High-Resolution Site Characterization for the Design of an In Situ Bioremediation System in Dual-Porosity Bedrock

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Background/Objectives. Historical manufacturing operations resulted in trichloroethene (TCE) impacts in a highly saline, confined, sedimentary bedrock aquifer below approximately 100 feet of low-permeability overburden deposits. Residual dense non-aqueous phase liquid (DNAPL) likely exists in overburden and bedrock below the manufacturing building due to vertical migration along structural pilings. A rock core microcosm study was conducted previously and demonstrated that biodegradation of TCE to vinyl chloride (VC) was possible using the native microbial population. Since that time, a groundwater pump and treat system was installed and now would protect against off-site migration, making in situ bioremediation a potentially viable remedial option for the site.

Approach/Activities. A focused characterization effort was conducted to gain an increased understanding of contaminant fate and transport within the proposed pilot test area. A 220-foot deep borehole was advanced to characterize bedrock properties in the plume core. Rock samples were collected by coring and analyzed for bulk porosity and pore water concentrations via microwave extraction. Geophysical tools including heat-pulse flow-meter, caliper, fluid temperature, fluid conductivity, optical televiewer and acoustic televiewer were used to collect vertical borehole flow and fracture data. Horizontal flow was evaluated with a continuous high resolution transmissivity profile. The borehole was finished with a seven-port multi-level system (MLS) equipped with pressure transducers to determine vertical hydraulic gradients.

To track distribution of a simulated injection of carbon amendments, 7,000 gallons of non-chlorinated freshwater was injected at a rate of 3 gallons per minute into the saline bedrock aquifer 20 feet upgradient of the MLS, while electric conductivity was measured in adjacent monitoring wells and the MLS. An in situ microcosm study is currently underway to determine the ratio of the specific strain of *dehalococcoides* capable of converting VC to ethene.

Results/Lessons Learned. The characterization results demonstrated uniform, sloping bedding planes with several intersecting fracture zones, and two significantly transmissive intervals (shallow and deep) that dominate groundwater flow intersecting the borehole. Downward vertical hydraulic gradients exist under pumping conditions. The freshwater injection test results suggested downward flow as the fresh water was only detected in one adjacent shallow rock well. Rock core analysis demonstrated a relatively high porosity, consistent with expectations for sedimentary bedrock. The core analysis of pore water showed that concentrations of volatile organic compounds are in equilibrium between groundwater and porewater within the rock matrix, demonstrating that significant contaminant mass is present within the primary porosity of the bedrock.

Over all, the bedrock characterization effort demonstrated that amendment injections can be carried out successfully, but at a relatively slow rate, and that fracture interconnectivity is not sufficiently understood to predict the spatial distribution of the remedial additive. Thus, implementation of a batch injection approach would likely result in limited distribution of the

remedial amendment. Therefore, a recirculation cell is being evaluated to allow increased control of the flow regime and amendment distribution within the target treatment zone.