No Further Action: A Case Study on High Resolution Site Characterization and Bioremediation in a Fractured Bedrock Setting

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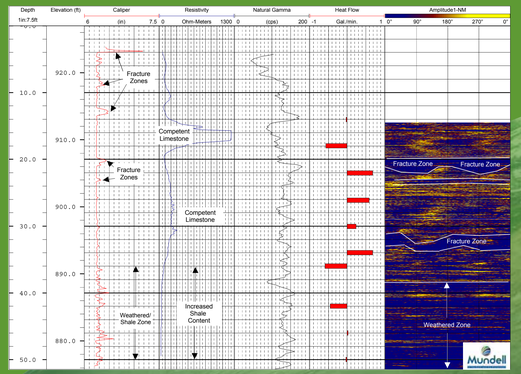
Background

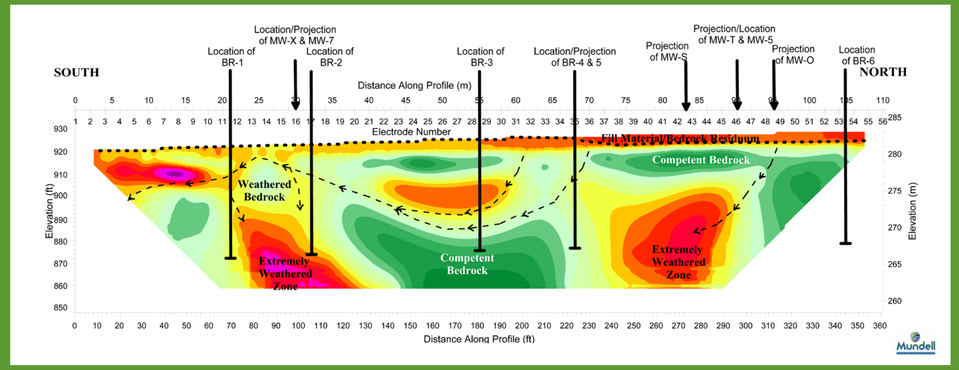
- The subsurface lithology at the site consists of Upper Ordovician Calloway Creek Limestone, Garrard Siltstone, and Clays Ferry Formation. Monitoring wells at the site were installed with screened intervals varying from 10 feet to 40 feet in length, and screened across multiple formations.
- Groundwater samples collected from nested wells indicated the presence of free phase and dissolved benzene in both the shallow and deep wells at various locations throughout the plume.

Remedial Design Characterization

- A 2-dimensional electrical resistivity imaging survey (2-D ERI) was performed to identify weathered zones where the characterization/injection points were installed.
- Borehole geophysical logging consisting of three arm caliper, natural gamma ray, electromagnetic resistivity, acoustic televiewer, and down-hole camera were used to delineate the vertical extent, orientation, and aperture size of the bedding planes and fractures that were targeted in the discrete groundwater sampling and injection. The heat pulse flow meter was employed to gain a better understanding of the vertical groundwater gradient controlling the benzene plume.
- Discrete groundwater samples were collected using a specially designed straddle packer configuration of 18 inches between the upper and lower packer to allow for the isolation of the bedding planes/fractures.
- Groundwater samples collected from discrete zones indicate that the contaminant mass is transporting along a bedding plane/fracture zones with low groundwater flow.



Borehole Geophysical Log of BR-5

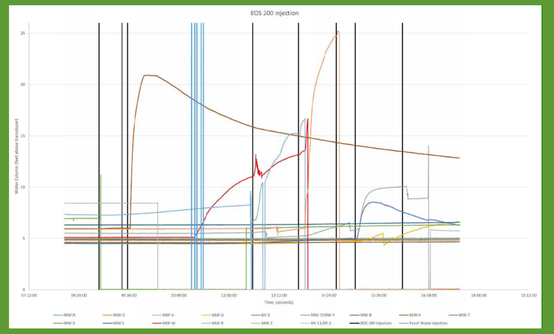


2-D Electrical Resistivity Image

Injection

- Based on the high levels of benzene observed at the site, and the need for long term treatment to control matrix diffusion, BOS 200® was selected as the in-situ technology. The BOS 200® slurry was injected via high pressure/high flow injections using Well Improvement Company's specialized pump and straddle packer system.
- Changes in groundwater levels were continuously monitored with the In-Situ Virtual Hermit system at observation wells throughout the treatment area. Groundwater level response varied from strong, immediate connection indicating direct conduit flow along the same bedding plane, to a delayed, subdued response indicating mixed conduit/diffuse flow between vertical fracture zones and bedding planes.
- All observations of BOS 200® in the wells were first noted during the injection with a substantial spike in the water column. After the injection was completed at each depth, a visual inspection of the well was performed by lowering a bailer to different depths in the well to establish where the connection was being made vertically at the observation well.
- Real time well response aided in optimizing the injection volume and confirmed that uniform distribution of the injection slurry was achieved.

Road cut of the ball-and-pillow structure observed on the 2-D ERI



Groundwater response of all observation wells during injection

Dissolved Benzene Concentration Trend

Well	Date	Benzene (mg/L)
MW-U	1/13/15	<0.0010
	10/16/14	<0.0010
	7/15/14	<0.0010
	5/13/14	<0.0010
	4/1/14	BOS 200 Full Scale Injection
	3/13/14	<0.0010
	7/18/13	0.03
	5/31/13	<0.0010
	5/1/13	BOS 200 Pilot Test
	9/17/12	6.4
	6/29/12	9.3
	9/15/11	3.4

Well	Date	Benzene (mg/L)
MW-W	1/13/15	0.002
	10/16/14	0.002
	7/15/14	<0.0010
	5/13/14	<0.0010
	4/1/14	BOS 200 Full Scale Injection
	3/13/14	0.0036
	7/18/13	1.4
	5/31/13	1.2
	9/17/12	1.2
	6/29/12	1.7
	9/15/11	1.4

Well	Date	Benzene (mg/L)
MW-X	1/13/15	<0.0010
	10/16/14	<0.0010
	7/15/14	<0.0010
	5/13/14	<0.0010
	4/1/14	BOS 200 Full Scale Injection
	3/13/14	0.34
	7/18/13	0.056
	5/31/13	0.27
	9/17/12	0.044
	6/29/12	0.030
	9/15/11	<0.0010

Well	Date	Benzene (mg/L)
MW-O	1/13/15	0.29
	10/16/14	0.25
	7/15/14	0.17
	5/13/14	<0.0010
	4/1/14	BOS 200 Full Scale Injection
	3/13/14	0.39
	7/18/13	0.72
	5/31/13	0.59
	9/17/12	1.7
	6/29/12	1.6
	9/15/11	1.9

Well	Date	Benzene (mg/L)
MW-8	1/13/15	<0.0010
	10/16/14	0.19
	7/15/14	0.038
	5/13/14	0.0049
	4/1/14	BOS 200 Full Scale Injection
	3/13/14	0.038
	7/18/13	0.23
	5/31/13	0.25
	9/17/12	0.34
	6/28/12	0.65
	9/15/11	0.58

Post-Injection Dissolved Benzene Concentrations

Results

- Use of the 2-D ERI to locate weathered zones within the bedrock was essential to the accurate placement of the injection point locations.
- Imagery from the 2-D ERI identified the presence of the ball-and-pillow structure controlling the transport of the benzene plume, which was targeted during the injection events.
- Borehole geophysical data collected from the injection points was critical in the design of the full scale injection, specifically the acoustic and optical televiewers and the heat pulse flow meter, which confirmed the varying vertical hydraulic groundwater flow at the site.
- Data collected from the pressure transducers during the full-scale injection show the area of influence of a 250-gallon injection ranged from 75-200 feet at the deeper injection intervals (deeper than 13 feet) and up to 50 feet in the shallower intervals (less than 10 feet).
- Groundwater data collected post pilot injection confirmed that the targeted monitoring well, with historical benzene concentrations greater than 6 mg/L, remained below target clean-up goals for seven consecutive quarters.
- Groundwater data collected post full scale injection demonstrates target clean-up goals have been achieved in all compliance-monitoring wells for three consecutive quarters.

A No Further Action letter was issued in February 2015.

Straddle packer system used for injection (left) and discrete groundwater sampling (right)

AST ENVIRONMENTAL, INC.

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RPI Group is a consortium of companies who are relentlessly dedicated to site cleanup. That is our mission.