

Remediation of a Large Gasoline Spill in Bermuda's Karst Terrane

Keith A. White, CPG (keith.white@arcadis.com)

(ARCADIS, U.S., Inc., Syracuse, NY, USA)

Ricardo Bastida, PG (ARCADIS, U.S., Inc., Boynton Beach, FL, USA)

John Perella (ARCADIS, U.S., Inc., Tampa, FL, USA)

Background/Objectives. A gasket failure on a fuel supply line resulted in the release of 17,200 gallons of gasoline to the surface in an aboveground petroleum storage and distribution terminal located along the Atlantic coastline. Except for the fraction that evaporated, the gasoline directly infiltrated the underlying karstic limestone bedrock – an eolianite containing significant matrix and solution porosity. The objectives of the work were to address the spill impacts in a manner appropriate for the complex geologic setting, and to mitigate impacts and reduce risks posed to human health and the environment. Primary risks posed to human health were the spread of vapors through the porous bedrock and impacts to the water quality of nearby residential wells.

Approach/Activities. An emergency response and interim remedial measures were implemented rapidly. A preliminary conceptual site model was developed, followed by a detailed site characterization, fate-and-transport assessment, and implementation of a full-scale bedrock vapor extraction remedy. The interim remedial measures included vacuum-extraction of gasoline vapors and migration control. Performance monitoring data were incorporated in a full-scale system design. A nearby office building was monitored for vapors and monitoring wells were installed at key locations. Rock structure was assessed through reconnaissance and mapping of bedding and fractures in outcrop and downhole geophysics. Data loggers were deployed to assess tidal influence and aid in groundwater flow interpretations. All data were used to develop a karst-specific conceptual site model. Multiple rounds of groundwater samples were collected from monitoring wells and local supply wells. Transport of impacted groundwater was modeled using an innovative approach that employed empirical relationships developed with data from dozens of tracer studies conducted in multiple karst aquifers.

Results/Lessons Learned. The bedrock was confirmed to represent a triple-porosity medium. Vacuum extraction was well-suited to this medium, removing the equivalent of 6,500 gallons of gasoline in 11 months; however, well-head vacuum was slight despite a high flow rate, making estimating the radius of vacuum influence difficult. Organic-vapor and water-quality measurements at observation wells show significant reduction based on operation, indicating system influence. While LNAPL penetrated the thick vadose zone in less than 48 hours, the volume found to be floating on the water table and subsequently removed was small. Vapors did not impact the office building, and groundwater impacts have attenuated remarkably rapidly. No verified groundwater fate-and-transport model for karst exists; however, the approach used provided a defensible means of predicting the maximum allowable source concentration that would be protective to offsite receptors. Counter to other fractured rock settings, mass recovery in certain karst environments can be successfully implemented. Results of this work should be applicable to other island-karst settings, which are common in the Caribbean.