UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
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Dr. Margaret S. Y. Chu
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Chu:

On February 24, 2003, the Nuclear Waste Technical Review Board's (Board) Panel on the Natural System and Panel on the Engineered System held a joint meeting in Las Vegas devoted to seismic issues. As indicated in the March 10, 2003, letter sent to you by William Barnard, it was a very informative and successful meeting. This was due in large part to the Department of Energy's (DOE) efforts and its willingness to discuss difficult topics where much of the information is preliminary and final positions have not yet been established. Reports by Board consultants who attended the meeting can be found on the Board's web site.

The DOE and its contractors, the U.S. Geological Survey, the U.S. Bureau of Reclamation, the University of Nevada at Reno (UNR), and others set a high standard in the basic geological and seismological studies on which seismic hazard at Yucca Mountain was evaluated. This information was incorporated in a state-of-the-art probabilistic seismic hazard analysis (PSHA) completed in 1998. The Board's assessment of the application of the PSHA to preclosure (approximately the first 100 years) and postclosure (the first 10,000 years) is based on the results that were available at the time of our February meeting. A basic concern of the Board is that although the PSHA is, in general, sound, extending it to very low probabilities results in ground-motion estimates about which there are serious technical questions. These relate to the lack of physical realism and the implications of these unrealistic estimates for performance assessment, design, and scientific confidence. Following is the Board's evaluation of the material presented, its strengths and weaknesses, and specific recommendations to the DOE on seismic issues.

Preclosure Ground Motions

With respect to preclosure, the ground motions proposed for design at annual probabilities of exceedance (APE) of 10^{-3} to 10^{-4} appear reasonable. However, as Bechtel SAIC (BSC) consultant Robert Kennedy stated, an evaluation to see if the surface facilities meet performance goals for critical systems, structures, and components could require using ground motions whose APE is as low as 10^{-6}. If physically unrealistic, as may be the case (as discussed below), such motions could pose an undue burden on the design and operation of these facilities.

Postclosure Ground Motions

In the Board's view, the very-low-probability (APEs of 10^{-6} to 10^{-8}) ground motions proposed for use in postclosure performance assessment are generally unrealistic, physically unrealizable, or outside the limits of existing worldwide seismic records or experience, particularly when Yucca Mountain source and site conditions are taken into account. These ground motions can require unrealistic source characteristics (e.g., stress drops) and unrealistic strains, which may exceed the ability of the rock to sustain without fracturing. For example, some of the real earthquake ground-motion recordings used in the consequence analysis for performance assessment are scaled up (increased) by factors higher than 100 to reach the "target" level of ground motions (e.g., 535 cm/sec peak ground velocity at an APE of 10^{-7}), which themselves are based on extending the results from the PSHA and modifying them to take into account local site conditions. In some cases, this method of scaling yielded peak ground accelerations and velocities (e.g., 20 g peak ground acceleration and 1790 cm/sec peak ground velocity) well above already unrealistic target levels. Many DOE and BSC presenters at the meeting shared many of these same views. However, as discussed later in this letter, differences of opinion may exist between the Board and the DOE on how to proceed, given this lack of physical realism.

The very-low-probability ground motions need to be bounded on the basis of sound physical principles. The DOE indicated that it is carrying out such studies (e.g., limitations posed by source conditions and local site conditions). The studies will be challenging. Aside from an ongoing study in Switzerland, we are not aware of other recent systematic attempts to place physical bounds on earthquake ground motion. Despite these difficulties, the Board strongly recommends that the DOE complete these studies, subject them to external peer review, and implement them accordingly to limit the proposed very-low-probability ground motions.

The DOE also should evaluate and consider the work being carried out by Dr. James Brune and his colleagues at UNR as an alternative line of evidence for limiting ground motions. The evaluation of precarious rocks and other formations at Yucca Mountain suggests that during the last 10,000,000 years, ground motions that have occurred at Yucca Mountain may be substantially less than those estimated by the PSHA. Dr. Brune attributes this to the incorrect handling of uncertainty in the PSHA and other seismic hazard analyses.

The Board notes two additional areas where lack of data may affect the magnitude of the estimated ground motions: insufficient geotechnical data on the Topopah Springs Lower Lithophysal unit (Tptpll), which constitutes some 80 per cent of the emplacement rock in the proposed repository and shear modulus data at strains larger than 0.1 per cent, the range of strains induced by the proposed very-low-probability ground motions.

Drift Degradation and Other Topics

The Yucca Mountain Project has made excellent progress in assessing underground opening stability and drift degradation due to both seismic and thermal processes. Models used to predict tunnel behavior need to be calibrated against the conditions expected in the repository (e.g., information obtained from the ESF and, in particular, the cross drift). Models used to predict tunnel performance under extreme dynamic loading should be compared to nuclear test damage data and rockburst damage observed in mines with comparable rock-mass conditions. Analyses also need to account for long-term behavior (e.g., static fatigue) using representative rock-mass properties to simulate raveling and spalling processes expected during preclosure and postclosure periods. Particular attention should be focused on rock properties and analytical models to understand brittle failure and to predict the outcome of the failure process for this heterogeneous rock mass with its spatial and temporal variability in properties.

Recent studies of brittle failure in heterogeneous rocks near excavations have shown that conventional linear or curved failure criteria may not be appropriate for the Tptpll unit. The Board recommends that models be adopted and developed that can properly simulate the strain-dependent tensile spalling mechanism clearly observed in the cross drift and that drift design be based on such failure criteria. If tunnel openings have the potential to collapse, raveling and failure processes will continue until rock mass bulking substantially fills the drift. During this process, dynamic forces and nonsymmetrical rock pressures will develop on the drip shield. The potential for drip shield deformation and corrosion under these conditions needs to be analyzed.

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 seismic activity, such modifications need to be evaluated in terms of their overall impact upon repository operations and performance.

Implications of Highly Conservative Assumptions

A number of highly conservative assumptions have been used in addressing seismic issues. The DOE may find conservatism attractive because it could provide a way to show regulatory compliance in the face of uncertainty. As stated above, DOE and BSC scientists agree that many of their estimates are highly conservative or physically unrealistic. The DOE maintains, however, that this is not necessarily a problem because the assumptions are consistently conservative and the repository system will still show regulatory compliance. It appears that the DOE intends to use the ground-motion bounding studies as evidence of conservatism rather than as a means of modifying the ground motion estimates themselves. Not all the assumptions in the Project's analysis of this complex, highly coupled system have been fully assessed, e.g., the effects of seismically and thermally induced drift degradation on seepage and local flow and transport, and consideration of seismically induced waste package failure modes not related to stress-corrosion cracking. These assumptions need to be evaluated. If they are important, the assumed level of conservatism could be affected.

The Board recommends that the DOE not take a physically unrealistic or highly conservative approach for several reasons: (a) High levels of conservativism can lead to a skewed understanding of repository behavior and the significance of different events; (b) High levels of conservatism can introduce consideration of events for which there is little or no understanding or engineering experience; (c) Compounding conservative assumptions does not always produce conservative results, e.g., the worst case for drift stability is not when the horizontal and vertical stresses are both very high; (d) High levels of conservatism may lead to unreasonably high costs and may have a serious effect on the eventual development of both surface and subsurface designs; (e) If conservatism stems from a lack of understanding, it tends to undermine confidence in the scientific basis of the process under consideration. Physically unrealistic results, inappropriately extrapolated from physically realistic databases and analyses, could cast unwarranted doubt on much of the truly excellent work carried out in this area; (f) Finally, if "unacceptable" consequences are discovered later, it may be more difficult to justify subsequent reductions of elevated ground-motion estimates previously assumed to be acceptable.

The Board thanks you and the DOE staff and contractors for the effort extended in making the meeting as successful as it was.

Sincerely,

Michael L. Corradini
Chairman