Department of Energy
Washington, DC 20585

June 26, 2003

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

Dear Dr. Corradini:

Thank you for your letter of March 5, 2003, providing the Nuclear Waste Technical Review Board's (Board) perspective on information presented by the U.S. Department of Energy (Department) at the Board's January 2003 meeting.

The Department appreciates the Board's continuing review of our activities as we continue development of science, design, and analysis, including a license application, for a repository at Yucca Mountain. Our responses to the views expressed by the Board are summarized in the enclosure to this letter.

The Department continues to benefit from the constructive views of the Board, and we look forward to continuing our dialogue.

Sincerely,

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

Enclosure:
Responses to the March 5, 2003 letter to the U.S. Department of Energy (DOE) from the Nuclear Waste Technical Review Board

Responses to the March 5, 2003 letter to the U.S. Department of Energy (DOE) from the Nuclear Waste Technical Review Board

Natural System

The Board continues to believe that the DOE should persist in its efforts to reach scientific consensus on the results of the chlorine-36 analyses and the implications of those results for fluid flow in Yucca Mountain.

Response:

The DOE agrees that it is important to resolve the discrepancies in results between two DOE-supported groups measuring the same phenomenon. As noted in our letter of January 24, 2003[1], DOE is pursuing resolution of the legacy discrepant data sets by

- having the institutions involved to date document the results to date and propose a plan to resolve the discrepancies, and
- considering an independent new validation study as a parallel, complementary effort.

Isotopic evidence of the existence of fast pathways has guided the development of the unsaturated-zone flow conceptual model which includes dual-permeability concepts that can capture the range of travel times corresponding to flow in the matrix and flow in fractures. The quantitative ^{36}Cl information has been compared with the numerical results of the model. The information is used as "supporting data" rather than as a target for model calibration. Even though the ^{36}Cl data were not used to calibrate the unsaturated flow model (CRWMS M&O 2000, Section 3.7.4.4[2]), the distribution of travel times predicted by the model is consistent with the data. The occurrence of some rapid transport has been built into the conceptual and numerical models of unsaturated-zone flow and transport to be consistent with isotopic evidence, and the TSPA calculations capture this behavior within the range of uncertainty in the existing isotopic data.

Field investigations and numerical modeling of heterogeneous alluvial sedimentary deposits show that even relatively thin low-permeability deposits can significantly alter directions and rates of water flow and chemical transport in the saturated zone. Ancient soils known as "paleosols" can form these thin low-permeability deposits within alluvial sedimentary sequences

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[1] Chu, Margaret, 2003. Letter to Michael L. Corradini responding to the views expressed by the Board on information presented in the September 2003 NWTRB meeting, with enclosure. January 24, 2003.

[2] CRWMS M&O 2000c. *Unsaturated Zone Flow and Transport Model Process Model Report.* TDR-NBS-HS-000002 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O.

and are known to occur in the Yucca Mountain region. Also, depending on their mineralogical properties, paleosols can potentially retard the chemical-transport rates of some radionuclides. Taken together, these characteristics suggest that paleosols merit exploratory investigation by project hydrogeologists.

Response:

At the January meeting, Dr. Graham Fogg from the University of California at Davis gave an interesting presentation[3] on the influence of paleosols on fluid flow and transport in complex alluvial sediments. The DOE will consider the merit of investigating paleosols in the alluvium along with other proposals for additional studies under consideration in the Science and Technology Program.

Engineered Barriers Corrosive Environments

Contractors for the State of Nevada presented experimental results showing that highly corrosive brines and condensates can be produced at laboratory scale by distillate boiling of concentrated synthetic pore waters at atmospheric pressure. However, the presentations did not include a specific sequence of events that would cause such corrosive solutions to develop in a repository at Yucca Mountain. . . . The Board does not know, at this point, whether a case can be made that corrosive solutions would be so likely and widespread that they would be a concern or whether a case can be made that they would be so unlikely and sparse that they would be insignificant. . . . Thus, we urge the Project to ensure that the analysis and model report (AMR) that deals with the evolution of chemical environments on waste package surfaces contains a defensible technical basis, including the full logic, explanations, and assumptions underlying the Project's view that widespread corrosive solutions are unlikely.

Response:

During the recent May NWTRB meeting, the DOE made an extensive set of integrated presentations[4] laying out why we believe that a strong case can be made for the efficacy of our current design approach. Both the in-drift environment and the corrosion resistance of the engineered barriers were discussed in detail. As usual, the interaction with the Board was very useful to us, because it brought forward issues and areas where we need to provide the Board with additional analysis and, in some cases, where we need to collect or analyze additional data to supplement the analyses and data that we presented.

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[3] Fogg, G. E. 2003. *Influence of Paleosols on Fluid Flow and Transport: Perspective on Alluvial Complexity and Hydrogeology.* Presentation to the Nuclear Waste Technical Review Board Winter Meeting, January 28, 2003. Las Vegas, Nevada.

[4] Boyle, W. 2003. *Logic for Evaluating Engineered Barrier Performance.* Presentation at the Nuclear Waste Technical Review Board Spring Meeting, May 13-14, 2003. Washington, DC; Bodvarsson, G. May 13-14, 2003. *The Character of the Unsaturated Zone.* Washington, DC; Peters, M. 2003. *The Character of the In-Drift Environment.* Presentation at the Nuclear Waste Technical Review Board Spring Meeting, May 13-14, 2003. Washington, DC; Farmer, J. 2002. *Materials Performance.* Presentation at the Nuclear Waste Technical Review Board Spring Meeting, May 13-14, 2003. Washington, DC.

The DOE agrees that documentation of the evolution of the chemical environment on waste packages surfaces should contain a defensible technical basis that clearly states the assumptions and conclusions supporting the definition of the environment. The DOE is preparing or updating several Analysis and Modeling Reports that will collectively address our understanding of the evolution of the in-drift environment and the effect of that environment on waste package and drip shield surfaces. The long-term performance of a repository as analyzed using our current approach depends on the longevity of the waste package (especially since, in our view, conservative assumptions about the natural system diminish the relative projected effectiveness of the natural barriers). While the material selected for the outer barrier of the waste package is a very corrosion resistant alloy, environments can be created in the laboratory where this material undergoes unacceptable rates of corrosion. However, in our May presentations to the Board, we provided the Project's basis for concluding that these environments will not exist in the repository itself.

The DOE looks forward to the Board's reaction to our May presentations, but more importantly to the Board's insights and recommendations. We believe that more such integrated presentations, in which we can provide a more integrated picture of the fundamental basis for the efficacy of our design, should be planned for future Board meetings.

We asked at the meeting whether a repository with lower peak temperatures of waste package surfaces would reduce the uncertainty, likelihood, or severity of corrosive solutions. However, the question was not answered directly. The Board believes that the Project should answer this question, and, if the answer is "Yes," a second question, "How much?" also should be answered. The technical basis for both answers should be documented carefully and completely in an AMR.

Response:

The DOE agrees that maintaining below-boiling rock would reduce the uncertainties related to coupled processes.

However, as we discussed in our presentations[5] during the recent May Board meeting, we believe that a higher-temperature operating mode will lead to the drifts being drier for much longer, limiting aqueous phase corrosion due to seepage. We look forward to further interactions with the Board as we explain our data and models on this aspect in more detail, and obtain more in-depth Board review and comment on them.

The DOE has clearly indicated its intention to proceed to License Application with a design that retains the flexibility to be operated in a cooler mode should that be deemed necessary. Testing and analysis are ongoing to improve the technical basis for selecting postclosure thermal conditions. This experimental program and associated analyses will continue. As additional data and analyses are completed, the DOE will re-evaluate the technical basis for the choice of postclosure thermal conditions.

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[5] Bodvarsson, G. 2003 (op. cit.); Peters, M. 2003. (op. cit.); Farmer, J. 2003 (op. cit.)

Materials studies

The Board was encouraged by the information presented on studies of corrosion in the presence of deliquescence, seepage, and $CaCl_2$ brines, but we note that many more studies, especially at elevated temperatures, will be needed to adequately explore potential corrosion mechanisms and corrosion rates in a high-temperature repository.

Response:

The DOE agrees that additional studies are needed to adequately explore potential corrosion mechanisms in relevant repository environments more fully, particularly at the higher temperatures that will exist for a certain period of time in the repository's future evolution. As we discussed during our presentations[6] to the Board in the recent May meeting, the DOE is conducting tests in highly corrosive environments such as concentrated bulk calcium chloride environments (8 to 9 molar) with and without nitrate at temperatures above 120°C to characterize high-temperature corrosion processes. Initial results show that there is little margin between Alloy 22 corrosion potential and the critical potential for the initiation of localized corrosion. However, as noted during the January Board meeting[7], and again during the May meeting[8], calcium chloride brines are unstable in open systems and are unrealistic in a repository at Yucca Mountain. The ongoing materials testing program will continue to provide additional data to strengthen the technical basis for our understanding of corrosion mechanisms in relevant repository environments.

The Board concurs with the observation of the Waste Package Materials Performance Peer Review Panel that the Project staff needs a senior-level, visionary leader with a strong background in materials science and engineering and with very good management credentials. Such a person could develop a systematic approach for identifying needed materials studies, ensure continuity of the effort, and enhance communication with the technical community.

Response:

The observations of both the Board and the Panel on the value of a senior-level, visionary leader for the materials program are appreciated, and we are taking them seriously.

Prototype manufacturing

The Board is pleased that the DOE plans to procure waste package prototypes and develop welding processes. Programs in other countries that have undertaken prototyping activities have learned a great deal. In fact, some programs have encountered surprises that have taken considerable time to resolve. Manufacturing waste packages to the specifications required for

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[6] Farmer, J. 2003. (op cit.)

[7] Farmer, J. C. 2003. *Chemical Environment Evolution on Alloy 22.* Presentation at the Nuclear Waste Technical Review Board Winter Meeting, January 28, 2003. Las Vegas, Nevada.

[8] Peters, M. 2003. (op. cit.); Farmer, J. 2003. (op. cit.).

a repository may require a significant development effort and corresponding lead-time before repository operations can begin. Information presented at the Board meeting did not contain detailed justification for the number of prototypes planned, but the Board concurs with the timing of the initial development effort. The Board strongly urges the DOE to begin prototype development as soon as possible.

As experience is gained, useful modifications of the waste package design may be identified. For example, the DOE may find that dual Alloy-22 lids may not be justified in light of the manufacturing complexity associated with a dual-lid design. The current plan not to stress-relieve or otherwise mitigate tensile stresses of the inner Alloy-22 closure weld also raises questions about the value of the dual-lid concept. Finally, because the trunnion-collar sleeves appear complex and their attachments to the waste package appear prone to crevice corrosion, there may be a need to reconsider these parts of the design during prototype manufacturing.

Response:

The DOE recognizes the importance of waste package prototypes and has included prototypes as a fundamental part of the design, procurement, and fabrication strategy of the project. The DOE considers the manufacture of prototypes to be an integral part of the design process and recognizes the valuable information and knowledge that will come from a waste package prototype program. Accordingly, the DOE has planned and implemented a waste package prototype design, development, and fabrication program that started this year.

At this stage of the project, the DOE has planned for a total of fifteen waste package prototypes. These prototypes will be used in various ways:

- Several prototypes will be used to verify the closure processes and systems. The lids will be welded on the prototypes to verify the welding process, nondestructive examination processes, stress mitigation process, inerting process, leak detection process, robotic systems, and control systems, and to develop processes to repair closures that do not meet all requirements, as well as the integration of all these processes and systems.

- Several prototypes will be used for potential future destructive and non-destructive testing. Depending on the information required and requested, it is anticipated that these tests could include ring core tests, American Society of Testing Materials proof tests, drop tests, metallography, and others.

- Several prototypes will be used in the proposed training facility to demonstrate waste package handling processes.

- Prototypes will be necessary in the Operational Readiness Review process.

- Prototypes will be used in the training facility to train operators for Operational Readiness Review, start-up, and actual operations.

The manufacture of fifteen waste package prototypes will allow significant flexibility. Numerous combinations of the ten waste package configurations could be manufactured depending on the project needs. These fifteen prototypes will be manufactured over a 4 to 5 year

period starting in 2004, so determinations can be made in the future as to which configurations need to be manufactured. Furthermore, if a greater number of prototypes were necessary for any of the previously mentioned reasons (closure, training, etc.), it would be possible to manufacture several ¼ or ½ scale mockups, or even just the tops, instead of a single full-sized prototype for approximately the same cost.

The DOE agrees with the Board that, as design progresses and post-closure performance predictions evolve, it may be determined that the inner Alloy-22 lid will not be necessary. Because that determination has not yet been made, however, the first waste package prototype will include the inner Alloy-22 lid.

The DOE also agrees with the Board that the trunnion-collar sleeves may need to be reconsidered for various reasons. Fabrication of the first waste package prototype will provide valuable information that will allow decisions to be made regarding the trunnion-collar sleeves and, in fact, the trunnion-collar itself.

Repository System and Integration

Barrier performance - The Board is pleased that the DOE continues exploring ways to determine and display the contributions of individual barriers to performance of the overall repository system. The Board believes that such analyses can provide important insights into the respective roles of the different barriers. Furthermore, there appear to be opportunities for improving both the analytical approach for analyzing the performance of individual barriers and the clarity of the presentation of study results. The Board urges the DOE to continue this effort.

Response:

The DOE agrees that analysis of the contribution of the natural and engineered barriers can provide important insights into repository performance and will continue to evaluate and improve the analytical approaches for analyzing the performance of individual barriers. As noted in our January letter to the Board[9], the barrier capability analyses may include evaluations of intermediate performance measures from the Total System Performance Assessment (TSPA) and pinch point analyses that report radionuclide mass flux or concentrations at selected interfaces between model components. These approaches to evaluating barrier capability are described in section 8.3 of the TSPA-LA Methods and Approach document[10]. These analyses will focus on the capabilities of these barriers to limit movement of water or radionuclides.

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[9] Chu, Margaret, 2003. Letter to Michael L. Corradini responding to the views expressed by the Board on information presented in the September 2002 NWTRB meeting, with enclosure. January 24, 2003.

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

On-going scientific studies – As the Yucca Mountain project focuses on licensing activities, the temptation may be to divert resources from scientific studies to the licensing effort. The Board encourages the DOE to institute mechanisms that will ensure adequate funding and management commitments to on-going scientific studies.

Response:

The DOE agrees that results of scientific studies will be valuable in increasing understanding of the potential behavior of the repository. To this end, DOE is planning additional scientific studies that will continue through the various stages of repository development, licensing, and operation as the project moves forward. This includes the Performance Confirmation program, which we expect will be the subject of a DOE presentation to the Board at a future meeting. The DOE has also initiated a Science and Technology Program with two objectives: 1) to improve existing and develop new technologies to achieve efficiencies, in terms of safety and savings, in the waste management system; and 2) to increase understanding of repository performance. An update on the Science and Technology program was presented at the May 2003 Board meeting. We look forward to continuing Board review as this new Program develops.

Waste Management System

With the approval of the site recommendation, the DOE's plans for operating the waste management system, including waste acceptance, transportation, and operations at a Yucca Mountain repository, have become extremely important. Since funding constraints in this area have caused plans to be deferred for several years, the Board is pleased to see that the DOE will resume work on the waste management system this year. The Board views this as a very important area and will hold additional meetings to review DOE plans in the coming months.

Response:

The DOE agrees that work on the waste management system is important and will be pleased to support future meetings with the Board to review DOE plans in this area.

The Board recommends that the transportation planning and development effort adopt a "systems" approach, addressing both strategic and operational considerations. The Board views the early involvement of external stakeholders as critical to developing a comprehensive plan for the waste management system and to building public confidence in those plans. Because proactive engagement of external stakeholders is a time-consuming process, the Board encourages the DOE to initiate this activity as soon as possible.

Response:

The DOE agrees with the Board's recommendation that transportation planning and development should use a systems approach for both strategic and operational concerns to ensure that the transportation system and its operation are safe, secure, and reliable. As we noted in the

February Panel meeting on the Waste Management System[11], the DOE is committed to an institutional process that includes working closely with states, tribes, and local governments affected by the transportation of Spent Nuclear Fuel and high-level waste to Yucca Mountain. The DOE will build on previous cooperative planning experience, such as our experience at the Waste Isolation Pilot Plant, in developing its transportation plan.

[11] Williams, J. 2003. *Developing a successful transportation program.* Presentation at the Nuclear Waste Technical Review Board Panel Meeting on the Waste Management System, February 25, 2003. Las Vegas, Nevada.