Integrating Diverse High-Resolution Data Sets to Assess Aquitard Integrity in a DNAPL-Contaminated Sedimentary Rock Aquifer System

Jessica R. Meyer (jessica-meyer@uiowa.edu) (University of Iowa, Iowa City, IA, USA)
Beth L. Parker (Morwick G360 Groundwater Research Institute, Univ. of Guelph, Guelph, ON, Canada)

Background/Objectives. Dense non-aqueous phase liquid (DNAPL) contaminants in fractured bedrock aquifers are complex hydrogeological systems to characterize. The contaminant distribution at aged sites is often highly heterogeneous due to the sensitivity of early time DNAPL migration to small scale changes in fracture network characteristics and connectivity and several decades of evolution due to dissolution, diffusion, and degradation. At a site in southern Wisconsin, a multicomponent DNAPL migrated through glacial sediments and sedimentary bedrock ultimately accumulating between 45 and 55 m below ground surface (bgs) in a fractured sandstone. Previous investigations noted there was not an obvious aquitard beneath the accumulated DNAPL leaving an important gap in the conceptual site model (CSM). The objective of this study was to improve the delineation and characterization of aquitard units at the field site to answer two key questions: (1) what aquitard characteristics contributed to stopping downward DNAPL migration and (2) do these same aquitard characteristics occur at other positions between the DNAPL and the underlying regional aquifer.

Approach/Activities. In this study, we identified and characterized aquitards within the sedimentary rock aquifer system at the site using a diverse set of high-resolution data sets. Here, an aquitard was defined as an interval of rock that produces a distinct increase in the vertical component of hydraulic gradient in a high-resolution (3 zones/10 m) head profile. The aquitards were then described within a sequence stratigraphic framework based on detailed sedimentological logs from core and natural gamma logs collected in the boreholes. Fracture network characteristics and connectivity were assessed using cores, borehole image logs, and outcrop observations. Estimates of bulk vertical hydraulic conductivity (K) were provided by a 3-D numerical groundwater flow model constructed and calibrated with emphasis on matching the observed high-resolution head profiles. The distribution of contaminants with depth was quantified based on results from detailed (≥1 sample/30 cm) sampling of continuous cores.

Results/Lessons Learned. The results indicated the DNAPL accumulated in HGU8, a 6 m thick maximum flooding interval with the lowest bulk vertical K at the site. Although defined as an aquitard, HGU8 also has one of the highest average bulk horizontal K values of the bedrock units due to laterally extensive bedding parallel fractures. Rock core contaminant profiles from the source zone showed high contaminant concentrations all the way to the bottom of HGU8 followed by a dramatic decline to non-detect concentrations. Consequently, lateral spreading in the HGU8 bedding parallel fractures likely contributed to cessation of downward DNAPL migration but was not sufficient to stop it completely. Fracture network data indicated poor vertical connectivity between the fracture networks in HGU8 and the underlying aquifer unit, that likely impeded further downward DNAPL migration. The aquitard integrity assessment also identified two additional aquitards with similar properties to HGU8 and at least one additional horizon with poor fracture network connectivity between the contaminated interval and the regional water supply aquifer. This study highlights the importance of multiple, high-resolution data sets for aquitard integrity assessments and demonstrates the potential for poor fracture connectivity across a contact to function as an aquitard, influencing groundwater pathways and impeding downward contaminant migration.