Mr. John Hauschild
Sandford Cohen & Associates, Inc.
8817 Newport Court
Springfield, VA 22153

JUN 20 1994

Dear Mr. Hauschild:

Per your request on June 7, 1994, I have enclosed the following documents:

1. The U.S. Nuclear Regulatory Commission, "Initial Demonstration of the NRC's Capability to Conduct a Performance Assessment for a High-Level Waste Repository," NUREG 1327, Washington, D.C. (May 1992).

2. Coplan, S. M., Eisenberg, N. A., and Randall, J. D., "Performance Assessment at the NRC: Current Issues and Recent Progress, Volume 1, High Level Radioactive Waste Management," 1990.

If I can be of any further assistance, please call me at (301) 415-7285.

Sincerely,

ORIGINAL SIGNED BY

Norman A. Eisenberg, Section Leader
Performance Assessment and
Health Physics Section
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PERFORMANCE ASSESSMENT AT THE NRC: CURRENT ISSUES AND RECENT PROGRESS

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ABSTRACT

Performance assessment plays a major role in the NRC's licensing program for the disposal of high-level radioactive waste. Planned and recent performance assessment activities include reactive work, such as the review of the Site Characterization Plan prepared by the U.S. Department of Energy for a repository at Yucca Mountain, Nevada, and proactive work such as development and deployment of an NRC-staff performance assessment capability, development of regulatory guidance in the form of technical positions, rulemakings, conduct of a research program, and participation in a variety of international activities.

I. INTRODUCTION

Performance assessment plays a major role in the NRC's licensing program for the disposal of high-level radioactive waste (HLW). Because the performance assessment of a repository of HLW involves comparing quantitative estimates of repository performance to quantitative performance standards, performance assessment is often the discipline or phase of repository development in which information and knowledge from a variety of technical and scientific disciplines are integrated into a few quantitative measures of performance. Performance assessment is the nexus of modeling, scientific and technical studies, and the safety regulations.

In order to address the technical and programmatic concerns of performance assessment adequately, the NRC staff has conducted and continues to conduct a performance assessment program involving reactive and proactive activities. Recent reactive activities include review of the U.S. Department of Energy (DOE) Consultative Draft Site Characterization Plan (CDSCP)[1], the statutory Site Characterization Plan (SCP)[2], and various study plans for the candidate HLW repository site at Yucca Mountain, NV. Recent and planned proactive activities include: development and deployment of an NRC-staff performance assessment capability, development of regulatory guidance in the form of technical positions, conduct of a research program, and participation in a variety of international activities.

II. REACTIVE ACTIVITIES

The NRC staff had concerns about the CDSCP in the area of performance assessment.[3] The primary concern was the need for a comprehensive and systematic consideration of alternative conceptual models of the Yucca Mountain site and the performance of the repository. Such considerations were needed to assure that site investigations would gather data to confirm or rule-out alternative conceptual models, in addition to gathering data to confirm the preferred concept. Other NRC staff comments on the CDSCP concerned: (1) the use of expert judgment, (2) the need to include human intrusion in the calculation of total system performance relative to the Environmental Protections Agency's overall HLW performance standard (40 CFR Part 191)[4], (3) the need to articulate a coherent method for identifying and screening scenarios for use in performance assessments, and (4) the link between the regulatory requirements (40 CFR Part 191 and 10 CFR Part 60[5]) and the site investigations. The SCP greatly improved the treatment of these issues. Among these improvements was the inclusion of an extensive set of Hypothesis Testing Tables, which improved the articulation of alternative conceptual models and the investigations needed to evaluate them. In addition, the linkage of the site investigations to issue resolution, including resolution of regulatory issues, was clarified through the use of improved performance allocation tables.

In spite of the SCP's notable improvements over the treatment of certain issues in the CDSCP and although a number of CDSCP comments and objections were resolved, the NRC staff still found some aspects of the SCP to be problematic.[6] Three major concerns were identified with respect to the post-closure performance assessment program. The foremost concern is that total system performance assessments do not appear to be planned to be carried out iteratively with site characterization activities, but are planned to be done only toward the end of site characterization. The NRC staff thinks that performance assessments should be conducted in an iterative fashion in coordination with site characterization to help evaluate the data gathered and to direct further site characterization activities. In particular, these performance assessments should

provide an early and continuing evaluation of whether any of the various potentially adverse conditions (delineated in 10 CFR Part 60.122) significantly affect the ability of the site to meet performance objectives. Another concern is that Section 8.3.5.20 of the SCP, Analytical Techniques Requiring Development, outlines a broad program for validation of models used in performance assessment, but does not delineate any specific validation studies for models that will be used to demonstrate compliance with the overall post-closure performance objective, 40 CFR 191. Finally, the NRC staff was concerned that the site characterization program might not acquire all the data needed for the performance assessment activities that would support DOE's HLW license application because of inconsistencies in the SCP's use of the term "scenario" and the SCP's approaches to inclusion or exclusion of scenarios in DOE's demonstration of compliance with 10 CFR Part 60 and 40 CFR Part 191. Because a preliminary scenario analysis is used in the SCP to define and screen a set of scenario classes on which its performance allocation tables are based, there is a concern that the site characterization program based on the SCP's performance allocation tables may not be adequate.

III. PROACTIVE ACTIVITIES

In addition to the review of DOE's major programmatic documents, the NRC has engaged in a variety of HLW performance-assessment-related activities intended to enhance the efficiency, timeliness, and reliability of the HLW licensing process. These activities include: (1) development and enhancement of an NRC staff capability to review critically the quantitative performance assessments expected to be submitted as part of DOE's HLW license application;[7] (2) development of a series of Technical Positions to provide guidance to the DOE for submitting adequate information in the HLW license application;[7] (3) drafting proposed modifications of 10 CFR Part 60 to reduce regulatory uncertainty that has been identified in it and to complete sections that had been reserved for future rulemakings;[7] (4) conduct of a research program to assure that adequate technological and scientific information is factored into NRC's regulatory requirements and HLW-licensing-related activities, guidance, and evaluations promulgated by the NRC; and (5) participation in a number of international studies and activities to broaden the base of information on which regulatory decisions are made.

A. NRC Staff Performance Assessment Capability

The NRC staff has been engaged in preparing a preliminary performance assessment for a repository located at Yucca Mountain, as part of the preparation to evaluate independently the license application to be submitted by the DOE. Although the NRC is not required to perform an independent performance assessment of a repository, one approach to evaluating the adequacy of a license application would have the NRC staff selectively and independently evaluating repository performance. A probabilistic total system performance assessment is being prepared, based on available site, design, and generic information. As site characterization and design proceeds, NRC plans to improve upon this preliminary assessment with more comprehensive data and improved models. A primary objective of this activity is to familiarize the NRC staff with the modeling approaches used to estimate repository performance, so that the staff will be better able to evaluate the adequacy of the current regulations and ultimately to evaluate DOE's HLW repository license application. Prior to the submittal of the license application, this work is expected to assist the NRC staff in the evaluation of DOE's site characterization activities. In addition, NRC staff expects that this work will provide valuable insights into the content and priority of various regulatory technical positions.

The approach to performance assessment used by the NRC staff is shown schematically in Figure 1. It generally follows and extends the methodology for performance assessment formulated by the Sandia National Laboratories for the NRC.[8,9,10] For the purposes of this paper, the only performance measure considered is the cumulative release of radionuclides to the accessible environment, as mandated by the EPA containment standard (40 CFR Part 191, parts of which have been remanded by the courts). Many of the same techniques and consequence models can be used in somewhat different configurations to estimate other performance measures and evaluate compliance with other standards for the repository.

The steps in performance assessment are:

1. System Description. In this step the various important components of the waste disposal system - the waste form, the engineered barrier (the canister, the repository, backfill, if any), and the site - are described in terms useful to modeling radionuclide migration to the environment. This step usually requires the synthesis of inputs from many different disciplines in the natural sciences and engineering. Also raw field and laboratory data must be analyzed to give parameters useful for performance assessment modeling. For example, pump tests are interpreted to yield hydraulic conductivity estimates.

2. Scenario Analysis. In this step a range of potential futures in which the repository must operate, called scenarios, are postulated and screened. Also the probabilities of

individual scenarios are estimated. The current approach is to build scenarios only from processes and events occurring in the environment external to the repository; uncertainty about events and processes occuring within the repository are considered as uncertainty in the description or modeling of the repository, rather than as separate scenarios. Scenarios are screened out if their probabilities are sufficiently low to warrant no further consideration. Scenarios which produce little or no change in performance are grouped together as the "undisturbed" or "base-case" scenario and the probability assigned is the sum of the individual scenarios in the group. The "undisturbed scenario" may not be the most likely scenario. Probabilities of scenarios are determined from the probabilities of their component events and processes, which are derived from field studies, analyses, and expert opinion. Scenario analysis is performed iteratively or in parallel with consequence analysis.

3. Consequence Analysis. The consequence analysis step estimates the performance of the repository for a given scenario. For the performance measure of interest, cumulative release of radionuclides to the accessible environment, consequence models need to treat the release of radionuclides from the repository to the host rock and the migration of radionuclides (as liquid or gas) through the geosphere. Modeling these processes may require detailed consideration of phenomena affecting these processes, such as groundwater flow and waste package degradation.

4. Performance Calculation. The performance calculation step combines the estimate of consequences with the corresponding probability of occurrence. The resulting distribution is displayed as a complementary cumulative distribution function (CCDF). Uncertainty about parameters is important in representing the repository system, because a highly variable natural system is an important component of the repository. Consequently this variablility in parameters describing the repository system is usually also folded into the CCDF representation.

5. Sensitivity and Uncertainty Analyses. In order to compare the characterization of the system obtained in Step 4 to the regulatory performance standards, the uncertainties inherent in the estimates of performance must be estimated and evaluated. Sensitivity analyses determine which parameters, phenomena, processes, and/or assumptions most greatly influence the estimated value of the performance measure. Uncertainty analysis attempts to delineate all the sources of uncertainty, quantify these uncertainties (at least in relative terms) and the uncertainty in the performance estimates, and relate the uncertainty in estimates of performance to the various sources of uncertainty.

6. Comparison to Regulatory Standard. In this step, judgment is used to evaluate whether the estimated performance, with its associated uncertainties, satisfies or fails to satisfy regulatory standards, which are limits on performance.

B. Technical Positions

The NRC HLW staff plans to issue a number of technical positions related to performance assessment to clarify expectations for demonstrations of compliance with the NRC regulations.[7] Currently, the technical positions related to repository performance that NRC plans to issue concern: (1) scenario identification, (2) model verification and validation, (3) formal use of expert judgment, and (4) treatment of data and parameter uncertainty.

C. Rulemaking

Although 10 CFR Part 60 appears to be a satisfactory rule in most respects, it contains sections that need clarification and revision due to ambiguities and evolving technical and regulatory developments in HLW disposal. With respect to HLW performance assessment, NRC plans to modify 10 CFR Part 60 to clarify the meaning of anticipated and unanticipated processes and events in the geologic setting, to set safety criteria for design-basis pre-closure accidents, and to conform to EPA's expected reissuing of 40 CFR Part 191.

D. Research Program

Since the late 1970's, NRC has been conducting a research program to support its capability to make HLW licensing decisions. The program has had projects to identify and quantify technical uncertainties in understanding how HLW repositories will perform. The largest part of the program has been devoted to uncertainties in the technical fields (e.g. metallurgy, ceramics, geochemistry, and hydrogeology) that have to be considered in predicting HLW repository performance.[11] The performance assessment component of the program has been devoted to quantification of technical uncertainties.

The NRC HLW research program is currently in a state of transition. Most of the research work formerly conducted at National Laboratories, universities, and other institutions is being phased out or transferred to the Center for Nuclear Waste Regulatory Analyses (CNWRA - a Federally Funded Research and Development Center established at the Southwest Research Institute specifically to serve the needs of NRC's HLW licensing mission).

Research work currently being conducted at the University of Arizona is investigating fundamental flow and transport processes in groundwater in tuff. These investigations, supported experimentally at the Apache Leap Tuff Site,[12,13,14] are also supporting NRC's participation in INTRAVAL, an international study on the validity of models of migration of radionuclides in the geosphere. The Sandia National Laboratories is completing the development of a methodology for performance assessment of a repository in partially saturated tuff.[15] The NRC staff plans to demonstrate the methodology's applicability to the Yucca Mountain site. The initial activities of the CNWRA in performance assessment are to acquire Sandia's NRC-supported performance assessment methodology, to assist the NRC staff in demonstrating the methodology through the preliminary performance assessment for the Yucca Mountain repository, to assist in the development of a review strategy for the license application, and to evaluate and develop models for migration of radionuclides through the geosphere. A long-term objective of CNWRA's performance assessment research is to integrate the results of more specialized NRC HLW research projects into the performance assessment methodology.

E. International Activities

The NRC is currently participating in a number of international activities including: (1) the OECD/Nuclear Energy Agency's (NEA's) Performance Assessment Advisory Group (PAAG), (2) the NEA Probabilistic System Assessment Code Group (PSAC), (3) the NEA Radioactive Waste Management Committee (RWMC), and (4) the INTRAVAL study. The PAAG advises and makes recommendations to the RWMC (the steering committee on radioactive waste management of the NEA) regarding performance assessment. An important activity conducted under the auspices of the PAAG has been a committee attempting to develop a consensus on the identification and screening of scenarios.[16] An issue arising out of these deliberations has been the relative merits of the scenario approach to evaluating a HLW repository compared with the alternative method of simulation, which was pursued by some DOE contractors about a decade ago[17,18] and which is currently being pursued by some investigators in the United Kingdom.[19] The PSAC group, which is an adjunct of the PAAG, has been conducting intercomparisons of various system codes.[20,21] The NRC anticipates that it will exercise its performance assessment capabilities, currently under development, in this arena. The NRC has been a participant in the INTRAVAL study since its inception.[22,23] The validation of performance assessment models, of which geosphere transport models are a very important subset, is considered to be a very important issue by the NRC. During the course of this study the NRC has contributed several test cases and is playing an active role in assimilating and integrating information from all the test cases. NRC also has bilateral cooperative agreements with HLW agencies in France, Japan, Sweden, and Switzerland.

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