Resurgence of In Situ Soil Mixing for Treating NAPL Source Areas

Prepared for:

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Presentation Objectives

- Introduce in situ soil mixing (ISSM)
- Brief ISSM history and recent resurgence
- Discuss current approach using clay and zero valent iron (ZVI)
- Present results of two recent case histories of clay/ZVI ISSM
- Summarize why you may or may not want to consider ISSM

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Technology Description

- Heavy equipment used to move and mix soil in situ
- Deliver and mix a variety of treatment chemicals:
  - Chemical oxidants (permanganate and persulfate)
  - Chemical reductants (ZVI)
  - Enhanced bioremediation reagents
  - Stabilizing/solidifying agents (cement, bentonite)
- Equipment ranges from a backhoe to specialty mixing augers
- Best suited for highly concentrated LNAPL or DNAPL source zones

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History of ISSM

- A subset of Deep Soil Mixing
  – 40+ years old in geotech industry
  – Primarily to treat soil by adding cementitious materials
- Used for environmental remediation since late 1980s (SITE program test in 1988)
  – In situ solidification/stabilization of soils and soil bentonite cut-off walls
  – Also used with hot air, steam, and oxidant injection/mixing
- Suffered from perception of high cost and limited applicability

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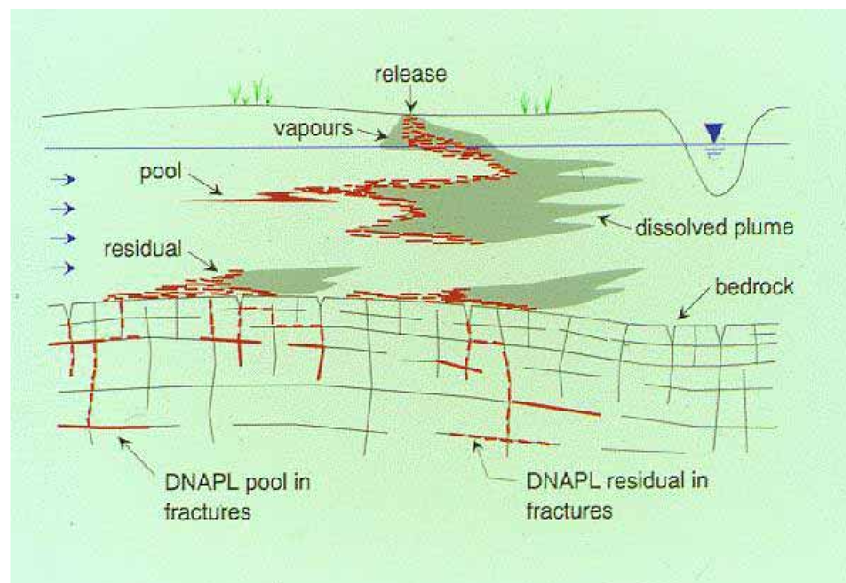
Challenges for NAPL Remediation Technologies

- Source zone heterogeneity and complexity
- Uniform chemical delivery to contaminants
- Adequate dose to meet treatment goal
- Adequate contact time
- Minimization of detrimental effects



Conceptual chlorinated solvent source zone (Kueper et al., 1993).

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Recent Resurgence of ISSM

- Adapted to address persistent source zones in complex matrices
- Historic failure of many in situ injections due to poor delivery and inadequate contact
- Very few options for source zones
- Concurrent treatment/containment strategies are attractive

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Current Approach using Clay/ZVI

- Concurrent in situ mixing and clay and ZVI slurry addition
- ZVI treats chlorinated contaminants
- Clay provides contaminant migration control
- Clay acts as lubricant during mixing
- Creates a relatively impermeable zone of soil to reduce contaminant mass flux
- Patented technology developed by DuPont (1998) and donated to Colorado State University (2003)

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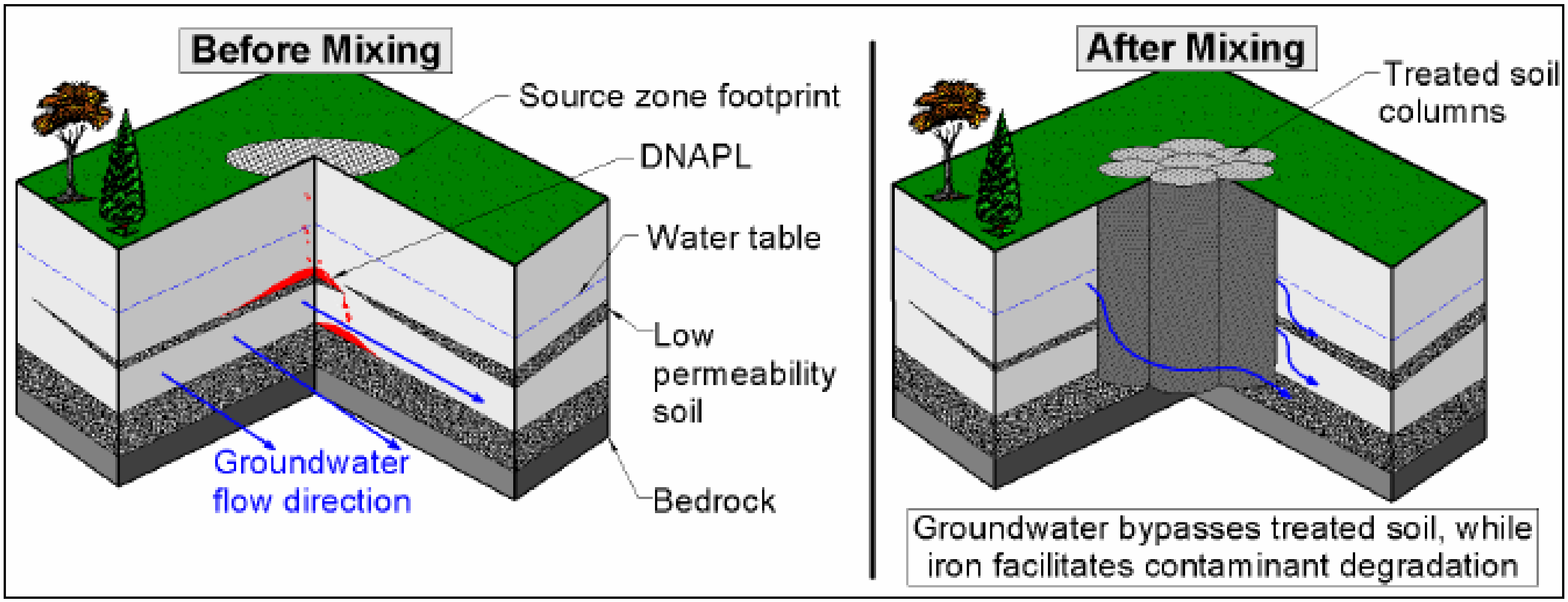
Conceptual Model of Mixing



Patented technology held by Colorado State University

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Site 88, Camp LeJeune, NC

- Former dry cleaning facility
- DNAPL present in two wells
- Dissolved PCE up to 64 mg/L
- Membrane interface probe (MIP) used to define target treatment zone (TTZ)

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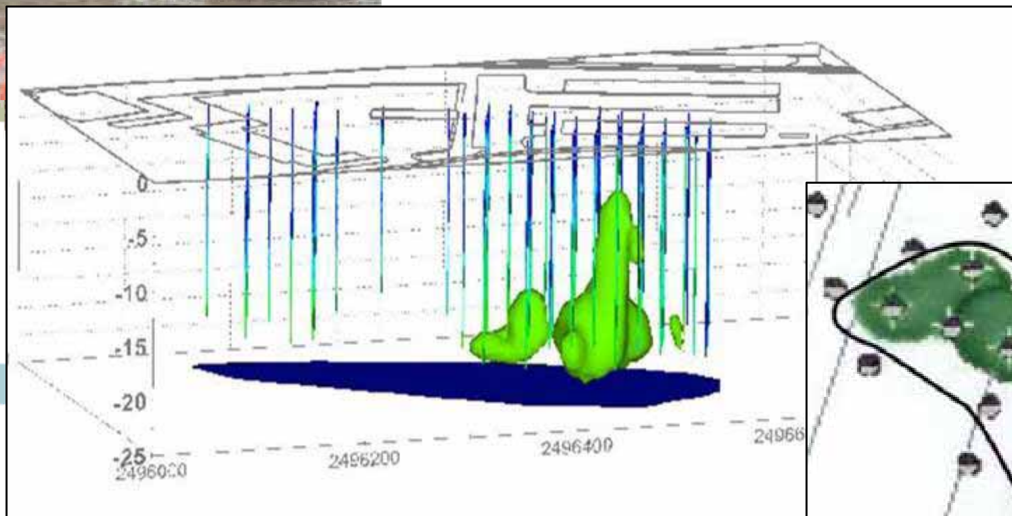
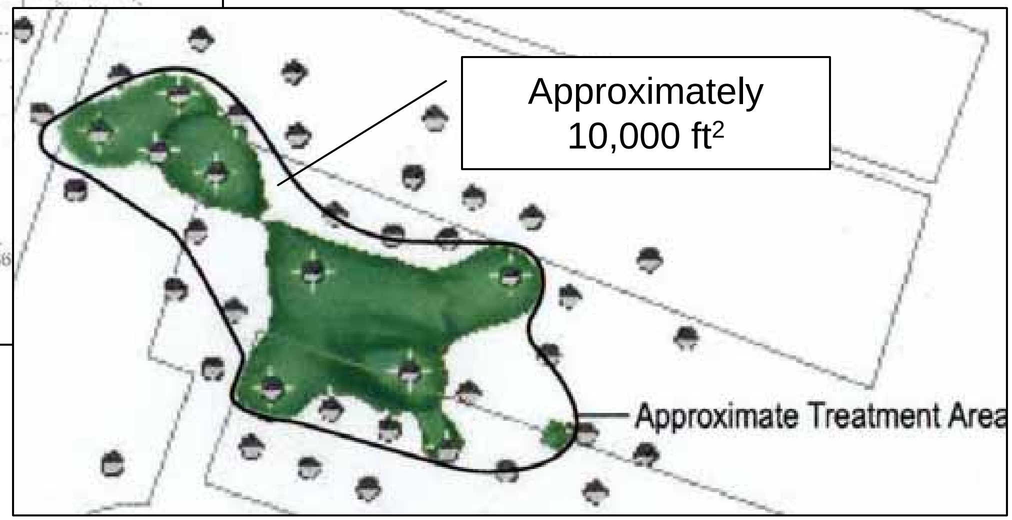
Site 88 Source Description





- TTZ: silts and sands, 10,000 ft^2 and 20 ft deep (7,000 yd^3)
- Site prep: limited overburden excavation, utility relocation (steam, water), slab removal, well abandonment

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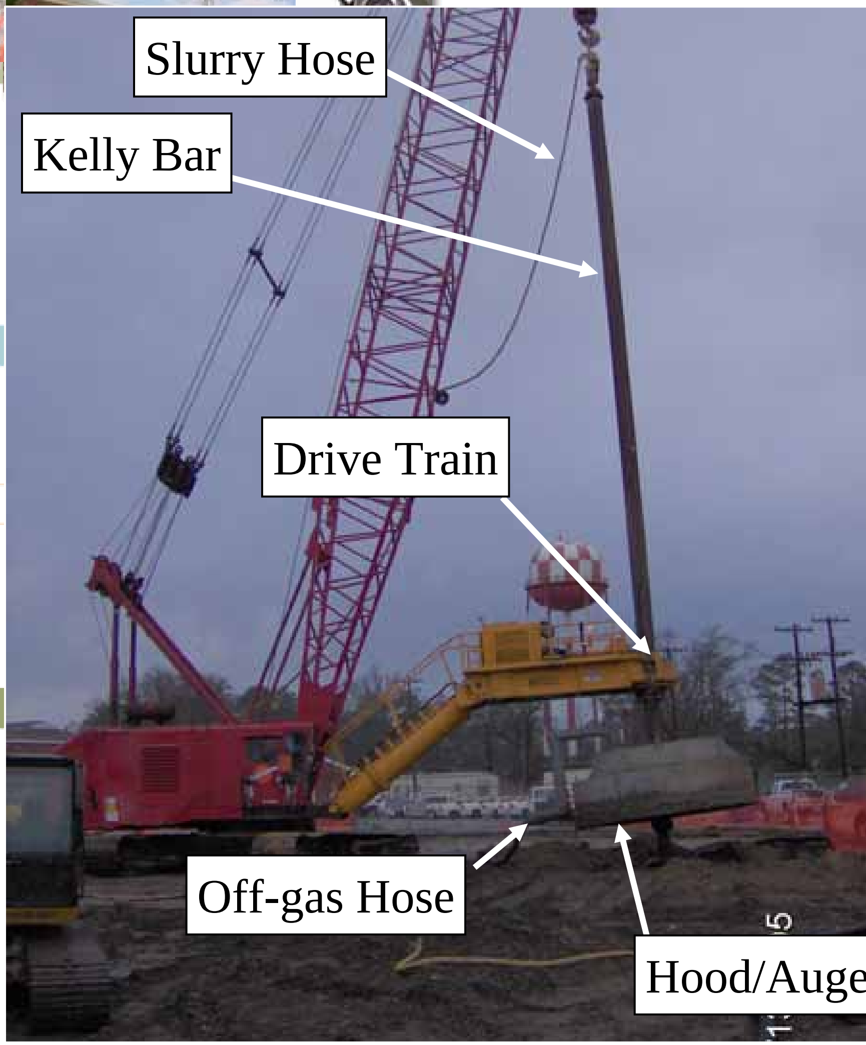
Site 88 Clay/ZVI ISSM Process (Feb-05)



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Site 88 – Treatment Stats

- Delivered 200 tons ZVI (2% by wt) and 100 tons bentonite (1% by wt)
- (146) 10-ft dia. columns to 20 ft bgs
- Treated 14 tons of PCE
- 17 days active mixing
- QA/QC sampling verified mixing effectiveness
- GAC offgas control was necessary

Soil Core of Mixed Material

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Site 88 - Before and After Conditions

BEFORE

AFTER

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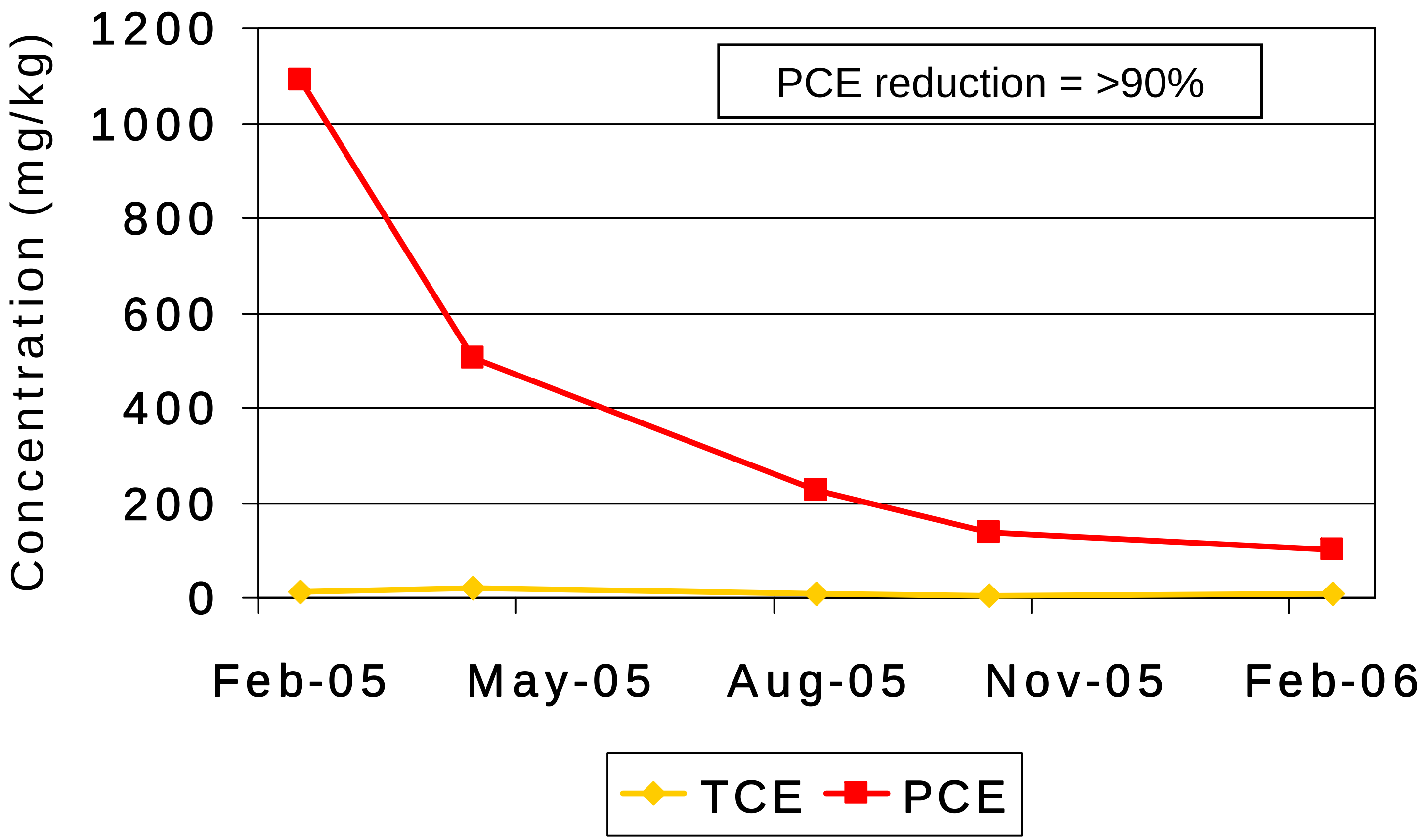
Site 88 - Soil Treatment

(wt. avg. 6 samples per event)



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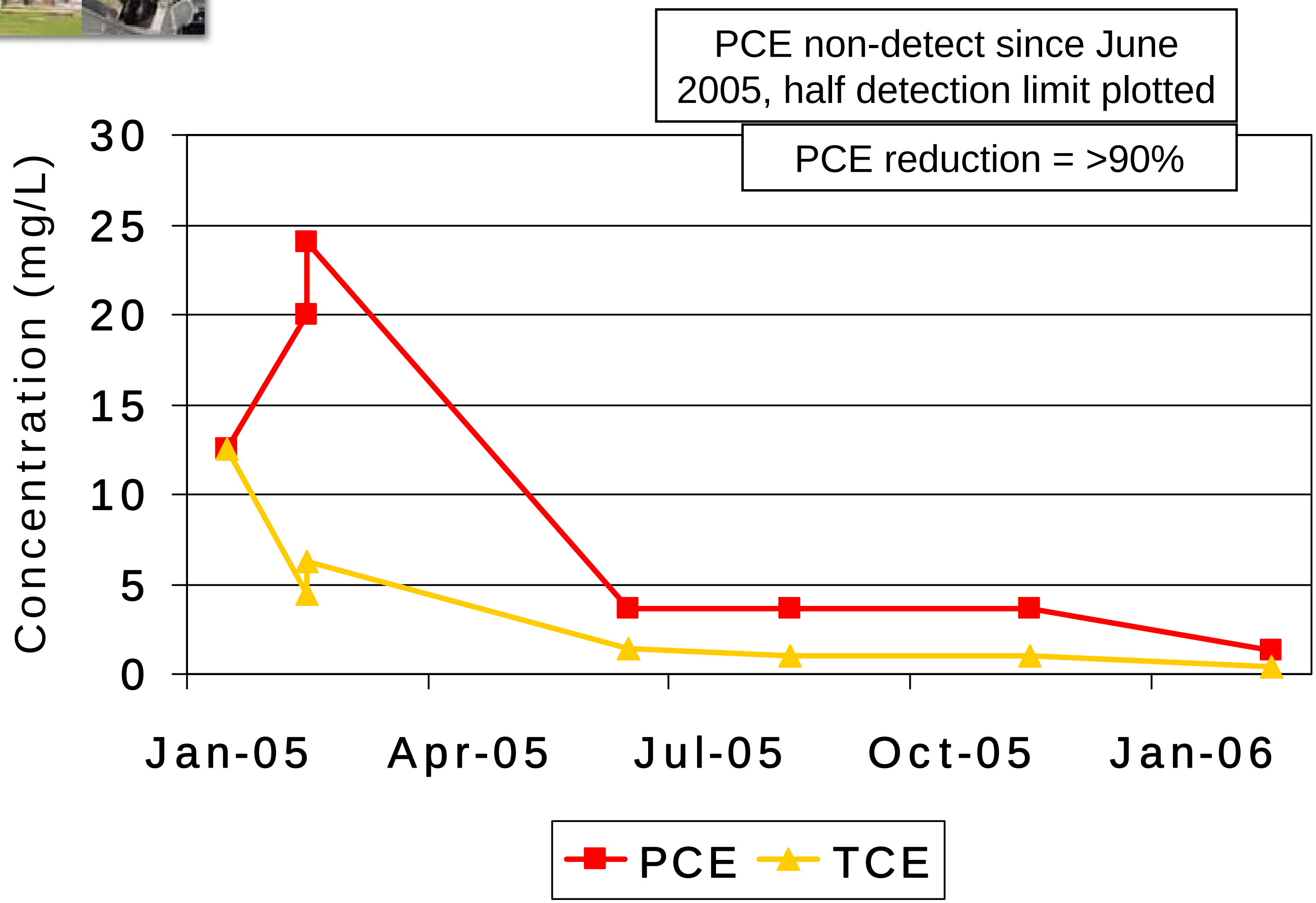
Site 88 - Groundwater Treatment (10-20 ft downgradient)



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Site 88 - Synopsis

- >90% contaminant reductions in soil, groundwater, and soil gas 1 year after treatment
- One to two orders of magnitude reduction in hydraulic conductivity (avg. final 0.01 ft/day)
- Mass flux reduction not quantified
- Land returned to beneficial use

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SWMU 16, Arnold AFB, TN

- Former burn and leach area
- Dissolved TCE up to 27 mg/L
- Residual DNAPL suspected
- MIP survey conducted
- Silty clay to clayey silt
- Vadose zone source removed prior to ISSM
- TTZ: 5,400 ft^2 and 16-24 ft deep (1,600 yd^3)
- Site prep included stripping top soil and silt fencing adjacent to reservoir and creek

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SWMU 16 – ISSM Process (Dec-05 to Jan-06)

- Lang Tool™ used to rototill and mix slurry
- 36 tons of iron (1.5%) and 48 tons of bentonite (2%) emplaced

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SWMU 16 - Before and After Conditions

BEFORE

AFTER – Mulch Drainage Layer

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SWMU 16 - Results

- Lang Tool process was power limited
- Required pre-excavation to loosen soil to achieve total depth
- Mixing in 6-ft lifts was effective
- No offgas control required
- QA sampling verified iron 1%-4%
- 2-ft surface settlement over 1 year
- ~70% reduction in groundwater concentrations

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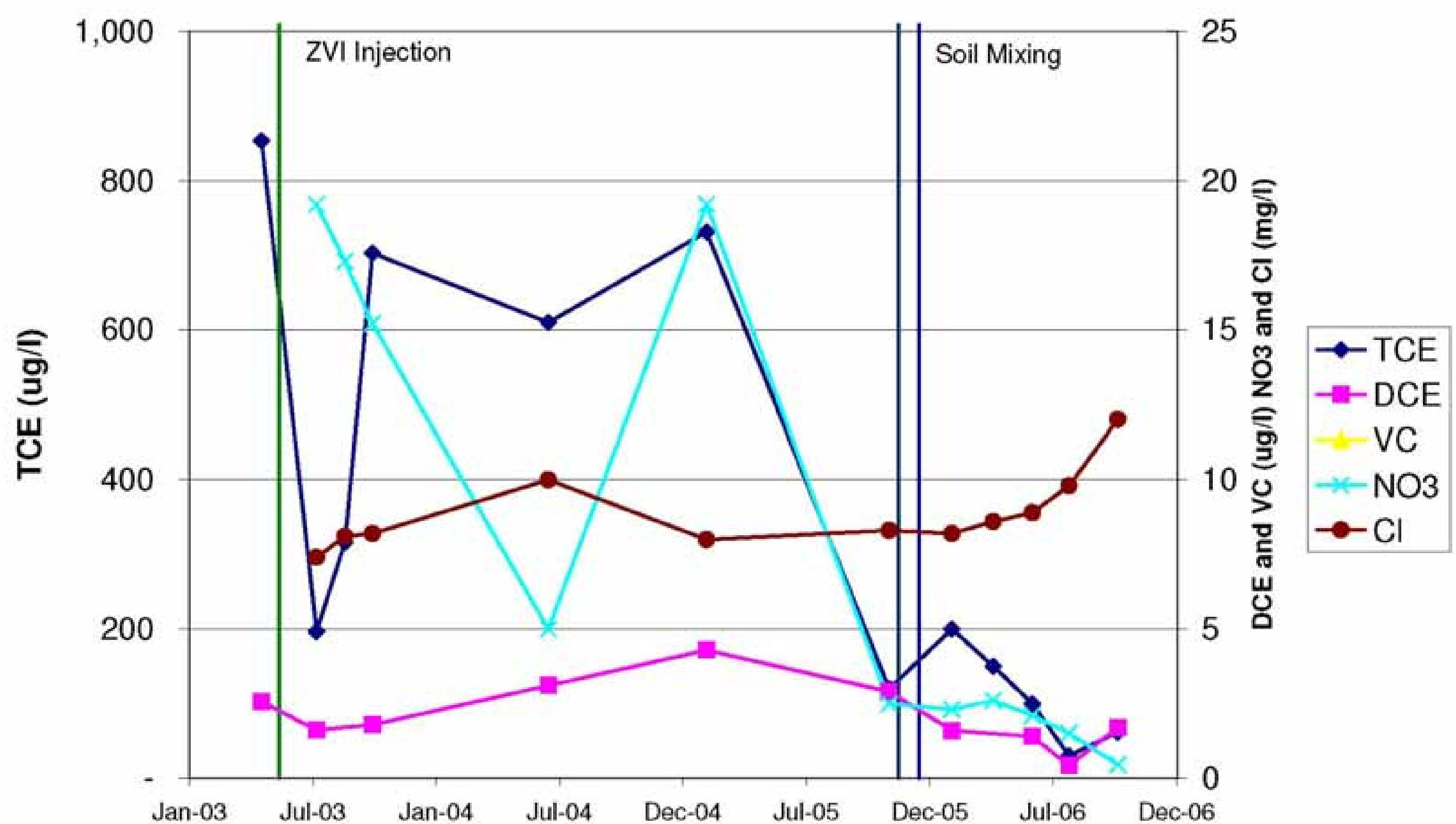
SWMU 16 - Groundwater Treatment (30' downgradient)



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Demonstrated Benefits of In Situ Soil Mixing

- Effective for heterogeneous source zones with free-phase DNAPL
- Cost and effectiveness varies with the type of equipment used
- Ballpark: \$50-\$200/yd^3, typically lower than in situ heating and hazardous waste dig and haul
- Solid-phase treatment chemicals effectively mixed with contaminated soil

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Presentation Synopsis

- Technology Advantages
  - Aggressive and effective for quick treatment of vadose and saturated source zones at NAPL sites
  - Cost competitive for high concentration hazardous waste sources in complex settings
  - Significantly reduces mass flux from source
- Technology Disadvantages
  - Large infrastructure and most applicable to open sites with few impediments
  - Relatively shallow depth (up to 40 ft bgs)
  - Long-term residue management is required (LUCs)
  - Relatively young technology still working on efficient field processes

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The End

- Any Questions?

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