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Data-worth analysis for multiobjective optimal design of pump-and-treat remediation systems

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Abstract

The design and the management of pump-and-treat (PAT) remediation systems for contaminated aquifers under uncertain hydrogeological settings and parameters often involve decisions that trade off cost optimality against reliability. Both design objectives can be improved by planning site characterization programs that reduce subsurface parameter uncertainty. However, the cost for subsurface investigation often weighs heavily upon the budget of the remedial action and must thus be taken into account in the trade-off analysis. In this paper, we develop a stochastic data-worth framework with the purpose of estimating the economic opportunity of subsurface investigation programs. Since the spatial distribution of hydraulic conductivity is most often the major source of uncertainty, we focus on the direct sampling of hydraulic conductivity at prescribed locations of the aquifer. The data worth of hydraulic conductivity measurements is estimated from the reduction of the overall management cost ensuing from the reduction in parameter uncertainty obtained from sampling. The overall cost is estimated as the expected value of the cost of installing and operating the PAT system plus penalties incurred due to violations of cleanup goals and constraints. The crucial point of the data-worth framework is represented by the so-called pre-posterior analysis. Here, the tradeoff between decreasing overall costs and increasing site-investigation budgets is assessed to determine a management strategy proposed on the basis of the information available at the start of remediation. The goal of the pre-posterior analysis is to indicate whether the proposed management strategy should be implemented as is, or re-designed on the basis of additional data collected with a particular site-investigation program. The study indicates that the value of information is ultimately related to the estimates of cleanup target violations and decision makers' degree of risk-aversion.

Keywords: Pump-and-treat remediation; Stochastic multiobjective optimization; Data worth; Decision analysis

1. Introduction

Remedial action decisions for groundwater contamination are generally made in an environment of uncertainties regarding the hydrogeological parameters characterizing the subsurface system. Lack of data often constitutes a major limitation that ultimately may produce overdesigned recovery systems and/or the acceptance of a certain probability of non-compliance with the cleanup goals.

In principle, the cost optimality and reliability of a cleanup system may be improved with the collection of data, by reducing parameter uncertainty. However, site investigation represents an additional cost that should be included in the overall cost of the remediation system. Since any site-investigation strategy is justified only if the reduction in overall management cost exceeds the cost of site investigation, one needs to identify the optimal tradeoff between increasing data-collection costs and decreasing management costs. This problem is often referred to as the "data-worth problem".

To date, considerable research has focused on the economic worth of information gained through sampling of the surface/subsurface environment. One of the first attempts to incorporate the worth of hydrologic data into economic decision making was presented by Davis et al.

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