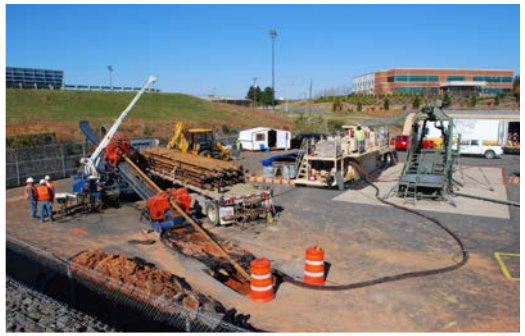
CH2MHILL®



Integrated Approach to the Remediation of Chlorinated Organic Compounds in Low Permeability Soils – 6 Years Post Injection

Leanne Murdie Austrins

Site Information

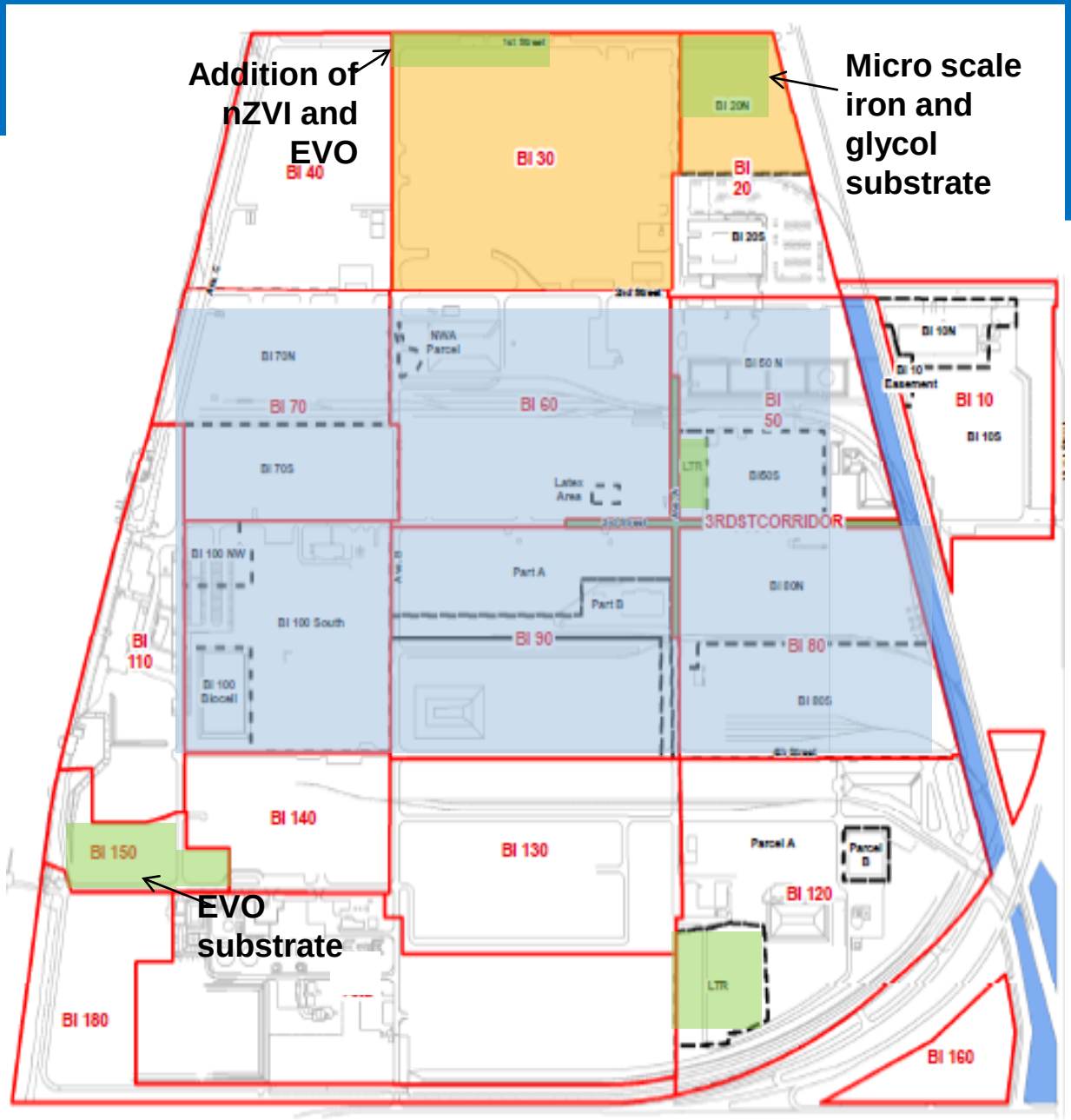


- Chemical production plant in operation from 1940's to 2009.
- 322 acres of property prepared for closure through a combination of dig and haul, *insitu* and *exsitu* remediation.
- Volatile Organics Compounds present in the subsurface for over 60 years.

Remedy Selection Process

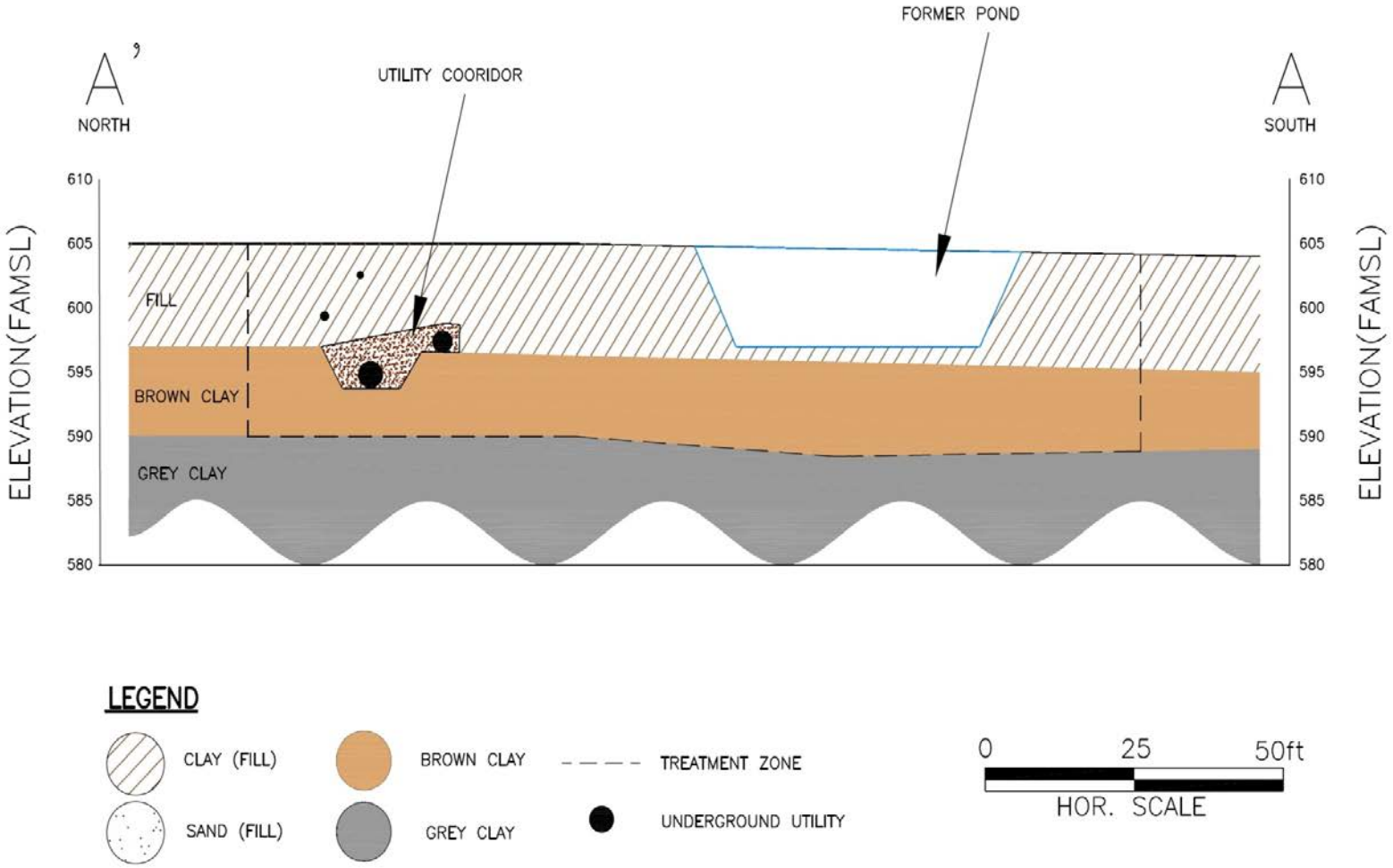
- Flow Chart Developed for Decision Making
  - CVOC Contaminated Soil to be Remediated:
    - DNAPL, >TCLP criteria, or posing risk to surface water
  - Treat in Soil Treatment Area (STA)
    - CVOCs > TCLP
  - Treat In Situ with Frac and Injection
    - Volume too large to treat in STA (>10,000 cys)
    - Soil cannot be excavated (below building, below piping)
    - Longer timeframe available

Where *Insitu and Exsitu* remediation were applied



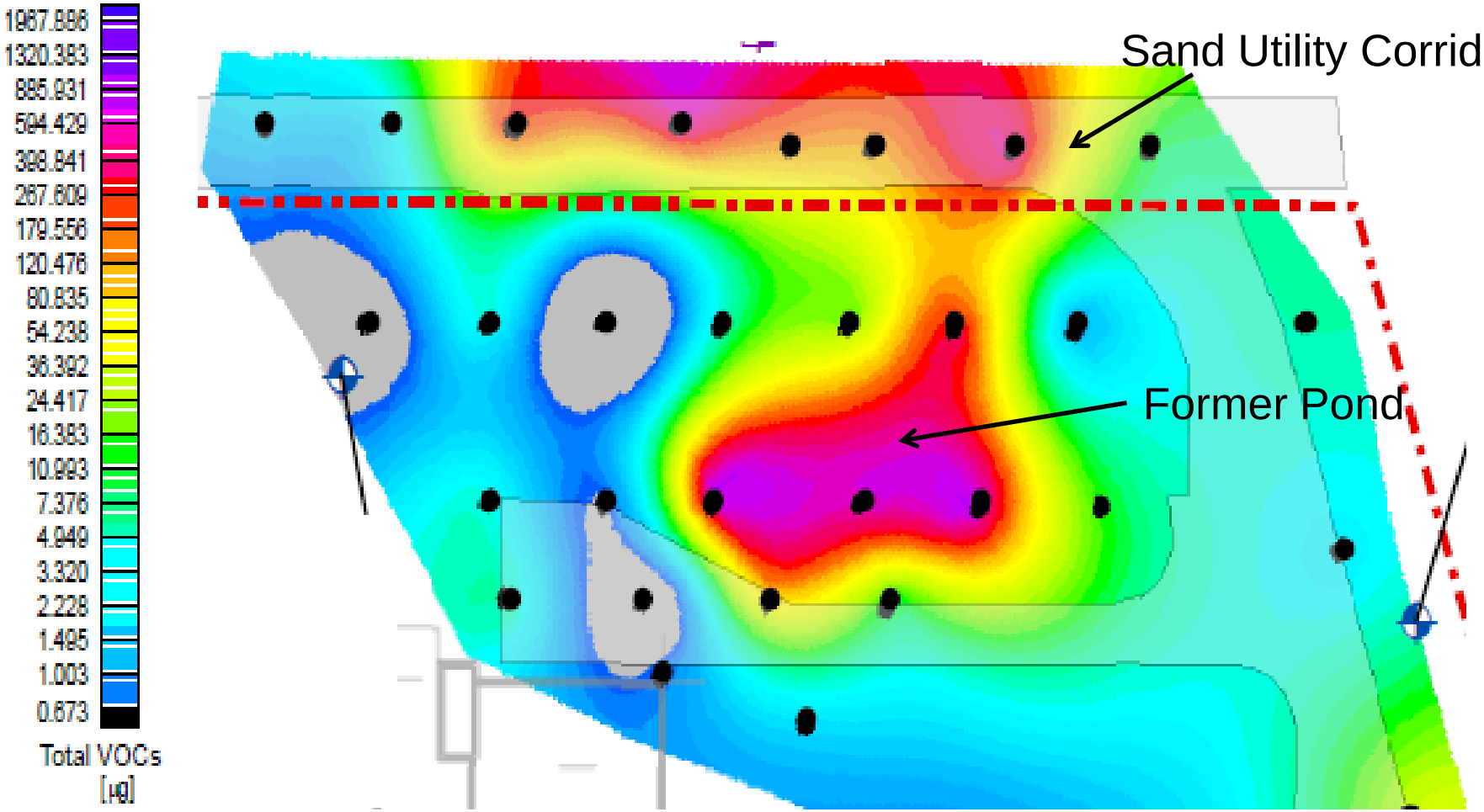
Block 20 Conceptual Site Model





Total VOC concentrations from GoreSorbers™





Design of Remedial Strategy

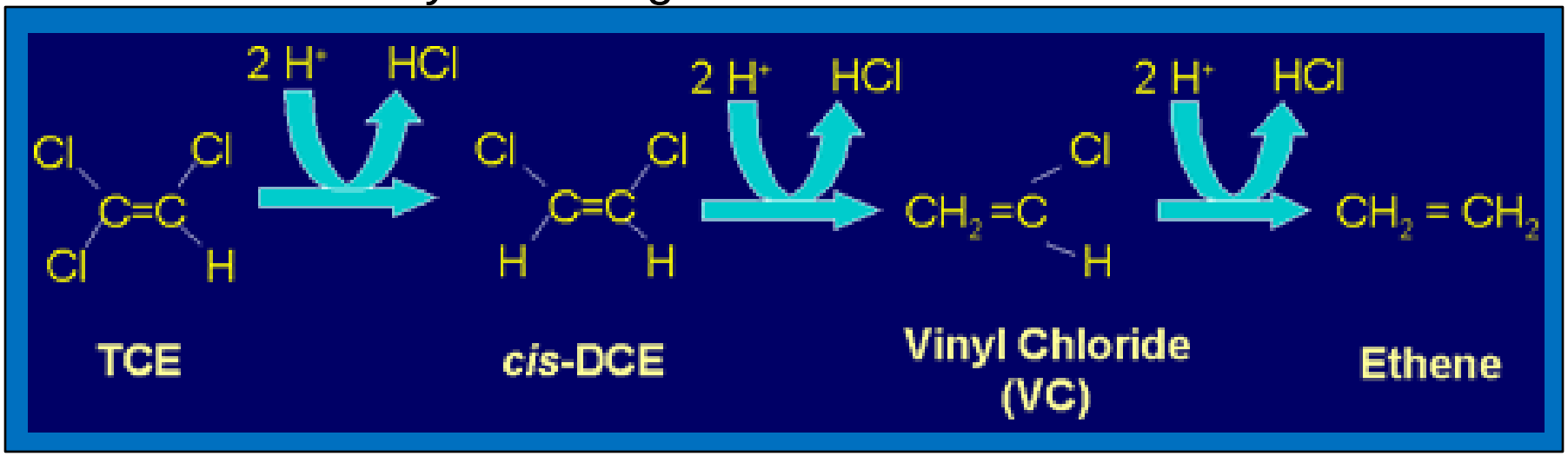


- Reach target concentrations in 5 – 7 years
- Must be cost effective based on volume of soil to be treated (22,000 cubic yards)
- Selected amendment must be able to treat DNAPL and dissolved phase contamination in soil and groundwater
- Amendment application technology must be able to treat low permeability soils

Bioremediation Process



- Enhanced reductive dechlorination (biotic reaction)
- Utilizes naturally occurring bacteria



- TCE/ cis-DCE/ VC/Ethene are daughter products and electron acceptors.
- Carbon is electron donor and food for native bacteria
- Fermentation of organic compounds produces H2 which serves as an additional electron donor
  (Gossett et al., 1997).

Iron Reactions

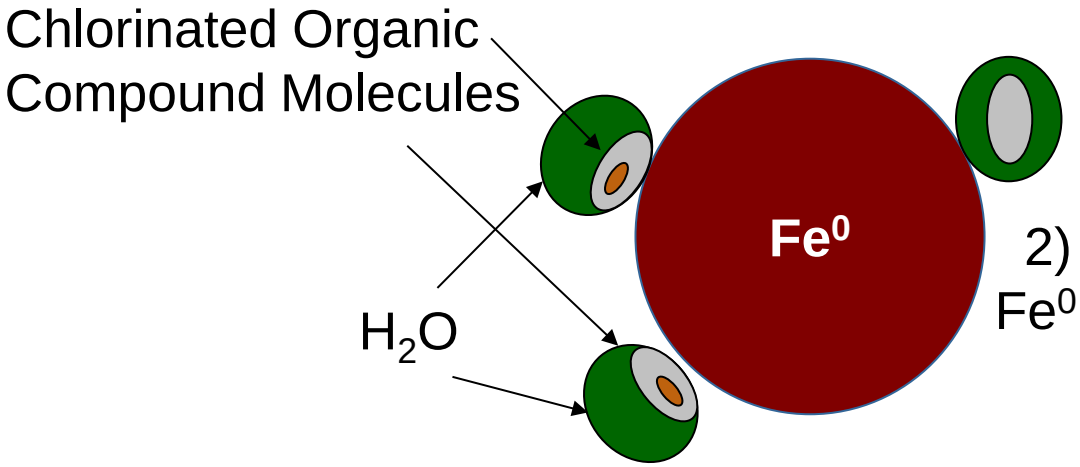


4) Aerobic iron corrosion:

$$2Fe^0 + O_2 + 2H_2O = 2Fe^{2+} + 4OH^-$$

3) Reductive dehalogenation by hydrogen gas:

$$H_2 + XCl = XH + H^+ + Cl^-$$



2) Anaerobic iron corrosion:

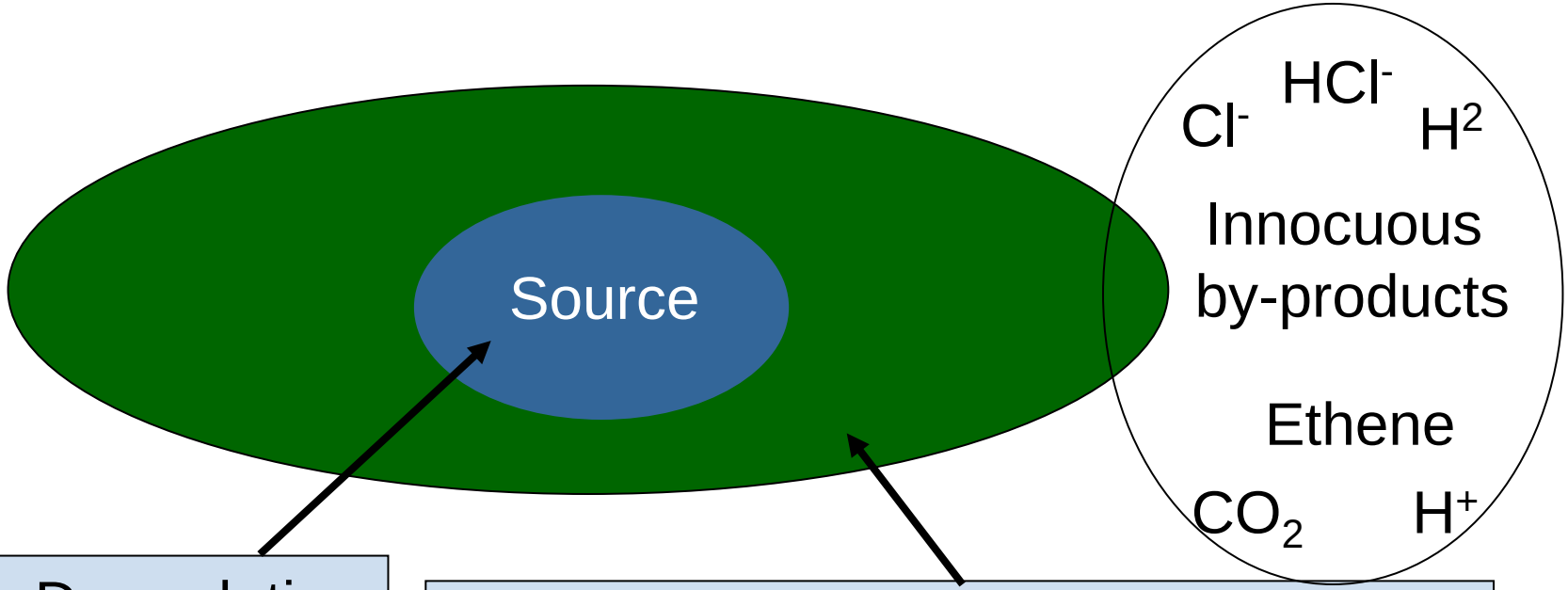
$$Fe^0 + 3H_2O = Fe^{2+} + 3OH^- + H_2 + H^+$$

1) Direct reduction on metal surface:

$$Fe^0 + H_2O + XCl = Fe^{2+} + OH^- + XH + Cl^-$$

Conceptual Model For Contaminant Reduction





Abiotic Degradation
- through chemical reduction

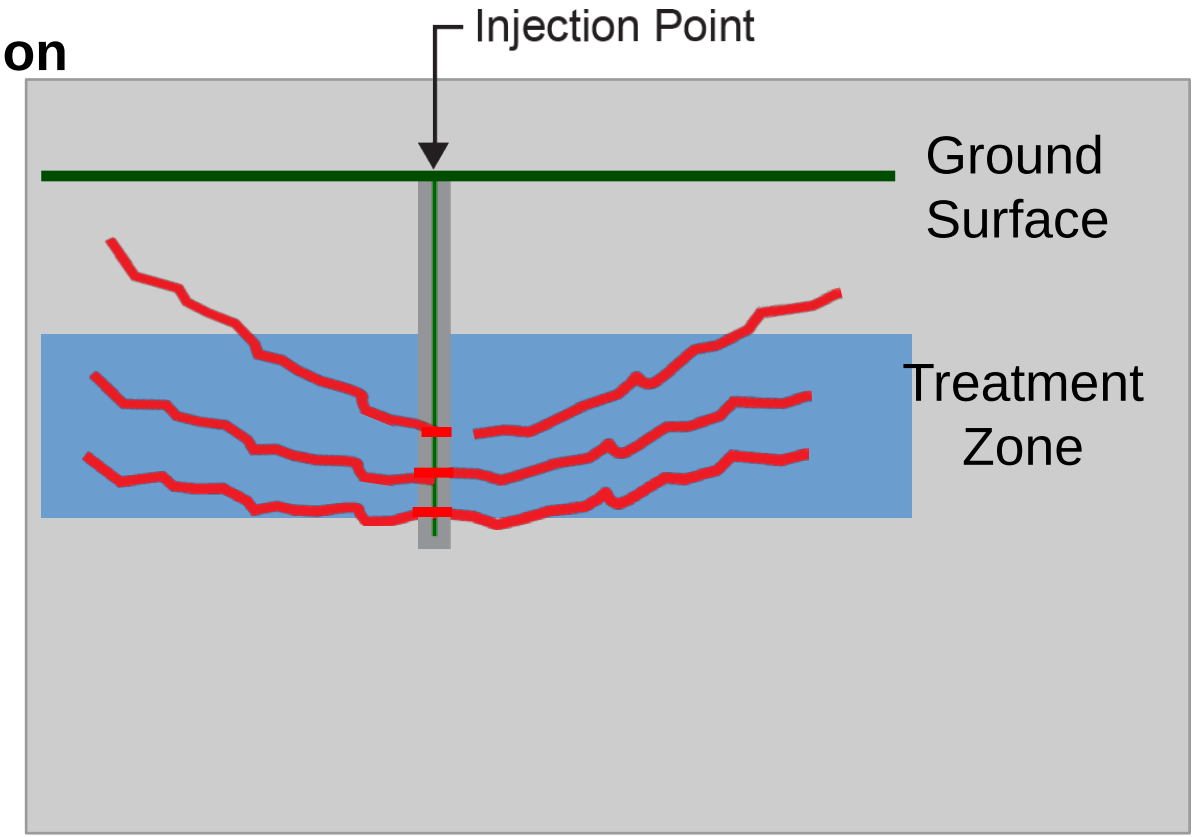
Biotic Degradation
-utilizes naturally occurring bacteria
-naturally occurring bacteria enhanced by amendment addition

Amendment Application Technology - Fracture and Injection

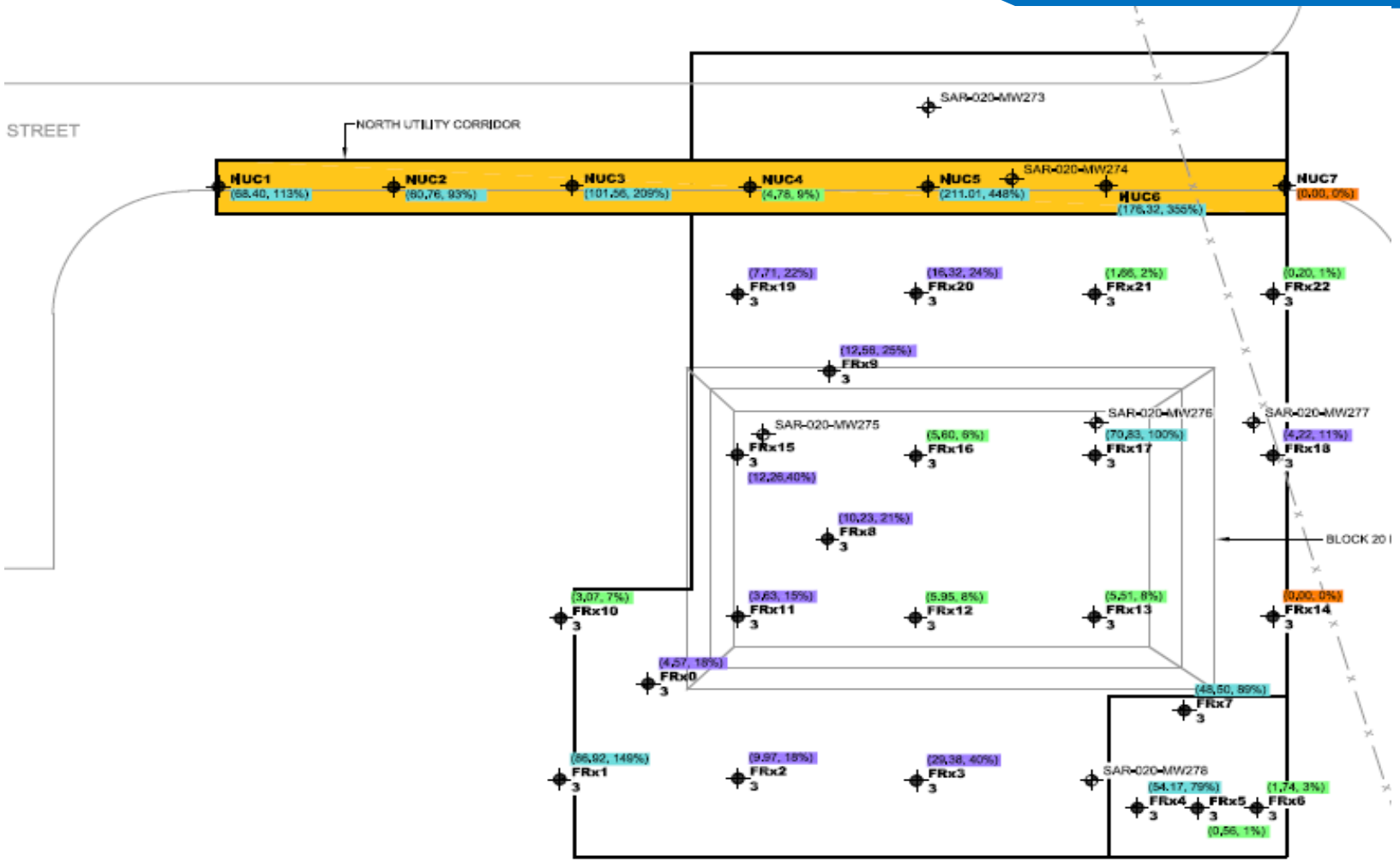


Amendment Composition

- Macroscale Zero Valent Iron for propant (20/40)
- Microscale Zero Valent Iron (LT80/120)
- Microscale emulsified Zero Valent Iron
- Guar
- Glycol



Block 20 Remedial Design Layout



Amendment Volumes

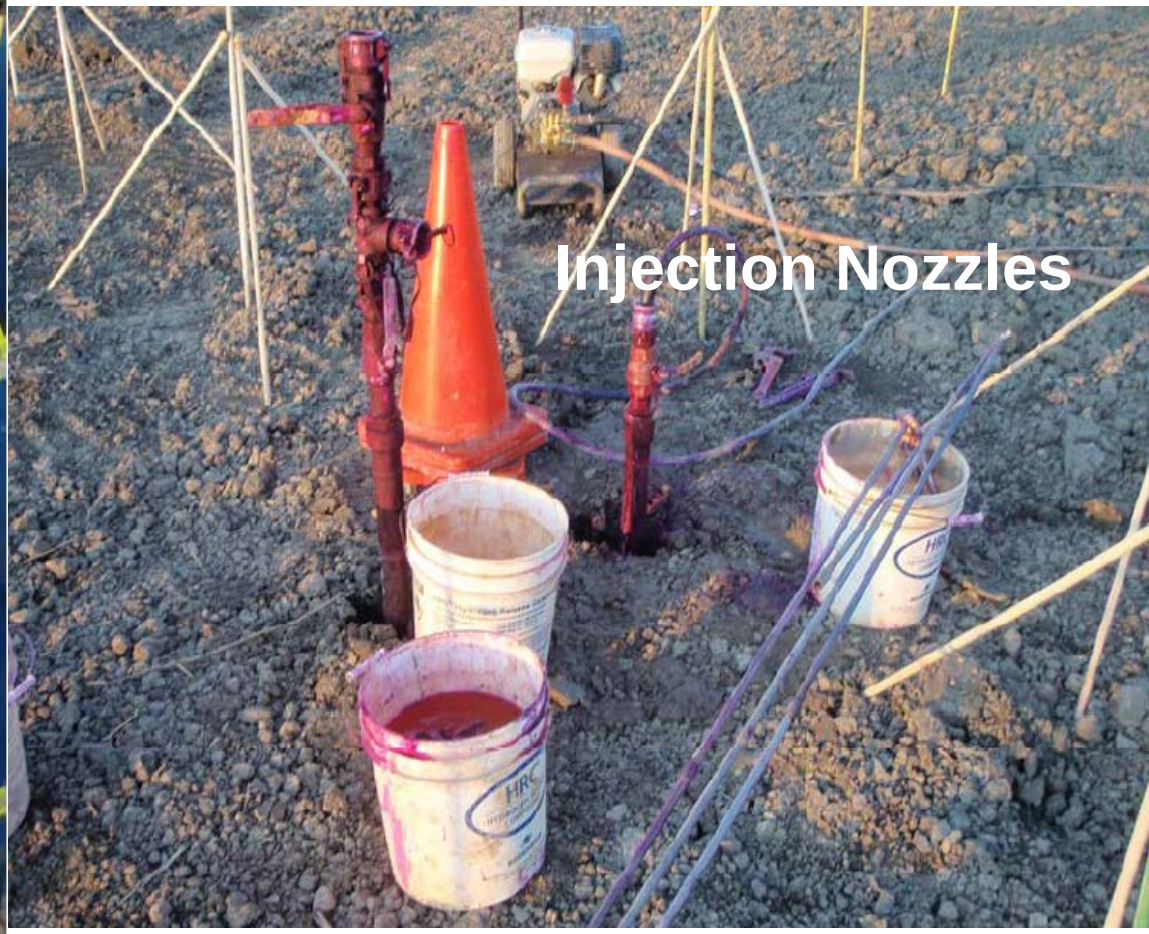


- 2,300 lbs. Iron per fracture
- 168,000 lbs. Total iron injected
- Average of 234 gal of Injectate material (Guar, Water, and Glycol) per Fracture
- 16,457 gal of Injectate total

Site Layout and Installation of Tilt-meters



Boring Installation



Injection Nozzles



Each location had 3 fracture depths, each finished with a 1” PVC temporary well

Confirmation Test Pits



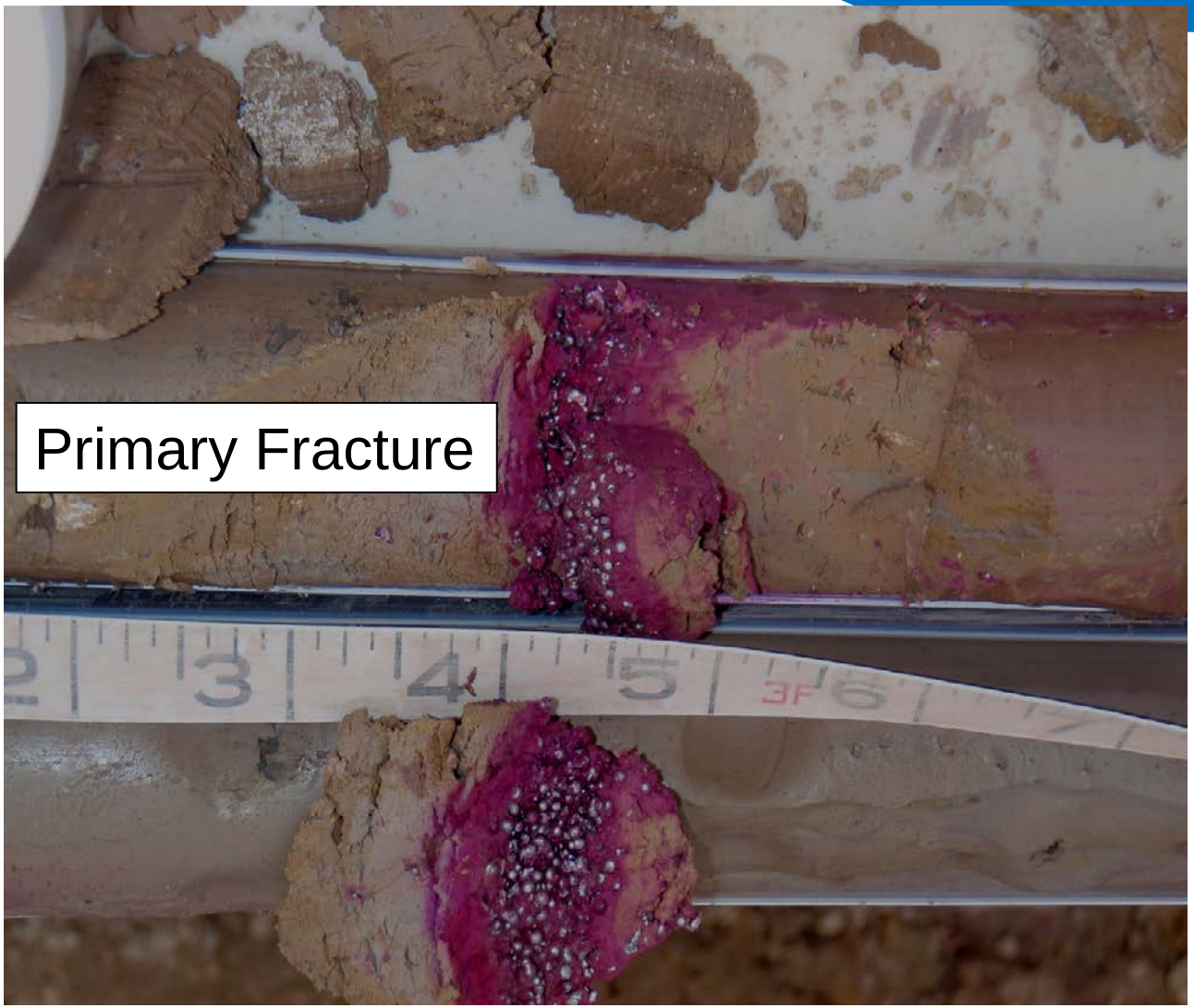
20 feet from Injection point

10 feet from Injection point

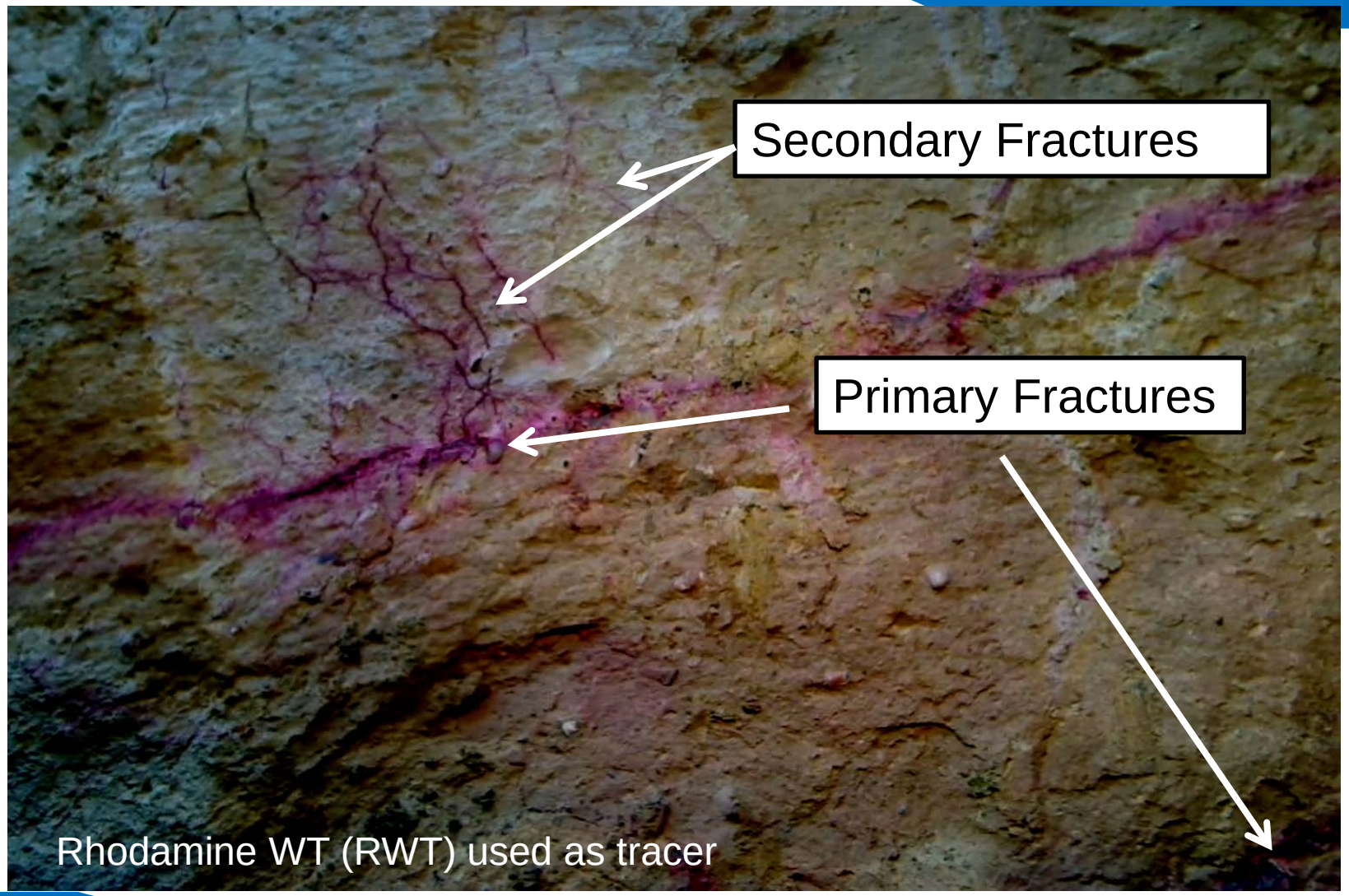
Video Logging







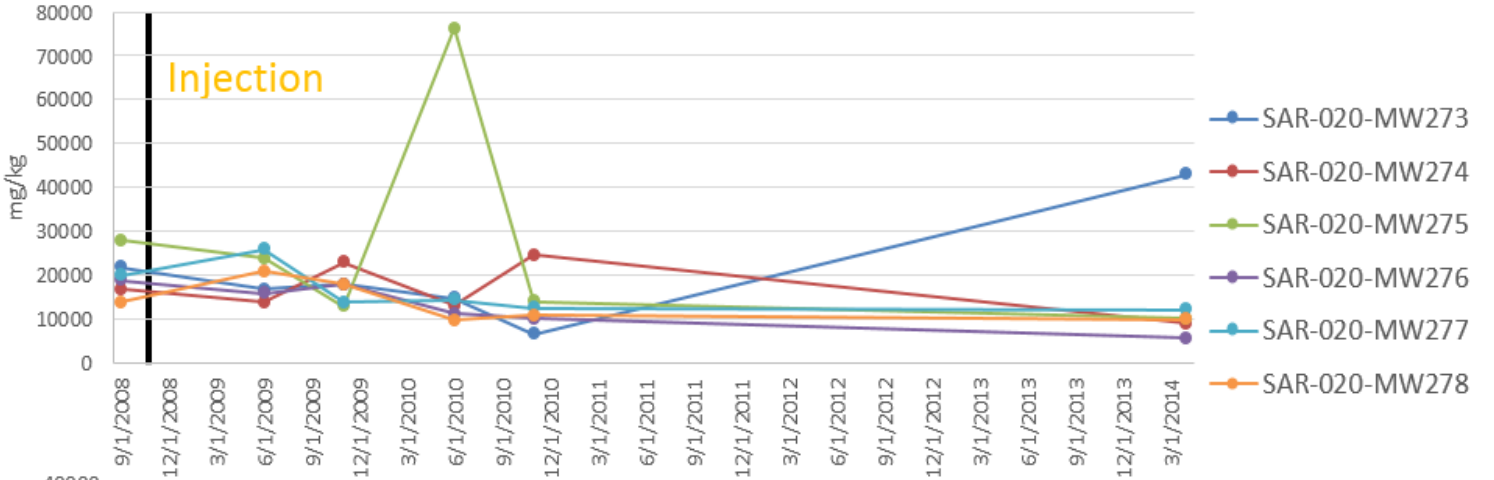




Soil

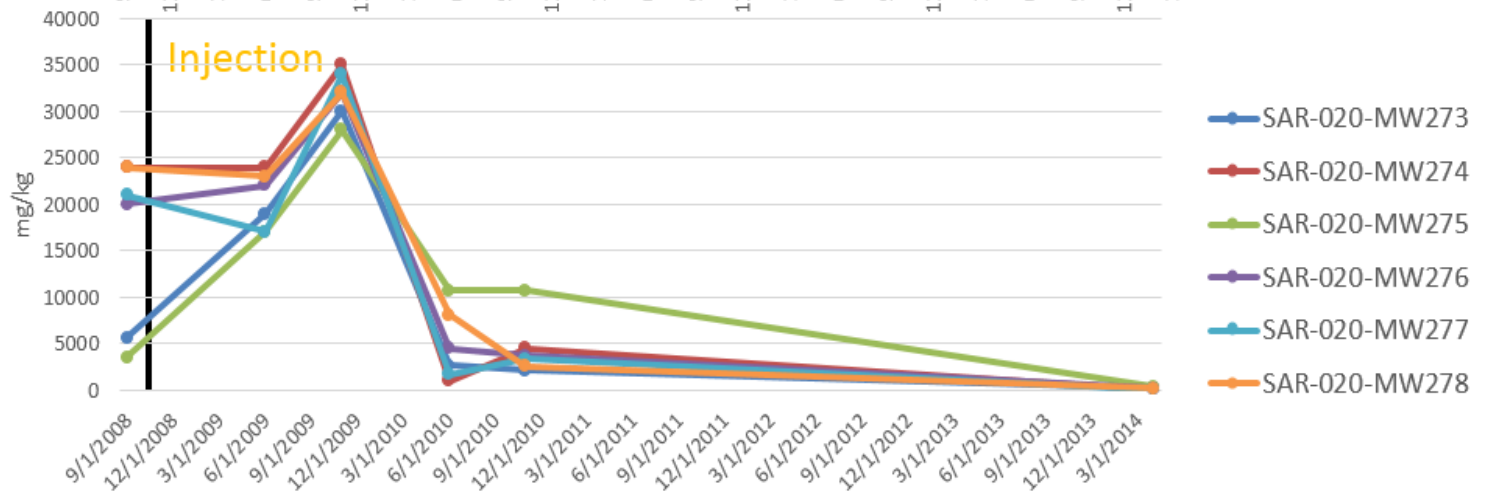


Iron



TOC

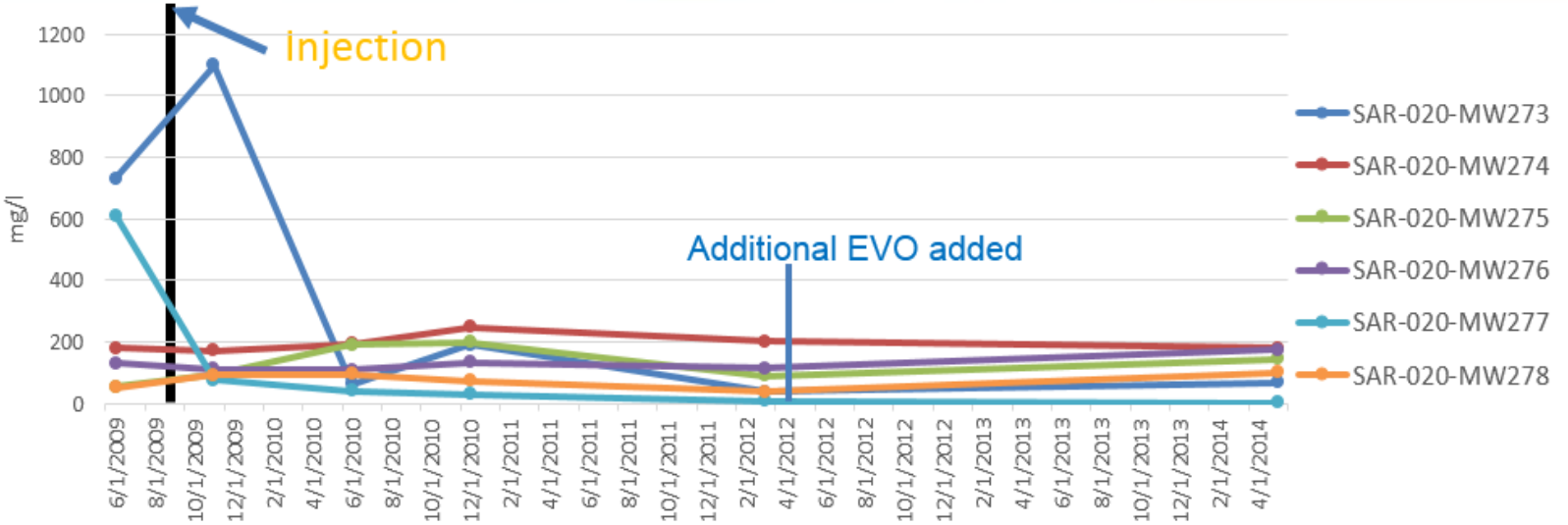
SB002 – 1.95 m
SB004 – 3 m
SB006 – 3.15 m
SB007 – 1.8 m
SB008 – 2.1 m
SB009 – 4.35 m



Groundwater

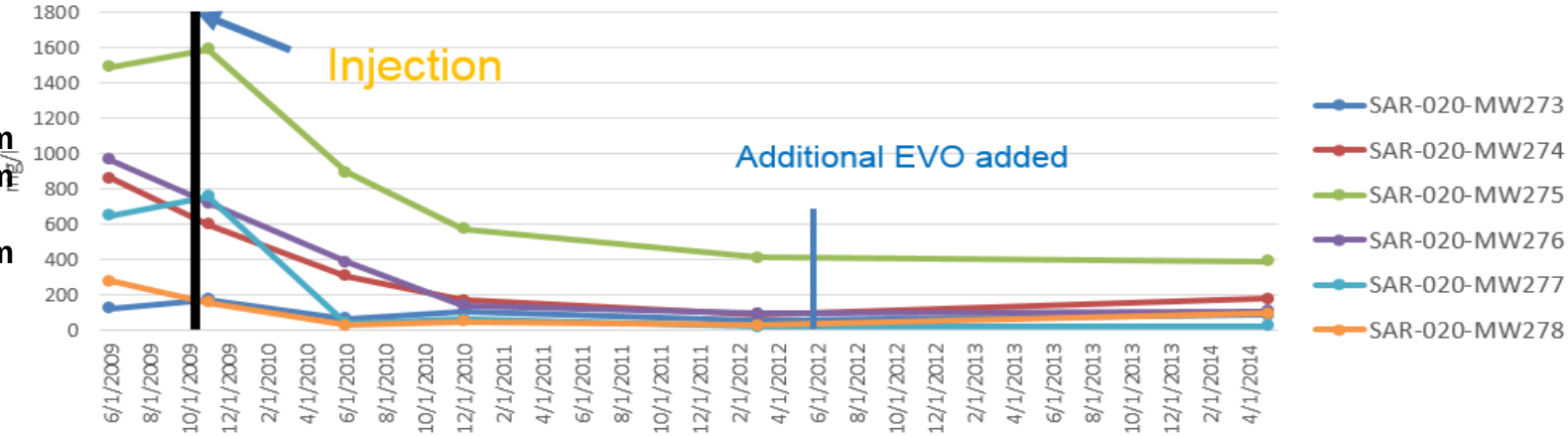


Iron (total)



TOC

MW273 – 4.35 m
MW274 – 3.15 m
MW275 – 1.8 m
MW276 – 1.95 m
MW277 – 2.1 m
MW278 – 3 m

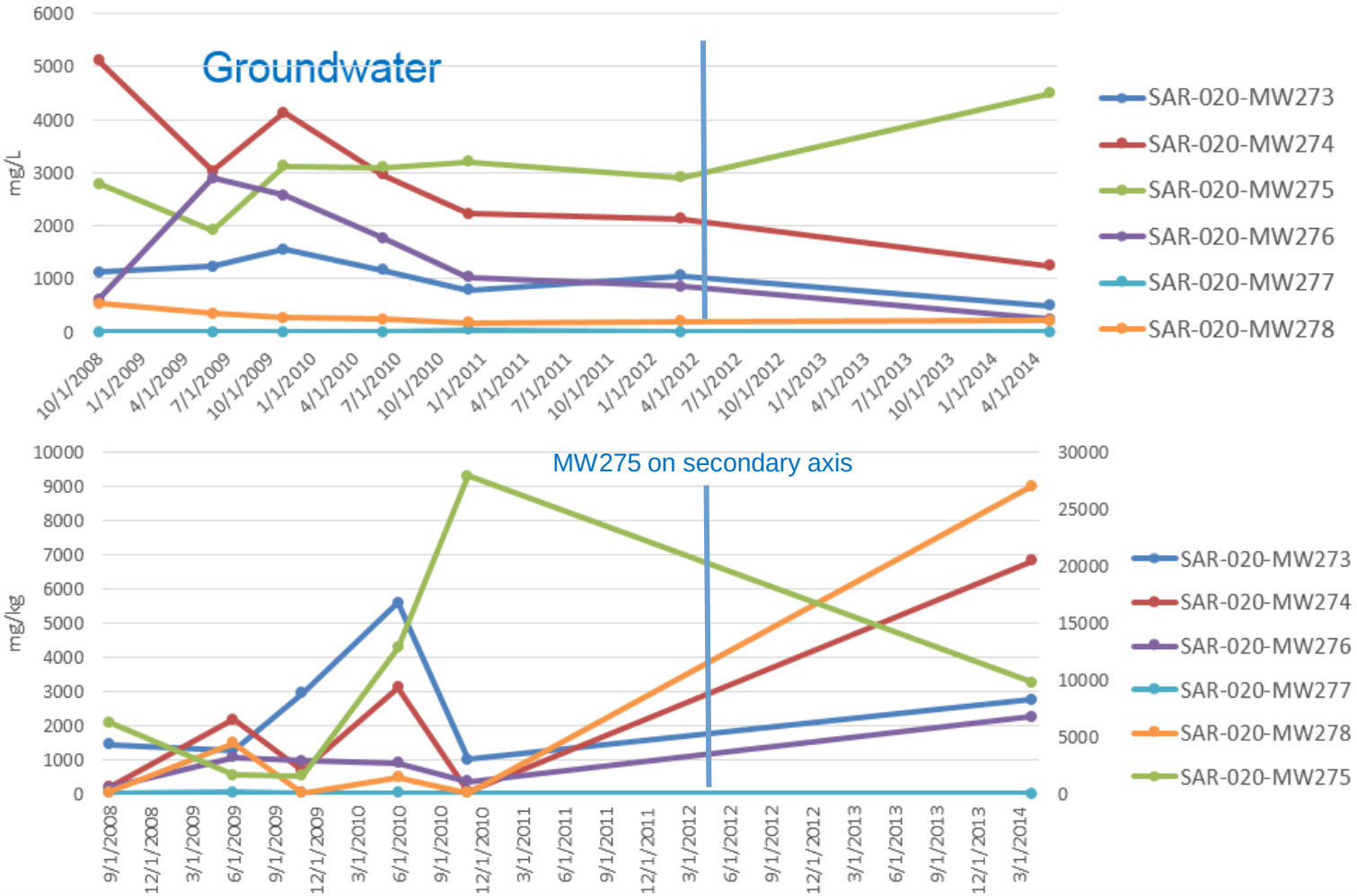


Total VOCs



MW273 – 4.35 m
MW274 – 3.15 m
MW275 – 1.8 m
MW276 – 1.95 m
MW277 – 2.1 m
MW278 – 3 m

Soil



Results



- Iron was successfully added to the subsurface through the F&I work and has resulted in the destruction of some CVOCs.
- Amendment detected throughout a 20 to 30 foot radius from the injection point and secondary fractures visible up to 12 inches vertically from the primary fractures.
- Organic carbon was successfully added to the subsurface and has been utilized for biodegradation as indicated by increases in biodegradation end products.
- May be seeing some rebound 6 years post injection.
- Data set still requires development to determine long term trends and predict timeframes for achieving desired endpoints.

Lessons Learned



- Baseline sampling should be collected before and immediately after injections to account for minor mobility and changed conditions created by the pressures of injections.
- Diffusion into the clay matrix will be a slow process, but is occurring.
- Groundwater results are indicative of processes occurring in soils, but can not be directly correlated to concentration reductions in soils, but is useful as a less expensive screening option.
- Samples at 6 month intervals may not have great value for a large scale project, one to two year sampling intervals are sufficient , with groundwater sampling used to indicate timeframe for soil sampling.
- Rebounding may be a significant issue.

Acknowledgements

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Questions/ Comments?