

CSM Development and In Situ Bioremediation Optimization in Fractured Bedrock Using 3-D Visualization and Analysis

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Background/Objectives. Previous operations at a former industrial site have contributed chlorinated volatile organic compounds (CVOCs) and 1,4-dioxane to a mixed, 132-acre plume in a fractured shale bedrock aquifer. An in situ bioremediation program was implemented in the source area. 3-D visualizations of the hydrogeologic setting and analyte spatial data were generated in Earth Volumetric Studio (EVS) software to gain a better understanding of contaminant migration pathways and remediation performance.

Approach/Activities. An accurate conceptual site model (CSM) was constructed in EVS displaying the bedrock stratigraphy and fracture network. Prior to remediation, a dye tracer test was conducted to provide further understanding of the fracture network and contaminant transport to improve remedial design. 3-D models were generated to document the time elapsed dye distribution and transport within fracture regimes. The remedial approach was developed to accommodate observed groundwater velocities and target the preferential pathways identified during the tracer test. 3-D visualization and analysis were performed on the contaminant mass and distribution, amendment distribution, and redox conditions. Modeled contaminant plume volumes in EVS were also used for mass calculations over time, providing a quantitative assessment of biodegradation.

Results/Lessons Learned. Simultaneous display of both the hydrogeologic framework and groundwater chemistry data provided both a qualitative and quantitative assessment of bioremediation performance. 3-D visualization illustrated contaminant migration along the fractured bedding-plane partings and tectonic fractures, position of subcropping discrete fracture zones with respect to source areas and injections, and evolving redox conditions. Delivery of amendments to targeted pathways and source areas within the fracture network was visually confirmed through 3-D display. Mass reduction and dechlorination were assessed using the 3-D volumetric contaminant and daughter product plume models. The ability to display geochemistry data within a 3-D hydrogeologic setting provided a powerful tool identifying active biodegradation zones and assessing hydrogeologic conditions promoting or inhibiting the remediation of the source area.