LNAPL Remediation in Complex Geologic Setting Using an Activated Carbon Based Injectate

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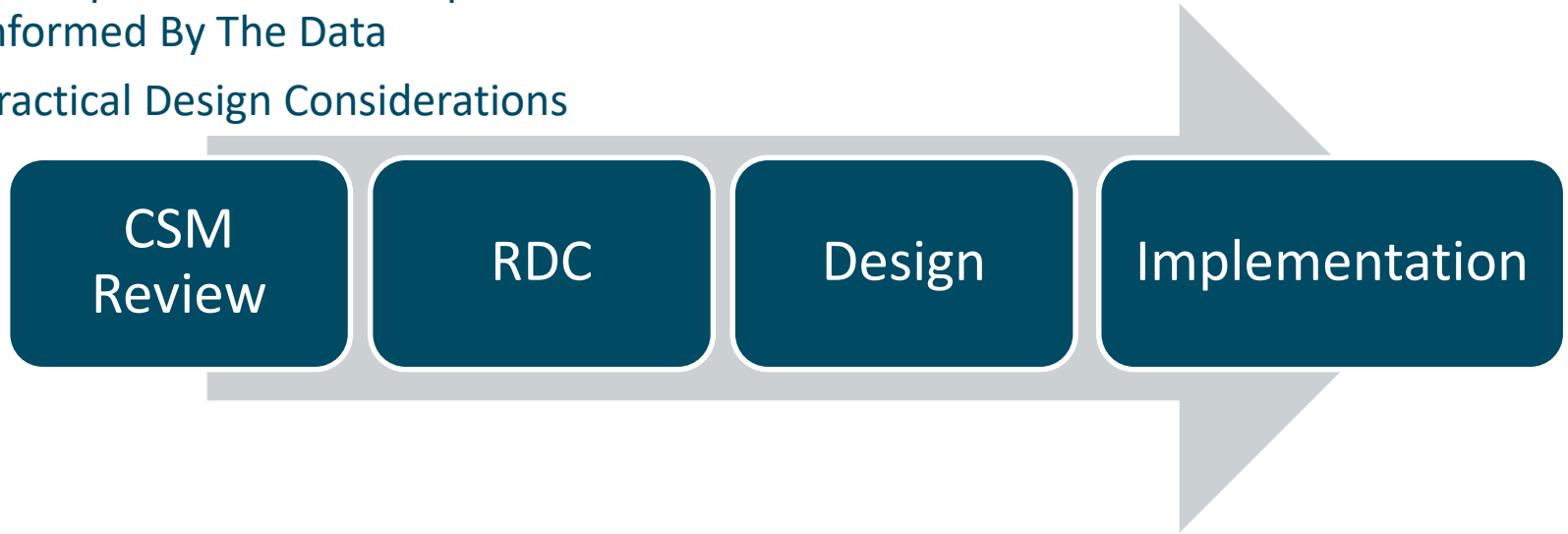
Systematic Remediation Process

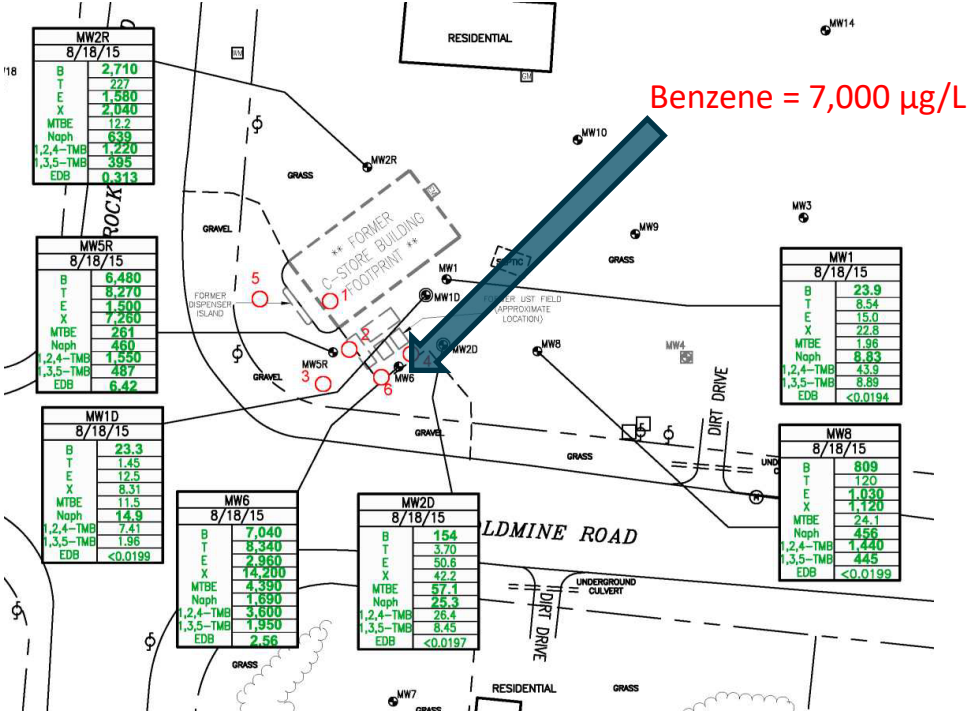
Remediation process includes:

- Systematic Planning
- Dynamic Work Strategies
- Conceptual Site Model Updates Informed By The Data
- Practical Design Considerations



Conceptual Site Model

- Historical release within tank pit and multiple remedial efforts
- Benzene exceeds GCL in MW-6 at residual LNAPL levels
- Piedmont Physiographic Province underlain by metamudstone
- Data gaps with lithology and contaminant distribution
- Selection of activated carbon based injectate (BOS 200®) for pilot scale
- Contemplated shallow bedrock injection

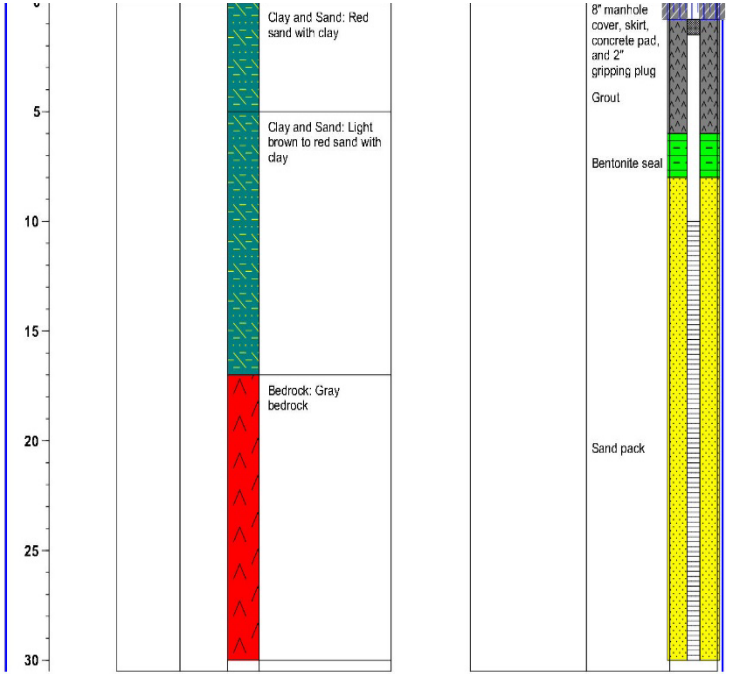


High Resolution Conceptual Site Model Development

- Detailed understanding of vertical and horizontal distribution of speciated mass
  - Dense vertical soil profiles (e.g. every 1-2 ft)
  - Hydropunch or nested temporary wells to define vertical distribution of groundwater impacts (critical for long MW screens)
    - Assist in distribution assessment during implementation phase
  - Integrate High Resolution Site Characterization tools when applicable (e.g. MiHPT, UVOST)
  - RPI Laboratory runs pro bono analysis (8260B, 300.1, RSK 175)
- Understanding of lithology and saturated soil mass is critical to successful in-situ remedial solution

Remedial Design Characterization

- Direct push borings to evaluate overburden mass and delivery feasibility
- Two bedrock wells to evaluate shallow bedrock conditions and potential use in pilot test
- Rock Coring
- Borehole Geophysics
- Packer Testing

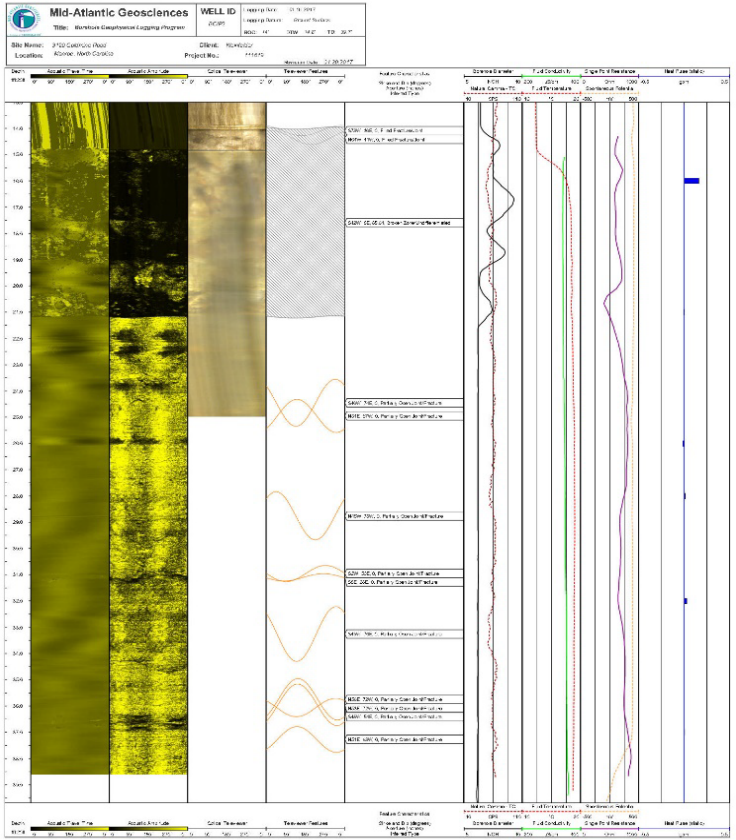


RDC - Borehole Geophysical Logs

Geophysical Tools

- 3 Arm Caliper
- Natural Gamma
- Resistivity
- Optical and Acoustic Televiewer
- Heat Pulse Flowmeter

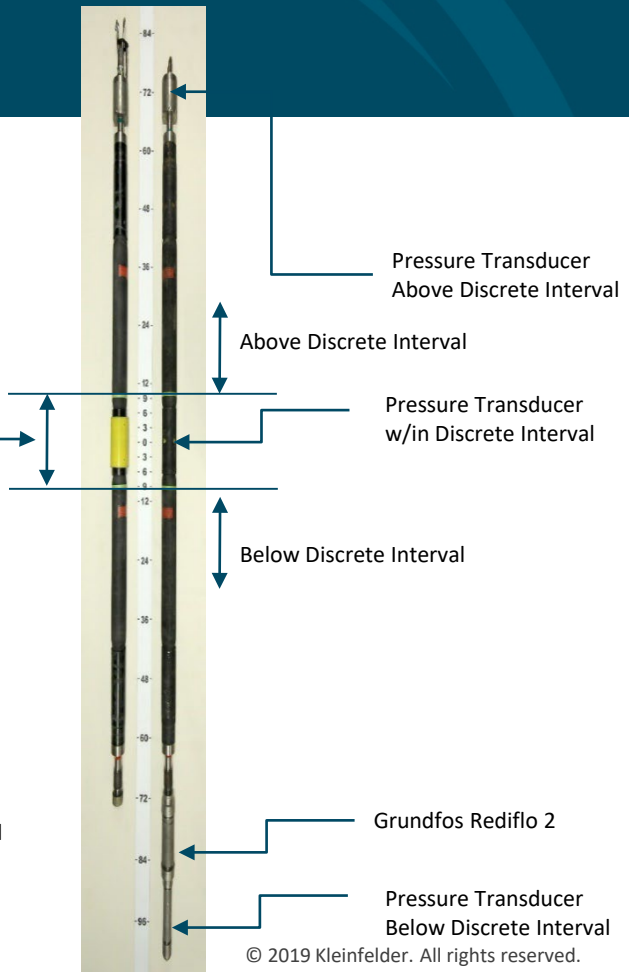
Data used to select packer testing intervals



High Density CSM – Bedrock Tools

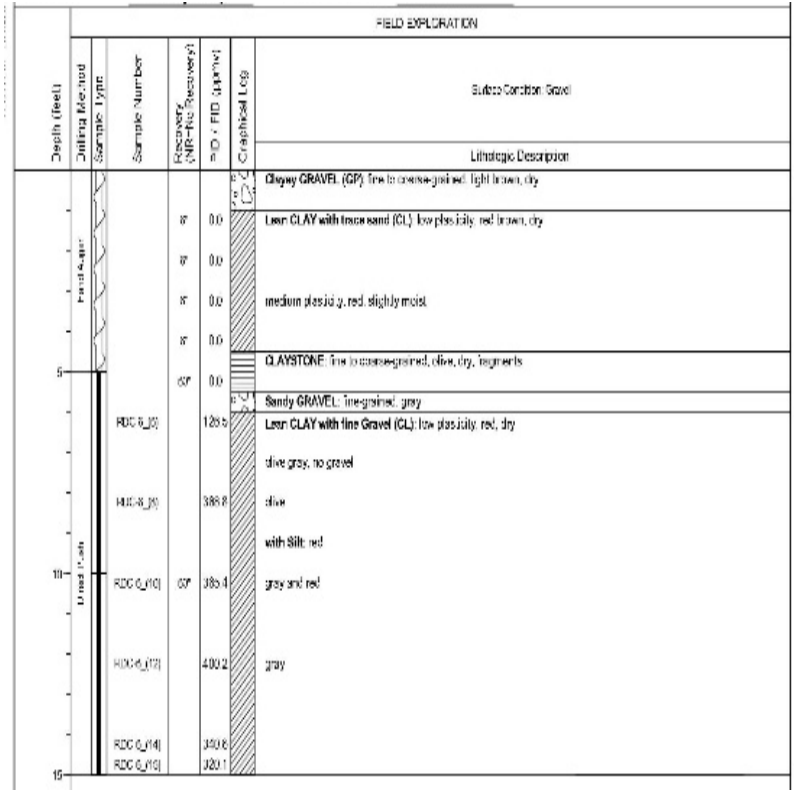
Groundwater Characterization

- Custom straddle packer
- Pressure transducers in pumping well and surrounding monitoring well network
- Discrete interval analytical sampling



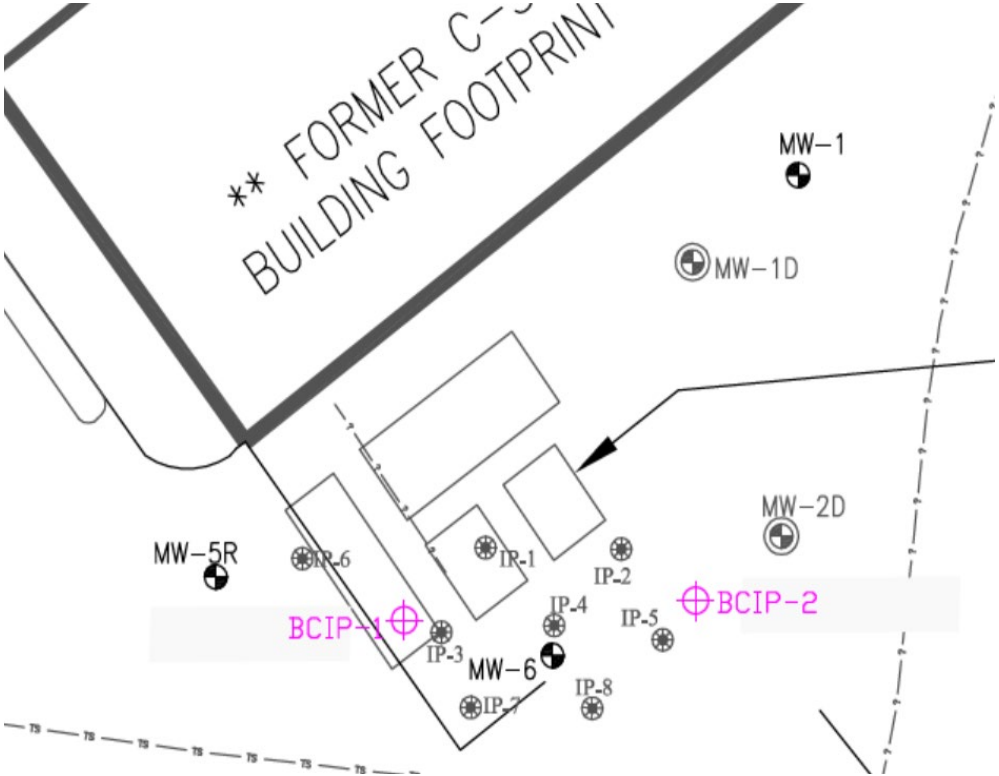
Post- RDC Conceptual Site Model Updates

- Direct push refusal 12 – 19 feet below grade whereas previous logs indicated shallow bedrock
- Impacted soils at 8 – 12 feet below grade and below remedial excavation
- No groundwater above direct push refusal
- Upward vertical fluid flow
- Groundwater results from packer testing < GCLs



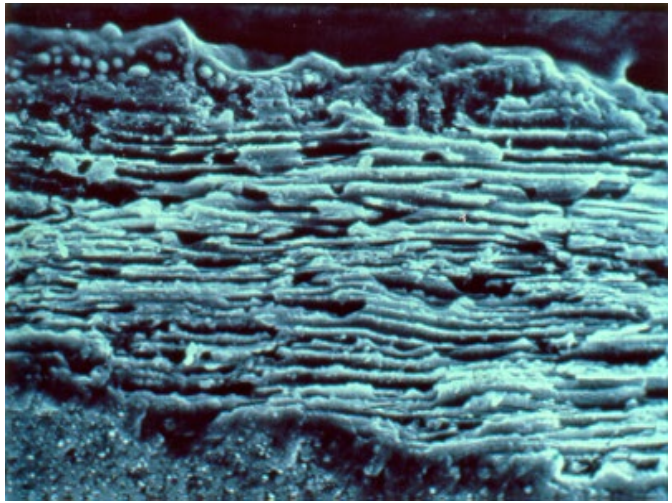
Final Design

- Confirmed selection of BOS 200® for pilot test
- Pilot test switch from bedrock application to transition zone (saprolite)
- Target injection depths less than 20 feet below grade
- Determined need for alternative delivery technique



Activated Carbon Injectate – BOS 200®

- BOS 200® - Accelerates biodegradation of various organic compounds on an activated carbon platform that includes:
  - Micro and macro nutrients
  - Time release of terminal electron acceptors
  - Blend of facultative organisms => key to efficiency
  - Designed to flourish within the aerobic to anaerobic conditions present in the pore structure of the carbon.
  - Primarily used to treat **petroleum hydrocarbons**



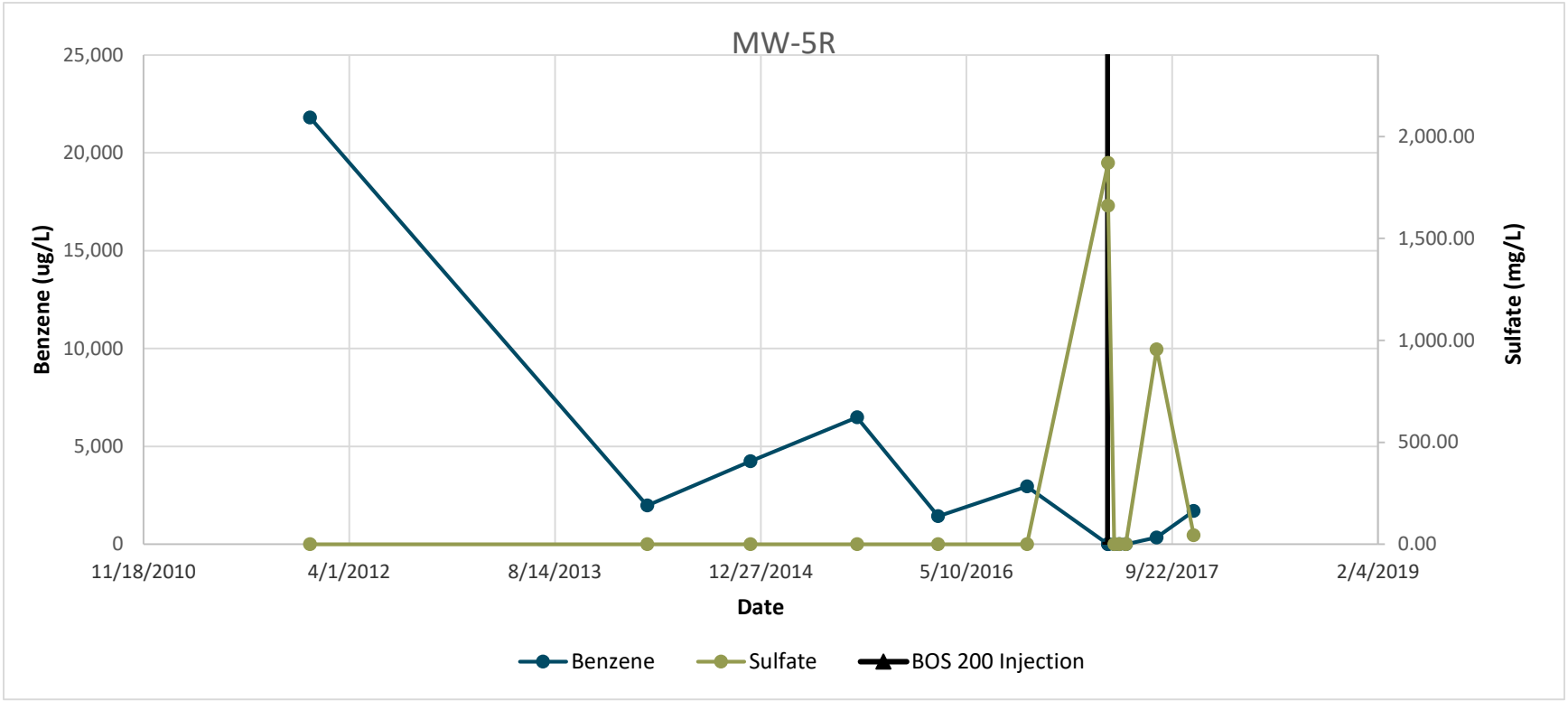
Pre-Drill Injection Technique

- Pre-Drill Injections
  - Useful for sites where DPT (by itself) cannot be used due to refusal, natural or manmade
  - Pre-drill using augers, air rotary or sonic to total depth, backfill with bentonite, and then direct push through bentonite
  - Injection fluid cuts though bentonite and into formation at target intervals
  - ~30 or sites or so completed to date
    - Application to 150 ft @ DOD site in SC currently
    - https://www.dvidshub.net/news/314382/cleaning-up-shaws-water

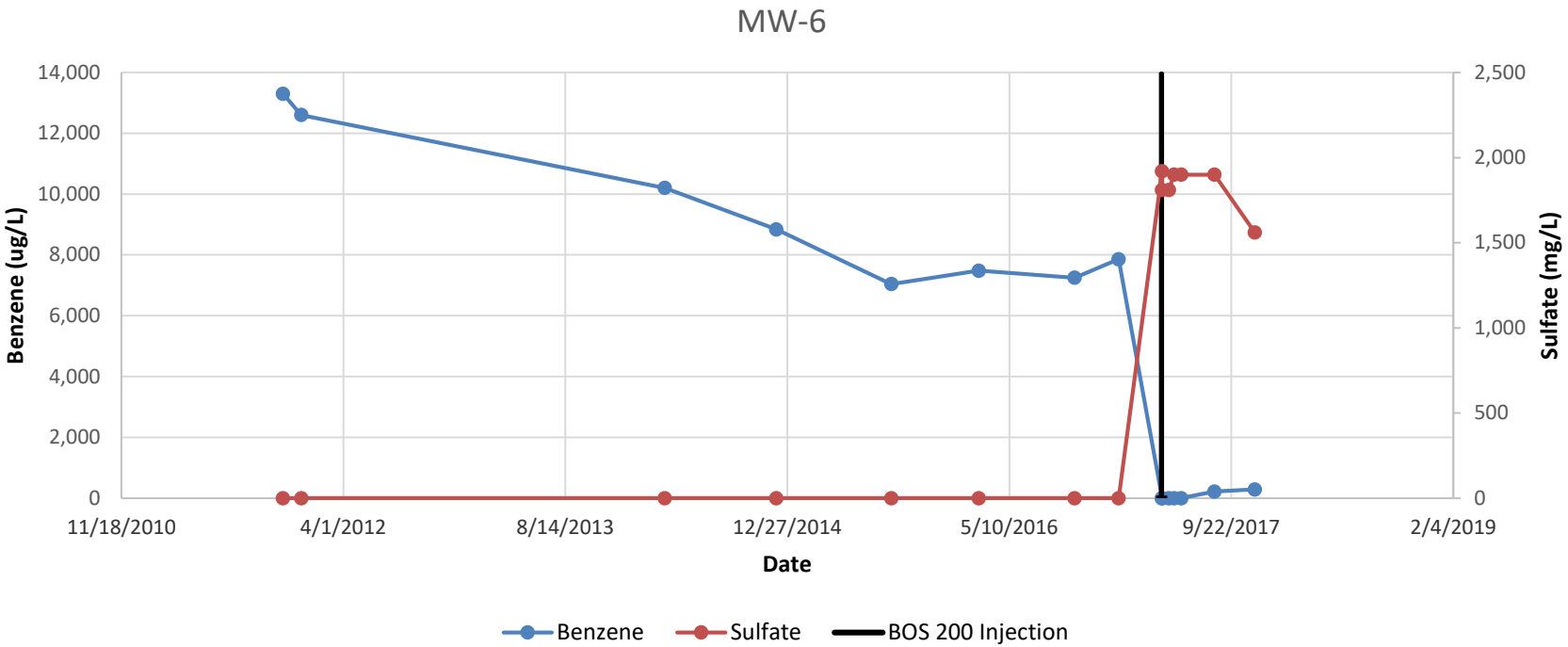
Activated Carbon Injection

- 8 injection points on 7.5-foot triangular centers
- Each location pre-drilled using HSA / air rotary to competent bedrock
- DPT delivery @ 120 – 440 psi
- 1,400 lbs BOS 200® (20 gallons per injection interval)
- 500 lbs Supplemental Gypsum
- 5-gallons Bacteria Concentrate

Groundwater Monitoring Results – Outside Treatment Area



Groundwater Monitoring Results – Treatment Area



Return on Investigation

Systematic remedial design characterization with high resolution data resulted in:

- Refinement of the CSM
- Development of a focused pilot testing plan
- Identification that alternative injection technique was necessary
- Pilot scale injection resulted in Notice of No Further Action
- 18-months from engagement to NFA