Appendix E

Communication Between U.S. Nuclear Waste Technical Review Board and U.S. Department of Energy

In addition to published reports, the Board periodically writes letters to the Director of the U.S. Department of Energy's (DOE) Office of Civilian Radioactive Waste Management (OCRWM). The letters typically provide the OCRWM with the Board's views on specific technical areas earlier than do Board reports. The letters are posted on the Board's Web site after they have been sent to the OCRWM. For archival purposes, the eight Board letters written during the period covered by this report are reproduced here.

The OCRWM typically responds to the Board's reports and letters, indicating its plans to respond to the Board's recommendations. Included here are the OCRWM's responses received by the Board during calendar year 2002. Inclusion of these responses does not imply the Board's concurrence.

- Letter from J. Russell Dyer, Project Manager, Yucca Mountain Site Characterization Office, to Jared L. Cohon; January 24, 2002.
  Subject: Fluid inclusions in mineral deposits at Yucca Mountain

- Letter from Jared L. Cohon to Lake Barrett, Acting Director, OCRWM; March 11, 2002.
  Subject: DOE's participation at the January Board meeting

- Letter from Margaret S. Y. Chu, Director, OCRWM, to Jared L. Cohon; April 1, 2002.
  Subject: DOE's responses to the January 24, 2002 letter report

- Letter from Jared L. Cohon to Margaret S. Y. Chu, Director, OCRWM; June 20, 2002.
  Subject: DOE's participation at the May Board meeting

- Letter from Margaret S. Y. Chu, Director, OCRWM, to Michael L. Corradini; August 5, 2002.
  Subject: DOE's responses to recommendations in the March 11, 2002 letter

- Letter from Margaret S. Y. Chu, Director, OCRWM, to Michael L. Corradini; September 6, 2002.
  Subject: DOE's responses to recommendations in the June 20, 2002 letter

- Letter from Michael L. Corradini to Margaret S. Y. Chu, Director, OCRWM; November 22, 2002.
  Subject: DOE's participation at the September Board meeting

- Letter from Margaret S. Y. Chu, Director, OCRWM, to Michael L. Corradini; January 24, 2003.
  Subject: DOE's responses to recommendations in the November 22, 2002 letter

Department of Energy
Office of Civilian Radioactive Waste Management
Yucca Mountain Site Characterization Office
P.O. Box 364629
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QA: N/A

JAN 24 2002

Dr. Jared L. Cohon
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Blvd.
Suite 1300
Arlington, VA 22201-3367

Dear Dr. Cohon:

On July 24, 1998, the Nuclear Waste Technical Review Board (the Board) provided the Acting Director, Office of Civilian Radioactive Waste Management with its evaluation of and conclusions about a set of material provided to it by the State of Nevada Attorney General's office. The set of material was presented as new evidence regarding the possible future upwelling of water into the proposed nuclear waste repository at Yucca Mountain. The Board concluded that the material it reviewed did not significantly affect the conclusions of the 1992 National Academy of Sciences (NAS) report on similar issues. The NAS considered such a scenario to be not credible. The U.S. Department of Energy (DOE) agreed with that conclusion then and now. The Board also suggested that DOE consider conducting some additional analyses to determine the ages of fluid inclusions in mineral deposits at Yucca Mountain.

As the Board suggested, the DOE funded a joint research program coordinated by Dr. Jean Cline, University of Nevada, Las Vegas (UNLV) in which scientists from the State of Nevada, the U.S. Geological Survey (USGS) and UNLV conducted detailed analyses of the fluid inclusions found in mineral deposits. Participants met on a regular basis between March 1999 and March 2001 to establish a common methodology for sample collection and handling and share the results of their investigations. The DOE appreciates the Board's ongoing interest in the fluid inclusions work, as evidenced by several invitations to Dr. Jean Cline and members of the working group of scientists, to present their findings to the Board. The Board staff and individual Board members also participated in the quarterly meetings and other fora where the work was presented.

Dr. Cline has given the DOE a two-part, draft report entitled "Thermochronological Evolution of Calcite Formation at the Potential Yucca Mountain Repository Site, Nevada: Part 1, Secondary Mineral Paragenesis and Geochemistry" (Wilson and Cline) and "Thermochronological Evolution of Calcite Formation at the Potential Yucca Mountain Repository Site, Nevada: Part 2, Fluid Inclusion Analyses and U-Pb Dating" (Wilson, Cline, and Amelin). The report was issued in draft form because the Harry Reid Center (HRC) acknowledges that there are some outstanding issues regarding the database generated by the scientists. Recent discussions with the HRC indicate these issues are nearly resolved and it is expected that the database will be submitted to the DOE Technical Data Management System in the near future.

The purpose of the Cline study was to independently examine the secondary mineral deposits and especially the fluid inclusions within these secondary minerals, and interpret the observations regarding the origin of the fluid inclusions and secondary mineralization. A reading of the report indicates the work provides independent confirmation of work on secondary minerals by DOE scientists. For example:

Dr. Jared L. Cohon -2- JAN 24 2002

Paces et al state in the abstract of the 2001 USGS report "Ages and Origins of Calcite and Opal in the Exploratory Studies Facility Tunnel, Yucca Mountain, Nevada": *The physical and isotopic data from calcite and opal indicate they formed from solutions of meteoric origin percolating through a limited network of connected fracture pathways in the unsaturated zone rather than by inundation from ascending groundwater originating in the saturated zone.*

Wilson, Cline, and Amelin state in the abstract for Part 2 of their report: *Results from this study are consistent with a model of descending meteoric water that infiltrated the cooling tuff sequence, became heated, and precipitated secondary minerals within the vadose zone.* And further, *This study demonstrates that the hypothesis of geologically recent upwelling hydrothermal fluids is untenable and should not disqualify the Yucca Mountain as a potential nuclear waste storage site.*

The position on this issue by scientists representing the State of Nevada seems unchanged. In a pre-publication excerpt from the "Scientific status of the lingering 'upwelling water' controversy in light of the joint UNLV/USGS/State of Nevada research project" by Jerzy S. Szymanski and Dr.Yuri V. Dublyansky, May 2001, pp. 19, *"The proposed conceptual model implies that vadose zone is occasionally subjected to an upward flux of heat and gas-charged fluid, in addition to being subjected to a small flux of infiltrating rainwater."*

The data collected by both DOE and UNLV researchers confirm that the conceptual model of descending percolation is correct. The DOE further concludes that the "upwelling waters" or "seismic pumping" hypotheses for the origin of secondary mineralization at the Yucca Mountain site have been adequately addressed and may be discounted. The DOE is continuing to examine secondary minerals in conjunction with studies involving infiltration, flux rates, thermal effects, waste package geochemistry, paleohydrology and for other studies. Specifically, DOE does have ongoing studies to investigate the thermal history of the younger inclusions. The DOE and our scientists remain open-minded and interested in the characterization of the geology and hydrology of the proposed Yucca Mountain site, and how it might perform as a repository for nuclear waste.

Sincerely,

J. Russell Dyer
Project Manager

OL&RC:CMN-0488

Dr. Jared L. Cohon -3- JAN 24 2002

cc:
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UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

March 11, 2002

Mr. Lake H. Barrett, Acting Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
RW-2/5A-085
Washington, DC 20585

Dear Mr. Barrett:

Thank you very much for the participation of the Department of Energy (DOE) and its contractors at the January 29-30, 2002, meeting of the U.S. Nuclear Waste Technical Review Board in Pahrump, Nevada. We very much appreciate the hard work and extensive preparation required for the meeting. The presentations and discussions were both interesting and informative.

On the basis of presentations at the meeting and its previous oversight activities, the Board has three principal recommendations. First, because of existing uncertainties, a sustained commitment to continued scientific and engineering investigations is required to improve the technical basis for evaluating the performance of the proposed nuclear waste repository at Yucca Mountain. Second, data and analyses from this research should be assimilated into a realistic total system performance assessment (TSPA) analysis. Third, the DOE needs to communicate its results more clearly and effectively to decision-makers and the public. The recommendations are explained further below.

Scientific and Engineering Investigations

It is very important that the DOE vigorously pursue sustained scientific and engineering investigations to improve understanding of the capability of the site and associated engineered systems to isolate radioactive waste.

The DOE has made considerable progress in quantifying uncertainties and conservatisms in many areas. The products of these efforts can help to guide or focus further scientific and engineering investigations. However, the Board is concerned that some hydrogeologic processes that may either substantially accelerate or retard radionuclide transport in the unsaturated zone and saturated zone in and under Yucca Mountain remain poorly understood. For example, colloid-facilitated transport may accelerate radionuclide migration, and secondary mineralization may retard it. Furthermore, there is not yet a technically credible analysis of water accumulation and movement in and around the bulkheaded section of the exploratory cross-drift, no empirical evidence exists to support the drift-shadow concept, no large-scale field measurements of hydraulic properties of major geologic faults at Yucca Mountain have ever been made, and

improvements in the regional saturated zone hydrogeologic model have not been incorporated in the site-scale model.

The DOE's current base-case repository design would produce temperatures on the waste package of 120 °C or higher for 500 to 1,000 years and peak temperatures as high as approximately 160 °C. The Board questions the DOE's conclusion that there is no significant long-term difference in repository performance predictions that is attributable to temperature. That conclusion appears to be inconsistent with statements by DOE scientists at the meeting indicating that uncertainties in hydrologic processes increase at higher repository temperatures. Furthermore, experimental work and analyses clearly indicate that potentially corrosive aqueous environments are possible in a repository at Yucca Mountain at temperatures up to approximately 160 °C. Yet, the DOE has essentially no corrosion data for Alloy 22 above 120 °C under repository-relevant conditions. Therefore, assessing the likelihood that localized corrosion could penetrate waste packages (causing them to fail) during the first few thousand years after repository closure is not possible currently. These uncertainties weaken the technical basis of the DOE's performance predictions.

Performance assessment calculations in the site recommendation show igneous activity to be the largest contributor to radioactive dose during the first 10,000 years. As discussed at the Board's September 2001 meeting, significant differences exist between Nuclear Regulatory Commission-sponsored models and the DOE models. The Board expressed its concerns about this situation in its October 17, 2001, letter to the DOE. On the basis of the reports of external experts, which were provided to the Board subsequent to that letter (all available at www.nwtrb.gov), the Board believes that the model proposed by the Nuclear Regulatory Commission-sponsored consultants may be overly conservative, and our concerns have lessened. However, because of the significance of igneous activity to the estimated dose, additional work leading to a better understanding of igneous consequences is needed to resolve this issue.

At the Board meeting and in a letter to the Board dated January 24, 2002, the DOE concluded that the hypotheses of hydrothermal upwelling proposed by Mr. Jerry Szymanski had been adequately addressed and may be discounted. These conclusions were based on the DOE's positive response to a Board recommendation that a joint federal-State of Nevada project be conducted to determine the ages of fluid inclusions at Yucca Mountain. A systematic joint study was coordinated by University of Nevada-Las Vegas scientists and can be considered a model for successful resolution of some contentious scientific issues. The Board concurs with the DOE's conclusions and considers this issue resolved. The Board also concurs with the stated commitment of the DOE to continue study of secondary minerals for the information they can provide about infiltration, flux rate, thermal effects, waste package geochemistry, paleohydrology, and radionuclide transport and to continue ongoing studies of the thermal history of the younger of the fluid inclusions.

Total System Performance Assessment

The DOE's compliance-oriented TSPA for site recommendation contains a mix of conservative, realistic, and nonconservative elements. Making performance estimates more realistic and characterizing the full range of uncertainty would increase confidence in the DOE's performance estimates and would provide a mechanism for assessing the magnitude of conservatism of the current compliance-oriented TSPA. Building confidence in the analyses is particularly important in light of the unique long-term implications of the policy decisions to be

made in the near future. A realistic analysis can yield a better understanding of the performance of the major subsystems for radioactive waste isolation at Yucca Mountain, and especially an improved understanding of the behavior of the unsaturated and saturated zones (without engineered barriers). To that end, the DOE should perform "one-on" TSPA dose calculations from waste initially exposed at the accessible environment boundary, then mitigated by transport through the unsaturated zone, then further mitigated by transport through the saturated zone, and finally mitigated by the cumulative effect of the engineered barrier system in concert with the natural barriers.

Clear and Effective Communication

Technical information and—as important—uncertainties associated with that information should be communicated clearly and effectively to decision-makers and the public. The meeting offered satisfactory and unsatisfactory examples of clear and effective communication. For example, the explanations presented at the Board meeting related to the evaluation of the uncertainties tabulated by the DOE were important and comprehensible. On the other hand, the risk curves of probability-weighted dose resulting from low-probability igneous events, although required for regulatory analyses, by themselves mislead diverse audiences who may be trying to better understand either the consequences or the probability of these events.

Thank you again for participating in the Board's meeting and for your cooperation with our ongoing efforts. We look forward to further interactions with the DOE on these issues.

Sincerely,

{Signed by}

Jared L. Cohon
Chairman

Department of Energy
Washington, DC 20585

APR 01 2002

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

Dear Dr. Cohon:

This letter transmits the U. S. Department of Energy's response to the Nuclear Waste Technical Review Board January 24, 2002, letter which provided the Board's comments on the Department's technical and scientific work related to a decision on a Yucca Mountain, Nevada, site recommendation.

The Department has developed technical analyses and regulatory evaluations that account for our understanding of the scientific and technical work in the Site Recommendation documents. Based on the analytical results and sound scientific principles, the Department has confidence that a Yucca Mountain repository would likely meet all applicable radiation protection standards.

The Board's letter recommends specific actions that the Department should consider if the Yucca Mountain site is designated, including:

- Systematically integrating new data and analyses from science and engineering investigations;
- Monitoring performance before, during, and after waste emplacement;
- Developing a strategy for modifying or stopping repository development if potential significant unforeseen circumstances are encountered; and
- Continued external review of the Department's technical activities.

The Department agrees with these recommendations. If the site is designated, the Department will continue to integrate the results of ongoing data and analyses from the science and engineering investigations. The Department's Test and Evaluation Plan, and supporting Performance Confirmation Plan, provide the preliminary strategy for continued testing and for monitoring performance before, during, and after waste emplacement. The Department also has procedures in place to modify or delay work if potential significant unforeseen circumstances are encountered. For example, our procedure for *Reportable Geologic Condition* (which was used to address Chlorine 36) defines a systematic process for evaluating technically significant conditions, including conditions that could adversely impact the waste isolation capability of the site, could be a potential radiological hazard, or could result in a deviation from the Project's design bases. For significant conditions, the procedure requires a decision to modify the testing program or to delay work, depending on the nature of the observation. Should the evaluation of conditions warrant it, the Department would define activities for stopping repository development.

The Department has implemented a number of external reviews of the scientific testing and analysis completed for the Yucca Mountain site. Recent examples include the ongoing peer review of the waste package materials performance, the International Peer Review of the Total System Performance Assessment (TSPA) for Site Recommendation, ongoing reviews by the U. S. Nuclear Regulatory Commission and the Board, reviews by Project Oversight Boards, and the recent Biosphere Peer Review. These reviews have provided beneficial feedback to the Project and resulted in improvements in the scope of testing activities and analytical approaches. If the site is designated, the Department will continue to use external reviews to increase confidence in our scientific and engineering work and improve the technical basis for a potential license application.

Over the past two years, the Department has focused considerable effort on the Board's four priority areas for Site Recommendation. A brief summary of each of these areas and of the Board's recommendation for continued study of the natural hydrogeologic barriers is provided in the following paragraphs.

Meaningful quantification of conservatisms and uncertainties

The Department began an effort to quantify previously unquantified uncertainties and conservatisms in the TSPA in 2000. You noted that we have made significant progress in this area. We are committed to continue quantifying uncertainties in performance assessment models, documenting the technical basis for these assessments, exploring avenues for reducing uncertainties, and defining ways to communicate uncertainty to decision-makers. The proposed guidance for continued work to quantify uncertainties

and conservatisms is documented in the *Uncertainty Analysis and Strategy* document, issued in November of 2001. This guidance has been further developed in the "Guidelines for Developing and Documenting Alternative Conceptual Models, Model Abstractions, and Parameter Uncertainty in the TSPA for Potential License Application," (March 2002). The guidance will be implemented throughout the performance assessment models and in the *TSPA Methods and Assumptions* document that is being developed for the TSPA for License Application, if the site is designated.

Progress in understanding the underlying fundamental waste package processes

The Department agrees with the Board that we have made significant progress in understanding fundamental corrosion processes. Consistent with the Board's recommendation to continue efforts in this area, the Department has an ongoing comprehensive program for materials testing, which has been reviewed with the Board, that will continue if the site is designated. The Waste Package Peer Review panel has recently completed its report. The Department expects to incorporate many of the recommendations from that panel in its materials testing program.

Evaluation and comparison of the base-case repository design with a low temperature design

The Department continues to focus on the refinement of a design that can function effectively over a range of thermal conditions. The Department believes that this course of action preserves the ability to react to new information and evolving technology. Until sufficient information is available to make a decision on optimal thermal operating conditions, and until this decision is necessary, the Department will maintain the flexibility to operate in either a higher or lower thermal condition. At the appropriate time, the Department will select a preferred thermal condition, based on postclosure performance, preclosure safety, cost and schedule, and future national policy decisions. The Department has ongoing research and analysis to strengthen the technical basis for both a higher and a lower temperature operating mode. This work will provide a stronger basis for any future decision on the postclosure thermal conditions.

Development of multiple lines of evidence that are independent of performance assessment

As noted by the Board, the Department has increased its use of analogs over the last three years and is now placing greater reliance on analogs to support parameter development and ranges of parameter values for some process models. If the site is designated, the

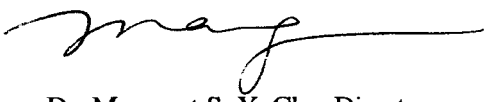
Department will continue to evaluate natural analogs and alternative models to provide independent lines of evidence to increase confidence in the conclusions reached in its safety assessments. The Department is also planning to complete "one-on" analyses in the fall time frame to provide insight on the effectiveness of individual barriers. These analyses will support our evaluation of defense-in-depth.

Natural hydrogeologic barriers

The Board recommends that the Department continue scientific studies to develop more realistic and technically defensible predictions of fluid flow and transport in the unsaturated and saturated zones at Yucca Mountain for the range of radionuclides that may be emplaced at Yucca Mountain. The Board's confidence in the Department's analyses of fluid flow and transport could be substantially increased if the Department completes a concentrated research effort over the next few years. Bechtel SAIC Company, LLC, is defining the work scope that will lead to a License Application in 2004. The scientific investigations and analyses necessary to support License Application will be prioritized and considered with other project activities, such as design, to produce a balanced program within the funding constraints dictated by our budget. As indicated above, additional scientific investigations and analyses to improve our understanding and confidence in how natural and engineered systems work is planned to continue during License Application preparation and beyond.

The Department has benefited from the constructive views of the Board leading to the development of the technical basis for the Secretary's Site Recommendation decision. If the site is designated and the Department proceeds to develop a License Application, we look forward to continuing our dialogue on these important issues with the Board.

Sincerely,



Dr. Margaret S. Y. Chu, Director
Office of Civilian Radioactive
Waste Management

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

June 20, 2002

Dr. Margaret S. Y. Chu
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, D.C. 20585

Dear Dr. Chu:

On behalf of the Nuclear Waste Technical Review Board, I would like to thank you and your colleagues from the Department of Energy (DOE) and its contractors who participated in the Board's meeting on May 7-8, 2002, in Washington, D.C. We appreciated your presentation and the presentation by Under Secretary of Energy Robert Card. We also were pleased that you were able to attend so much of the two-day meeting. The Board found it especially useful that, to varying degrees, all the presentations at the meeting touched on the important task of increasing confidence in the technical basis for the DOE's repository performance estimates.

Increasing Confidence

Waste Package Corrosion and Repository Design

Two presentations directly addressed two Board priorities: (1) progress in understanding the underlying fundamental processes involved in predicting the rate of waste package corrosion and (2) an evaluation and a comparison of the DOE's base-case (high-temperature) repository design with a low-temperature design.

The Board commends the DOE for convening the Waste Package Materials Performance Peer Review Panel, whose excellent final report is both comprehensive and timely. The report contains many recommendations for further research and development that should increase confidence in the technical basis for predictions of the long-term performance of the waste package. The Board strongly endorses the recommendations in the report, especially the recommendation for better addressing issues related to waste package design, fabrication, and closure. Because of the importance to repository performance of the Alloy 22 protective passive layer, the Board continues to believe that the technical basis for extrapolating corrosion behavior over thousands of years needs to be more firmly established. The DOE should continue to search diligently for natural and archaeological analogues and should perform experimental and analytical studies on the analogues that appear to have been protected for long periods by passive layers.

One objective of repository design is to provide tunnel environments that will slow waste package corrosion and minimize its associated uncertainties. As you know, the Board believes that high temperatures increase uncertainties and decrease confidence in the predictions of performance of waste package materials. Therefore, the Board is encouraged that the DOE is

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committed to preserving the option of a low-temperature repository. However, the technical basis for the DOE's selection of a high-temperature repository design for a potential license application remains unclear to the Board, particularly in view of the uncertainties associated with a high-temperature design and the lack of data on high-temperature corrosion. Furthermore, the DOE's current high-temperature repository design differs from the one assumed in the documentation for the site recommendation in key areas, such as waste package spacing. Finally, design flexibility deserves further analysis in light of recent ventilation calculations and the current uncertainties about the thermal conductivity of the rocks in the repository horizon. Seriously considering designs other than the DOE's current high-temperature base-case design may be of considerable value to the program if it proceeds into the licensing phase.

Repository Safety Case and Performance Confirmation

As stated in previous correspondence from the Board to the DOE, the Board strongly supports the DOE's efforts to develop a repository safety case now for supporting a potential license application and for improving the DOE's communication with decision-makers and the public. The safety case should explain how a repository at Yucca Mountain would isolate radioactive waste for many thousands of years and should rely on the numerical analyses used to predict repository performance as well as other evidence that supports those numerical analyses. Such supporting evidence addresses two other Board priorities: (1) meaningful quantification of conservatisms and uncertainties in performance assessments and (2) development of multiple lines of evidence to support the repository safety case. Consistent with the approach taken in other countries, the Board recommends that the DOE prepare a working draft of its safety case as soon as possible to provide ample opportunities for modification and refinement in response to technical and public comment.

The Board believes that performance confirmation should focus on evaluating the validity of estimates of long-term repository performance and challenging their underlying assumptions. However, the DOE presentations did not make clear to the Board what the DOE's overall goal for performance confirmation is or how the DOE intends to validate its predictions of repository performance. Progress in developing a meaningful performance confirmation plan will be limited until a safety case has been drafted. Development of a meaningful plan may be complicated further by the potential for competing interpretations of the data that are gathered (e.g., efforts to explain chlorine-36 data and the appearance of water in the closed-off section of the cross-drift).

Adaptive Staging

Adaptive staging is a management approach that could potentially increase confidence in the DOE's repository development efforts by ensuring that the logic and the underlying technical arguments of the safety case will be reviewed periodically and that midcourse corrections will be made if necessary. As the National Research Council's panel on repository staging notes in its recently released progress report, adaptive staging differs significantly from a linear, predetermined repository development process, which is characterized by an unwavering commitment to a single course of action to secure a fixed outcome. The panel observes that adaptive staging is a "promising approach," but the panel also cautions that systematic organizational learning—a key requirement for adaptive staging—is challenging under the best of circumstances. The Board encourages the DOE to develop a better understanding of adaptive

staging and to analyze the implications of this approach for its present organization and for its interaction with the public.

The presentation on flexible repository design and thermal operating conditions came closest of all the presentations at the meeting to illustrating how adaptive staging might work during performance confirmation. In that presentation, discrete decision points were identified, additional data that need to be collected and integrated were specified, milestones for reevaluating and reassessing decisions were established, and choices that might foreclose future options were clearly highlighted. Just as technical flexibility will be a prerequisite for adaptive staging, it is essential that the DOE be willing to make midcourse technical or programmatic corrections during performance confirmation if they are required. In summary, using adaptive staging will require that the DOE address with specificity the following questions: What information can be gathered over what time frame? How will that information be used to determine whether previous decisions and assumptions about repository performance remain valid? What midcourse corrections or remedial actions, if any, are warranted?

New Organizational Structure

As noted in the Board's January 24, 2002, letter report to Congress and the Secretary of Energy, improving understanding and filling in existing data gaps are important for increasing confidence in estimates of repository performance and for better defining necessary activities associated with performance confirmation. At the May meeting, the DOE informed the Board that it had established a task force to develop options for increasing fundamental understanding of the proposed repository system and for increasing confidence in projections of repository performance. Of course, the Board expects that work directed toward a potential license application would increase confidence as well. New information and analyses may have important implications for the development of a safety case as well as for repository design.

Any work undertaken by this task force not only should supplement but also should be integrated with the work already planned for a potential license application. The Board looks forward to reviewing the studies initiated by the new task force as well as the ongoing efforts to refine parameter estimates, models, and scenarios and to develop the next iteration of performance assessment.

Again, the Board thanks you, the DOE staff, and the DOE's contractors for supporting its May Board meeting. It looks forward to your promised September update, which could provide more details about investigations to improve understanding of the role of natural barriers, such as the saturated zone, in containing and isolating waste. The Board also would like to hear how the DOE plans to address the issues discussed in this letter.

Sincerely,

{Signed by}

Jared L. Cohon
Chairman

cc: Robert G. Card

Department of Energy
Washington, DC 20585

AUG 05 2002

Dr. Michael L. Corradini, Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201-3367

Dear Dr. Corradini:

This is in response to Dr. Jared Cohen's letter of March 11, 2002, providing the Nuclear Waste Technical Review Board's (Board) perspective on information presented by the U.S. Department of Energy (DOE) at the Board's January 2002 Board Meeting. Based on the presentations at the meeting and previous oversight activities, the Board provided three principal recommendations for DOE to consider in planning future studies at the Yucca Mountain, Nevada site:

- Sustained commitment to continued science and engineering investigations.
- Assimilation of the data and analyses from these investigations into a realistic total system performance assessment.
- Clear and effective communication to decision makers and the public.

The DOE fully concurs with the Board in the importance of these recommendations to the Office of Civilian Radioactive Waste Management program. Our current plans include work that will address all three of your recommendations. Each of these recommendations is discussed in the enclosure to this letter.

The DOE has benefited from the constructive views of the Board. As DOE proceeds to develop a license application, we will look forward to continuing our dialogue with the Board on these and other important issues.

Sincerely,

Dr. Margaret S. Y. Chu, Director
Office of Civilian Radioactive
Waste Management

Enclosure:
U.S. Department of Energy's Responses to Recommendations in the March 11, 2002, Letter from the Nuclear Waste Technical Review Board

Dr. Michael L. Corradini

cc w/encl:
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L. J. Desell, DOE/YMSCO, (RW-2), FORS

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Enclosure

U.S. Department of Energy (Department) Responses to Recommendations in the March 11, 2002, Letter from the Nuclear Waste Technical Review Board (Board)

Sustained Commitment to Scientific and Engineering Investigations

The Department believes that the work currently planned and funded to strengthen the technical basis for a potential license application is adequate to request a construction authorization from the U.S. Nuclear Regulatory Commission (NRC). However, the Department is committed to continuing scientific and engineering investigations that will be structured to focus on scientific and technical issues that, if resolved satisfactorially, could bring significant cost reductions and systems enhancements to the implementation of a repository at the site. Such investigations would also be structured to provide increased confidence in the understanding of the physical processes at Yucca Mountain and to improve the defense of long-term projections of site performance. In addition, this effort will evaluate new and emerging technologies for the waste management system. In general, information resulting from these continuing science and technology efforts will not be available for the initial license application, but will be made available throughout the licensing and operational phase of the repository. As such, science and technology related activities not currently underway for the development of the license application can still be undertaken in the continuing scientific and engineering investigations effort, should funding be available.

The Board has identified areas of investigation that could improve understanding of the capability of the site and the engineered system to limit releases to the accessible environment. The Department will be planning scientific and engineering investigations in the areas identified by the Board discussed below and will consider other areas of investigation to enhance our fundamental understanding of system performance.

Hydrologic processes that accelerate or retard radionuclide transport in the unsaturated and saturated zone

The Board notes that some hydrologic processes that may either substantially accelerate or retard radionuclide transport in the unsaturated and saturated zones are poorly understood. The Board's examples are discussed in the following paragraphs.

Current work on transport in the unsaturated and saturated zone is primarily focused on the evaluation, and validation as appropriate, of existing models. Ongoing transport testing work at Busted Butte will be completed, but planned field tests of colloid transport for the unsaturated zone has been cancelled. For the saturated zone, enhancements to the colloid transport model are not planned in the near term. Uncertainty in the colloid transport models for the unsaturated and saturated zones will be evaluated through sensitivity analyses. After submitting information feeds to performance assessment for use in the Total System Performance Assessment (TSPA) for

License Application, the Department will evaluate technical issues related to colloid transport in the unsaturated and saturated zone to determine the need for additional work on colloids both in terms of strengthening the license application case for subsequent updates and improving scientific understanding.

Testing in the bulkheaded section of the Exploratory Studies Facility (ESF), Cross Drift is continuing to focus on evaluating the accumulation and movement of moisture in and around the drift. Available chemical analyses suggest that the source of water in this section of the ESF Cross Drift is condensate rather than seepage. Monitoring will continue to evaluate the source of this moisture.

The predicted consequence of preferential diversion of water around underground openings is the development of a dry-out zone beneath the opening. If a dry-out zone or drift shadow zone of drier conditions exists beneath the drifts at Yucca Mountain, advective and diffusive transport would be greatly reduced in the vicinity of potential points of radionuclide release, leading to longer transport times in the region directly below the waste emplacement drifts. To date, the Department has only partly included the concept in performance assessment calculations of transport in the unsaturated zone. Additional studies to evaluate this concept are likely necessary to take credit for the full shadow zone concept in performance assessment calculations. There is a potential for significant delay in and lowering of peak dose, if diffusive and advective transport rates from the engineered system into the mountain-scale flow system are significantly lowered.

More realistic models of the flow of water in the system after a return to ambient temperature conditions and a more realistic look at the potential for no continuous moisture pathways from the waste form to the invert are additional areas that might lead to increased confidence in system performance. If this work is coupled with drift shadow zone work, it promises to have an impact on both the overall scientific understanding of the system and on calculations of expected dose in the very long term.

Large scale measurement of hydraulic properties of faults

Although there are no large-scale field measurements of hydraulic properties of major geologic faults in the saturated zone at Yucca Mountain, flow in the tuff aquifer is believed to occur in a fracture network that exhibits a preferential north-south strike. Faults mapped at the surface have a similar preferred orientation and are represented implicitly both in the new regional flow model and in the site-scale flow and transport model as zones of enhanced permeability.

It is reasonable to expect variability in fault properties in the saturated zone. The field testing in the area of the Paintbrush Fault penetrated in the well UE25 p-1 indicates that the Paintbrush Fault system at this locality serves as a barrier to flow. However, in other areas, air permeability and flow tests suggest that the fracture and fault zones in Tertiary volcanics exhibit a fairly high permeability relative to the non-faulted rock. The Department believes that the current approach to modeling fault properties in the

saturated zone as zones of enhanced permeability is consistent with the data, however, in some areas of the site this may be conservative. Additional long-term field-testing may lead to a more representative saturated zone flow and transport model.

In the unsaturated zone, direct measurements of fault-specific properties of the Bow Ridge Fault and the Ghost Dance Fault have been conducted using air-injection tests in the ESF. These data suggest that, within the welded units of the Topopah Spring and the Tiva Canyon tuffs, the fractures in the fault zones are more permeable and porous than the fractures in the formation. From these data, it is inferred that faults within the Paintbrush and Calico Hills nonwelded units have higher permeabilities than the adjacent non-faulted rock.

Natural variability in fault properties could result in low permeabilities in portions of these units and retard movement of water. This would lead to slower transport to the water table. Faults are modeled as high permeability structures in the Paintbrush and Calico Hills nonwelded units because there is insufficient data to limit interpretations to a single conceptual model. Long-term testing and analyses may reduce the conservatism in this model and lead to greater performance from the unsaturated zone.

The primary focus of ongoing work on the site-scale saturated zone model is evaluation of this model, and validation as appropriate. The effort is taking into account new data from the Nye County wells and single-well tests at the Alluvial Testing Complex and a comparison of the updated, 2001 United States Geological Survey model with the site-scale saturated zone model. This work will provide the inputs from the site-scale saturated zone model to performance assessment analysts for development of the TSPA for the License Application. The United States Geological Survey is continuing to develop their regional saturated zone model.

Localized Corrosion

The Department has a comprehensive ongoing and planned experimental program to investigate localized corrosion in repository-relevant conditions. The Department has been considering a range of thermal conditions for the repository. At the high end, this range includes thermal conditions in which the surface temperature of the waste package is expected to be less than 180°C. At the low end, this range includes thermal conditions in which the surface temperature of the waste package is expected to be less than 85°C. A key concern for the higher end of the range of thermal conditions is the time at which the surface temperature of the waste package approaches 120°C. That is the temperature at which salts could facilitate formation of moisture on the waste package surface and is the subject of continuing investigations. Continued investigations will focus on the range of susceptibility.

Under projected repository conditions, aqueous solutions at elevated temperatures (>120°C) could occur if chloride salts of calcium ($CaCl_2$) or magnesium ($MgCl_2$) are present. In support of understanding the effect of these hygroscopic salts, atmospheric corrosion studies (i.e. aqueous thin film studies) with deposited $CaCl_2$ are being

conducted at temperatures up to 150°C using a thermogravimetric analyzer and an environmental chamber. The project is addressing the likelihood of $CaCl_2$ and $MgCl_2$ deposition on the waste packages and the quantities that could be expected. Thermodynamic modeling is also underway to understand the compositions of aqueous solutions that could develop under the projected temperature and relative humidity conditions.

Consequences of Igneous Activity

The Department agrees with the Board's assessment that the model proposed by the NRC consultants is overly conservative. The Department has planned additional work to improve the understanding of the consequences of igneous activity, because performance analyses indicate that igneous activity is potentially the largest contributor to the probability-weighted mean annual radioactive dose during the first 10,000 years. An external peer review of the planned work on potential consequences of igneous activity is now underway. The peer review panel is reviewing the current technical basis for the evaluation of the consequences of igneous activity, proposed work to analyze the consequences of igneous activity, and the adequacy of the associated modeling program. They will recommend any augmentations to planned work that would strengthen the technical basis for the evaluation of consequences from igneous activity.

Hydrothermal Upwelling

The Department is pleased that the Board considers the issue of hydrothermal upwelling resolved. As discussed in our letter (Dyer to Cohen, 1/24/02), while the issue of upwelling is closed, we plan to continue the study of secondary minerals to provide additional insights into the understanding of various aspects of flow and transport in the unsaturated and saturated zones.

Assimilation of the data and analyses from these investigations into a realistic total system performance assessment

As we noted at the January 2002 Board Meeting, the TSPA for a potential License Application will, to the extent practicable, include a better treatment of uncertainty than previous iterations of TSPA. The Project is following the approach presented in the 2001 *Uncertainty Analyses and Strategy Letter Report*[1] in developing the TSPA for a potential license application. This is a continuing effort to replace single bounding values with probability distribution values that is highly dependent on the nature and quantity of data available and obtainable. Analyses of the impact of that uncertainty on subsystem and system performance will be included. The Department will continue to assimilate the results of ongoing scientific and engineering investigations into future iterations of the TSPA; however, some conservatism will, of necessity, remain due to the nature of the parameter being considered.

The Department is conducting sensitivity analyses to increase our understanding of the significance of the influence of various components used in the TSPA model. These

analyses include "one-off" neutralization analyses, "one-on" analyses to look at individual barriers, and sequential analyses in which barriers are added one at a time to observe the combined effects of the barriers for gaining insight on individual and combined barrier effects.

[1] Nancy H. Williams. 2001. "Contract Number DE-AC08-01RW12101, *Uncertainty Analyses and Strategy Letter Report*, Revision 00, Activity #SA011481M4." Letter from N. H. Williams (BSC) to S. J. Brocoum (DOE/YMSCO), November 19, 2001, JM:cs-1116010483, with enclosure. ACC: MOL.20020109.0064.

Clear and Effective Communication

The Department agrees that clear and effective communication of technical information and the uncertainties in that information to decision makers and the public is important. The Department has also learned from experience that conveying highly technical information to those same audiences is difficult. The 2002 *Uncertainty Analyses and Strategy Letter Report* provides initial guidance on methods for expressing and communicating uncertainty, including examples of approaches used by other projects to communicate uncertainty. This guidance is being implemented in the development of alternative conceptual models, model abstractions, and parameter uncertainty for the next iteration of the TSPA. The Department is evaluating comments and recommendations from the recent international review of the TSPA, completed to support Site Recommendation, to see how best to communicate highly technical concepts, such as probabilistic calculations and their results and uncertainties, to diverse audiences.

Department of Energy
Washington, DC 20585

September 6, 2002

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

Dear Dr. Corradini:

On behalf of the Department, I would like to extend my congratulations on your appointment as Chairman of the Nuclear Waste Technical Review Board. I look forward to a long and positive association with you and the Board. I would also like to take this opportunity to extend my thanks to the outgoing Board Chairman, Dr. Jared L. Cohon, and to Dr. Donald D. Runnells, Dr. Alberto A. Sagüés, and Dr. Jeffery Wong for their years of dedicated service as members of the Board.

In his June 20, 2002, letter, Dr. Cohon provided the Board's perspective on information presented by the Department at the Board's May 2002 Board Meeting. Based on the presentations at that meeting and previous oversight activities, the Board provided comments in two general areas for the Department to consider in planning future studies at the Yucca Mountain site:

- Increasing confidence in the understanding of waste package corrosion and long term repository performance

- The potential value of a new organizational structure that will increase fundamental understanding of the repository system

The DOE agrees with the Board about the importance of both of these topics. Our current plans include work that will address the comments that the Board provided in its June letter. Those comments are discussed in the attachment to this letter.

The Department has benefited from the constructive views of the Board. We appreciate the Board's review of our activities as we develop a license application for a repository at Yucca Mountain, and look forward to continuing our dialogue with the Board on these and other important issues.

Sincerely,

Dr. Margaret S.Y. Chu, Director
Office of Civilian Radioactive
Waste Management

Enclosure

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DOE discussion of NWTRB Comments on Increasing Confidence in the Technical Basis for Estimates of Repository Performance, June 20, 2002

Waste Package Corrosion

> *The Board commends the DOE for convening the Waste Package Materials Performance Peer Review Panel, whose excellent final report is both comprehensive and timely. The report contains many recommendations for further research and development that should increase confidence in the technical basis for predictions of the long-term performance of the waste package. ...The Board continues to believe that the technical basis for extrapolating corrosion behavior over thousands of years needs to be more firmly established. The DOE should continue to search diligently for natural and archaeological analogues and should perform experimental and analytical studies on the analogues that appear to have been protected for long periods by passive layers.*

The DOE agrees that this Peer Review produced an excellent and comprehensive review of the current basis for predicting the long-term performance of waste package and drip shield materials and the adequacy of plans for future study. The DOE is in the process of evaluating the Panel recommendations as we plan testing and analysis for the next phase of the Yucca Mountain Project. We will continue to look for natural and archaeological analogs that appear to have been protected by passive layers for long periods. If found, they would be excellent candidates for experimental work to establish independent lines of evidence for the behavior of passive layers.

Repository Design

> *...the Board is encouraged that the DOE is committed to preserving the option of a low-temperature repository. However, the technical basis for the DOE's selection of a high-temperature repository design for a potential license application remains unclear to the Board in view of the uncertainties associated with a high-temperature design and the lack of data on high-temperature corrosion.*

In 1998, the DOE did evaluate a high temperature design with a drift spacing of 28 meters as the base case for the Viability Assessment (VA). The performance assessment analyses for that design projected postclosure thermal conditions in which the boiling zones of adjacent drifts coalesced. For the Site Recommendation (SR), we selected a single design with a drift spacing of 81 meters. Analyses of that design showed postclosure thermal conditions that were lower than those projected for the VA design. Moreover, the SR design accommodates a range of preclosure operating modes that can be used to modify the early postclosure conditions. For the base-case operating mode of the SR design, drift wall temperatures are projected to be above boiling in the early phases of the postclosure scenario and a dry-out zone extends several meters into the rock around the drifts, but a portion of the pillars between drifts remains below the boiling point of water. This concept is intended to promote drainage of thermally mobilized

water through the central portion of the pillars and thus to ensure hydrologic independence of the individual drifts. The lower temperature postclosure conditions in the base-case SR design, compared to the Viability Assessment design, have tended to increase confidence and reduce uncertainties in the analysis and modeling of thermal effects on the natural system. This results from reducing the volume of rock and water that is perturbed by the thermal pulse.

DOE also analyzed the SR design for an alternative case where preclosure operating modes were used to modify the postclosure thermal conditions, keeping the average surface temperature of the waste package below 85°C. In comparing the postclosure results of the two cases, the uncertainties in the base-case SR design may be greater than the cooler alternative case during the first few thousand years. However, those uncertainties are primarily related to the subsystem performance calculations for the near-field environment, and there is no discernable difference in uncertainty as measured in the current total system performance assessment models. Results of the total system performance assessment analyses for both cases indicate that calculated dose rates using the SR design are well below the limits set by the Nuclear Regulatory Commission and the Environmental Protection Agency. The DOE believes that the base-case operating mode for the SR design, that results in postclosure thermal conditions at the higher end of the expected range, provides a better balance of postclosure thermal conditions and preclosure advantages for construction and operations, flexibility, and cost. While this operating mode has been selected for evaluating repository performance in the Total System Performance Assessment for the License Application (TSPA-LA), DOE will continue to evaluate the lower temperature option as an alternative operating mode. The lower temperature option will be carried forward with the objective of minimizing impacts on the overall schedule if this option is selected. For the purpose of the License Application, it is necessary to analyze the proposed operating mode in order to demonstrate whether or not the repository system meets the Nuclear Regulatory Commission's applicable regulatory criteria. If a different operating mode is eventually selected, then that mode would require approval by the NRC.

The DOE has decided to provide a repository design that will allow loading the repository to accommodate a range of operating modes and to defer the final decision on postclosure thermal conditions until more data are available to support this decision. These data may be collected as part of our baseline program, or as part of the new Science and Technology Program. We have also laid out a time frame to monitor ongoing data collection and to evaluate if new data support a decision on the postclosure thermal conditions, as presented to the Board in May 2002. In the Waste Package Material Performance Peer Review[1], the Panel concludes that

> "...the benefits of moving from the high temperature operating mode, as currently defined, to a low temperature operating mode are not clearly greater and might be

[1] Beavers, J.A.; Devine, T.M., Jr.; Frankel, G.S.; Jones, R.H.; Kelly, R.G.; Latanision, R.M.; and Payer, J.H. 2002. *Final Report, Waste Package Materials Performance Peer Review Panel, February 28, 2002.* [Las Vegas, Nevada]: Waste Package Materials Performance Peer Review Panel.

> offset by the effects of radiolysis, in addition to long-term ventilation and increased area for the repository."

The DOE concurs with the Panel's conclusion with respect to the postclosure thermal conditions. As noted above, testing and analyses are ongoing to improve the technical bases for projecting both higher and lower postclosure thermal conditions. As additional data and analyses are completed, the DOE will re-evaluate the postclosure thermal strategy.

> *...DOE's current high-temperature repository design differs from the one assumed in the documentation for the site recommendation in key areas, such as waste package spacing.*

The current baseline design is the SR design. This design has fixed engineering parameters, such as drift spacing and drift diameter, and variable operating parameters, such as areal mass loading, average waste package spacing and ventilation system operation. Various combinations of operating parameters were used to evaluate different postclosure thermal conditions that can be achieved with the SR design. These scenarios included average waste package spacing that varied from 0.1 meters to 6 meters. While all permutations of operating parameters were not evaluated, DOE is confident that the combinations that were evaluated adequately bound the postclosure conditions. Current design considerations are consistent with the SR approach and within the range of operating parameters considered for the SR design. As discussed previously, the DOE will evaluate repository performance in the TSPA-LA based on an operating mode that results in above boiling conditions in the early phases of the postclosure period.

Repository Safety Case

> *...the Board strongly supports the DOE's efforts to develop a repository safety case now for supporting a potential license application and for improving the DOE's communication with decision-makers and the public.*

The DOE believes that the case for safety of a repository will be embodied in the licensing bases being developed for the LA. The licensing bases for both preclosure and postclosure repository performance will include the results of quantitative assessments of the performance of the repository system, as well as other lines of evidence that provide confidence that the results are reasonable and robust. For the postclosure evaluation, these additional lines of evidence will include the description of multiple natural and engineered features and systems that will act as barriers to the migration of radionuclides and the use of natural and man-made analogs to assess the reliability of the systems performance models. The licensing bases will also include a commitment to a performance confirmation (PC) program. For preclosure, the evaluation will include a quantitative safety analysis of all repository structures, systems, and components. Additional confidence building measures defined for the preclosure licensing bases include the use of margin and defense-in-depth in design, consequence analysis of

beyond-design basis events, reliance on commercial nuclear reactor precedent and experience, and compliance with all license specifications and surveillances.

Performance Confirmation

> *...The Board believes that performance confirmation should focus on evaluating the validity of estimates of long-term repository performance and challenging their underlying assumptions.*

The Test and Evaluation Program and the Performance Confirmation (PC) Program are being revised in response to the issuance of 10 CFR Part 63[2] and the draft Yucca Mountain Review Plan[3]. Analysis of the regulation identified seven types of required testing, one of which is performance confirmation. DOE has developed an approach to manage these seven types of testing in an integrated manner, and has identified interfaces between them as well as the overlap of some tests among multiple regulatory requirements. 10 CFR 63.2 defines Performance Confirmation as "the program of tests, experiments, and analyses that is conducted to evaluate the adequacy of the information used to demonstrate compliance with the performance objectives of Subpart E of this part" (10 CFR Part 63).

10 CFR Part 63 Subpart F defines the requirements for a PC program. In developing the PC program, DOE will define the parameters and the extent of testing and monitoring for each parameter using a risk-informed performance-based approach. A decision analysis process is underway to develop and apply parameter selection criteria. The risk-informed approach to PC program definition is strongly related to the licensing bases, which includes numerical analyses and qualitative arguments of the complementary performance of nine individual natural and engineered barriers. Thus, the revision of the PC program and the development of the licensing bases are being conducted in tandem.

Adaptive Staging

> *The Board encourages the DOE to develop a better understanding of adaptive staging and to analyze the implications of this approach for its present organization and for its interaction with the public.*

The concept as described in the National Research Council panel's interim report[4] was generic - intended to be broadly applicable to any repository program at any stage of development. In the United States (U.S.), a comprehensive law specifying national policy, court-affirmed contractual obligations for the Federal government to accept and dispose of spent fuel, a fully-developed regulatory framework, and formal designation of

[2] 66 FR 55732. Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, NV. Final Rule 10 CFR Part 63.

[3] Center for Nuclear Waste Regulatory Analyses. 2002. *Yucca Mountain Review Plan, Draft Report for Comment.* NUREG-1804, Rev. 2. Washington, D.C.: U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards.

[4] National Research Council. 2002. Principles and Operational Strategies for Staged Repository Systems: Progress report. Washington, D.C.: National Academy Press.

a site at Yucca Mountain are already in place. DOE believes that the elements of adaptive staging already exist in the U.S. waste management system but are constrained by the realities of where the DOE is in the repository development process. The program has changed in many ways over the years in response to new information from various affected and interested parties, including the NWTRB. DOE expects that there will be continued opportunities to make improvements to design and operations as information is obtained from the Science and Technology Program that was described at the Board's May 2002 meeting. DOE also believes that there may be better ways to stage repository development within the present regulatory and legislative constraints. DOE is looking forward to the findings and recommendations of the panel concerning the application of the concept of adaptive staging to the specific case of the Yucca Mountain project and will give careful consideration to any findings and recommendations.

> *The presentation on flexible repository design and thermal operating conditions came closest of all the presentations at the meeting to illustrating how adaptive staging might work during performance confirmation. In that presentation, discrete decision points were identified, additional data that need to be collected and integrated were specified, milestones for reevaluating and reassessing decisions were established, and choices that might foreclose future options were clearly highlighted. Just as technical flexibility will be a prerequisite for adaptive staging, it is essential that the DOE be willing to make midcourse technical or programmatic corrections during performance confirmation if they are required. In summary, using adaptive staging will require that the DOE address with specificity the following questions: What information can be gathered over what time frame? How will that information be used to determine whether previous decisions and assumptions about repository performance remain valid? What midcourse corrections or remedial actions, if any, are warranted?*

The DOE agrees that the approach being developed for dealing with postclosure thermal conditions through use of a design with flexible preclosure operating modes may be a good example of the application of adaptive staging during the repository development and operations phase. DOE also expects to extend that approach to other aspects of repository development that could be affected by new information that could become available during repository construction and operation.

The DOE will make any changes to the program necessary to assure worker and public health and safety, in response to new information gained during repository development through the NRC licensing process, if necessary. The NRC requires continued evaluation of new information obtained during licensing, construction, operation, and monitoring of the repository to determine whether the essential assumptions and bases for the postclosure compliance evaluation are within the limits assumed in the licensing review and are functioning as intended and anticipated. DOE must report significant deviations from expected conditions and recommend any action (including design changes or even retrieval of emplaced waste) that might be required in accordance with 10 CFR 63.44. These requirements are an example of how the existing U.S. system for managing high-level waste already contains significant elements of adaptive staging as described by the National Research Council.

DOE is establishing a separate group to deal with research and development activities that are not directly linked to the licensing and regulatory process but that could lead to improvements that could be incorporated into the system at some stage during repository development and operation. Such improvements will include developing a better understanding of the coupled (thermal-chemical-hydrologic-mechanical) processes that will affect repository performance. If any of these activities support a conclusion that a change to the reference design or operating plan would be desirable, we would certainly consider proposing such a change and seeking a license amendment if that were required. As you know, we are also considering adoption of a modular construction approach that would further enhance flexibility to incorporate design or operational changes during the course of repository development.

New Organizational Structure

> *As noted in the Board's January 24, 2002, letter report to Congress and the Secretary of Energy, improving understanding and filling in existing data gaps are important for increasing confidence in estimates of repository performance and for better defining necessary activities associated with performance confirmation. At the May meeting, the DOE informed the Board that it had established a task force to develop options for increasing fundamental understanding of the proposed repository system and for increasing confidence in projections of repository performance. Of course, the Board expects that work directed toward a potential license application would increase confidence as well. New information and analyses may have important implications for the development of a safety case as well as for repository design.*
>
> *Any work undertaken by this task force not only should supplement but also should be integrated with the work already planned for a potential license application.*

The DOE fully agrees with the Board about the value of improving understanding and addressing data gaps related to repository performance. As a result of the work of the DOE Science and Technology Task Force described at the May meeting, we are establishing a Science and Technology program aimed at increasing confidence in repository performance and improving safety, operations, schedule, and cost over the many decades of the repository's operating life. Such a program has been recommended by the National Research Council[5] and DOE's Strategic Laboratory Council[6]. This effort will engage the expertise of the National Laboratories, universities, and the international scientific community. It will seek to increase confidence in the repository by advancing the basic scientific and technical understanding of the waste isolation processes at Yucca Mountain and exploring technological improvements that could improve repository

[5] National Research Council. 2001. A Strategic Vision for Department of Energy Environmental Quality Research and Development. Washington, D.C., p.50.

[6] Department of Energy. September 2000. Adequacy Analysis of the Environmental Quality Research and Development Portfolio. Washington, D.C., p. 27.

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performance and increase system efficiency. It will also continue to refine and optimize the repository system design and operating plan, based on laboratory and university research, value engineering, and the experience from the initial period of repository operation. Improvements can be incorporated, consistent with the concept of staged development. As noted earlier, activities in this program will focus on areas that are important to our mission, but may not be immediately incorporated into the licensing and regulatory process. DOE will also continue its Core Science Program and Performance Confirmation activities that are required for the near-term licensing effort. As suggested by the Board, the work in the new Science and Technology program will be coordinated and integrated with these other activities directed towards the licensing process.

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
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November 22, 2002

Dr. Margaret S. Y. Chu
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Dear Dr. Chu:

On behalf of the Nuclear Waste Technical Review Board, I thank you for participating in the Board's meeting on September 10, 2002, in Las Vegas, Nevada. We appreciated your program overview and were pleased that you were able to stay for so much of the day's proceedings. Board members, especially the new members, found the technical presentations by individuals from the Department of Energy (DOE) and its contractors very useful. Members also feel that the field trip to Yucca Mountain was a valuable experience. The Board realizes that the high quality of the meeting and the site visit was due in great part to the effort put forth by your team.

The DOE is entering a new phase of its activities as it prepares an application to the U.S. Nuclear Regulatory Commission (NRC) for constructing a repository at Yucca Mountain. The Board's role, however, has not changed from what was envisioned by Congress in the 1987 Nuclear Waste Policy Amendments Act. It will continue to carry out a broad scientific and technical review of the DOE's work and will make recommendations on improving the technical defensibility of that work.

In that light, the Board presents in this letter its views on three areas covered at the meeting and, where appropriate, references your letter September 6, 2002, to the Board. The three areas are (1) the DOE's technical analyses of the potential repository's natural system, (2) the DOE's technical analyses of the potential repository's engineered system, and (3) the DOE's integration of the potential repository's natural and engineered systems.

Natural System

The Board believes that the interim report of the DOE-supported Yucca Mountain Igneous Consequences Peer Review Panel is a significant accomplishment and that the panel has made progress in defining the fundamental processes. This work is very important because on

the basis of the most recent performance assessment, volcanism appears to be the largest potential contributor to dose. For this reason, the Board waits with interest for the panel's final report.

The Board also is pleased that one of the priorities you have given the new Science and Technology unit is to determine whether the potential repository's natural system makes a greater contribution to isolating and containing waste than current performance assessments suggest. If a *strong technical case* can be made for such an increased contribution, it would provide additional defense-in-depth, thereby increasing confidence that public health, safety, and the environment would be protected over the longterm. For this reason, the Board believes that work in this area could have a major payoff and suggests that it be accelerated.

For nearly two years, the DOE has been trying to explain two conditions that have been observed at Yucca Mountain. The first involves two independent laboratory analyses that result in contradictory data with respect to the presence of bomb-pulse chlorine-36 at the repository horizon. The second condition involves moisture observed within the closed-off part of the cross-drift and whether this moisture is due to condensation or infiltration. To date, the DOE has not provided a persuasive explanation for either of these two conditions.

The Board strongly urges the DOE to continue its efforts in these two areas and looks forward to reviewing the work in the near future. The Board believes that it is essential that the DOE develop an understanding of key processes affecting repository performance, specifically seepage and the potential for waste package corrosion when packages are subjected to a range of conditions representative of the postclosure in-drift environment.

Engineered System, Including Repository Design

The Board has reviewed your letter of September 6, 2002, and the DOE presentations on repository design at the Board's May and September meetings. Still unclear to the Board are what decisions the DOE has made about repository design. However, in your September 6, letter and the DOE presentations, the DOE appears to have decided to seek a license for constructing a repository based on a design "... *that results in thermal conditions at the higher end of the expected range, provides a better balance of postclosure thermal conditions and preclosure advantages for construction and operations, flexibility and cost.*" We request that the DOE provide the Board with the criteria, analyses, and weighting factors that constitute the technical basis for the apparent selection of the repository design as stated in your September 6, letter.

According to the DOE presentation made at the September Board meeting, the DOE's design decision seems to be supported by the following two conclusions: (1) projected performance for the high-temperature design is comparable to a low-temperature design and, in any case, is well below the regulatory limit; and (2) *overall* uncertainty in the projected performance of the two designs is roughly equivalent. In response to the DOE's decision, the Board has several comments on the technical basis for these assertions.

The DOE's presentation on corrosion testing may call into question the first conclusion. The increase in corrosion potential due to the presence of nitrate leads to less of a margin at

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temperatures above 140°C. Moreover, in back-up material from the presentation, the short-term weight-loss measurements based on linear polarization, when extrapolated to higher temperatures, show a significant increase in the rate of corrosion and indicate a definite thermal dependency that is not reflected in current models of performance assessment. The Board encourages continued corrosion testing and analysis supporting *basic understanding* of waste package corrosion and the in-drift environment.

Regarding the second conclusion, the DOE asserted at the meeting that performance assessment shows that the ranges of dose uncertainty for high- and low-temperature repository designs are similar. The Board notes that performance assessment is not capable of showing uncertainty unless the models appropriately incorporate uncertainty. Some parts of some key performance assessment models for the evolution of waste package environments and for corrosion at high temperatures are not based on data but on a number of *assumptions.* For example, TSPA assumes that there will be no liquid water above 120°C and no significant separation of chloride ions from beneficial anions and that low-temperature corrosion models are valid at high temperatures. To use these assumptions about high-temperature uncertainties as input into TSPA models and then say that performance assessment reveals that uncertainties are equivalent for high- and low-temperature operations constitute, in the Board's view, circular and therefore faulty reasoning.

The Board has noted for quite some time that the DOE's estimates of the total uncertainty in projected repository performance presume that the underlying conceptual models used to analyze both the low-temperature design and the high-temperature design are appropriate. For example, the models should capture relevant thermal sensitivities in a technically defensible manner. Many experiments, such as the drift-scale thermal test and additional high-temperature material investigations, have not been completed. Thus, the DOE's second conclusion may be premature.

Integrated Repository System

The Board understands that the DOE realizes that the repository safety case not only must rely on complex calculations of performance assessment but also must include multiple lines of evidence and argument, which could include natural and man-made analogues and traditional notions of defense-in-depth. The Board also supports the DOE's recognition that the safety case needs to address various audiences, including those not directly involved in the licensing process. International organizations, such as the Nuclear Energy Agency of the Organization for Economic Cooperation and Development, have assembled reports on this subject. The Board recommends that the DOE give serious consideration to the logic developed in those reports as well as the specific suggestions they contain.

Presentations at the meeting and the short roundtable discussion at the end of the meeting highlighted several points. The DOE's projections of repository performance, derived from performance assessment, have varied considerably over the last two years and differ in many important respects from those carried out by the Electric Power Research Institute and other groups. Many of these differences can be traced to the assumptions used and the influence of new data. However, confidence in these projections will depend in part on understanding and

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explaining clearly why variations arise. The Board therefore urges the DOE to analyze the different estimates, assess their significance, and address any concerns that may arise about the overall uncertainty in estimating repository performance. The stability of these projections is an important element in building confidence.

The Board is pleased that the DOE has carried out the "one-on" barrier analysis. The roundtable discussion on this topic at the meeting suggested both the value and the potential limitations of such analyses. On balance, however, the Board believes that such analyses utilizing different approaches can provide important insights into the roles of the different natural and engineered barriers. For that reason, the Board urges the DOE to continue supporting this kind of work and to consider using it to better articulate its repository safety case.

The Board still has questions about the relative role and scope of the DOE's proposed research and development, science and technology, and core science programs. As indicated in the DOE's letter, the scope of performance confirmation (PC) is limited to a regulatory context. The Board believes that a PC program should focus on confirming the safety case by challenging the validity of estimates of long-term repository performance and their underlying assumptions. The Board would like to understand the key elements of the DOE's PC plan; the specific tests and related analyses considered a priority for the PC plan for license application; the testing that will be undertaken during repository construction; and how PC information will be integrated and used by the project.

The Board believes that the DOE's commitment to "jump-starting" transportation planning and activities is imperative, in particular the DOE's recognition of the need to reactivate institutional activities to address the concerns of the State, Tribes, and affected counties.

Once again, I thank you, the DOE staff, and the DOE's contractors for supporting the Board's September meeting. The Board looks forward to continuing to review and comment on DOE activities.

Sincerely,

{Signed by}

Michael L. Corradini
Chairman

mlc003vf

Department of Energy
Washington, DC 20585

January 24, 2003

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

Dear Dr. Corradini:

Thank you for your letter of November 22, 2002 expressing the Board's perspective on information presented by the Department at the Board's September 2002 meeting and on information from my letter to you of September 6, 2002.

DOE appreciates the Board's continuing review of our activities as we develop a license application for a repository at Yucca Mountain. Our responses to the views expressed by the Board are discussed in the attachment to this letter.

The Department has benefited from the constructive views of the Board. As the Department proceeds to develop a license application, we look forward to continuing our dialogue with the Board.

Sincerely,

Dr. Margaret Chu, Director
Office of Civilian Radioactive
Waste Management

Enclosure

Responses to the September 22, 2002 letter to DOE from the Nuclear Waste Technical Review Board

Natural System

The Board believes that the interim report of the DOE-supported Yucca Mountain Igneous Consequences Peer Review Panel is a significant accomplishment and that the panel has made progress in defining the fundamental processes. This work is very important because on the basis of the most recent performance assessment, volcanism appears to be the largest potential contributor to dose. For this reason, the Board waits with interest for the panel's final report.

Response: The DOE agrees with the Board's assessment of the interim report from the ongoing Igneous Consequences Peer Review Panel[1]. We are looking forward to the Panel's final report. The interim report summarizes the Panel's key issues, including dike and crack propagation, particularly in the vicinity of the repository, and the complex processes that occur once magma interacts with the repository drifts. Within these areas, we believe that four issues are of particular importance, and discuss briefly below how the Project is addressing these issues.

1. Dike tip phenomena during dike ascent and dike/drift interaction

   The dike tip cavity region may have an important impact on dike propagation and the nature of the initial magma/drift interaction. There are complex interacting processes that control the cavity size. Because we have little information to predict the details of the cavity region in a propagating dike, our approach is to parameterize this zone with respect to length and pressure and perform parametric studies to assess the effects under a wide range of conditions. In the dike propagation code, the cavity pressure will be specified and the appropriate cavity length that is required to accommodate this pressure will be calculated.

2. Magma viscosity as a function of temperature, volatile content, and bubble content, and its impact on magma migration down drifts and magma/waste package interactions

   The effects of temperature, dissolved volatile content, and exsolved vapor bubbles on the shear viscosity of basaltic melt should be included in future studies of the material properties of potential disruptive Yucca Mountain basalt. We plan to do calculations with higher and/or lower viscosities. The numerical model in the baseline version of the Computational Fluid Dynamics Library will only allow a fixed Newtonian viscosity. However, we plan to incorporate variability in viscosity related to

[1] Budnitz, R.J., Detournay, E.M., Mastin, L., Pearson, J.R.A., Rubin, A.M., and F.J. Spera 2001. *Yucca Mountain Igneous Consequences Peer Review Panel Interim Report.* Las Vegas, Nevada: Igneous Consequences Peer Review Panel. ACC: MOL.20011010.0084.

temperature and volatile-content this year. Incorporation of the effects of bubbles with a capillary number approach will be considered in plans for later years, and could yield useful confirmatory information.

3. The dog-leg scenario (magma intrudes drifts and initiates a second dike at some distance from the original dike)

   Magma/drift interaction modeling will include 3-D models to simulate magma flow from a dike into a drift, as well as the continuation of magma flow upward within the original dike and within a possible second dike. Two cases will be modeled to assess the plausibility of including the dog-leg scenario in the Total System Performance Assessment (TSPA). The first case will assume a short secondary dike has formed at the end of a drift in order to determine initial magma injection flow rates or pressure within the second dike for input into dike propagation models. The second case will assume a second dike has formed at the end of a drift in order to determine the difference in magma flow rates within the primary and secondary dikes due to viscous drag within the intervening drift and differences in the hydraulic properties of the two dikes.

4. A shock wave propagates down a drift following explosive magma decompression

   The Panel concluded that rising magma would be partially degassed before it intersects a drift, minimizing to some extent the magnitude of a potential shock wave traveling down a drift. Scoping calculations that take into account the geometry of initial dike/drift intersection and the presence of waste packages within the drift also indicate that shock wave formation will be diminished given more realistic models of dike/drift interactions. Modeling planned for this year will provide a more detailed and realistic technical basis to assess shock wave phenomena within drifts.

The Board also is pleased that one of the priorities you have given the new Science and Technology unit is to determine whether the potential repository's natural system makes a greater contribution to isolating and containing waste than current performance assessments suggest. If a strong technical case can be made for such an increased contribution, it would provide additional defense-in-depth, thereby increasing confidence that public health, safety, and the environment would be protected over the long term. For this reason, the Board believes that work in this area could have a major payoff and suggests that it be accelerated.

Response: The DOE agrees with the Board's recommendation that the new Science and Technology (S&T) Program should have as one of its priorities to work on improving our understanding of natural-system performance. We are currently evaluating a whole range of ideas for the first round of projects to be supported under the S&T Program, and ideas related to studying the natural system are certainly among those high on our list, along with ideas involving new or improved technologies that can achieve efficiencies and savings. However, it is important to note that benefits in all of these areas may take years to realize.

The S&T program objectives continue to be a) to improve existing and develop new technologies to achieve efficiencies and savings in the waste management system; and, b) to increase understanding of repository performance. Major additional benefits will include promoting technical excellence, maintaining leadership in nuclear waste management, and assuring cognizance of emerging technical developments. Our current efforts include developing long-term strategic research plans for all of the technical areas within OCRWM's purview (with the assistance of external subject-matter experts). A subset of these technical areas will be selected for initiation in Fiscal Year 2003. The balance will help us as we develop the long-term program (Fiscal Year 2004 and later).

Any technical insights, technical data, or new technical tools derived from the S&T work will be folded into the LA process wherever appropriate.

For nearly two years, the DOE has been trying to explain two conditions that have been observed at Yucca Mountain. The first involves two independent laboratory analyses that result in contradictory data with respect to the presence of bomb-pulse chlorine-36 at the repository horizon. The second condition involves moisture observed within the closed-off part of the cross-drift and whether this moisture is due to condensation or infiltration. To date, the DOE has not provided a persuasive explanation for either of these two conditions.

The Board strongly urges the DOE to continue its efforts in these two areas and looks forward to reviewing the work in the near future. The Board believes that it is essential that the DOE develop an understanding of key processes affecting repository performance, specifically seepage and the potential for waste package corrosion when packages are subjected to a range of conditions representative of the postclosure in-drift environment.

Response: The DOE agrees, and is continuing investigations focused on these two issues (^{36}Cl and moisture in the cross-drift). The linkage to potential waste-package corrosion is discussed later in this letter.

With respect to the chlorine-36 issue, the DOE is pursuing a resolution of the legacy discrepant data sets by (1) having the institutions involved to date document the results to date and propose a path forward for resolution of the discrepancies, and (2) conducting an independent new validation study as a parallel, complementary effort. Individuals from domestic or foreign academic/technical organization(s) with the requisite expertise will be selected to conduct this new study. One of the key criteria for selection of the individual(s) will be no prior involvement in the ^{36}Cl/Cl work at Yucca Mountain. The independent validation study will include a new sampling and analysis program to attempt to better understand the previous ^{36}Cl/Cl observations. The background, about which we believe the Board is fully aware, is that because of differences in the implications for unsaturated-zone flow between important ^{36}Cl data and other data, the DOE initiated a validation project in 1999 to address the presence of bomb-pulse ^{36}Cl at

the repository horizon. All of the analytical data generated during this ^{36}Cl ongoing validation project are being compiled and a summary report, due June 11, 2003, is being prepared jointly by the United States Geological Survey (USGS), Los Alamos National Laboratory (LANL), and Lawrence Livermore National Laboratory (LLNL). The report will contain a recommendation for a path forward based upon a review and interpretation of the existing data.

The report will include the latest analyses conducted in the spring of 2002 that focused on core from Niche 1 in the Exploratory Studies Facility where previous LANL results indicated a high probability of finding bomb-pulse ^{36}Cl. Selected intervals of remaining core samples were split and allocated to the USGS and LANL for processing. Isotopic analyses of rock leachates were conducted by LLNL. USGS leachates yielded $^{36}Cl/Cl$ ratios of 244 E-15 to 708 E-15 with Cl concentrations ranging from 0.17 to 0.26 mg/kg. LANL leachates yielded larger values of 1140 E-15 to 8580 E-15 with Cl concentrations of 0.13 to 0.67 mg/L. Because the water-to-rock ratios are 1:1, the measurements of Cl concentrations are comparable. To further investigate the source of the differences, the USGS crushed and leached 99.999 percent pure computer-chip grade silicon and determined that the crushing blanks used in the analysis were acceptable. . LANL investigators have not yet performed a similar test. The reasons for the disagreement in the USGS and LANL results are not currently understood, which is why we have decided to pursue the new independent validation study.

DOE looks forward to providing further details and results of the independent validation study at future Board meetings.

With respect to the second issue, moisture was found in several segments of the closed-off section of the cross drift during entries between September 1999 and June 2002 to collect samples, install additional bulkheads, and conduct other construction and repair activities. The moisture was observed at different locations at different times. There is indication that the amount of moisture decreases with time, especially in 2002 after the power to the tunnel boring machine was cut off. This trend will be further confirmed in the next entry. All available data, including geochemical measurements of water collected, indicate that the moisture observed in the closed off sections of the cross drift is likely to be condensate. The water samples collected in the June 2000 entry had low chloride and silicate contents (Cl was 0.23-1.44 mg/L as compared to cross drift pore water data of 19-66 mg/L. SiO_2 was 0.24-0.42 mg/L as compared to cross drift pore water data of 40-65 mg/L). The moisture is likely driven by temperature gradients, possibly associated with residual heat from cross drift excavation, power consumed by the tunnel boring machine parked at the terminal end of the cross drift, and other electrical instrumentation underground. Other indicators of condensation include the observation in October 2001 of droplets on a painted surface where the paint effectively isolated the exposed surface from the underlying rock. Droplets and rust were observed on other metal surfaces of underground structures during the entries. Observations and

early data are documented in the report *In Situ Field Testing of Processes.*[2] This report will be revised in 2003 to include additional data collected in the cross drift.

Only limited samples have been collected in the cross drift so far. In response to the need to distinguish clearly whether the moisture observed is due to condensation or seepage, DOE increased the number of instruments emplaced in the closed-off sections of the cross drift in October and November 2001 and installed a fourth bulkhead. The first two bulkheads were installed in June 1999 and the third bulkhead in July 2000 to isolate the tunnel boring machine. The first bulkhead has been open since July 2002 to accommodate activities related to rock properties testing. The last three sections of the cross drift are expected to be closed off for at least another year so that we can continue the investigation of moisture observed in the cross drift. The currently available instruments in the closed-off sections include hanging tarps, pH strips, relative humidity, temperature, and pressure sensors, electrical resistance probes along the drift floor, psychrometers installed in boreholes, and dedicated water collectors at a location that was previously observed to be wet. The transducers at the bottom of water collectors have detected no signal so far, indicating no collection of water at this location. The collectors are designed either to collect pure condensate or to collect condensate and seepage. We will use the information from the collectors and all other instruments to help resolve the source of moisture observed within the closed-off part of the cross drift and to evaluate whether this moisture is due to condensate or seepage.

In addition to field monitoring activities, DOE has started a modeling study aimed at developing a better understanding of the moisture and gas flow within the closed-off sections, taking into account the evaporation and condensation processes and moisture movement in the surrounding fractured rocks. The surrounding rocks provide water and vapor for condensation and flow paths for seepage into the drift.

Engineered System, Including Repository Design

The Board has reviewed your letter of September 6, 2002, and the DOE presentations on repository design at the Board's May and September meetings. Still unclear to the Board are what decisions the DOE has made about repository design. However, in your September 6, letter and the DOE presentations, the DOE appears to have decided to seek a license for constructing a repository based on a design "... that results in thermal conditions at the higher end of the expected range, provides a better balance of postclosure thermal conditions and preclosure advantages for construction and operations, flexibility and cost." We request that the DOE provide the Board with the criteria, analyses, and weighting factors that constitute the technical basis for the apparent selection of the repository design as stated in your September 6, letter.

Response: As a general matter, OCRWM has not developed or used quantitative "weighting factors" in an explicit sense in any of its decisions about the thermal-

[2] BSC (Bechtel SAIC Company) 2001. *In Situ Field Testing of Processes.* ANL-NBS-HS-000005 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20020108.0351

operating-mode issue. The issue is much too complex, involving as it does judgmental tradeoffs among factors that we have not expressed in a common framework for explicit "weighting."

The criteria that the Department used as the basis for selecting the design to be used as the basis for the LA were documented in the report *License Application Design Selection (LADS).*[3] The LADS study describes these criteria as being applied qualitatively rather than quantitatively. Of the criteria, the most important was the objective criterion of long term performance. That criterion did not dominate the decision, because all of the designs examined in the LADS study were found to meet the postclosure performance criterion by a large margin, regardless of whether they employed hotter or cooler operating modes. The postclosure criterion used in the LADS study is consistent with the standard promulgated by the EPA in 2001.

The selection of the preferred design of the LADS study instead involved balancing a potential reduction in uncertainty in long term performance, for which there is a large safety margin, that could be obtained by lower-temperature operation, against a certain increase in worker health effects, operational impacts, and cost resulting from the measures needed to achieve a lower-temperature mode. This balancing was inherently judgmental, and supported a decision to select a hotter operating mode as the basis for LA. There have been subsequent refinements of the design concept selected in the LADS study. However, the Department's considerations still involve the same balancing between potential reductions in uncertainty in postclosure performance projections that are well below regulatory limits, and certain increases in impacts in the preclosure period.

Of course, the Department recognizes that a crucial element of NRC's regulatory decision will be whether the analyses and data submitted by the applicant (DOE) are adequate to support a positive decision, and that uncertainties in the analyses are a central part of why the regulatory decision will not be easy. However, even if the uncertainties in analyzing a colder operating mode are smaller than those for a hotter operating mode, which may or may not turn out to be the case in the end, it is DOE's current judgment that either operating mode will meet the NRC standards for post-closure performance with a large margin, and that uncertainties arising elsewhere in the overall analysis dominate.

Undersecretary Card stated at the NWTRB meeting in May 2002 that the Department is committed to maintaining a colder-operating-mode option until it is either selected or no longer important. The Department has done conceptual design work and layouts for such an option, but based on the above its License Application will be based on a hotter operating mode.

According to the DOE presentation made at the September Board meeting, the DOE's design decision seems to be supported by the following two conclusions: (1) projected performance for the high-temperature design is comparable to a low-temperature design

[3] CRWMS M&O 1999. *License Application Design Selection Report.* B00000000-01717-4600-00123 REV 01 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990908.0319.

and, in any case, is well below the regulatory limit; and (2) overall uncertainty in the projected performance of the two designs is roughly equivalent. In response to the DOE's decision, the Board has several comments on the technical basis for these assertions.

The DOE's presentation on corrosion testing may call into question the first conclusion. The increase in corrosion potential due to the presence of nitrate leads to less of a margin at temperatures above 140°C. Moreover, in back-up material from the presentation, the short-term weight-loss measurements based on linear polarization, when extrapolated to higher temperatures, show a significant increase in the rate of corrosion and indicate a definite thermal dependency that is not reflected in current models of performance assessment. The Board encourages continued corrosion testing and analysis supporting basic understanding of waste package corrosion and the in-drift environment.

Regarding the second conclusion, the DOE asserted at the meeting that performance assessment shows that the ranges of dose uncertainty for high- and low-temperature repository designs are similar. The Board notes that performance assessment is not capable of showing uncertainty unless the models appropriately incorporate uncertainty. Some parts of some key performance assessment models for the evolution of waste package environments and for corrosion at high temperatures are not based on data but on a number of assumptions. For example, TSPA assumes that there will be no liquid water above 120°C and no significant separation of chloride ions from beneficial anions and that low-temperature corrosion models are valid at high temperatures. To use these assumptions about high-temperature uncertainties as input into TSPA models and then say that performance assessment reveals that uncertainties are equivalent for high- and low-temperature operations constitute, in the Board's view, circular and therefore faulty reasoning.

The Board has noted for quite some time that the DOE's estimates of the total uncertainty in projected repository performance presume that the underlying conceptual models used to analyze both the low-temperature design and the high-temperature design are appropriate. For example, the models should capture relevant thermal sensitivities in a technically defensible manner. Many experiments, such as the drift-scale thermal test and additional high-temperature material investigations, have not been completed. Thus, the DOE's second conclusion may be premature.

Response: DOE agrees with the Board comment on the need for continued corrosion testing and analysis to improve basic understanding of waste package corrosion and of the in-drift environment. DOE has been developing new data to support development of and validation of our corrosion models. The new testing and results presented to the Board at the September 10, 2002 meeting are part of the Project's ongoing work to enhance basic understanding of the corrosion processes and improvement of the models. An increase in the corrosion potential with nitrate-containing solutions above 120°C

(Gordon[4], Slide 13) is observed. Nitrate solutions are known to be oxidizing under acidic conditions. The oxidation-reduction characteristics of the nitrate-nitrite-ammonium-nitrogen system are complex and the Project is analyzing this system in terms of the expected repository conditions. In addition, the Project believes that the possibility of development of such corrosion environments to a significant extent on the surface of the waste package is highly unlikely due to the presence of the drip shield.

With the drip shield intact, the potential waste package surface environment is expected to be a thin aerated brine film formed by deliquescence of soluble salts in the dust deposits. Chemical analysis of typical dust deposits suggests that the brines likely to form from the deliquescence of these deposits will not evolve to calcium and/or magnesium chloride type brines. Thus, the maximum expected boiling point of these aqueous films are approximately 125°C to 135°C, characteristic of a concentrated sodium/potassium chloride/nitrate environment. Such an environment is similar to the Simulated Saturated Water environment that has been used for testing at 120°C. Cyclic polarization tests indicate that there is greater than a 450 to 700 mV margin between the corrosion potential and any apparent passive film breakdown potential at temperatures up to 120°C (Figure 3-444, page 3-58, of the *Waste Package Degradation Process Model* report[5]). Thus, the assumptions related to applicable environments for extrapolation of corrosion rates appear to be supported by the new data.

The temperature dependency cited by the Board is being evaluated within the on-going testing program. The short-term electrochemical tests (linear polarization tests shown in Gordon[6], Slide 25) are intended to provide only the temperature dependency i.e., the slope, and not absolute corrosion rates. The rates for uniform general corrosion will continue to be obtained from the Long-Term Corrosion Test Facility. The project also believes that the temperature dependency observed from the tests should be regarded as a weak dependency, with the activation energies in the range of 17 to 23 kJ/mole. Extrapolation of the corrosion rates to 140°C and 160°C using these activation energies would result in a corrosion rate increase of approximately 2 to 2.5 times. This increase would have insignificant effect on the waste package performance in view of the extremely low corrosion rates measured in the Long-Term Corrosion Test Facility (0.01 microns/year after a two-year exposure).

The temperature dependency of the corrosion rates was included in the analyses documented in Section 7.3.5 of the *FY 01 Supplemental Science and Performance Analyses* (SSPA) report[7]. These analyses were conducted with significantly higher

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[4] Gordon, G. 2002. *Update on Corrosion Testing.* Presentation at the Nuclear Waste Technical Review Board Fall Meeting, September 10, 2002. Las Vegas, Nevada.

[5] CRWMS M&O 2000. *Waste Package Degradation Process Model Report.* TDR-WIS-MD-000002 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001228.0229.

[6] Gordon, G. 2002 *(op. cit.)* .

[7] BSC (Bechtel SAIC Company) 2001. *FY 01 Supplemental Science and Performance Analyses, Volume 1: Scientific Bases and Analyses.* TDR-MGR-MD-000007 REV 00 ICN 01. Las Vegas, Nevada: Bechtel

general corrosion rates at higher temperatures to account for the uncertainties in the Long-Term Corrosion Test Facility corrosion measurements and the possibility of the occurrence of magnesium/calcium-chloride environments. General corrosion rates for Alloy 22 at 25, 60, 125, and 165°C were calculated using a temperature dependent corrosion model with activation energy of about 36 kJ/mole for the temperature dependency. The temperature of 165°C was selected to represent the highest temperature for an aqueous condition that may result from deliquescence of highly hygroscopic salts such as $CaCl_2$ and $MgCl_2$ that could be deposited on the waste package surface from dripping water. The median of our distribution for the general corrosion rate at 165°C is about 1.0 micron/year and the upper bound is about 3.0 microns/year. Although it is not expected that aqueous conditions can be sustained on the waste package at 165°C, even with the use of these high corrosion rates the waste package failure times are significantly beyond the regulatory period of 10,000 years. The variation in the general corrosion rate is considered to be solely due to uncertainty.

It should also be pointed out that the Project removed the temperature dependent corrosion model from the *Final Environmental Impact Statement* (FEIS)[8] because the model showed the waste package failure times are significantly longer than those calculated without the temperature dependant model. This is due to the fact that the waste packages remain at high temperatures for a relatively shorter period of time compared to the low temperature regime. The decision to remove this model was made to provide more conservative dose estimates.

In summary, DOE is continuing to develop data contributing to a better understanding of corrosion processes and will incorporate these data into the models supporting the TSPA for the LA.

The DOE agrees with the Board that "performance assessment is not capable of showing uncertainty unless the models appropriately incorporate uncertainty." To that end, the Project has been working on several fronts to develop models that represent advances compared to those used in the TSPA-SR. Some of the Board comments above seem to be based on assumptions in the TSPA-SR that have now been supplemented by data to provide the firmer foundation that the Board apparently feels was lacking earlier. This is particularly true for Board concerns about the TSPA approach regarding waste package environment and corrosion. For the high-temperature and low-temperature operating modes considered by the Project, the TSPA models associated with the waste package environment and corrosion are equally applicable based on the available data. Regardless

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SAIC Company. ACC: MOL.20010801.0404; MOL.20010712.0062; MOL.20010815.0001; BSC (Bechtel SAIC Company) 2001; *FY01 Supplemental Science and Performance Analyses, Volume 2: Performance Analyses.* TDR-MGR-PA-000001 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010724.0110.

[8] DOE (U.S. Department of Energy) 2002. *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada.* DOE/EIS-0250. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20020524.0314; through; MOL.20020524.0320.

of the thermal strategy adopted, the temperature at which the liquid contacts the waste package for the initiation of corrosion is dependent on the deliquescence of the soluble species in the waste package surface deposits.

In order to characterize high-temperature corrosion processes, the Project is conducting tests in highly corrosive environments such as concentrated bulk calcium chloride environments (8 to 9M) with and without nitrate at temperatures above 120°C. The preliminary results from these tests were presented to the Board in September 2002. These results showed that there is little margin between Alloy 22 corrosion potential and the critical potential for the initiation of localized corrosion. However, the presentation also included results of aqueous film corrosion tests (Gordon[9], Slides 14-15) with temperatures as high as 150°C and 22.5% relative humidity using polished Alloy 22 specimens. The calcium chloride concentrations were very high (up to ~62% calcium chloride) under these test conditions. Results to date indicate no evidence of localized corrosion attack under these aqueous film conditions.

The temperature dependency for the extrapolation of low-temperature general corrosion rate data to higher temperatures was discussed above in response to the Board's comment on thermal dependency, and was shown to have an insignificant effect on waste package performance.

The Board observes that future results of ongoing experiments such as the drift-scale thermal test could provide additional information relevant to modeling of thermal processes, and that some of DOE's conclusions may therefore be premature. We agree. However, we believe that the information available and used to date is sound enough to support all decisions made to date.

Integrated Repository System

The Board understands that the DOE realizes that the repository safety case not only must rely on complex calculations of performance assessment but also must include multiple lines of evidence and argument, which could include natural and man-made analogues and traditional notions of defense-in-depth. The Board also supports the DOE's recognition that the safety case needs to address various audiences, including those not directly involved in the licensing process. International organizations, such as the Nuclear Energy Agency of the Organization for Economic Cooperation and Development, have assembled reports on this subject. The Board recommends that the DOE give serious consideration to the logic developed in those reports as well as the specific suggestions they contain.

Response: The DOE appreciates the Board's observations that the safety case will need to address audiences beyond those involved directly in the NRC licensing process. The

[9] Gordon G. 2002. *(op. cit.)*

licensing process itself will address multiple lines of evidence such as those suggested by the Board, for example through the requirements for descriptions of capability of the natural and engineered barriers included in the system, and through DOE's use of analogue information as an additional line of evidence to support several of the analyses.

The DOE also recognizes the need for effectively presenting the safety case to broader audiences. The DOE will continue to evaluate recommendations from the Nuclear Energy Agency and others in the international community both for improving the way the Program's safety-case logic is presented, and for improving the safety-case presentation itself.

Presentations at the meeting and the short roundtable discussion at the end of the meeting highlighted several points. The DOE's projections of repository performance, derived from performance assessment, have varied considerably over the last two years and differ in many important respects from those carried out by the Electric Power Research Institute and other groups. Many of these differences can be traced to the assumptions used and the influence of new data. However, confidence in these projections will depend in part on understanding and explaining clearly why variations arise. The Board therefore urges the DOE to analyze the different estimates, assess their significance, and address any concerns that may arise about the overall uncertainty in estimating repository performance. The stability of these projections is an important element in building confidence.

Response: The DOE recognizes the value of such comparative analyses as the Board is recommending. To this end, the Project included discussions of model changes since TSPA for Site Recommendation and their impacts at the subsystem and system level in the SSPA (Volume 2, sections 3 and 4). Summaries of the SSPA model changes and their impacts were presented to the Board in June of 2001. Briefer discussions of model changes were included in the documentation of the TSPA update to support the FEIS.

Recent EPRI results were not available at the time of the SSPA and FEIS, and differences between the EPRI and the DOE analyses were therefore discussed only in very general terms (e.g., presence or absence of a model for diffusive transport, differing assumptions about water consumption by the receptor) at the Board meeting in September 2002. Because both the DOE and EPRI models are continually evolving, the DOE expects to do a detailed comparison between the two only after the completion of the TSPA-LA. In the interim, the Program will attempt to understand the reasons for any important differences, so that this understanding can inform the ongoing TSPA work.

The Board is pleased that the DOE has carried out the "one-on" barrier analysis. The roundtable discussion on this topic at the meeting suggested both the value and the potential limitations of such analyses. On balance, however, the Board believes that such analyses utilizing different approaches can provide important insights into the roles of the different natural and engineered barriers. For that reason, the Board urges the DOE

to continue supporting this kind of work and to consider using it to better articulate its repository safety case.

Response: The DOE recognizes both the value of the "one-on" style of analyses in providing insights into barrier performance and the potential limitations noted during the roundtable discussion at the September 2002 Board meeting. As discussed in Section 7.2.3.1 of the *TSPA-LA Methods and Approach* document[10], the DOE may use sequential one-on analyses as one of several types of analyses included in the confidence-building activities that will support validation of the TSPA-LA model. Other types of possible analyses include comparisons to simplified models, detailed analysis of selected deterministic cases, and neutralization or "one-off" cases. For the descriptions of 10,000-year barrier capability required by 10 CFR Part 63.115[11], the DOE proposes to supplement these analyses with additional techniques including intermediate performance measures from the full TSPA and pinch point analyses that report radionuclide mass flux or concentrations at selected interfaces between model components (Section 8.3 of the *TSPA-LA Methods and Approach* document).

The Board still has questions about the relative role and scope of the DOE's proposed research and development, science and technology, and core science programs. As indicated in the DOE's letter, the scope of performance confirmation (PC) is limited to a regulatory context. The Board believes that a PC program should focus on confirming the safety case by challenging the validity of estimates of long-term repository performance and their underlying assumptions. The Board would like to understand the key elements of the DOE's PC plan; the specific tests and related analyses considered a priority for the PC plan for license application; the testing that will be undertaken during repository construction; and how PC information will be integrated and used by the project.

Response: The DOE believes that the Performance Confirmation program will represent only a subset of a much more comprehensive test and evaluation program.

Based on the language in 10 CFR Part 63[12], the DOE is revising its PC program to focus resources using a risk-informed, performance-based (RIPB) approach. A formal decision analysis process is being used to evaluate the value (in terms of confirming expected barrier performance) and cost of several hundred combinations of a PC parameter and a data-acquisition method. The results are being assembled into several alternative portfolios. One portfolio will be selected soon for development to support the LA. The

[10] BSC (Bechtel SAIC Company) 2002. *Total System Performance Assessment-License Application Methods and Approach.* TDR WIS-PA-000006, Rev. 00, Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.200202923.0175.

[11] 66 FR 55732. Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, NV. Final Rule 10 CFR Part 63. US Nuclear Regulatory Commission.

[12] *Ibid.*

alternative portfolios under development include activities to confirm barrier performance (using the RIPB approach), as well as activities to meet NRC requirements in 10CFR63 Subpart F that must be addressed independent of their significance to barrier performance or total-system performance.

In addition to the baseline work, the Science and Technology Program may develop data, test techniques, or design enhancements that could be brought into the testing programs after initial submittal of a license application or at an appropriate time during the construction and operation of a repository at a later stage.

The proposed PC program is expected to be mature enough to present to the NWTRB at its May 2003 meeting, if that is the desire of the Board.

The Board believes that the DOE's commitment to "jump-starting" transportation planning and activities is imperative, in particular the DOE's recognition of the need to reactivate institutional activities to address the concerns of the State, Tribes, and affected counties.

Response: DOE believes that it is critical to "jump-start" the transportation program and agrees with the Board's observation that resumption of institutional activities is very important. To accomplish the re-emphasis on the transportation activities DOE has requested Fiscal Year 2003 funds to restart the Transportation Program. The Secretary of Energy has committed to Congress to have a transportation plan prepared by the end of this fiscal year. This plan is currently in preparation. We look forward to working with you as the plans develop on this vitally important issue. We will also, of course, support the February 25 meeting on this subject with your Panel on the Waste Management System.

Appendix F

Communication Between the U.S. Nuclear Waste Technical Review Board and Congress

- Letter from Jared L. Cohon to Senator Harry Reid; January 24, 2002.
  Subject: Responses to questions posed in letter of November 26, 2001
- Letter from Jared L. Cohon to Senator John Ensign; January 24, 2002.
  Subject: Responses to questions posed in letter of November 26, 2001
- Letter from Jared L. Cohon to Congressman Joe Barton; January 24, 2002.
  Subject: Responses to questions posed in letter of December 11, 2001
- Letter from Jared L. Cohon to Congressman John Shimkus; January 24, 2002.
  Subject: Responses to questions posed in letter of December 5, 2001
- Testimony of Jared L. Cohon before the U.S. House of Representatives, Subcommittee on Energy and Air Quality; April 18, 2002.
- Letter from the Honorable Joe Barton to Jared L. Cohon; April 22, 2002.
  Subject: Questions from members of the U.S. House of Representatives, Subcommittee on Energy and Air Quality
- Letter from Jared L. Cohon to Congressman Joe Barton; May 22, 2002.
  Subject: Responses to questions posed in letter of April 22, 2002
- Testimony of Jared L. Cohon before the Senate Committee on Energy and Natural Resources; May 23, 2002.
- Letter from Jared L. Cohon to Senator Jeff Bingaman, May 31, 2002.
  Subject: Responses to questions posed by the Committee on May 29, 2002

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

January 24, 2002

Honorable Harry Reid
United States Senate
528 SHOB
Washington, DC 20510-2893

Dear Senator Reid:

Enclosed are responses to the questions posed in letter of November 26, 2001 from you and Senator John Ensign. As you know, the Board provides independent advice on the technical issues associated with the management of the country's commercial spent nuclear fuel and defense high-level radioactive waste. The Board offers its technical views to help inform the larger consideration of issues that face the Department of Energy and Congress in their evaluation of the suitability of the Yucca Mountain candidate repository site.

The Board is keenly aware that many of the issues that must be considered in making decisions in this policy area are technical ones, but that other issues are not. We believe that Congress and the Secretary will find it useful to have our views on the technical and scientific information related to a possible site recommendation. As noted in our responses, policy-makers will decide how much technical certainty is acceptable for a site recommendation.

Please let me or the Board's staff know if we can provide you or your staff with additional information on the enclosed responses.

Sincerely,

{Signed by}

Jared L. Cohon
Chairman

Enclosure

NUCLEAR WASTE TECHNICAL REVIEW BOARD
RESPONSE TO QUESTIONS FROM
SENATORS HARRY REID AND JOHN ENSIGN
JANUARY 24, 2002

1. How strong is the current technical basis for DOE's repository design and for the analysis that supports the site recommendation?

In evaluating the DOE's technical and scientific work related to individual natural and engineered components of the proposed repository system, the Board finds varying degrees of strength and weakness. Such variability is not surprising, given that the Yucca Mountain project is in many respects a first-of-a-kind, complex undertaking. When the DOE's technical and scientific work is taken as a whole, the Board's view is that the technical basis for the DOE's repository performance estimates is weak to moderate at this time. As discussed in the Board's January 24, 2002 letter to Congress and the Secretary of Energy, the Board believes that it is possible to increase confidence in the DOE's projections of repository system performance.

The DOE's estimates of repository performance currently rely heavily on engineered components of the repository system, making corrosion of the waste package very important. High temperatures in the DOE's base-case repository design increase uncertainties and decrease confidence in the performance of waste package materials. Confidence in waste package and repository performance potentially could increase if the DOE adopts a low-temperature repository design. However, a full and objective comparison of high- and low-temperature repository designs should be completed before the DOE selects a final repository design concept.

The Board makes no judgment on the question of whether the Yucca Mountain site should be recommended or approved for repository development. Those judgments, which involve a number of public policy considerations as well as an assessment of how much technical certainty is necessary at various decision points, go beyond the Board's congressionally established mandate.

2. How confident are you that the current DOE program would lead to a safe repository that protects human health and the environment at Yucca Mountain?

At this point, no individual technical or scientific factor has been identified that would automatically eliminate Yucca Mountain from consideration as the site of a permanent repository. The Board believes, however, that specific activities can and should be pursued to increase confidence in the projections of performance of the proposed repository at Yucca Mountain. Those activities include identifying, quantifying, and communicating clearly the extent of the uncertainty associated with the DOE's performance estimates; comparing and evaluating a low-temperature repository design with the DOE's current base-case high-temperature design; increasing the fundamental understanding of the potential behavior of the proposed repository system; developing multiple lines of evidence; and strengthening arguments about defense-in-depth (or redundancy). The Board also believes that uncertainties related to the performance of waste package materials under high-temperature conditions should be addressed.

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The Board's January 24, 2002 letter to Congress and the Secretary of Energy also contains suggestions about new initiatives that the DOE might undertake to increase confidence. Many factors, such as the DOE's ability to improve the integration of scientific and engineering activities, are likely to influence whether those activities can be successfully completed.

3. Is it premature for the DOE to make a recommendation that the site is suitable for a geologic repository?

The timing of a decision on whether the Yucca Mountain site should be recommended or approved for repository development is a judgment involving a number of public policy considerations as well as an assessment of how much technical certainty policy-makers believe is necessary at the time decisions are made. As stated in the answer to question 1, these judgments go beyond the Board's congressionally established mandate.

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

January 24, 2002

Honorable John Ensign
United States Senate
364 SROB
Washington, DC 20510-2805

Dear Senator Ensign:

Enclosed are responses to the questions posed in letter of November 26, 2001 from you and Senator Harry Reid. As you know, the Board provides independent advice on the technical issues associated with the management of the country's commercial spent nuclear fuel and defense high-level radioactive waste. The Board offers its technical views to help inform the larger consideration of issues that face the Department of Energy and Congress in their evaluation of the suitability of the Yucca Mountain candidate repository site.

The Board is keenly aware that many of the issues that must be considered in making decisions in this policy area are technical ones but that other issues are not. We believe that Congress and the Secretary will find it useful to have our views on the technical and scientific information related to a possible site recommendation. As noted in our responses, policy-makers will decide how much technical certainty is acceptable for a site recommendation.

Please let me or the Board's staff know if we can provide you or your staff with additional information on the enclosed responses.

Sincerely,

{signed by}

Jared L. Cohon
Chairman

Enclosure

NUCLEAR WASTE TECHNICAL REVIEW BOARD
RESPONSE TO QUESTIONS FROM
SENATORS HARRY REID AND JOHN ENSIGN
JANUARY 24, 2002

1. How strong is the current technical basis for DOE's repository design and for the analysis that supports the site recommendation?

In evaluating the DOE's technical and scientific work related to individual natural and engineered components of the proposed repository system, the Board finds varying degrees of strength and weakness. Such variability is not surprising, given that the Yucca Mountain project is in many respects a first-of-a-kind, complex undertaking. When the DOE's technical and scientific work is taken as a whole, the Board's view is that the technical basis for the DOE's repository performance estimates is weak to moderate at this time. As discussed in the Board's January 24, 2002 letter to Congress and the Secretary of Energy, the Board believes that it is possible to increase confidence in the DOE's projections of repository system performance.

The DOE's estimates of repository performance currently rely heavily on engineered components of the repository system, making corrosion of the waste package very important. High temperatures in the DOE's base-case repository design increase uncertainties and decrease confidence in the performance of waste package materials. Confidence in waste package and repository performance potentially could increase if the DOE adopts a low-temperature repository design. However, a full and objective comparison of high- and low-temperature repository designs should be completed before the DOE selects a final repository design concept.

The Board makes no judgment on the question of whether the Yucca Mountain site should be recommended or approved for repository development. Those judgments, which involve a number of public policy considerations as well as an assessment of how much technical certainty is necessary at various decision points, go beyond the Board's congressionally established mandate.

2. How confident are you that the current DOE program would lead to a safe repository that protects human health and the environment at Yucca Mountain?

At this point, no individual technical or scientific factor has been identified that would automatically eliminate Yucca Mountain from consideration as the site of a permanent repository. The Board believes, however, that specific activities can and should be pursued to increase confidence in the projections of performance of the proposed repository at Yucca Mountain. Those activities include identifying, quantifying, and communicating clearly the extent of the uncertainty associated with the DOE's performance estimates; comparing and evaluating a low-temperature repository design with the DOE's current base-case high-temperature design; increasing the fundamental understanding of the potential behavior of the proposed repository system; developing multiple lines of evidence; and strengthening arguments about defense-in-depth (or redundancy). The Board also believes that uncertainties related to the performance of waste package materials under high-temperature conditions should be addressed.

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The Board's January 24, 2002 letter to Congress and the Secretary of Energy also contains suggestions about new initiatives that the DOE might undertake to increase confidence. Many factors, such as the DOE's ability to improve the integration of scientific and engineering activities, are likely to influence whether those activities can be successfully completed.

3. Is it premature for the DOE to make a recommendation that the site is suitable for a geologic repository?

The timing of a decision on whether the Yucca Mountain site should be recommended or approved for repository development is a judgment involving a number of public policy considerations as well as an assessment of how much technical certainty policy-makers believe is necessary at the time decisions are made. As stated in the answer to question 1, these judgments go beyond the Board's congressionally established mandate.

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

January 24, 2002

Honorable Joe Barton
Chairman
Subcommittee on Energy and Power
Committee on Energy and Commerce
U.S. House of Representatives
Room 2125, Rayburn House Office Building
Washington, DC 20515-6115

Dear Mr. Barton:

Enclosed are responses to the questions posed in your letter of December 11, 2001. As you know, the Board provides independent advice on the technical issues associated with the management of the country's commercial spent nuclear fuel and defense high-level radioactive waste. The Board offers its technical views to help inform the larger consideration of issues tha face the Department of Energy and Congress in their evaluation of the suitability of the Yucca Mountain candidate repository site.

The Board is keenly aware that many of the issues that must be considered in making decisions in this policy area are technical ones but other issues are not. We believe that Congre and the Secretary will find it useful to have our views on the technical and scientific informatio related to a possible site recommendation. As noted in our responses, policy-makers will decid how much technical certainty is acceptable for a site recommendation.

Please let me or the Board's staff know if we can provide you or your staff with additional information on the enclosed responses.

Sincerely,

{Signed by}

Jared L. Cohon
Chairman

Enclosure

NUCLEAR WASTE TECHNICAL REVIEW BOARD
RESPONSE TO QUESTIONS FROM
REPRESENTATIVE JOE BARTON
JANUARY 24, 2002

1. Does the Board have any reason to believe that the site currently being studied at Yucca Mountain could not be made suitable for the development of a repository? If so, please explain any such reason(s)?

At this point, no individual technical or scientific factor has been identified that would automatically eliminate Yucca Mountain from consideration as the site of a permanent repository. However, the DOE uses a complex integrated performance assessment model to project repository system performance. Performance assessment is a useful tool because it assesses how well the repository system as a whole, not just the site or the engineered components, might perform. However, gaps in data and basic understanding cause important uncertainties in the concepts and assumptions on which the DOE's performance estimates are now based. Because of these uncertainties, the Board has limited confidence in current performance estimates generated by the DOE's performance assessment model. This is not an assessment of the Board's level of confidence in the Yucca Mountain site.

The Board believes that confidence in performance estimates can be increased. Future scientific investigations may show that components of the repository system perform better than or not as well as the DOE's performance assessment model now projects. It is impossible to know with absolute certainty whether issues or concerns that cannot be mitigated might arise in the future. This would be the case at any potential repository site.

2. What improvements can DOE make in its research and design that would improve the effectiveness of a repository at that location? In keeping with the "step-wise repository development" approach recommended by the National Academy of Sciences, how can such improvements best be phased into the evolving repository design?

If policy-makers decide to approve the Yucca Mountain site, the Board strongly recommends that in addition to demonstrating regulatory compliance, the DOE continue a vigorous well-integrated scientific investigation to increase its fundamental understanding of the potential behavior of the repository system. The Board believes, in addition, that specific activities can and should be pursued to increase confidence in the projections of performance of the proposed repository at Yucca Mountain. Those activities include systematically integrating new data and analyses produced by ongoing scientific and engineering investigations; identifying, quantifying, and communicating clearly the extent of the uncertainty associated with its performance estimates; comparing and evaluating a low-temperature repository design with the DOE's current base-case high-temperature design; increasing the fundamental understanding of the potential behavior of the proposed repository system; developing multiple lines of evidence; and strengthening arguments about defense-in-depth (or redundancy). The Board also believes that uncertainties related to the performance of waste package materials under high-temperature conditions should be addressed.

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The Board has not evaluated the implications of a "step wise" approach to repository development. However, in its January 24, 2002 letter to Congress and the Secretary of Energy, the Board suggests several new actions that should be considered if policy-makers approve the Yucca Mountain site, regardless of the development approach used. The actions include monitoring repository performance before, during, and after waste emplacement; developing a strategy for modifying or stopping repository development if potentially significant unforeseen circumstances are encountered; and continuing external review of the DOE's technical and scientific activities. The Board notes that the National Academy of Sciences (NAS) is scheduled soon to release a preliminary report describing the advantages and disadvantages of applying a step wise approach specifically to the development of a repository at Yucca Mountain. As part of its ongoing evaluation, the Board will review the technical and scientific validity of any plans that the DOE adopts in response to the NAS report.

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

January 24, 2002

Honorable John Shimkus
Committee on Energy and Commerce
U.S. House of Representatives
Rayburn House Office Building
Washington, DC 20515-1320

Dear Mr. Shimkus:

Enclosed are responses to the questions posed in your letter of December 5, 2001. As you know, the Board provides independent advice on the technical issues associated with the management of the country's commercial spent nuclear fuel and defense high-level radioactive waste. The Board offers its technical views to help inform the larger consideration of issues that face the Department of Energy and Congress in their evaluation of the suitability of the Yucca Mountain candidate repository site.

The Board is keenly aware that many of the issues that must be considered in making decisions in this policy area are technical ones but that other issues are not. We believe that Congress and the Secretary will find it useful to have our views on the technical and scientific information related to a possible site recommendation. As noted in our responses, policy-makers will decide how much technical certainty is acceptable for a site recommendation.

Please let me or the Board's staff know if we can provide you or your staff with additional information on the enclosed responses.

Sincerely,

{signed by}

Jared L. Cohon
Chairman

Enclosure

NUCLEAR WASTE TECHNICAL REVIEW BOARD
RESPONSE TO QUESTIONS FROM
REPRESENTATIVE JOHN SHIMKUS
JANUARY 24, 2002

Are you aware of any technical issues or concerns applicable to the site recommendation phase of the Yucca Mountain Project, that directly and negatively impact human health and safety, that could not be mitigated prior to the closure of the repository, which under current design, would occur 100-300 years after its opening?

At this point, no individual technical or scientific factor has been identified that would automatically eliminate Yucca Mountain from consideration as the site of a permanent repository. However, the DOE uses a complex integrated performance assessment model to project repository system performance. Performance assessment is a useful tool because it assesses how well the repository system as a whole, not just the site or the engineered components, might perform. However, gaps in data and basic understanding cause important uncertainties in the concepts and assumptions on which the DOE's performance estimates are now based. Because of these uncertainties, the Board has limited confidence in current performance estimates generated by the DOE's performance assessment model. This is not an assessment of the Board's level of confidence in the Yucca Mountain site.

The Board believes that confidence in performance estimates can be increased. Future scientific investigations may show that components of the repository system perform better than or not as well as the DOE's performance assessment model now projects. It is impossible to know with absolute certainty whether issues or concerns that cannot be mitigated might arise in the future. This would be the case at any potential repository site.

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Statement of
Dr. Jared L. Cohon, Chairman
U.S. Nuclear Waste Technical Review Board
Before the
Subcommittee on Energy and Air Quality
Committee on Energy and Commerce
U.S. House of Representatives
April 18, 2002

Good morning, Mr. Chairman and members of the Subcommittee. I am Jared Cohon, Chairman of the Nuclear Waste Technical Review Board. All members of the Board are appointed by the President and serve on a part-time basis. In my case, I also am president of Carnegie Mellon University in Pittsburgh, Pennsylvania.

I am pleased to be here today to present the Board's technical and scientific evaluation of the Department of Energy's work related to the recommendation of a site at Yucca Mountain in Nevada as the location of a permanent repository for spent nuclear fuel and high-level radioactive waste. We hope that the Subcommittee and other policy-makers will find the Board's technical and scientific evaluation useful as you consider the various issues that will affect a decision on whether to proceed with repository development. With your permission, Mr. Chairman, I will summarize the Board's findings, and I request that my full statement and the Board's January 24, 2002, letter report to Congress and the Secretary of Energy be included in the hearing record.

As you know, Mr. Chairman, Congress created the Board in the 1987 amendments to the Nuclear Waste Policy Act. Congress charged the Board with performing an ongoing independent evaluation of the technical and scientific validity of activities undertaken by the Secretary of Energy related to disposing of spent nuclear fuel and high-level radioactive waste. The Board also reviews the DOE's activities related to transporting and packaging such waste. Since the Board was established, its primary focus has been the DOE's efforts to characterize a site at Yucca Mountain in Nevada to determine its suitability as the location of a potential repository.

Early last year, Secretary of Energy Spencer Abraham indicated that he would make a decision at the end of 2001 on whether to recommend the Yucca Mountain site for repository development. As the Secretary's decision approached, the Board decided it was important to comment to the Secretary and Congress, within the context of the Board's ongoing evaluation of the technical and scientific validity of DOE activities, on the Doe's work related to a site recommendation. So, in November 2001, the Board met to review comprehensively the DOE's efforts in this area. In December 2001, the Board sent a letter to the Secretary indicating that the Board would provide its comments within a few weeks. The Board conveyed those comments in a letter, which included attachments with supporting details, that was sent to Congress and the Secretary on January 24, 2002.

I will now summarize the Board's review procedures and the results of the Board's evaluation.

The Board's evaluation represents the collective judgment of its members and was based on the following:

- The results of the Board's ongoing review of the DOE's Yucca Mountain technical and scientific investigations since the Board's inception.
- An evaluation of the DOE's work on the natural and engineered components of the proposed repository system, using a list of technical questions identified by the Board.

- A comprehensive Board review of draft and final documents supplied by the DOE through mid-November 2001.
- Field observations by Board members at Yucca Mountain and related sites.

To focus its review, the Board considered the following 10 questions for components of the repository system:

1. Do the models used to generate input to the total system performance assessment (TSPA) and the representations of processes and linkages or relationships among processes within TSPA have a sound basis?
2. Have uncertainties and conservatisms in the analyses been identified, quantified, and described accurately and meaningfully?
3. Have sufficient data and observations been gathered using appropriate methodologies?
4. Have assumptions and expert judgments, including bounding estimates, been documented and justified?
5. Have model predictions been verified or tested?
6. Have available data that could challenge prevailing interpretations been collected and evaluated?
7. Have alternative conceptual models and model abstractions been evaluated, and have the bases for accepting preferred models been documented?
8. Are the bases for extrapolating data over long times or distances scientifically valid?
9. Can the repository and waste package designs be implemented so that the engineered and natural barriers perform as expected?
10. To the extent practical, have other lines of evidence, derived independently of performance assessments, been used to evaluate confidence in model estimates?

In evaluating the DOE's work related to individual natural and engineered components of the proposed repository system, the Board found varying degrees of strength and weakness. For example, the Board considers the DOE's estimates of the probabilities of volcanic events and earthquakes at Yucca Mountain strengths, while the lack of data related to corrosion of materials proposed for the waste packages under conditions that would likely be present in the repository and the very short experience with these materials are considered weaknesses.

This kind of variability is not surprising, given that the Yucca Mountain project is a complex, and in many respects, a first-of-a-kind undertaking. An important conclusion in the Board's letter is that when the DOE's technical and scientific work is taken as a whole, the Board's view is that the technical basis for the DOE's repository performance estimates is weak to moderate at this time.

The Board made no judgment in its January 24 letter on the question of whether the Yucca Mountain site should be recommended or approved for repository development. Those judgments, which involve a number of public-policy considerations as well as an assessment of how much technical uncertainty is acceptable at various decision points, go beyond the Board's congressionally established mandate.

Let me explain in a little more detail, Mr. Chairman, the basis for the Board's conclusion on performance estimates. The DOE uses a complex, integrated performance assessment model to project repository system performance. Performance assessment is a useful tool because it assesses how well the repository system as a whole, not just the site or the engineered components, might perform. However, gaps in data and basic understanding cause important uncertainties in the concepts and assumptions on which the DOE's performance estimates are now based. Therefore, while no individual technical or scientific factor has been identified that would automatically eliminate Yucca Mountain from consideration at this point, the Board has limited confidence in current performance estimates generated by the

DOE's performance assessment model. As I will discuss in just a moment, the Board believes that confidence in the DOE's projections of repository performance can be increased.

But first let me clarify the comment I just made on the current state of knowledge of technical and scientific factors that could potentially eliminate Yucca Mountain from consideration. The Board considers the very precise statement in its letter that at this point, no individual technical or scientific factor has been identified that would automatically eliminate Yucca Mountain from consideration a necessary condition for a discussion of site suitability to take place. But this threshold condition, by itself, is not necessarily sufficient for a definitive determination of site suitability.

How can confidence in the DOE's performance estimates be increased? As noted in the Board's letter, the Board believes that a fundamental understanding of the potential behavior of a proposed repository system is very important. Therefore, if policy-makers decide to approve the Yucca Mountain site, the Board strongly recommends that, in addition to demonstrating regulatory compliance, the DOE continue a vigorous, well-integrated scientific investigation to increase its fundamental understanding of the potential behavior of the repository system. Increased understanding could show that components of the repository system perform better than or not as well as the DOE's performance assessment model now projects. In either case, making performance projections more realistic and characterizing the full range of uncertainty could increase confidence in the DOE's performance estimates.

The DOE's estimates of repository performance currently rely heavily on engineered components of the repository system, making corrosion of the waste package very important. As the Board has mentioned in many of its previous reports and letters over the last 11 years, we believe that high temperatures in the DOE's base-case repository design increase uncertainties and decrease confidence in the performance of waste package materials. It is possible that confidence in waste package and repository performance could increase if the DOE adopts a low-temperature repository design. However, the Board continues to believe that the DOE should complete a full and objective comparison of high- and low-temperature repository designs before it selects a final repository design concept.

Over the last several years, the Board has made several other recommendations that could increase confidence in the DOE's projections of repository performance. For example, the Board recommended that the DOE identify, quantify, and communicate clearly the extent of the uncertainty associated with its performance estimates. The Board also recommended that the DOE use other lines of evidence and argument to supplement the results of its performance assessment. Moreover, the DOE could strengthen its arguments about how multiple barriers in its proposed repository system provide "defense-in-depth" (or redundancy). Although the DOE has made progress in each of these areas, more work is needed.

Other actions that might be considered if policy-makers approve the Yucca Mountain site include systematically integrating new data and analyses produced by ongoing scientific and engineering investigations; monitoring repository performance before, during, and after waste emplacement; developing a strategy for modifying or stopping repository development if potentially significant unforeseen circumstances are encountered; and continuing external review of the DOE's technical and scientific activities.

Mr. Chairman, eliminating all uncertainty associated with estimates of repository performance would never be possible at any repository site. Policy-makers will decide how much scientific uncertainty is acceptable at the time various decisions are made on site recommendation or repository development. The Board hopes that the information provided in the testimony and in its letter report to Congress and the Secretary will be useful to policy-makers faced with making these important decisions.

Not surprisingly, Mr. Chairman, people have drawn from the Board's January 24 letter the points that support their case. The Board is concerned, however, that lifting individual statements from the letter and using them without context can be confusing for policy-makers and the public. Therefore, we urge those charged with making decisions about Yucca Mountain to consider the full text or our 3-page letter.

Thank you very much, Mr. Chairman. I will be happy to respond to questions.

APR 2 9 2002

ONE HUNDRED SEVENTH CONGRESS

U.S. House of Representatives
Committee on Energy and Commerce
Washington, DC 20515–6115

W.J. "BILLY" TAUZIN, LOUISIANA,
CHAIRMAN

April 22, 2002

Dr. Jared L. Cohon
Chairman
Nuclear Waste Technical Review Board
Suite 1300
2300 Clarendon Boulevard
Arlington, VA 22201

Dear Dr. Cohon:

I am writing to thank you for appearing before the Subcommittee on Energy and Air Quality on April 18, 2002, to present testimony on President's recommendation to develop a nuclear waste repository at Yucca Mountain, Nevada. Your testimony allowed the Subcommittee's Members to gain a better understanding of this extremely important issue.

Pursuant to the Chair's order of April 18, 2002, the record of the Subcommittee's hearing remains open to permit Members to submit questions to witnesses in writing. Attached you will find questions submitted by Members of the Subcommittee. I would appreciate it if you could respond to these questions in writing no later than the close of business on May 17, 2002, in order to facilitate the printing of the hearing record.

Thank you again for your time and effort in preparing and delivering testimony before the Subcommittee.

Sincerely,

Joe Barton
Chairman
Subcommittee on Energy and Air Quality

Attachment

Questions from Congressman Ed Markey:

1. In addition to the Nuclear Waste Technical Review Board (NWTRB), the International Atomic Energy Agency/Nuclear Energy Agency has reviewed the scientific and technical work of the DOE. They state in their review that "In general, the level of understanding of the hydro-geology of the site... is low, unclear and insufficient to support an assessment of the realistic performance." They continue "Until these questions are answered, it is not possible to develop a realistic conceptual model of the site, or to build a probabilistic saturated zone local model." Do you agree with their assessment? Is the DOE's model unrealistic because of lack of data and basic understanding of physical processes?

2. The DOE is relying heavily on the ability of the canisters to withstand corrosion and contain the radioactive waste for long periods of time. The NWTRB report states that essentially no corrosion data exists for conditions above 275 degrees (120 C), despite the fact the repository could reach temperatures as high as 350 degrees (165 C). In your opinion, can the DOE make any real assessment of the engineered barriers above 275 degrees? What are some of the effects that elevated temperatures could have on the canisters?

3. The DOE only has 2 years of corrosion data for alloy 22 based canisters, yet they are extrapolating this data to 10,000 years. Is this acceptable? Is there currently anyway to adequately determine the integrity of these canisters 10,000 years in the future?

4. The Chlorine -36 "fingerprints" of above ground nuclear testing have been found in the interior of Yucca Mountain, suggesting that water from the surface can migrate 1000 feet to the repository level of the mountain within 50 years. What are the implications of this data for contamination of the ground water below the repository? What are the implications for corrosion of the canisters?

5. Secretary Abraham said in his testimony that Yucca Mountain will meet the EPA radiological exposure standard. But the NWTRB report notes that DOE has not published updated calculations of radiological doses based on the recent travel time estimates. Is the Secretary's statement premature? Can DOE be confident that Yucca Mountain will meet the EPA's standard without having completed these calculations?

6. Spent fuel – uranium dioxide – will be the majority of the stored waste in Yucca Mountain. What will happen to the fuel rods as they sit in the repository? Will they rust? Has the DOE considered the effect of rusting in their assessment of Yucca Mountain and containment of the radioactive waste?

Questions from Congressman George Radanovich:

1. Would you agree with the statement "Geologic isolation cannot and will not play any significant role at the Yucca Mountain repository?"

2. What is the NWTRB opinion of the ability of the man-made containers to meet the NRC and EPA standards for radioactive release into the environment?

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

May 22, 2002

Honorable Joe Barton
Chairman
Subcommittee on Energy and Air Quality
Committee on Energy and Commerce
U.S. House of Representatives
2125 RHOB
Washington, DC 20515-6115

Dear Mr. Barton:

Thank you very much for the opportunity to present the views of the Nuclear Waste Technical Review Board at a hearing before the Subcommittee on Energy and Air Quality on April 18, 2002. Enclosed are responses to questions from Representatives Ed Markey and George Radanovich that were enclosed in your letter of April 22, 2002. The questions follow up on issues raised during the hearing.

As you know, the Board is charged by Congress with conducting an ongoing and independent review of the technical and scientific validity of activities undertaken by the Secretary of Energy associated with the management of the country's commercial spent nuclear fuel and defense high-level radioactive waste. The Board provides its technical views to help inform the larger consideration of issues that face the Department of Energy and Congress related to nuclear waste disposal.

Please do not hesitate to contact me or have your staff contact Bill Barnard, Board Executive Director, if you have questions related to the Board's responses or any other issue related to the Board's technical and scientific review.

Sincerely,

{Signed by}

Jared L. Cohon
Chairman

Enclosure

Questions from Congressman Ed Markey:

1. *In addition to the Nuclear Waste Technical Review Board (NWTRB), the International Atomic Energy Agency/Nuclear Energy Agency has reviewed the scientific and technical work of the DOE. They state in their review that "In general, the level of understanding of the hydro-geology of the site. . .is low, unclear and insufficient to support an assessment of the realistic performance." They continue "Until these questions are answered, it is not possible to develop a realistic conceptual model of the site, or to build a probabilistic saturated zone local model." Do you agree with their assessment? Is the DOE's model unrealistic because of lack of data and basic understanding of physical process?*

   Answer: We agree generally with the concerns expressed by the International Atomic Energy Agency/Nuclear Energy Agency Peer Review Panel (International Panel) but would like to make several observations to put their comments in perspective. The International Panel comment cited above includes three elements: (1) an assessment of the realistic performance, (2) a realistic conceptual model of the site, and (3) a saturated zone local model. (In the context of this question, *realism* may be viewed as the set of models and assumptions that most nearly describes the natural and engineered repository system and produces neither overly pessimistic nor overly optimistic predictions of waste isolation.) The three elements are interlinked: A realistic performance assessment requires a realistic saturated zone site-scale model, and that requires a realistic conceptual model. Although the general concepts of the Yucca Mountain hydrogeologic system are understood, important details remain unresolved. Consequently, the performance estimates for the saturated zone in the Total System Performance Assessment for Site Recommendation (TSPA-SR) may not be realistic. The TSPA-SR was the sole focus of the International Panel. Since that time, results released by the DOE in subsequent documents indicate that some progress has been made in addressing questions raised by the International Panel and in developing a credible conceptual model of the site. Those results have not been incorporated in performance assessments, however, and substantial work remains to be done to develop a realistic saturated zone site-scale model on which a realistic assessment of performance attributable to site hydrogeology could be based.

   In answer to your question on the DOE's model, the Board stated in its January 24, 2002, letter report to Congress and the Secretary of Energy that it has limited confidence in current DOE performance estimates because of uncertainties created by gaps in data and basic understanding of the proposed repository system (including the saturated zone). The Board has recommended that, if policy-makers decide to approve the Yucca Mountain site, the DOE should continue a vigorous, well-integrated scientific investigation to increase its

fundamental understanding of the potential behavior of the repository system. Increasing understanding could show that components of the repository system, including the saturated and unsaturated zones, perform better than or not as well as the DOE's performance assessment model now projects. In either case, making performance projections more realistic and characterizing the full range of uncertainty could improve the DOE's performance estimates.

2. *The DOE is relying heavily on the ability of the canisters to withstand corrosion and contain the radioactive waste for long periods of time. The NWTRB report states that essentially no corrosion data exists for conditions above 275 degrees (120° C), despite the fact the repository could reach temperatures as high as 350 degrees (165° C). In your opinion, can the DOE make any real assessment of the engineered barriers above 275 degrees? What are some of the effects that elevated temperatures could have on the canisters?*

   Answer: To answer your second, more general, question first: The severity of corrosion tends to increase with increasing temperatures. In fact, some forms of corrosion are not even observed unless the temperature exceeds a certain threshold value. This applies to essentially all alloys and metals used as construction materials, including Alloy 22, the material that the DOE has chosen to provide corrosion resistance for its waste package. In addition, and perhaps more important, predicting the chemistry (composition and strength) of salt solutions contacting the waste packages becomes more difficult and more uncertain with increasing temperature. The type and severity of corrosion depend on the makeup of those solutions.

   Regarding your first question, data on the chemistry of salt solutions that may contact the waste package as well as data on corrosion of Alloy 22 exposed to such waste package environments are both essentially nonexistent for temperatures above 120° C. These key data needed to assess the likelihood that corrosion could penetrate waste packages during the 10,000-year regulatory period. This absence of information weakens the technical basis of the DOE's performance estimates for its high-temperature, base-case repository design. Uncertainty about waste package performance decreases, however, with lower repository temperatures because more corrosion data and more data on the chemistry of salt solutions that may contact waste package surfaces are available. Uncertainty also is reduced with low temperatures because corrosion severity generally decreases as temperatures decrease. The Board believes, therefore, that confidence in waste package and repository performance potentially could increase if the DOE adopts a low-temperature repository design. However, a full and objective comparison of high- and low-temperature repository designs should be completed before the DOE selects a final repository design concept.

3. *The DOE only has 2 years of corrosion data for alloy 22 based canisters, yet they are extrapolating this data to 10,000 years. Is this acceptable? Is there currently any way to adequately determine the integrity of these canisters 10,000 years in the future?*

   Answer: Alloy 22 relies on the formation of an ultrathin passive (i.e., nonreactive) film for its corrosion resistance. The DOE's models predict that corrosion will not penetrate Alloy 22 waste packages for at least 10,000 years, perhaps for longer than a million years. However, experience with Alloy 22 and comparable alloys spans only several decades, and experience with alloys that rely on passive films for corrosion resistance spans only about a century. Although a few natural or man-made materials have been identified that might provide insights into the long-term passivity of metals, none has been confirmed yet as a suitable analogue. Thus, this type of corrosion resistance over many thousands of years can be extrapolated only by using theories and assumptions. At this point, on the basis of the information developed by the DOE and others, Board members believe that claims of minimum waste package durability of a few thousand years to a few tens of thousands of years are not out of the question. Underlying this belief are the following suppositions: that temperatures and chemical conditions on the waste-package surface will be no more severe or uncertain than those in the DOE's preliminary analysis of the low-temperature operating mode; that supporting research will be continued to fill in data gaps and to rule out unexpected modes of failure; that research, development, and demonstration of waste-package welding, fabrication, and inspection are completed successfully; and that no major "surprises" are found.

4. *The Chlorine-36 "fingerprints" of above ground nuclear testing have been found in the interior of Yucca Mountain, suggesting that water from the surface can migrate 1000 feet to the repository level of the mountain within 50 years. What are the implications of this data for contamination of the ground water below the repository? What are the implications for corrosion of the canisters?*

   Answer: The discovery of elevated amounts of chlorine-36 (a product of nuclear testing in the 1950's) at the depth of the proposed repository at Yucca Mountain would provide direct evidence of the existence of "fast paths" through which rainwater could travel from the surface of Yucca Mountain to the repository horizon within about 50 years. However, questions have been raised about the validity of the results of the original chlorine-36 study that showed evidence of such fast paths. In 1999, the DOE sought to validate the original tests. Scientists using different testing procedures have shown differing estimates of the amount of chlorine-36 present in the underground rocks. The validation study is still under way, and the DOE has not reached any conclusions. The DOE's current models of repository performance are based on the general assumption that some fast-flow paths *do* exist in Yucca Mountain.

To answer the question on the effects of possible fast paths on groundwater contamination, it would be necessary to verify that they exist and to estimate the volume of water being transported along the pathways under current and future climate conditions. The chlorine-36 validation study may resolve the question of the presence or absence of fast pathways for water flow. Estimation of the volumetric flux associated with fast pathways requires additional investigations, some of which are ongoing and some of which are planned.

In terms of the effects of fast paths on waste package corrosion rates, if the assumption is (as the DOE's is) that corrosion proceeds as rapidly under high-humidity conditions as under dripping conditions (a reasonable assumption), whether fast paths are present or absent has essentially no effect on waste package corrosion rates. However, larger fluxes of water generally result in shorter times of radioactive waste isolation. Current models, based on multiple lines of evidence, do not allow for large volumes of water to flow through these fast pathways. If the current thinking is found to be incorrect, then radionuclide transport predictions may need to be revised.

5. *Secretary Abraham said in his testimony that Yucca Mountain will meet the EPA radiological exposure standard. But the NWTRB report notes that DOE has not published updated calculations of radiological doses based on the recent travel time estimates. Is the Secretary's statement premature? Can DOE be confident that Yucca Mountain will meet the EPA's standard without having completed these calculations?*

   Answer: The DOE's performance calculations should be updated to take into account new information on travel-time estimates. However, because many things, in addition to groundwater travel times, affect the DOE's projections of compliance, the effect of revised travel-time estimates on judging compliance with the EPA standard may not be large. For example, current DOE models show that the waste package will last longer than the 10,000-year compliance period.

   The Board believes that the technical basis for the DOE's current repository performance estimates is weak to moderate. The question of whether the Secretary's statement is premature depends on how much uncertainty one finds acceptable at this decision point. That is a policy question, which is outside the Board's technical and scientific mandate.

6. *Spent fuel – uranium dioxide – will be the majority of the stored waste in Yucca Mountain. What will happen to the fuel rods as they sit in the repository? Will they rust? Has the DOE considered the effect of rusting in their assessment of Yucca Mountain and containment of the radioactive waste?*

   Answer: The spent-fuel rods consist of uranium dioxide pellets enclosed in metallic cladding. The cladding for the vast majority of the rods is zircaloy, a very corrosion-resistant alloy of zirconium. Once the cladding is exposed to aqueous or high-humidity environments (e.g., after penetration of the waste package), the cladding will begin to corrode. Eventually, corrosion will cause the cladding to fail after thousands of years. The DOE has considered cladding corrosion in its performance assessment models. However, the Board believes that the DOE's current level of understanding of cladding performance is incomplete and should be improved.

Questions from Congressman George Radanovich:

1. *Would you agree with the statement "Geologic isolation cannot and will not play any significant role at the Yucca Mountain repository?"*

   Answer: No, the statement is too strong. Although the DOE's current estimates of repository performance rely heavily on components of the engineered barrier system, the natural barriers do play a role. Further analysis and the reduction of uncertainties will permit a more realistic assessment of the relative significance of the contribution of the engineered and natural barriers in the proposed repository system.

2. *What is the NWTRB opinion of the ability of the man-made containers to meet the NRC and EPA standards for radioactive release into the environment?*

   Answer: At this point, on the basis of the information developed by the project (and others), Board members believe that claims of minimum waste package durability of a few thousand years to a few tens of thousands of years are not out of the question under relatively mild and less uncertain (lower temperature) in-drift conditions. Underlying this belief are the following suppositions: that temperatures and chemical conditions on the waste-package surface will be no more severe or uncertain than those in the DOE's preliminary analysis of the low-temperature operating mode; that supporting research will be continued to fill in data gaps and to rule out unexpected modes of failure; that research, development, and demonstration of waste-package welding, fabrication, and inspection are completed successfully; and that no major "surprises" are found.

Statement of
Dr. Jared L. Cohon, Chairman
U.S. Nuclear Waste Technical Review Board
Before the
Committee on Energy and Natural Resources
U.S. Senate
May 23, 2002

Good morning, Mr. Chairman and members of the Committee. I am Jared Cohon, Chairman of the Nuclear Waste Technical Review Board. All members of the Board are appointed by the President and serve on a part-time basis. In my case, I also am president of Carnegie Mellon University in Pittsburgh, Pennsylvania.

I am pleased to be here today to present the Board's technical and scientific evaluation of the Department of Energy's work related to the recommendation of a site at Yucca Mountain in Nevada as the location of a permanent repository for spent nuclear fuel and high-level radioactive waste and to respond to questions posed by the Committee in its invitiation letter. We hope that the Committee and other policy-makers will find the Board's testimony useful as you consider the various issues that will affect a decision on whether to proceed with repository development. With your permission, Mr. Chairman, I will summarize the Board's findings, and I request that my full statement and the Board's January 24, 2002, letter report to Congress and the Secretary of Energy be included in the hearing record.

As you know, Mr. Chairman, Congress created the Board in the 1987 amendments to the Nuclear Waste Policy Act. Congress charged the Board with performing an ongoing independent evaluation of the technical and scientific validity of activities undertaken by the Secretary of Energy related to disposing of spent nuclear fuel and high-level radioactive waste. The Board also reviews the DOE's activities related to transporting and packaging such waste. Since the Board was established, its primary focus has been the DOE's efforts to characterize a site at Yucca Mountain in Nevada to determine its suitability as the location of a potential repository.

Early last year, Secretary of Energy Spencer Abraham indicated that he would make a decision at the end of 2001 on whether to recommend the Yucca Mountain site for repository development. As the Secretary's decision approached, the Board decided it was important to comment to the Secretary and Congress, within the context of the Board's ongoing evaluation of the technical and scientific validity of DOE activities, on the DOE's work related to a site recommendation. So, in November 2001, the Board met to review comprehensively the DOE's efforts in this area. In December 2001, the Board sent a letter to the Secretary indicating that the Board would provide its comments within a few weeks. The Board conveyed those comments in a letter, which included attachments with supporting details, that was sent to Congress and the Secretary on January 24, 2002.

I will now summarize the Board's review procedures and the results of the Board's evaluation. Questions posed by the Committee in its invitation letter are addressed in the context of the Board's evaluation.

The Board's evaluation of the DOE's work represents the collective judgment of its members and was based on the following:

- The results of the Board's ongoing review of the DOE's Yucca Mountain technical and scientific investigations since the Board's inception.
- An evaluation of the DOE's work on the natural and engineered components of the proposed repository system, using a list of technical questions identified by the Board.

- A comprehensive Board review of draft and final documents supplied by the DOE through mid-November 2001.
- Field observations by Board members at Yucca Mountain and related sites.

To focus its review, the Board considered the following 10 questions for components of the repository system:

1. Do the models used to generate input to the total system performance assessment (TSPA) and the representations of processes and linkages or relationships among processes within TSPA have a sound basis?
2. Have uncertainties and conservatisms in the analyses been identified, quantified, and described accurately and meaningfully?
3. Have sufficient data and observations been gathered using appropriate methodologies?
4. Have assumptions and expert judgments, including bounding estimates, been documented and justified?
5. Have model predictions been verified or tested?
6. Have available data that could challenge prevailing interpretations been collected and evaluated?
7. Have alternative conceptual models and model abstractions been evaluated, and have the bases for accepting preferred models been documented?
8. Are the bases for extrapolating data over long times or distances scientifically valid?
9. Can the repository and waste package designs be implemented so that the engineered and natural barriers perform as expected?
10. To the extent practical, have other lines of evidence, derived independently of performance assessments, been used to evaluate confidence in model estimates?

In evaluating the DOE's work related to individual natural and engineered components of the proposed repository system, the Board found varying degrees of strength and weakness. For example, the Board considers the DOE's estimates of the probabilities of volcanic events and earthquakes at Yucca Mountain strengths and the lack of data related to corrosion of materials proposed for the waste packages under conditions that would likely be present in the repository and the very short experience with these materials weaknesses.

This kind of variability is not surprising, given that the Yucca Mountain project is a complex, and in many respects, a first-of-a-kind undertaking. An important conclusion in the Board's January letter is that when the DOE's technical and scientific work is taken as a whole, the Board's view is that the technical basis for the DOE's repository performance estimates is weak to moderate at this time. However, if all the recommendations in the Board's January 24, 2002, letter report are implemented and no surprises are found,the Board's view of the technical basis would likely improve. The predicted repository performance, however, might be either better or worse, depending on what is discovered.

The Board concurs with the consensus within the international scientific community that deep geologic disposal is technically feasible at a suitable site. However, the Board made no judgment in its January letter on the question of whether the Yucca Mountain site should be recommended or approved for repository development. Those judgments, which involve a number of public-policy considerations as well as an assessment of how much technical uncertainty is acceptable at various decision points, go beyond the Board's congressionally established mandate.

Let me explain in a little more detail, Mr. Chairman, the basis for the Board's conclusion on performance estimates. The DOE uses a complex, integrated performance assessment model to project repository system performance. Performance assessment is a useful tool because it assesses how well the repository system as a whole, not just the site or the engineered components, might perform. However, gaps in data and basic understanding cause important uncertainties in the concepts and assumptions on which the DOE's performance estimates are now based. Therefore, while no individual technical or scientific factor has been identified that would automatically eliminate Yucca Mountain from consideration at this point, the Board has limited confidence in current performance estimates generated by the DOE's performance assessment model.

But first let me expand a bit on the comment I just made that at this point, no individual technical or scientific factor has been identified that would automatically eliminate Yucca Mountain from consideration. The Board considers this minimum threshold finding to be a necessary, but by itself not a sufficient, condition for a positive determination of site suitability.

How can confidence in the DOE's performance estimates be increased? As noted in the Board's January letter report, the Board believes that a fundamental understanding of the potential behavior of a proposed repository system is very important. Therefore, if policy-makers decide to approve the Yucca Mountain site, the Board strongly recommends that, in addition to demonstrating regulatory compliance, the DOE continue a vigorous, well-integrated scientific investigation to increase its fundamental understanding of the potential behavior of the repository system. Increased understanding could show that components of the repository system perform better than or not as well as the DOE's performance assessment model now projects. In either case, making performance projections more realistic and characterizing the full range of uncertainty could improve the DOE's performance estimates.

The DOE's estimates of repository performance currently rely heavily on engineered components of the repository system, making corrosion of the waste package very important. As the Board has mentioned in many of its previous reports and letters, we believe that high temperatures in the DOE's base-case repository design increase uncertainties and decrease confidence in the performance of waste package materials. Confidence in projections of waste package and repository performance potentially could increase if the DOE adopts a low-temperature repository design. However, the Board continues to believe that the DOE should complete a full and objective comparison of high- and low-temperature repository designs before it selects a final repository design concept.

Over the last several years, the Board has made several other recommendations that could improve the DOE's projections of repository performance. For example, the Board recommended that the DOE identify, quantify, and communicate clearly the extent of the uncertainty associated with its performance estimates. The Board also recommended that the DOE use additional lines of evidence and argument to supplement the results of its performance assessment. Moreover, the DOE could strengthen its arguments about how multiple barriers in its proposed repository system provide "defense-in-depth" (or redundancy). Although the DOE has made progress in each of these areas, more work is needed.

Other actions that might be considered if policy-makers approve the Yucca Mountain site include systematically integrating new data and analyses produced by ongoing scientific and engineering investigations; monitoring repository performance before, during, and after waste emplacement; developing a strategy for modifying or stopping repository development if potentially significant unforeseen circumstances are encountered; and continuing external review of the DOE's technical and scientific activities.

Mr. Chairman, your letter of invitation asked what the Board's views are on whether sufficient technical information is or will be available to the Nuclear Regulatory Commission to enable it to assess the safety and environmental impact of a repository at Yucca Mountain.

This is the Board's answer to that question. The NRC issued the following statement in November 2001, "The NRC believes that sufficient at-depth site characterization analysis and waste form proposal information, although not available now, will be available at the time of a potential license application such that development of an acceptable license application is achievable." The NRC and the DOE have agreed on a list of "key technical issues" (KTI) that need to be addressed in the DOE's license application. The NRC, not the Board, will judge the adequacy of the DOE's efforts to resolve these issues for a license application. However, the Board believes that given the significant uncertainties associated with the DOE's current performance estimates, addressing all of the KTI's in the 2004 time frame that has been discussed will be an ambitious undertaking.

Mr. Chairman, let me close by observing that eliminating all uncertainty associated with estimates of repository performance would never be possible at any repository site. Policy-makers will decide how much scientific uncertainty is acceptable at the time various decisions are made on site recommendation or repository development. The Board hopes that the information provided in this testimony and in its letter report to Congress and the Secretary will be useful to policy-makers faced with making these important decisions.

Thank you for the opportunity to present the Board's views. I will be happy to respond to additional questions from the Committee.

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

May 31, 2002

The Honorable Jeff Bingaman
Chairman
Committee on Energy and Natural Resources
U.S. Senate
Washington, DC 20510-6105

Dear Senator Bingaman:

Thank you very much for the opportunity to present the views of the Nuclear Waste Technical Review Board at the hearing of the Committee on Energy and Natural Resources on May 23, 2002. Following up on issues raised during the hearing, the Committee sent questions to the Board on May 29, 2002. Enclosed are the Board's responses to those questions.

As you know, the Board is charged by Congress with conducting an ongoing and independent review of the technical and scientific validity of activities undertaken by the Secretary of Energy associated with the management of the country's commercial spent nuclear fuel and defense high-level radioactive waste. The Board provides its technical views to help inform policy-makers as they deliberate on issues that face the Department of Energy related to nuclear waste disposal.

Please do not hesitate to contact me or have your staff contact Bill Barnard, the Board's executive director, if you have questions related to the Board's responses or any other issue related to the Board's technical and scientific review.

Sincerely,

{Signed by}

Jared L. Cohon
Chairman

RESPONSES TO QUESTIONS ASKED BY THE SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES

Could you further explain what you meant in your testimony about "gaps in data and basic understanding cause important uncertainties in ... DOE's performance estimates"?

Gaps in data and basic understanding exist in a number of areas including: the hydraulic properties of faults and other significant rock-mass discontinuities at Yucca Mountain; thermal, hydrologic, and mechanical characteristics of the repository rock formations (especially thermal conductivity); the properties of the in-drift environment; fundamental mechanisms underlying long-term corrosion and passive-film behavior; the chemical composition of salt solutions on the waste package surface that could promote corrosion; colloid formation and dissolution; modeling of rock-matrix diffusion and radionuclide transport in the drift shadow; oxidation-reduction conditions in the saturated zone; and consequences of igneous activity. Because of the cumulative effect of these and other uncertainties, the Board has limited confidence in current estimates of repository performance generated by the DOE's performance assessment model. Increased understanding in these key areas could show that components of the repository system perform better than or not as well as the DOE's performance assessment model now projects.

Based on the International Atomic Energy Agency's (IAEA) assertion that the modeling already incorporates many conservatisms, do you believe that many of the uncertainties in the performance estimates may already be well within an acceptable risk range?

Although the IAEA peer review group pointed out a number of conservatisms, it also mentioned a number of potential non-conservatisms and areas where additional data are required to achieve an increased level of understanding and confidence. More specifically, in the Board's view, the DOE's current performance estimates for Yucca Mountain are based on a mix of conservative, realistic, and non-conservative models and assumptions. This mix and the gaps in data and basic understanding, such as those mentioned above, make it very difficult to estimate what the "true" overall level of uncertainty is and whether or not this uncertainty lies within an acceptable range of risk. So that policy-makers can determine whether the risks and associated uncertainties are acceptable, the Board has recommended that meaningful quantification of conservatisms and uncertainties be a high priority for the DOE.

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