Design, Installation, and Post-Installation Performance Monitoring of a ZVI PRB in a Residential Neighborhood

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A zero valent iron (ZVI) Permeable Reactive Barrier (PRB) was installed to treat VOC-impacted groundwater in a fine grained aquifer. The goal of treatment is to reduce VOC migration into a residential setting where vapor intrusion has affected indoor air quality.

- The PRB was installed using vertical hydraulic fracturing. The PRB is 480 ft long, 33 feet tall (from 15 to 48 ft bgs), and is 3 to 4.5 inches thick of ZVI. This method proved to be ideal for residential construction and beneath existing subsurface utilities.
- Seven of the 8 monitoring wells installed immediately downgradient of the PRB have shown total VOC concentration reductions ranging from 88% to 97%. The remaining well has dropped 36% and concentrations are trending downward.
- The primary contaminant, TCE, has been reduced to below the MCL in 6 of the 8 adjacent downgradient wells.
- This PRB is a great GREEN remediation alternative. It used recycled drill tailings from engine blocks, there are no toxic byproducts in the aquifer, no operation or maintenance requirements, no reinjection of chemicals, no air pollution from pumping systems, no water consumed, and the surface land was fully restored for public use.

The PRB has reduced TVOC concentrations in 7 of 8 nearby downgradient wells by 88% to 97%.

The Problem

Vapor intrusion was identified as an exposure pathway that required remediation

- ➢ Crawl space vapor intrusion prevention systems are effective in reducing indoor air concentrations, but the ground water source requires cleanup to eliminate the source of VOC vapors that cause indoor air exposures.
- ➢ The uppermost aquifer is a fine grained silt with thin and highly stratified sand stringers
- ➢ Pump and treat methods would be ineffective because of low yield of fine grained soils
- ➢ High soil oxidant demand of silts and clays prohibited treatment using ISCO
- ➢ Complete degradation needed – potential stalling or production of VC unacceptable due to residential setting and known vapor intrusion impacts.

PRB Design

- Completed pre-installation CPT/MIP borings and pulse-interference hydraulic tests along proposed PRB alignment
- Completed bench scale column/treatability studies using three ZVI vendors.
- Completed probabilistic design using hydraulic testing data, ZVI reaction rates, and other solute transport properties. Design also included modeling of ZVI passivation effects due to carbonates and other inorganics in groundwater.

PRB Construction

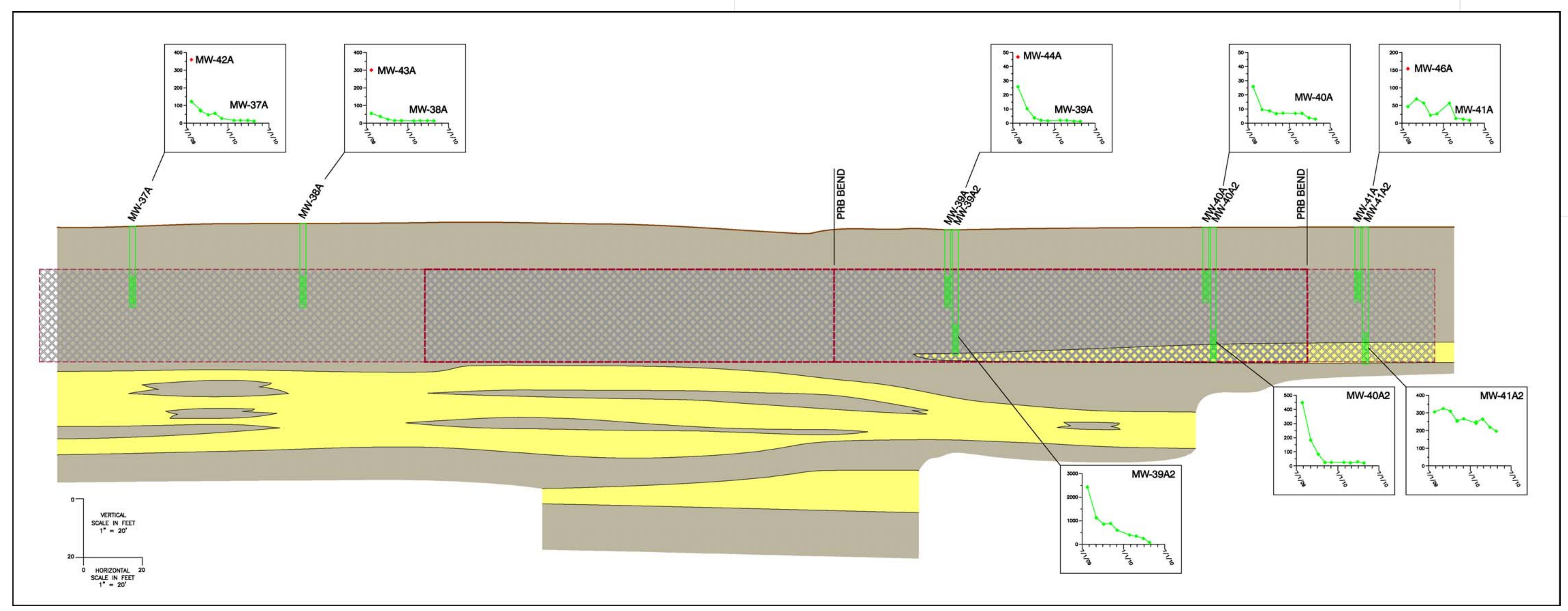
- The PRB was constructed in a residential park and city streets between April and July 2009.
- The PRB was installed using azimuth-controlled vertical hydraulic fracturing using cross-linked guar gum to create the fractures and distribute the iron. The cross-linked guar gum/iron mix is broken down to iron and sugar water within 30 minutes using enzymes added to the injected solution immediately before injection.
- The PRB is 480 ft long, 33 feet tall (from 15 to 48 ft bgs), and is 3 to 4.5 inches thick.
- The PRB is installed perpendicular to groundwater flow, with the exception of a portion of the PRB that was installed along the edge of a city street, which allowed the PRB to be placed as close to the residential properties as possible.
- In situ electrical resistivity probes allowed for real time monitoring of the injection process.
- Borehole magnetometer testing and soil cores completed from angled rotosonic borings verified design thickness in several locations across the PRB. Multiple closely-spaced fractures of varying thickness were identified in each boring, but total design thickness was achieved.

Hydraulic Responses to PRB Installation

- Permeability in the upper portion of the PRB (A-Zone), which is installed across finer-grained deposits, is lower than the deeper portion of the PRB (A2-Zone), which is installed across slightly coarser deposits.
- Post-installation water level data showed temporary A-Zone head differentials up to 1.1 ft across the PRB. Head differentials in the upper-most A-Zone wells are now steadily decreasing. Head differentials in the deeper (A2-Zone) have remained low, consistent with expected head differences based on regional gradient.

PRB Effectiveness in Reducing VOCs

- Seven of the 8 monitoring wells installed immediately downgradient of the PRB have shown total VOC concentration reductions ranging from 88% to 97%. The remaining well has dropped 36% and concentrations are trending downward.
- The primary contaminant, TCE, enters the PRB between 50 and >500 ppb, and has been reduced to below the MCL in 6 of the 8 adjacent downgradient wells.
- Only 1 well has detected increased concentrations of cis-1,2-DCE and vinyl chloride, which are potentially attributed to biodegradation of TCE via the organic carbon introduced to the aquifer through the breakdown of the guar gum. Concentrations of these byproducts are now decreasing.
- VOC reductions are just beginning to be observed in monitoring wells farther downgradient within the neighborhood. Future monitoring will be required to verify long-term effectiveness of the PRB.



Cross section of PRB with Total VOC concentrations after installation. Wells shown are all within 10 feet downgradient of PRB. Red data points on graphs are from upgradient companion wells.

Frac casing alignments in park and street

ERM