
# *Overburden and Bedrock Remediation Using Activated Carbon Based Injectates*

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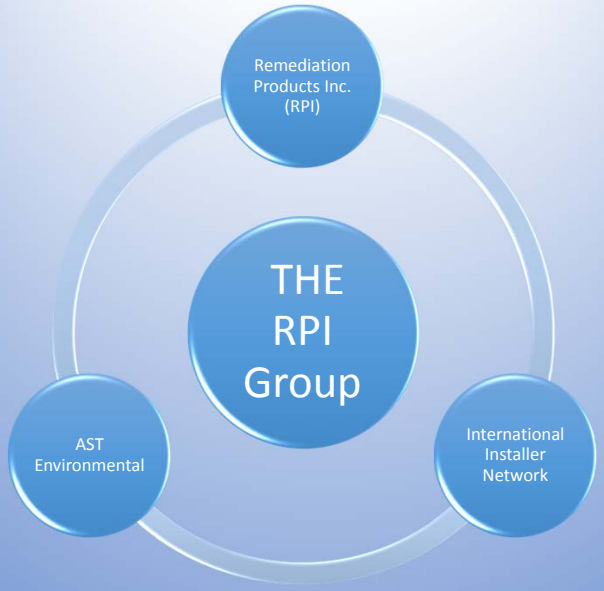


# "Trap and Treat" Concept

- Contaminants sorb to activated carbon "trap"
  - Decreases groundwater mass immediately
  - Disrupts groundwater/soil mass equilibrium to help drive desorption
  - Concentrated mass accelerates degradation rates
- Various degradation mechanisms are used to "treat"
  - Bioremediation (aerobic/anaerobic)
  - Chemical reduction/oxidation



# Technology Specifics

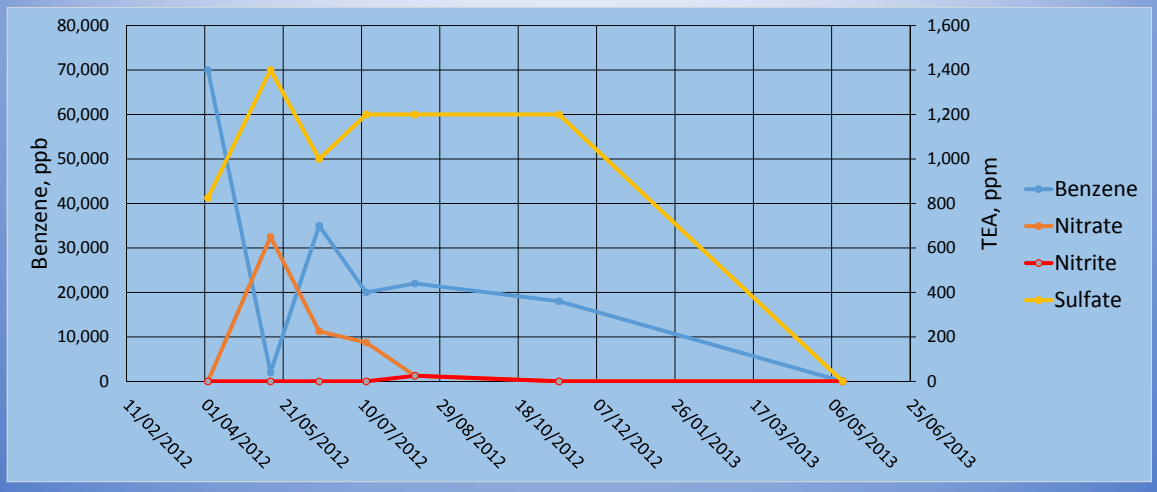
- BOS 100®
  - Specially manufactured activated carbon impregnated with metallic iron
  - Primarily used to treat chlorinated solvents (ethenes, ethanes, methanes) via beta elimination
- BOS 200®
  - Primarily used to treat petroleum hydrocarbons
  - Product consists of:
    - Activated Carbon
    - Terminal electron acceptors
    - Micro and macro nutrients
    - Consortium of facultative bacteria

# Evidence for "Treat"

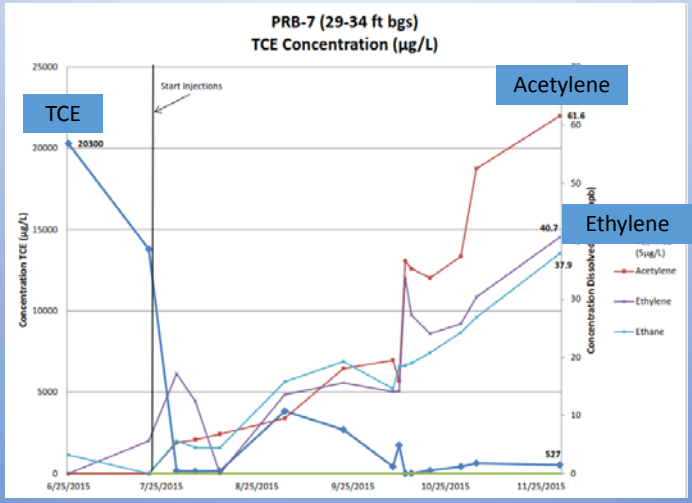
- BOS 100®
  - Dissolved Gases (e.g. ethane, ethylene, acetylene)
  - Chloride generation
- BOS 200®
  - Terminal electron acceptor depletion (e.g. $NO_3$ => $NO_2$)
  - Volatile fatty acid generation (e.g. acetate)
- Both
  - Total mass reduction (groundwater + soil)



# Terminal Electron Acceptor Depletion



# Dissolved Gas Generation





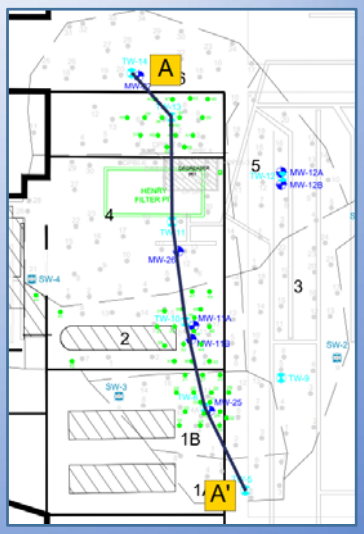

# A Few Comments Before We Continue…….

- Remediation chemistries work in a beaker/column – so why so many failures?
  - Loading/Dosing
    - Contaminant mass distribution is complex and scales with the heterogeneity of the lithology
    - Soil mass contribution is typically underestimated (90/10 ratio observed)
  - Contact
    - We all know contact is critical to success
    - Assess distribution to confirm design spacing/injection volumes

# Remedial Design Characterization (RDC)

| | A (North) | | | | | A' (South) |
|---|---|---|---|---|---|---|
| Depth below grade (ft) | TW-14 | TW-13 | TW-11 | TW-10 | TW-6 | TW-5 |
| 0 | 51 | 87 | 63 | 69 | 2,862 | 414 |
| 1 | | | | | | |
| 2 | 106 | 85 | 58 | | | 841 |
| 3 | | | | | | |
| 4 | 159 | 2,430 | 841 | 612 | 1,247 | 3,710 |
| 5 | | | | | | |
| 6 | 1,570 | 7,195 | 183 | 3,068 | 887 | 3,277 |
| 7 | | | | | | |
| 8 | 2,220 | 16 | 1,560 | 1,180 | 1,789 | 1,973 |
| 9 | | | | | 5,433 | |
| 10 | 4,191 | 60 | 29 | 18 | 50 | 37 |
| 11 | | | | 245 | | |
| 12 | 3,160 | 191 | 80 | Refusal | Refusal | 16 |
| 13 | | | | | | Refusal |
| 14 | 2,515 | 42 | 116 | | | |
| 15 | | 455 | | | | |
| 16 | Refusal | Refusal | 245 | | | |
| 17 | | | Refusal | | | |

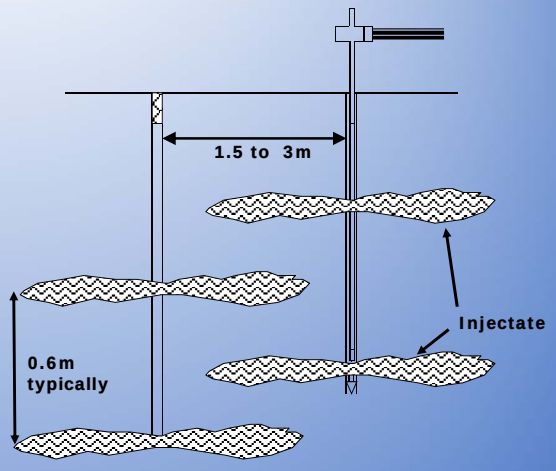
Notes:
Values are summation of PCE, TCE, cis-1,2 DCE and VC in ug/kg
Data generated by RPI Laboratory (Golden, CO)






# Slurry Application Best Practices

- Proper equipment and field staff
- Develop high resolution (surgical) injection plan
- Assess distribution during pilot test or full scale startup
  - Use implants or nested temp wells and soil coring
- Be prepared to alter spacing, injection volumes, injection tip geometry, etc.
- Top-down critical to success



# Bedrock Applications

- Portfolio of bedrock applications growing
- Characterization (geophysics) critical to success
- Proper packer and pumping system selection will help minimize # of injection wells

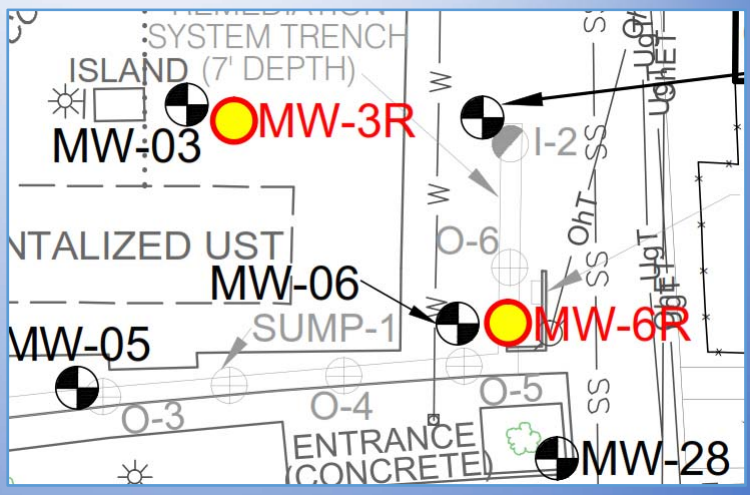



# Monitoring Well Impacts

- Monitoring wells may be intersected by carbon injectates
- Methodologies in place to minimize injection effects and rehab wells
- Some wells may need to be replaced

# Replacement Wells

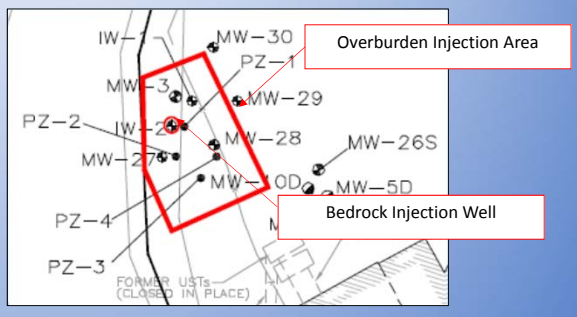
| | Benzene | | |
|---|---|---|---|
| MW Pairs | Baseline (ppb) | Last Sampling Event (ppb) | % Reduction |
| MW-3 | 4,260 | ND | 100% |
| MW-3R | | 96 | 98% |
| MW-6 | 441 | ND | 100% |
| MW-6R | | 41 | 91% |






# Project Summary #1

- Former Retail Gas Station
- Impacted groundwater within fractured bedrock (schist) and overburden soil
- Shallow bedrock ~ 3 m bgs
- The initial objective was to evaluate the performance of BOS 200® injections in bedrock
- Overburden injections followed in 2nd mobilization
- Groundwater concentration targets:
  - B = 510 ug/L
  - T = 110 ug/L
  - E = 970 ug/L
  - X = 6,700 ug/L



# Remedial Design Characterization - Bedrock

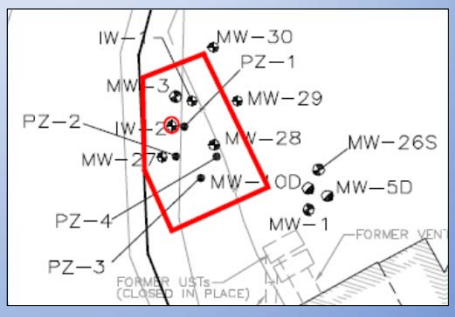
- Open rock borehole (IW-2) installed for characterization and injection
  - Down hole video logging used to identify fractures (6)
  - Clean water pump tests performed at all fractures
    - Determine ability of features to accept fluid and design volumes
    - Samples collected from transmissive zones (4)
    - Transducers placed in nearby wells to assess connectivity
      - Influence observed at all wells within test area (farthest 8 m) with minimal influence in overburden

B @ 4.1 m = 801 ug/L
B @ 4.9 m = 829 ug/L
B @ 6.5 m = 577 ug/L
B @ 6.7 m = 545 ug/L



# Remedial Design Characterization - Overburden

- 4 overburden soil sampling locations selected (sampling every 0.6 m vertically, 1.6-3.5 ft bgs)
  - Locations converted to temporary piezometers
  - Max Benzene in groundwater = 9.89 mg/L (PZ-1)

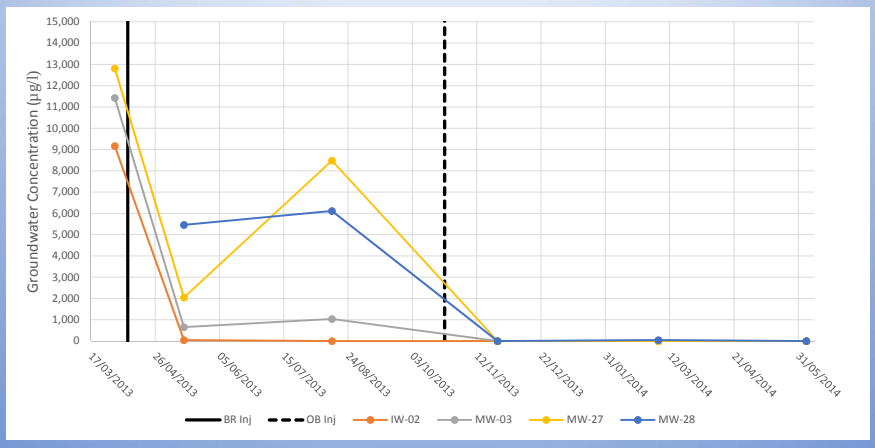


# Implementation

- Bedrock: 1,020 kg BOS 200® (4,320 L)
  - Flow rate = 115-192 lpm
- Overburden: 870 kg BOS 200® injected into 44 pts on 1.6 m spacing (5,900 L)
  - Site divided into two treatment areas based on RDC soil/gw data
  - Injection Zone = 1.6-3.5 m bgs
  - Flow rate = 115-134 lpm

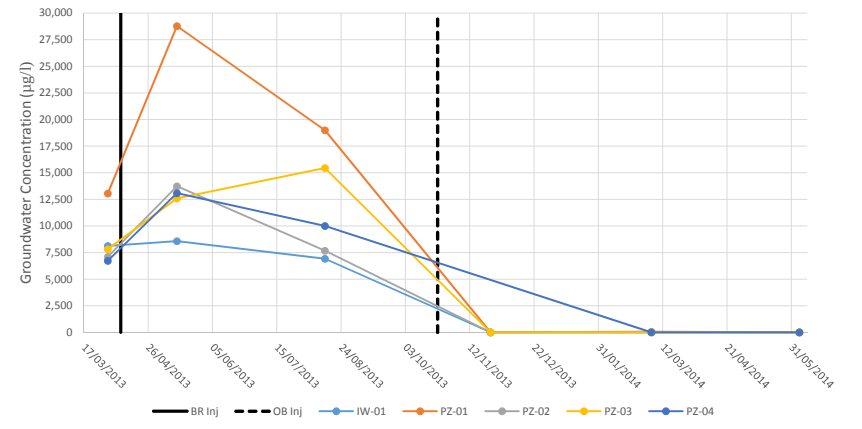


# Bedrock/Transition Well Data




BTEX + MTBE Data

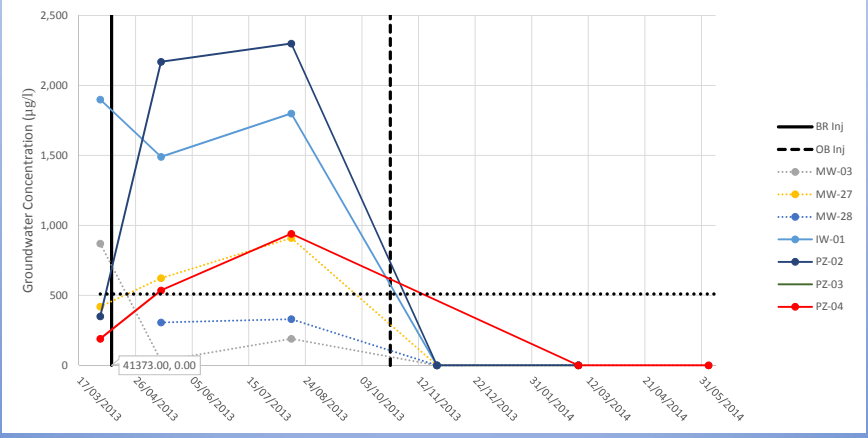
# Overburden Well Data




BTEX + MTBE Data

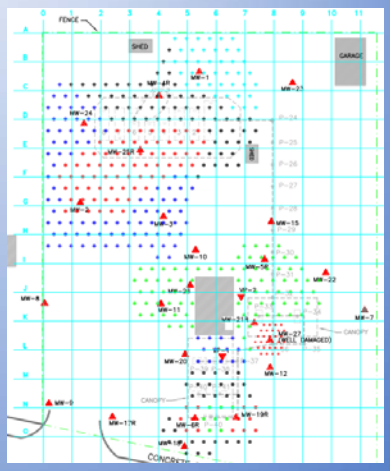


# Benzene Only Data



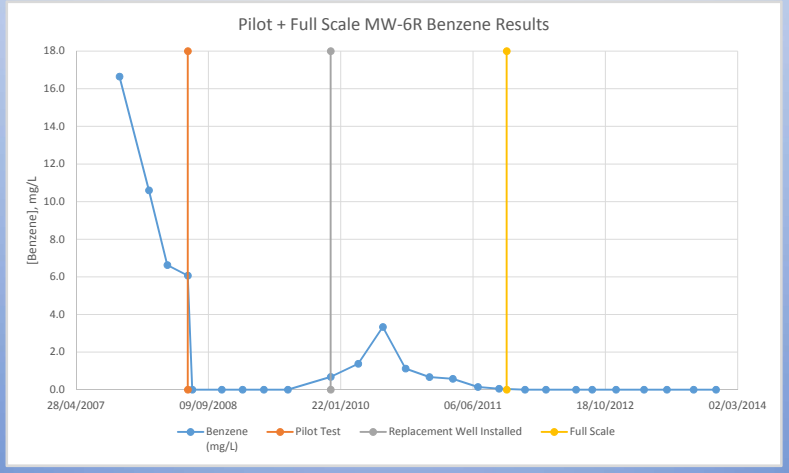
# Project Summary #2

- Former bulk storage facility
- Extensive excavation (performed by others)
- BOS 200® pilot test performed 2008
- Remedial Design Characterization and Full Scale performed 2011/early 2012
- NFA granted after 8 quarters
  - Post injection soil sampling completed to compare against RDC data

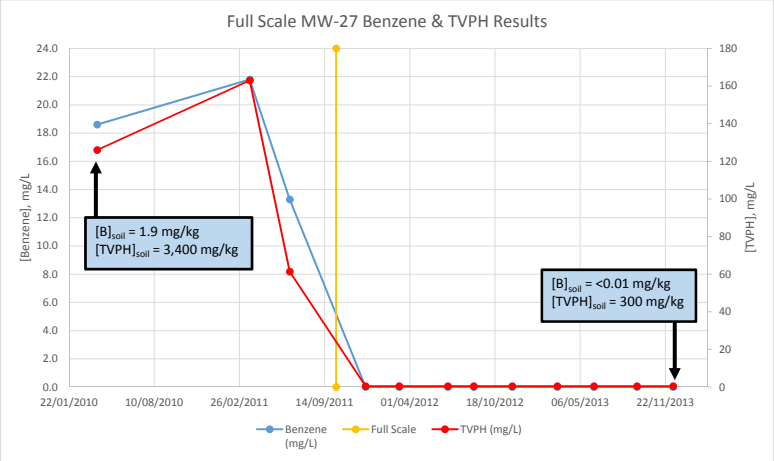




# Pilot Test + Full Scale Data



# Pre and Post Injection Soil Sample Data






# Technology Adoption

**Consultants**

- AECOM/URS
- Kleinfelder
- AMEC FW
- Stantec
- Antea
- CH2M
- Parsons
- Weston
- Arcadis
- ERM
- +Others

**Responsible Parties**

- Exxon Mobil
- BP
- Shell
- Chevron
- 7-11
- Conoco-Phillips
- CSX
- GE
- Noble Energy
- DOD/DOE
- +Others

Thank you for your time.

Questions?