# Site-Specific Geochemical and Mass Flux Assessments for Metals Lead to Optimized Groundwater Remedial Approach Adjacent to a River

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**Background/Objectives.** Developing and validating a comprehensive conceptual site model (CSM) for remediation sites with metals impacts requires a thorough assessment of site-specific geochemical, hydrogeological and hydrological conditions. A large-scale groundwater extraction system (GWES) had been operating at a former dye manufacturing site for over a decade, which consisted of a shallow alluvial French drain system spanning the site and deeper bedrock pumping wells. Historical remedial objectives targeted a large suite of constituents. Significant reductions in constituents of concern (COCs) were achieved in shallow groundwater; however, pumping increased vertical migration to deeper groundwater. In addition to the large volume of groundwater extracted (70,000 gallons/day), a high-cost GWES upgrade was being discussed. The objectives of the CSM were to assess the geochemical constraints on the fate and transport of metals at the site; redefine the constituents driving the need for containment; refine the understanding of groundwater flow; identify areas with the highest potential for mass flux; and focus remedial efforts on only potentially-mobile COCs which potentially drive risks. The refined understanding of site conditions led to development of a Remedy Optimization Plan, to optimize groundwater extraction using performance goals appropriate for current site conditions.

**Approach/Activities.** Available data and supplemental field investigation data were evaluated to better define the geochemical properties and contaminant distribution found in soil and groundwater at the site and to assess the performance of the GWES. Data were available from the completion of bedrock cores, downhole geophysics, pumping tests, and test pitting and soil borings along the GWES French drain. A series of supplemental field activities included sampling and analysis of soil; monitoring of groundwater response to recharge and river level fluctuations; and groundwater sampling and geochemical assessments including the analysis of dissolved, colloidal and total metal fractions. Geochemical speciation and mixing modeling was performed to determine dilution attenuation factors for groundwater-surface water discharge. These assessments were used to identify the limited number of metals that were potentially mobile and to calculate protective thresholds for surface water discharge.

**Results/Lessons Learned.** Geochemical modeling explained the limited mobility of most metals (barium, cadmium, lead, mercury, molybdenum and zinc), and groundwater monitoring for these metals was terminated. Hexavalent chromium and cyanide exhibited limited sorption under the mainly alkaline groundwater conditions at the site and were determined to be the higher priority COCs. Operation of the bedrock extraction wells was found to be facilitating vertical flux of impacts into the deeper bedrock and exacerbating groundwater impacts through the addition of oxygenated water low in calcium, which limited complexation and precipitation of metals. Modeling identified the key area of potential hexavalent chromium and cyanide flux as overburden groundwater discharging to surface water in the central area of the site. Pumping was suspended from one-third of the French drain and all 20 bedrock extraction wells, leading to a 30 percent reduction in pumping rates. Thresholds for surface water discharge, which were orders of magnitude above groundwater standards, were used as performance standards.