THE NUCLEAR REGULATORY COMMISSION STRATEGIC PLAN FOR POSTCLOSURE PERFORMANCE ASSESSMENT ACTIVITIES FOR THE HIGH-LEVEL WASTE GEOLOGIC REPOSITORY

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ABSTRACT

This document constitutes the Nuclear Regulatory Commission (NRC) high-level waste (HLW) Performance Assessment Strategic Plan (PASP). As such, it defines the goals, objectives, and general activities of the Performance Assessment (PA) program from the present to the time the U.S. Department of Energy (DOE) submits the license application (LA) for the proposed HLW repository at Yucca Mountain (YM) (currently planned for the year 2001). This PASP is consistent with the NRC Overall Review Strategy (ORS), however, it only covers postclosure PA activities; preclosure PA activities will be included in a later version of this plan.

The PA program activities herein discussed arise from five sources: (i) legislative mandates, (ii) interactions with DOE, (iii) the Systematic Regulatory Analysis (SRA) process and the preparation of the License Application Review Plan (LARP), (iv) the need to develop independent technical assessment capabilities, and (v) general support to the NRC HLW Program. These activities support the long-term objectives of the PA program which are: (i) maintain and refine the regulatory structure related to PA, (ii) develop a technical assessment capability in total-system and subsystem PA needed for prelicensing and licensing reviews, (iii) conduct prelicensing reviews and quality assurance (QA) audits, (iv) identify and prioritize research needs, and (v) monitor progress of activities designed to meet those needs.

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NOMENCLATURE

ACNW	Advisory Committee on Nuclear Waste
CNWRA	Center for Nuclear Waste Regulatory Analyses
DHLWM	Division of High-Level Waste Management
DOE	U.S. Department of Energy
EBS	Engineered Barrier System
ENPA	Energy Policy Act of 1992
EPA	U.S. Environmental Protection Agency
HLW	high-level waste
IPA	Iterative Performance Assessment
LA	license application
LARP	License Application Review Plan
NRC	U.S. Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act of 1982
ORS	Overall Review Strategy
PA	Performance Assessment
PASP	Performance Assessment Strategic Plan
RES	Office of Nuclear Regulatory Research
SCP	Site Characterization Plan
SNL	Sandia National Laboratories
YM	Yucca Mountain

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EXECUTIVE SUMMARY

The Performance Assessment Strategic Plan (PASP) defines the goals, objectives, and general activities of the Nuclear Regulatory Commission (NRC) high-level waste (HLW) performance assessment (PA) program. The goals, objectives, and general activities herein presented will be carried out from the present to the receipt of the license application (LA) submitted by the U.S. Department of Energy (DOE) for the proposed HLW repository at Yucca Mountain (YM). This PASP is a supporting document to the NRC Overall Review Strategy (ORS) for the HLW program. The ORS requires a PASP that addresses both preclosure and postclosure PA activities. This version of the PASP, however, only covers postclosure activities—a revised version of the PASP will be published at a later date to include preclosure PA activities. The PASP will be updated as warranted, and the progress of the PA program is expected to be periodically reported.

The PA program supports the NRC Division of High-Level Waste Management (DHLWM) program in the following areas:

- Quantitatively evaluating technical uncertainties identified in the NRC License Application Review Plan (LARP)
- Addressing regulatory uncertainties associated with the implementation of regulatory requirements
- Contributing to the integration of technical assistance and research projects
- Providing input to the prioritization of Office of Nuclear Regulatory Research (RES) activities
- Identifying the key processes and factors controlling the performance of the total disposal system and its components

The implementors of the PA program are the Director, DHLWM, and the Chief, Hydrology and Systems Performance Branch. The supported organizations are the Director, Office of Nuclear Material Safety and Safeguards (NMSS) and the Commission.

Consistent with the goals of the HLW management program stated in the ORS, the goals of the PA program are to:

- Conduct PA-related activities
- Develop regulatory products
- Train and maintain staff in total-system PA and subsystem PA

To achieve these goals, specific objectives will be met in four areas:

- Maintain and refine the regulatory structure pertaining to PA

- Develop a technical assessment capability in total-system PA and subsystem PA for conducting pre-LA and LA reviews

- Conduct pre-LA reviews and support observation of QA audits and inspections

- Identify and prioritize PA user needs and monitor progress of activities designed to meet those needs

To meet its goals and objectives, the PA program requires a multidisciplinary group of scientific and technical experts that would be difficult to assemble within a single organization. Thus, the PA program participants include a variety of NRC staff within NMSS and RES, as well as external organizations such as the CNWRA.

A wide spectrum of activities is needed to meet the goals and objectives of the PA program. These activities are grouped into five major categories. The titles of these categories reflect the origin and nature of the PA activities. The five categories are:

- Legislative mandates

- Interactions with DOE

- Systematic Regulatory Analysis (SRA) and preparation of the LARP

- Technical assessment and research

- Support to HLW management program

A number of subcategories exist under each of these categories. Each of these subcategories is briefly discussed here.

Legislative mandates arise from the Energy Policy Act (ENPA) of 1992 and the Nuclear Waste Policy Act (NWPA) of 1982, as amended. Under the ENPA of 1992, the PA staff will interact with the National Academy of Sciences (NAS) and the U.S. Environmental Protection Agency (EPA) as the former develops recommendations and the latter considers those recommendations for the revision of 40 CFR Part 191 for application at YM. To support the HLW management activities mandated by the NWPA of 1982 and its amendments, technical reviews will be performed: (i) to achieve closure of technical and regulatory issues related to the implementation of 10 CFR Part 60 (i.e., closure of regulatory uncertainties), (ii) of DOE Site Characterization Plan (SCP) progress reports, study plans, and the Early Site Suitability Evaluation Reports, and (iii) of DOE repository and waste package designs, waste-form proposals, and site characterization analyses.

Interactions with DOE will include: (i) review of DOE total-system performance assessments (TSPAs) and sub-system PA-related topical reports and the LA Annotated Outline, (ii) participation in PA technical exchange meetings, technical meetings, and QA audits, and (iii) preparation of guidance in the elicitation and use of expert judgments, definition of scenarios, construction of a complementary cumulative distribution function (CCDF) of radionuclide releases to the accessible environment, model validation, and biosphere transport.

The SRA process for the preparation of the LARP identified key technical uncertainties (KTUs) and regulatory uncertainties that need to be addressed by the staff in order to conduct effective pre-LA and LA reviews and resolve uncertainties regarding the definition and implementation of the performance objectives in 10 CFR Part 60. The PA program will carry out activities to address the following KTUs: conceptual model uncertainty, appropriateness of assumptions and simplifications in mathematical models, validation of mathematical models, variability of parametric values, and prediction of future system states. These KTUs will be addressed to the extent needed to develop the capability to review the LA. The PA program will address regulatory uncertainties associated with the prewaste emplacement groundwater travel time (GWTT), substantially complete containment for the waste package, and the controlled release rate from the engineered barrier system (EBS).

In order to effectively evaluate the DOEs demonstrations of compliance to be included in the LA, the staff will develop an independent technical assessment capability. Specific activities include the conduct of Iterative PA (IPA) exercises, the development of a geological model and computer code, the development of a geochemical model and computer code, the development of geotechnical model and computer code, the development of a hydrologic model and computer code, and the development of an EBS model and computer code.

The PA program will also provide support to the HLW management program in four general areas: (i) activities of the Advisory Committee on Nuclear Waste, (ii) international activities, (iii) preparation of user needs, and (iv) general support to HLW management.

Finally, it is likely that the number of activities undertaken by the PA program will be greater than can be realistically conducted given budgetary, schedule, and staff-level constraints. Therefore, the PA program will implement a strategy that will allow it to prioritize the activities and make decisions regarding those activities that should be undertaken and when they will be started. Activities will be first assigned to one of three categories: (i) activities that the NRC is mandated by law to conduct, (ii) activities that the DOE should undertake, and (iii) NRC discretionary activities. Activities in the first category will be assigned highest priority, while activities in the second category will be suggested to DOE through pre-LA consultations. NRC discretionary activities will be evaluated and prioritized using an explicit utility system that determines: (i) the expected benefit of an activity, (ii) the programmatic risk associated with undertaking the activity (e.g., technical feasibility, timeliness, and ability to recover from failure), and (iii) cost of the activity.

1 INTRODUCTION

1.1 PURPOSE AND SCOPE

The primary purpose of this Performance Assessment Strategic Plan (PASP) is to define the major elements of the Nuclear Regulatory Commission (NRC) performance assessment (PA) program that are essential to the effective implementation of the NRC proactive and reactive regulatory programs for the disposal of high-level waste (HLW). The PASP lays out the goals and objectives of the PA program as well as the spectrum of activities that will be conducted from the present to the time of submittal of the license application (LA) for the proposed HLW repository at Yucca Mountain (YM). It is expected that the PA program activities will continue beyond the LA submittal and into the operating and performance confirmation period.

During the pre-LA period, the NRC will use the PASP to guide activities in five major areas: (i) fulfillment of legislative mandates, (ii) technical interactions with the U.S. Department of Energy (DOE) and its contractors, (iii) contributions to the License Application Review Plan (LARP), (iv) building a technical assessment capability, and (v) supporting other activities of the HLW management program. The PA program outlined in the PASP is expected to establish the planning basis for:

- Developing the NRC independent capability to evaluate the performance of the proposed repository

- Providing timely and meaningful feedback on technical issues to the DOE during the prelicensing phase, in fulfillment of its statutory duties

- Providing input to key decision points, as outlined later in this document

- Integrating the NRC schedule of PA activities with that of the DOE

In addition, the PASP will serve as a vehicle for informing other organizations, such as the NRC Advisory Committee on Nuclear Waste (ACNW), the State of Nevada, and other affected parties about the long-range plans for the NRC PA program.

As outlined in the DHLWM program's Overall Review Strategy (ORS) (Johnson, 1993), the PASP is required to address both preclosure and postclosure PA activities. The present version of the PASP focuses only on the postclosure PA of the proposed HLW repository. A later version of the PASP will include the preclosure PA activities. The PASP is a working document that will be periodically updated. The status of progress made by the PA program in executing the elements of the PASP is expected to be reported on a periodic basis.

It is important to state that the PASP does not address the qualitative and other quantitative assessments that must be conducted by the NRC outside of PA. The PA program is not concerned with the determination of the presence (or absence) of favorable conditions (FACs) and potentially adverse conditions (PACs), but it is concerned with the impacts on repository performance of those FACs and PACs determined to be present. The determination of presence or absence of FACs and PACs is being addressed by other elements of the HLW management program.

1.2 ROLE OF PERFORMANCE ASSESSMENT

The U.S. Environmental Protection Agency (EPA) regulation of 40 CFR 191.12(q) formally defines PA as:

> "... an analysis that (1) identifies processes and events that might affect the disposal system; (2) examines the effects of these processes and events on the performance of the disposal system; and (3) estimates the cumulative releases of radionuclides, considering the associated uncertainties, caused by all significant process and events. These estimates shall be incorporated into an overall probability distribution of cumulative release to the extent practicable."

The EPA definition for PA emphasizes the calculational process that is required to assess compliance with the containment requirement of 40 CFR Part 191. However, the NRC adopts a much broader view of PA, namely, that it is an intricate combination of modeling, scientific and technical studies, and safety regulations (Coplan et al., 1990).

Under the provisions of the Nuclear Waste Policy Act (NWPA), as amended, the DOE and the NRC have different responsibilities related to the disposal of HLW in a geologic repository. The DOE is responsible for the siting, design, demonstration of compliance with the requirements of 10 CFR Part 60, construction, decommissioning, and closure of the HLW repository. Consequently, the role of PA in the DOE program is to address such issues as: (i) understanding how the different components of the disposal system affect the overall performance and guiding the repository design, (ii) utilizing long-term PAs to guide the site characterization program, and (iii) conducting total-system PAs (TSPAs) and subsystem PAs to demonstrate compliance with the applicable regulations.

In contrast, the NRC has statutory responsibility for:

- Evaluating the DOE LA
- Making a determination of the adequacy of the DOE demonstration of compliance
- Making a decision regarding the issuance of a construction authorization for the proposed HLW repository

Thus, the NRC will use its PA program as one of the vehicles to develop the independent review capability to evaluate the DOE PAs during the prelicensing phase, as well as in the LA. It is expected that the DOE PAs may be considerably more comprehensive in both depth and breadth than the NRC PAs. Because of resource constraints, the NRC will perform in-depth reviews and independent analyses of selected aspects of the DOE PAs deemed of critical importance to a determination of regulatory compliance.

The PA activities will play a major role in providing input to the regulatory framework developed by the HLW management, as well as to the identification and prioritization of research needs for the Office of Nuclear Regulatory Research (RES). Some specific areas where PA will make direct contributions include:

- Quantitatively evaluating the closure of individual KTUs identified in the NRC LARP
- Assessing regulatory uncertainties associated with the implementability of regulatory requirements
- Contributing to the integration of technical assistance and research projects
- Providing input to the prioritization of the NRC RES activities
- Identifying the key processes and factors controlling the performance of the total disposal system and its components

These and other PA-related activities are important in achieving the basic goals of the HLW management program.

Many relatively complex technical issues of a multidisciplinary nature are involved in assessing the isolation performance of a HLW repository. To meet the NRC mission of protecting public radiologic health and safety, the NRC must, during the licensing process, take positions regarding the behavior of the repository in the context of the regulatory performance objectives. In addition, the NRC will comment on and provide guidance to the DOE on the completeness and adequacy of the site characterization program and engineering design, as well as on the DOE LA to construct, operate, and close the proposed YM repository. The PA program will provide a sound technical basis for the NRC positions and comments on the DOE repository program within the framework of regulatory performance objectives.

1.3 HISTORY OF THE NUCLEAR REGULATORY COMMISSION PERFORMANCE ASSESSMENT PROGRAM

The NRC PA program was originated in the early 1970s. In 1976, the NRC contracted Sandia National Laboratories (SNL) to develop a comprehensive PA methodology for the evaluation of HLW disposal in bedded salt formations, which was one of several disposal media under consideration at that time. The various components of the PA methodology were developed and applied to a hypothetical HLW repository in salt (Cranwell et al., 1987). The SNL PA methodology was later revised and extended to HLW repositories in other media, namely basalt and tuff. The revised PA methodology is described in Bonano et al. (1989) which includes an example application to a hypothetical repository in basalt. The methodology was further extended for a repository in unsaturated fractured tuff formations (Gallegos, 1991). In contrast to the previous SNL studies for the bedded salt and basalt geologies, the latter study did not demonstrate the PA methodology on a hypothetical repository in tuff.

In 1988, the NRC initiated the Iterative Performance Assessment (IPA) exercises for the purpose of maintaining and enhancing the NRC staff's independent capability to evaluate the DOE TSPAs for the proposed repository at YM. The Phase 1 exercise of IPA, which was conducted in CY89 with minimal participation of the NRC contractors, provided an initial demonstration of a PA methodology applicable to the YM site (Codell et al., 1992). IPA Phase 2, which was initiated in CY90, was a much broader effort and involved both the NRC and the Center for Nuclear Waste Regulatory Analyses (CNWRA) staff (Federline et al., 1994). The recently completed IPA Phase 2 exercise provided several benefits to the PA program, including:

- Contributing to understanding the relative roles of potential disruptive events (i.e., future states)

- Contributing to identifying the key factors controlling the estimation of total-system performance

- Providing the experience and insights necessary for effective prelicensing interactions with the DOE

- Establishing the knowledge base necessary for contributing to the Systematic Regulatory Analysis (SRA) process and development of the LARP

The final report for IPA Phase 2 is being completed concurrently with this document.

1.4 REPORT ORGANIZATION

In addition to this introduction chapter, the PASP includes three other chapters:

- Chapter 2—Goals and Objectives of the PA program

- Chapter 3—Situation Analysis of HLW PA program

- Chapter 4—PA program Activities

In Chapter 2 of the PASP, the primary goals and objectives of the PA program are identified and described in the context of their relationship to the goals and objectives of the overall HLW management program. The content of Chapter 3 summarizes the current status of the PA program and describes: (i) program participants, (ii) strengths and problem areas, (iii) the regulatory environment, and (iv) planning assumptions. Chapter 4 describes the major PA activities to be conducted from present to the time of LA submittal. In addition, the chapter presents the approach to be used to prioritize future PA activities.

2 GOALS AND OBJECTIVES OF THE PERFORMANCE ASSESSMENT PROGRAM

The goals and objectives of the PA program dictate the spectrum of activities that must be conducted between the present and the submittal of the LA. As used here, goals are those strategic positions that will be attained before the completion of the HLW management program. In contrast, objectives represent the intermediate accomplishments of the program. The PA program goals are derived directly from the top-level goals of the HLW management program. Because of the first-of-a-kind nature of the HLW repository program, many diverse and complex issues must be addressed in order to meet the program goals. For each of those issues, the approaches that will lead to its resolution will be discussed. These approaches are translated into specific activities. The issues and approaches (or strategies) are discussed in Chapter 4.

2.1 GENERAL BACKGROUND

The NRC has the statutory responsibility for evaluating the DOE LA and other actions related to construction, operation, and closure of a HLW geologic repository; the only site under present consideration for such a repository is YM in Nevada. In its LA, the DOE will need to provide "compliance demonstrations" to show that the YM site repository would meet the applicable regulatory requirements. Consistent with its mandate under the Nuclear Waste Policy Act of 1982 (NWPA), the NRC staff will review the compliance demonstrations in the LA and conduct independent PAs to arrive at "compliance determinations." The NWPA, as amended, gives the NRC the broad mandate for:

- Promulgating regulations
- Reviewing and commenting on the DOE Mission Plan
- Providing input to the DOE Project Decision Schedule
- Reviewing and commenting on the sufficiency of the DOE site characterization plans
- Providing preliminary comment on the sufficiency of the DOE analysis of site characterization data and waste-form proposal
- Supporting state, local, and tribal participation
- Preparing status reports in its LA review to Congress
- Making a licensing decision for Construction Authorization
- Focusing on the YM site

This mandate requires the NRC staff to conduct proactive prelicensing interactions with the DOE. These interactions will involve a significant effort to review the DOE estimates of the projected preclosure safety analyses and postclosure PAs for the proposed repository at YM.

The NRC regulation, 10 CFR Part 60, establishes specific performance objectives for the preclosure (§ 60.111), and the postclosure periods (§ 60.112) for the overall system and for particular barriers (§ 60.113). The performance objectives of § 60.111 concern protection against radiation exposures and the release of radioactive materials until permanent closure of the repository, and retrievability of emplaced wastes. The NRC regulation incorporates the U.S. Environmental Protection Agency (EPA) standards by reference in § 60.112 which requires that releases from the repository to the accessible environment, following permanent closure, conform to the standards established by the EPA. The EPA standard, 40 CFR Part 191, specifies three broad quantitative performance requirements for the overall repository system:

- Limits on the cumulative release of radioactivity at the accessible environment boundary over 10,000 yr (Containment Requirements)
- Limits on dose to individuals for the first 1,000 yr (Individual Protection Requirements)
- Limits on permissible concentrations of radionuclides in special sources of groundwater for the first 1,000 yr (Groundwater Protection Requirements)

Originally promulgated in 1985, the EPA regulation was later remanded by court order. Currently, a revised set of standards specific to the YM site is being developed in accordance with the provisions of the Energy Policy Act of 1992 (ENPA). It is anticipated that the revised EPA standards for the YM site will not be substantially different from those currently contained in 40 CFR Part 191, particularly as they pertain to the need to conduct a quantitative PA as the means to estimate postclosure performance of the repository system. Repository system, as used here, refers to the combination of (i) emplaced wastes, (ii) the engineered barrier system, (iii) the engineered disposal facility, and (iv) the geologic medium surrounding the facility (i.e., within the controlled area).

The regulations in § 60.113 establish specific performance objectives for the repository subsystems: (i) geologic setting and (ii) engineered barrier system (EBS). These performance objectives require the following:

- Substantially complete containment of waste in the waste packages for a minimum period of 300 to 1,000 yr after closure [§ 60.113(a)(1)(i)(A) and 60.113(a)(1)(ii)(A)]
- Controlled fractional release rate from the EBS based on the inventory at 1,000 yr after closure [§ 60.113(a)(1)(i)(B) and 60.113(a)(1)(ii)(B)]
- Prewaste-emplacement groundwater travel time (GWTT) of at least 1,000 yr [§ 60.113(a)(2)]

The use of subsystem performance objectives is consistent with the multiple barrier concept and contributes to developing reasonable assurance that the EPA standards will be met.

2.2 PROGRAM GOALS

As stated in the ORS (Johnson, 1993), one of the overall goals of the NRC HLW management program is to "help ensure that the Commission can make its construction authorization decision within the 3-yr statutory mandated time period," regarding construction authorization for a HLW repository. Consistent with this overall goal, the PA program goals are to:

- Conduct PA-related activities (e.g., IPA, subsystem PAs, evaluations of KTUs)

- Develop regulatory products [e.g., technical guidance and positions, compliance determination methods (CDMs), and reviews of DOE study plans and TSPA reports]

- Maintain and refine the staff expertise in areas related to TSPA and subsystem PA (necessary to carry out the NRC statutory responsibilities)

These goals consist of establishing, maintaining, refining, and applying a suitable capability in PA in the conduct of all prelicensing and licensing activities.

2.3 PROGRAM OBJECTIVES

The HLW management Plan identifies four major program objectives consisting of: (i) refine 10 CFR Part 60 so that it is clear and complete, provide DOE with formal guidance documents regarding a complete and high-quality LA; (ii) develop the staff's review capability (i.e., LARP, IPA, technical analysis methods) to support both prelicensing and LA reviews; (iii) conduct research that is integrated with LARP development and supports the staff's pre-LA activities and LA reviews; and (iv) conduct pre-LA reviews and Quality Assurance (QA) audits to provide guidance to DOE on-site characterization requirements, ongoing design work, and licensing issues important to DOE's development of a complete and high-quality LA.

The general objectives of the PA program, to a large degree, parallel the overall objectives of the HLW management program, but the former are focused on only PA aspects. Thus, the four PA program objectives are: (i) maintain and refine the regulatory structure pertaining to PA (i.e., 60.111, 60.112, 60.113, and 60.122), (ii) develop a technical assessment capability in total-system and subsystem PA for conducting prelicensing and licensing reviews, (iii) conduct pre-LA reviews and support QA audits, and (iv) identify and prioritize user needs in PA (i.e., basis for research projects) for RES, and monitor progress towards meeting those needs.

3 SITUATION ANALYSIS OF HIGH-LEVEL WASTE PERFORMANCE ASSESSMENT PROGRAM

Before describing the PA program activities in detail, it is beneficial to first give a brief situation analysis of the current program. The situation analysis for the NRC HLW PA program consists of the following:

- Owners and customers of the HLW PA program
- NRC HLW program participants
- Strengths and problem areas of the HLW PA program
- Expected regulatory environment
- Planning premises

As used here, the owners and customers refer to the organization responsible for implementing the PASP and those utilizing the technical and regulatory products of the PA program activities, respectively.

3.1 OWNERS AND CUSTOMERS OF THE HIGH-LEVEL WASTE PERFORMANCE ASSESSMENT PROGRAM

There are two owners of the NRC HLW PA program: (i) the Director of the Division of High-Level Waste Management, Office of Nuclear Material Safety and Safeguards (NMSS), and (ii) the Chief of the Hydrology and Systems Performance Branch, HLW/NMSS. These two individuals have both technical and programmatic responsibility for the implementation of the PA program. The technical aspects of the PA program are the responsibility of the Section Leader in charge of the Repository Performance Assessment Section. This individual guides the conduct of the IPA, the development of models and associated computer codes, the maintenance and refinement of staff expertise, and the closure of technical issues that feed directly into the PA approach or methodology.

The prime customer of the PA program is the Director, NMSS, to whom the Commission has delegated this responsibility. The authority and responsibility of the Director and Commissioners are conferred in 10 CFR Part 60 (e.g., § 60.18, § 60.31). For that reason, the Commission is also a customer of the PA program.

3.2 NUCLEAR REGULATORY COMMISSION HIGH-LEVEL WASTE PROGRAM PARTICIPANTS

The NRC HLW program consists of several different NRC-internal and -external organizations. The NRC management in the NMSS and HLW has responsibility for the technical and programmatic implementation of the program. Within the HLW management, the Hydrology and System Performance Assessment Branch and the Repository Performance Assessment Section have programmatic and technical responsibility for the implementation of the PA program. Other organizations within the HLW management actively participating in the PA program include:

(i) HLW/NMSS Hydrologic Transport Section

(ii) HLW/NMSS Geology-Geophysics Section

(iii) HLW/NMSS Geotechnical Section

(iv) HLW/NMSS Materials Section

(v) RES Waste Management Branch/Hydrology and PA Section

(vi) HLW/NMSS Projects Section

(vii) Various elements of the CNWRA

As indicated above, the NMSS, RES, and CNWRA staff actively participate in all aspects of the PA program.

The ACNW, in its advisory role, interacts frequently with HLW PA program participants in both NMSS and RES. Therefore, the ACNW is considered a program participant. Occasionally, the Commission, individual Commissioners, and their staffs also interact with the HLW PA program participants. Finally, there is the CNWRA, which provides programmatic and technical support to the NRC in all aspects of the HLW PA program.

3.3 STRENGTHS AND PROBLEM AREAS OF THE HIGH-LEVEL WASTE PERFORMANCE ASSESSMENT PROGRAM

The strengths of the NRC HLW PA programs are many, but two are particularly important. First, the HLW PA program through the years has developed and maintained an excellent technical and regulatory staff. This excellence is recognized by the many key roles that the NRC staff have been requested to fill in international organizations such as the Nuclear Energy Agency (NEA) and the International Atomic Energy Agency. The NRC staff capabilities are supplemented by the excellent staff at the CNWRA. Second, because the NRC programs are considerably smaller than those at the DOE, the NRC has more agility than the latter, and in turn, can address issues in a much shorter timeframe than their DOE counterparts.

Some of the problem areas encountered by the PA program include:

(i) The unexpected changes to the schedule of the repository program and focus of the DOE work (both of which are beyond the NRC control) force the NRC to frequently revise its program accordingly

(ii) The need for frequent interactions with the DOE can adversely impact the timely completion of long-term developmental activities

(iii) The challenge of integrating many different disciplines, some of which are traditionally qualitative, under the quantitative perspective of PA

(iv) The need to conduct analyses of a broad technical scope with a small number of staff members and contractors

(v) The need to achieve effective communication, coordination, and resolution of logistic issues with staff spread among three different organizations (NMSS, RES, and CNWRA)

(vi) The need to continue to improve the infrastructure (computers, support staff, etc.) required to support the successful and timely implementation of the PA program

3.4 EXPECTED REGULATORY ENVIRONMENT

The NRC has promulgated regulations dealing with public radiological health and safety aspects of the disposal of HLW in geologic repositories. These regulations are contained principally in 10 CFR Part 60, but also include provisions in Part 2 relating to procedural aspects of the LA review process and provisions in Part 51 pertaining to implementation of the National Environmental Policy Act (NEPA). The regulations, which conform to the requirements of Section 121(b) of the NWPA, as amended, address certain pre-LA reviews as well as the review of the LA. Other regulations that might influence the design of the HLW repository are 10 CFR Parts 71 (transportation) and 72 (fuel cycle facilities). These regulations define interfaces among the transportation and interim storage facilities and the repository, particularly with regard to the design requirements in 10 CFR Part 60.

In 1985, the EPA promulgated its standard for the disposal of spent fuel, high-level, and transuranic waste (40 CFR Part 191). This regulation contained three postclosure requirements: (i) containment, (ii) individual protection, and (iii) groundwater protection. In 1987, the U.S. Court of Appeals for the First Circuit vacated the individual protection and groundwater protection requirements, and remanded the regulation to the EPA for revision and repromulgation. As a result of this court action, the EPA recently issued a revision of 40 CFR Part 191 applicable to disposal of spent fuel, high-level, and transuranic wastes in facilities other than those under the purview of the NWPA of 1982, as amended. The EPA plans to promulgate a revision to 40 CFR Part 191 that is applicable to facilities that come under the NWPA, as amended.

In 1990, the Radioactive Waste Management Committee of the National Academy of Sciences (NAS) published a document advocating a re-examination of the U.S. HLW repository program. One of the issues discussed in that document was the need for a thorough examination of the regulations (both EPA and NRC) governing the disposal of HLW to determine the scientific and soundness of the specific requirements contained in those regulations.

The ENPA of 1992 raised three issues which the NAS has been tasked to comment on: (i) whether a health-based standard, based on doses to individual members of the public, would be reasonable; (ii) whether postclosure oversight of a repository, based on active institutional controls, can prevent an unreasonable risk in breaching of the repository's barriers or of causing unacceptable radiation doses to the public; and (iii) whether it is possible to make scientifically supportable predictions of the probability of human intrusion for 10,000 yr.

The most immediate impact, regardless of any changes to the EPA standard, is the need for significant staff interactions with both the NAS and the EPA over at least the next two years as each organization responds to the ENPA. Additional staff analyses and modeling will be required to support staff interactions on specific options to be considered by the NAS. The staff estimates that this would require a reallocation of resources and delay some work in the program. In addition, the schedule for the staff's already planned rulemaking to conform 10 CFR Part 60 to the revised EPA standard would need to follow the aggressive statutory schedule mandated by ENPA. Meeting such a schedule would mean partially overlapping the NRC schedule with the EPA schedule for revising 40 CFR Part 191.

As a result of NAS recommendations on 40 CFR Part 191 and on HLW disposal regulations in general, some revisions to 10 CFR Part 60 may be necessary. The nature and scope of those revisions are unknown and, therefore, specific impacts to the activities in the PA program cannot be identified.

3.5 PLANNING PREMISES

The PA program outlined in this document is based on both basic and detailed planning assumptions. Any changes in these assumptions may result in the need to re-examine the HLW management program's approach, and/or the associated activities and schedules. Therefore, to place this document in its proper perspective, these planning premises are briefly discussed below.

The Commission is required to make a construction authorization decision regarding a HLW geologic repository at YM (the only Congressionally-mandated candidate site) within three years of a DOE LA submittal (a 1-yr extension is allowed, if necessary). This means the staff review of the LA must be focused on areas of critical importance to compliance determinations. These critical areas will be identified and addressed through: (i) extensive prelicensing interactions with the DOE and review of the DOE documents, (ii) the SRA process for developing the LARP (including interactions with PA), (iii) the development of an independent PA capability, and (iv) focused research to identify and build a scientific basis for assessing significant phenomena and processes.

The DOE is charged with evaluating the suitability of the YM site for the long-term disposal of HLW, and if found to be suitable, demonstrating to the NRC that the requirements applicable to the repository will be met. The DOE is directed by law to adequately characterize the site and demonstrate the long-term performance of a repository in isolating waste. They are expected to predict overall system and subsystem performance through the use of mathematical models and numerical codes supported by an appropriate combination of field and laboratory tests, natural analog studies, etc. The mission of the NRC, on the other hand, is to assure that the public's radiological health and safety are adequately protected. Therefore, the NRC staff will need to assess the DOE compliance demonstrations and determine whether the regulations have been met with reasonable assurance.

In the PA area, the NRC approach will be one of reviewing the DOE's entire PA at a broad level of detail and conducting more detailed reviews in the most significant or critical areas. In addition, the NRC staff will develop an independent estimate of overall repository performance for comparison to the DOE estimate, although not at an equivalent level of precision or with the same level of detail. In its prelicensing and licensing review activities, the staff will rely, to a great extent, on the site data collected by the DOE, supplemented by independent analysis of such data, and additional data and interpretations gathered through NRC independent research. Also, due to resource constraints that limit the amount of mathematical model and computer code development, the staff may need to acquire and evaluate computer codes developed by the DOE or other outside organizations and implement them within the IPA activity.

Other planning premises include:

(i) The quality and quantity of the NRC and their contractor staff will remain stable.

(ii) The regulatory structure for the U.S. HLW program is likely to change and the NRC needs to participate in crafting these changes.

(iii) The NRC can benefit technically and programmatically through participation in selected international PA activities.

(iv) Because there is no formal training available to gain necessary expertise in PA, the expertise necessary for the NRC PA program to fulfill its mission will, by necessity, be developed through the actual conduct of PA exercises and calculations. It is imperative that a cadre of individuals experienced in PA be maintained because the NRC cannot readily acquire this expertise due to a limited pool of talent being available nationally and internationally.

These assumptions are based on currently available information. Changes to these assumptions could result from changes to the DOE HLW program, such as: (i) acceleration (or deceleration) of the program, (ii) disqualification of the YM site, or (iii) introduction and/or implementation of a co-disposal concept.

Since issues that precluded the DOE from initiating the site characterization of YM (i.e., the NRC Site Characterization Analysis objections and permits by the State of Nevada) have been largely resolved, the DOE has requested a significant increase in its resources to implement the site characterization program at a much higher level than originally planned. If the DOE were to be successful in implementing such an accelerated site characterization program, the NRC may have to increase the level of effort devoted to its reactive activities. If such a situation were to arise and additional resources were not forthcoming, the NRC may have to conduct the reactive activities at the expense of curtailing its proactive program, a situation that would most likely delay critical PA activities.

If the YM site were to be disqualified, the immediate impact would be stoppage of all site-specific activities, including review of site-specific documents, development of site-specific components of the LARP, and development of site-specific technical assessment capabilities (TACs). However, other activities such as refinement of regulatory requirements and the Format and Content Regulatory Guide (FCRG), as well as the development of capability to perform IPAs and preparation of general analysis methods, would be minimally impacted, since they support activities needed in any repository licensing program.

Other, perhaps less obvious, issues that could impact the NRC program are decisions by the DOE to dispose of greater-than-class-C low-level wastes (LLW) in deep geologic repositories or dispose of liquid HLW contained at several defense sites (primarily at the Hanford, Washington Reservation). In the first situation, the staff would need to examine 10 CFR Part 60 and determine: (i) what additional design criteria would be needed, and (ii) what changes would be needed in the performance objectives. In the second case, NRC on-site licensing of the Hanford HLW tanks would have to be considered, because that appears to be the DOE preferred method for disposal of those wastes.

4 PERFORMANCE ASSESSMENT PROGRAM ACTIVITIES

Within the planning horizon of the PASP, a broad spectrum of PA activities will be conducted by the NRC staff and the CNWRA. These PA activities are aimed at fulfilling the broad program goals and objectives as well as responding to the primary activity drivers of the HLW management program. These PA activities can be grouped into five categories. These categories are titled to succinctly indicate the origin and nature of the PA activities:

- Legislative mandates
- Interactions with the U.S. DOE
- SRA and preparation of the LARP
- Technical assessment and research
- Support to HLW management program

The following sections discuss the basis for PA activities and outline the associated PA activities.

4.1 LEGISLATIVE MANDATES

The NRC HLW program is primarily shaped by the statutory requirements of the NWPA, the Energy Policy Act of 1992 (ENPA) and the regulatory requirements of 10 CFR Part 60. This section describes the PA activities that are determined by these statutory and regulatory requirements.

4.1.1 Energy Policy Act-Related Activities

Under the provisions of the ENPA, the EPA was required to commission a study with the National Academy of Sciences (NAS) to develop the technical bases for standards applicable to the YM site. In accordance with Section 801(a)(2) of the ENPA, an NAS panel is conducting a study to provide findings and recommendations to the EPA for use in formulating revised standards. The NAS panel is specifically charged with addressing three questions:

(i) Whether a health-based standard, defined by doses to individual members of the public from release of radionuclides to the accessible environment, will provide a reasonable standard for protection of the health and safety of the general public

(ii) Whether it is reasonable to assume that a system for postclosure oversight of the repository can be developed, based upon active institutional controls, that will prevent an unreasonable risk of breaching the repository's engineered barriers, or increasing the exposure of individual members of the public to radiation beyond allowable limits

(iii) Whether it is possible to make scientifically supportable predictions of the probability that the repository's engineered or geologic barriers will be breached as a result of human intrusion over a period of 10,000 yr

The NAS panel is scheduled to complete and present their study results to the EPA by the end of CY94. The EPA is required by the ENPA to promulgate a standard for YM based upon and consistent with the NAS findings and recommendations. These standards are to be promulgated within 1 yr of receipt of the findings and recommendations.

The NRC is an active participant in the ongoing NAS panel meetings and is currently formulating positions on various aspects of the EPA standard. A wide variety of PA activities are envisioned such as: (i) examining the regulatory history of radiation protection standards, (ii) searching for references in the 10 CFR Part 60 statements of consideration that relate to the persistence and effectiveness of institutional controls, (iii) reviewing and evaluating the NAS panel's consultant reports, and (iv) articulating the NRC positions in formal presentations to the NAS panel.

Because of possible inclusion of a dose standard in 40 CFR Part 191, the NRC will need to study the implementability of such a standard as well as the possible use of the reference biosphere concept. Such studies would be conducted in conjunction with the IPA exercises. In addition, the NRC staff will review and comment on the final EPA standards as well as determine what conforming amendments to 10 CFR Part 60 must be made. The schedules for these PA activities are contingent upon the schedule of the NAS panel and the EPA.

4.1.2 Nuclear Waste Policy Act-Related Activities

In general terms, the NWPA, as amended, outlines nine items that define the NRC's responsibilities in the repository program. These items consist of: (i) promulgating regulations; (ii) reviewing and commenting on the DOE Mission Plan; (iii) providing input to the DOE Project Decision Schedule; (iv) reviewing and commenting on the DOE site characterization plans; (v) providing preliminary comment on the sufficiency of the DOE at-depth site characterization analysis and waste form proposal; (vi) supporting State, Local, and Tribal participation; (vii) preparing status reports on its LA review to Congress; (viii) making a licensing decision for construction authorization; and (ix) focusing on the YM site. Since the passage of the NWPA of 1982, many of these items have been achieved, or progress has been made toward achieving them.

In relation to the mandated items, PA activities during the prelicensing period will require technical reviews of the following:

- 10 CFR Part 60 to resolve regulatory and technical issues related to its implementation (i.e., regulatory uncertainties)
- DOE Site Characterization Plan (SCP) progress reports, SCP study plans, and the periodic Early Site Suitability Evaluation (ESSE) reports
- DOE repository and waste package designs, waste-form proposals, and site characterization analyses

The PA activities in these areas will be conducted with the aim of ensuring a sound regulatory framework and providing early feedback to the DOE on their site characterization and design programs.

4.2 INTERACTIONS WITH THE U.S. DEPARTMENT OF ENERGY

Interactions with the DOE on PA topics and issues is an essential prerequisite to developing consensus on: (i) PA methodology applicable to the YM site and (ii) appropriate methods for demonstration of compliance with the regulations. The NRC PA activities involving interactions with the DOE fall into three general areas:

- Reviews of the DOE TSPAs and subsystem PAs, related topical reports, and LA Annotated Outline (AOs)
- Participation in PA technical exchange meetings, technical meetings, and QA audits
- Preparation of guidance on PA methodology

Interactions with the DOE and its contractors are highly beneficial to the NRC in highlighting differences in PA modeling approaches, assumptions, and data. In addition, they aid in identifying areas requiring regulatory guidance.

4.2.1 Review of U.S. Department of Energy Technical Reports

The objective behind staff reviews of the DOE pre-LA activities and documents is to provide guidance to the DOE on site characterization requirements, ongoing design work, and licensing issues important to the development of a complete and high-quality LA. These reviews help to ensure that the NRC can fulfill its statutory responsibilities requiring: (i) comments on the sufficiency of the DOE site characterization program and waste form proposal, and (ii) a licensing decision for construction authorization. Reviews are conducted consistent with the general phases and schedule of the DOE activities so the NRC staff can provide timely guidance and avoid delays to the DOE program.

The staff's approach is intended to focus on potential licensing issues and to review in detail how the DOE is addressing these issues in its site characterization and design program. This will be accomplished through staff reviews of the DOE program documents such as SCP progress reports, study plans, topical reports, major design reports, LA AOs, TSPAs, and subsystem PAs. Another focus of the review will be the resolution of previously raised concerns. Furthermore, concerns documented as a result of technical reviews that might lead to the staff not docketing the LA (i.e., objections to LA submittal) if not resolved by the DOE, will also be considered by the staff in preparing its preliminary comments on the sufficiency of site characterization, as required by the NWPA, as amended.

Staff comments will provide the DOE with guidance for revising its program. Such guidance is needed to help ensure that radiological health and safety are appropriately considered in all phases of the program. By providing early guidance, the staff is able to minimize impacts on schedule.

Reviews will be supported by analyses, such as the staff's IPA activities conducted during the pre-LA phase and work being completed in the development of other technical assessment methods. The staff will also use results of its efforts on reducing the regulatory uncertainties related to performance objectives in 10 CFR Part 60 to develop guidance on how the rule will be implemented. This will allow the staff to provide comments to the DOE, during site characterization, that will be consistent with the manner in which the NRC will conduct its licensing review.

4.2.2 Participation in Meetings and Audits

The PA staff will take part in formal interactions (i.e., technical meetings) with the DOE and its contractors and other stake holders (i.e., State of Nevada, affected counties, and Indian tribes). Technical meetings are periodically held to: (i) review and consult on interpretations of data, (ii) identify potential licensing issues, (iii) agree upon the sufficiency of available information and data, and (iv) agree upon methods and approaches for the acquisition of additional information and data as needed to facilitate NRC reviews and evaluations and the resolution of potential licensing issues. These meetings may be a forum for the expression of technical/regulatory policy, and negotiation of commitments and agreements on the acceptability of actions with all involved parties. Technical exchanges, on the other hand, are conducted to discuss a specific technical and/or regulatory topic. Their primary purpose is to work toward the resolution of technical or regulatory issues. Although these interactions are intended to raise issues as early as possible and work toward their resolution in order to facilitate efficient review of the LA in the mandated timeframe, issues cannot be fully resolved prior to the licensing process except by rulemaking.

The HLW management staff will be reviewing the DOE QA program, conducting a limited number of independent audits, observing the DOE audits, and conducting surveillance prior to the LA submittal. The purpose of these reviews and audits is to determine the acceptability of the DOE QA procedures and gain confidence that the overall QA program is being implemented in an acceptable manner. In addition, the observation audits and inspections provide the staff an opportunity to judge the effectiveness of the DOE audits of its own QA program. As site characterization and design work increase, the staff anticipates that the number of DOE QA audits and its level of effort will increase accordingly. The PA staff may participate as observers in the audits of the DOE and its contractors. As observers, the staff will have the opportunity to examine first hand the inner workings of the DOE PA program.

This approach has several benefits. First, it ensures that the DOE has developed acceptable QA plans, and that they are being properly implemented. This will give the NRC staff confidence that the data being collected can be confidently used in the licensing process. Second, confidence in the acceptability of the DOE QA program complements the audit approach of both the pre-LA technical reviews and the LA compliance reviews. Finally, based on years of reviews and audits, the staff will gain the necessary experience to determine whether the DOE compliance demonstrations in the LA have been prepared under acceptable QA programs.

4.2.3 Guidance Preparation

One of the outcomes of interactions with the DOE at technical exchanges and technical meetings is the identification of areas in which the NRC will provide guidance to the DOE regarding approaches that will be acceptable to the staff. To date, five such areas related to PA have been identified in which the staff is expected to develop guidance in the PA: (i) the elicitation and use of expert judgments, (ii) the definition of scenarios and estimation of their probability of occurrence, (iii) the construction of the complementary cumulative distribution function (CCDF) of radionuclide releases to the accessible environment over 10,000 years, (iv) model validation, and (v) biosphere transport. Each of these areas and the specific activities that the staff will conduct to develop the basis for guidance are described below.

4.2.3.1 Elicitation and Use of Expert Judgments

The elicitation of expert judgments has become an integral part of PAs. Bonano et al. (1990) reviewed the areas and techniques that can be used to elicit expert judgments in: (i) selection of scenarios, (ii) development of conceptual models, (iii) model validation, (iv) quantification of parameter uncertainty, and (v) decisions on data collection. The DOE has made abundant use of expert judgments to quantify parameter uncertainties for the YM TSPA (Barnard et al., 1992), and is expected to continue to use expert judgments in the YM project.

Therefore, the NRC has begun addressing the issues and techniques associated with the elicitation and use of expert judgments in PA. NRC-sponsored studies include the review of PA areas where the formal elicitation of expert judgments is warranted and the techniques that could be employed to obtain the judgments (Bonano et al., 1990). More recently, DeWispelare et al. (1993) applied an elicitation procedure largely following that recommended by Bonano et al. (1990) to elicit judgments for estimating the probability of climate change in the YM vicinity. These studies have allowed the NRC to gain a better understanding of the critical issues; two such issues have surfaced: (i) the potential substitution of expert judgments for the collection of data, and (ii) the use of formal expert elicitation. With the expected extensive use of expert judgments by the DOE for the YM TSPA and subsystem PAs, the staff needs to be in a position to determine whether the DOE: (i) restricts the use of expert judgments to those situations for which data collection is not practically possible, and (ii) uses a formal process to elicit the judgments.

The NRC activities are aimed at developing a sound foundation for providing guidance to the DOE on the acceptable use of formal judgment elicitation techniques. The emphasis of such guidance will be on techniques for: (i) selecting experts, (ii) identifying areas to be addressed by the experts, (iii) structuring the elicitation process, and (iv) documenting the process. Guidance on the identification of areas in need of expert judgement will stress the NRC's position that judgments should not be a substitute for the collection of data and/or the conduct of detailed analysis, rather, judgments should be a last recourse when it has been determined that the acquisition of the information using more objective approaches is not feasible.

The NRC's activities consist of five major components: (i) identify specific areas of the DOE PAs where expert judgments are likely to be used, (ii) develop staff experience in applying elicitation techniques, (iii) monitor and review the elicitation and use of expert judgments in other waste disposal programs, (iv) participate in technical exchanges and technical meetings with the DOE related to expert judgments, and (v) develop guidance for the DOE.

4.2.3.2 Definition of Scenarios

Scenario development is another area in which guidance may be necessary. In the staff's analysis of the DOE SCP, the NRC commented that the DOE site characterization program might not acquire all the data necessary for PA activities used to support a LA (Nuclear Regulatory Commission, 1989; Comment 95). This concern was related to inconsistencies in the DOE use of the term "scenario" and approaches used to decide on the inclusion or exclusion of scenarios in the demonstration of compliance with the performance objectives in 10 CFR Part 60. Since the DOE planned to use a preliminary scenario analysis to define and screen a set of scenario classes on which its performance allocation tables were to be based, there is a concern that the SCP performance allocation tables may not be adequate. The anticipated NRC guidance will help define the term "scenario" and address the staff's concern. This guidance will also address the issue of constructing scenarios from fundamental causative events and processes, and screening the resulting scenarios for inclusion in the PA they support.

Scenario probabilities play a central role in the TSPA required by 40 CFR Part 191. Methods for determining the probabilities of plausible future states of the repository environment (e.g. faulting, climate change, volcanism) are not well established, especially for the long period over which repository performance needs to be predicted. This problem is exacerbated for human intrusion scenarios; recent efforts in assessing a probability for human intrusion have not met much success, as pointed out by Bonano and Baca (1994). Guidance on procedures for developing scenario probabilities and the scientific and technical investigations needed to support such probability estimates is needed to clarify the staff's expectations on these matters. Such guidance will need to be developed in concert with the appropriate earth science and/or engineering disciplines.

As discussed in Section 4.3.1, one of the KTUs identified in the application of SRA related to TSPA is the uncertainty in forecasting the future state of the system. Conventionally, this uncertainty is addressed by postulating a set of scenarios; each scenario representing a possible realization of that future state. There are a number of issues associated with the use of scenarios as the vehicle to address this uncertainty. Some of these are: (i) definition of the term "scenario," (ii) assurance of "completeness," (iii) screening of processes, events and scenarios, (iv) consideration of future human actions, and (v) estimation of the probability of events, processes, and scenarios. Each of these issues is discussed more thoroughly in Section 4.3.1.5. Because of the significance of this KTU, the NRC has undertaken a series of activities designed to provide the staff with the necessary insights to address it. These activities, in addition to technical exchanges and technical meetings with the DOE on the development of scenarios and associated probabilities of occurrence, will form the basis for developing and providing guidance to the DOE on this topic.

4.2.3.3 Complementary Cumulative Distribution Function

The remanded version of 40 CFR Part 191 requires that the results of TSPAs be assembled into a CCDF that indicates the probability of exceeding various levels of releases of radionuclides to the accessible environment for 10,000 years following closure of the repository. Thus, the CCDF is a fundamental indicator of whether compliance with the release limits in 40 CFR Part 191, implemented in 10 CFR 60.112, has been demonstrated. A key concern of the staff is that the DOE represents, in the CCDF, the information needed to evaluate the safety of the repository. However, perhaps more important is the approach used by the DOE to decide that a given condition, process, and/or scenario does not impact the performance of the system, and therefore, need not be considered in constructing the CCDF. There are a number of important considerations that go into developing a meaningful CCDF, and development of guidance in this area by the staff is expected. In its review of DOE's TSPA-91 for YM (Barnard et al., 1992), the NRC expressed concern with the method used by SNL to construct the CCDFs.

Through the IPA effort, the staff will evaluate different ways of generating the overall CCDF for cumulative releases, such as the generation of an expected value CCDF by using scenario probabilities to combine conditional CCDFs (Bonano and Wahi, 1990) or the development of a family of CCDFs from which a mean CCDF can be obtained (Helton, 1993). By examining different mathematical approaches for the construction of the CCDF, the staff will be able to reach consensus and provide guidance to the DOE regarding its construction. Important aspects of the NRC's evaluation of CCDF construction approaches will be ensuring that: (i) the approach selected allows the staff to discern the impact of the different sources of uncertainty on the shape of the CCDF, (ii) the approach used to decide those uncertainties quantified and included in the construction of the CCDF is systematic and defensible, and (iii) the CCDF is constructed in a manner that has meaning for protecting public health and safety.

4.2.3.4 Model Validation

Validation of the models used in a PA is likely to be a major issue in the licensing of an HLW repository because the demonstration of compliance will largely rely on the results from predictive PA models; of course, the case for licensability will be supported by extensive qualitative and quantitative evidence provided by site characterization, laboratory studies, natural analogues, etc. Because the usual procedures for validation of engineering models and comparison of predictions to experimental results is precluded for the time periods of interest for the repository, an alternative that will provide an acceptable degree of validation (partial validation) is needed. This issue has been the subject of considerable discussion among international modeling experts. Previous efforts to arrive at a consensus have not been fruitful. It is important that guidance on validation be produced as soon as possible since the DOE is already using models that will have to be validated in some manner, and because even partial validation of models is likely to require experiments over long periods of time.

Similar to the use of scenarios, model validation is another PA-related KTU identified through the SRA process. Therefore, it is discussed more thoroughly in Section 4.3.1.3. The NRC has undertaken a number of activities regarding model validation, and these are discussed in that section. Through these activities, the staff will be able to gain the insights necessary to determine what constitutes adequate validation for PA models. These insights will be used to develop and provide guidance to the DOE on an acceptable model validation approach.

4.2.3.5 Biosphere Transport

One key issue that the NRC will address, as the EPA reviews and acts upon the NAS recommendations on revisions to 40 CFR Part 191, is the possible need to revise the PA methodology to accommodate a health-based standard. It is too early, however, to speculate as to the potential impacts of a revised 40 CFR Part 191 on the PA methodology. The NRC will work closely with both the NAS and the EPA to the extent practicable to address this issue as soon as possible.

Through the IPA effort, the NRC will examine the potential affects on the implementation of 40 CFR Part 191 if the NAS recommends that the EPA use dose or risk as a performance measure. Specific to the issue will be the postulation of assumptions and development of models for exposure pathways that are adequate for prediction over long periods of time (e.g., 10,000 yr).

Many of the important considerations in a strategy for a dose (or risk) model are similar to those required for other models used in PA. A few additional considerations that are specific to a dose (risk) model will be identified. An assessment of dose to demonstrate public health and safety will be a function of the assumptions regarding the characteristics of the members of future societies and how the calculation are performed. Some of the types of assumptions that need to be made include:

- Who is exposed: the maximally-exposed individual (adult, child), the average member of a critical group, a population? What are nutritional requirements of these persons? What is their physiological makeup? What are their lifestyles (outside activities, work locations, etc.).

- Where are the exposed persons located: in the vicinity of the repository, in the region, in the continental USA, globally? Will the size of the exposed population be limited by truncation of dose?

- Which exposure pathways should be considered and what criteria should be used to exclude pathways that make insignificant contributions to dose? Are the pathways constant over time (how is the concept of a reference biosphere applicable to the site selected for the repository?).

- What is the exposure period of concern: 1 yr, 10,000 yr, or more? Is truncation of the time period of exposure appropriate?

- Should the dose (risk) estimates be prepared from a deterministic (best estimate) or a probabilistic assessment?

- How well do the estimates of individual (collective) dose (risk) generated by the models correspond to actual doses (risks)?

- Which type(s) of distributions should be used to express any uncertainties in the results of these analyses, and how should the statistical measures of dose (risk) (e.g., median, mode, percentiles) be used to demonstrate compliance with regulatory limits?

A number of activities are planned to address these considerations. First, the HLW PA program will exploit the expertise already resident at the NRC in the LLW PA program related to the assessment of exposure pathways for determining compliance with 10 CFR Part 61 (e.g., Kozak et al., 1990; Kozak et al., 1993). Other sources of expertise on exposure pathways assessment include the NRC staff involvement in risk assessment studies for nuclear materials facilities, power plants, and decommissioning studies. Second, because the current NRC expertise on exposure pathways assessment has been applied primarily to short-term regulatory periods (e.g., regulatory timeframes for LLW disposal are in the order of hundreds of years), the NRC will participate in international activities, such as the BIOsphere MOdel Validation Study (BIOMOVS), to take advantage of experiences in other radioactive waste disposal programs that are analyzing the level of confidence that can be placed on predictions of biosphere transport for radionuclides over thousands to hundreds of thousands of years (Grogan, 1990). Third, the NRC will investigate the rationale used by other countries (that currently rely on a dose assessment as the primary safety standard for radioactive waste disposal) to propose the inclusion of secondary-derived standards, such as calculated releases of radioactivity to a reference biosphere environment (a similar criterion to that in the containment requirements in 40 CFR 191.13). Apparently, uncertainties associated with predictions of long-term human behavior needed for dose calculations have led regulatory organization such as the U.K. Department of Environment to adopt secondary criteria such as the radionuclides released from the repository should not lead to a significant increase in the radioactivity naturally occurring in the general locality of the facility (Nuclear Energy Agency, 1991). A study in the Nordic countries has led to a proposal for a similar secondary performance measure (Nuclear Energy Agency, 1991).

The information generated from these activities will allow the NRC staff to develop the necessary expertise to: (i) effectively interact with both the NAS and the EPA regarding the practical applicability of a dose-to-man performance measure for HLW disposal, (ii) develop the models and codes necessary to estimate this performance measure, should it be included in a revised EPA standard, and

(iii) provide sound guidance to the DOE in approaches for estimating the dose-to-man performance measure.

4.3 SYSTEMATIC REGULATORY ANALYSIS AND PREPARATION OF THE LICENSE APPLICATION REVIEW PLAN

Implementation of SRA for preparation of the LARP helped focus the staff efforts on key areas to help optimize resource allocation during the review of the LA. The SRA helped identify KTUs and regulatory uncertainties that need be addressed to allow the staff to ensure that it develops the necessary capabilities to conduct effective pre-LA and LA reviews and resolves uncertainties in the definition and implementation of the performance objectives in 10 CFR Part 60 that will ensure the DOE submits a complete and acceptable LA. The SRA process identified PA-related KTUs and regulatory uncertainties. Thus, the discussion that follows addresses these two types of uncertainties:

- PA KTUs

- Regulatory uncertainties

4.3.1 Performance Assessment Key Technical Uncertainties

Using the SRA process, technical uncertainties have been defined to exist where there is a lack of certitude as to how to demonstrate (by DOE) or determine (by NRC) compliance with a regulatory requirement in 10 CFR Part 60. This includes lack of certitude (even controversy) about: (i) methods for obtaining information, (ii) methods for analyzing information, or (iii) the understanding of conditions or processes. It also includes staff concerns with the DOE program documented as objections, comments, or questions.

A KTU is a technical uncertainty which poses a high risk of noncompliance with a performance objective in 10 CFR Part 60. For example, a KTU exists when there is a lack of certitude about the method, approach, and/or technique needed to either demonstrate or determine compliance with a given performance objective. A KTU also exists when (i) there is a lack of understanding about a condition and/or process, (ii) the condition and/or process is plausible, and (iii) the condition and/or process could have either a significant adverse or favorable effect on repository performance.

KTUs are initially identified through staff judgments in the course of its review of the applicable regulatory requirements that the DOE will have to demonstrate compliance with in the LA. KTUs for each applicable regulatory requirement are documented in the LARP. Identification of a KTU will require a more detailed staff review of that portion of the LA. The staff's initial judgments will be examined in the IPA effort to assess the significance of these KTUs on compliance with the appropriate regulations. Additional KTUs may also be identified through the staff's IPA effort as well as other analyses on specific issues believed to be important to repository performance. A formal process will be developed to address KTUs identified outside of the SRA process, for they will need to be formalized.

The SRA process identified five KTUs pertaining to PA: (i) conceptual model uncertainty, (ii) mathematical model and computer code uncertainty, (iii) model validation, (iv) model parameter uncertainty, and (v) uncertainty in the future state of the disposal system. Each of these KTUs and the associated ongoing or planned activities are summarized in the following sections.

4.3.1.1 Conceptual Model Uncertainty

A conceptual model describes the conditions and/or processes believed to exist in the system under consideration (e.g., the total repository system or a specific subsystem thereof), the geometry and dimensionality of the system, the temporal and spatial scales of the conditions and/or processes, the parameters governing the conditions and/or processes, and the initial and/or boundary conditions imposed on the system. Data collected through the DOE site characterization program, coupled with results from laboratory studies and analog studies, will be used to develop a conceptual understanding of conditions at YM, with particular attention to how the system, the site, and the region may evolve over the next 10,000 yr. Examples of conceptual models proposed for YM include models for (i) fluid flow through the fractured-porous rock (Wilson, 1992), (ii) the nature of infiltration or recharge (Lehman, 1992), and (iii) the thermo-mechanical-hydrological-chemical (TMHC) environment around the waste package (O'Connell, 1992; Hodgkinson and Apted, 1992; Walton, 1993, among others).

There are two sources for conceptual model uncertainty. First, different interpretations of data may lead to speculations about the particular conditions and/or processes that exit, or are expected to exist, in the system and the coupling between them. Second, the paucity of data makes it difficult for analysts to decide the level of detail necessary to model the behavior of each identified condition or process. For example, the gamut of interpretations about how to simulate groundwater flow through unsaturated, fractured media ranges from detailed fracture models, to dual-porosity models, to equivalent single porosity models. There are three basic issues associated with conceptual model uncertainty. First, there is a need for a systematic approach to formulate conceptual models from the available data. This lack of uniqueness in the approach to formulate conceptual models may make it difficult to reconcile the NRC and the DOE differences in interpretations. Second, there is a need for a systematic approach for deciding the type of data that should be collected to allow discrimination between different conceptual models and eventually to be able to eliminate one or more conceptualizations from further consideration in the PAs. Third, because data collection is not without limit, it is likely that several alternative conceptual models will remain at the completion of the site characterization program. Therefore, methods need to be explored for representing this residual uncertainty in the estimate of the performance measure(s).

Because an acceptable procedure has not been developed for addressing conceptual model uncertainty, the NRC needs to select the approach the staff will use to determine the representativeness and completeness of conceptual models used by the DOE in their PAs. To decide on the appropriate approach, the staff will conduct activities in four areas:

(i) Detailed reviews of the DOE field studies, and laboratory experiments used to develop, support, and investigate alternative conceptual models

(ii) Review of the DOE YM TSPAs and subsystem PAs

(iii) Evaluation of the effects of alternative conceptual models through the NRC IPA effort and other detailed analyses

(iv) Independent NRC confirmatory research in selected aspects of given conceptual models

By reviewing the data collected by the DOE to develop, support, and investigate alternative conceptual models, the staff should be able to determine the adequacy of each of its conceptual models. The reviews focus on the determination of:

(i) The degree to which the assumption(s) in a given conceptual model is(are) consistent with the available data

(ii) The manner in which contradictory evidence regarding the assumptions is handled (i.e., rejected or used to formulate other alternative conceptual models)

(iii) The manner in which expert judgments were used to formulate conceptual models

The adequacy of a conceptual model depends on two factors: (i) the level of agreement of the assumption(s) imbedded in the model with the available data and established theory, and (ii) the impact of any residual uncertainties in the model on the PA results. To evaluate these factors, the staff will review the DOE TSPAs and subsystem PAs. Such reviews will allow the staff to examine, when a set of models is used in PA analyses, whether there is consistency in the assumption(s) for each of the models in the set. Inconsistencies among the assumptions from one model to the other can easily occur for a complex system such as a HLW repository in deep geologic unsaturated, fractured media. This is particularly important when each model (and the associated computer codes) is developed by a different individual or group of individuals. Finally, by reviewing the DOE's YM PAs, the staff will be able to determine whether the DOE has adequately addressed the impact of alternative conceptual models.

The review of the DOE activities will be crucial for the staff to provide comments and guidance, if necessary, to the DOE during pre-LA. However, the difficulties associated with the formulation of conceptual models, the inherent uncertainty, and its potential significant impact on PA results require that the staff undertake independent activities related to the resolution of this KTU. Formulation and analysis of conceptual models are, and will continue to be, integral parts of the NRC IPA effort. The staff will test selected DOE conceptual models it deems of potential significance. The staff will explore new or revised conceptual models that, based on insights gained, could also be significant to PA and the demonstration (DOE) and determination (NRC) of compliance. These assessments will identify aspects of the DOE or NRC conceptual models that need to be examined in more detail via the collection of new or additional data. This information will be converted into guidance to the DOE in its site characterization program. The staff may also decide to undertake confirmatory research activities needed to examine specific conceptual models or aspects thereof.

The suite of activities just described will help the staff to: (i) explore different approaches for the development of conceptual models, (ii) be prepared to assess the adequacy of the DOE conceptual models both during pre-LA reviews and to provide comments and guidance as necessary, and (iii) determine the adequacy of the DOE representation of residual conceptual model uncertainty in the LA.

4.3.1.2 Appropriateness of Assumptions and Simplifications in Mathematical Models

In order to predict the performance of the system, conceptual models need to be translated into mathematical equations. The set of one or more equations that represents a given conceptual model is the associated mathematical model. The need for solution tractability, in general, requires that simplifying assumptions be involved to reduce the qualitative description in the conceptual model to mathematical equations. Because the validity of the assumptions used in the formulation of the mathematical models cannot be ascertained *a priori*, there is uncertainty associated with these models. The simplifying assumptions leading to a mathematical model notwithstanding, the models used to simulate the behavior of the repository system, or any of its subsystems, are relatively complex and generally are not amenable to analytical solutions. Instead, the solution of these models often requires the use of numerical techniques (such as finite elements and finite differences) implemented in computer codes. The need for computer codes to implement the solution of mathematical models also arises because of the large number of repeated calculations conventionally used to propagate uncertainty in PA models (e.g., Monte Carlo simulation). The use of computer codes introduces uncertainty due to: (i) limitations on computer resources, (ii) computer truncation errors, and (iii) user errors, among others.

The equations in mathematical models can vary in complexity, for example, from simple algebraic expressions to highly nonlinear partial differential equations. The more complex the equations expressing the model, the more difficult it becomes to ascertain the validity of the underlying assumptions. The complexity and size of the associated computer code(s) generally increase commensurately with the complexity of the mathematical model. There is also a general tendency to develop computer codes that eventually grow too large and complex (Morgan and Henrion, 1990). This tendency is driven by the desire, on the part of the developers, to provide analyst with codes that are very flexible and can accommodate a sophisticated mathematical and detailed conceptual models. One such example is the SWIFT code which was developed in the 1980s by SNL for the NRC HLW Program (Reeves et al., 1986). Such codes are hard to use by analysts other than the code developers, and consequently, their application is highly prone to user errors.

Similar to the treatment of conceptual model uncertainty, there is no unique approach for the development and application of mathematical models and computer codes in TSPAs and subsystem PAs. Therefore, the staff will determine the appropriate approach to establish the representativeness and adequacy of mathematical models and computer codes used by the DOE in its PAs. The decision of the appropriate approach will be based on evaluations consisting of:

(i) Detailed review of the DOE mathematical models and computer codes and the process used in developing them

(ii) Review of DOE YM TSPAs and subsystem PAs

(iii) Evaluation of different modelling assumptions through the IPA effort and other detailed analyses

(iv) Development of selected NRC computer codes

By reviewing the approach the employs to develop its PA models and codes, the staff will be in a position to determine:

(i) The adequacy of the mathematical model abstraction process employed to simplify detailed mechanistic model(s) to arrive at the models and codes used in TSPAs and subsystem PAs

(ii) The consistency of DOE mathematical models and computer codes with the associated conceptual models

(iii) The extent to which solution tractability has dominated the selection of simplifying assumptions

(iv) The extent to which the assumptions in the models and codes have been demonstrated to be applicable

(v) The adequacy of documentation and the adherence to QA standards that will facilitate the determination of reliability of the PA codes

The review of the DOE TSPAs and subsystem PAs will allow the staff to determine the adequacy and difficulty (or lack thereof) of applying the models and codes. Of particular interest in this review be:

(i) The consistency between the models imbedded in a computer code and the conceptual model(s) being considered

(ii) The applicability of a general computer code to simulate various conceptual models

(iii) The examination of unique issues arising from the use of the numerical compute code (e.g., mesh design, time-stepping, convergence criteria, etc.)

Through the conduct of the IPA effort and other detailed analyses, the staff will examine the effect of assumptions imbedded in the DOE models and codes on the PA results. This will allow the staff to: (i) identify those assumptions having the largest impact and (ii) identify, from this group, the applicability of those assumptions to the PA for the YM site.

Finally, to adequately review the DOE use of specific mathematical models and the associated computer codes, the NRC may decide to develop independent mathematical models/computer codes. However, the NRC will not undertake major code developments unless they are shown to be warranted. If the staff determines, from the activities already described, that: (i) a model/code does not exist to carry out the necessary review analysis or (ii) a model/code exists that could be utilized, but the staff does not have enough confidence in it, then sufficient justification may exist for the NRC to develop an independent model/code.

4.3.1.3 Validation of Mathematical Models

Conceptual models, mathematical models, and computer codes used by the DOE in the demonstrations of compliance with the overall system and subsystem performance objectives in 10 CFR Part 60 will be based on simplifying assumptions. Therefore, the staff will need to ascertain whether these models and codes, given their intended use, adequately represent the conditions and/or processes existing in the system. Due to the timeframe over which predictions of system or subsystem performance will be made and the complexity of the system, it is not possible to completely validate, in the strict scientific sense, the models (e.g., by comparing the model output to the real world over 10,000 yr). As a result, uncertainty is present. If any confidence is to be placed in the estimates of overall system and subsystem performance, then a sufficient level of confidence must exist that the models and codes used are adequate, given their purpose. This is implied in 10 CFR 60.21(c)(1)(ii)(F):

> "Analyses and models that will be used to predict future conditions and changes in the geologic setting shall be supported by using an appropriate combination of such methods as field tests, *in situ* tests, laboratory tests which are representative of field conditions, monitoring data, and natural analog studies."

The need to build confidence in the models and codes used in PA calculations has been long recognized by the international community. Several international groups, exercises, and forums have been organized to address this important issue. Some examples are the International Transport Code Intercomparison (INTRACOIN) exercises, the Hydrologic Code Intercomparison (HYDROCOIN) exercises, Probabilistic Safety Assessment Group (PSAG) of the NEA, the Chemical Code Validation (CHEMVAL) exercises, the International Transport Model Validation (INTRAVAL) exercises, the Development of Thermo-Mechanical-Hydrological Coupled Validation Exercises (DECOVALEX), and the Validation of Geosphere Flow and Transport Models (GEOVAL) symposia, among others. The aggressive manner in which the international community has pursued the development of a general model validation approach notwithstanding, little progress has been achieved to date. Several limitations are responsible for this lack of progress, namely: (i) the lack of well-defined, meaningful performance measures and/or acceptable criteria directly related to the intended use of the models in PA; (ii) the small temporal and spatial scale of the experiments preclude resolution of the uncertainty due to extrapolation of the data; and (iii) the fact that the experiments tend to capture isolated conditions or processes leaves potentially important couplings untested.

It is recognized that validation is the ideal method for reducing model uncertainty. However, the temporal and spatial scales of the repository system make it impossible to validate models in the strict scientific sense. Therefore, both the DOE and the NRC have adopted the use of the term "partial validation" as indicative of the fact just stated, and of the purpose of validation being to build confidence in the models and not to produce validated models.

There are two major issues that need to be addressed in validation activities: (i) the establishment of meaningful performance measures that resemble the intended use of the models, and (ii) building confidence in the extrapolation ability of the models from data obtained over scales several orders of magnitude smaller than that of the repository system. The first issue is important because it is not practically possible to construct a universal model that is applicable under all different sets of conditions or circumstances. Instead, as long as the models perform well for those conditions relevant to the repository system, it could be claimed that the models are adequate for their intended use and the results they generate will be reliable. The second issue is also important because the demonstration of compliance requires predictions over temporal scales in the order of tens of thousands of years and over areal extents of tens of kilometers.

The NRC's activities for addressing model validation have three basic components: (i) develop, through PA research activities, a systematic procedure for model validation; (ii) continue to participate in bi-lateral (e.g., NRC/SKI) and multilateral (e.g., INTRAVAL) international model validation activities;

and (iii) develop guidance to the DOE regarding the model validation approach. The latter will be the result of experience and insights gained from the previous two components.

The NRC research projects, such as the Las Cruces Trench Site (Wierenga et al., 1991; Hills et al., 1991) and the Apache Leap Test Site (ALTS) [Organization of Economic Cooperation and Development (OECD), 1991] studies, are allowing the staff to gain valuable insights into the model validation strategies. A systematic procedure for model validation is emerging as a result of these studies.

The insights gained from the NRC-sponsored model validation studies are presented and discussed in international forums which generate constructive criticisms that help ensure: (i) the objectivity of the approach being developed by NRC, (ii) the adequacy of the technical and scientific basis for the approach, and (iii) the representativeness and completeness of the hypotheses (i.e., conceptual models) regarding system behavior. Furthermore, discussions at these forums allow the NRC to obtain feedback regarding the adequacy of those aspects of the models (i.e., couplings between processes and/or phenomena) that could not be tested in the experiments; the technical peer review step in the NRC validation procedure aforementioned.

Finally, through the experience gained from the previous two sets of activities, the staff will formulate judgments and views about adequate validation for PA models. The staff will be able to review and provide useful feedback to the DOE about its model validation strategy. Eventually the staff will be able to provide guidance to the DOE on an acceptable model validation approach.

4.3.1.4 Variability of Parametric Values

The numerical values of the parameters needed to exercise the models and codes are obtained through an estimation process involving interpretation and/or analysis (e.g., parameter fitting, interpolation, scaling, etc.) of typically sparse field and/or laboratory data. There are limitations to the ability to fully characterize a repository system and its inherent temporal and spatial variability. The physical dimensions of the site, coupled with the natural variability of the system, preclude a complete understanding of the system. Similarly, the time available for testing is limited to, at most, a few decades; thus, requiring extrapolations of measured information over three to four orders of magnitude to the regulatory period of interest (currently, 10,000 yr). Finally, even when measurements are possible, there may be significant uncertainties associated with the applicability of test methods, potential instrument errors, and procedural errors.

When direct measurements of repository characteristics are not possible, the regional and local geologic record, as well as analogies with similar geologic structures elsewhere, may provide information about the characteristics of the system, such as the rates of active tectonic processes and the likelihood of potentially disruptive events. The usefulness of such sources of information will depend on the completeness of the geologic record or on the degree of similarity between the site of interest and the other sites. This will inevitably be a source of uncertainty.

Parameter uncertainty arises from two sources: (i) the inherent uncertainty in the measured data from which the numerical values of the parameters are inferred, and (ii) the uncertainty introduced by the interpretation of the data. Quantification of parameter uncertainty is typically in the form of statistical representations (Davis et al., 1990) or probability density functions (PDFs). Once quantified, the parameter uncertainty can be propagated through the PA codes using Monte Carlo simulation

(Zimmerman et al., 1990); both the NRC and the DOE are using such an approach (Codell et al., 1992; Wilson et al., 1991).

Both the DOE and the NRC advocate the use of an IPA approach to increase the likelihood that data collection is aimed at generating information most critical for the demonstration (DOE) or determination (NRC) of compliance. The approach advocated by the NRC involves: (i) relating the uncertainty in performance measures to uncertainties in input parameters, and (ii) identifying those parameters that have the largest influence on the performance measure (i.e., sensitivity analysis). From this information, data collection can be focused on the most important parameters. The DOE is also using the information generated from its IPA approach to design the performance allocation; that is, based on the relative importance of each of the uncertain parameters, the performance of different components of the system needed for demonstration of compliance can be allocated. The DOE is expected to estimate the value of the input parameters and their statistical distributions from a synthesis of site characterization data and design data, augmented as required by expert judgments (see Barnard et al., 1992).

The issues related to the resolution of parameter uncertainty are: (i) the reduction of the uncertainty, particularly of those parameters deemed to be most important to the prediction of repository performance, and (ii) the quantification of the uncertainty. Each of these issues requires a different approach, and, hence, a different set of activities.

The NRC activities to address parameter uncertainty consist of:

(i) Independent PA's to assess the propagation of parameter uncertainty and sensitivity analysis to identify the relative importance of the different uncertain parameters

(ii) Review of the DOE parameter estimation and uncertainty reduction techniques and the basis for the assignment of distribution functions to represent parameter uncertainty.

The conduct of independent PAs will allow the staff to identify the important parameters, and through pre-LA reviews of the DOE TSPAs and subsystem PAs, the staff will be able to provide guidance to the DOE about those parameters. In this manner, the NRC will provide guidance and recommendations on site characterization activities. This will ensure that the DOE is doing the best practically possible job in focusing the data collection on the truly important parameters by obtaining data that: (i) allows inference of the values of the parameters, and (ii) provides information about the values so that meaningful statistical distributions are developed to represent parameter uncertainty.

As part of the IPA effort, the staff will examine different procedures to construct the distributions needed to represent parameter uncertainty; the most common statistical distribution being a PDF. Thus, as both the DOE and the NRC proceed with their IPA efforts, the staff will be able to review the latter's methods for refining the PDFs of those parameters emerging as the most relevant ones.

4.3.1.5 Prediction of Future System States

The performance of the proposed repository must be estimated over 10,000 yr. Such estimation will need to consider the possible future state of the repository system over that timeframe. The complexity of the system and the length of the regulatory period constrain the accuracy of model predictions of geologic evolution over 10,000 yr; thus, the source of uncertainty. The current approach taken by the NRC to account for this uncertainty is to develop scenario classes. Each scenario is believed to represent a realization of the possible future state of the system. The current version of 40 CFR Part 191 assumes that PAs need not consider categories of events or processes that are estimated to have less than one chance in 10,000 of occurring over 10,000 yr; that is, events or processes with a probability of less than 10^{-8} per yr need not be included in PAs. Therefore, some precision in the estimation of probability of occurrence is required.

There are several issues associated with the development and selection of scenarios that need to be addressed. First is the definition of the term scenario. Second is "completeness;" that is, assurance that all potentially significant processes and events have been identified and considered. Third is the screening, initially, of processes and events, and later of scenarios to eliminate those that are not deemed significant to repository performance. Fourth is the consideration of future human actions. Fifth is the estimation of the probability of events and processes and their use in estimating the probability of scenarios.

The lack of uniqueness in scenario-development approaches makes the resolution of those issues difficult. More fundamental, however, have been the criticisms levied against the scenario approach, in general (Thompson, 1988). Thompson argued that the scenario approach suffers from various severe limitations; namely: (i) lack of uniqueness in the definitions of the term scenarios and in the scenario-development approach; (ii) inability to account for time-dependence of the onset and evolution of the processes and phenomena governing the long-term behavior of the repository system; (iii) lack of scientific basis; and (iv) the heavy reliance on expert judgments, primarily to estimate the probability of occurrence; among others.

Particular areas requiring staff attention during the review of the DOE PA include: (i) the DOE definition of the term scenario and how this concept has been propagated through the analysis to the construction of the CCDF; (ii) the methodology and justifications used to screen processes, events, and scenarios from consideration; and (iii) the data, analyses, and support for the estimates of probabilities of occurrence for the relevant processes and events.

The NRC activities to address uncertainty in the future state of the repository system started in the early 1980's with work sponsored at SNL. Cranwell et al. (1990) developed a methodology for the systematic development and selection of scenarios that has been extensively used by the NRC and its contractors. This methodology has also been the foundation for scenario development in many member countries of the OECD (Nuclear Energy Agency, 1992). The application of this methodology to a number of different candidate HLW disposal sites since the early 1980's has allowed the NRC to gain first-hand valuable experience into the difficulties associated with scenario development.

The NRC continues to develop expertise related to the development of scenarios. The NRC is conducting a number of research projects at the CNWRA directly aimed at understanding issues associated with potential disruptive events and processes at the YM site and vicinity. Some examples are: (i) Volcanic Systems of the Basin and Range, (ii) Tectonic Processes in the Central Basin and Range Region, and (iii) the elicitation of expert judgments for estimating the modes and probability of climate change. This expertise is augmented by review of scenario development activities in other national and international programs. Reviews of such programs are commissioned periodically to keep abreast of current developments as well as to evaluate future international activities in which participation may be warranted.

Finally, through the review of the DOE TSPA exercises and technical exchanges and technical meetings with the DOE, the staff will examine the current DOE approach for scenario selection. The results from the aforementioned activities will allow the NRC staff to comment on the DOE scenario approach and provide guidance regarding the definition of the term "scenario," an acceptable approach for scenario selection, and an acceptable approach for estimating the probability of occurrence of individual processes and events and of scenarios.

4.3.2 Address Regulatory Uncertainties

The SRA process and interactions with DOE have identified three specific regulatory uncertainties associated with 10 CFR Part 60. These regulatory uncertainties consist of:

- Pre-waste Emplacement GWTT

- Substantially Complete Containment (SCC) for Waste Package

- Controlled Release Rate from EBS

Recently, the NRC has elected to designate the SCC as a technical uncertainty rather than a regulatory uncertainty. Because of its importance, this technical uncertainty is described here.

4.3.2.1 Prewaste Emplacement Groundwater Travel Time

Significant regulatory and technical uncertainty exists with respect to the requirements of 10 CFR 60.113(a)(2), the subsystem performance objective for the geologic setting (GS). This uncertainty is related to the definitions of "the fastest path of likely radionuclide travel" and "the disturbed zone," as well as to whether postclosure effects on the prewaste emplacement GWTT are adequately covered by the concept of "the disturbed zone." In addition, there are concerns regarding the utility of GWTT in unsaturated conditions because only liquid pathways, and not potential gaseous pathways, of radionuclide travel are considered.

Closure of these issues will require mathematical definitions that will be, in technical terms, the bases for an acceptable modeling strategy. To address these issues, the staff is identifying the technical approaches available to assess GWTT. It is anticipated that this activity will indicate the need for detailed technical guidance.

The NRC will undertake studies related to the evaluation of GWTT requirements that will allow the staff to: (i) evaluate the significance of episodic recharge and transient flow through unsaturated media; (ii) evaluate the significance of fracture flow versus porous flow in variably saturated, fractured porous tuff; and (iii) examine the impact of computational limitations on the application of unsaturated flow and transport codes to consider three-dimensional (3D), strongly heterogeneous fractured-porous media. To address the first issue, the NRC will (i) conduct parametric and sensitivity hydrologic modeling studies to gain a better understanding of the relationships among focused recharge, moisture redistribution in the unsaturated zone, and GWTT; (ii) utilize data collected by both the DOE and the U.S. Geological Survey for infiltration at YM in GWTT analyses to examine the impact of different data interpretations on the estimate of GWTT; and (iii) review and evaluate independent focused recharge studies by the State of Nevada. The question of fracture flow versus porous flow at YM has been delayed since the inception of that project. Data on seepage from a fracture at G-Tunnel in Rainier Mesa at the Nevada Test Site (NTS) suggests that flow through the unsaturated zone may be occurring primarily as a result of transient, episodic rainfall events. To address this issue, the NRC will (i) conduct auxiliary analyses evaluating alternative conceptual models; (ii) evaluate findings from the NRC-sponsored research on flow through unsaturated, fractured media; and (iii) review and evaluate data from the DOE-sponsored research and site characterization activities. Finally, to address the issue of the potential impact of computational limitations on the ability to perform realistic simulations of moisture movement through the unsaturated zone at YM, the NRC will examine the applicability of advanced computational fluid mechanics techniques used in other applications to solve strongly nonlinear and hyperbolic equations.

4.3.2.2 Substantially Complete Containment

The meaning of the phrase "substantially complete containment" for a HLW package for a minimum period of no less than 300 yr and not more than 1,000 yr following permanent closure of the repository in 10 CFR 60.113(a)(1)(ii)(A) needs to be clarified in order for both the DOE and the NRC staff to fully understand the intended scope of the requirement. Uncertainty exists not only in the regulatory meaning of this phrase, but also in the technical basis and achievability of such a performance objective.

To address the regulatory uncertainty related to SCC, the staff is currently developing the methodology and approaches for providing numerical guidance on its meaning. A preferred approach will be identified that will enable the development of guidance for incorporation into a staff technical position or in the LARP. To address questions about the technical basis and achievability of the performance objective, there is an ongoing effort to assess the current technological state-of-the-art with respect to waste package containment. For the waste package containment assessment, the staff has chosen a representative waste package design and repository environment, and is conducting a failure analysis to determine the expected waste package lifetime. This analysis will either enhance the technical basis for the rule and validate the containment requirement as an appropriate minimum performance objective, or indicate the need for rulemaking.

Since interpretation of the meaning of SCC, as well as the technical basis/achievability (or lack thereof) can significantly effect the DOE testing and design program for the waste package, it is important that these issues be closed in a timely fashion. If staff activities indicate the need for rulemaking to change these requirements, there could be a significant adverse impact on the DOE waste package development program. Therefore, it is imperative that the regulatory framework be established as soon as practicable to reduce the potential for any adverse impacts on the DOE waste package program.

4.3.2.3 Controlled Release Rate from Engineered Barrier System

Uncertainty exists with respect to the controlled EBS release rate requirement in 10 CFR 60.113(a)(1)(ii)(B). The staff is concerned that the subsystem requirement for the EBS release rate may not have an adequate technical basis to support its use as a valid and achievable standard.

The EBS release rate requirement, like the other two subsystem requirements in 10 CFR 60.113, was originally established as a means of providing reasonable assurance of adequate isolation performance. However, compliance with this, or for that matter any of the subsystem requirements in 10 CFR 60.113, does not guarantee compliance with the total-system requirements in 40 CFR Part 191. However, in light of the ENPA and the EPA having to revise the standard for HLW disposal, the staff will take the opportunity to examine the consistency of the EBS release rate requirement with a revised 40 CFR Part 191.

Independent of any technical linkage between EBS release rate limits and the total-system release limits in the current or revised 40 CFR Part 191, the staff has undertaken an effort to establish a technical basis for the EBS release rate limits, to examine the uncertainties associated with the determination of compliance with this requirement, and to examine methods that can reduce these uncertainties. This effort, like the SCC guidance development discussed in Section 3.3.1.2, will support the decision regarding the need for rulemaking, and therefore, should be completed in a timeframe that will allow timely feedback to the DOE waste package development program.

4.4 TECHNICAL ASSESSMENT AND RESEARCH

In order to effectively evaluate the DOE compliance demonstrations to be included in the LA, the NRC staff will need to develop an independent understanding of not only the processes and conditions the DOE deems important to predicting repository performance but, in addition, any processes and conditions the staff consider significant to long-term repository performance. This will involve, in part, developing a sound conceptual understanding of: (i) the coupling(s) between the natural and engineered components of the disposal system and their responses to changes in the environment; (ii) the causal relationships between the controlling physical and chemical processes; and (iii) the nature and propagation of uncertainties associated with these processes, events, and their future states to the estimates of the relevant performance measures.

Activities that the staff has undertaken to develop the necessary independent technical assessment capability include:

- Conduct of IPA Exercises
- Geological Model and Code Development
- Geochemical Model and Code Development
- Geotechnical Model and Code Development
- Hydrological Model and Code Development
- EBS Model and Code Development

The development of different models and codes is conducted in elements of the HLW Program other than PA. These models and codes are, by and large, aimed to provide tools that the staff can utilize to determine the presence (or absence) of FACs and PASs. PA is concerned, as stated earlier in Section 1.1, with estimating the impact of FACs and PASs on repository performance. Even though, the development of the different models and codes falls outside the purview of PA, the PA staff works closely with staff responsible for the development of the models and codes dealing with the different scientific disciplines that provide input to PA. This interaction ensures: (i) effective integration between PA and other elements of the HLW Program and (ii) the availability of the necessary tools in a timely fashion for use in the IPA exercises. Therefore, activities associated with model and code development are herein discussed to demonstrate this integration.

4.4.1 Conduct of Iterative Performance Assessment Exercises

An independent capability to conduct IPA is a key element in effective NRC conduct of pre-LA and LA reviews. PA is composed of synthesis of data and information, modeling and computation to estimate the performance of the repository and important subsystems of the repository, and auxiliary analyses. The purpose of the auxiliary analyses is to evaluate assumptions used in obtaining the estimates of performance, synthesize data into parameter sets used as input to numerical codes for estimating performance, and consider alternative conceptual models. IPA exercises are conducted iteratively as more refined additional site data are obtained and synthesized. The primary purpose of IPA is to develop and maintain: (i) the staff capability, (ii) an appropriate array of quantitative tools, (iii) the scientific and technical currency, and (iv) the staff, support, and management infrastructure required to conduct these assessments. More importantly, IPA provides the framework for the staff to explore the likely impact of different phenomena and processes (and their respective interactions) on repository performance. By gaining these insights, the staff will be in a position to develop guidance and comments to the DOE during the pre-LA phase and develop the necessary expertise to conduct the LA review.

This assessment capability is expected to be used during the LA evaluation, and prior to that time, to provide an independent evaluation of the DOE estimates of repository performance. The ongoing efforts in IPA are expected to contribute significantly to other regulatory products identified in this plan. These contributions include: (i) technical insights and practical experience to assist in the development of regulatory guidance, (ii) ongoing evaluation of the DOE site characterization activities and PA program, and (iii) insights into the definition and resolution of technical topics and prioritization of the NRC and DOE program activities, including HLW research. IPA provides quantitative information that helps to determine the importance of various topics, activities, data, and models. However, these quantitative estimates must always be considered in the context of the scientific bases that support them and the judgment of the analysts that derived them. Early phases of IPA have focused on developing the technology and analytical teams to execute PA at the NRC. Subsequent phases of IPA are expected to focus more on evaluation of the DOE IPAs and their implications for site investigations and design.

Development of models and codes for IPA covers the various component disciplines of PA, including geology, hydrology, geochemistry, climate, waste package and waste-form behavior, rock mechanics, thermohydraulics, and corrosion science. These models and codes will be integrated through a program of total-system PA. The total-system PA methodology requires additional developmental work in various areas, including: (i) scenarios, (ii) uncertainty analysis, (iii) sensitivity analysis, and (iv) modeling methods. IPA Phase 2 was completed in late CY93 and Phase 3 should begin in FY94, to be followed by subsequent phases at appropriate time intervals. Reviews of the DOE IPA program are currently scheduled during prelicensing at approximately 2-yr intervals, and at the time of LA submittal, currently in FY01.

Knowledge gained through PA will be used to reevaluate the significance of PA-related KTUs, and thereby provide a quantitative basis for determining the need to revise these KTUs and associated review strategies in the LARP. In this way, the staff's initial judgment in identifying the KTUs can be confirmed or refuted. Currently a formal strategy for implementing this evaluation does not exist. In developing a formal KTU evaluation process for IPA, several approaches for implementation will need to be addressed (and may be employed). One approach would be to evaluate individual KTUs through modeling (either in a total-system PA or in more detailed auxiliary analyses), via the use of various modeling assumptions. In this way, the sensitivity of the model results could tie directly to the assumptions made to accommodate the KTU. This approach would make use of the in-house model and computer codes already in use, but it would also likely require development or acquisition of, and staff familiarization with, new computer codes.

A less resource-intensive approach would be a direct comparison of the system KTUs identified to-date by the staff with the results from the recently completed IPA Phase 2 effort, especially with the results of the uncertainty analyses and sensitivity analyses. This could provide an initial confirmation of the staff's judgment in identifying the KTUs if a strong correlation existed. A weakness to this approach is that the IPA Phase 2 effort was not designed to address KTUs, and therefore, the assumptions and databases necessary to treat many of the KTUs were not incorporated into Phase 2. As a result, the sensitivity of the results to particular KTUs may not have been addressed.

It is anticipated that a combination of these two approaches (i.e., staff judgment and uncertainty analyses and sensitivity analyses) may need to be employed, with the direct comparison approach providing an initial evaluation of the sensitivity of the results to individual KTUs. However, in the end, a more explicit treatment of the KTUs (i.e., through incorporation into TSPAs or auxiliary analyses) may be required to provide the necessary quantitative basis for the staff's initial judgment. As stated previously, this would mean placing a greater emphasis on the development of appropriate assumptions and data sets, and on running existing in-house codes as well as newly developed and acquired codes. Results of independent NRC research will be needed to augment the data collected by the DOE, and to develop the assumptions and databases.

Additionally, greater emphasis will likely be placed on more detailed analyses to determine sensitivities prior to the incorporation of simplifying assumptions and data sets into a total-system PA. This would mean a change in focus for the IPA effort, away from the production of total-system PAs (e.g., in IPA Phases 1 and 2) and towards more subsystem PAs and discipline-specific modeling. Such a change in focus would make liberal use of other models and codes (see below).

4.4.2 Geological Model and Code Development

The staff is currently involved in an assessment of codes that use probabilistic methods in the consideration of fault displacement hazards and seismic hazards. Principal among the codes being examined is the SEISM1 code, a Lawrence Livermore National Laboratory (LLNL) code, funded by NRC/Office of Nuclear Reactor Regulation (NRR) for evaluation of the seismic design basis for Nuclear Power Plants (NPP) in the eastern U.S. Activities to date have demonstrated that, with modification, SEISM1 code may be applicable to the assessment of seismic and fault displacement design bases for a geologic repository. The trend in the derivation of seismic design basis is towards the use of probabilistic methods. It is important that the staff develop the capability to independently assess the seismic design basis that the DOE will submit in the LA, which pre-LA reviews suggest will be probabilistically based. The development of the analysis capability for the probabilistic design basis will assist in the staff review of the DOE topical reports related to seismic hazards.

Independent assessment activities related to geometric analysis and cross-section balancing of faulting at YM will also continue in response to the generation of additional data by the DOE. This effort will continue in order to further develop the capability to assess the validity of geologic cross sections through the repository block and across the geologic setting. This effort will be used to provide guidance to the DOE regarding site characterization activities and the development of conceptual tectonic models for the site. An analysis of the current state-of-the-art in 3D geometric cross-section balancing methods and codes will be performed. All of these activities will support staff reviews of the DOE documents related to the probabilistic assessment of faulting and the development of a final tectonic model. In addition, because fault displacement is a significant concern at YM, near-field seismic ground motion may also be of concern. Therefore, the staff will undertake efforts to acquire computer codes for modeling near-field ground motions that may be input to analyses of underground structures. Part of this effort will involve the acquisition of software and data from the Institutions for Research in Seismology (IRIS).

In addition, the staff is exploring the use of models and codes to develop the capability to assess dynamic models of fault displacement at repository scale. These activities are being pursued in order to develop CDMs for assessing compliance with containment and total-system performance requirements considering fault displacement as a disruptive process. Codes currently under consideration include ABAQUS, SANGRIA, and GEOSYM. It is anticipated that the implementation of codes will provide the link between conceptual models of repository-scale deformation and the quantitative inputs necessary to assess repository performance. This capability will also assist the staff in the review of the DOE report on the effects of faulting on waste packages.

Risks associated with igneous activity are another area of staff concern. Initial efforts to address the risks attributed to volcanism were incorporated into IPA Phase 2. However, staff analysis regarding probability derivations for future volcanism have shown that, for the YM region, the distribution of volcanic centers is not adequately described by a homogenous Poisson model as was used in IPA Phase 2 and favored by the DOE. As a result, such derivations may not be adequate as currently conducted. Additionally, modeling to-date of consequences resulting from volcanism does not appear to appropriately incorporate all relevant processes and factors (e.g., the percentage of volatiles in the parent magma). The staff intends to explore the use of other models for volcanic risk in attempts to provide technically defensible models for incorporation into staff efforts to develop the capability to make assessments of overall system performance.

The staff is also pursuing the modeling capability necessary to permit visualization and manipulation of geologic features. This capability will be used to assess repository characteristics and demonstrate the potential effects of changes in the geologic characteristics of the site on repository performance. In addition, this capability will provide decision-makers with the opportunity to visualize repository characteristics and changes to those characteristics by such processes as faulting and intrusion by igneous dikes.

4.4.3 Geochemical Model and Code Development

To address key technical uncertainties (KTUs) related to the geologic setting at YM, the staff will continue to develop independent conceptual and mathematical models of the geochemical system. Ultimately, the experience gained will be used to develop CDMs for FACs and PACs related to geochemistry. This work will continue during site characterization by DOE to incorporate new and existing data and evaluate proposed assumptions and modeling strategies.

The staff is currently involved in exploring the application of existing codes to both near- and far-field geochemical conditions relevant to YM. Codes that are currently being used include EQ3/6 (Wolery, 1992) and MINTEQA2 (Allison et al., 1991). Much of this work focuses on the review of existing data and development of the thermodynamic databases that are necessary to model the chemistry of key radioelements. The staff is also working towards gaining an understanding of the stability of waste forms, containers, and mineral phases considered to be important to the performance of the natural system barriers at YM. Current efforts are focusing on understanding the stability of minerals such as the zeolites clinoptilolite and analcime in response to potential changes in water chemistry. Additional studies of natural analogs to YM are developing models of the long term behavior of minerals that provide a point of comparison to experimental studies of waste form alteration and dissolution. These efforts are aimed at providing the expertise necessary to evaluate the geochemical aspects of DOE's LA.

Studies are also ongoing in geochemical issues related to radionuclide transport such as ion exchange, sorption, and gas transport. Carbon-14 release from waste forms, multiphase models of the carbon system to better predict ^{14}C transport, and models of radioelement sorption as a function of chemistry are being proposed for investigation under IPA Phase 3. These and other efforts are supported by experimental studies being conducted at CNWRA. Additionally, ongoing investigations of fracture and matrix transport at analog sites provide a means of calibrating and testing long term predictions by radionuclide transport models at a variety of scales.

The staff is also developing an independent understanding of the geochemistry in the YM vicinity on both regional and local scales. This involves accumulating, evaluating and entering geochemical data into a computerized geographic database that will enable identification of spatial trends. Much of this work can continue in response to the generation of additional data by DOE site characterization efforts. These trends will provide a means of developing (or confirming) conceptual models of groundwater flow and transport. These data may also provide an independent set of boundary and initial conditions for developing future numerical models.

4.4.4 Geotechnical Model and Code Development

The staff is currently involved in the assessment and modifications of numerical models and computer codes for coupled thermo-mechanical (TM) and thermo-mechanical-hydrological (TMH) analyses in the near-field, which includes both emplacement borehole and emplacement drift scales. These activities are being pursued in order to provide input for developing CDMs for assessing compliance with containment and total-system performance requirements. Although not addressed in this version of the PA Strategic Plan, these codes also play a central role in preclosure PA. The staff has selected the distinct-element computer codes UDEC and 3DEC for use, with the necessary modifications, for the prediction of stability of emplacement drifts/boreholes due to thermal and repetitive seismic effects, and their potential impacts on failure of the waste canisters.

The staff is evaluating the finite-element code ABAQUS to assess its TMH modeling capability including prediction of mechanical-effect-dependent unsaturated fracture flow. The primary objective of the coupled TMH modeling of the near-field using ABAQUS is to provide estimates of changes in permeability with time and space so that they can be taken into account in subsystem near-field PA and total-system PA calculations. ABAQUS will also be used to verify the various assumptions relevant to mechanical-effect-dependent fluid flow that the available hydrologic codes will make in the near-field PA and total-system PA calculations.

The coupled codes UDEC, 3DEC, and ABAQUS will provide input to the subsystem PA code EBSPAC, IPA codes SOurce TErm Code (SOTEC) and SEISMO, and total-system PA code TPA. These codes will receive some input from SOTEC and seismic hazard code SEISM1, and will interact with various PA auxiliary analysis codes including V-TOUGH.

4.4.5 Hydrological Model and Code Development

The staff will need to develop an independent understanding of groundwater flow conditions and potential radionuclide transport at YM to evaluate the DOE modeling assumptions and support compliance determinations with certain of the hydrology-related requirements in 10 CFR Part 60. Models to be used to simulate groundwater conditions and radionuclide transport at the site are considered state-of-the-art in that the collection of data (primarily in the unsaturated zone), interpretation of such data, and the availability of acceptable model codes to evaluate site data are relatively new to the scientific community. Because of this, the NRC staff will need to develop expertise and knowledge about unsaturated flow in order to effectively evaluate assumptions in the DOE model to make meaningful licensing decisions. This work will continue through the end of the DOE site characterization program and the development of the DOE saturated and unsaturated zone hydrologic models and codes.

The analysis of GWTT and perched-water bodies will require development of independent models and codes as well as some independent data collection, because both the DOE and the NRC approaches to modeling unsaturated flow conditions will be very controversial and will result in uncertainties that could significantly affect the analysis of total-system performance. Currently, the DOE program is involved in determining whether fractures and/or fracture systems are barriers to, or conduits for, liquid water flow. This work is crucial for the development of conceptual models of the site.

Finally, for the evaluation of overall repository performance, integration of: (i) hydrologic modeling of both saturated and unsaturated conditions; and (ii) near- and far-field geochemical modeling, will be required. This integration requires the development of both models/codes and supporting data. Work in this area is ongoing.

4.4.6 Engineered Barrier System Model and Code Development

The staff will continue development of its independent capability (i.e., models and computer codes) to assess compliance with the waste package containment and EBS release rate subsystem requirements. Ultimately, Engineered Barrier System Performance Assessment Codes (EBSPACs) will be used in the development of the CDM for the EBS. Model (and code) development is also needed to provide the staff with the capability to carry out its SCC and release rate analyses to assess the validity and implementability of those objectives in 10 CFR Part 60. Early development of this capability is needed in order for the staff to evaluate the adequacy of the associated regulatory requirements.

In the long term, these codes will be useful in supporting the review of the DOE on-going and future TSPAs and subsystem PAs and design work for compliance with the subsystem performance objectives. Code development in support of the review of the DOE PA program is generally referred to as development of the EBSPAC group of computer codes. A series of detailed models in EBSPAC will provide the basis for the development of the simplified source-term models to be incorporated in the SOurce TErm Code (SOTEC). SOTEC will provide the source terms for total repository system PA. Both EBSPAC and SOTEC are used to conduct the staff's ongoing (i.e. IPA Phase 2) and planned IPA. In addition, EBSPAC will be used to identify parameters important to performance that the staff may transmit to the DOE as those that need to be addressed in site characterization activities related to material testing.

The EBSPAC group of codes includes a sizable number of individual models that are being developed and updated. Recently, versions of the spent fuel dissolution, crevice corrosion and pitting corrosion model were developed. Work on stress corrosion cracking models is also ongoing. Additional activities will include evolution or development of glass waste dissolution, partially failed container, and transient wetted area models. These models must be developed early to support the conduct of the NRC IPA, review of the DOE IPAs, and development of the technical bases for the engineered subsystem PAs.

The staff expects to develop other needed models for incorporation into EBSPAC. For example:

- Thermohydraulics and fluid flow, radiolysis, and mass transport
- Geochemical effects of elevated temperatures and galvanic corrosion
- General corrosion and mechanical stress
- Material degradation and alternative corrosion mechanisms

The staff has also identified research needs to support model development related to the DOE candidate waste package materials. Some of this research has already commenced.

4.5 SUPPORT TO HIGH-LEVEL WASTE MANAGEMENT PROGRAM

The PA program also provides support to the HLW program in a several general areas, such as:

- Support ACNW activities
- Support international activities
- Support NRC management activities
- Prepare RES user needs

4.5.1 Support Advisory Committee on Nuclear Waste Activities

In October 1990, the ACNW and the NRC Executive Director for Operations completed a Memorandum of Understanding regarding the ACNW review and comment on nuclear waste management issues. The function of the ACNW is to examine and report to the Commission on "those areas of concern referred to it by the Commission or its designated representatives, and will undertake other studies and activities on its own initiative related to those issues directed by the Commission." Thus, the NRC staff will need to periodically interact with the ACNW to give briefings on the PA program.

Specific areas and topics of interest to the ACNW are safety-related areas including:

- Rules, policy matters, and regulatory guidance (proposed, revised, or withdrawn)
- Licensing activities
- Selected prelicensing activities for HLW

PA activities associated with the ACNW include the transmittal of requested information or responding to ACNW comments on the HLW program. Information can be transmitted to the ACNW in written form or through technical presentations.

4.5.2 Support International Activities

PA methodology and technology development is vigorously being pursued by a number of other countries with ongoing geologic repository programs. The NRC has a number of bi- and multi-lateral agreements with the HLW programs in several of these countries. In addition, the NRC actively participates in many PA-related activities sponsored by the OECD's NEA. Participation in these international PA activities is motivated by the need to: (i) stay abreast of new developments in PA technology; (ii) obtain broad-based peer review of the NRC PA models, codes, and approaches; and (iii) leverage available resources by participating in activities of interest to the NRC. At present, the NRC is participating in six major international PA activities:

- NEA Performance Assessment Advisory Group (PAAG)
- NEA Probabilistic Systems Analyses Group (PSAG)
- International Model Validation Activities (INTRAVAL) coordinated by Sweden
- Swedish Nuclear Power Inspectorate (referred to as SKI) model validation exercise
- DECOVALEX Coupled TMH Model Validation activities
- BIOMOVS Environmental pathways activities

Under the auspices of the PAAG, activities have focused on developing consensus on approaches for treatment of disruptive scenarios. This group has evaluated two general approaches to scenario selection and characterization.

The PSAG, an adjunct of PAAG, is a working group organized to discuss the issues involved in probabilistic assessments of the deep geologic repositories. While this group is currently focusing on probabilistic models for subsystem PA, it will be reformulated to include aspects of total-system PA. In particular, it is anticipated that benchmarking (i.e., code-to-code comparisons) of total-system PA codes will be conducted.

The INTRAVAL activity (Andersson and Skagius, 1992) is addressing the challenging issue of validating flow and transport models used in subsystem PA. The NRC is one of twenty-one organizations from twelve nations participating in this activity. Data from laboratory and field experiments, including analog studies, are being used in systematic attempts to formulate and test validation methods. An international consensus on model validation may be very beneficial to the NRC in developing guidance for validation of the DOE PA codes.

More recently, the NRC has initiated participation in a joint PA activity with the Swedish government. This collaborative and cooperative activity is on the topic of developing a regulatory perspective on validation of hydrologic models. This activity will produce a white paper discussing the regulatory issues related to validation and potential strategies for the resolution of these issues.

The DECOVALEX study is focused on the validation of near-field models where simultaneous TMH effects are important. In this study, the participants will attempt to validate numerical models that describe the coupling between TMH processes.

The BIOMOVS II study is an international cooperative effort to test models designed to quantify the transfer and bioaccumulation of radionuclides and other trace substances in the environment. BIOMOVS II was initiated to follow on from the first phase of BIOMOVS which was officially launched at a meeting in Paris in 1986, and finished in Stockholm in 1990.

The primary objectives of BIOMOVS II are threefold and are given in the official BIOMOVS II proposal:

- To test the accuracy of the predictions of environmental assessment models for selected contaminants and exposure scenarios
- To explain differences in model predictions due to differences in model structure, modeling assumptions, and/or differences in selected input data
- To recommend priorities for future research to improve the accuracy of model predictions

Another objective of the study is to act as a forum for the exchange of ideas, experience, and information in order to improve the confidence with which the environmental behavior of trace substances in the biosphere can be assessed quantitatively.

4.5.3 Support Nuclear Regulatory Commission Management Activities

On an as needed basis, the PA program staff will provide support to the NRC management in the conduct of programmatic activities. This support typically consists of preparing papers and presentation materials for various management meetings, interactions with the ACNW, and briefing the commissioners.

4.5.4 Prepare Research User Needs

The NRC research activities are conducted under RES and are consistent with the agency's licensing role and responsibilities. A number of research projects are currently being conducted at the CNWRA and the University of Arizona which are aimed at: (i) developing the tools and technical bases necessary to judge the adequacy of the DOE's LA, (i) ensuring a sufficient independent understanding of the basic physical processes taking place at the geologic repository, and (iii) maintaining an independent confirmatory research capability. The specific research projects are initiated on the basis of user needs identified by the NMSS staff.

As the LARP is developed and IPA is conducted, the NMSS staff identify user needs that are essential to: (i) addressing KTUs, (ii) enhancing total-system and subsystem PA methodologies, and (iii) providing data for PA calculations. The research needs identified as a result of LARP/IPA review strategy development will be compared to the ongoing research program, and necessary adjustments will be made. As research work progresses, the staff will evaluate the results to determine if additional research is needed to satisfy review needs.

4.6 PRIORITIZATION STRATEGY

It is likely that the number of activities identified as needed within the PA program will be considerably higher than can be realistically conducted given budgetary, schedule, and staff-level constraints. Therefore, decisions need to be made with respect to which of those activities will be undertaken and when they will be initiated.

The basic tenet of the prioritization methodology is that decisions regarding those activities that will be undertaken, and those that will not, will be reached using an explicit utility system. An utility system is used to determine the value of different alternatives and the selection of one of them when the decision involves an element of risk or uncertainty (Goodwin and Wright, 1991). This approach will be used to prioritize the activities that the NRC will undertake, and will consist of three basic components: (i) the determination of the expected benefit of an activity, (ii) the programmatic risk associated undertaking the activity (e.g., technical feasibility, timeliness, and ability to recover from failure, and (iii) cost of the activity. That is, from the suite of proposed activities, those that offer the greatest value to the accomplishment of the program's goals, will be ranked higher than those that do not. Prior to the implementation of the prioritization strategy, proposed activities will be classified into one of three major categories:

Category I: Activities mandated by law

Category II: Activities that DOE should undertake

Category III: Discretionary activities

NRC is required to undertake those activities that fall within Category I; therefore, these will automatically be assigned the highest priority and will not be subjected to further evaluation. Category II activities will become DOE's responsibility, and the NRC will ensure, through pre-LA consultations, that (i) these activities are undertaken, and (ii) progress is monitored periodically. Decisions to undertake activities within Category III will be based on an evaluation of each of the proposed activities using a set of attributes such as:

- Activity supports the development of the NRC's capability to determine compliance with the requirements in 10 CFR Part 60

- Activity has a high likelihood of technical feasibility

- Activity is timely and cost-effective

- Activity represents the "preferred" method to gain the needed insight within the existing constraints of the NRC's HLW program

The definition of the appropriate set of attributes will not be trivial, and it must be done with caution to ensure that the attributes are (i) relevant in terms of assessing the value of each activity, and (ii) discriminatory so that the similarities and differences between the proposed activities, particularly those activities in the same general technical area, can be elucidated.

For each attribute, several evaluation criteria must be developed to allow the determination of the degree to which each proposed activity exhibits the attribute. The evaluation criteria should be chosen to include all of the possible ways in which an activity can exhibit a particular attribute. Some activities are either mandated by law, others are DOE's responsibility, and yet others at are NRC's discretion. Evaluation criteria do not apply to activities that fall under the first two categories (mandated by law or are DOE's responsibility). However, evaluation criteria will be necessary to prioritize those activities that will be undertaken at NRC's discretion. Examples of evaluation criteria that can help determine the technical and regulatory merit of an activity include, but are not limited to:

- The activity will generate data or information to satisfy a need identified in the IPA effort

- The activity will generate data or information that the staff believes could have a serious deleterious effect on repository performance if proven true (e.g., characterization of a fault displacement hazard and seismic hazard)

- The activity will allow the staff to determine the extent to which the closure of a given KTU is practically possible (e.g., uncertainty in conceptual model and model validation)

- If the activity is not undertaken, the impact on the NRC's HLW program will be detrimental, in terms of the ability of the staff to make a sound determination of compliance

The technical feasibility of an activity could de discerned using evaluation criteria such as:

- The relationship of the activity to other NRC HLW program activities

- The technical acceptability of the approach proposed for the activity

- The availability of existing technical methods to conduct the activity

The timeliness and cost-effectiveness of an activity could be determined from criteria such as:

- The compatibility of the time required to complete that activity with the schedule of the different elements of the NRC's HLW program

- The cost to complete the activity relative to its contribution to the success of the NRC's HLW program

- The staff resources needed to complete the activity
- The availability of alternative sources of information within and without the U.S. HLW program that can generate similar, if not identical, information as that expected from the activity

The prioritization methodology, shown schematically in Figure 4-1, will follow the basic framework of decision analysis. The NRC staff will identify attributes and, within each attribute, the evaluation criteria that will be used to evaluate each activity. An NRC HLW management team will have responsibility for the actual evaluation of the proposed activities. The team will examine the attributes and evaluation criteria, and will provide feedback on their appropriateness. This will serve a dual purpose: (i) it will provide a mechanism for ensuring consistency in the purpose and expected product of the evaluation, and (ii) it will provide a "reality check" for the attributes and evaluation criteria. Both of these are critical steps, for the quality of the prioritization will largely depend on the attributes and associated evaluation criteria and the manner in which the team carries out the evaluation process. The management team will also assign relative weights to each attribute indicating the attribute's relative contribution to determining the utility of each activity. The next step in the methodology is the evaluation of the proposed activities. A numerical score will be calculated for each activity based on the applicable attribute(s), and this will be the basis for ranking the activities. Potential differences or inconsistencies discovered during the evaluation will be resolved.

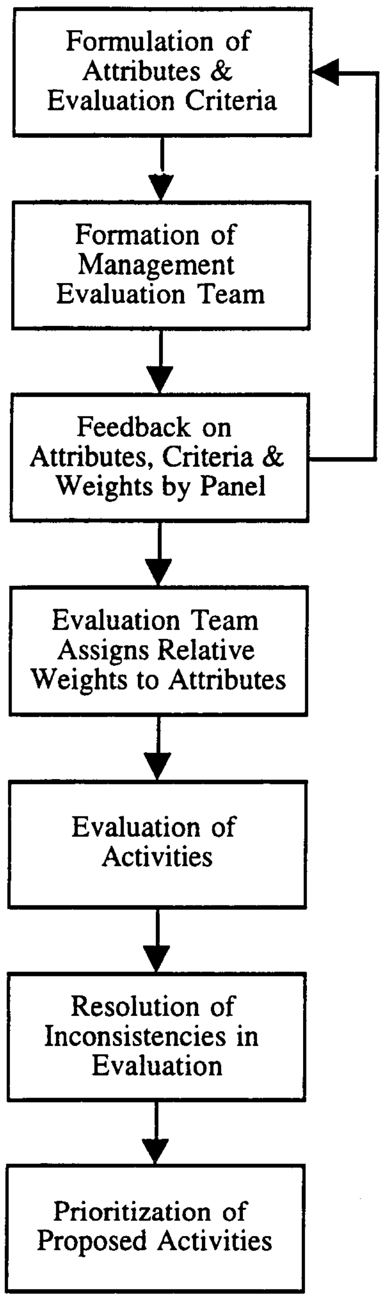

Figure 4-1. Steps in priorization methodology

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