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Using Uncertainty to Guide Characterization, Closure, and Long-term Management of an Underground Nuclear Test Site

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No feasible remediation technology has been identified for nuclear test cavities such that site management and institutional controls must be relied on to minimize the possibility of public exposure to these legacies of the Cold War. The most common exposure pathway of concern is migration of radionuclides with groundwater. Prediction of flow and transport behavior in the sparsely observed subsurface environment is inherently uncertain, but developing effective management strategies demands such predictions. An agreement between the U.S. Department of Energy (DOE) and the State of Nevada provides a framework for addressing uncertainty in site management decisions. The central element of the framework is calculation of a predictive contaminant boundary at a specified confidence interval. This boundary is defined as a three-dimensional region encompassing all groundwater that contains radionuclides at concentrations higher than Safe Drinking Water Act limits at any time through a 1,000-year period, at a 95-percent confidence interval. In the process of predicting this boundary at the Shoal underground nuclear test site in rural Nevada, some interesting challenges were encountered. A stochastic groundwater flow and transport model was developed for the site using historic site data and information from four characterization wells drilled in 1996. Though the predicted mean transport plume was located within the existing site land boundary, uncertainty in the predictions was very large such that the 95-percent confidence interval extended beyond the site boundary. This level of uncertainty was unacceptable to DOE, prompting additional site characterization with the goal of reducing the uncertainty in contaminant migration predictions. The numerical groundwater flow model was used to identify the optimum data collection activities for uncertainty reduction. This Data Decision Analysis guided drilling and testing of additional wells. Significant revision occurred to the groundwater model as a result of the new data. The revised model was deemed acceptable by both DOE and the State of Nevada, and has been used to determine the contaminant boundary for the site, the calculation of which required choices regarding risk or concentration metrics and whether to focus on the uncertainty of where the contaminants might be or where the groundwater is free of contaminants. The model was also used to develop an optimum monitoring system, the installation of which provided another opportunity to reduce uncertainty as data were collected for model validation. The short-term validation process, and long-term monitoring, provide data that can feed back into the stochastic flow and transport model to cull poorly performing model realizations and reduce uncertainty in the model predictions.