quantitative High Resolution Site Characterization (*q*HRSC) to Support Petroleum Remediation in Piedmont Geology

Nathan Thacker

Senior Geologist

Harrisonburg, VA

AST ENVIRONMENTAL, INC.

NORTH CAROLINA Environmental Quality

ATLAS ATC ASSOCIATES OF NORTH CAROLINA, P.C.

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UST Project – Southeast US

Former service station operating from 1950's through 1981; 2003 nearby water supply well impacted; 2006 USTs and 150 tons of soil removed

Additional soil removal: 2010 (690 tons); 2018 (270 tons)

Municipal water not available. Eight private drinking water supply wells with gasoline compounds, up to 900 feet from the source area.

Multiple rounds of groundwater assessment. No LNAPL in monitoring wells. Benzene and 1,2-DCA exceeding GCLs.

What is qHRSC?

- Quantitative High Resolution Site Characterization: soil and groundwater sampling
- Identify zones of residual contaminant mass in soil and groundwater (data gaps) not identified using typical site characterization sampling practices
- Provides a 3-D quantitative data model for project decisions, setting client expectations, and developing cost-effective remedial approaches

qHRSC Components

- Review historical data and data gap identification
- Remedial Design Characterization (RDC)
  - High density sampling and laboratory data
  - Lithological logging
  - HRSC (if appropriate)
- 3-D Quantitative CSM
- 3-D Remedial Design

1) Historical data review and data gap identification

- Collaborative
  existing soil/gr
  quality data ar
  geological/hyd
  data
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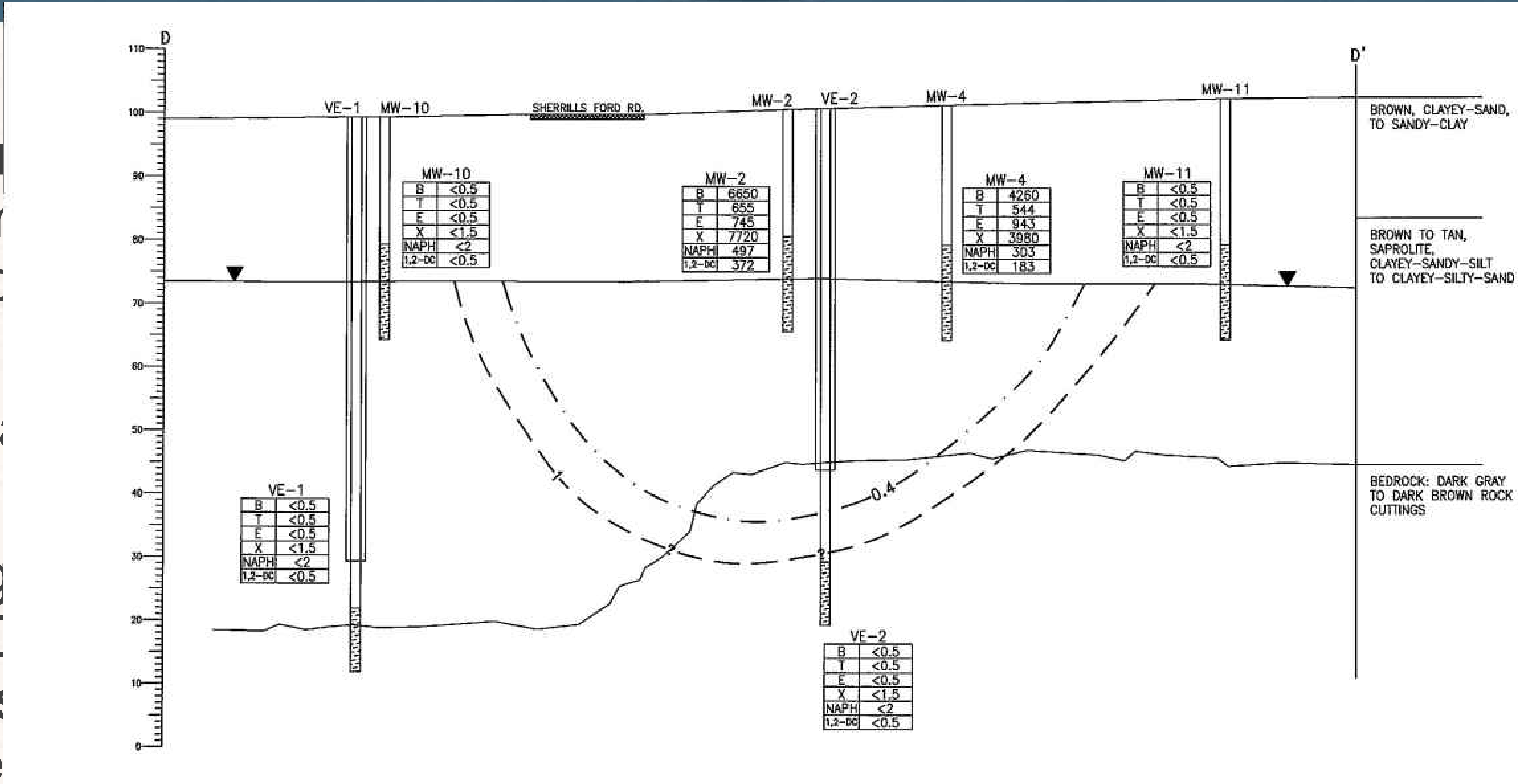
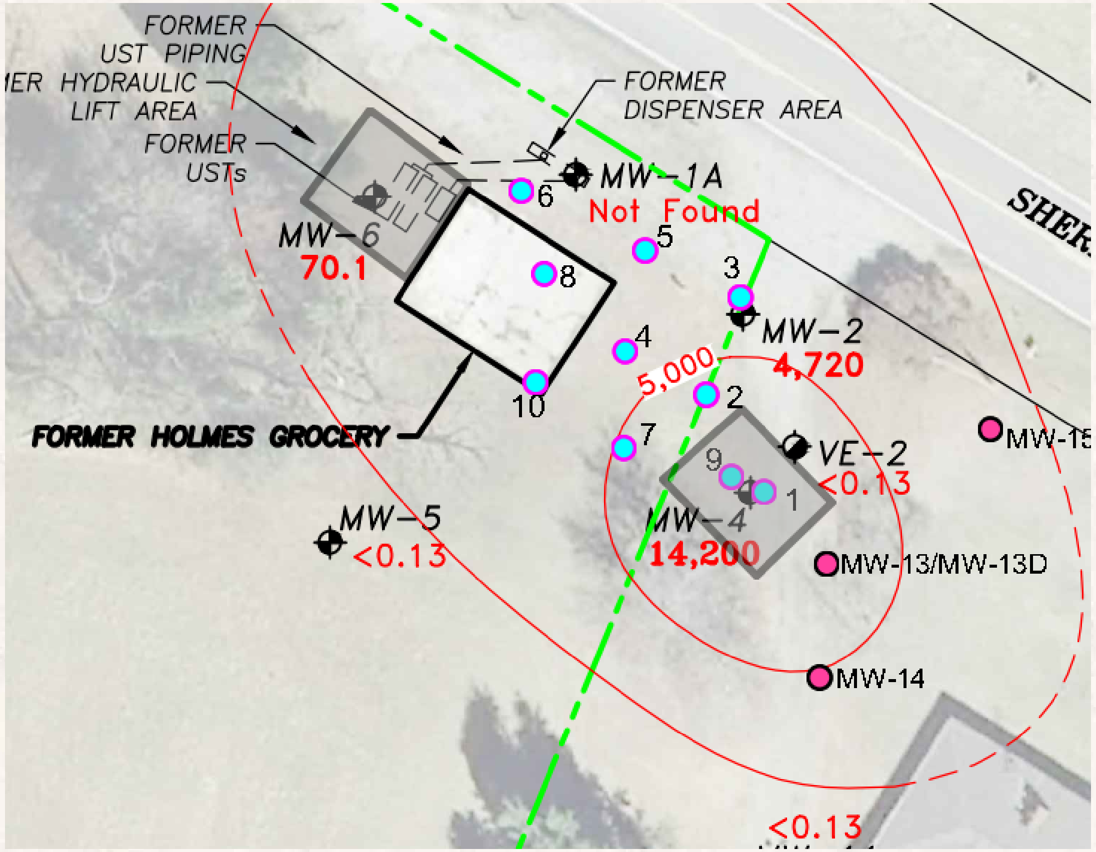
- Identify data g
  HRSC and RD
  be used to cos
  update and re



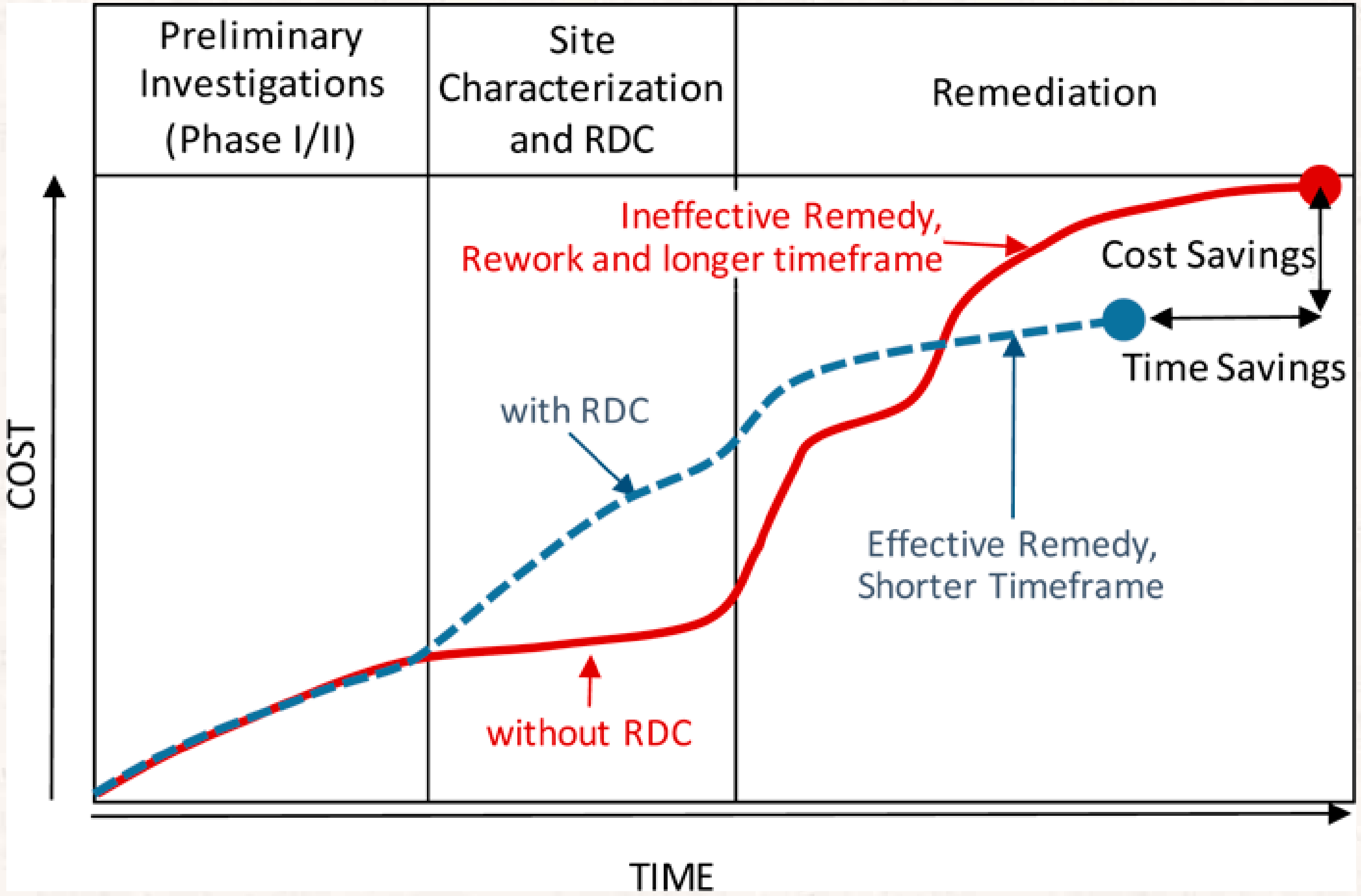
2) Remedial Design Characterization (RDC)

- High Density (areally and vertically) sampling of soil and groundwater to quantify (and speciate) contaminant mass and lithological variations
- Dense soil (typ. 1-2 ft) and groundwater sampling
- Establish expectations with respect to time, budget, and remediation endpoint(s)
- RPI Project Support Lab (Denver) - soil and groundwater analytical testing for Remedial Design (BOS 200)



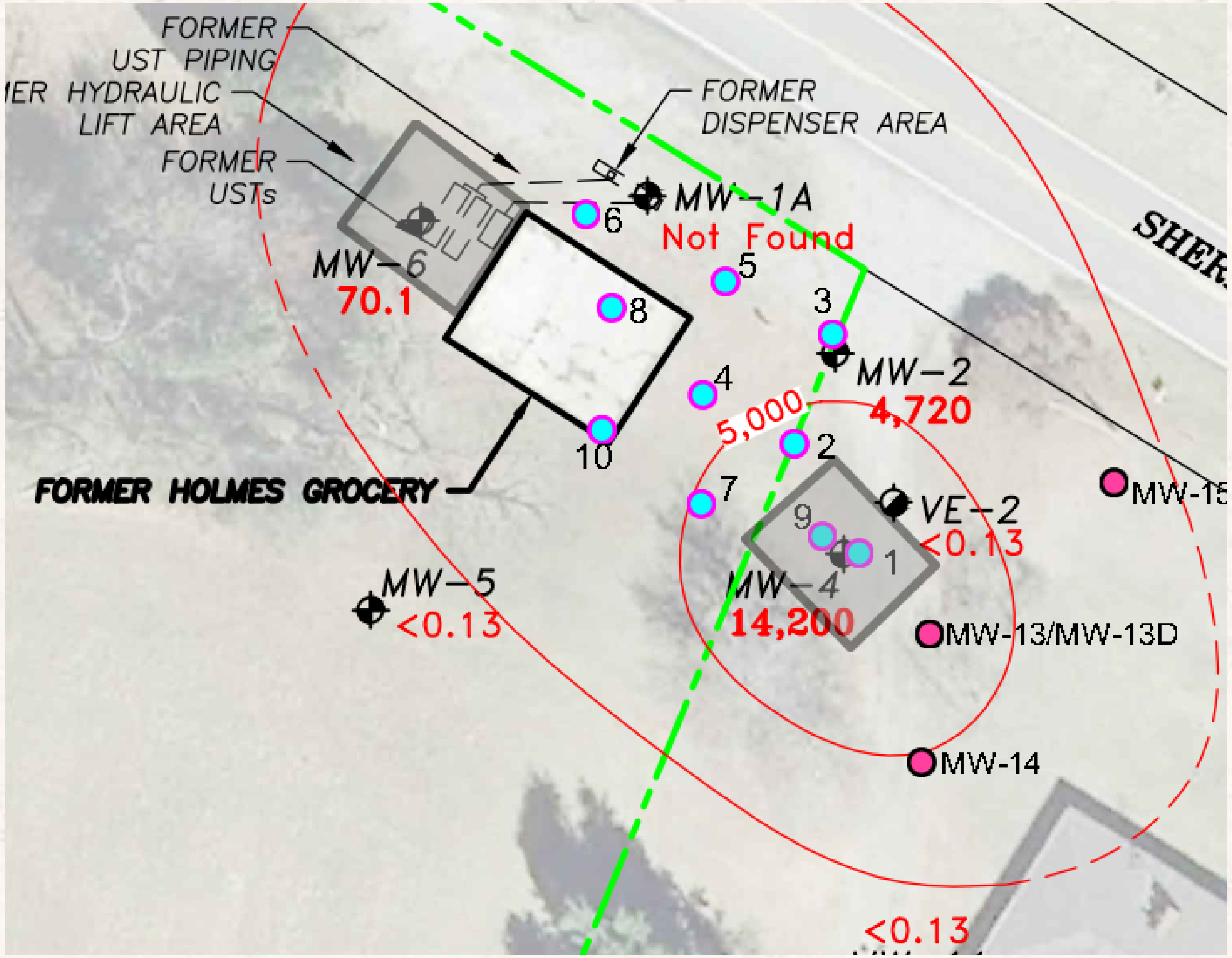
RDC and Long-Term Remedial Cost

- Project time and cost savings (in most situations)
- Avoid the land mines (e.g. unknown or unidentified source areas
- Manage expectations
- Combine remedies
- Sampling a fraction ($) of HRSC surveys and overall project cost



Source: Optimizing Injection Strategies and In-situ Remediation Performance

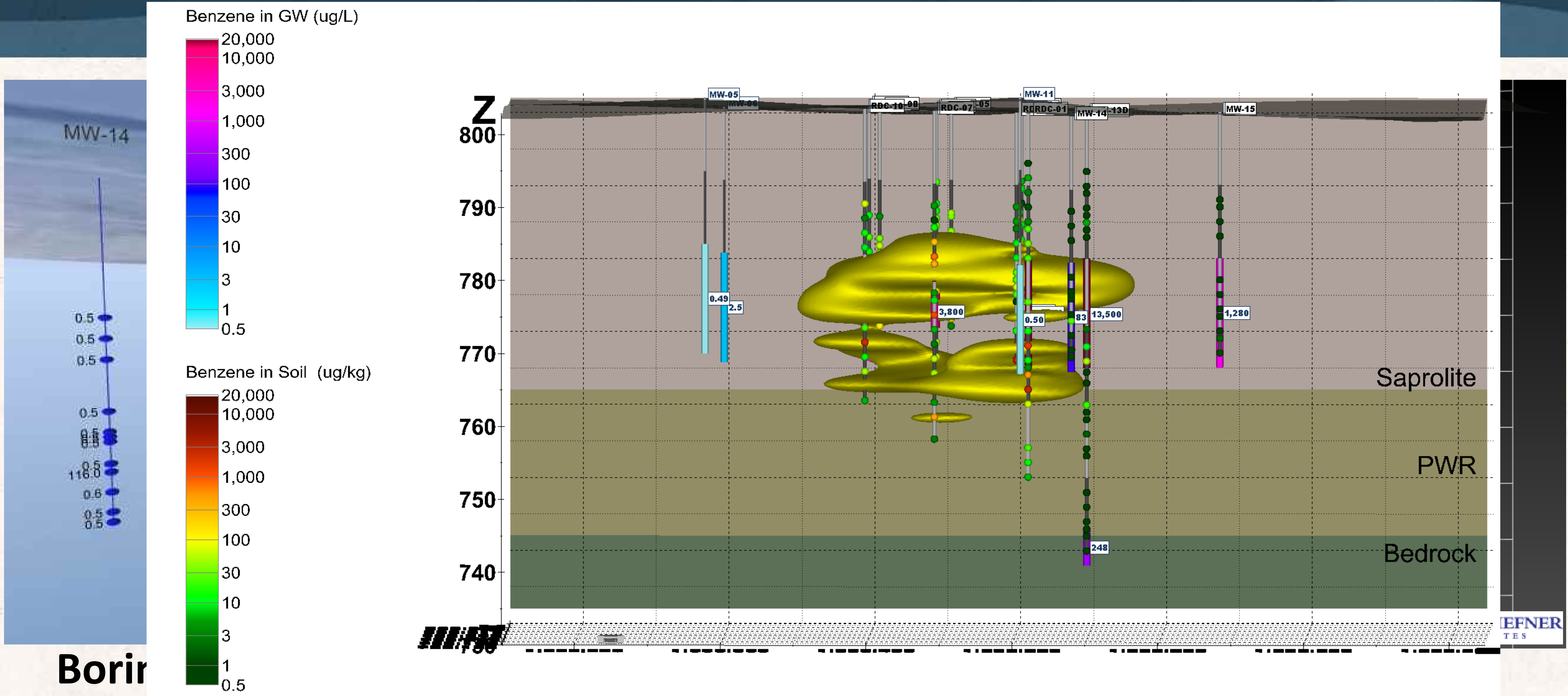
Remedial Design Characterization



Two RDC events conducted between 2018 and 2019

- 13 borings (direct push and Sonic)
- 11 temporary and 4 permanent wells
- Lithology
  - Saprolite: 0 to 40 ft-bgs
  - Partially Weathered Rock: 40 to 60 ft-bgs
  - Bedrock: 60+ ft-bgs
- Significant saturated soil impacts
- Residual high angle fractures

Remedial Design Characterization



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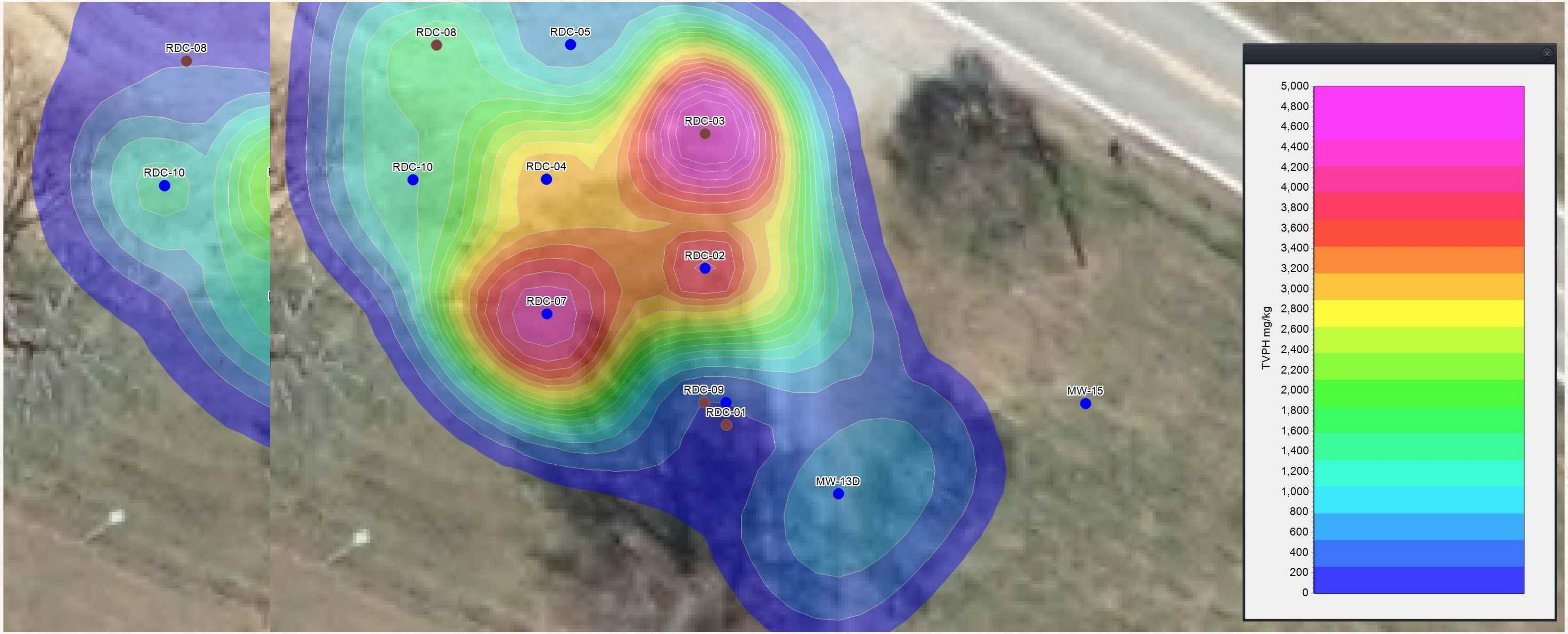
3-D Remedial Design Model

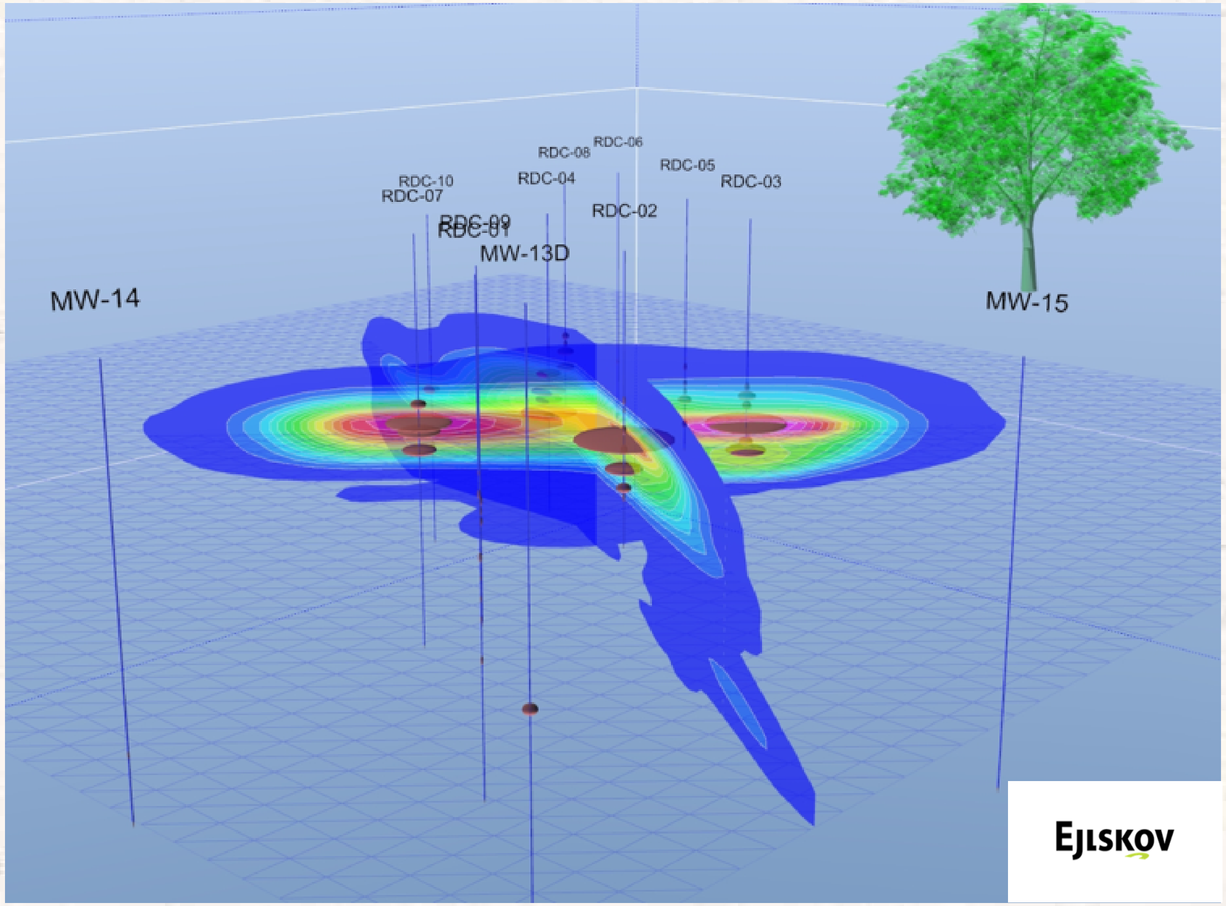


2.) Remedial Design Characterization (RDC)

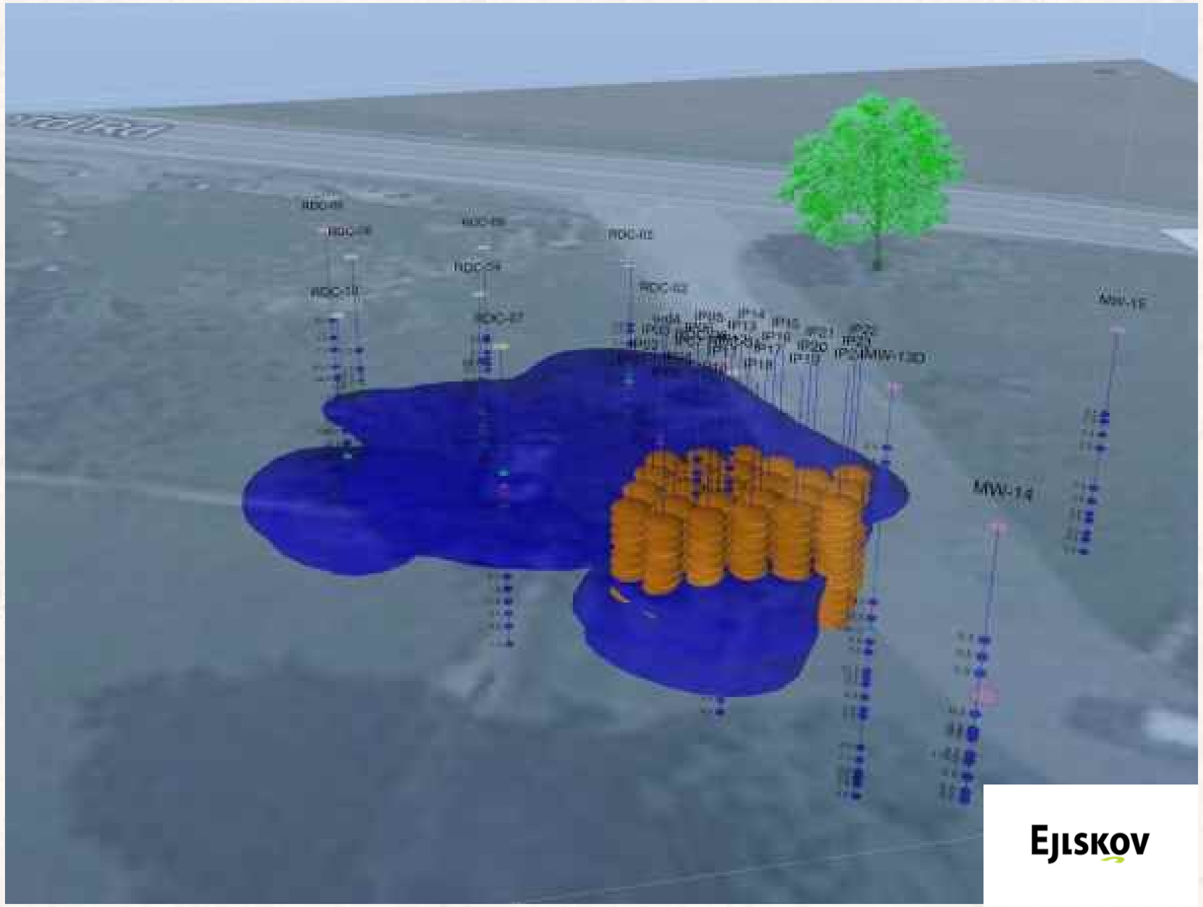
HRSC Data Integration

- Where appropriate, HRSC tools may be integrated into the qHRSC program. The HRSC screening tools provide qualitative data that may help guide and optimize RDC sample location selection
- Be aware of what these HRSC tools tell you, and what they do not
  - e.g. MIP provides a qualitative to semi-quantitative data set (μV), does not speciate, and does not discern phase
- Don’t use confirmation samples to correlate
  - Per ITRC “Lithology, saturation, the presence of multiple compounds, and other factors make direct correlation of MIP response to compound concentrations problematic.”

3-D Remedial Design Model

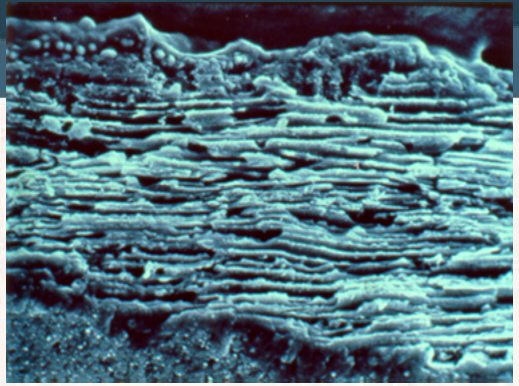


qHRSC 3D - Contaminant Mass



Remedial Design – BOS 200 Injection

BOS 200® Technology Overview & Chemistry



5 grams of carbon has an internal surface area equivalent to the surface of a professional football field

"Trap and Treat" Mechanism

- Contaminants sorb to activated carbon "**Trap**"
  - Decreases dissolved mass immediately
  - Increases desorption from source
- Aerobic and anaerobic biological degradation to "**Treat**" contaminant mass

BOS 200® - Accelerates biodegradation of various organic compounds on an activated carbon platform that includes:

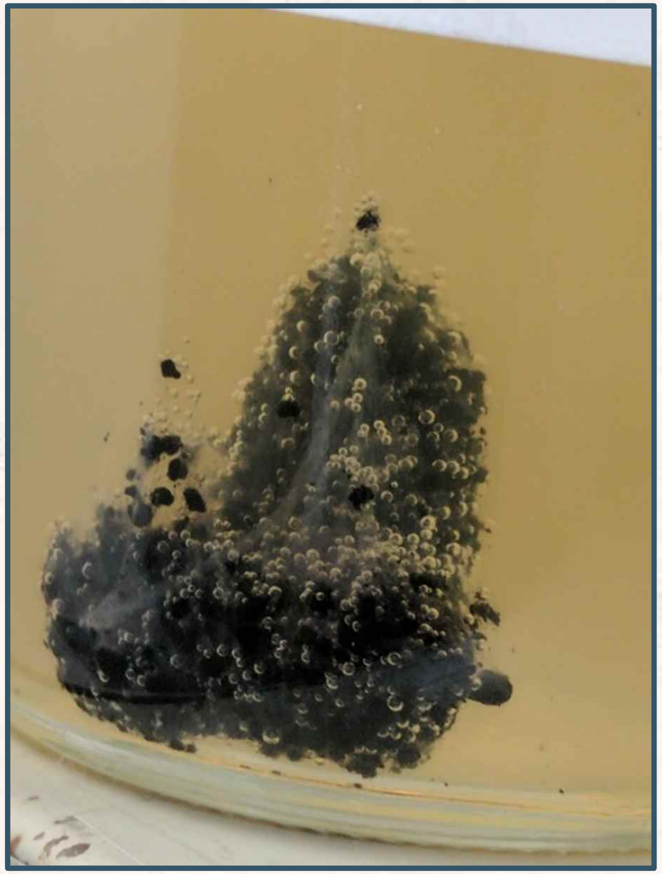
- Micro and macro nutrients
- Slow-release TEAs critical for Benzene degradation
  - **Nitrate** – Short-term (1 to 2 months)
  - **Sulfate** – Long-term (6 to 12 months)
- Blend of facultative organisms => key to efficiency
- Primarily used to treat **petroleum hydrocarbons**

BOS 200+®: BOS 200® with electron donor (food grade starch, yeast extract, bacteria)

Evidence for Treatment

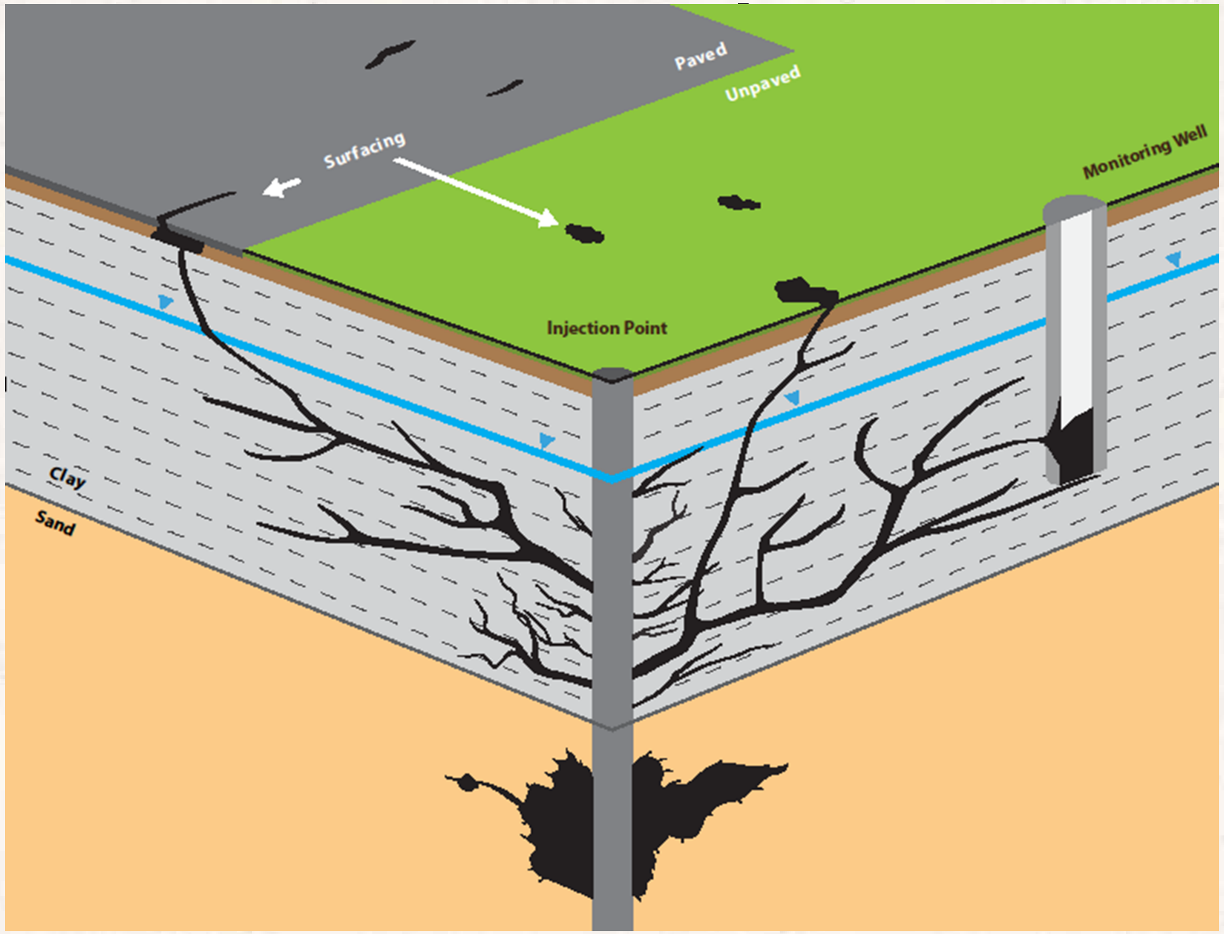
"**Trap**" is understood……evidence for "**Treat**"?

- Total mass reduction (groundwater + soil)
- Terminal electron acceptor depletion (e.g. NO_3 => NO_2, SO_4
- Dissolved gas generation
- Microbial Diagnostics
- Laboratory mass balance experiments



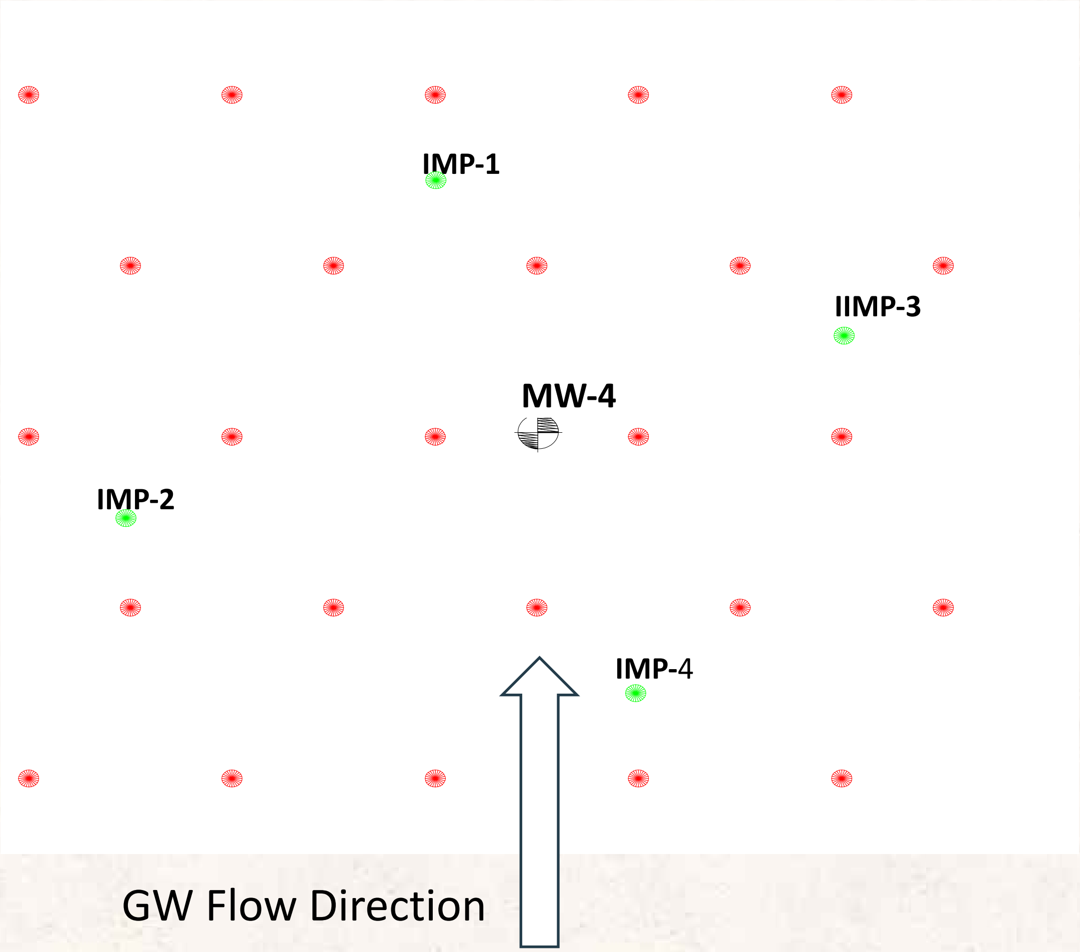
Slurry Application Best Practices

- Proper equipment/contractor
- Develop high resolution injection plan
- Be realistic with injection point spacing
- Assess distribution during pilot test or full-scale startup
  - Use implants or nested temp wells
- Top-down critical to success



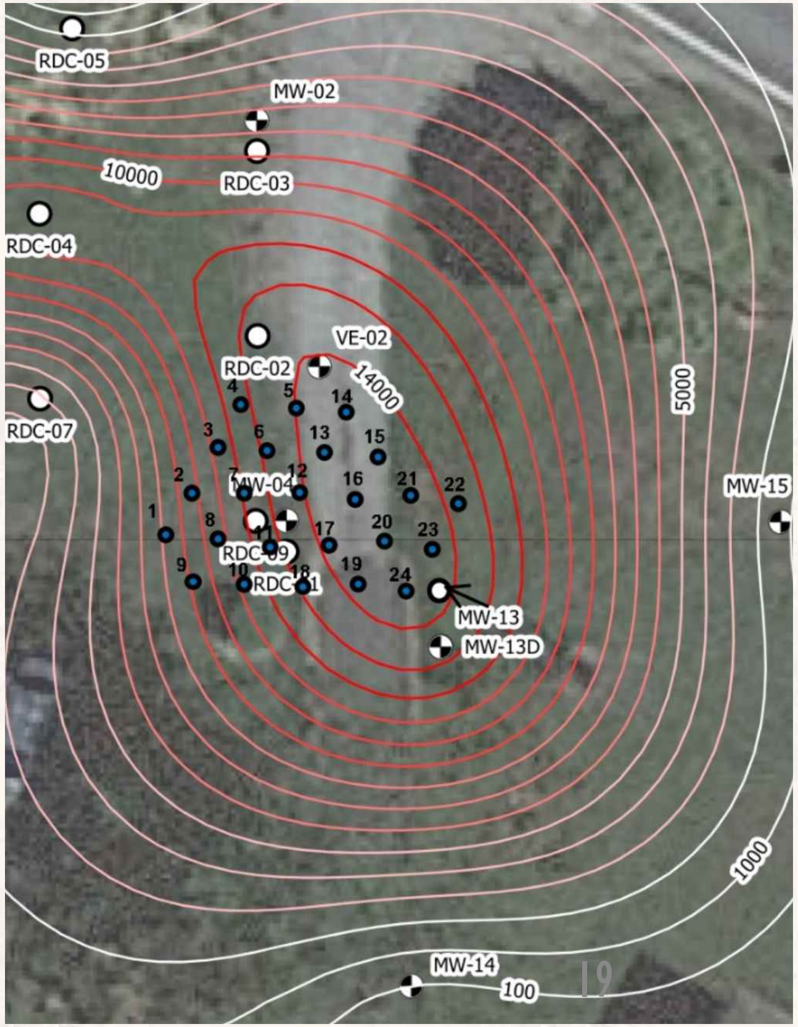
Grid Based Design

- Triangular grid pattern
- Spacing = function of depth and lithology
- Spacing is tight, typically ranges from 5-ft to 10-ft (1.5-m to 3.1-m)
- Off-set intervals (interleaving)

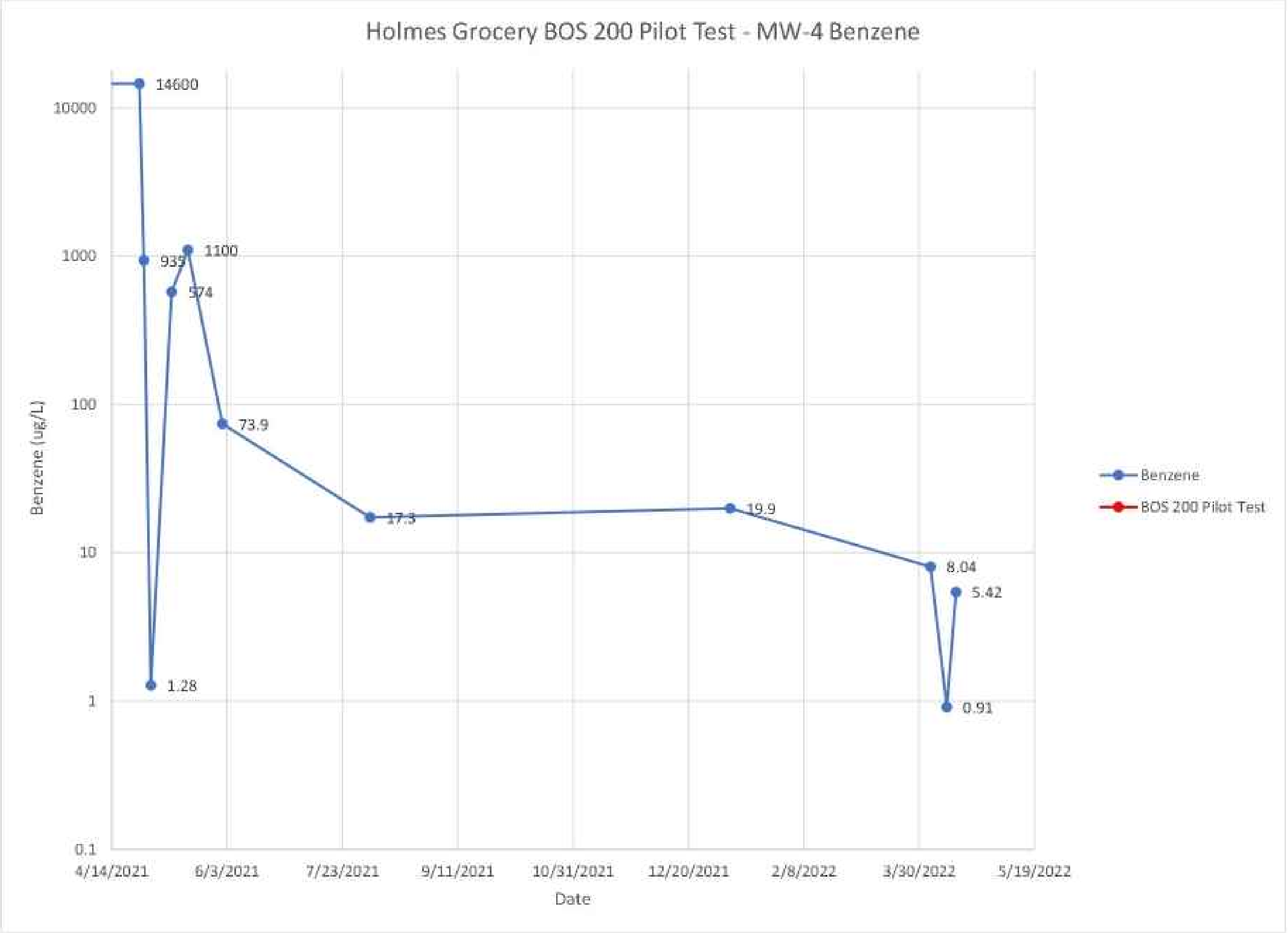


Pilot Test Area – Show maps of RDC soil data

- Pilot Test BOS 200+ (4/27/21-5/1/21):
  - 24 injection points, 5-foot centers, off-set
  - 500 square foot area
  - 18 to 36 feet injection depth (groundwater surface to “refusal” depths
  - 18,800 pounds of BOS 200+ including amendments
  - 9,000 cubic feet treatment volume



BOS 200$^+$ Injection Results



>99% reduction after 100 days, maintained after 354 days

Return on Investigation

Systematic remedial design characterization with high resolution data resulted in:

- Refinement of the CSM
- Development and implementation of a focused BOS 200+ pilot test, with positive results in reduction of dissolved contaminant concentrations
- Implementation of a full scale injection

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