Department of Energy
Washington, DC 20585

October 10, 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 June 30, 2003, providing the Nuclear Waste Technical Review Board's (Board) initial reactions to information presented by the U.S. Department of Energy (Department) at the Board's May 2003 Summer Board 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 looks forward to the Board's detailed comments on the technical basis for our thermal analyses along with other aspects of the Department's licensing case.

Sincerely,

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

Enclosure:
Responses to Initial Comments from the Nuclear Waste Technical Review Board on U.S. Department of Energy presentations in the May 2003 Full Board Meeting

Responses to Initial Comments from the Nuclear Waste Technical Review Board (Board) on U.S. Department of Energy (DOE) presentations in the May 2003 Full Board Meeting

Safety Case:
The Board continues to believe that the concept of a "safety case", which is endorsed strongly by virtually all the major nuclear waste management programs abroad, has considerable merit. In fact, during the meeting, Project scientists were able to verbalize why they believe that a Yucca Mountain repository would isolate and contain waste effectively. An updated written narrative description similar to those oral comments would make the Project's approach to ensuring safety more transparent and understandable.

Response:
The DOE agrees with the Board as to the importance of transparent communications. We are currently developing a series of technical basis reports to clearly document the Project's approach to ensuring safety of the repository system. These reports describe the various barriers of the repository system and the technical basis for performance of each barrier. In the May 2003 Board meeting, DOE presented an integrated basis for performance in the unsaturated zone above the drifts, in the in-drift environment, and in material performance. In the September 2003 meeting, we continued with this approach, addressing the detailed technical basis for flow and transport in the unsaturated zone and the saturated zone.

The Project delivered three major presentations related to in-drift thermohydrology, in-drift thermohydrochemistry, and Alloy-22 corrosion. ...The Board's initial reaction is that potentially significant questions remain about the technical basis for the Project's thermal analyses. These questions include concerns about the initiation of localized corrosion and the technical basis underlying Project claims about capillary and vaporization barriers. The Board is in the process of carefully evaluating the DOE's presentations from the May Board meeting and will be preparing more detailed comments for the DOE on these subjects.

Response:
The DOE looks forward to the Board's more detailed comments on the character of the unsaturated zone, the character of the in-drift environment, and materials performance.

As the DOE presented in the May and September Board Meetings, our technical basis continues to be based on: a) no significant corrosion above the boiling point of water because of a lack of seepage and the presence of primarily benign deliquescent brines; b) no significant corrosion at and near the boiling point of water because of the presence of primarily benign seepage and deliquescent brines and the presence of the drip shield; c) no significant corrosion below the boiling point of water because of the presence of primarily benign seepage brines and the presence of the drip shield.

The DOE has clearly indicated its intention to proceed to License Application with a design that would operate at a higher-temperature, but that retains the flexibility to be operated in a cooler mode should that be deemed necessary. Ongoing testing and analyses continue to improve the technical basis for the models used in the performance assessments over the range of possible postclosure thermal conditions. This testing and analytical program includes corrosion testing, prototype testing, near-field environment characterization using such tests as the Drift Scale Test, and unsaturated zone flow and seepage investigations. Finally, the DOE continues to develop the Total System Performance Assessment for the License Application where the above models are being integrated. This model will be used to conduct additional sensitivity analyses related to all barriers important to waste isolation, including the near-field environment and corrosion processes to better understand and communicate the technical basis for postclosure thermal conditions and impacts to total system performance. As additional testing and analyses are completed, the DOE will re-evaluate the technical bases and refine the operational parameters for the repository as needed. The DOE looks forward to continuing the discussion of the ongoing work and long-term strategy with the Board.

Science and Technology (S&T) Program

The Board is pleased that the Project is committed to sponsoring long-term research on "outside the box" scientific and technical issues. It is not yet clear, however, how data and analyses from the Science and Technology Program will be integrated into the license application process or the performance confirmation effort mandated by the U.S. Nuclear Regulatory Commission.

Response:

The Science and Technology Program is by design distinct from the mainline Office of Civilian Radioactive Waste Management (OCRWM) activity of developing the License Application. However, as the S&T Program completes various projects over the long-term, the results could impact either our

understanding of the way the repository will perform, or our repository design. In either case, the new information, including any data, models, analysis tools, new technologies, or different design approaches, will be used on a case-by-case basis either to amend the License Application or to support its technical basis. If anything adverse is discovered, it will be made available publicly as soon as feasible. However, the S&T Program does not have as an objective to support the initial License Application.

The relationship of the S&T Program to OCRWM's Performance Confirmation (PC) Program is to provide long-term technical support. Specifically, S&T will likely support some projects that could, if successful, provide better methods that the PC Program could use in carrying out its mandate. These might include developing improved measurement methods or improved instrumentation, or proving out novel proposed approaches for ascertaining whether a given aspect of repository performance is or is not performing according to expectations. If a new method or tool is successfully developed, OCRWM expects it to be integrated into an updated PC Program appropriately.

Igneous Consequences Peer Review Report:
The Board recommends that the DOE give the most emphasis to three areas.

The first area is the use of upgraded modeling techniques that take into account conditions such as compressible inviscid flow that may be present at repository depth. Past models based on incompressible flow may not give a true picture of dike behavior and magma-drift interaction. Such modeling also would help evaluate the likelihood of the so-called "dog-leg" scenario as proposed by Woods and others. . . . The Board concurs with the Panel that the likelihood of the generation of strong shock waves, as proposed by Woods and others, is negligible.

Response:
Current modeling of dike propagation uses a 2-dimensional hydrofracture code that includes free surface effects but is limited to an incompressible fluid model. Limited 2-dimensional modeling has also been done with a different code suggesting that the effects of order-of-magnitude changes in magma compressibility have a negligible effect on dike crack propagation. The DOE is considering development of a new hydrofracture code to include compressible fluids using the approach defined by the Igneous Consequence Peer Review Panel (Appendix 3.3 of the final report of the Peer Review).

The DOE intends to continue the 3-dimensional modeling completed thus far to investigate the effect of finite strike-length of the crack tip acceleration as the tip approaches the free surface. This latter activity addresses a potential non-

conservatism relevant to the "dog leg" scenario due to increased confinement as the crack tip reaches the free surface.

The current modeling presents magma flow as an incompressible viscous fluid and is expected to provide a reasonable basis for description of effusive flow from a dike into a drift. The DOE is considering 2- and 3-dimensional models that will permit better simulation of effusive flow and that will permit simulation of both pyroclastic flow and transitional flow between effusive and pyroclastic. These models will include multiphase flow with exchange of momentum and energy between phases. Inclusion of energy exchange will permit calculation of magma cooling rates in the dike, in a drift, and in a potential "dog-leg" crack growing out of a drift. Exchange of momentum is necessary for accurate portrayal of the multiphase flow.

The DOE is considering the feasibility of combining the 2- and 3-dimensional multiphase code for modeling simulation of transitional and/or pyroclastic flow in a dike to the new compressible hydrofracture code in order to develop a better understanding of the effect of such flow on dike propagation.

The second area is the need to study aeromagnetic anomalies in the vicinity of Yucca Mountain that could signify buried volcanoes. Such studies may involve additional aeromagnetic surveys (at appropriate altitudes); drilling; and dating, which could help determine the existence, age, and volume of the possible volcanoes.

Response:
The DOE has developed plans to initiate activities to evaluate potential buried volcanic centers in the vicinity of Yucca Mountain, including Crater Flat, Jackass Flat, and a section of the Amargosa Desert south of Crater Flat and Yucca Mountain. The investigations will consist of flying low altitude, combined aeromagnetic and electromagnetic surveys along a very closely spaced survey grid. These will be used to produce high-resolution aeromagnetic maps that will more accurately identify and define any potential buried volcanic centers including those anomalies identified from the 1999 U.S. Geological Survey (USGS) aeromagnetic data. A two-phased drilling program will initially drill up to six anomalies identified from the 1999 USGS aeromagnetic data. During the second phase, we will drill any new high-probability anomalies identified from the new aeromagnetic survey to confirm the presence or absence of buried volcanic centers. Chemical analyses and age dating will be performed on any basalts encountered from drilling. Additionally, limited age dating and chemical analyses will be performed on samples collected from the known volcanic centers in Crater Flat to better constrain eruptive sequences.

The field and laboratory program will begin in early fiscal year (FY) 2004 and continue through FY 2005. Information will be made available as the activities proceed, and a final report will be available in early to mid 2006. Information from this field and laboratory program will be used in an update of the Probabilistic Volcanic Hazard Assessment.

The third area is the need to address subjects that were not within the range of the Panel's expertise, i.e., waste package-magma interaction and waste entrainment in both the volcanic eruption scenario and the groundwater release scenario. The Panel confined itself to evaluating magma-drift interaction in the volcanic eruption scenario. These subjects are of great importance in any consequence analysis. The DOE should address them using the advice of outside reviewers. The DOE also should consider experimental studies for analyzing and verifying key phenomena and parameters (e.g., chemical and mechanical effects of magma on waste packages).

Response:
DOE recognizes the need to address subjects that were not within the range of the Panel's expertise. While DOE has no plans for conducting another peer review, we have developed a report, *Igneous Intrusion Impacts on Waste Packages and Waste Forms* (MDL-EBS-GS-000002). The purpose of this model is to assess the potential impacts of igneous intrusion on waste packages and waste forms, including deleterious dynamic, thermal and chemical impacts. The results (expected dynamic conditions) are corroborated by relevant experimental and industrial analogs. The models for waste package and waste form response during igneous intrusion consider the following: Zone 1, which includes the emplacement drift intruded by the basalt dike and Zone 2, which includes the emplacement drifts adjacent to Zone 1. This report combines the following assessments:

- Impacts of magma intrusion on the performance of engineered barrier system (drip shields, cladding and waste packages) in emplacement drifts in Zone 1, and the fate of waste forms,
- Impacts of intrusion-related thermal conduction/convection and emanating magma gases on the drip shields, cladding and waste packages in the Zone 2-emplacement drifts, adjacent to the intruded drift, and
- Impacts of intrusion on in-drift thermal and geochemical environments, including seepage hydrochemistry, which may affect the release, and fate and transport of radionuclides.

The results of this model study will provide inputs to the *Igneous Intrusion Groundwater Transport* and to the *Waste Form Degradation and Mobilization Sub-models* of the Total System Performance Assessment model.

Based on the numerical simulations of non-steady state heat conduction with radial flow and simulations of flow of volatile gas from cooling magma, the report concludes that thermal effects and effects of corrosive gases on waste packages in Zone 2-emplacement drifts will be negligible. The maximum expected temperature rise in the Zone 2-emplacement drifts is less than 10° C. The low-thermal conductivity and the 80-meter distance separating drifts limit the thermal effects. Constraints on the effects of corrosive gases include (1) the limited amount of initial gases that could exsolve from the cooling intruded magma and that could reach waste packages in Zone 2 emplacement drifts, and (2) the dominance of the gas phase by water.

Eventual release of radionuclides potentially trapped in the magma would be minimal because of several factors, including: (a) low dissolution rate of basalt by incoming seepage water, (b) the development of stable waste-mineral phases in the basalt, and (c) the fact that waste form solubility, and especially fissile uranium solubility, is controlled by solution pH. Solution pH for seepage water equilibrated with basalt is in a range that causes precipitation of solubilized radionuclides and sorption of waste mineral phases in the basalt. Based on the results of the preceeding analyses, DOE will consider experimental studies (e.g., chemical and mechanical studies) to the extent that they are required to support our license application case.

In all of these investigations, it is very important that DOE maintain an integrated team of field experts, modelers, engineers, and performance assessment analysts. If, after considering the consequences and the risks posed to the public, the DOE decides to modify the repository design to mitigate the effects of igneous activity, such modifications would need to be evaluated in terms of their overall impact upon repository operations and performance.

Response:
The DOE agrees that it is essential to maintain an integrated team to complete these investigations as well as any future analyses involving volcanism and engineered barrier performance. The DOE is currently evaluating the potential effects (beneficial and adverse) of using durable barriers to limit flow of magma from potential future dikes that could intersect the repository as an integrated effort that includes experts in disruptive events and waste package analyses. This and any other proposed changes to repository design to mitigate the potential effects of igneous activity will be processed through our design control procedures to evaluate the overall impact on repository operations and performance.

Peña Blanca

. . . Peña Blanca offers the opportunity to test a number of the proposed models and assumptions underlying the DOE's analyses of Yucca Mountain and to examine alternatives to these models. They include, but are not limited to, models and assumptions related to waste form dissolution (the source term), unsaturated zone flow and transport, and the active fracture model. . . . The additional information that comes from studying this site could show that the repository system would perform better or not as well as current performance estimates now project. However, either way, these tests could increase understanding of the processes and their associated uncertainties. For this reason, the Board strongly recommends continued support for studies at this unique site.

Response:
The DOE agrees that the ongoing work at Peña Blanca provides an opportunity to examine alternative models and to test proposed models and assumptions. A scientific plan, supported by the S&T Program, is under development for expanded studies at this site in the areas of hydrology, transport, and geochemistry. This plan will be considered for funding in FY 2004.