Characterization and Pilot Testing to Demonstrate Innovative Amendment Emplacement for In Situ Biological/Chemical Reduction of VOCs (as DNAPL) in Bedrock

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Background/Objectives. Characterization and remediation of DNAPL in fractured crystalline bedrock can be the most challenging and expensive of remediation efforts. High concentrations (270,000 µg/L) of cis-DCE detected in an "upgradient" well to a municipal landfill initiated efforts to identify the source, characterize the plume, and generate a remedial strategy. Recognizing that potential DNAPL in fractured bedrock would present technical, regulatory and financial challenges for the municipality, an efficient, adaptive, phased bedrock characterization program was implemented, resulting in delineation of DNAPL in fractured bedrock and ultimately to a remedial design of a biological/chemical reduction permeable reactive barrier (PRB) for plume containment.

Approach/Activities. Initial fracture mapping in exposed outcrops and a review of regional geologic structure informed the initial CSM regarding bedrock fabric and potential preferential flow pathways and identified possible receptors. Bedrock monitoring well installation occurred in two phases: the first informed by fracture patterns from the outcrop mapping, and the second based on downhole geophysics, hydraulic heads, and contaminant distribution from Phase I. The presence of TCE DNAPL was confirmed and offsite migration was identified, resulting in assessment and mitigation. The overall approach to characterization and design was to install boreholes that would be used for pre-design characterization but would also become part of the PRB.

To support the remedial design, injection testing was performed to assess substrate injection rates, and bench-scale testing established the optimum amendments for a PRB that would feature chemical and biological reduction at the property boundary. For the bedrock pilot, permeability enhancement (hydraulic fracturing) was used to deliver an amendment slurry consisting of zero valent iron, emulsified vegetable oil, and a sand proppant into seven existing fractures in three boreholes. Tiltmeter monitoring was performed to assess fracture propagation and amendment distribution, and groundwater monitoring was conducted to assess performance. A separate pilot was performed to assess amendment delivery in the overburden. Following pilot activities, a final remedial design was created for the PRB, which involves remediation both in the overburden and in underlying bedrock.

Results/Lessons Learned. Results from the pilot indicate that amendment was distributed at least 20 ft from all fractures (the pilot design was a minimum of 15 ft), and in some case up to 50 ft or more. Preliminary results show substantial increases in total organic carbon, creation of strongly reducing conditions, and widespread VOC degradation within two months of amendment emplacement. Overall, the characterization and pilot approach maximized the use of available information, performed work in structured phases, reassessed and updated the CSM throughout the process, and combined pre-design characterization with installation of initial remedial infrastructure. The result is a cost effective, technically sound remedial design for a challenging project for a municipality with its inherent schedule and budget constraints.