

The Successful In-Situ Treatment of a TCE Plume Using a Combination of Reduction, Sorption, and Anaerobic Bioremediation

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InSitu Remediation Services

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Agenda

- Study Site
- Background
- Remedial Option Review
- Methodology
- Results
- Summary



Study Site

Geology

- Silty till
- Clay confining layer (~7.0 mbgs)
- Discontinuous Sand lens

Hydrogeology

- Water table (~2.5 mbgs)
- Unconfined
- $V = < 1 \text{ cm/day} (< 3 \text{ m/year})$
- Effective porosity ~0.2



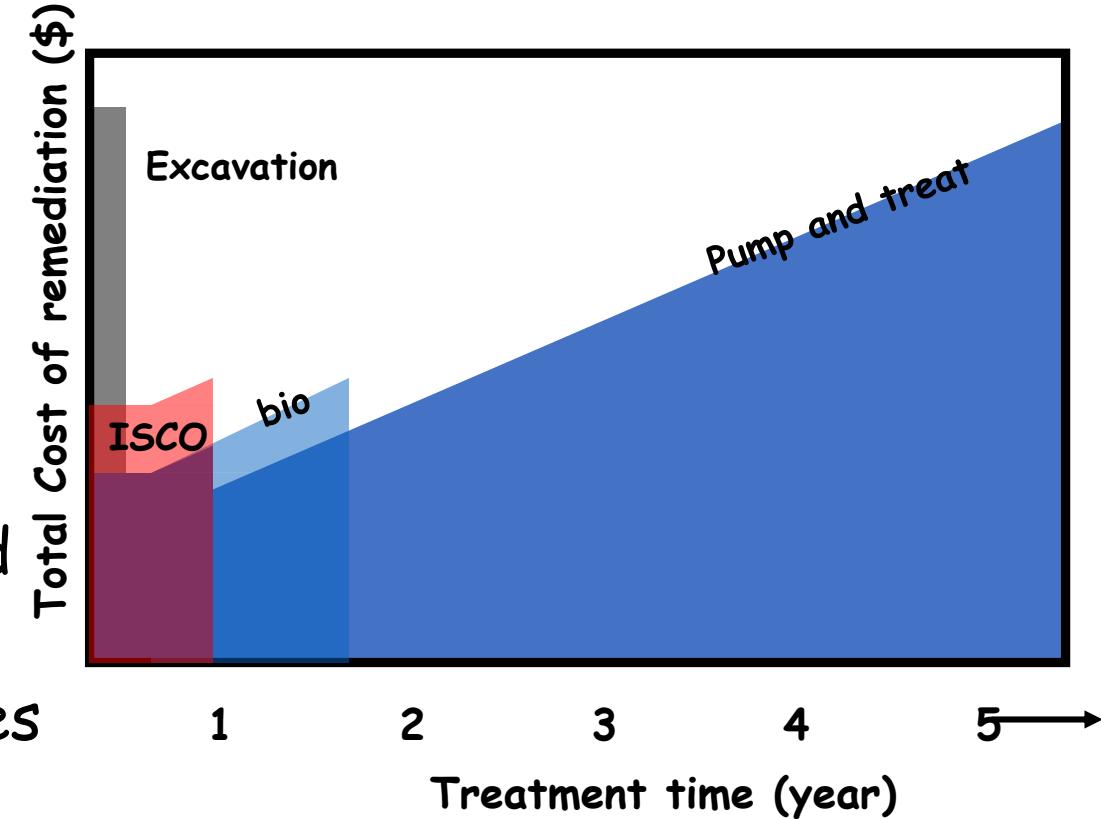
Study Site

- Former Industrial Facility
 - Chlorinated ethene groundwater impacts
 - TCE up to 2,290 µg/L (target 17 µg/L)
 - cis-1,2-DCE up to 2,580 µg/L (target 17 µg/L)
 - Vinyl chloride up to 165 µg/L (target 1.7 µg/L)
 - Trace PHCs above standard
 - Source Under/Near Building
 - Plume Flowing Off Site
 - Residential Down Gradient
 - Public Safety/Avoid Litigation



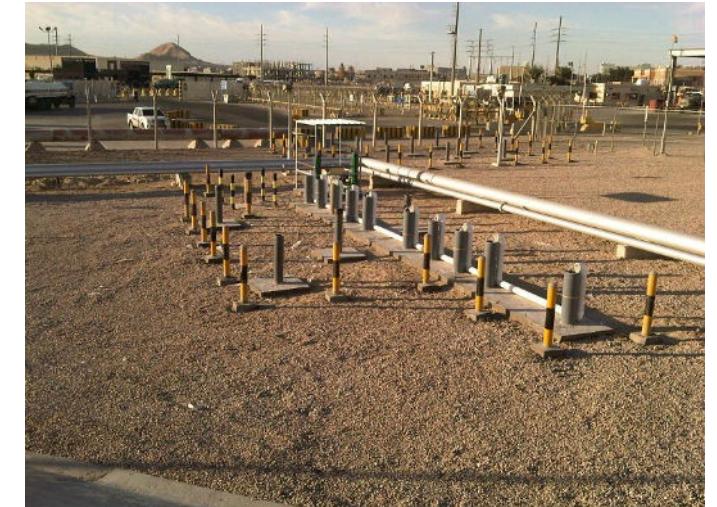
Remedial Options

- Ex Situ Treatment Options
 - Dig & Dump
 - Pump & Treat
 - Air sparging/Soil vapour extraction
- Challenges
 - Low remedial concentrations required
 - Back diffusion and rebound
 - Geologic and infrastructure challenges
 - Cost



Remedial Options

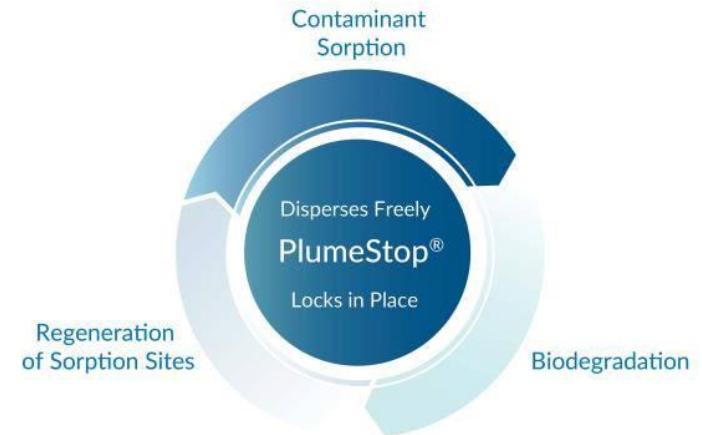
- In Situ Treatment Options
 - Chemical oxidation
 - Chemical reduction
 - Enhanced bioremediation
 - Bioaugmentation
 - Surfactant
 - Thermal
 - Sorptive
- Challenges
 - Low remedial concentrations required
 - Matrix diffusion and rebound
 - Geologic challenges
 - Distribution of reagents
 - Persistence



Remedial Review

- Chemical Reduction, Enhanced Anaerobic Bioremediation, Sorption Approach Chosen
 - Chemical Reduction (S-MicroZVI™)
 - Chemical reduction
 - Beta elimination
 - Anaerobic bioremediation
 - Reductive dechlorination
 - Hydrogen Releasing Compound™
 - Anaerobic bioremediation
 - Reductive dechlorination
 - Colloidal Activated Carbon (PlumeStop™);
 - Sorption
 - Adsorption and Adsorbtion
 - Anaerobic bioremediation
 - Reductive dechlorination

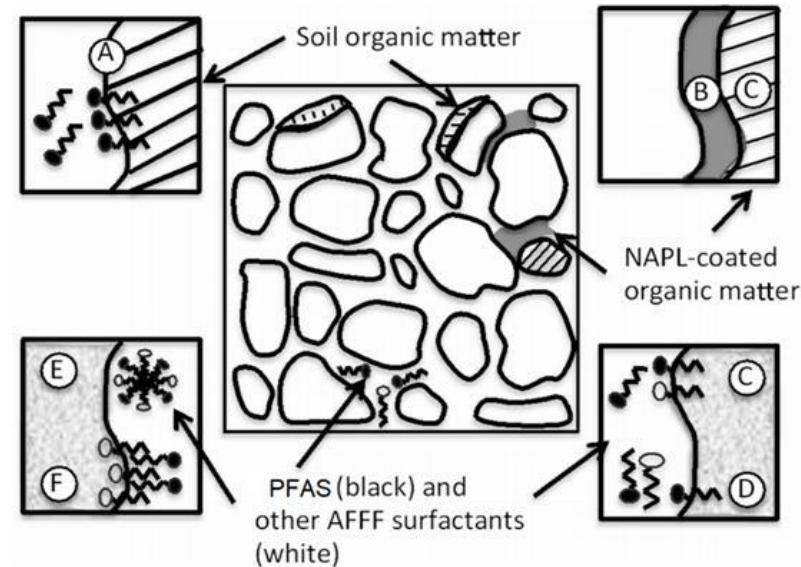
THE PLUMESTOP SORPTION AND BIODEGRADATION CYCLE



Courtesy: Regenesis

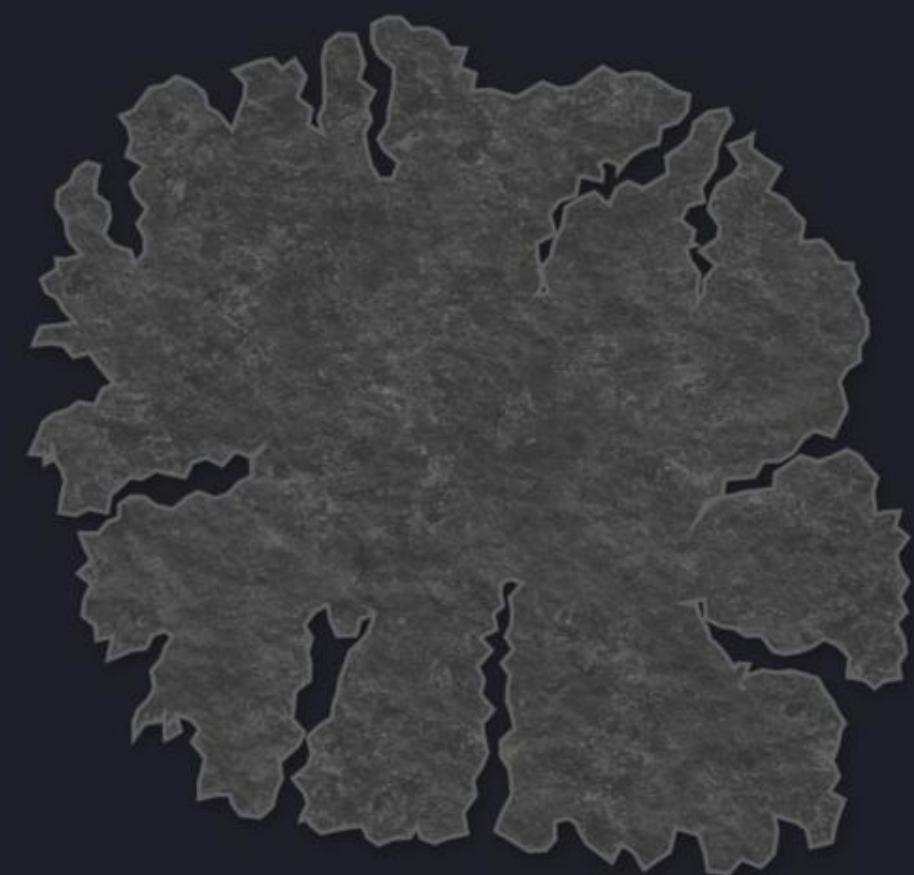
Remedial Options

- Activated Carbon
 - Well demonstrated for above ground treatment
 - Challenges for in situ
 - Injectability
 - Distribution
 - Lifespan
 - Finite sorptive sites
 - Capacity differs for various compounds
 - Competition for sorption sites
 - Destruction vs removal from solution
 - Salinity issues



Source: Guelfo & Higgins, 2013

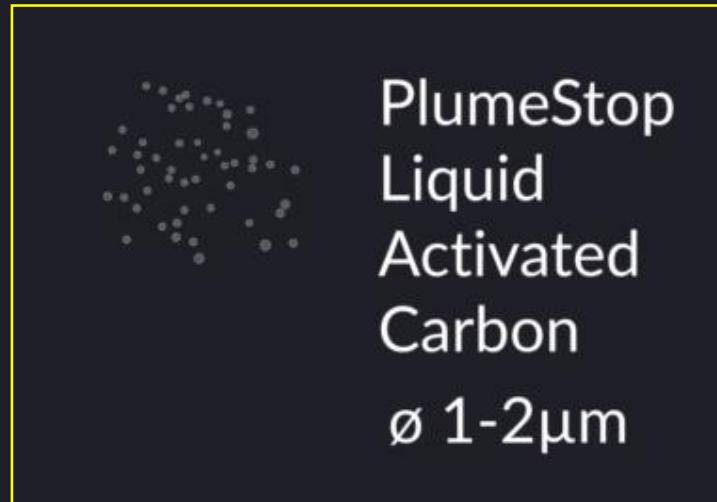
Remedial Options



Granular Activated Carbon
 $\varnothing 1000\mu\text{m}$



Powdered
Activated
Carbon
 $\varnothing 75\mu\text{m}$



PlumeStop
Liquid
Activated
Carbon
 $\varnothing 1-2\mu\text{m}$

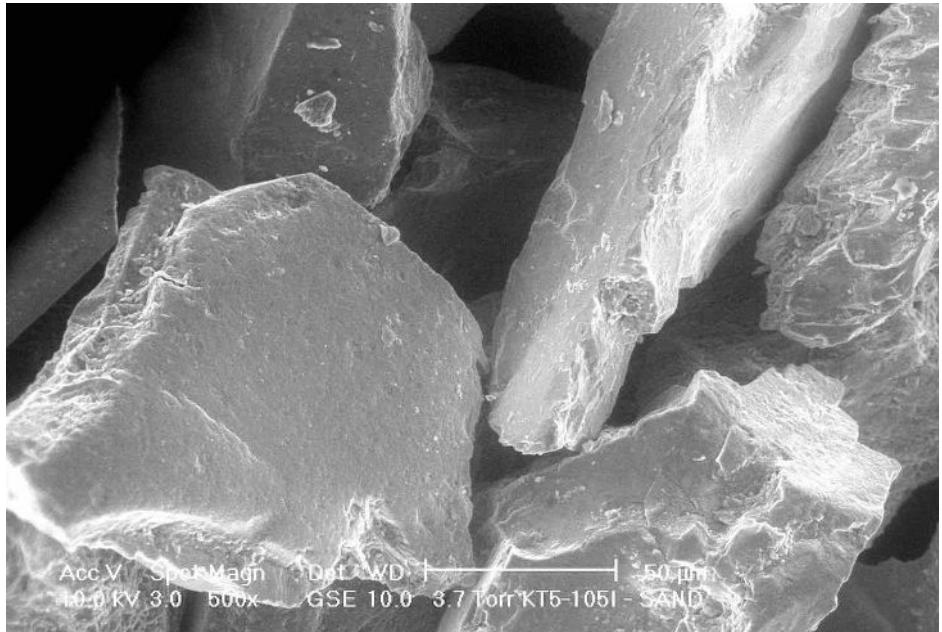
Remedial Options

- Why colloidal activated carbon (PlumeStop™)?
 - >450 sites worldwide
 - >50 sites in Canada
 - Excellent injection “properties”
 - Viscosity and density of water
 - Colloidal (1-2 microns)
 - Very high surface area
 - Mobile when injected, settles out over time
 - Can be “parked”
 - Potentially quick
 - One time application
 - Less disruption
 - Minimal health and safety issues

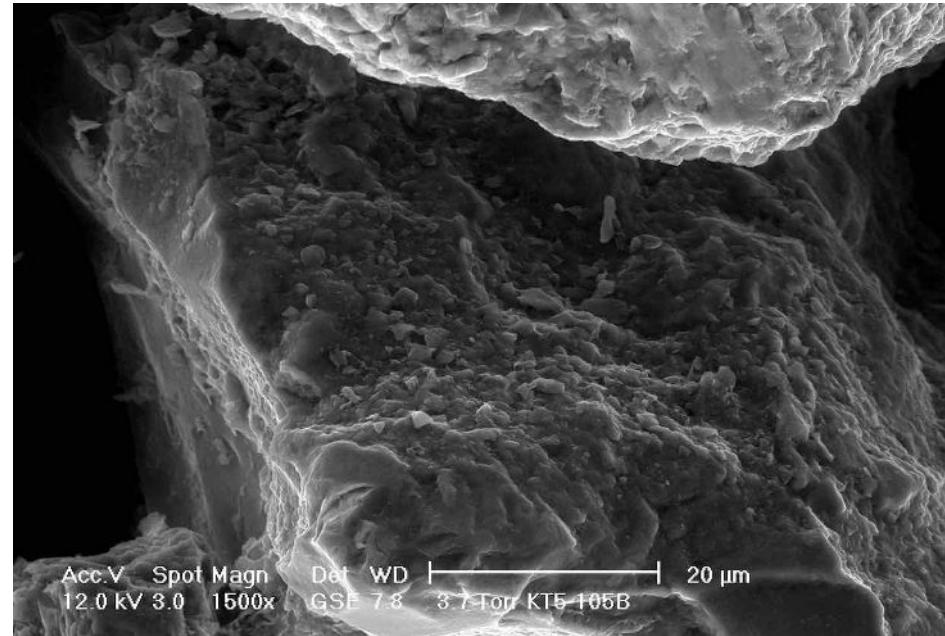


Remedial Options

SEM Photography Sand Grain



SEM Photography Sand Grain with PlumeStop



Courtesy: Regenesis

Remedial Options

- Why Sulphidated Micro ZVI?
 - ZVI well proven and demonstrated
 - >275 sites worldwide
 - >25 sites in Canada
 - Excellent injection “properties”
 - Viscosity and density of water
 - Colloidal (<5 microns)
 - Up to 40 wt % SZVI
 - Very high surface area
 - Mobile when injected, settles out over time
 - Sulfidated
 - “Targeted” production of hydrogen
 - Higher reaction rate than traditional ZVI
 - Extended lifespan



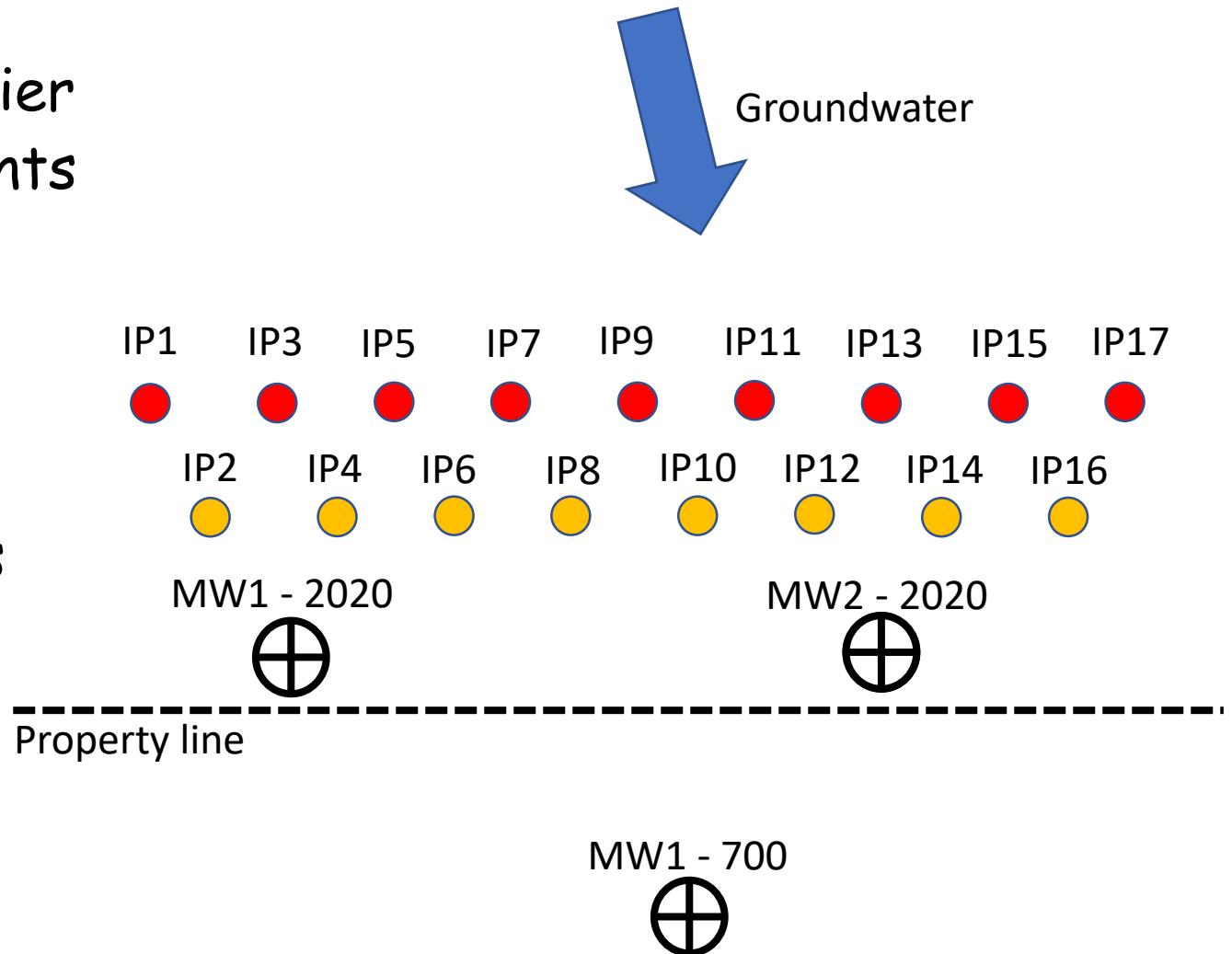
Remedial Options

- Why polylactate (HRC)?
 - Lactate well proven and demonstrated
 - >100 sites in Canada
 - Excellent injection “properties”
 - Viscosity and density of water when mixed
 - Polylactates
 - Mixture of various lactates
 - Short and long term release
 - Buffered



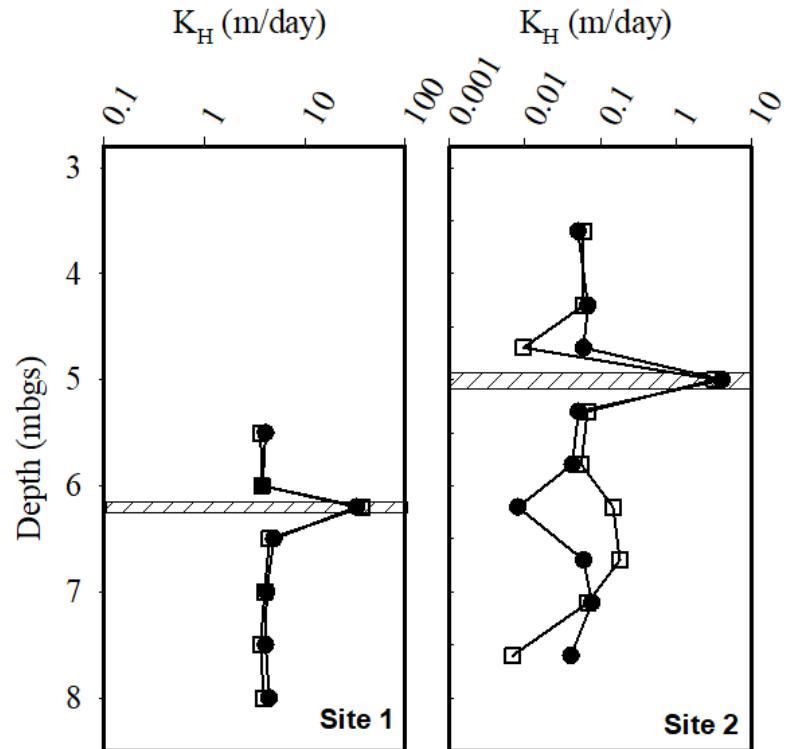
Methodology - PRZ

- Based on Mass Flux
 - Target 3.0 m wide barrier
 - Two offset rows of points
 - 1.25 m spacing
- Direct Push
- Geology Specific Tools
- Multiple Lateral Locations
- Multiple Vertical Intervals
- Low Pressure
 - Less than 40 psi
- Low Volume
 - ~200 litres/interval



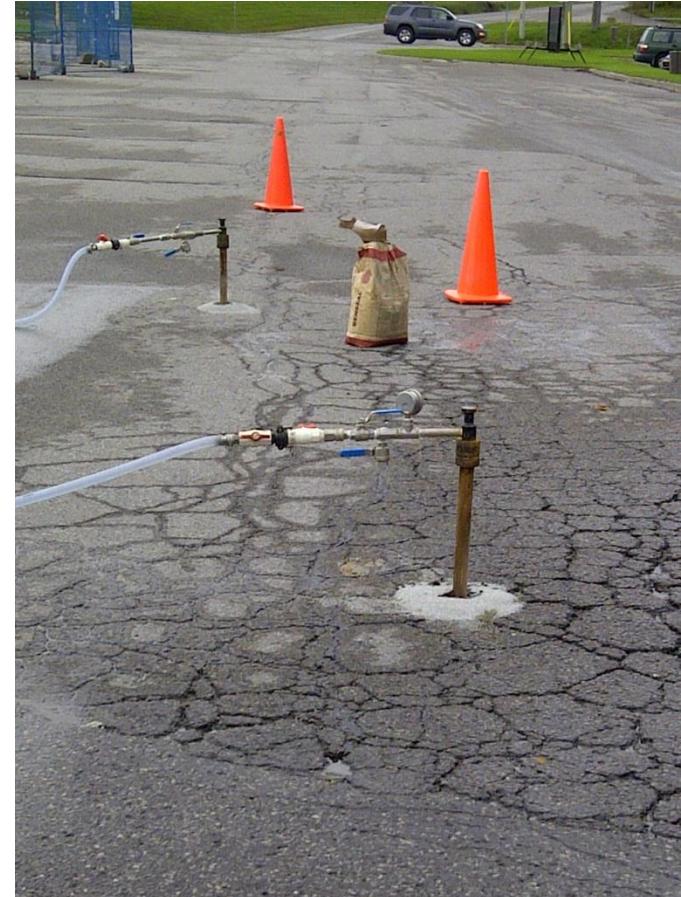
Detailed Monitoring

- Independent consultant
 - General chemistry
 - Inorganic chemistry
 - Organic chemistry
 - Bulk hydraulic conductivity
 - Passive diffusive bags vs low-flow
- IRSL valued added
 - Microbiological DNA
 - CSIA for Cl and H
 - Detailed analysis of cores for CAC distribution
 - Detailed hydraulic conductivity testing



Methodology

- Multi-Technology In-Situ Approach
 - 2,700 kg of PlumeStop S
 - 1,150 kg of S-Micro ZVI
 - 1,100 kg of HRC
 - 65,000 litres of water
 - 70 locations (90 m long)
 - 1.25 m lateral spacing
 - ~90 m long PRB
 - Multiple vertical intervals
 - 0.5 m



PRB Injection Boreholes

WATER TABLE

SHALLOW INJECTION INTERVAL

INTER. INJECTION INTERVAL

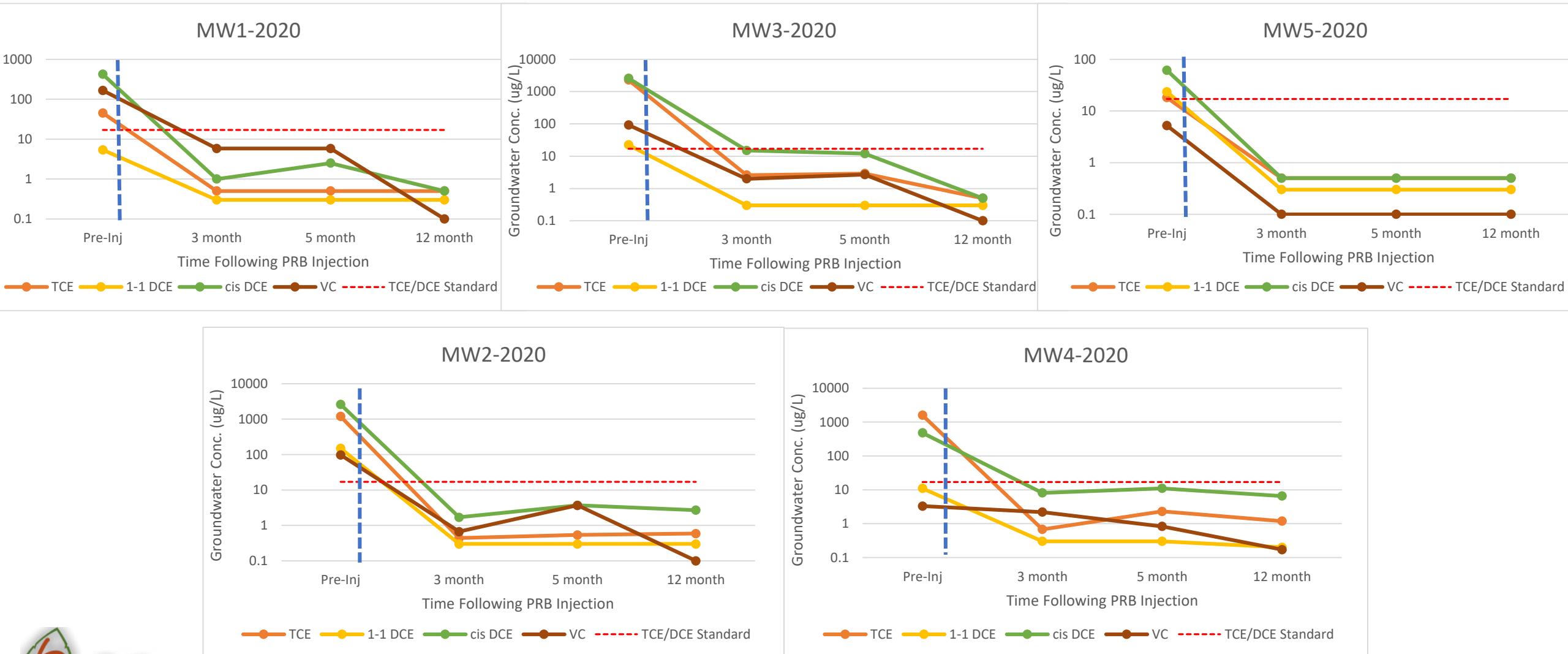
MID INJECTION INTERVAL

INTER. INJECTION INTERVAL

DEEP INJECTION INTERVAL

CLAY CONFINING LAYER

Results: Onsite

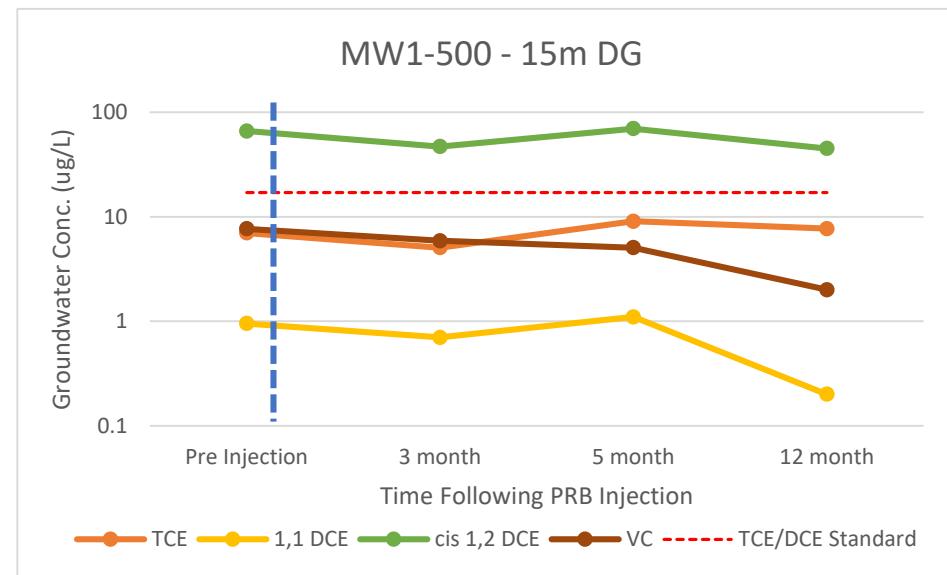
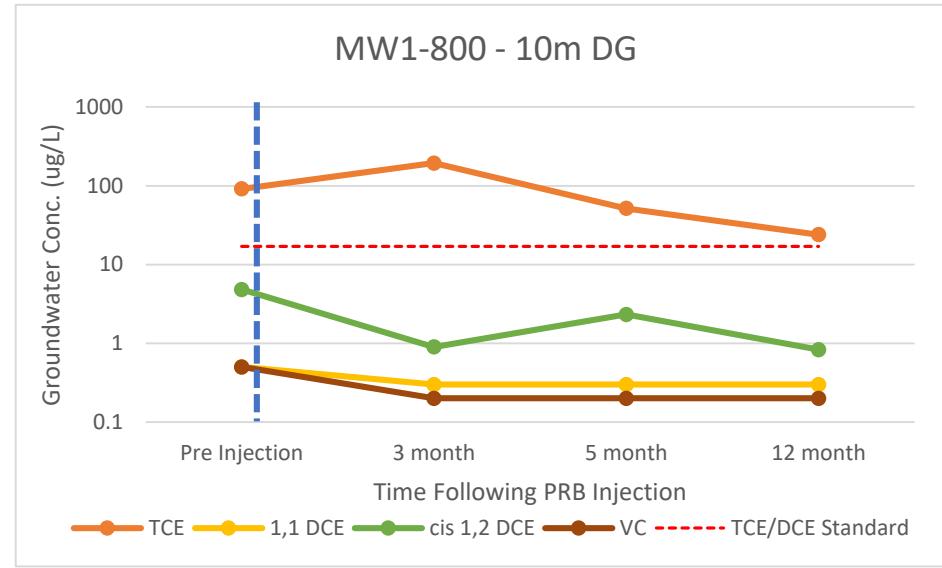
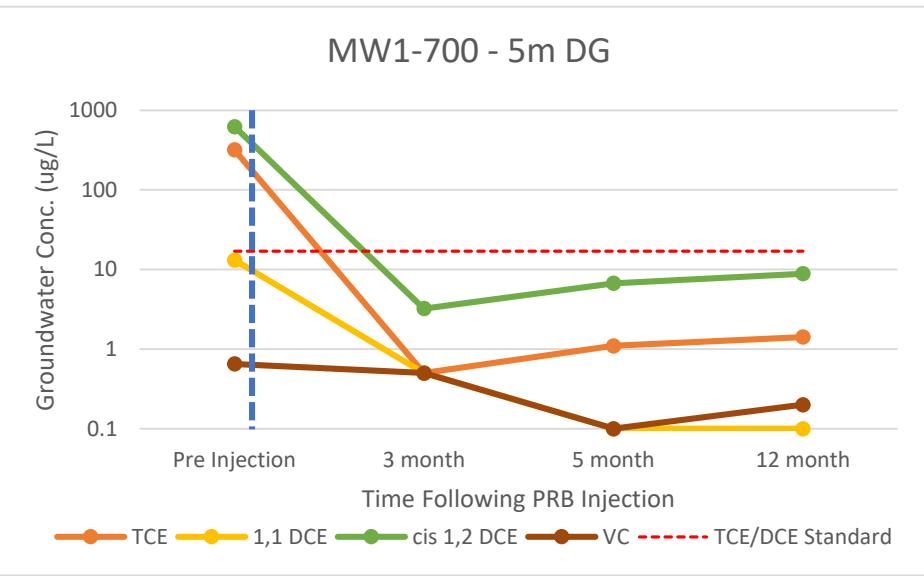


Results: Onsite

- Distribution
 - Visual presence of CAC/mSZVI at all wells - 1 week
 - "Precipitation" of CAC/mSZVI approximately 6 weeks after injection
- cVOCs
 - 3 and 5 months
 - TCE = >99.9%
 - cis-1,2-DCE = >99.5%
 - VC = >96.0%
 - 12 months
 - TCE = >99.9%
 - cis-1,2-DCE = >99.8%
 - VC = >99.8%
- Other Compounds
 - PHCs below standards



Results: Downgradient

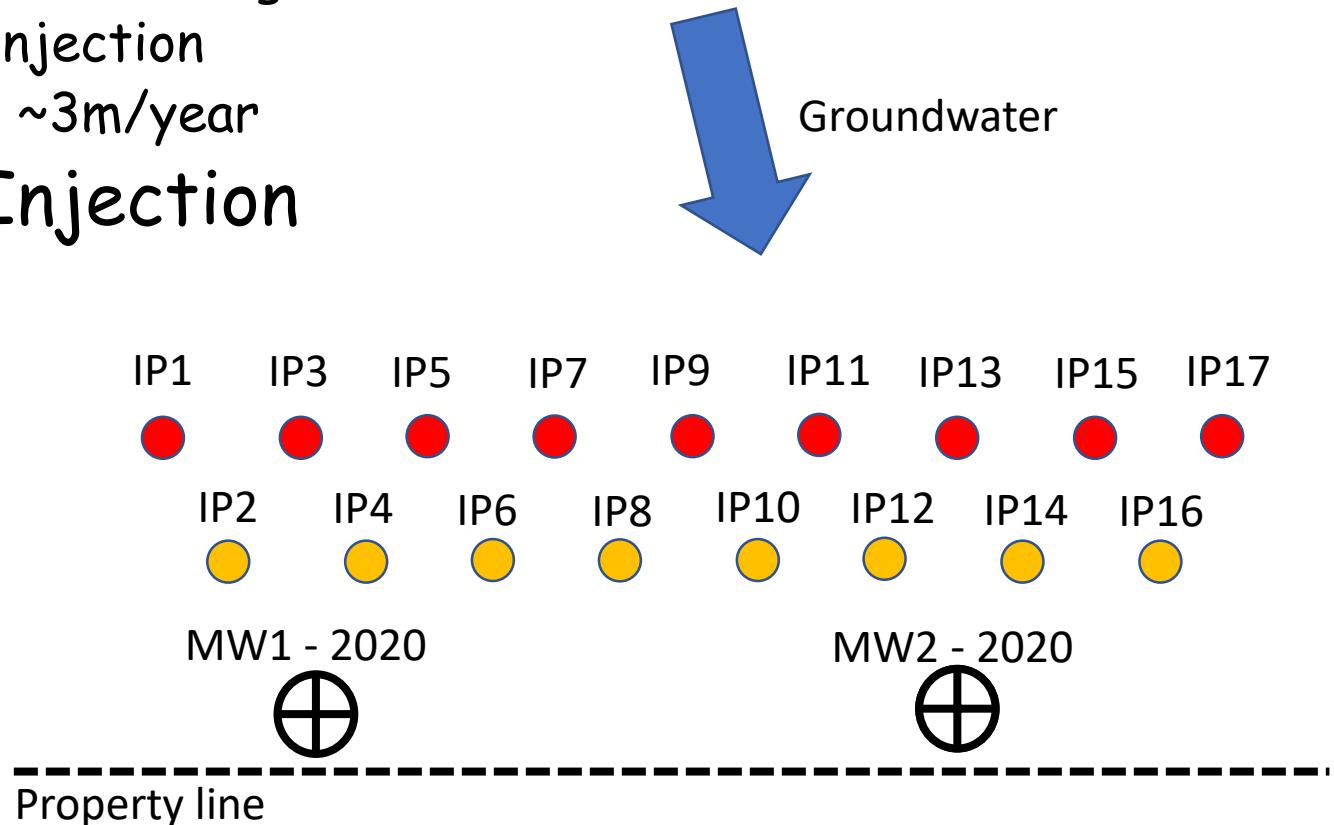


Results: Downgradient

- Project Goals
 - Initial project goals did not include downgradient remediation
 - Enhanced MNA following PRZ injection
 - Estimate groundwater velocity ~3m/year

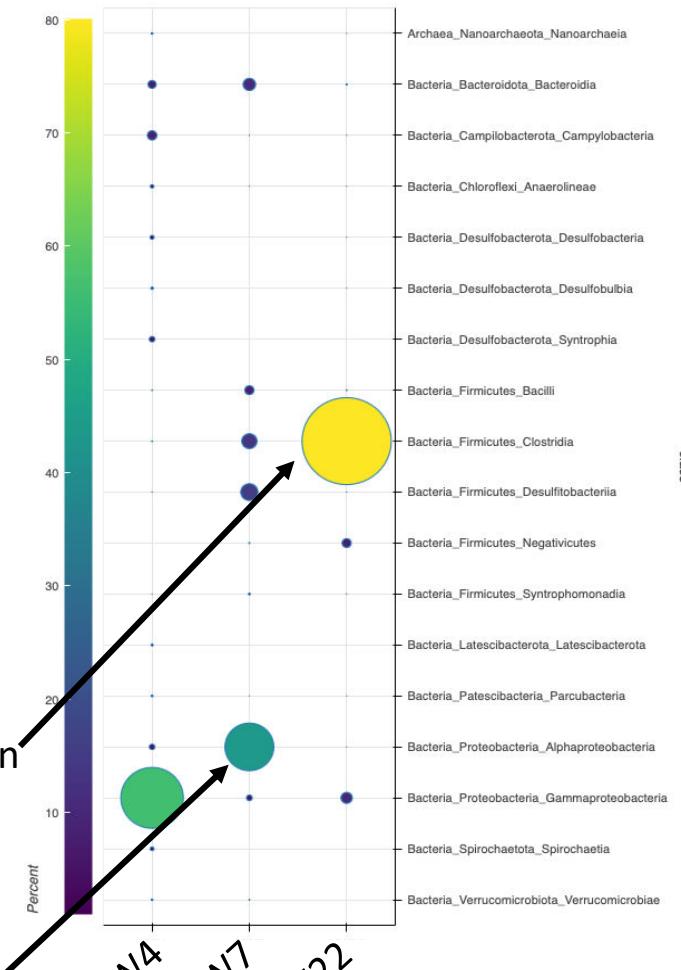
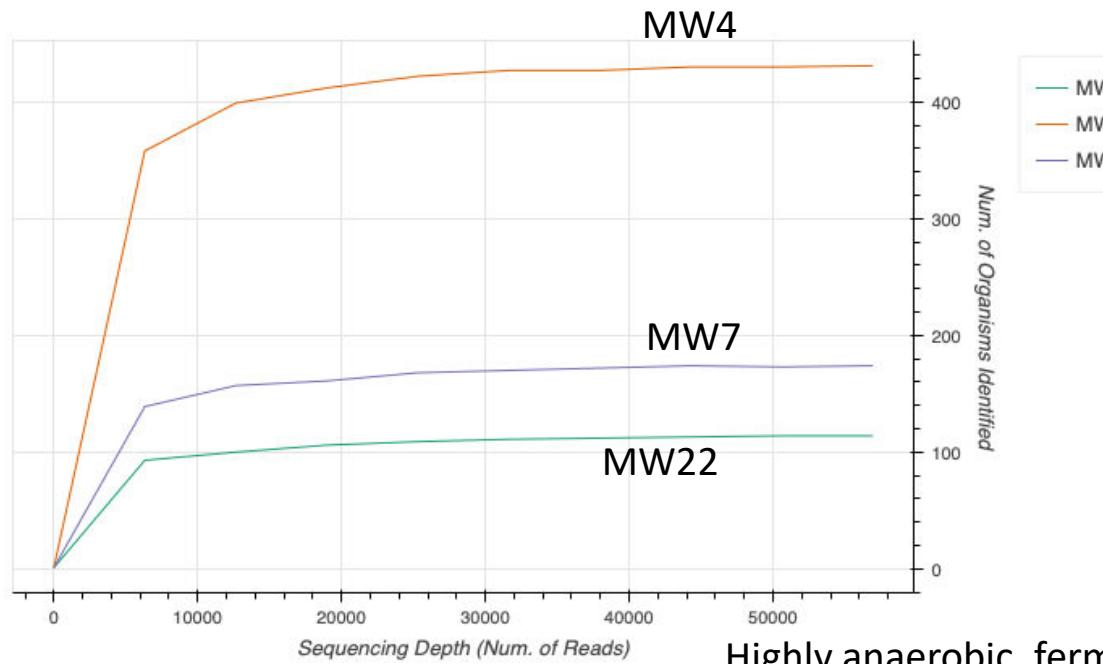
• VOCs - 12 Months Post-Injection

- 5 m downgradient
 - TCE: >99%
 - cis-1,2-DCE: >98%
 - VC: ND
- 10 m downgradient
 - TCE: > 74%
 - cis-1,2-DCE: > 82%
 - VC: ND



Results: Microbiology

- Microbiome determination and functionality
 - Look at before and after effects on microbiology



MW4: No treatment
MW7: Source
MW22 Edge of Plume

Results: Summary

- Budget
 - Under time
 - 3 weeks vs 4 weeks planned
 - Under budget by 9.5%
 - Minimal reagent waste
 - Less than 3% of locations daylighted
 - Less than 0.1% of total solution
- Outcome
 - Success of PRB
 - 2021 Source Remediation



Study Site: Source

- Industrial Facility
 - Source under and near building
 - Majority of source inaccessible with dig and haul
 - Chlorinated ethene groundwater impacts
 - TCE up to 11,300 ug/L
 - cis-1,2-DCE up to 2,300 ug/L
 - Vinyl chloride up to 36 ug/L
 - Trace PHCs above standard
 - Chlorinated ethene soil impacts
 - TCE up to 40 ug/g
 - Vinyl chloride up to 2,360 ug/L
 - Trace BTEX above standards



Methodology: Source

- Based on Pore Volume
 - Target ~0.3 pore volume
 - ~2.5 m grid spacing
- Source Reduction to Extend PRB Life
- Allow for redevelopment of land
- Direct Push
- Geology Specific Tools
- Multiple Locations
- Multiple Intervals
- Low Pressure
- Low Volume



Methodology: Source

- Same Technologies as PRB
 - 2,950 kg of PlumeStop S
 - 1,150 kg of S-Micro ZVI
 - 2,200 kg of HRC
 - ~70,000 litres of water
 - 73 locations
 - ~525 m²
 - Low Pressure
 - Up to 25 psi
 - 78% below 15 psi
 - Low Volume
 - ~350 litres solution
 - Up to 3 intervals/location



Results - Source Reduction

- Budget
 - On time - Under budget
- Minimal reagent waste
 - Less than 2% of locations daylighted
 - Less than 0.05% of total solution
- Groundwater - 4 months
 - TCE: 98% reduction
 - cis-1,2-DCE: >99.5% reduction
 - VC: >96.0% reduction
 - PHCs: below standards
- Groundwater - 4 months
 - All parameters below standards



Questions