Performance of Combined Bioremediation and ZVI Emplacement Remedy for Chlorinated Solvent Source Area Treatment

Bountiful/Woods Cross Operable Unit 1 Superfund Site

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April 11, 2018

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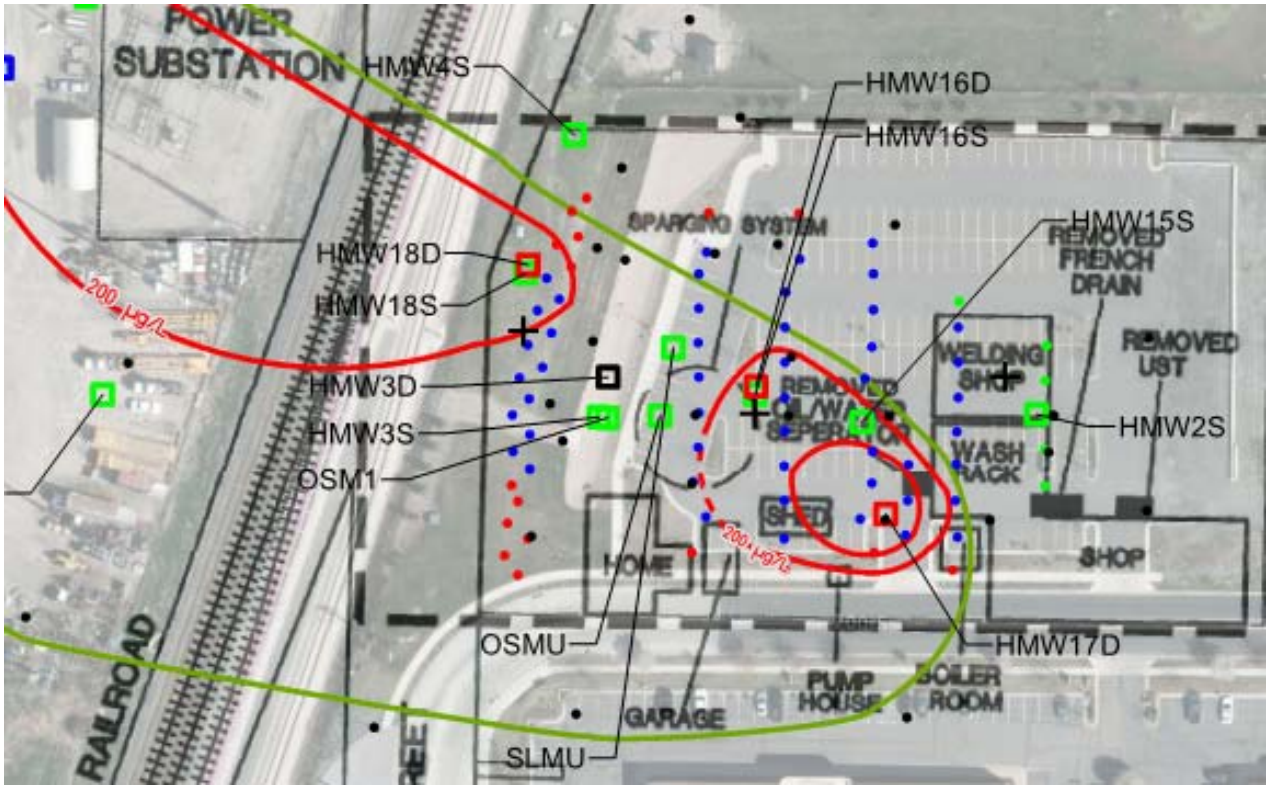
Eleventh International Conference on Remediation of Chlorinated and Recalcitrant Compounds
April 8-12, 2018 | Palm Springs, California

Presentation Outline

- Site Overview and Background
- Source Area Remediation Approach
  - Bioremediation
  - ZVI Emplacement via Hydraulic Permeability Enhancement (Fracturing)
- Performance Monitoring and Results

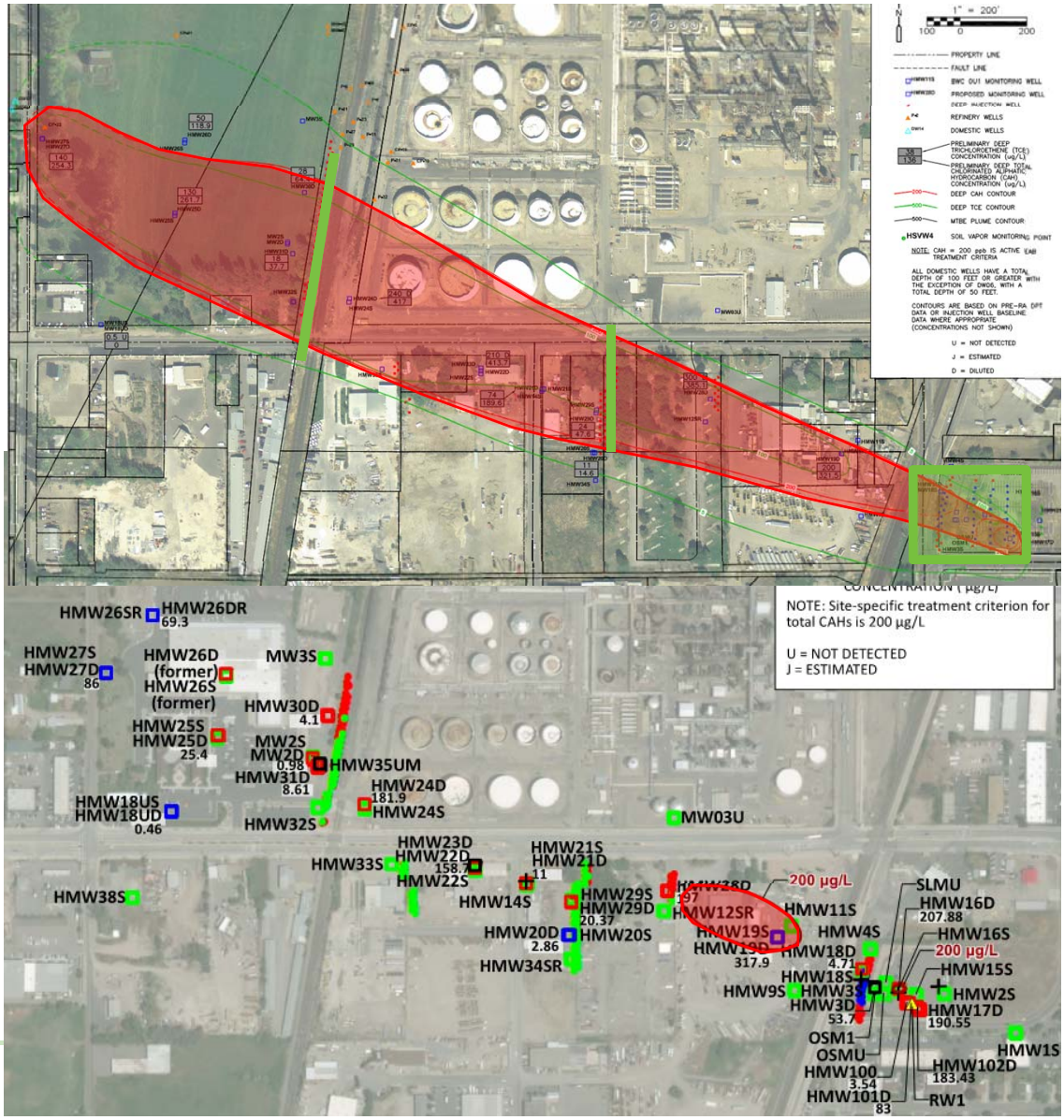
Bountiful/Woods Cross Superfund Site OU1

- Source - Former trucking facility with wash rack and drain
- High concentration (residual DNAPL) TCE source – HMW-17D
- Dissolved plume > 1 mi
- Interbedded sands / silts / clays
- Shallow (25-40 ft bgs) and deep (45-70 ft bgs) aquifer intervals



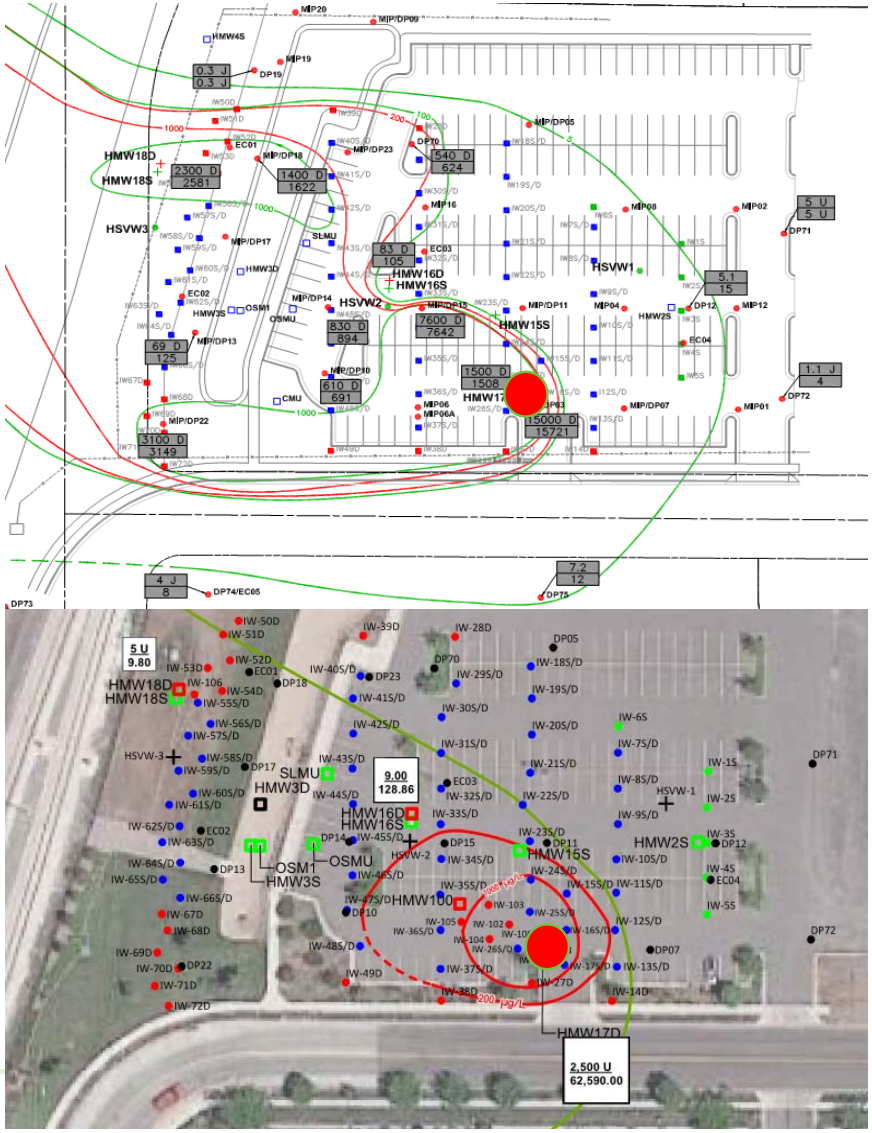
Remedial Strategy

- In situ bioremediation with MNA
- Source Area remedy – 2009
  - Injection well grid
  - Biobarrier #1
- Downgradient Plume remedy – 2011
  - Biobarriers #2 and #3
- Source treatment and Biobarriers have effectively reduced flux to downgradient areas
  - Majority of site below 200 µg/L total chlorinated ethenes



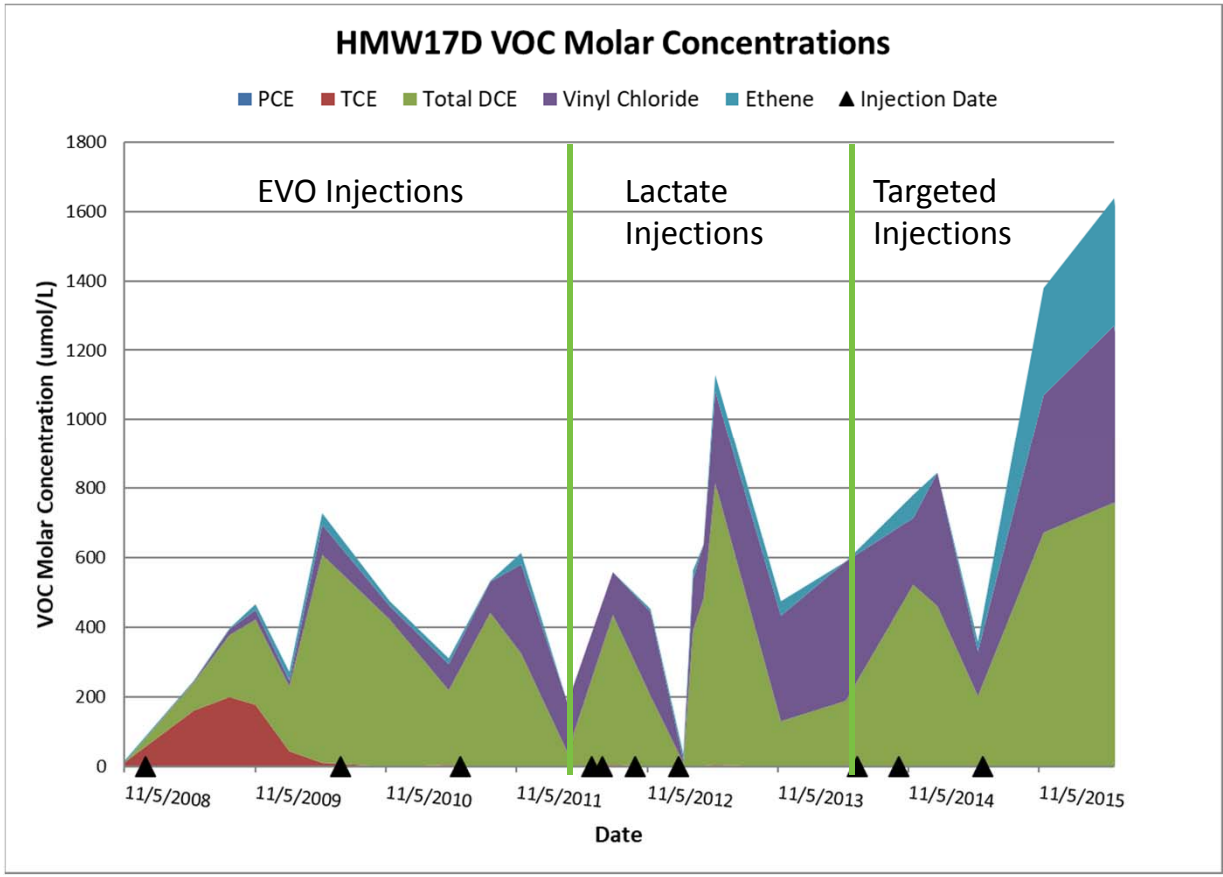
OU1 Source Area Overview

- Majority of source reduced to below 200 ppb by 2012
- Localized source at HMW-17D
  - up to 100,000 μg/L total chlorinated ethenes
- More aggressive approach
  - Quarterly sodium lactate injections (Wilclear Plus®)
  - Targeted lactate injections near HMW-17D



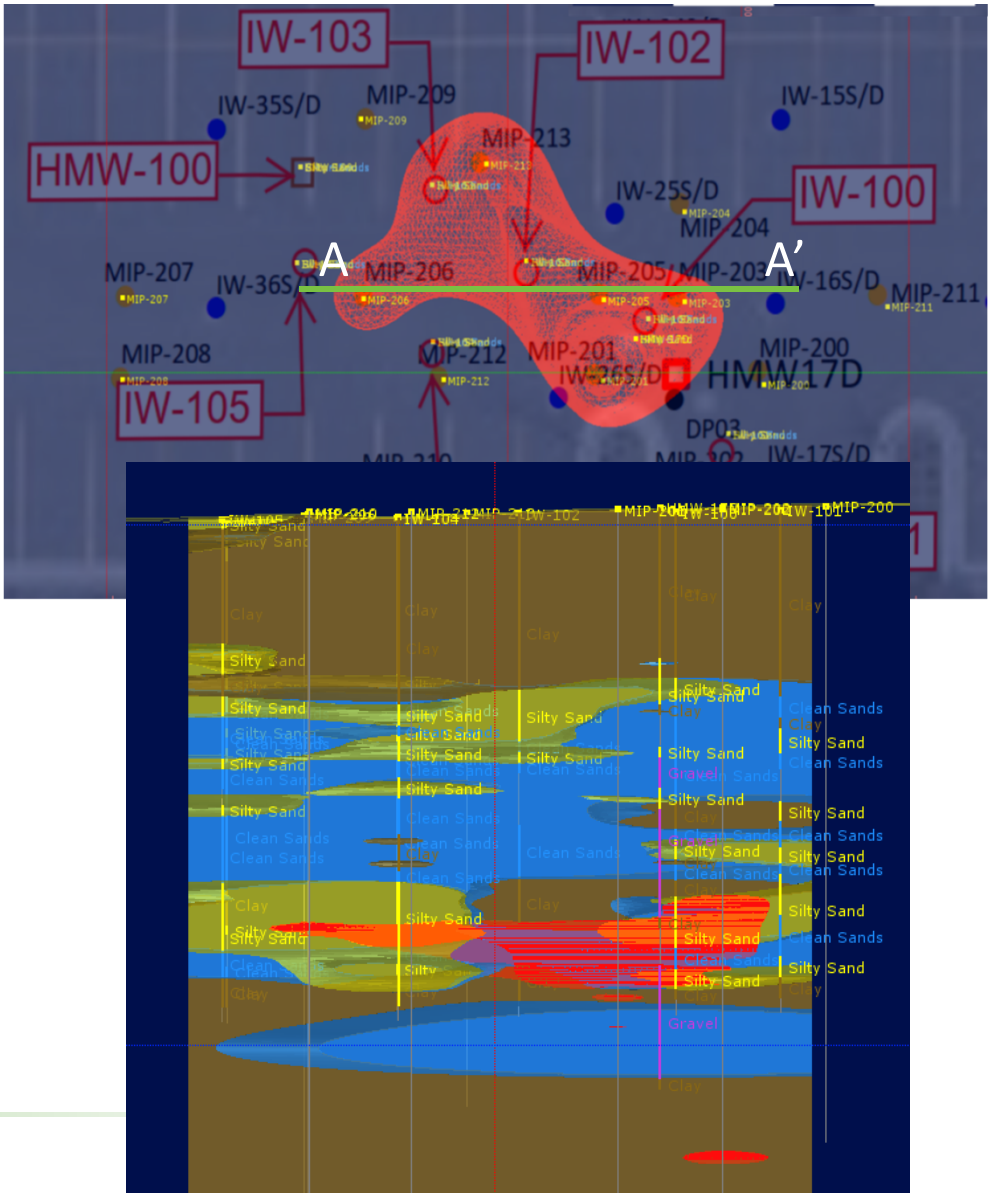
OU1 Source Area Overview

- Most recent lactate injection January 2017
- Observed enhanced mass transfer but no sustained declining trends
- EPA and Utah desired a more aggressive approach for addressing localized source mass near HMW-17D
  - ROD specifies in situ biological or chemical treatment



Source Area Characterization

- MIP/EC logging
- Leapfrog® 3D to visualize high-concentration source mass and lithology
- VOC mass was present in low-K layers and in interbedded silty sands
  - Depth intervals between 35 and 70 feet
- Depth-discrete GW samples confirmed up to 7,000 µg/L VOCs in deeper (60-75 ft) interval

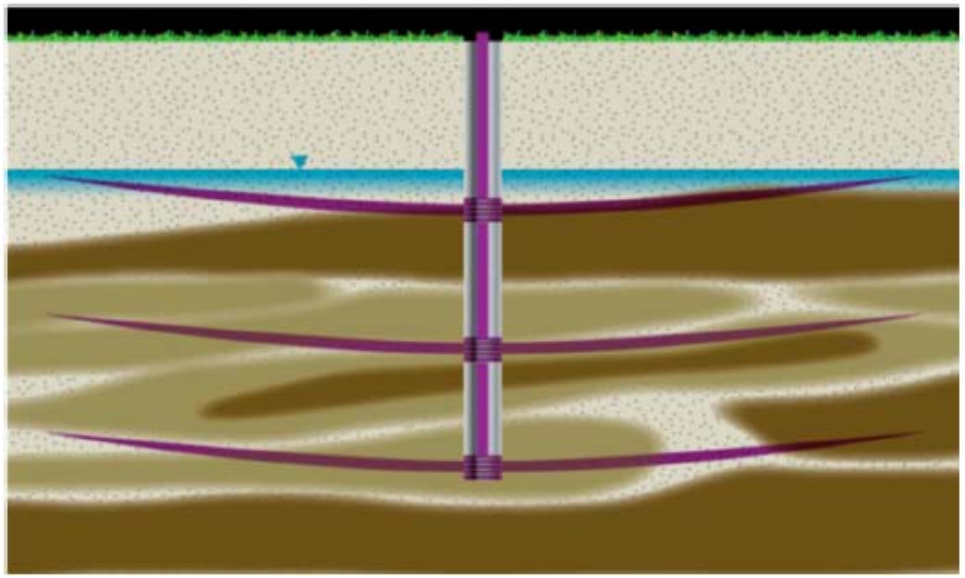


Selection of Approach for Remedy Enhancement

- Evaluated multiple technologies for targeted, aggressive hot spot treatment
  - Continued quarterly injections
  - Thermal-enhanced bioremediation
  - In situ stabilization
  - Thermal
  - **Hydraulic permeability enhancement (fracturing) with biorecirculation**
    - Selected based on cost, likelihood of success, and within selected remedy

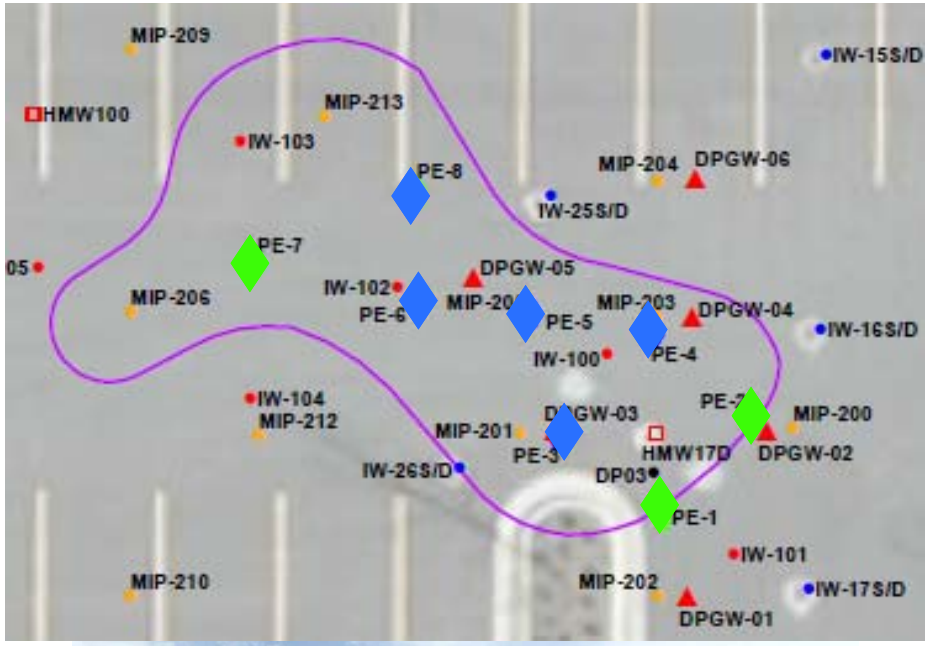
Why Hydraulic Permeability Enhancement?

- Increase contact between amendment and contaminant in low-permeability layers
  - ZVI and bioremediation amendments
- Hydraulic Permeability Enhancement (Fracturing)
  - High pressure injection of viscous slurry
    - Guar and proprietary cross linker
  - Creates fracture in target zones with emplaced amendment and sand proppant



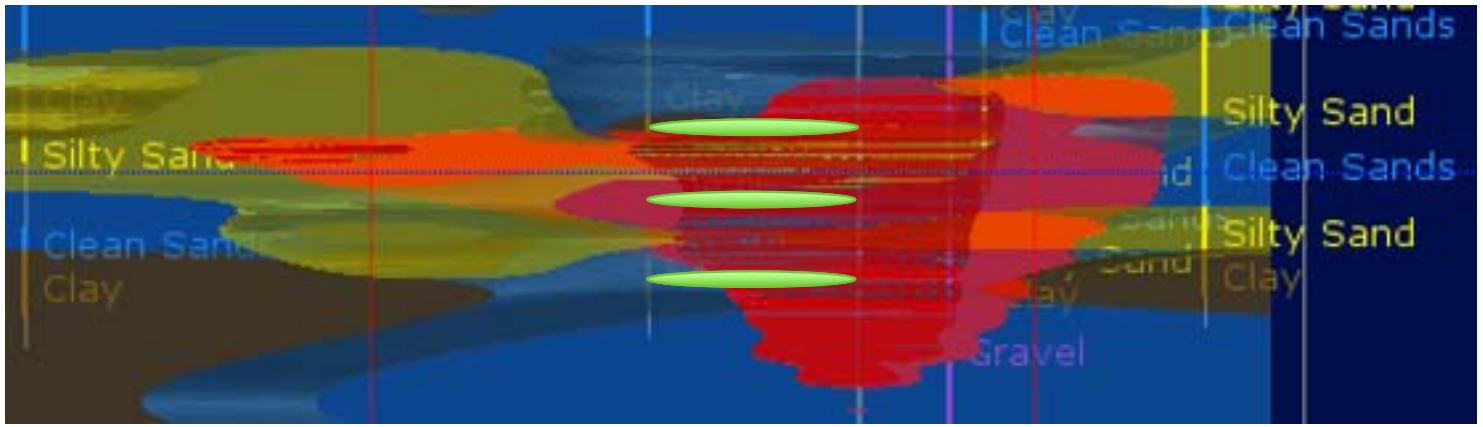
Permeability Enhancement Approach

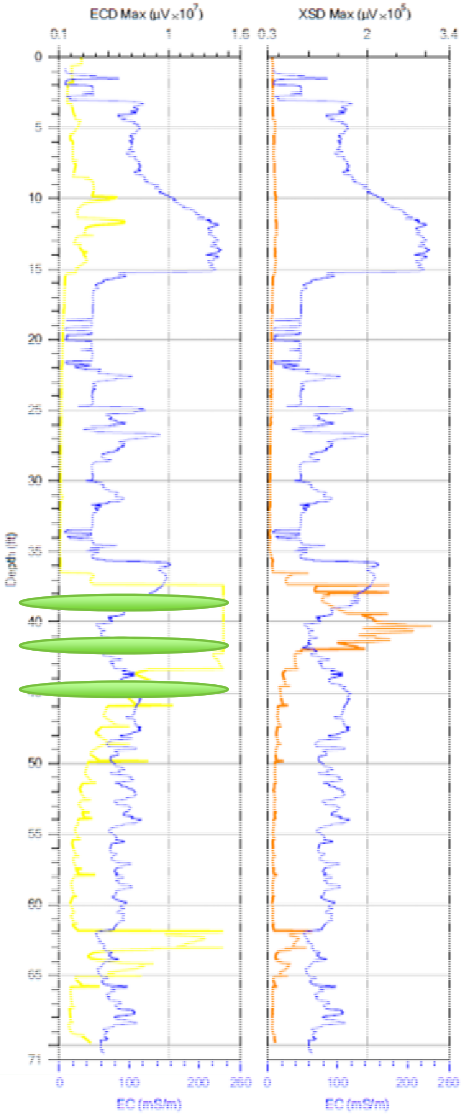
- Create a dense network of relatively small fractures
- Eight boreholes, each with between 3 and 6 fractures
- Each fracture contained:
  - 140 gallons of slurry
  - 550 pounds of iron (C.E.R.E.S. micro-scale iron)
  - 550 pounds of 20/40 silica sand proppant
- Total of 39 fractures emplaced



Permeability Enhancement and ZVI Emplacement

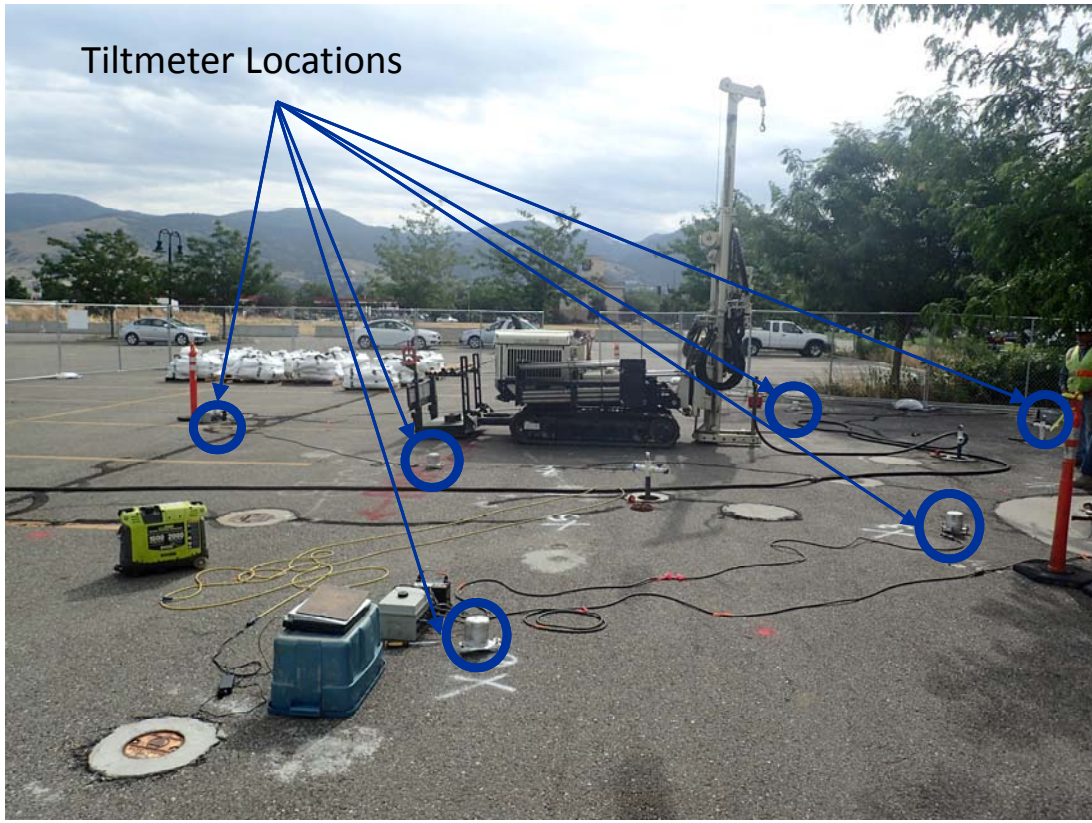
- Depths for fracture initiation determined based on MIP logs and 3D visualization
- Planned to follow up with biorecirculation through fracture network





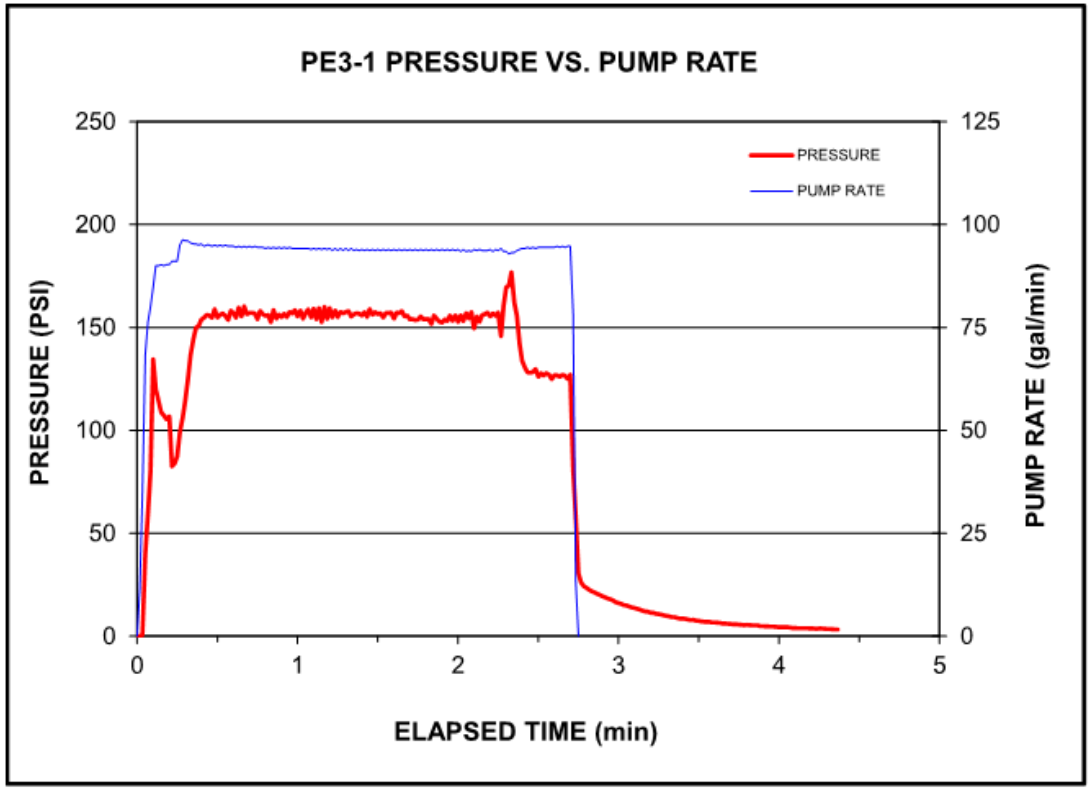
Tiltmeter Monitoring

- Tiltmeters measure very small deflections in the ground surface in response to fracture initiation
- Concentric array of tiltmeters around fracture borehole
- Modeled to estimate fracture orientation



Permeability Enhancement Implementation – Pressures and Flow

- Fracture initiation pressures ranged from 80 – 240 psi
- Propagation pressures ranging from 105-220 psi
- Pump rate 80-110 gpm



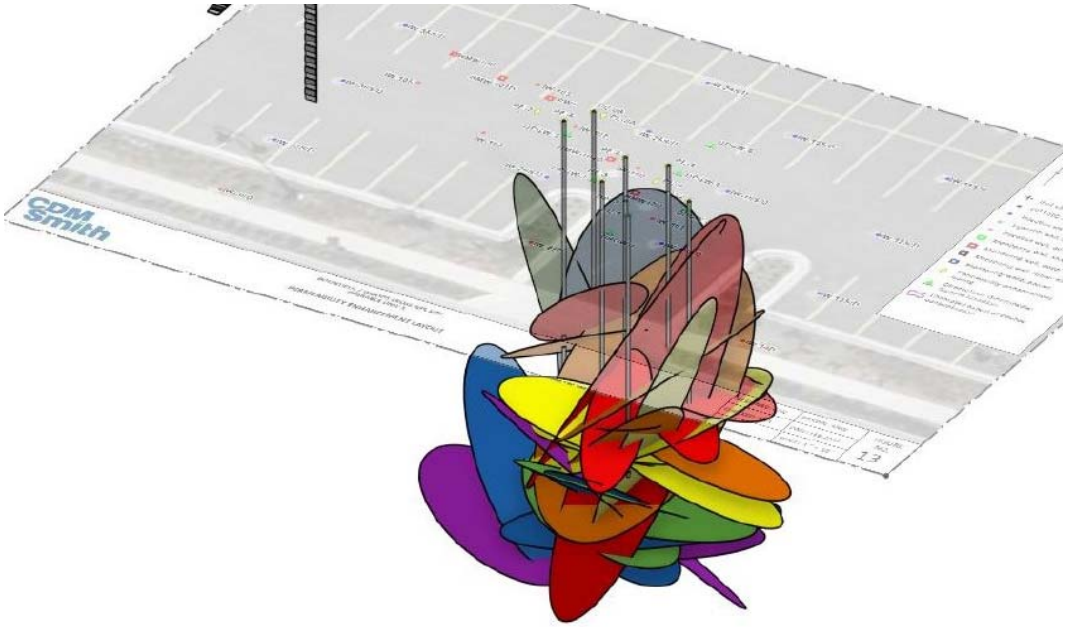
Fracturing Results - Emplacement

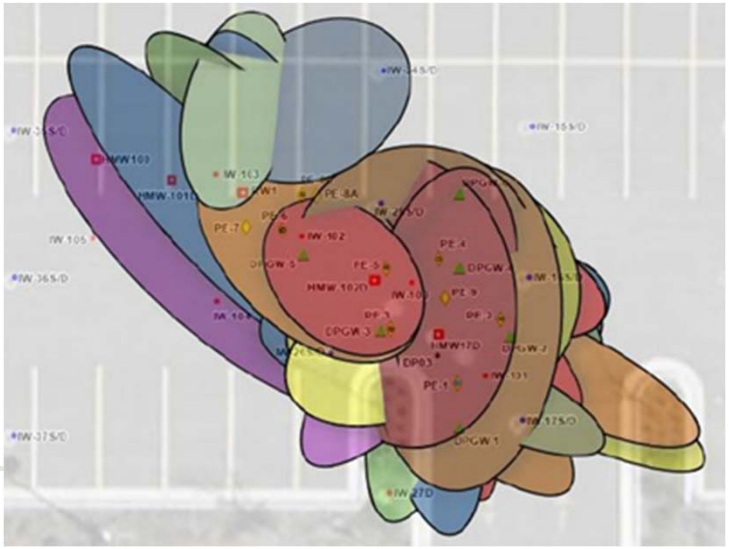
- Iron presence in boreholes within target treatment area
  - Boreholes 5-12 feet away from fracture initiation points
  - Fractures with sand proppant observed
  - Leak-off of iron into sand lenses

Sand and iron filled fracture

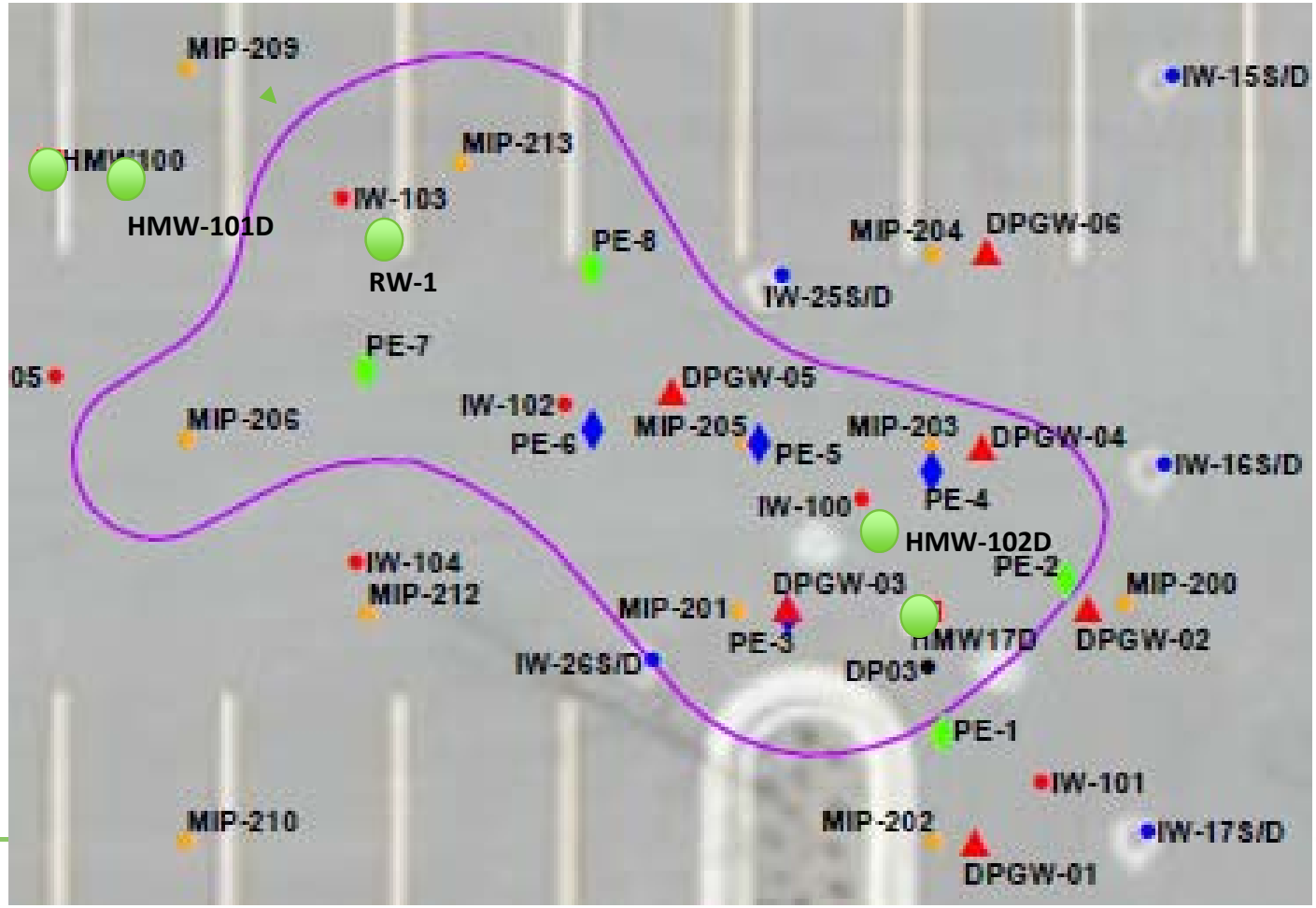
Tiltmeter Results

- Tiltmeters indicated network of dense, interconnected/ overlapping fractures
  - Generally confirmed by observations in boreholes
- Fractures had dip angles between 0 and 60 degrees



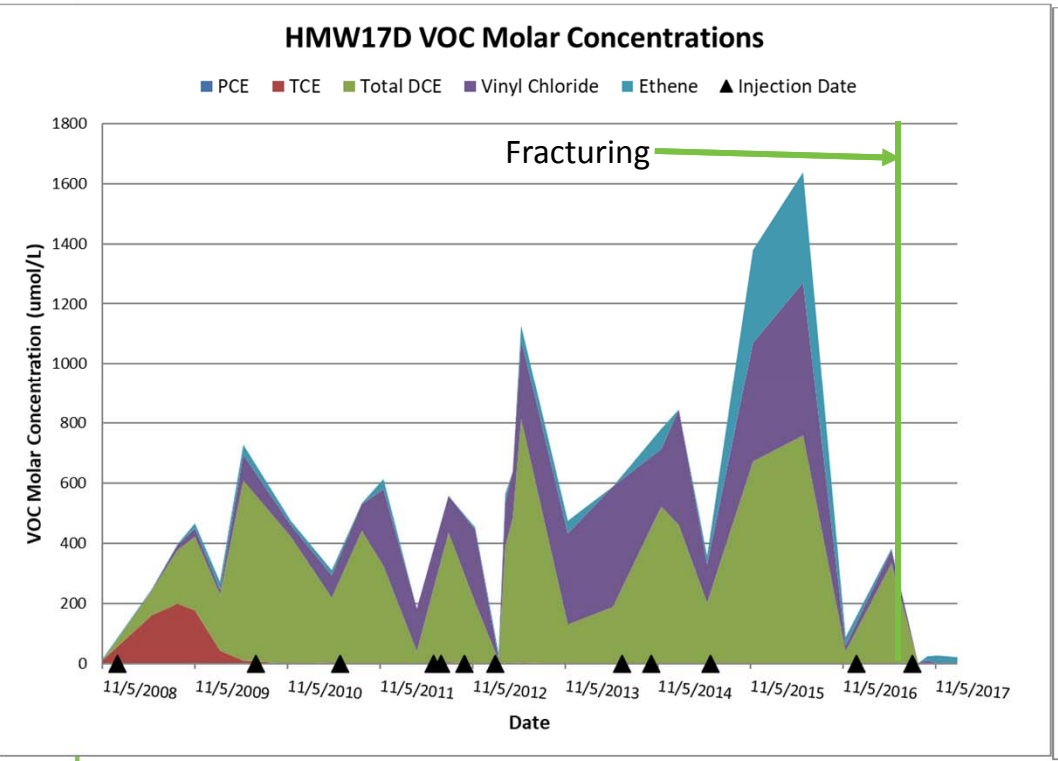


Performance Monitoring Locations

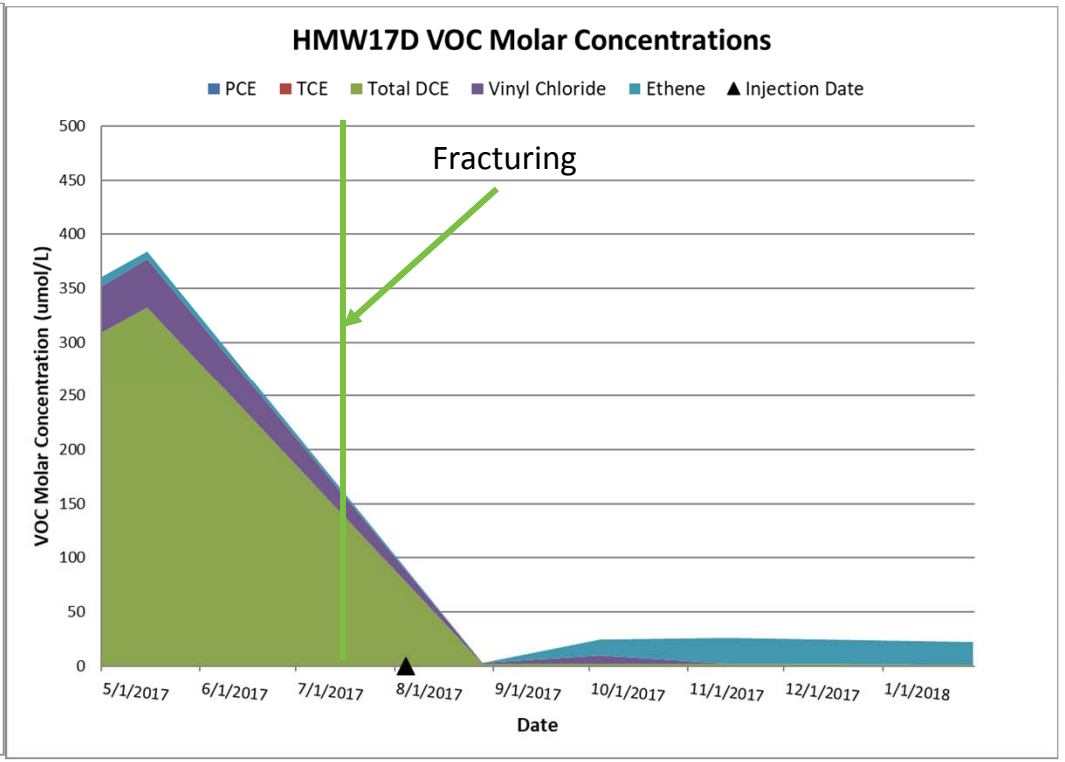


HMW-17D Area – Molar VOC Concentrations

- Complete Data Set

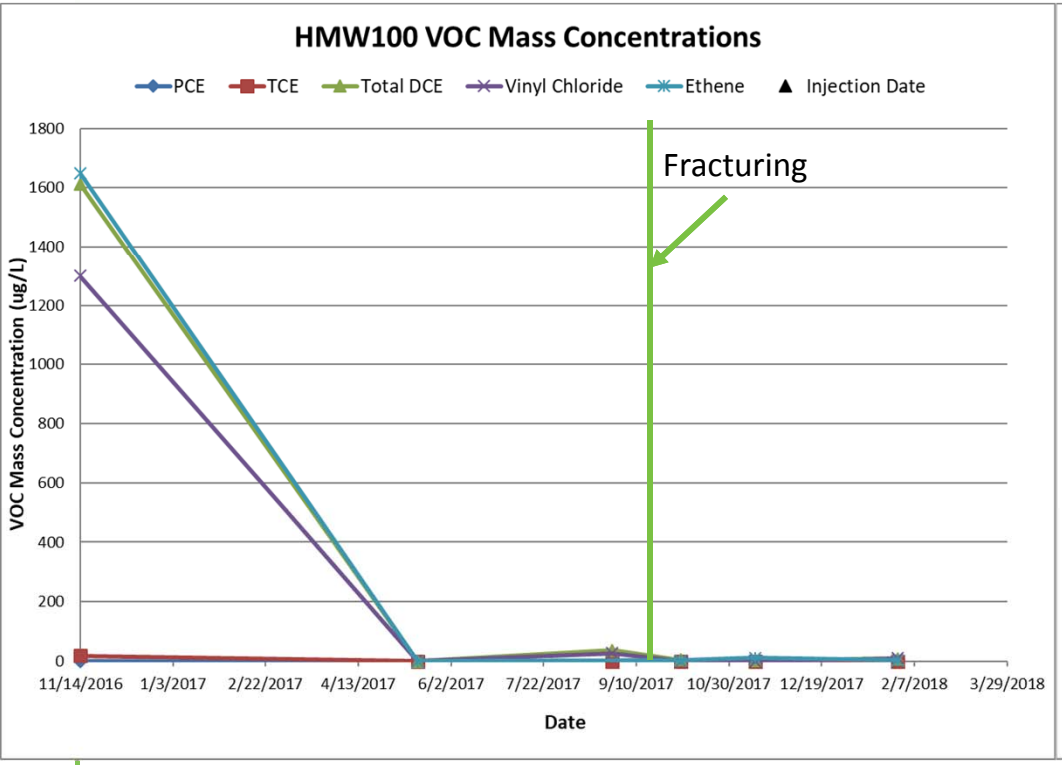


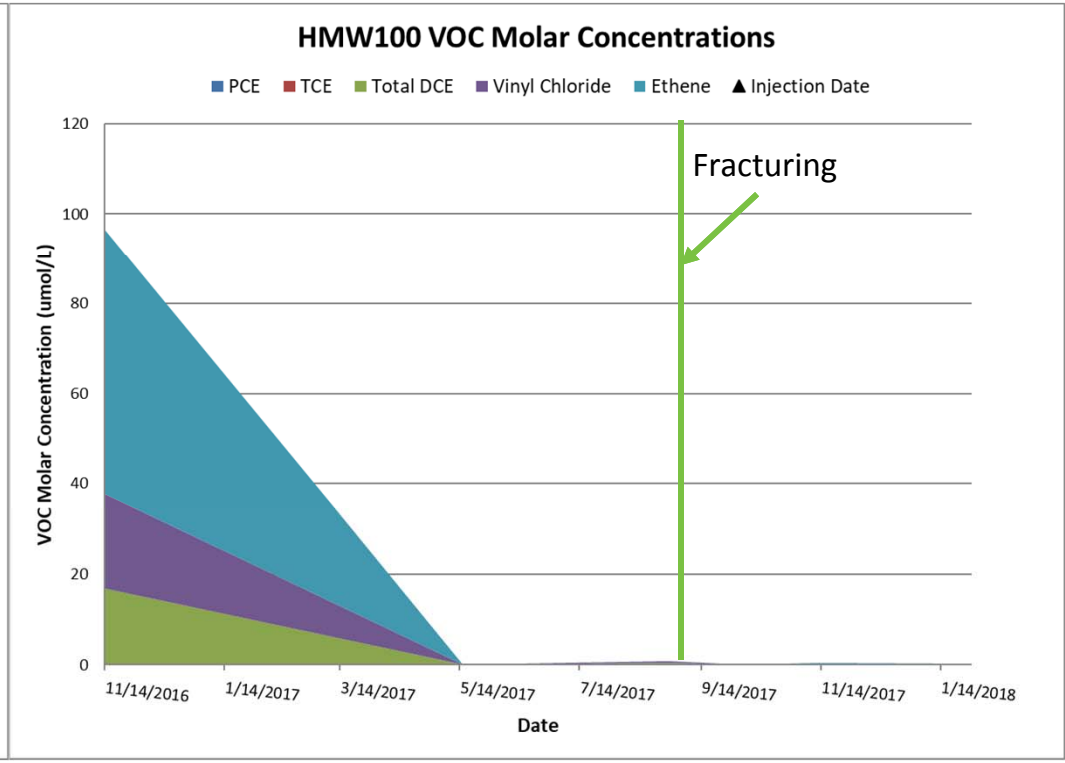
- Post-Fracturing



Post-Fracturing Analytical Results - Downgradient

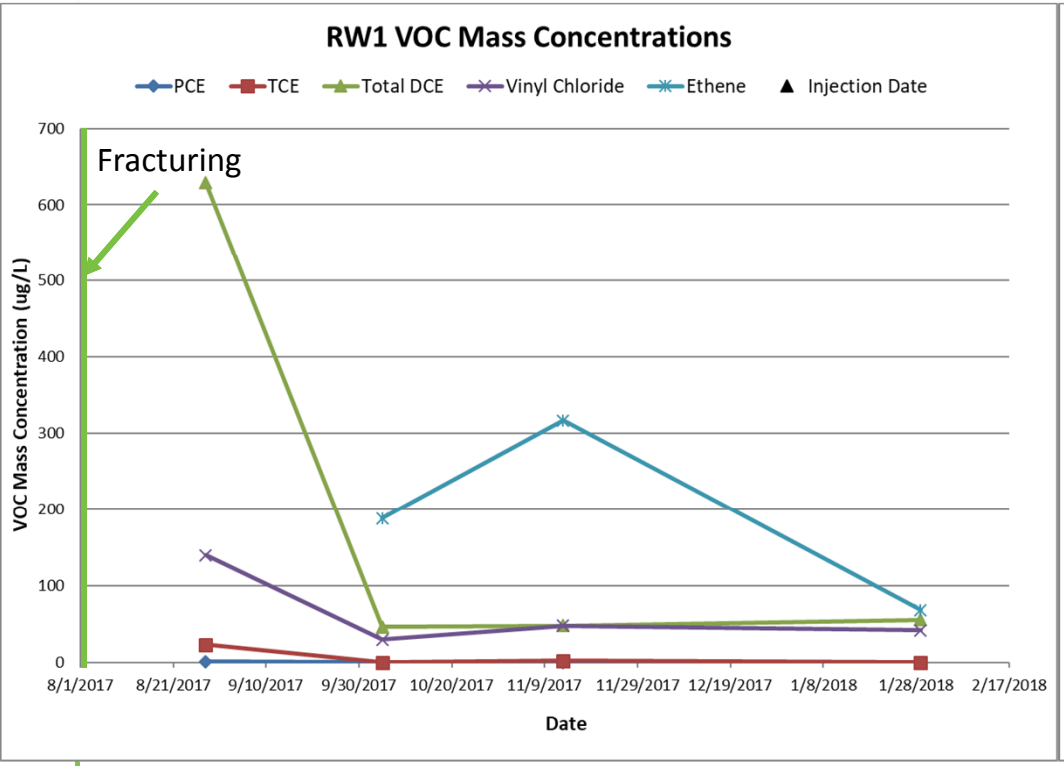
- HMW-100

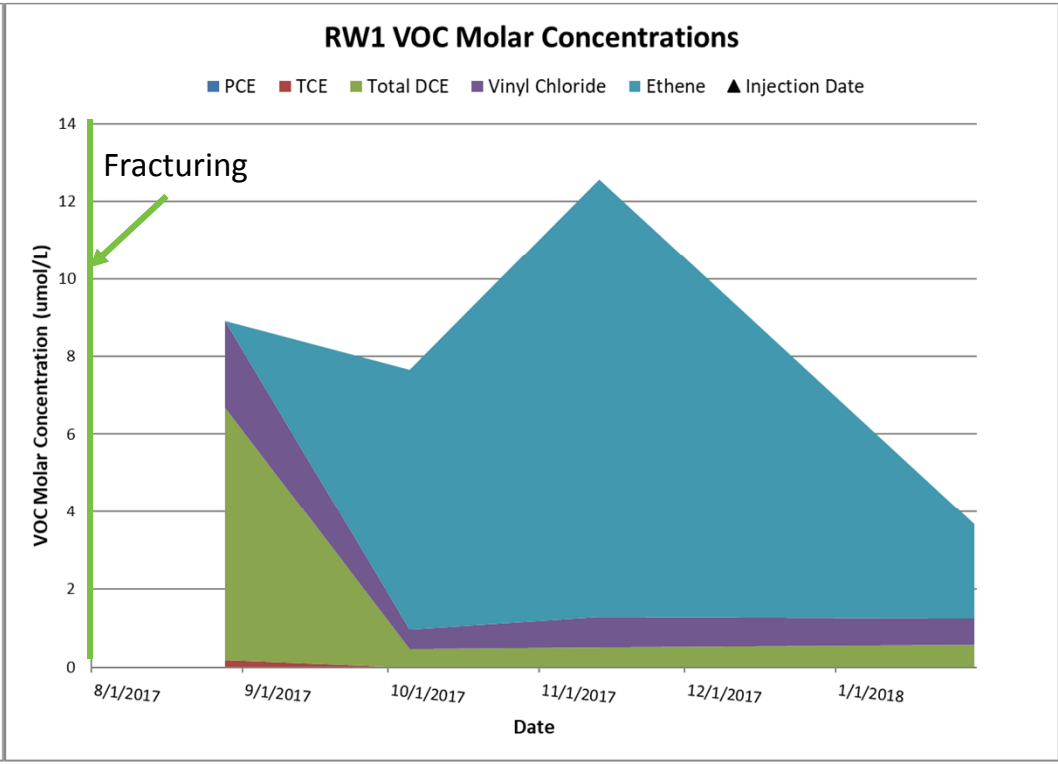




Post-Fracturing Analytical Results – Treatment Area

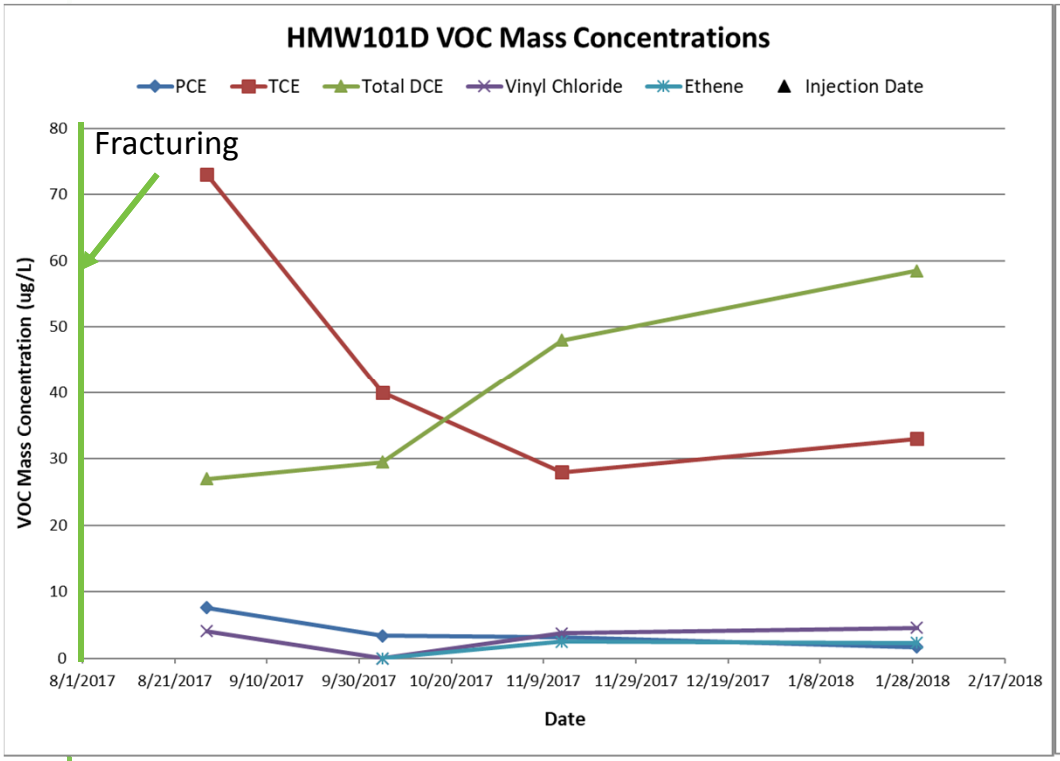
- RW-1

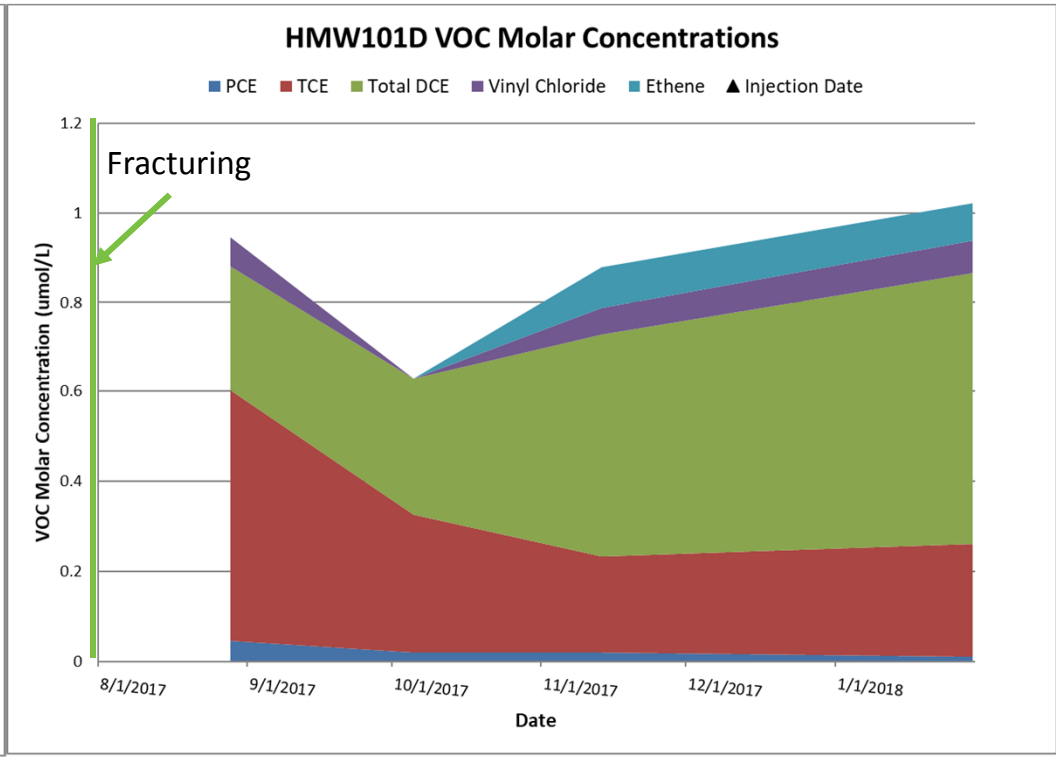




Post-Fracturing Analytical Results – Treatment Area

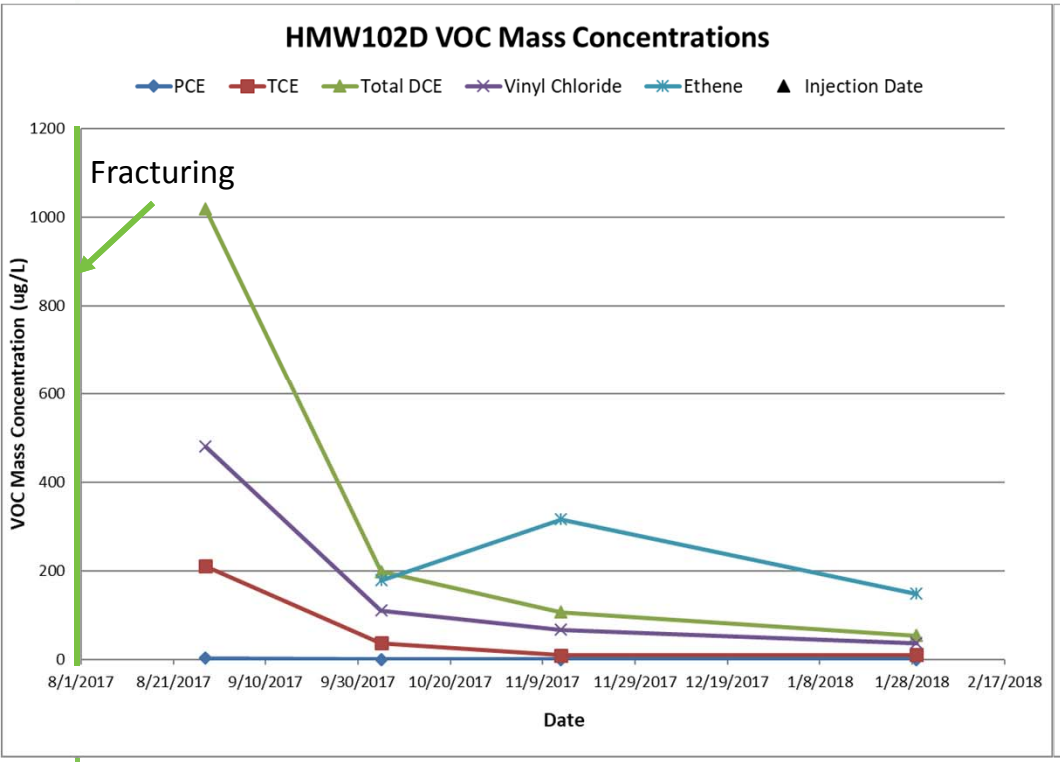
- HMW-101D

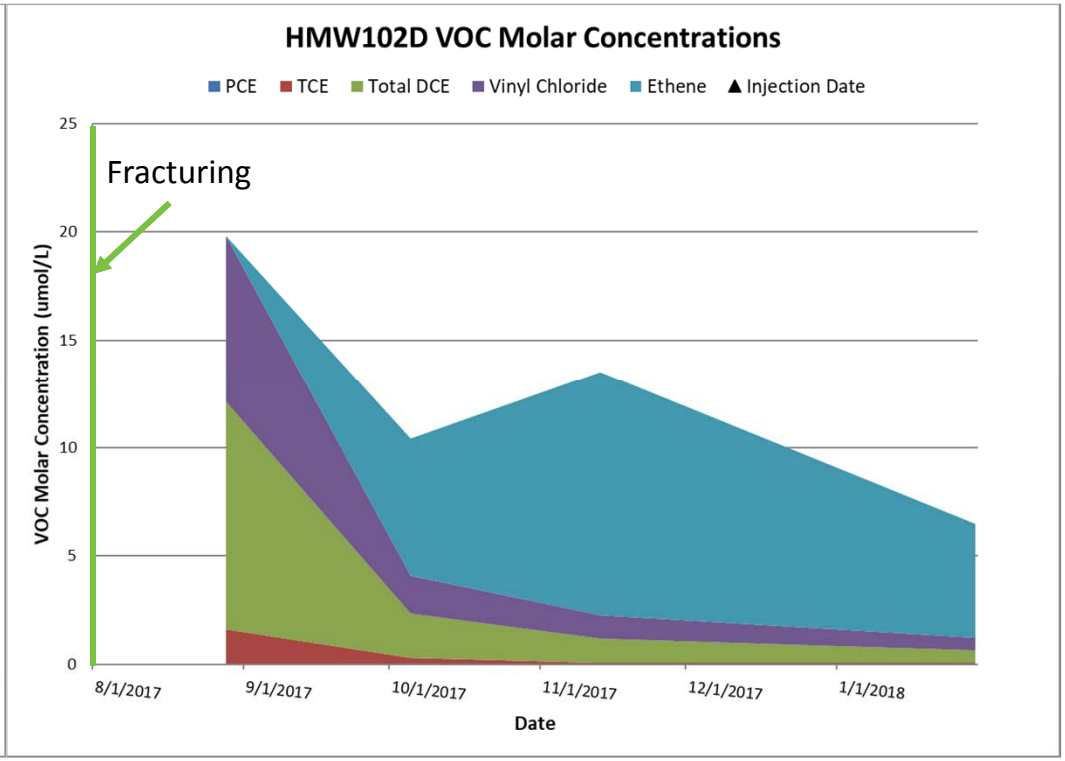




Post-Fracturing Analytical Results – Treatment Area

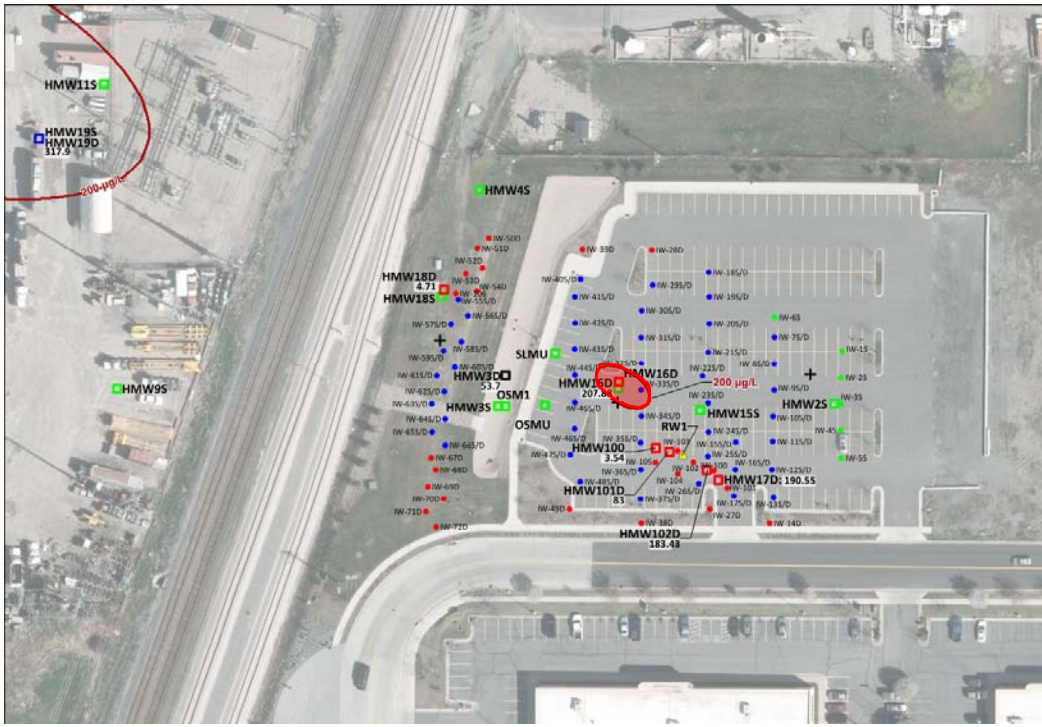
- HMW-102D





Conclusions

- Delineation of source using HRSC was critical to targeting implementation
- Fracturing was effective at distributing ZVI and contacting contaminant in low-permeability areas
- Sustained contaminant reduction – 99.5% reduction sustained for 7 months
  - Biorecirculation not necessary at this time



Acknowledgements

- CDM Smith
  - Tom Cook
  - Michelle Goldberg
  - Mike Lamar
- Wasatch Environmental
- Utah Department of Environmental Quality
  - Michael Storck
- Geotactical Remediation
  - Heather Sturm
  - Andreea Mogos

Questions?