The Heterogeneous Homogeneous Aquifer: Remediation Geology from Lessons Learned at CFB Borden

Derek W. Tomlinson (GEI Consultants, Exton, PA, USA)
Neil R. Thomson (University of Waterloo, Waterloo, ON, Canada)

Background/Objectives. Numerous pilot-scale experiments have been performed at the University of Waterloo Groundwater Research Facility at the Canadian Forces Base (CFB) Borden located near Alliston, ON, Canada over the last 25+ years. These experiments span the spectrum from understanding the migration and fate of non-aqueous phase liquids (NAPLs), formation of dissolved-phase plumes, assessing air distribution during in situ air sparging (IAS), to quantifying the effectiveness of amendments to treat source zones. A constant during these experiments is the unconfined CFB Borden aquifer. This aquifer is well-sorted fine to medium-grained sandy aquifer with a hydraulic conductivity of 6.0×10^{-6} to 2.0×10^{-4} m/s. Micro-scale heterogeneities exist in the form of silty sand and coarse sand lenses. While the Borden aquifer is commonly referred to as a homogenous sandy aquifer, these micro-scale heterogeneities have given rise to interesting observations and associated processes, which have provided the groundwork for many fundamental concepts accepted within the scientific and engineering remediation community.

Approach/Activities. The effects of lithology were first observed at CFB Borden through the controlled releases of dense NAPL (DNAPL) to understand the role of geologic structure on the spread of gravity driven multi-phase flow. In addition to controlled DNAPL releases, emplaced light NAPL (LNAPL) and DNAPL sources have also aided in understanding how micro-scale permeability variations affect advective and diffusive processes, and hence dissolved-phase plume development and structure. Observed air channel breakthrough at the water table and the effects of heterogeneity on in situ air distribution during the injection of air into the saturated zone aided our understanding of this complex multi-phase flow process. The lithology hampered several efforts to flush amendments to treat a source zone despite repeated attempts to overcome these micro-scale heterogeneities.

Results/Lessons Learned. Through the use of an array of measurement techniques during each of the various experiments, now being referred collectively as high-resolution site characterization (HRSC)", the understanding of migration of multi-phase fluids (NAPL or air), or dissolved-phase plumes have been well understood at CFB Borden. These included visual observation of the distribution of DNAPL through removal of aquifer material at the centimeter scale, evolving to development of detailed coring and sampling methods, use of geophysical methods, tracers for dissolved- and vapor-phase transport, and detailed permeameter measures of lithological variability. The array of HRSC measures over the years confirmed the control micro-scale heterogeneities have on contaminant transport and remediation of NAPL sources and associated pathways. An overview of the lessons learned at CFB Borden will be presented as they are still applicable today.