Innovative and Sustainable Fractured Bedrock Remediation via a Surfactant-Enhanced Aquifer Remediation Approach

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Overview

- Background & Site History
- Site Conditions
- Remediation Alternatives
  - SEAR
    - Bench-Scale Treatability Study
    - In Situ Pilot Study
- Lessons Learned

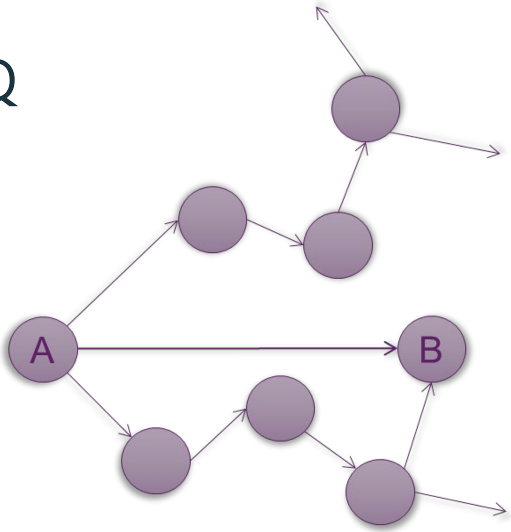
Background & Site History

Background

- Cutting blade manufacturing facility
- Solvents, oil and metals contamination
- LNAPL & DNAPL identified near main plant
- P&T for hydraulic control to protect receptor

Site History

- ➢ Owner assumed environmental liability without knowing full onsite extent
- ➢ Inadequate regulatory program but need concurrence on closure. Multiple regulatory pathways:
  - Previous Regulatory Pathway – VADWQ
  - CERCLA or RCRA Pathway
  - Voluntary Remediation Program
- ➢ Ineffective remediation
- ➢ Control costs

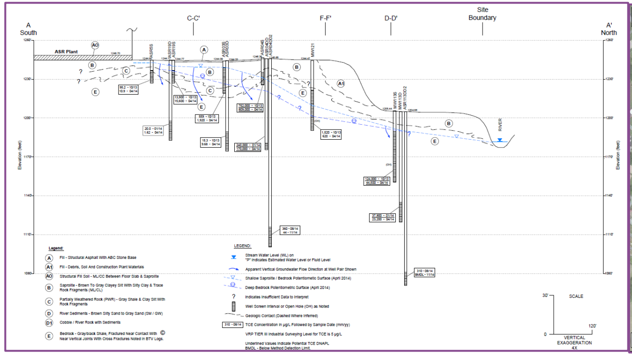


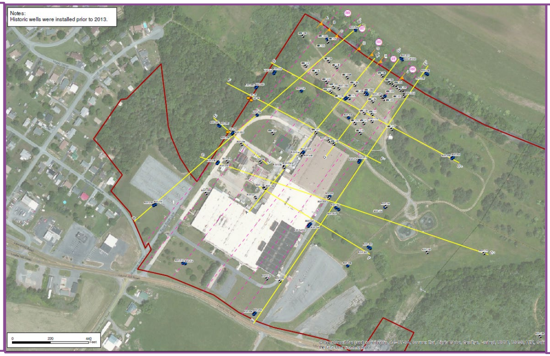
Site Conditions

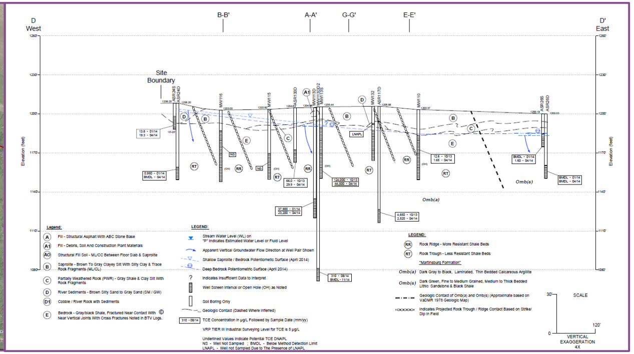
Site Conditions - Fractured Bedrock Geology

Complex Site Geology

- Saprolite underlain by PWR and bedrock
- Buried debris and construction material
- Cross-bed and fracture communication
- Regional synclinorium



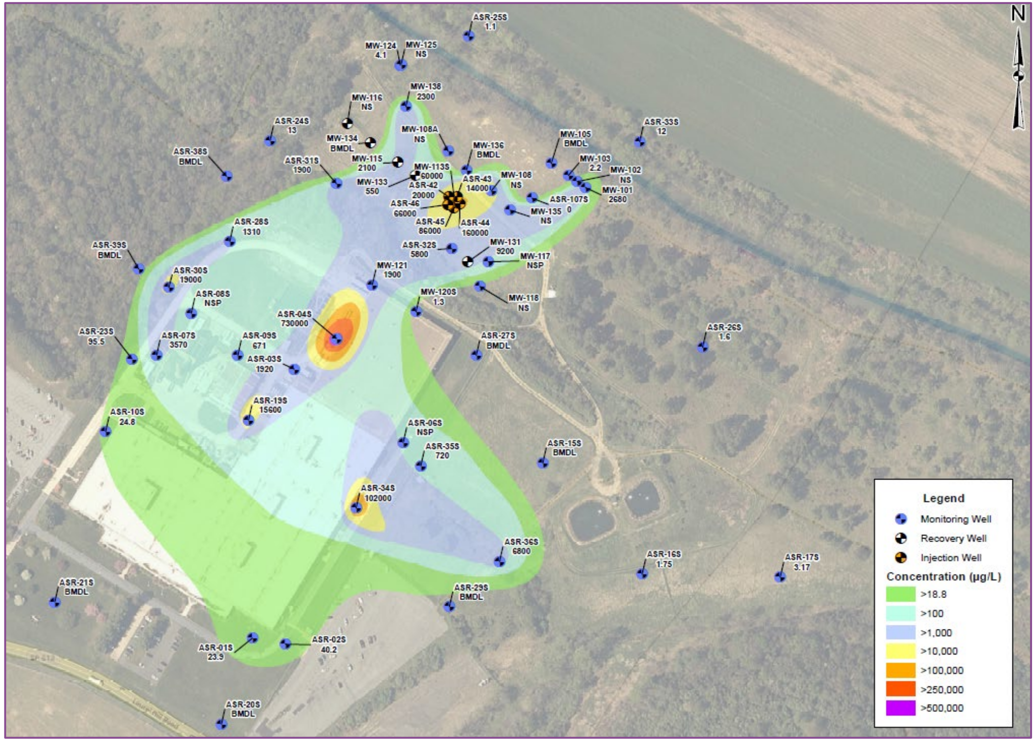




Site Conditions – Multi-Media Impacts

Complex Issues

- COCs
  - Primary: TCE
  - Secondary: Cutting Oil
- Comingled LNAPL/DNAPL plumes
- Groundwater plume in complex fractured bedrock geology
- Cross-bed communication between shallow PWR and deep fractured bedrock
- Multiple media impacted

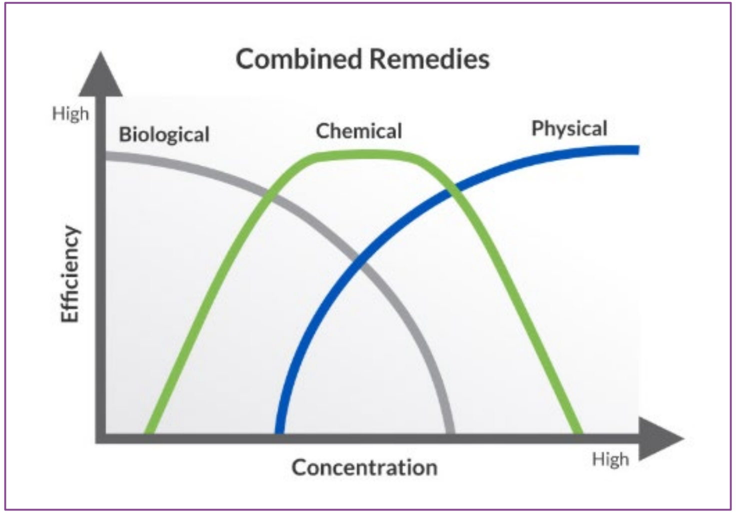


Remediation Alternatives

Remediation Alternatives

Approach

- Aggressive remediation approach
- Combined remedies to address comingled LNAPL/DNAPL plumes and other impacted media
- Several pilot tests implemented:
  - *Soil Vapor Extraction*
  - *Aggressive Fluid Vapor Recovery*
  - *In Situ Chemical Oxidation*
  - *Enhanced Bioremediation*
  - ***Surfactant-Enhanced Aquifer Remediation***



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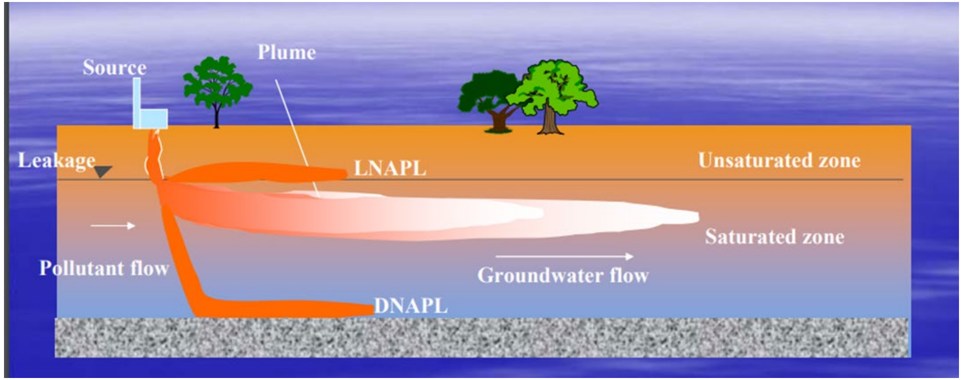
Surfactant-Enhanced Aquifer Remediation (SEAR)

Application of SEAR for DNAPL Removal

- **Problem Statement**: Large mass + Low solubility + Low MCLs = Increased timeframe for containment remediation.
- **Solution**: Identify optimum surfactant formulation for efficiently mobilizing and removing DNAPL from aquifer.
- **Objective**: Evaluate effectiveness and feasibility of SEAR to remove DNAPL from shallow and bedrock aquifer zones at Site.



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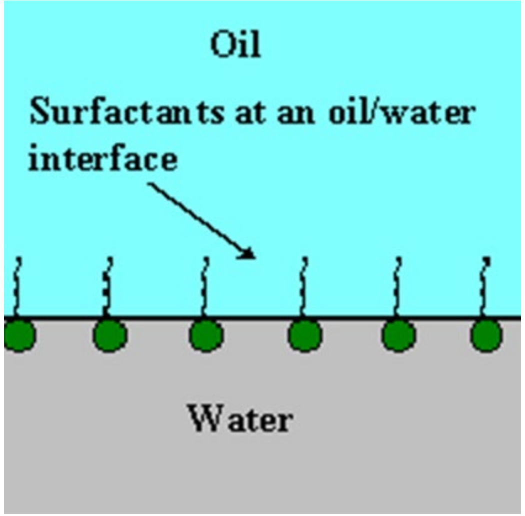
Surfactants

What are surfactants?

- Surface Active Agent
  - A substance which reduces the surface tension of a liquid in which it is dissolved
  - Found in everyday products



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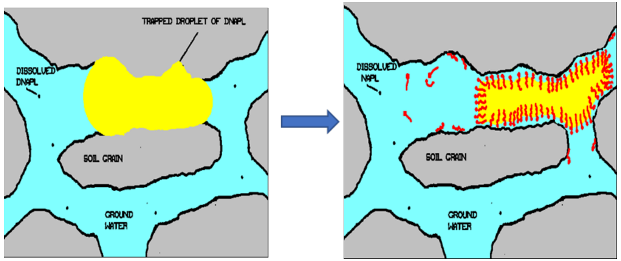
Surfactants

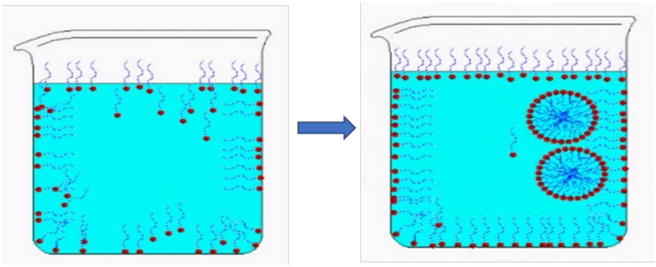
How do surfactants work?

Mobilize vs. Solubilize

(capillary displacement)

(in micelles)





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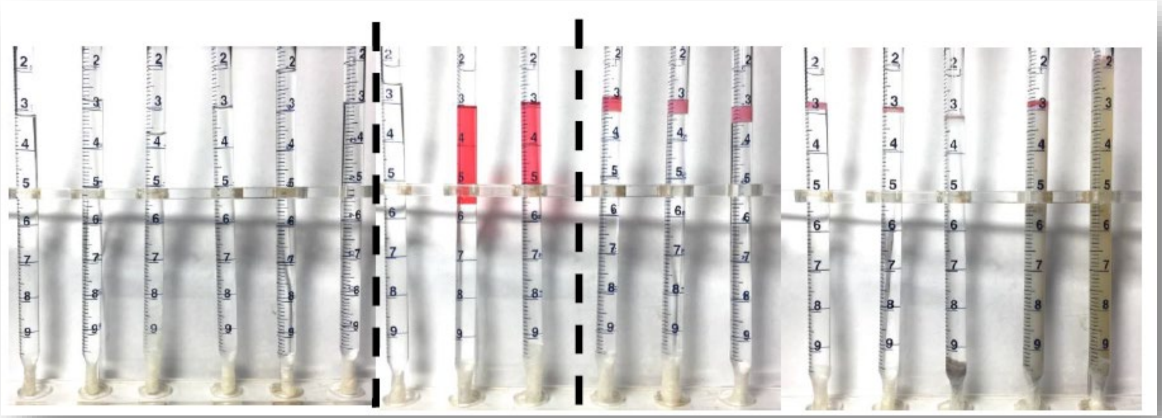
SEAR – Bench-Scale Treatability Study

Development of Optimal Surfactant Formulation

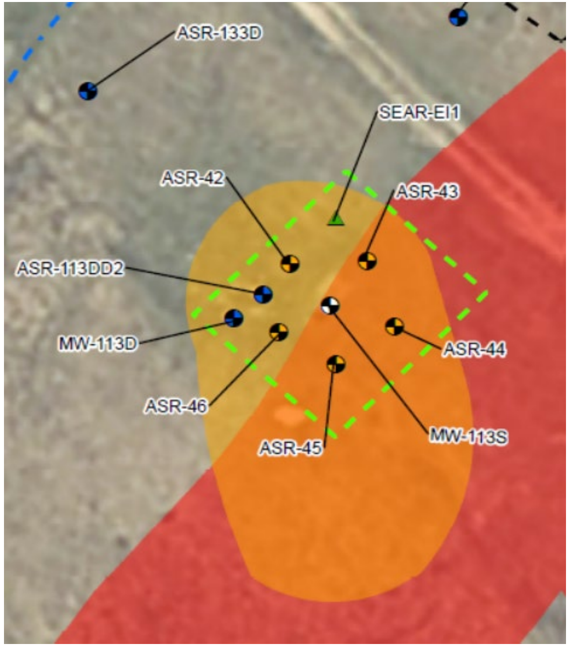
- Designed to develop a stable surfactant and co-solvent microemulsion
- Achieve neutral buoyancy of TCE for mobilizing DNAPL
- Single solution to simplify field operations and injection activities



SEAR – In Situ Pilot Study

Effectiveness & Feasibility Evaluation

- Outside-In Approach: Recovery well in center of injection well array
- Multi-Step Process
  - Recovery well pumping test
    - Evaluate hydraulic connectivity of injection wells
  - Conservative Inter-Well Tracer Test
    - Estimate pore volume and residence time
    - Evaluate tracer recovery
  - Partitioning Inter-Well Tracer Test
    - Estimate amount of DNAPL
  - Surfactant & Co-Solvent Micro-Emulsion Injection
  - Post-SEAR Injection Partitioning Inter-Well Tracer Test
    - Estimate the residual volume of DNAPL remaining



SEAR – In Situ Pilot Study Surfactant Injection

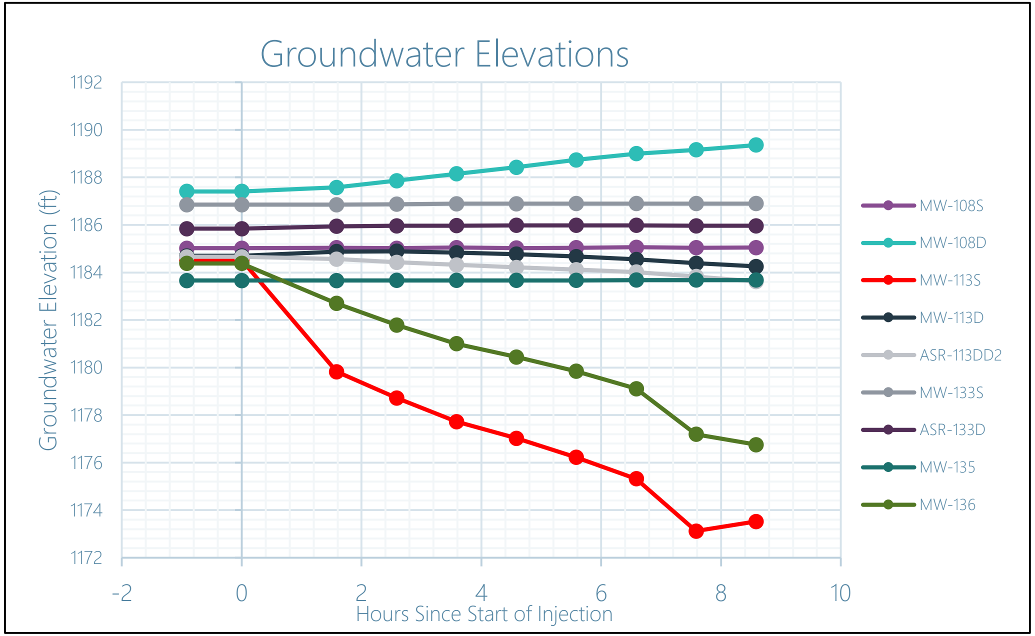
Surfactant & Co-Solvent Injection

- Multi-Step Injection Process:
  - Step 1: Pre-surfactant electrolyte flood
  - Step 2: Surfactant Injection
    - TASK^{tm} Soy
    - TASK^{tm} Surfactant
  - Step 3: Post-surfactant electrolyte flood

SEAR – In Situ Pilot Study Surfactant Injection

Injection/Extraction Process

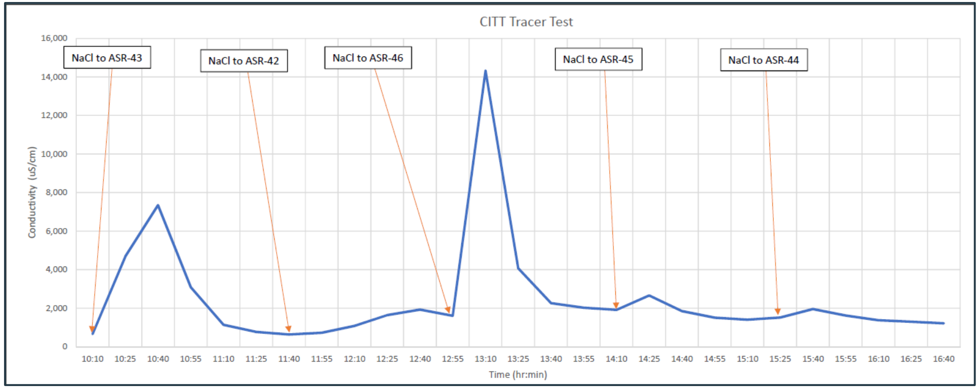
- Injection rate
  - 8 gpm total
  - 5 injection wells
- Extraction rate
  - 10 gpm
  - 1 recovery well
- Influences observed outside target treatment zone



SEAR – In Situ Pilot Study Field Results

Initial Field Results

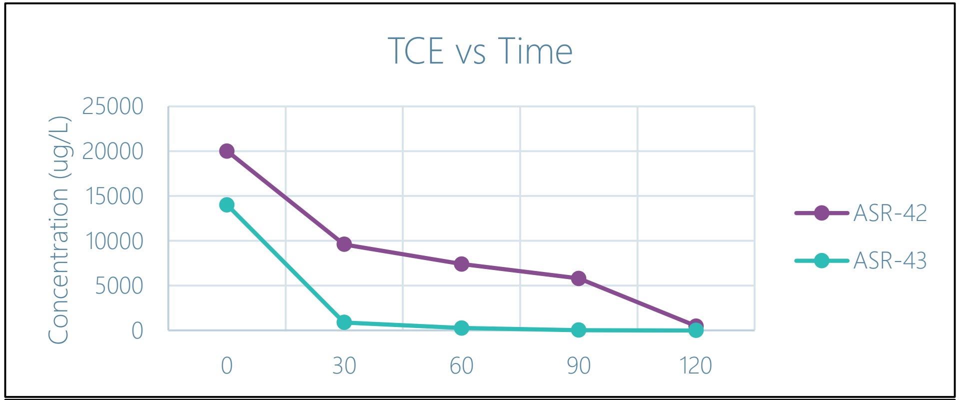
- Recovery well pumping test
  - Extraction rate effective in creating a groundwater sweep zone
- Conservative Inter-Well Tracer Test
  - Non-partitioning tracer showed immediate and observable influence from 4 out of 5 injection wells
- Partitioning Inter-Well Tracer Test
  - Pore volume ~2,200 gal
  - DNAPL saturation of 3.23%

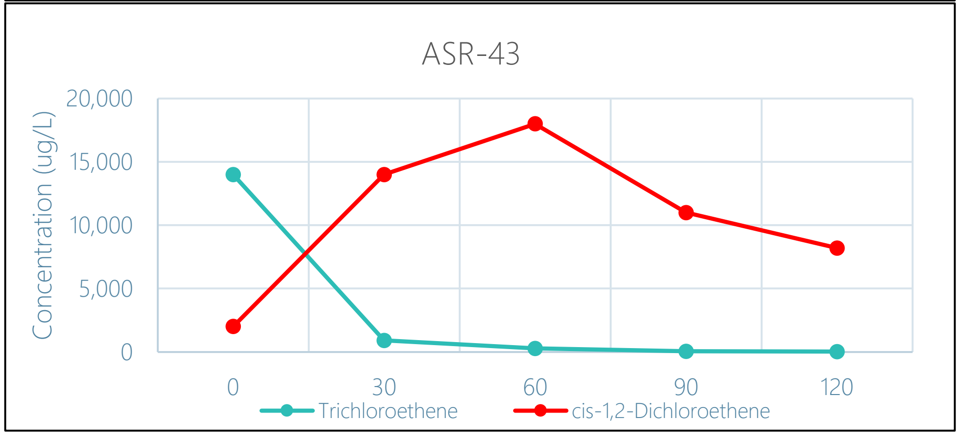


SEAR – In Situ Pilot Study Analytical Results

Analytical Results

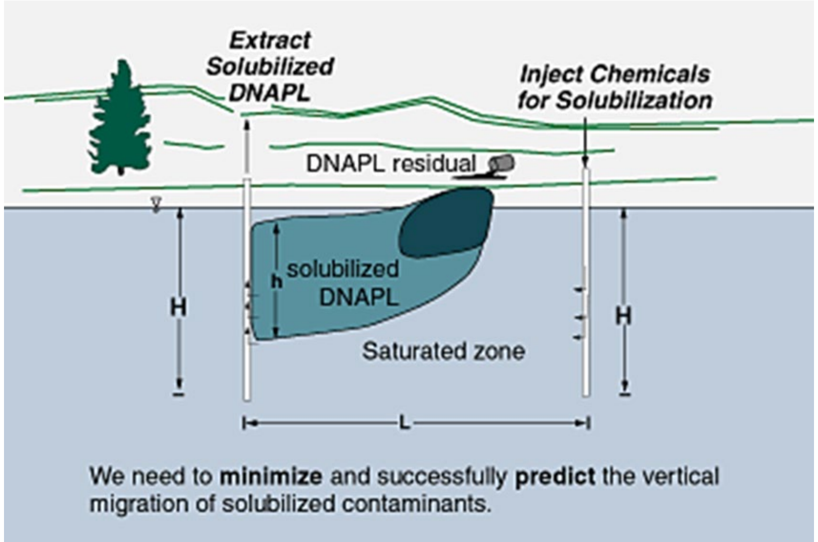
- Post-SEAR Injection PITT
  - More DNAPL extracted than originally estimated to be present
  - 118 gallons of DNAPL removed
- Post-Injection Performance Monitoring
  - TCE concentrations reduced by >90% in well network
  - TCE daughter product concentrations inversely proportional to TCE reductions in well network





Lessons Learned

- Modify design as an "inside-out" configuration
- Implementation would consist of targeted treatment areas across the Site
- Bioremediation may be occurring due to residual surfactant solution
- Analytical trends indicate SEAR is compatible with enhanced bioremediation as a polishing technology for residual COCs



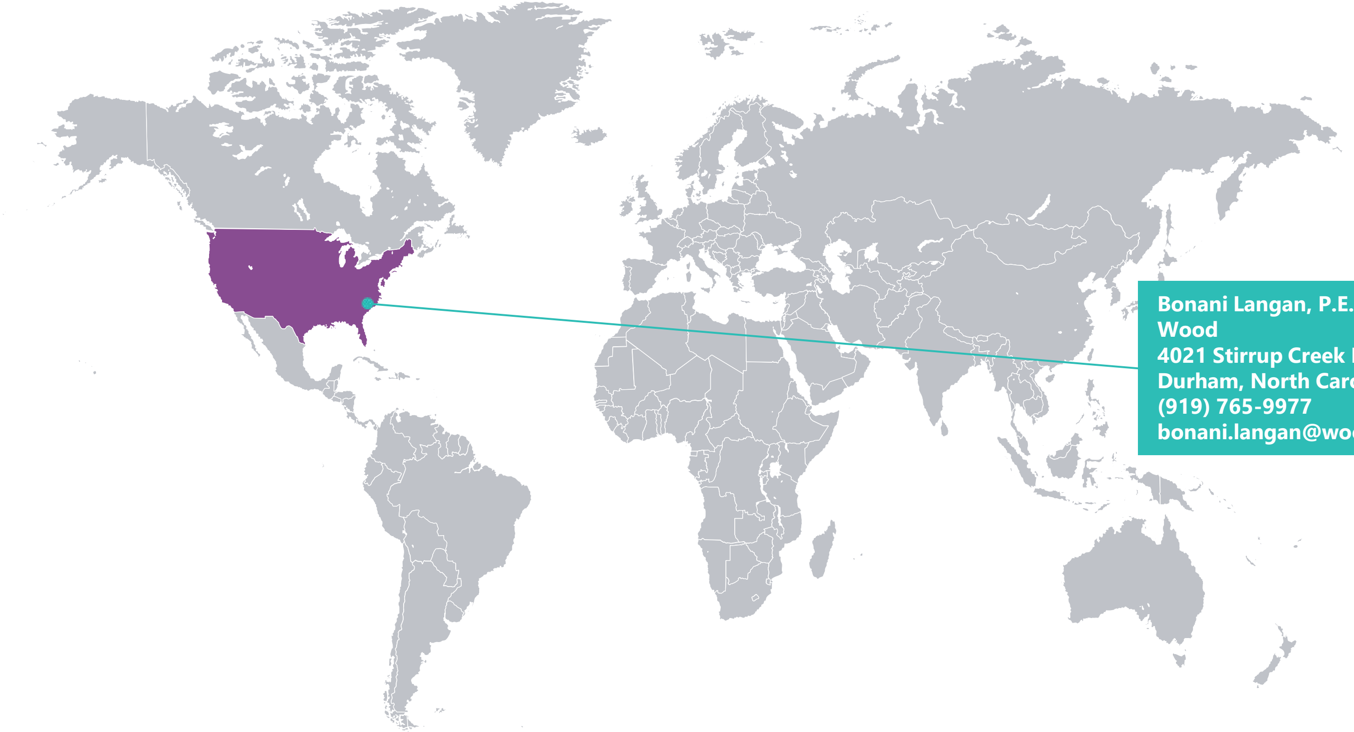
Questions

Thanks to our collaborators at Tersus Environmental

David Alden, P.E.

Sangho Bang, Ph.D.

Thank You



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