UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

August 31, 1998

Dr. B. John Garrick, Chairman
Advisory Committee on Nuclear Waste
U.S. Nuclear Regulatory Commission
Washington D.C. 20555

SUBJECT: COMMENTS ON NRC'S TOTAL SYSTEM SENSITIVITY STUDIES FOR THE PROPOSED HIGH-LEVEL RADIOACTIVE WASTE REPOSITORY AT YUCCA MOUNTAIN, NEVADA

Dear Dr. Garrick:

I am responding to your letter of July 29, 1998, to the Chairman, providing the Advisory Committee on Nuclear Waste's (hereafter, the Committee's) observations and recommendations on the staff's Total System Performance Assessment (TPA) code for the proposed Yucca Mountain (YM) repository. Your comments were based on results of sensitivity studies presented by the staff on April 21-23, 1998. The staff appreciates the Committee's thoughtful comments and compliments on the TPA effort. We agree with the Committee's recommendations, and believe we are on a path to satisfying them. Below are specific responses to your comments and recommendations:

1. The Committee recommended that staff develop an understanding of moisture movement near the drifts.

   The staff agrees that this is an important area for further enhancements of its capabilities, as demonstrated by the impact that waste-form wetting has on the results of the TPA analyses. The current TPA methodology represents the phenomenon of waste-form wetting as a combination of deep infiltration at the repository scale and channeling and diversion of infiltrating water at the drift and waste-package (WP) scales. Channeling and diversion are represented in the present model by several interrelated factors derived from consideration of spatial variability in hydraulic conductivity of the rock and infiltration rates; the spatial scale of these variabilities, relative to the scale of the drifts and WPs; an understanding of dripping phenomena, based on off-line modeling studies and empirical observations in tunnels; and engineering judgement on the behavior of water drips onto intact and failed WPs.

   The models of infiltration and dripping in TPA Version 3 are highly abstracted, but, nevertheless, represent a considerable improvement over previous NRC models of repository performance. Staff is working to improve its code in this area. However, the phenomena that relate to seepage and dripping of water from the drifts, the entry of dripping water into the WP, the wetting of the waste form, and the transport of radionuclides from the WP are extremely complex. Individual phenomena are, for the most part, poorly understood. Mechanistic models that directly simulate dripping on the drift and WP scales have only recently become available and they have not received extensive verification against experimental data.

Recent drift-scale experiments in the YM Exploratory Studies Facility (ESF) are beginning to fill the data void. Percolation studies in the ESF should lead to drift-scale quantification of fluxes into mined openings and can determine the hydrological and moisture conditions for the waste emplacement drifts. The U.S. Department of Energy (DOE) is conducting *in situ* cross-hole pneumatic and liquid-release tests in the ESF to evaluate fluid flow in the unsaturated zone. The results will be used to adjust the site-scale and drift-scale models in support of DOE's Viability Assessment and License Application. The staff is closely following the development of these experimental and modeling studies, and intends to include relevant information in the TPA abstractions, wherever and whenever possible.

The U.S. Nuclear Regulatory Commission (NRC) and the Center for Nuclear Waste Regulatory Analyses (CNWRA) staff have developed the necessary understanding and modeling approaches to account for the physical and chemical processes that govern moisture movement in and around the drift. Considerable effort is being expended on analytical models and laboratory experiments to evaluate coupled effects in the near-field environment, including the effects of ventilation, fracture/matrix transfer, thermal refluxing, and precipitation/dissolution processes. The staff will apply its knowledge of physical processes, DOE experiments, and the NRC TPA sensitivity studies to determine which phenomena are most important to performance.

Staff will continue to use detailed models such as MULTIFLO to evaluate moisture flow and coupled geochemical processes in the near-field environment and probe the important areas of DOE's modeling. Evaluation of the effects of concrete on near-field flow and chemistry for the "Evolution of the Near Field Environment" (ENFE) key technical issue (KTI) was conducted in fiscal year 1998 (FY98) and will continue in FY99. These model studies will extend NRC's understanding of phenomena related to spatial and temporal distribution of moisture flux, and establish a tool that can be used to complement the TPA code in probing DOE's three-dimensional models.

2. The Committee recommended that staff include more details of the total WP protective system in its model activities to detail more fully the contribution to performance of specific engineered systems.

The staff has considered drift-scale models of dripping phenomena that will lead directly to an understanding of the interactions of the engineered systems with dripping water. Backfill would have several effects that are not currently incorporated in the TPA methodology, such as protecting the WP from rock falls and possibly providing a hydrologic capillary barrier against dripping flow impinging onto the WP. Staff has not as yet included the effect of WP protective systems like ceramic coatings and drip shields in its analyses, but these topics (as well as the effects of backfill) are being followed and are identified for consideration in the FY99 operations plan for the "Container Life and Source Term" (CLST) KTI. They will also be addressed in future versions of the CLST Issue Resolution Status Report (IRSR). The TPA code currently takes partial account of the effect of backfill as a thermal insulator of the WP, which, in

the models, has the effect of retarding the onset of corrosion, because above-boiling temperatures will persist longer.

3. The Committee recommended that staff begin to integrate the IRSRs into the Standard Review Plan (SRP), and update connections between current knowledge and the KTIs.

   The staff recognizes the importance of integrating the IRSRs into the Yucca Mountain Review Plan (YMRP) and will initiate its efforts to develop a formal YMRP in FY99. Consistent with the Committee's recommendation, staff is using and will continue to use the results of TPA sensitivity studies in the development of IRSRs and KTIs to accommodate updates to NRC's knowledge base. The "Total System Performance Assessment and Integration" (TSPAI) IRSR and those of other KTIs include acceptance criteria, review methods, and technical bases for issues and subissues believed to be important to performance. In developing the YMRP, the staff will use the proposed framework in the TSPAI IRSR to establish a top-down, risk-informed, performance-based YMRP. Acceptance criteria, review methods, and technical bases from the other KTIs will be integrated into this framework.

4. The Committee's fourth recommendation reiterated previous recommendations about the need for a probabilistic performance assessment tool that can operate on the outputs of the TPA model, to rank-order scenarios and classes of scenarios with respect to repository performance.

   The staff believes that the current TPA tool is useful for this purpose. The staff is continuing to examine additional approaches to increase the transparency of its calculations and the effectiveness of the TPA code to evaluate DOE's performance assessment. In response to previous Committee concerns, the staff is looking into ways that the current TPA code can be restructured to provide this information. Current ideas along this line include: (1) reordering the Monte Carlo results to more clearly distinguish connections between ranges of input parameters and the dose outputs; (2) developing alternative sampling algorithms to implement the event-tree approach directly, as opposed to Monte Carlo sampling; and (3) using intermediate results at pinch points such as the integrated releases from the source term, unsaturated zone, and saturated zone sub-models, to investigate sensitivities of particular barriers.

   In addition, the staff has used the TPA code to investigate the effects of alternative conceptual models and scenarios on repository performance. Several of these runs have been used to evaluate individual barrier performance such as waste package integrity and geochemical retardation. A special version of the TPA code's executive driver has been developed to automate the procedure for evaluating the effect of removing individual barriers.

The staff is working iteratively to enhance its TPA capability and will do so throughout the prelicensing phase of the repository. Additional work is necessary in some areas because of the limitations of our knowledge about the site and the physical phenomena associated with a repository. Knowledge limitations are being reduced through the continuing review of DOE's site characterization activities, as well as through laboratory experiments and model studies being conducted by DOE, CNWRA, and others. The staff is making the TPA code more flexible

by developing a version to run in the personal computer environment. A second version of the code will run on a network of engineering work stations connected as a parallel computer. In this way, NRC staff will be in position to independently evaluate, in an effective and efficient way, DOE-inspired changes to the repository system.

Sincerely,

L. Joseph Callan
Executive Director
Operations

cc: Chairman Jackson
Commissioner Diaz
Commissioner McGaffigan
SECY

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Sincerely
Original Signed by
L. J. Callan
L. Joseph Callan
Executive Director
for Operations

cc: Chairman Jackson
Commissioner Diaz
Commissioner McGaffigan
SECY

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L. Joseph Callan
Executive Director
for Operations

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Commissioner McGaffigan
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Executive Director
for Operations

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In conclusion, the staff is working iteratively to enhance its TPA capability and will do so through licensing. Additional work is necessary in some areas because of the limitations of our knowledge about the site and the physical phenomena associated with a repository. Knowledge limitations are being reduced through the continuing review of DOE's site characterization activities, as well as through laboratory experiments and model studies being conducted by DOE, CNWRA, and others. Resource limitations are being addressed by conducting iterative performance assessments to inform decisions on the priority of NRC activities, and by changes in the TPA code to use more efficiently the available computer resources. Examples of the latter include adapting the TPA code to run in the PC environment, and developing a version of the code to run on a network of engineering work stations connected as a parallel computer. The TPA methodology requires key sub-systems (e.g., source term, saturated zone) to be accounted to provide credible representations of performance sufficient for making regulatory decisions. Wherever these limitations apply, the staff has attempted to use conservative approaches in the TPA code, which will be upgraded or replaced as the technology and data improve. Other limitations of the TPA methodology reflect the staff's belief that the particular processes are unimportant or that the abstractions are adequate to represent or bound the processes involved.

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For,

Sincerely

L. Joseph Callan
Executive Director
for Operations

cc:	Chairman Jackson	SECY	OGC
	Commissioner Diaz	OCA	CIO
	Commissioner McGaffigan	OPA	CFO

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B. John Garrick, ACNW

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TO:

Chairman Jackson

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Callan, EDO

DESC:

COMMENTS ON NRC'S TOTAL SYSTEM SENSITIVITY STUDIES FOR THE PROPOSED HIGH-LEVEL RADIOACTIVE WASTE REPOSITORY AT YUCCA MOUNTAIN, NEVADA

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AFFILIATION: ADVISORY COMMITTEE ON NUCLEAR WASTE

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UNITED STATES
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WASHINGTON, D.C. 20555-0001

July 29, 1998

The Honorable Shirley Ann Jackson
Chairman
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

SUBJECT: COMMENTS ON NRC'S TOTAL SYSTEM SENSITIVITY STUDIES FOR THE PROPOSED HIGH-LEVEL RADIOACTIVE WASTE REPOSITORY AT YUCCA MOUNTAIN, NEVADA

Dear Chairman Jackson:

This letter provides comments and recommendations from the Advisory Committee on Nuclear Waste (ACNW) on the NRC staff's total system sensitivity studies for the proposed high-level radioactive waste repository at Yucca Mountain, Nevada. The staff is conducting these studies as part of its overall effort to develop the necessary tools and capability to evaluate a license application from the Department of Energy (DOE).

The staff has made exemplary progress in developing and applying sensitivity studies for understanding the important assumptions and parameters in its Total System Performance Assessment (TPA) model of the geologic repository system. This work has allowed the staff to identify major features, events, and processes of the system model that contribute significantly to performance.

During its 100th meeting on April 21-23, 1998, the Committee was presented with material that identified the important parameters in terms of their impact on the final dose as calculated for the repository design with the TPA-3 Code. The staff identified areas in which further improvements in the model and better understanding of the system are needed. The staff is also attempting to close out issues of lesser concern (e.g., the low consequences of fault displacement).

The staff has identified necessary model changes to accommodate design modifications such as DOE's selection of the nickel-based alloy C-22 as the corrosion-resistant material for the waste canister. As the DOE design evolves, the NRC staff will need a flexible tool for evaluating the importance of those design changes to repository performance.

The modeling performed by the staff shows that parameters that govern the spatial and temporal distribution of water in the near-field environment are critical to the final dose. Currently, the model uses various "factors" to account for diversion of moisture away from the disposal drifts and the canisters. This analysis is performed in such a way that only a small

fraction of the moisture flux at the repository horizon enters the waste package and dissolves radionuclides in the spent fuel. These factors are based on statistical and empirical analyses rather than on a mechanistic model of moisture flow on the drift scale. The ACNW recommends that the staff develop the necessary understanding and modeling approaches to account for the physical and chemical processes that govern moisture movement in and around the drift. This effort will include the ability to review DOE's three-dimensional drift-scale models and supporting process-level information.

There are a number of other near-field issues that the ACNW is pursuing with respect to the Engineered Barrier System (EBS). Recently, the ACNW held a 2-day working group meeting on the performance of the EBS in the near-field environment. The Committee will provide recommendations to the Commission on this important topic in a separate letter. The increased role of the EBS in the performance of the proposed Yucca Mountain repository drives many of the near-field issues. The Committee considers that the primary NRC issue is the ability of the staff to adjust to the resulting change in emphasis on engineered systems to make a significant contribution to repository performance. We recommend that the NRC staff include more details of the total waste package and waste package protective system (e.g., ceramic coatings, drip shields, and backfill) in its modeling activities to expose more fully the contribution to performance of specific engineered systems.

The importance of the TPA total system sensitivity studies goes beyond the details of modeling different repository designs. Issues identified in the studies are being incorporated into acceptance criteria in the Issue Resolution Status Reports (IRSRs) that will eventually become components of the Standard Review Plan (SRP). The ACNW recommends that the staff begin as soon as possible the process of integrating the IRSRs into the SRP. The staff also needs to revisit and update connections between the NRC's current knowledge base and the Key Technical Issues (KTIs).

An important outcome of the sensitivity studies is the identification of how different components of the system contribute to performance. The quantification of the performance of individual barriers for both the natural and engineered systems is an important element of demonstrating compliance. The ACNW reiterates previous recommendations about the need for a probabilistic performance assessment tool that can operate on the outputs of the TPA model to identify scenarios and classes of scenarios (ACNW letter from B. John Garrick, Chairman, ACNW, to The Honorable Shirley Ann Jackson, Chairman, NRC, entitled "Application of Probabilistic Risk Assessment Methods to Performance Assessment in the NRC High-Level Waste Program," dated October 31, 1997). Such a tool can be used to provide a rank ordering of these scenarios with respect to the performance of the repository, as measured against a dose standard. The result would be the identification of licensing and rulemaking issues that derive directly from sensitivity analyses.

In summary, progress has been made through sensitivity studies to highlight important contributors to repository performance. The need exists to strengthen the tools, and possibly staff capabilities, in the important area of engineering analysis and design to meet the changing

landscape of the licensee's performance assessment of the Yucca Mountain repository. The KTIs and their supporting bases should also be reexamined in light of recent analyses, including work associated with the Issue Resolution Status Reports and the sensitivity studies.

Sincerely,

B. John Garrick
Chairman