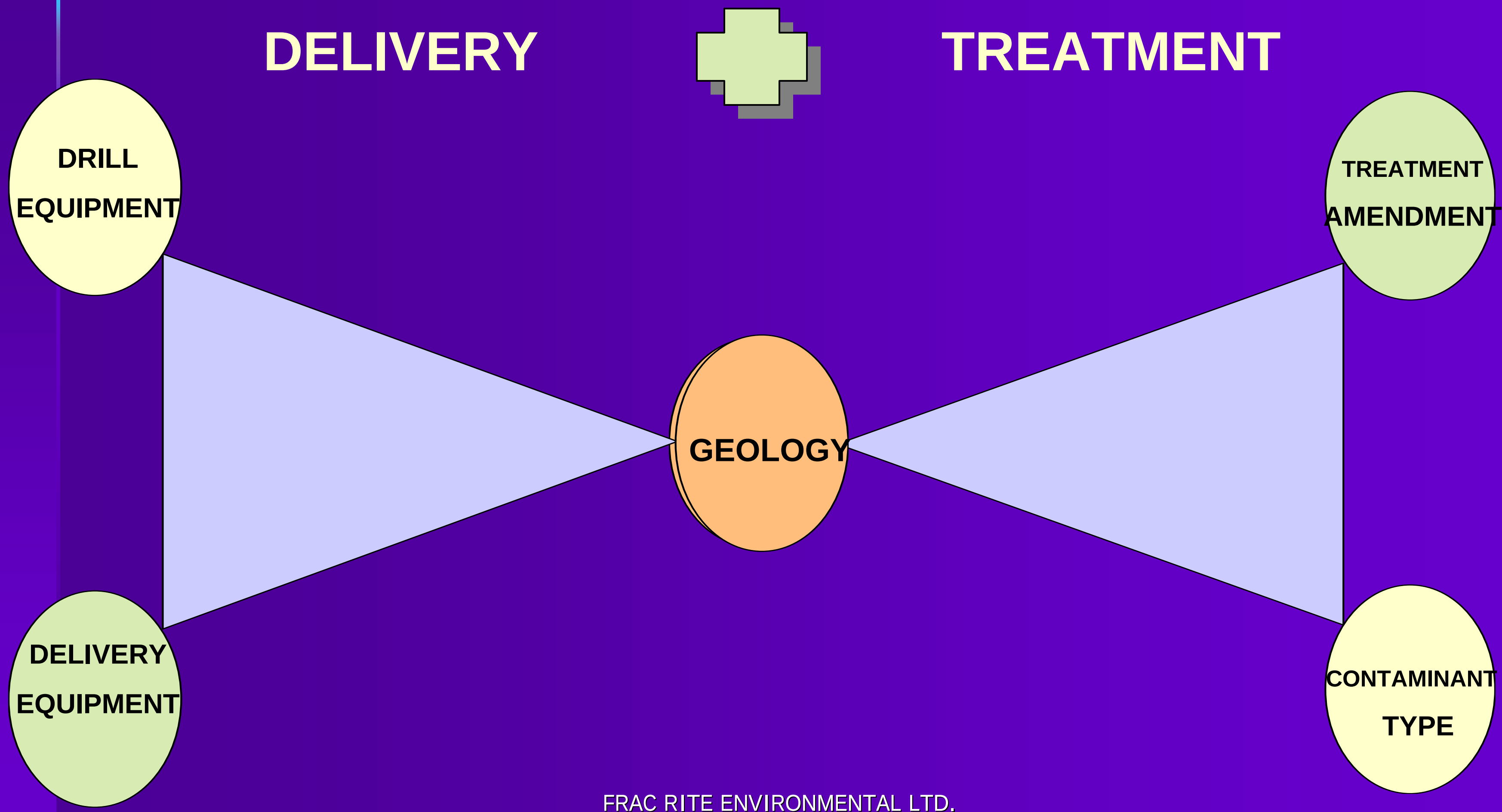
- Selection of appropriate Amendments
- Distribution of Amendments (CONTACT)
- Incompatibilities with Geology
- Effectiveness Verification

Amendment Delivery Assessment Tool

Systematic approach to ISR using Treatment Amendments:

- Geology
- Nature of Contaminant
- Remedial Approach
- Treatment Amendment
- Delivery System & Equipment
- Remedial Effectiveness Verification

Elements for Success



Treatment Amendments

AMENDMENT	EXAMPLES	PROCESS	CONTAM.
Peroxygen Chemicals **(powder slurry)**	Calcium & Magnesium Peroxide	Oxidation and Aerobic Bio-degradation	Residual Phase and Dissolved HCs
Zero Valent Iron **(solids slurry)**	CGI, MSI, NSI	Abiotic Reductive Dehalogenation	Chlorinated solvents
Zeolites/Humates **(solids slurry)**	Clinoptilolite/ Leonardite	Cation Exchange/ Adsorp & Chelatn	Salts, metals, hydrocarbons
Surfactants **(solution)**	Non-ionic, alcohol based	Reduced IFT; enhanced Bio-availability	Residual or Free Phase HCs

Amendment Delivery

- Passive (e.g. gravity)

\- Advection and Dispersion : GW Velocity

- Pressure injected (below frac P)

\- Pore space permeation: Ø, % fines

- Pressure injected (above frac P)

\- Discrete fractures: K, P_f

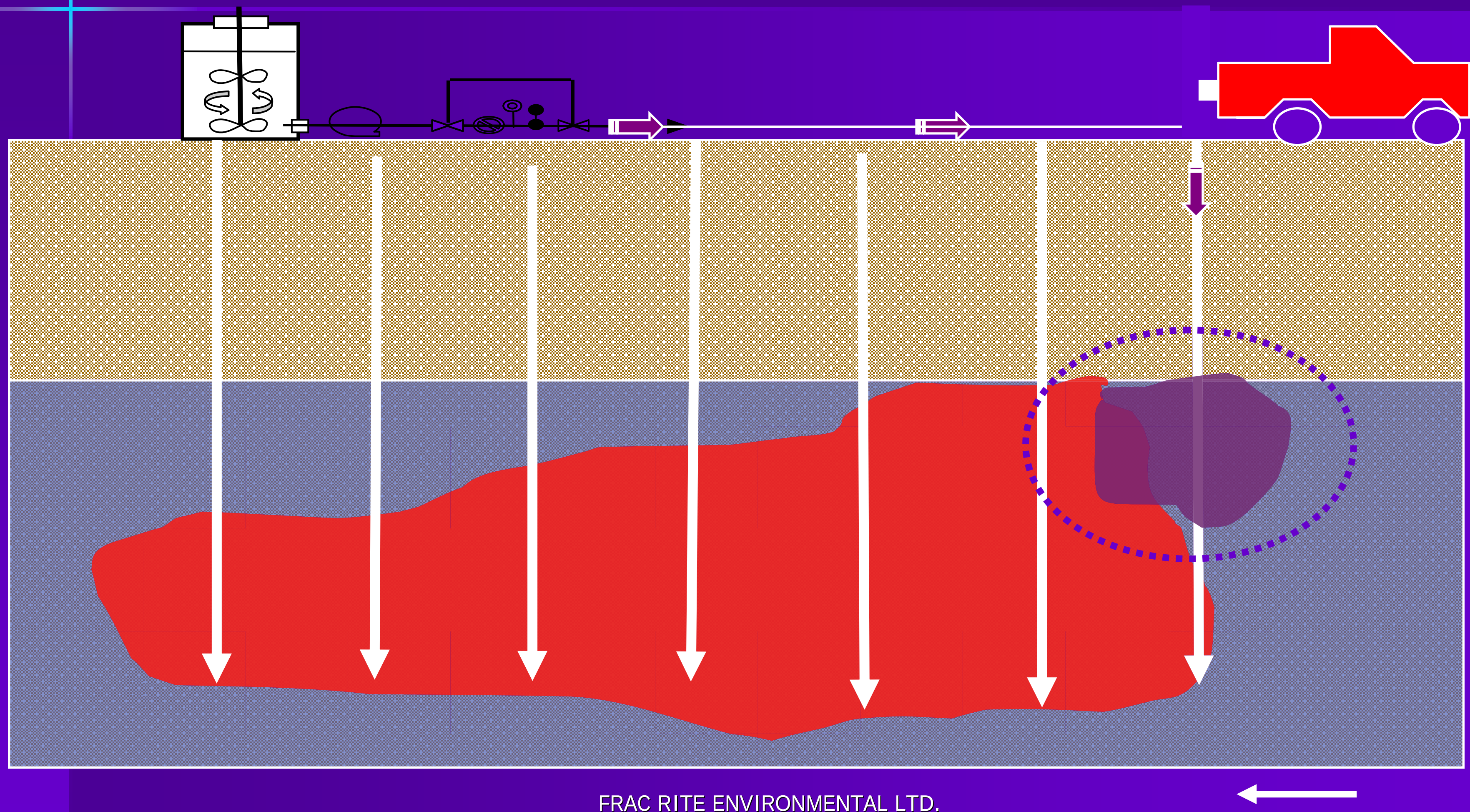
Which Delivery System ?

- Remedial Objective:
- Injection only? One-time or multiple events?
- Injection and Permeability Enhancement

- Physical properties of Amendment
- solution, slurry, solids – density, size, abs.vol.

- Properties of receiving geology
- Clay content and mineralogy, GSD, K, density, cohesion, groundwater geochemistry

Simplified "Direct Push" Injection (Permeation)



Permeation Injection

- Only works if amendment can pass through the mean pore throat diameter of a soil, i.e. when:

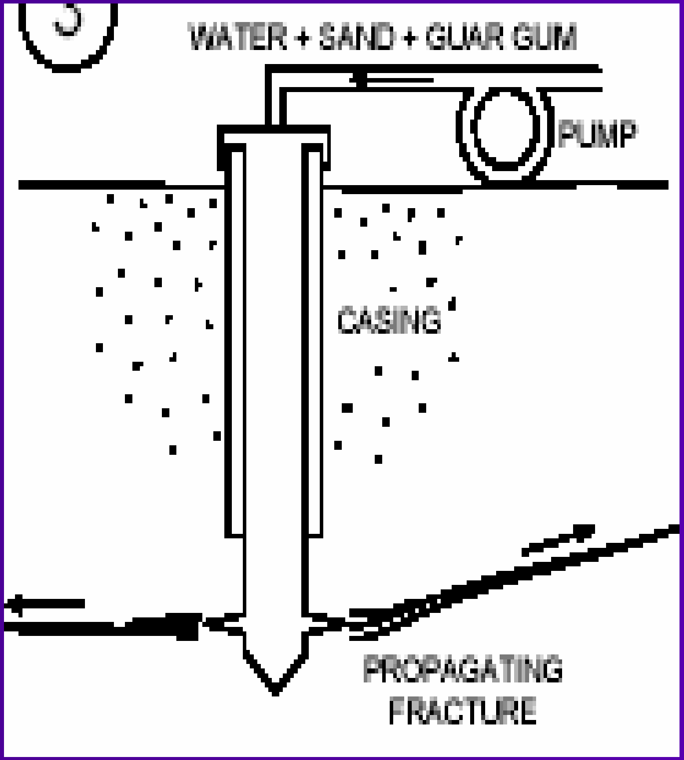
Amendment Particle size,

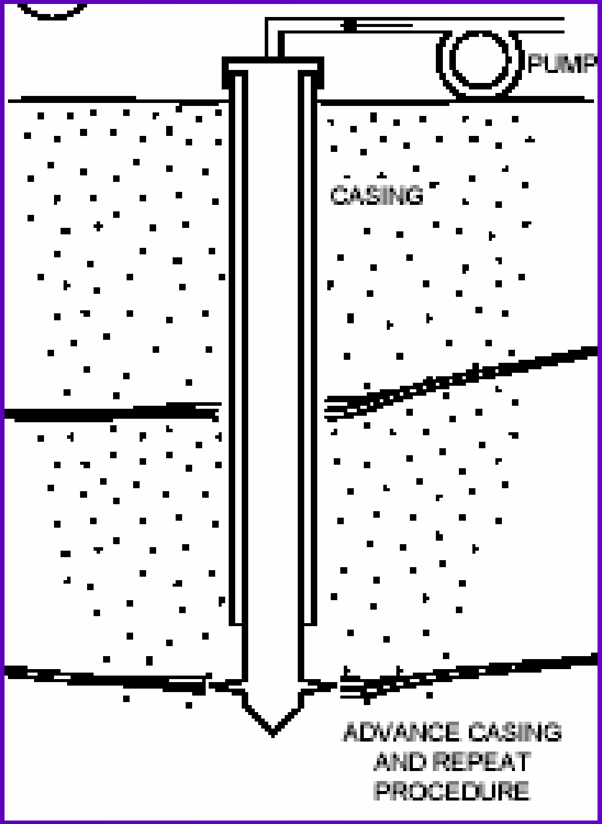
$$Ps < \sqrt{K/7}$$

Ps in microns and K in md (Haris and Odum, 1982)

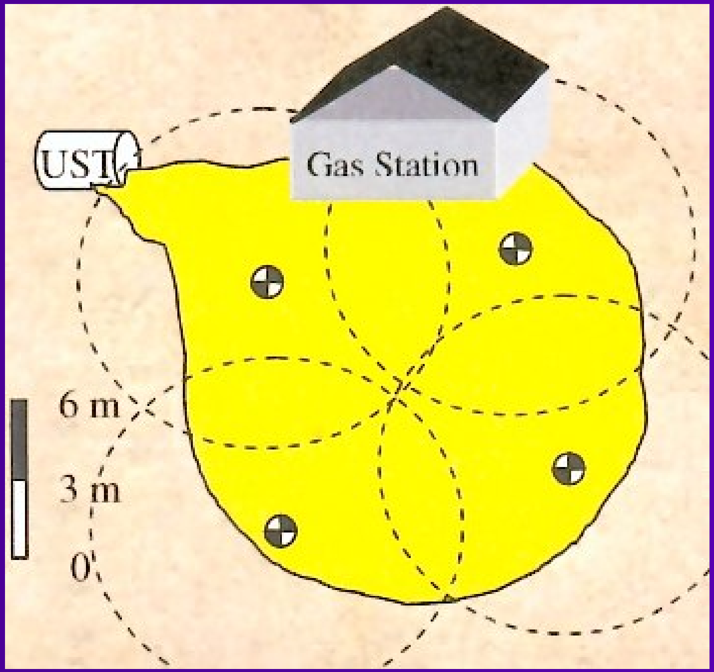
Otherwise, you are fracturing!!!

Fracture Emplacement of Amendments

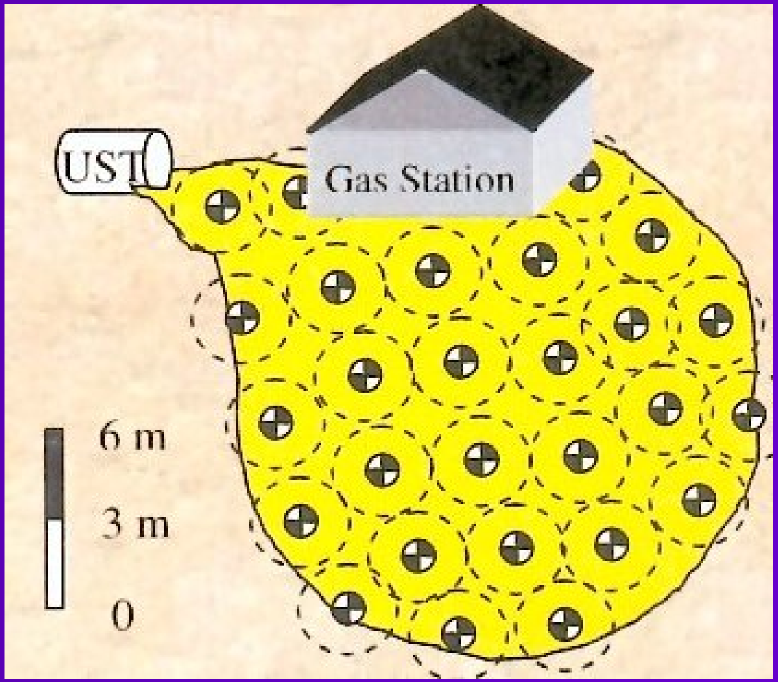




Plan View of Amendment Distribution



FRACTURE EMPLACEMENT



PERMEATION INJECTION

Low Density Solid Bioamendment (Chitin)

High density Solid Amendment (ZVI)

Base Gel (Guar) carrier fluid

- Water based,
  natural or hydroxyl propyl guar polymers
- pH buffer & clay stabilizer
- Crosslinker
- Breaker
- Sand proppant
- Amendments

In Situ Amendment Delivery Requirements

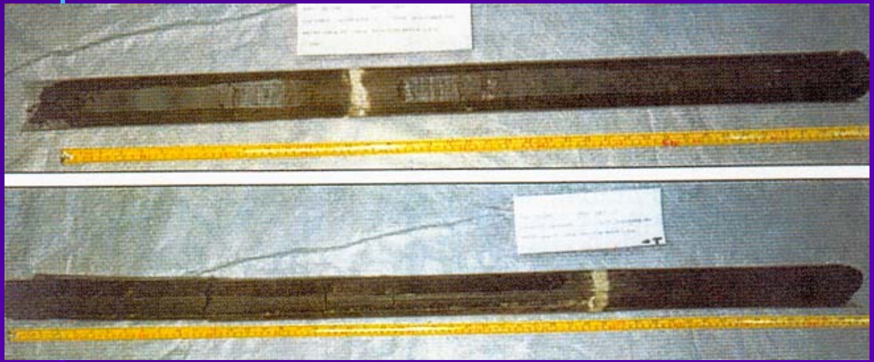
- Mobile mixing tank and pumps
- Drilling equipment
- Downhole tools
- Instrumentation
- Geophysical mapping equipment

Verifying Amendment Distribution

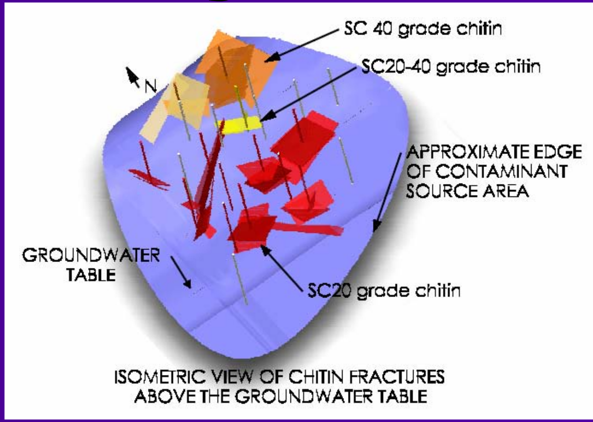
- Visually: Excavation, soil coring
- Geophysics: Tiltmeters, GPR, EC
- Indirect methods: Tracers
- Effects on GW geochemistry

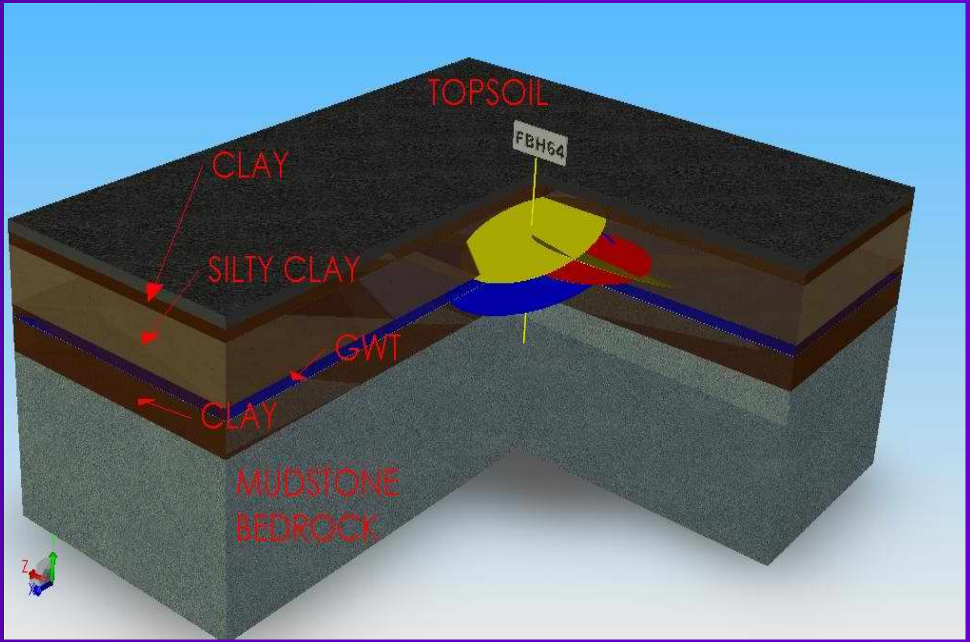
Verification of fracture-emplacement in excavation

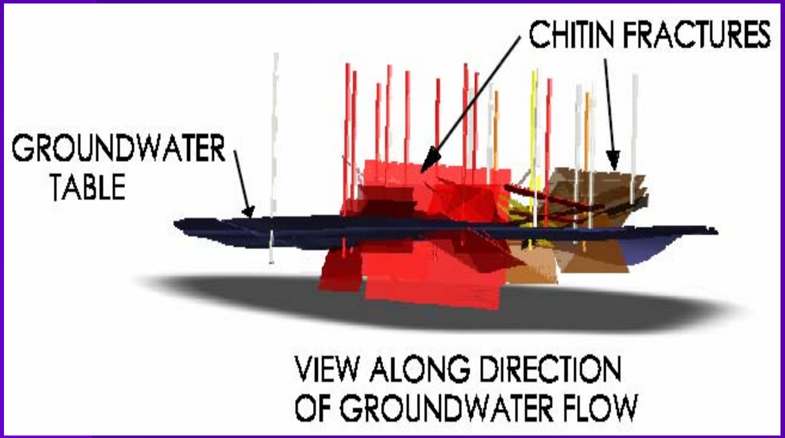
Verification of amendment delivery by soil coring



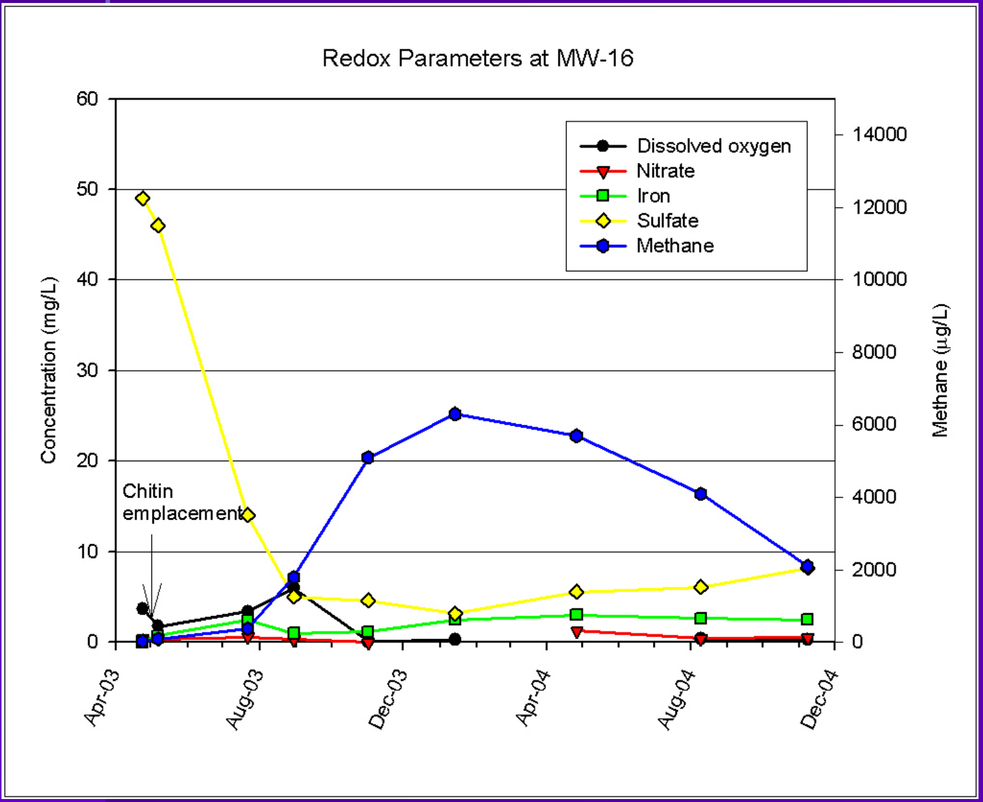
Verification of amendment distribution by tiltmeter geophysics

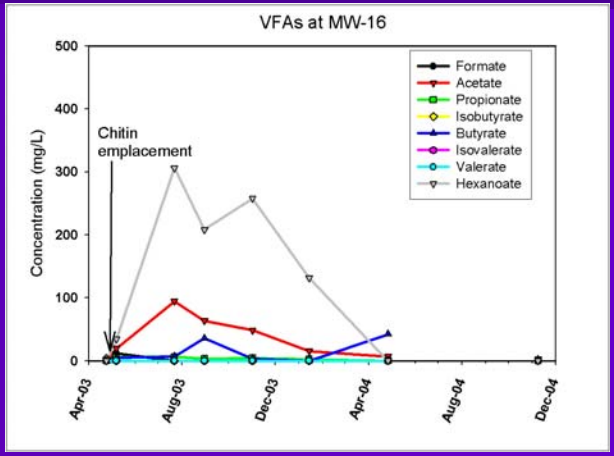


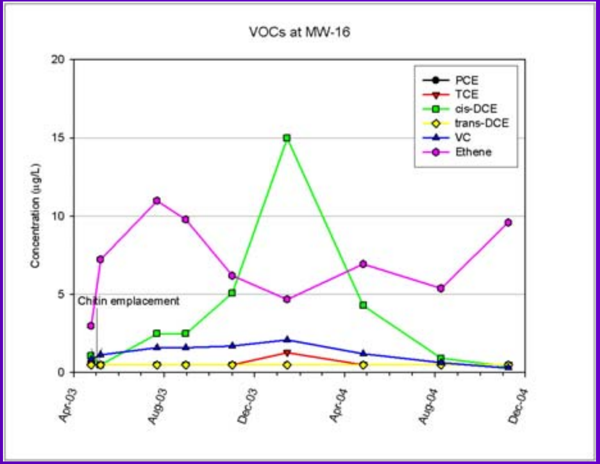




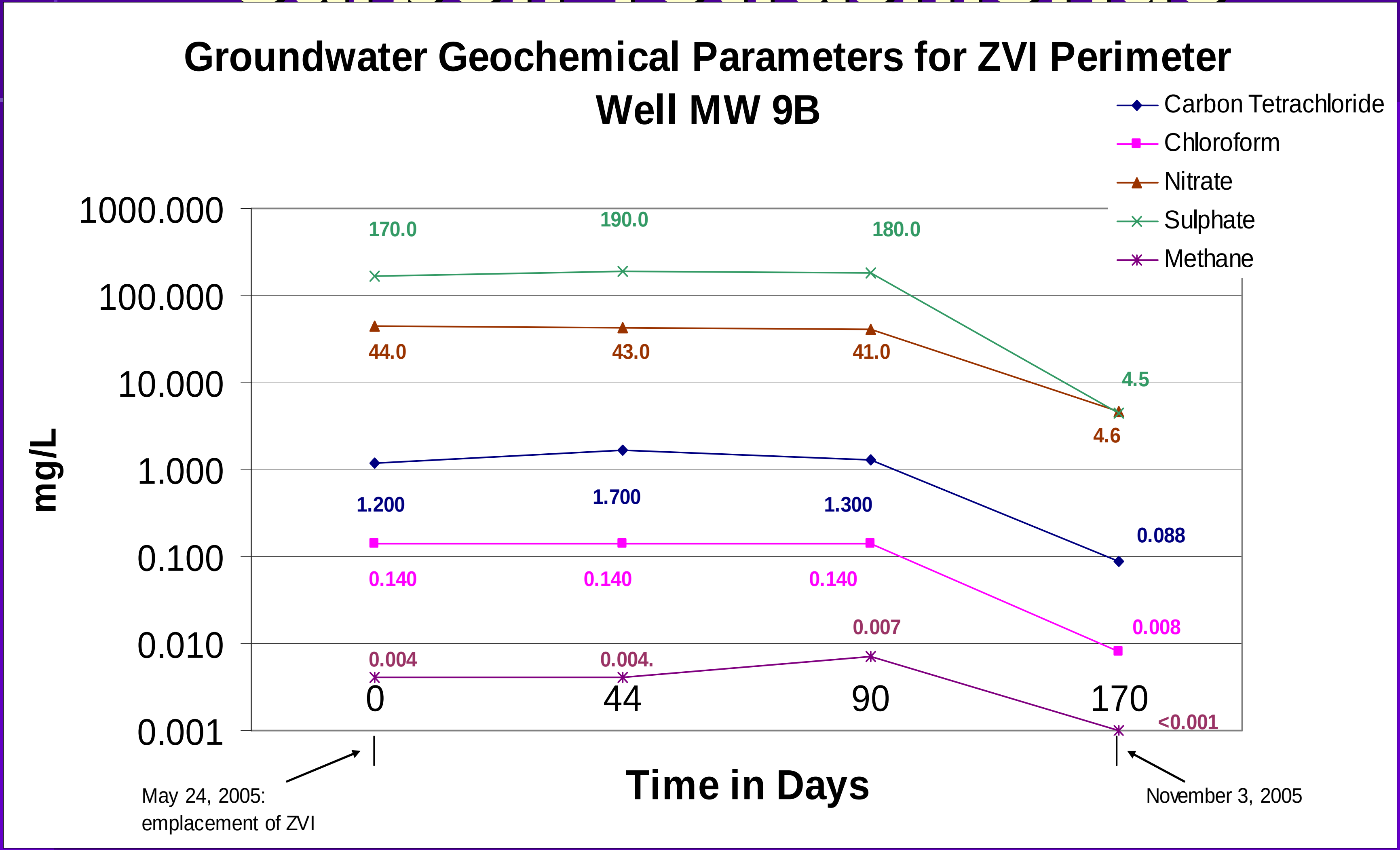
Geochemistry for Anaerobic Reductive Dehalogenation of TCE







Abiotic Reduction of Carbon Tetrachloride



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Summary

- Cost-effective in situ remediation using treatment amendments requires careful consideration of compatibilities between geologic conditions, delivery methods, and amendment-contaminant interactions.

- Verification techniques improve ability to optimize remedial performance and effectiveness monitoring