Design Optimization of Environmental Contamination Projects Using Massively Parallel Simulation and Optimization Solution Methods

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Background/Objectives. Environmental remediation has been ongoing in the United States for several decades. While some successes have been realized, the more challenging sites remain resistant to efficient and effective remediation. Optimal design tools can help alleviate this. Specifically, extensions to HydroGeoLogic's Physically Based Management Optimization (PBMO^{TM}) now include implementing it as a massively parallel and efficient computational optimization technology. This enables its use for optimally managing environmental remediation project and programs by reducing remediation design analysis timeframes and analysis costs. This enables the development of formal, physically consistent and robust analysis of optimal remedial designs for environmental contamination problems of any level of complexity including automated model calibration and formal evaluation of uncertainty in design performance. Results demonstrate proven capabilities to generate high quality results far beyond those achievable using the heuristic or trail-and-error exploration methods regularly used in current practice.

Approach/Activities. Newly developed and extended breadth and depth search strategy with automated adaptive partitioning to simultaneously evaluates multiple promising design strategies. Algorithm automatically adapts to the characteristics of the search space being interrogated. Base computational capacity capable of executing fifty-thousand (50,000) model simulations in parallel, which can be increased if needed. Programmed as a set of modules using modern FORTRAN for the intensive and parallel numerical computations, Julia and Python for some of the processing and control functions and various web languages.

Results/Lessons Learned. Two examples are provided that demonstrate the effectiveness of the optimization method by documenting PBMO^{TM} ability to solve mixed integer non-linear programming (MINLP) problems with thousands of decision variables and millions of constraints.

> Example 1: Garvey Elevator Superfund Site, Hastings NE. Optimal remedy design for a 4-mile long chlorinated solvent plume proximate to off-site TNT issue. Remedial design objective is to minimize total life cycle costs. Complex design challenge with 4,514 decision variables and over 2.2 million constraints. Flow and transport model comprised of over 1,000,000 grid cells in a multi-level aquifer environment. This effort represents one of the most challenging problems ever successfully solved with an optimization software.

> Example 2: Fort Ord, CA. Optimal remedy design and implementation at the former U.S. Army base. Performance-Based Remediation (PBR) with the objective of site closure at Operable Unit (OU)-1. Optimized site exit strategy achieved remedial-action completion in 2014 and obtained regulatory concurrence in 2016, ahead of schedule and below estimated cost of remedy in place of $661,502. Optimal strategy was implemented resulting in an actualized optimal remedy cost of only $172,121; an actualized cost savings of $489,381.

This work recently received the 2017 Grand Prize Award (Research category) from the American Academy of Environmental Engineers and Scientists.