Department of Energy
Washington, DC 20585

NOV 26 2001

NOV 20 2001

Dr. Jared L. Cohon
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Arlington, VA 22201-3367

Dear Dr. Cohon:

Thank you for your letter of October 17, 2001, providing the Board's perspective on information presented by the Department of Energy (DOE) at the Board's September meeting and from the Board's preliminary review of recent DOE/contractor reports. These reports included the Yucca Mountain Science and Engineering Report, the Preliminary Site Suitability Evaluation, and the Supplemental Science and Performance Analysis Report. The Board's letter indicates that there are some specific gaps in data and analyses that are making the Board's evaluation of the status of the Department's program more difficult. In an attempt to help the Board's evaluation process, we have provided the Board with reports, such as the Technical Update Impact Letter Report, that contain additional information on the Board's specific concerns, as noted in enclosure 1. DOE and contractor staff have been in regular and frequent contact with the Board's staff, as suggested in your letter. We trust that the information provided to your staff through telephone conversations and transmittals of requested information has been helpful to your understanding of the program.

We look forward to continuing our discussion on these issues with the Board.

Sincerely,

Lake Barrett, Acting Director
Office of Civilian Radioactive
Waste Management

Enclosures

Enclosure 1

Department of Energy Responses to the October 17, 2000, Letter From the Nuclear Waste Technical Review Board

The following text addresses the four key examples of the Board's concerns that there may be gaps in data and analyses as was highlighted in the October 17, 2000, letter from the Board:

The Board expressed concern that there is not, as yet, a complete comparison of high- and low-temperature repository designs

As was discussed in its May 30, 2001 letter to the Board, the DOE is preparing a more complete integrated evaluation and comparison of high- and low-temperature operating modes, based on available information. This comparison draws on the postclosure performance analyses in the *Supplemental Science and Performance Analyses* (SSPA) and the preclosure safety analyses in the *Preliminary Preclosure Safety Assessment for Monitored Geologic Repository Site Recommendation Report*. It also considers economic costs and the timeframe for construction, operation, ventilation, and closure. All of this information exists in various documents and reports that are available to the public. DOE plans to complete this comparison in the January timeframe.

This evaluation builds on previous work that addressed the risk/cost/benefit aspects of repository performance as a function of postclosure thermal conditions. In 1999, the DOE conducted a series of meetings and workshops on the topic culminating in the License Application and Design Selection Report (LADS)(CRWMS M&O 1999[1]). Board members and staff attended and contributed to many of those internal meetings. The final report and its supporting documents were transmitted to the Board as they were completed. A number of studies and reports have looked at the design concepts and performance implications of operating the repository in a below boiling configuration. They include:

- Draft Environmental Impact Statement (EIS) for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County Nevada and Supplement to the Draft EIS
- License Application Design Selection Report
- Operating a Below-Boiling Repository: Demonstration of Concept
- Natural Ventilation Study: Demonstration of Concept
- Three Lower Temperature Operating Mode Scenarios - Aging, Waste Package Spacing, and Drift Spacing
- Yucca Mountain Science and Engineering Report
- Supplemental Science and Performance Analyses Report
- Life Cycle Cost Analysis for Repository Flexible Design Concepts

[1] CRWMS M&O 1999, *License Application Design Selection Report.* B00000000-01717-5705-00131 REV 00. Las Vegas, Nevada.

- December 12, 2000, PORB Position Paper

- July 9, 2001, Memorandum from Michael Anderson to Elwood Stroupe: Repository Thermal Operating Curves for Nominal and 120 meter Drift

Each of these documents is briefly summarized with respect to examining cold operating modes in enclosure 2.

The repository design is flexible, and can be constructed and operated in various modes to achieve specific technical objectives, accommodate policy decisions, and address new information. As the Board has noted, the performance assessment results described in the SSPA do not show significant differences over the long term between the lower-temperature operating mode (LTOM) and the higher-temperature operating mode (HTOM). There are, however, measurable differences in performance at the subsystem level. Differences at the subsystem level do not appear at the total system level primarily because the duration of these changes is relatively short-lived (hundreds of years) in comparison to the duration of the regulatory time period (10,000 years) and to the time to calculated peak dose (~1,000,000 years). The degree of uncertainty associated with performance analyses during the first few thousand years may well be greater for the HTOM case than for the LTOM and uncertainty in the risk analysis could vary between different design/operating mode options. However, in either case the performance is well below limits set by the EPA and NRC for public health and safety.

To better understand uncertainties, DOE has conducted numerous tests and analyses, performance assessments, and peer reviews, over the last ten years. This helped to assure that uncertainties are appropriately identified and addressed in documentation supporting any Site Recommendation decision. We have also relied upon the reviews by the NRC, the Board, and other oversight bodies, as well as comments from the public and the State of Nevada as valued input into this process. DOE is confident that the following activities have addressed uncertainties at a level appropriate for the Site Recommendation decision:

- Scientific testing and analysis to quantify the uncertainty
- Iterative performance assessments to assess the significance of uncertainties
- Peer reviews of scientific bases to assess strengths, weaknesses, and the degree of confidence in projections of performance
- Reviews by the Nuclear Regulatory Commission, Nuclear Waste Technical Review Board and other oversight groups
- Comments by the public, Clark and Nye Counties and the State of Nevada

Each of these activities is briefly discussed in enclosure 2.

The DOE is continuing to investigate the sensitivity and uncertainty of performance analyses to design and operating mode decisions and to identify specific activities that will enhance the evaluation of lower temperature operating modes. This work is being done in anticipation of development of a license application and for other research needs,

should the site be designated. Planned work related to uncertainties in thermal conditions, beginning in FY 2002, includes:

- Continued waste package passive film corrosion material testing program to better understand underlying fundamental scientific processes.
- Continued review and modification of the Performance Confirmation Plan to provide for continued performance testing in the preclosure operational phase to better quantify performance uncertainties.
- Continued modeling activities to incorporate multiple lines of evidence for processes that affect long term performance.
- Performance of additional uncertainty and sensitivity analyses to better understand major contributors to long term performance.
- Continued review and validation of parameter ranges and Features, Events and Processes (FEP's) screening to ensure proper insight into total system performance.

Based on preliminary results from the latest evaluation of operating modes and results of all previous work, taken together with comments on the technical basis for Site Recommendation from the Board, USGS, Nye County, and other interested parties regarding the potential benefits of lower temperature postclosure conditions, the DOE is directing our contractor to implement work activities that will supplement information on the low-temperature operating mode. Updated results from the testing program will be used to expand the technical basis for this end of the flexible design for inclusion in a License Application. As was discussed in a recent meeting, DOE will invite the Board to participate in semi-annual meetings to discuss items of mutual interest such as the hot vs. the cold operating options. Updated information about the enhanced cold operating mode analyses is expected to be available to support the first of these meetings in the next several months.

The Board indicated that it still has questions about the contributions of natural and engineered barriers. In particular, the Board noted that it has suggested that the program conduct an alternative analysis in which barriers would be incrementally added *to the repository system to determine the contribution of each barrier to overall repository performance.*

An analysis was completed to provide some insight into the role of the natural and the engineered barriers, using the neutralization concept (*Figure 3-2, Revision 4 of the Repository Safety Strategy*[2]) and the TSPA model for Site Recommendation (TSPA-SR). This figure shows the annual dose without the benefit of any repository system barriers along with the annual dose for natural barriers alone, and the annual dose with full contribution of all barriers. The Electric Power Research Institute has used "Hazard Index" analyses to provide rough, quantitative estimates of the importance of important

[2] CRWMS M&O 2001. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations.* TDR-WIS-RL-000001 REV 04 ICN 01. Two volumes. Las Vegas, Nevada.

features, events, and processes (FEPs) by artificially turning off all FEPs and then adding in successive FEPs to evaluate their contribution to the total reduction in Hazard Index (EPRI 2000[3]). DOE has begun additional analyses of this type using the TSPA-SR model. As these analyses are completed and reviewed, DOE will share them with the Board.

The Board expressed concern that there is a lack of rationale for going forward in the face of unresolved issues. In particular, the Board expressed concern that the DOE has not presented a clear and persuasive rationale for going forward with a site recommendation before resolving the issue of differences of between volcanism models and the issue of the origin of moisture in the Cross Drift.

As set out in DOE's site suitability guidelines, a site suitability determination requires not a determination by DOE that all issues have been resolved, but rather a determination that a repository sited at Yucca Mountain would likely meet EPA's radiation protection standards and hence be licensable. DOE is continuing the process of determining whether to recommend the Yucca Mountain site for the location of a repository. During this process and in the future, if the site is designated, the DOE will continue to evaluate issues identified from its own ongoing science investigations as well as those identified by the NRC, the Board, and other interested parties. DOE's evaluation of a given issue may include internal technical review, additional testing, additional analyses, or peer review to responsibly address the issue. If DOE finds an issue significant enough to stop the site recommendation or licensing process, the DOE will do so. As noted in the NRC letter[4] (and its attachment) on sufficiency of site characterization, the NRC has reasonable confidence that, based on the information DOE has obtained or has agreed to obtain, development of an acceptable license application is achievable.

Igneous consequence models

Recent research sponsored by Center for Nuclear Waste Regulatory Analyses (Center) provides an initial attempt to model consequences of dike-drift interactions in more detail. These analyses suggest that more waste packages may be adversely affected than previously documented in performance assessment analyses (see the *Technical Update Impact Letter Report*, Section 4 and Appendices I and L). The Center-sponsored research focused on idealized conceptual models based on a single drift that is not reflective of the repository system. Their analysis did not address the probability of the various cases occurring, the probability distribution of one or more drifts being intercepted, the quantification of the number of packages damaged, or the extent of damage to the packages. To evaluate the potential implications of the Center-sponsored research, the DOE has completed a very rough estimate of the number of waste packages that may be affected, using the Center's idealized conceptual model. If one presumes that all the

[3] EPRI 2000. *Evaluation of the Candidate High-Level Radioactive Waste Repository at Yucca Mountain Using Total System Performance Assessment, Phase 5.* 1000802. Palo Alto, California: Electric Power Research Institute.

[4] Richard A. Meserve to Robert G. Card, letter and attachment dated November 13, 2001.

assumptions and conservatisms contained in the Center's model are valid and incorporates these assumptions into the DOE's supplemental performance model, the

number of damaged waste packages is not expected to increase more than an order of magnitude. The dose, in turn, is also not expected to increase by more than an order of magnitude over the 0.08 mrem/yr dose calculated for the combined probability-weighted mean dose for direct and indirect releases during the regulatory period, reported in the *Preliminary Site Suitability Evaluation*. Therefore the releases would remain below the EPA standard.

The DOE and NRC have reached agreement on a path forward for further analyses of igneous consequences to resolve the differing points of view. Having considered the Center's research, the DOE continues to believe that the technical basis for igneous consequences is sufficient to support evaluations of site suitability. Some observations that support this position include the following:

- Low probability of an event,
- Robustness of the hazard estimate,
- Waning character of volcanism in the region,
- Localization of igneous activity away from Yucca Mountain, and
- Conservatism included in the consequence analyses

Water in the bulkheaded section of the Cross-Drift

Recent observations and test results from the Cross-Drift Bulkhead Moisture Monitoring test are summarized in the *Technical Update Impact Letter Report* (Section 4 and Appendices B and L). Based on the observations of moisture in the most recent bulkhead entry, the DOE has decided not to move the bulkhead at station 17+63 in the cross Drift so that monitoring can continue over the same section of the Cross Drift. Results of analyses to date indicate that water sampled behind the bulkhead is low in chloride and silica, consistent with condensate as the source of the water. The DOE is collecting additional water samples to further evaluate the source of the water. In terms of postclosure performance, it is important to note that condensate water has little effect on waste-package and drip-shield corrosion models. These models assume aqueous conditions at low relative humidities and are not sensitive to the quantities of water present. In addition, there is little effect of seepage or condensation on transport in the unsaturated zone. Condensate might result in more advective releases from waste packages, but the impact of this is not expected to be large, especially considering the range of percolation and seepage included as uncertainty in the analyses. The potential impact on dose is expected to be minor.

Activities DOE has undertaken to examine cold operating modes

While these documents may not have fully addressed the Board's concerns, the following is a brief summary of documents that discuss activities DOE has undertaken to examine cold repository operating modes. For completeness we list all documents that relate to the cold operating mode:

Published Reports

Draft Environmental Impact Statement (EIS) for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County Nevada (DOE 1999) and Supplement to the Draft EIS (DOE 2001)

While it contains no new or original evaluations of the operating modes, the Draft EIS does include an evaluation of the environmental impacts of high, intermediate, and low thermal load scenarios. The Supplement to the Draft EIS includes an evaluation of impacts over a range of thermal operating modes from higher-temperature (equivalent to Draft EIS intermediate thermal load) and lower-temperature (equivalent to the range between the Draft EIS low and intermediate thermal loads).

License Application Design Selection Report (CRWMS M&O 1999)

This report evaluated five Enhanced Design Alternatives (EDA) which range in thermal operating modes from "cool" (boiling at the drift wall) to "hot" (above boiling) at the drift wall and throughout the pillar. These five EDAs easily meet postclosure performance (peak dose in 10,000 years) standards. The recommended Design Alternative is known as EDA-II, and its thermal operating mode is characterized by "boiling" at the drift wall and "below boiling" in a portion of the pillar. This design is a moderate thermal load compared to others considered and the Viability Assessment Design

Operating a Below-Boiling Repository: Demonstration of Concept (CRWMS M&O 2000)

This study demonstrates that the Site Recommendation design can be operated below boiling. The below-boiling repository can be achieved, by various combinations of: staging on the surface, changing the distance between waste packages within the emplacement drifts, and/or adjusting emplacement drift ventilation duration.

Natural Ventilation Study: Demonstration of Concept (CRWMS M&O 2000)

This study concluded that a combination of forced ventilation and natural ventilation is a technically viable option for keeping repository temperatures substantially lower. Certain

combinations of forced air ventilation and natural ventilation would result in below boiling drift wall temperatures.

Three Lower Temperature Operating Mode Scenarios - Aging, Waste Package Spacing, and Drift Spacing (CRWMS M&O 2000)

This analysis documents that the Site Recommendation reference design can be modified so that the waste-package surface temperature after closure remains at or below 85°C for the majority of waste packages. Three scenarios were evaluated; these included increasing drift spacing and allowing 300 years of active ventilation; a combination of aging, increasing waste package spacing, and at least 75 years of active ventilation; and increasing the drift spacing and 100 years of active ventilation.

Yucca Mountain Science and Engineering Report (DOE 2001)

This report provides a summary of analyses to assess the performance of a flexible design concept that includes lower- and higher-temperature operating modes.

Supplemental Science and Performance Analyses Report, Volume 1 (BSC 2001)

The effects of a range of thermal operating modes were evaluated. At the process model level, analyses indicate that the thermal operating mode does not significantly influence the natural processes over the long term. Lower temperature operating modes have less impact effects on the processes operating in the thermally perturbed region near emplacement drifts. For the higher temperature operating modes, the effects of coupled processes are generally small, and relatively short-lived. At the repository system level, the maximum differences in annual dose are approximately a factor of 10 while still achieving acceptable performance. The choice of thermal operating mode does not strongly influence overall conclusions from these supplemental analyses.

Life Cycle Cost Analysis for Repository Flexible Design Concepts (BSC 2001)

This report documents a life cycle cost analysis for repository flexible design and operating modes to provide input to the total system life cycle cost estimate for Site Recommendation and the Final Environmental Impact Statement.

YMSCO Internal Documents

December 12, 2000, PORB Position Paper

This position paper defines six scenarios that illustrate combinations of operating parameters to achieve goals for operating the reference repository design in lower-temperature operating modes. It also provides criteria to be met by a potential representative low-temperature operating mode for the Monitored Geologic Repository.

July 9, 2001, Memorandum from Michael Anderson to Elwood Stroupe: Repository Thermal Operating Curves for Nominal and 120 meter Drift

Repository thermal operating curves were generated to assess the difference in repository thermal performance for the nominal drift separation of 81 meters and an extended drift separation of 120 meters. These were evaluated for a peak waste package-surface temperature of 85°C.

Activities the Department of Energy has Undertaken to Improve Quantification of Uncertainties in Projections of Post Closure Performance

DOE is constantly seeking to improve the characterization of the Yucca Mountain site and engineered barriers that are potentially important to the assessment of post closure performance. Part of this characterization is to improve the sound scientific basis for the models used to project performance for the 10,000-year regulatory time period and longer. This characterization recognizes that residual uncertainties will remain after each characterization phase and that these uncertainties need to be evaluated to provide a meaningful assessment of risks to decision makers and the public.

To this end, DOE has conducted several activities to assure that uncertainties are appropriately identified and addressed in the development of the Site Recommendation. Each of these activities is briefly discussed below.

Scientific Testing and Analysis to Quantify Uncertainty

The scientific method is one of developing hypotheses and testing those hypotheses and, as additional testing is conducted, modifying hypotheses as necessary. This method includes subjecting scientific bases to reviews by peers. This method has been used for over 20 years of site characterization and engineered materials testing for the Yucca Mountain Project. This testing has formed the basis for models of post closure performance and provided uncertainty distributions in the forms of a) alternative models that explain the observations, b) spatially variable geologic and hydrologic properties that define the range of the environments expected, and c) parameter uncertainty associated with the behavior of the waste packages and waste forms in this range of environments.

Iterative Performance Assessments

DOE has conducted five major performance assessments of the Yucca Mountain site and engineered barriers in the past 10 years. Each of these analyses has used continually refined models based on the most current science available. Each analysis has evaluated the uncertainty in the projected performance through a range of quantitative uncertainty and sensitivity analyses. These analyses have assisted in defining the key components of the repository system and the important uncertainties affecting the performance. These analyses by DOE have been compared to similar analyses conducted over the same time

frame by the NRC and the Electric Power Research Institute (EPRI) that have identified very similar key aspects and uncertainties affecting the performance of a Yucca Mountain repository.

Peer Reviews

An important part of the scientific method is subjecting work to review by peers. Within the Yucca Mountain project, all scientific work is internally reviewed by the contractor staff or staff of the DOE National Laboratories or the US Geological Survey. The work by the National Laboratory staff is also internally reviewed by the management of the labs to assure it is appropriate for the decisions at hand. In addition, DOE has chartered independent external reviews of the scientific activities in a number of crucial areas, including the waste package degradation model and the Total System Performance Assessment model. Also, several external groups, notably the USGS, have provided independent reviews of the science at critical decision points for the Project such as the Viability Assessment and now the Site Recommendation. These peer reviews have identified areas of scientific weakness and the need for additional testing in certain areas to enhance the confidence in the projections of performance.

External Reviews by NRC and NWTRB

The NRC has been reviewing the scientific basis and uncertainty characterization as well as the incorporation of this basis and uncertainty in the Yucca Mountain performance assessment since the development of DOE's Site Characterization Plan in 1987. These reviews benefited from NRC staff's own Iterative Performance Assessment analyses. These reviews culminated in a series of NRC Key Technical Issue Technical Exchanges on the scientific basis for the Site Recommendation models. Additional reviews have been conducted by the Nuclear Waste Technical Review Board. These reviews have resulted in recommendations for the quantification of uncertainty to aid the decision maker in fully exploring the range of possible performance projections.

Comments by the Public and Affected Units of Government

The science developed for the Yucca Mountain Project has been commented on in various forums by local governments and the State of Nevada consultants. Clark County commented on the Viability Assessment and both Nye County and the State of Nevada consultants have commented on the saturated zone modeling in the vicinity of Yucca Mountain. Some of the comments included recommendations for alternative interpretations and models. These alternative interpretations and models have been reviewed by DOE, contractor, and national laboratory staff in their development of the Site Recommendation.