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Quantifying LNAPL Mobility in Fractured Rock: An Equivalent Porous Media Approach

Alec Danielson (adanielson@barr.com) and Joe Berns (Barr Engineering, Minneapolis, MN, USA)
Patrick McHugh (PS&S, Yonkers, NY, USA)

Background/Objectives. A remedial objective of many environmental regulatory agencies at sites with light nonaqueous phase liquid (LNAPL) present involves removal of LNAPL to the maximum extent practicable which requires an assessment of mobility. Quantifying LNAPL mobility in fractured rock geology can be difficult due to the unknowns of fracture geometry, fracture density, and LNAPL connectivity between fractures. The challenge of characterizing LNAPL mobility makes assessing remedial alternatives or evaluating potential LNAPL migration complicated, leaving site managers with highly variable technical bases and potentially large investigation/monitoring data needs to evaluate those sites.

Numerous LNAPL investigations and significant LNAPL recovery efforts have been completed over the past 30 years at a confidential site in the upper Midwest (Site). The Site is comprised of petroleum storage tanks, pipelines, and loading racks from which numerous releases of a variety of petroleum products occurred. The Site geology consists of a thin layer (0-5 feet) of unconsolidated deposits overlying fractured dolomite. Fracture density generally decreases with depth; however, the degree of fracturing is highly variable across the Site. An assessment of LNAPL mobility was conducted within newly installed monitoring wells at a portion of the Site to assess the recoverability of LNAPL and potential LNAPL migration risk.

Approach/Activities. LNAPL baildown tests were conducted at the installed wells consistent with the methods of ASTM E2856. The behavior observed during LNAPL baildown tests at approximately 75% of the wells was similar to perched or confined conditions (as expected for fractured rock). The behavior at approximately 25% of the wells was similar to porous media as demonstrated by linear correlations between LNAPL drawdown and LNAPL thickness and between LNAPL drawdown and LNAPL discharge. Equivalent LNAPL transmissivities were calculated at wells that demonstrated equivalent porous media behavior using the modified Bouwer-Rice method. The Cooper-Jacob and Cooper, Bredehoeft, and Papadapulos methods are not considered valid for calculation of equivalent LNAPL transmissivity because there was insufficient information on the fracture density, fracture geometry, LNAPL connectivity, and effective porosity to validate the empirical assumption of storativity used by those methods.

Results/Lessons Learned. Data from baildown tests can be used to test the hypothesis of equivalent porous media to calculate an equivalent LNAPL transmissivity when certain conditions are met. The frequency of LNAPL and groundwater elevation measurement and the thickness of the LNAPL-impacted unit are important considerations in assessing LNAPL mobility in fractured rock. If the frequency of measurement is tightly spaced, the calculated LNAPL discharge oscillated between measurement periods even though an overall trend was evident. In addition, if the starting LNAPL thickness was not large enough to span multiple sets of fractures, the equivalent porous media behavior was not observed throughout a baildown test.

Quantifying LNAPL mobility allowed the Site managers to compare equivalent LNAPL transmissivity to industry standards for recoverability, assess Site variability with a consistent standard, and assess temporal changes following LNAPL recovery efforts.