Modeling and Uncertainty Analysis for Remedy Selection and Design to Address Groundwater Discharging to Surface Water

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Background/Objectives. Groundwater flow and solute transport modeling can be effective tools for understanding and managing environmental risks throughout the life of a remediation project, including evaluating and comparing the effects of potential remedial alternatives on future site conditions. At a former manufactured gas plant (MGP), remedial alternatives were evaluated to mitigate MGP-related impacts in sediments within a river adjacent to the site and address conditions at the groundwater-surface water interface. Complex site features, including a partially penetrating river controlled by a dam and uncertain future operation of the dam in a developed urban setting, created the need for a modeling tool to aid in evaluation of remedial alternatives. A numerical groundwater model was used to evaluate groundwater flow conditions and the influence of the river on groundwater flow, movement and natural decay of compounds in groundwater, and future conditions with various dredging and capping alternatives and the anticipated future condition of the dam. Further, the modeling results were used for communication with regulatory and other stakeholders.

Approach/Activities. An existing MODFLOW-SURFACT model for the site was updated and calibrated with site characterization data collected since the model's initial development, resulting in a robust modeling tool for evaluating past, current, and potential future conditions. Uncertainty in model estimates is often evaluated using a traditional sensitivity analysis, where model parameters (i.e., inputs) are adjusted away from calibrated values, and the model is run multiple times; however, when using parameter values that are arbitrarily adjusted away from calibrated values, the model may not honor the calibration data. Therefore, calibration-constrained Null Space Monte Carlo (NSMC) techniques were used to test the uncertainty of model estimates by generating multiple parameter sets that also result in a nearly-calibrated model. Fifty parameter sets were generated by simultaneously varying parameter values within user-specified, reasonable ranges and refined to provide near-calibrated parameter sets. Minimal computational efforts were then employed to reasonably recalibrate the parameter sets, and remedial alternative scenarios were run with the 50 parameter sets. Concentration and mass flux results were compared between scenarios using the range of results from the NSMC analysis to quantify the uncertainty of model estimates for more informed decision-making.

Results/Lessons Learned. Based on the modeled groundwater flow and solute concentrations from the NSMC uncertainty analysis, two dredging and capping alternatives were carried forward in the feasibility study, and a uniform, impermeable cap was ultimately selected for design. Modeling results indicated the impermeable cap would be effective at limiting groundwater discharge to surface water from the areas of greatest groundwater impacts, and groundwater flow paths to post-remedy surface water discharge locations would be lengthened after cap installation. Concentrations are expected to attenuate along the lengthened flow paths prior to discharge to surface water. Informed by the NSMC analysis, a monitoring plan was developed to assess compliance with cleanup criteria following the sediment response action and included areas of greatest uncertainty.