UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

June 2, 1999

Mr. Lake H. Barrett, Acting Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy, Headquarters
1000 Independence Avenue, S.W.
Washington, DC 20585

SUBJECT: U.S. NUCLEAR REGULATORY COMMISSION STAFF REVIEW OF THE U.S. DEPARTMENT OF ENERGY VIABILITY ASSESSMENT FOR A HIGH-LEVEL RADIOACTIVE WASTE REPOSITORY AT YUCCA MOUNTAIN, NEVADA

Dear Mr. Barrett:

In December 1998, the U.S. Department of Energy (DOE) completed its viability assessment (VA) for a potential high-level radioactive waste repository at Yucca Mountain, Nevada. Although the VA is a management tool to provide DOE with a basis for making an informed assessment of the feasibility of proceeding with site characterization and the process of potential licensing and construction of a repository at Yucca Mountain, the U.S. Nuclear Regulatory Commission (NRC) staff has reviewed the VA as part of its prelicensing consultation with DOE under the Nuclear Waste Policy Act of 1982 (NWPA). It is believed that the results of the review will facilitate DOE's development of a complete and high-quality license application (LA). NRC staff believes that DOE's analyses are adequate to make an informed decision whether to continue with site characterization of Yucca Mountain in anticipation of a potential site recommendation, and staff agrees with DOE's decision to continue site characterization.

Staff interactions with DOE over the past 18 months have facilitated the NRC staff review of the VA. These interactions focused on elements of DOE's ongoing work that formed the basis for the VA. The VA reflects substantial progress by DOE in focusing its program on the issues that need to be addressed prior to a licensing decision. It describes significant DOE progress in areas such as data collection, data synthesis, performance assessment modeling, and documentation of results. There is general agreement that DOE's planned work appears adequate in several technical areas including: mechanical disruption of waste packages; spatial and temporal distribution of flow; distribution of mass flux between fracture and matrix; and dilution of radionuclides in soil.

Staff comments on the VA are intended to facilitate DOE's efforts to focus its program and develop a high-quality LA. The staff reviewed the preliminary design concept, total system performance assessment (TSPA), and LA Plan. Supporting documents such as the TSPA-VA Technical Basis Document were also examined. In formulating our comments, the staff took into account supporting information, importance to performance or licensing, and DOE's plans for addressing these topics, as documented in the LA Plan. The comments developed by the staff are not new and have been the subject of earlier public meetings and NRC staff documents.

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The staff notes that in the TSPA-VA, DOE placed heavy reliance on engineered barriers (e.g., waste package performance, cladding credit, etc.) to achieve isolation. In addition, the discussion of "defense-in-depth" in the LA Plan considers additional engineered features (drip shields, backfill, ceramic coatings) to compensate for uncertainty and provide a margin of safety. In the Statement of Considerations for proposed 10 CFR Part 63, the Commission stated its expectation that natural and engineered barriers would each make a definite contribution to the isolation of waste in order to provide reasonable assurance that the overall safety objective would be met. In any future LA, DOE is expected to demonstrate that natural barriers and the engineered barrier system work in combination to enhance overall performance of the geologic repository. Additional attention needs to be given to how this demonstration will be made.

The staff comments in the enclosure cover the reference design, technical topics related to the data or models associated with several aspects of DOE's TSPA (i.e., performance of the waste package, seepage into the drifts, saturated zone flow, and analysis of the consequences of volcanism), and the LA plan. More detailed comments on the VA will be provided to DOE through updates to Issue Resolution Status Reports, interactions, and correspondence, as appropriate. The staff will continue to evaluate these topics, interact with DOE, and provide timely feedback. It is important for the prelicensing consultations to proceed in order for a possible LA to be of sufficient quality that the staff will be able to complete its review in the time frame required by the NWPA.

Enclosed, along with the staff evaluation, is a copy of a letter dated April 8, 1999, to Chairman Jackson/NRC, from B.J. Garrick/Advisory Committee on Nuclear Waste, on the DOE VA. This letter is being provided for your information only.

Sincerely,

Carl J. Paperiello, Director
Office of Nuclear Material Safety
and Safeguards

Enclosures: As stated
cc: See attached list (w/encl)

TICKET: EDO 199800034/NMSS 199800236(new ticket)

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Letter to L. Barrett from C. Paperiello dated: June 2, 1999

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U.S. Nuclear Regulatory Commission's Staff Evaluation of U.S. Department of Energy's Viability Assessment

The U.S. Nuclear Regulatory Commission (NRC) staff reviewed the U.S. Department of Energy's (DOE's) Viability Assessment (VA) for a potential high-level radioactive waste (HLW) repository sited at Yucca Mountain, Nevada (YM). This review was conducted as part of the staff's prelicensing activities and included the preliminary design, total system performance assessment (TSPA), and License Application (LA) Plan. Based on this review, the staff identified several challenges for DOE to assemble a complete and high-quality LA within the time frame envisioned in the LA Plan.

The review of the VA indicates that DOE has made significant progress in a number of areas such as: data collection, data synthesis, performance assessment (PA) modeling, and documentation. However, additional work will be needed in order for DOE to be able to prepare a complete and high-quality LA. The LA Plan provides a high-level description of where DOE believes progress is required and the priority that DOE is assigning to particular objectives.

The TSPA will be an important element in DOE's LA. The staff conducted concurrent reviews of the TSPA-VA and the LA Plan. Through these reviews, the staff identified a set of technical comments regarding the supporting data and models within the TSPA. These comments address key elements of DOE's PA, and -- based on the review of the LA Plan -- may represent challenges for DOE to develop a complete and acceptable LA. There are areas where the staff does not have major comments at this time. These areas include: mechanical disruption of waste packages (WPs); radionuclide release rates and solubility limits; spatial and temporal distribution of flow in the unsaturated zone (UZ); distribution of mass flux between fracture and matrix in the UZ; retardation in fractures in the UZ; retardation in water-production zones and alluvium; dilution of radionuclides in groundwater from well pumping; airborne transport of radionuclides; dilution of radionuclides in soil; and location and lifestyle of the critical group. The most significant staff comments are summarized below.

Repository Design

Comment:

The reference repository design presented in VA keeps open numerous options such that the overall concept remains fluid. Significant changes in the repository design may affect the timely availability of data and well developed supporting information to be used for repository PA that is necessary for developing a complete and defensible LA. Although appreciating the importance and need for flexibility in design, the lack of a more focused design may not permit DOE sufficient time to address all pertinent issues and prepare a complete LA within its current schedule.

Importance:

Many aspects related to the repository design, especially the thermal load and temperature alternatives; option for backfilling the emplacement drifts and its timing; ground support options and maintenance of underground facility; selection of emplacement stratum; and ventilation alternatives may be important to understanding repository performance. Design alternatives being considered by DOE could result in substantially different approaches than the current reference design. Design options being considered (U.S. Department of Energy, 1998) include different thermal loads, backfilling of the emplacement drifts, continuous pre-closure ventilation, timing of repository closure, type of ground support systems, near-field rock treatment, and repository horizon elevation. Additional enhancement features such as drip shields and Richard's barrier are also being studied. Adequate documentation of design development and traceability of design changes are very important to the completeness and defensibility of the DOE LA. It is important to establish that the data being gathered and the suite of analyses being performed are sufficient to cover all the design alternatives under consideration. It is equally important to develop analytical tools that can make quantitative comparisons of alternatives so that the preference of one over the rest could be established on a rational basis and in a transparent manner.

Status of Resolution:

The NRC has to date concentrated on the design control process being employed by the DOE to document design changes for the exploratory studies facility. However, the staff has yet to review the DOE process for the design of the repository. The staff has been observing many DOE meetings and workshops where design alternatives are being discussed and compared based mostly on engineering judgment or qualitative criteria. NRC recognizes the importance of allowing for certain design improvements and data gathering during the pre-closure period that could improve repository safety and reduce uncertainties in the predicted performance of the repository. However, it must also be recognized that the LA and supporting information must be well developed to allow NRC to make a finding of reasonable assurance of safety. DOE plans to complete the selection of the LA design in May 1999 and the final design in November 2000 (U.S. Department of Energy, 1998).

Additional Background:

None.

Basis:

DOE presented its first conceptual design for the proposed repository at Yucca Mountain in its Environmental Assessment (in 1984) and then again in its Site Characterization Plan (in 1987). Over the years, the initial design concepts have undergone several iterations with many minor and some major changes to reflect newly acquired information as well as to respond to comments raised by oversight and regulatory bodies. At present, DOE is considering several design alternatives and design options that could significantly affect the repository performance; generate new demands for data and model development; and raise associated uncertainties. For example, depending on the thermal load option selected for final consideration, the technical issues that need to be addressed by DOE and evaluated by NRC could be different. Backfilling the emplacement drifts can change the WP degradation and disruption scenarios to a large extent. Considering the current DOE schedules for addressing the issue of design alternatives, there is a risk that data, models, and analysis results will not be sufficient for a complete and high-quality LA. This might result in NRC requesting additional information at the time of LA review and thus prolong the review period.

References:

McKenzie, III, D.G. 1998. Alternative repository designs. Presented to the *Drift Stability Workshop*. North Las Vegas, NV: U.S. Department of Energy, Office of Civilian Radioactive Waste Management.

U.S. Department of Energy. 1998. *Viability Assessment of a Repository at Yucca Mountain, Volume 4: License Application Plan and Costs.* North Las Vegas, NV: U.S. Department of Energy, Office of Civilian Radioactive Waste Management.

Waste Package Corrosion

Comment:

It is unclear whether DOE will be able to acquire sufficient data, applicable to conditions at the proposed repository, in time to demonstrate compliance with NRC requirements. This comment is applicable to the VA design of the waste package (WP) and other aspects of the Engineered Barrier System (EBS).

Importance:

Container life is an important factor in limiting the dose to the critical group and in providing defense-in-depth for the repository system. For example, DOE sensitivity analyses in the TSPA-VA show that by decreasing the corrosion rate of the inner overpack material by a factor of 60, the annual dose at 10,000 years decreases from 2 mrem to less than 10^{-3} mrem. The corrosion rate of the inner overpack material is one of the many WP parameters affecting the prediction of WP lifetime in the TSPA-VA. Several WP parameters have been defined based on expert elicitation rather than long-term test data, especially those for the corrosion-resistant material (CRM). Even if the design were fixed today, only very limited data will be available to substantiate the adequacy of the waste package design for LA.

The continued consideration of alternate designs (in all areas including the EBS and repository) further complicates this subject. It will be even more difficult to gather sufficient and applicable data in the far shorter time-frame between the next design decision (May 1999) and LA. In addition to the time required for testing new materials and concepts, and developing the appropriate modeling when different failure modes may be involved, fabrication issues -- including the problem of closure welding -- will require time for development and evaluation prior to completing the LA.

Status of Resolution:

DOE has testing programs in place for many WP parameters, particularly those relating to the CRM. NRC and DOE staff have had ongoing discussions and interactions regarding these programs and the validity of the values selected by expert elicitation. DOE has described an ambitious testing program in the LA Plan.

DOE has continued the evaluation of alternative designs for WPs, and a decision is expected in May 1999. One alternative to the current design includes the use of Alloy-22 as an outer barrier and titanium Grade 7 or 16 as an inner barrier. Other options include a three-wall design in which nuclear grade stainless steel (i.e., 316 NG) will be used to provide structural integrity. The reverse design of that proposed in VA, consisting of Alloy-22 as an outer barrier and the steel as an inner barrier providing structural integrity, is also being considered. The issues related to the performance of the alternate designs, including data collection and fabrication issues, are currently being reviewed by NRC and will be addressed in the next revision of the Issue Resolution Status Report (IRSR) on Container Life and Source Term (CLST).

Additional Background:

There are a number of ancillary subjects associated with data collection. In addition to data sufficiency and applicability to the repository environment, there are issues associated with the qualification of data. Another issue is the appropriate role of data collected during the performance confirmation period, relative to data available at the time of Construction Authorization. Although it is appropriate for DOE and NRC to take into consideration more long-term data at later times (i.e., license to receive and possess, repository closure), sufficient data must be available to support the LA. Finally, the bulk of the long-term data used in the TSPA is gathered from expert elicitations and literature reviews, rather than measured under the environmental conditions at Yucca Mountain; including water chemistry, gamma radiation, and the variation of temperature with time.

Basis:

Sensitivity analyses indicate that the lifetime of the WPs has a significant effect on dose to the receptor group. Consequently, corrosion performance of the WPs is a critical factor that may be affected by detrimental interactions between different materials and/or prompted by a specific fabrication process. Additional testing may be required to provide support for any new design. In particular, DOE has recognized in VA that "the primary weakness of the [waste package] model is the overall reliance on expert elicitation rather than on long-term test data of corrosion rates for corrosion-resistant material."

References:

U.S. Nuclear Regulatory Commission, *Issue Resolution Status Report (Key Technical Issue: Container Life and Source Term, Revision 0)*, Washington DC: U.S. Nuclear Regulatory Commission, 1998a.

Quantity and Chemistry of Water Contacting Waste Packages and Waste Forms

Comment:

The data and models used in the VA to calculate the quantity and chemistry of water dripping on WPs are inadequate to describe the process and extent of potential dripping under ambient and thermally-altered conditions. This is an issue because both DOE and NRC PA analyses indicate that the fraction of WPs contacted by water is the most important factor affecting dose for the groundwater pathway. Further, NRC staff considers that the current DOE testing and modeling plans are not sufficient to resolve the issue prior to LA. There are activities that DOE could complete prior to LA that would provide additional support for addressing this issue.

Importance:

The quantity and chemistry of water contacting the WP are the major factors in determining the lifetime of the WP. Radionuclide release rates from breached WPs are also dependent on the quantity and chemistry of water contacting the WPs and, subsequently, the waste forms. Degradation of WPs by corrosion and alteration of waste forms is accelerated in the presence of water and certain dissolved aqueous species. Differences in the amount of seepage into the emplacement drifts and onto WPs lead to calculated radionuclide releases that vary by several orders of magnitude.

Status of Resolution:

DOE recognizes that there are few data -- and the need for additional data -- regarding seepage into drifts, the effects of heat and excavation on flow at the drift scale dripping onto WPs, and the chemistry of water on WPs. In addition, DOE has recognized that its current PA models do not adequately capture the effects of coupled processes on the quantity and chemistry of water contacting WPs. DOE has assigned a high priority to both the data collection and modeling efforts, and is conducting a peer review on drift seepage to guide its pre-licensing scientific activities. The range of activities outlined in the LA Plan are unlikely to provide an adequate licensing basis for assessing the quantity and chemistry of water contacting WPs and waste forms. For instance, it was noted at the Drift Seepage Peer Review Meeting on January 11-13, 1999, that the niche studies that have been conducted and proposed to be completed prior to license application, do not provide an adequate basis to support the seepage abstraction (Hughson, 1999). However, two activities were suggested by members of the peer review panel (Hughson, 1999). It is likely that they could be completed prior to LA and would lead to a more defensible approach for addressing the quantity and chemistry of water contacting the WPs and waste forms. First, systematic air permeability measurements conducted in horizontal boreholes in the three repository host rock units could provide data on the scales of variability and heterogeneity in rock properties that are necessary to describe seepage. Second, additional model development efforts should focus on explaining the observed patterns of seepage in the niche experiments.

Additional Background:

The data and processes necessary to describe the quantity and chemistry of water contacting the WPs and waste forms through abstraction in a PA have been addressed in several IRSRs (U.S. Nuclear Regulatory Commission, 1998a, 1998b, 1998c, and 1998d). In addition, the importance of characterizing thermal perturbations to UZ flow fields during the heating phase and considering coupled thermal-hydrologic-chemical-mechanical processes in PAs was raised in letters to DOE (U.S. Nuclear Regulatory Commission, 1997, 1998e).

Basis:

An ongoing peer review of the DOE drift seepage approach has identified inadequacies in the data, experiments used to collect the data, the models used to describe the seepage process, and the methods used to abstract seepage into performance assessments (Hughson, 1999). Both laboratory scale heater tests and analog site heater tests have indicated the potential for liquid water to contact a heat source under heterogenous or transient boiling conditions. Both: (1) the potential for gravity-driven refluxing during the thermal period and other coupled processes; and (2) the importance of these processes for adequately describing WP performance has been presented to DOE (U.S. Nuclear Regulatory Commission, 1997, 1998c). Drift collapse may also significantly alter effective parameters describing moisture retention characteristics of the fracture continuum, and thus result in more seepage for a given percolation flux. On the very small scale of a drift wall, the presence of surface irregularities and conducting fractures that dead-end at the drift crown will result in less capillarity and thus less diversion of percolation flux around the drift (Hughson, 1999). Many alteration products of tuff and engineered materials are likely to affect the chemistry of water contacting WPs, which in turn can affect corrosion rates, waste form alteration rates, and radionuclide solubility and speciation (U.S. Nuclear Regulatory Commission, 1998d). Although an effort was made to address this subject, there are many limitations in the data used and the extent of phases considered. Additional data and analysis of seepage under both isothermal and thermal conditions will be required for a complete LA. The amount of data required for the LA, and the need to confirm expected performance of the evolving repository system, will depend on the importance of the quantity and chemistry of water contacting WPs and waste forms to the DOE safety case.

References:

Hughson, D., *Drift Seepage Peer Review,* Trip Report, Las Vegas, Nevada, January 11–13, 1999, Center for Nuclear Waste Regulatory Analyses, San Antonio, TX, 1999.

U.S. Nuclear Regulatory Commission, *Comments on the Department of Energy Thermohydrology Testing and Modeling Program,* letter dated January 23, 1997, from M.J. Bell, U.S. Nuclear Regulatory Commission, to S.J. Brocoum, U.S. Department of Energy, 1997.

U.S. Nuclear Regulatory Commission, *Issue Resolution Status Report (Key Technical Issue: Total System Performance Assessment and Integration, Revision 1)*, enclosure to letter dated December 8, 1998, from M.J. Bell, U.S. Nuclear Regulatory Commission, to S.J. Brocoum, U.S. Department of Energy, 1998a.

U.S. Nuclear Regulatory Commission, *Issue Resolution Status Report (Key Technical Issue: Unsaturated and Saturated Flow Under Isothermal Conditions, Revision 1),* enclosure to letter dated October 7, 1998, from M.J. Bell, U.S. Nuclear Regulatory Commission, to S.J. Brocoum, U.S. Department of Energy, 1998b.

U.S. Nuclear Regulatory Commission, *Issue Resolution Status Report (Key Technical Issue: Thermal Effects on Flow, Revision 1),* enclosure to letter dated October 1, 1998, from M.J. Bell, U.S. Nuclear Regulatory Commission, to S.J. Brocoum, U.S. Department of Energy, 1998c.

U.S. Nuclear Regulatory Commission, *Issue Resolution Status Report (Key Technical Issue: Evolution of the Near-Field Environment, Revision 1)*, enclosure to letter dated August 28, 1998, from N.K. Stablein, U.S. Nuclear Regulatory Commission, to S.J. Brocoum, U.S. Department of Energy, 1998d.

U.S. Nuclear Regulatory Commission, *U.S. Nuclear Regulatory Commission Comments on the U.S. Department of Energy Total System Performance Assessment,* letter dated July 6, 1998, from M.J. Bell, U.S. Nuclear Regulatory Commission, to S.J. Brocoum, U.S. Department of Energy, 1998e.

Saturated Zone Flow and Transport

Comment:

In NRC sensitivity studies, flow in the saturated zone has been shown to be an important component of the natural barrier. At this time, the saturated zone (SZ) has not been sufficiently characterized from the repository out to the proposed 20-km receptor location to adequately assess its contribution to performance. This is an issue because it creates uncertainty about the SZ flow and transport models and the SZ representation in the TSPA. Furthermore, it may render the LA incomplete because the SZ remains an integral part of the DOE repository safety strategy.

Importance:

The SZ is the primary pathway for radionuclide transport from the repository to the receptor location, and is an integral part of the DOE repository safety strategy. The SZ has been identified in the TSPA-VA as one of 19 "principal factors" affecting postclosure performance. In its 1998 report to Congress, the Nuclear Waste Technical Review Board (NWTRB) stated that it believes that the SZ "is an essential natural component of a defense-in-depth repository design for Yucca Mountain" (NWTRB, 1998, PP 45).

DOE indicates that radionuclide travel time in the SZ constitutes a significant fraction of the 10,000 year compliance period (DOE, 1998a: Vol 3, pp 6-16). In addition, sensitivity analyses performed by DOE (DOE, 1998a: Vol 3, pp 4-71-80; 5-40-43) indicate that all three SZ attributes examined in the analyses (SZ dilution, method of combining flow in the SZ flowtube model, and the alluvium fraction in the SZ flow path) have some measure of importance to repository performance, and that SZ dilution is an important parameter affecting the calculated dose for the 10,000-year simulation. Sensitivity analyses by NRC and Center for Nuclear Waste Regulatory Analyses (CNWRA) staff suggest that the SZ is a relatively important subsystem for overall repository performance (Jarzemba et al., 1998).

Status of Resolution:

DOE has low "current confidence" and a low "confidence goal" in the SZ flow and transport representation in the TSPA (DOE, 1998a: Volume 4, pp 2-20, 2-38). DOE plans to conduct additional SZ work activities to improve confidence in the SZ representation in the TSPA for the LA (DOE, 1998a: Vol 4, pp 2-47; pp 3-15, 3-16). In cooperation with DOE, Nye County will implement an "Early Warning Drilling Program," involving installation and testing of shallow and deep wells downgradient of the repository. These wells are expected to provide data about the hydraulic and transport properties of the aquifers along the flow path downgradient from the repository. The scope of the drilling program is limited, however, and may not adequately characterize the SZ, especially the alluvial aquifer. According to DOE (DOE, 1998a: Volume 4, pp 2-39, 3-13), the scope of the planned SZ work was constrained by the available time before the site recommendation (SR) decision and the LA submittal. Furthermore, DOE has assigned a relatively low priority to the planned SZ work (DOE, 1998a: Volume 4, pp 2-20, 2-39).

In addition, some of the planned work activities will extend beyond the cutoff dates for the planned refinement and update of the site-scale and regional SZ flow models. These include (DOE, 1998: Vol 4, pp 3-16): (1) downgradient alluvial hydraulic and tracer testing; (2) K_d determination of alluvium samples obtained from the Nye County wells; and (3) downgradient hydraulic and tracer testing of the volcanic rocks in the area between 5 and 20 km from the repository. DOE states that data obtained from the first two activities and early data from the third activity will be available for use in the TSPA for the LA, but it is not clear how this will be achieved.

It may be possible for DOE to implement, in a relatively short time prior to the LA, some additional field work independent of the Nye County drilling program, possibly including exploratory drilling and surface geophysical investigations to specifically delineate and characterize the alluvium along the flowpath downgradient from the repository. However, DOE currently has no plans to address this.

Additional Background:

The M&O (1998) and DOE (1998a) suggest that the SZ flow system in the YM vicinity has not been adequately characterized. There are very limited field data to characterize the SZ flow between about 5 km and 20 km downgradient from the repository (DOE, 1998a: Volume 4,pp2-38), and limited data to define the SZ transport along the SZ flow path from the repository to the receptor location (DOE, 1998a: Vol 3,pp6-36). In addition, conceptual uncertainties associated with SZ flow and transport have also been reported by the U.S. Geological Survey and others (Luckey et. al., 1996; Czarnecki et., el., 1997; D'Agnes, et., al., 1997; DOE: 1998b; Geomatrix Consultants, Inc.,1998; Gelhar, 1998; and NWTRB, 1998).

The uncertainties about SZ flow and transport at YM have been documented in two IRSRs (NRC, 1998a,b). The flow rate in water production zones has been identified by NRC staff as a key element of subsystem abstraction (KESA) in the TSPA models, and the acceptance criteria are in the Unsaturated and Saturated Flow Under Isothermal Conditions IRSR (NRC 1998a,b).

Basis:

The presence of alluvium along the SZ flow path is expected to significantly delay the arrival of radionuclides at the receptor location due to enhanced sorption and dilution; however, the location of the water table transition from tuffs to alluvium is not yet reasonably characterized. There is uncertainty as to where SZ flow enters the alluvium along the flowpath from the repository or even if flow occurs within the alluvium within 20 km (DOE, 1998a: Volume 3, pp 6-24). This is especially important considering the potentially higher sorption coefficients of some radionuclides which are key contributors to dose, such as neptunium in the alluvium (DOE, 1998a: Volume 3, pp 6-24 - 6-25).

The flow rate in water production zones is affected by the basin scale groundwater flow and may, therefore, be controlled by high permeability features or channelized flow pathways in the aquifer. The presence of preferential and/or fast pathways, due to geologic structural controls, could significantly reduce the transport time. In the YM vicinity, the faults locally control groundwater flow and may represent pathways for upward flow from the deeper carbonate

aquifer (Fridrick et al., 1994; Bredehoeft, 1997; Geomatrix Consultants, 1998). Such flow channeling along preferred pathways is common in fractured and faulted rock (Tsang and Neretnieks, 1998). Interpretation of aquifer borehole tests indicate that permeability at YM is anisotropic (Geldon, 1996). The anisotropic permeability due to structural features downgradient of YM may result in more southerly-directed flow paths than currently modeled by the DOE. The radionuclides in this southerly flow path could remain in the volcanic tuff aquifer all the way to the receptor location at 20 km, since there is no alluvium or a much reduced alluvium fraction in this direction (Frizzel and Shulters, 1990).

DOE has characterized the uncertainties in SZ flow and transport to the TSPA as "moderate", but states that the uncertainty could increase as the model more realistically accounts for processes that reduce radionuclide concentration (DOE, 1998a: Volume 4, pp 2-38). Furthermore, a "moderate" ranking of the SZ uncertainties appears inconsistent with the results of the sensitivity analyses performed by either DOE or NRC/CNWRA.

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Volcanic Disruption of the Waste Package

Comment:

DOE concludes in the TSPA-VA that there are no risks from volcanism during a 10,000 yr post closure period, based on models assuming waste package resilience and limited HLW entrainment during a volcanic eruption (CRWMS M&O, 1998). NRC staff review concludes (i) these analyses are based on assumptions of physical conditions that are not representative of Yucca Mountain basaltic volcanism, (ii) data are insufficient to evaluate waste package and HLW behavior under appropriate physical conditions, and (iii) model assumptions are incongruent with those used elsewhere in the TSPA-VA, for example, in enhanced source-term analyses.

Importance:

TSPA-VA analyses may underestimate the contribution to risk associated with future igneous activity at the proposed repository site. Current NRC calculations suggest that the probability-weighted risk from volcanic disruption of the proposed repository is low (on the order of 1 mrem), however this value has sizeable model and parameter uncertainty. DOE has not identified in the VA plans to conduct additional investigations necessary to support igneous activity risk assessment. Unavailability of acceptable consequence models to support igneous activity risk assessment is an issue, in that a process with a potential to be an important contributor to total system risk would not be supported adequately in the LA.

Status of Resolution:

While the VA License Application Plan (DOE, 1998b) indicates no planned activities to resolve these issues, recent informal staff interactions, including participation at DOE workshops, suggest that workplans are being developed which, if implemented, could resolve them. These plans are expected to be completed in late March. The staff will review these plans as they become available and discuss their implementation with DOE in future DOE/NRC Technical Exchanges and other interactions (DOE, 1998a, Section 6.5.3.8) to determine if the issues can be resolved at the staff level prior to licensing. In addition the staff is critically evaluating its modeling of volcanism to confirm that it does not include excessive conservatism. The staff will continue to work closely with DOE to resolve the issue of volcanism. The staff position will be well documented in future IRSRs.

Additional Background:

The issues associated with the DOE igneous activity program, including the relationship to TSPA modeling, have been raised in comments on DOE study plans 8.3.1.8.1.1 (Holonich, 1994a), 8.3.1.8.1.2 (Holonich, 1994b), 8.3.1.8.5.1 (Holonich, 1994c), numerous interactions with DOE at Technical Exchanges, Appendix 7 Meetings, meetings and workshops with the Advisory Committee on Nuclear Waste and the NWTRB, interactions associated with the DOE Probabilistic Volcanic Hazard Assessment, and most recently through detailed comments in the

Igneous Activity Issue Resolution Status Reports (NRC, 1997, 1998). Acceptance criteria contained in the IA IRSR (NRC, 1998) delineate an acceptable technical basis for evaluating risks associated with future igneous events.

Basis:

In the TSPA-VA, it is assumed that a waste package with >50 percent of the original corrosion resistant material thickness (i.e., >1 cm) will not fail when exposed to the extreme physical conditions of a volcanic eruption except through occasional end-cap failure. This assumption precludes any direct HLW entrainment or release from any volcanic event occurring within the first 100,000 yr post-closure (CRWMS M&O, 1998). This assumption is based on extrapolation of limited data from <430 °C to likely magmatic temperatures around 1100 °C. In contrast, similar data are used to conclude that an intact waste package will fail mechanically when exposed to magma intruded into repository drifts (i.e., enhanced source-term analysis), even when temperatures significantly below expected intrusion temperatures are used in the analysis (CRWMS M&O, 1998). The TSPA-VA analysis of waste-package resilience also does not address the dynamic force imposed on a waste package entrained into a volcanic conduit. As outlined in the IA IRSR (NRC, 1998), staff analyses of limited available data conclude waste-package breach is likely under volcanic eruption conditions. Models proposing waste-package resilience during igneous events are nonconservative and will need robust support through analyses and data that examine physical, chemical, and thermal conditions representative of likely future igneous activity in the YM region.

Another key assumption in the TSPA-VA that is not supported by available information is that magma particle sizes or particle velocities are insufficient to entrain HLW fragments (CRWMS M&O, 1998). Although the expansion of dissolved volatiles in ascending magma may be sufficient to form a two-phase flow regime at repository depths, the fragmented particles are still at temperatures around 1100 °C. Particles will be larger average size than observed at completely cooled and fragmented fall deposits, and will impact HLW fragments elastically. In addition, assumed HLW particle sizes do not account for the extreme physical conditions associated with igneous disruption. As outlined in the IA IRSR (NRC, 1998), staff concludes that HLW particle sizes will be reduced substantially when exposed to the physical, thermal, and chemical environment associated with YM igneous events. Models proposing a lack of entrainment in potential repository-penetrating igneous events will need support through analyses and data.

References:

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U.S. Department of Energy. 1998b. *Viability Assessment of a Repository at Yucca Mountain, Volume 4: License Application Plan and Costs.* DOE/RW-0508/V4. North Las Vegas, NV: U.S. Department of Energy, Yucca Mountain Site Characterization Office.

Quality Assurance

Comment:

Although NRC staff has reviewed and accepted the DOE Quality Assurance (QA) program, DOE has consistently had problems implementing the program. Deficiencies identified during DOE audits and surveillance of its suppliers raised the issue of whether the data/products produced by these suppliers will be acceptable and appropriately qualified for licensing. DOE audits have identified that some data in the Management and Operating Contractor's (M&O's) technical data base are not traceable to their origins and could not be ensured to be applicable, correct and technically adequate. The Technical Basis Document, which supports the TSPA-VA, indicates that a major portion of the data supporting VA is not qualified. DOE's LA Plan does not recognize the current situation with regard to implementation of its QA program and the activities needed to address it.

Importance:

To obtain authorization to construct a HLW repository, DOE must be able to demonstrate in its LA that data, analysis, and designs of barriers and systems important to safety or waste isolation meet QA requirements of Appendix B to CFR Part 50.

The QA program applies to all systems, structures, and components important to safety and waste isolation, including: design and characterization of barriers important to waste isolation; activities such as site characterization, facility and equipment construction; facility operation; performance confirmation; permanent closure; and decontamination and dismantling of surface facilities. Confidence in the adequacy of data, data analyses, construction activities, and other items and activities associated with the LA is obtained through a QA program.

Status of Resolution:

DOE recognizes the need to improve the implementation process to qualify data, models, and codes and has assigned a high priority to these activities based on questionable data in the M&O technical data base and its associated references. DOE has also issued Yucca Mountain Administration Procedure YAP-SIII.1Q, Revision 3, ICN0 to improve the process of qualifying unqualified data.

During the NRC/DOE QA meeting of December 9, 1998, DOE committed to the development of an overall data qualification strategy/plan by December 21, 1998. The plan should include: 1) identification of unqualified data sets approved for qualification; 2) methods of qualification and rationale; 3) technical disciplines required; 4) data evaluation criteria including size of sample to be tested, statistical method to be used, and identification of computer codes to be used; 5) criteria for changing data status from "non-qualified" to "qualified;" and 6) a schedule for completing the work. NRC staff is currently reviewing the "Data, Model and Code Qualification/Validation and Control Plan."

Meanwhile, an NRC QA Task Force was formed to conduct an independent and objective review of the DOE HLW QA program and its implementation. A Task Force review of the "DOE

Management Plan and Responses to Corrective Action Request (CAR) and Status of Implementation of Corrective Actions" document, dated January 25, 1999, is underway. The Task Force will also review, and formally comment on, the Root Cause Analysis/Corrective Action Report conducted by DOE.

Additional Background:

None.

Basis:

The NRC On-Site Representative's reports (ORRs) and Observation Audit Reports (OARs) on the Yucca Mountain Project are documented to alert NRC staff, managers and contractors to information on DOE programs for site characterization, repository design performance assessment, and environmental studies that may be of use in fulfilling NRC's role during pre-licensing consultation. As noted in the ORRs and the OARs, deficiencies have been identified questioning the accuracy, qualification and traceability of data.

References:

NUREG-1298 - Generic Technical Position (GTP) on "Qualification of Existing Data for High-Level Nuclear Waste Repositories," dated February 1998.

YAP-SIII.1Q, Revision 3, ICN0 - Yucca Mountain Administration Procedure on "Qualification of Unqualified Data," dated November 13, 1998.

"Data, Model and Code Qualification/Validation and Control Plan," dated December 1998.

"DOE Management Plan and Responses to Corrective Action Request (CAR) and Status of Implementation of Corrective Actions," dated January 25, 1999.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON NUCLEAR WASTE
WASHINGTON, D.C. 20555-0001

April 8, 1999

The Honorable Shirley Ann Jackson
Chairman
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Dear Chairman Jackson:

SUBJECT: COMMENTS ON THE DEPARTMENT OF ENERGY'S VIABILITY ASSESSMENT FOR THE PROPOSED HIGH-LEVEL RADIOACTIVE WASTE REPOSITORY AT YUCCA MOUNTAIN, NEVADA

In this letter, the ACNW offers comments on the Viability Assessment (VA) of a Repository at Yucca Mountain, which was released by the U.S. Department of Energy (DOE) on December 18, 1998. The ACNW reviewed the primary VA reports, the technical basis document supporting the Total System Performance Assessment for the VA (TSPA-VA), the Repository Safety Strategy, and the most recent NRC Issue Resolution Status Reports. The Committee heard presentations on the VA from DOE representatives at its 105th and 106th ACNW meetings. In addition, the Committee heard a presentation from the NRC staff at the 106th meeting on its preliminary review comments on the VA. The Committee also had the benefit of observing presentations to the Commission on the VA by representatives of a variety of organizations and groups.

A summary of our recommendations follows. These recommendations can be implemented as part of guidance development or made part of the 10 CFR Part 63 rulemaking.

Recommendations

1. The NRC should require DOE to provide a total system performance assessment (TSPA) model of sufficient technical clarity (transparency) so that the staff can readily determine the interrelationships among all modules of the system. This recommendation could be implemented as part of the 10 CFR Part 63 rulemaking.

2. The NRC should require DOE to provide, in the license application (LA) data and information packages, the supporting evidence to the performance assessment (PA) at the module level. This recommendation could be implemented as part of the 10 CFR Part 63 rulemaking.

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Enclosure 2

3. The NRC should provide guidance in the Yucca Mountain License Application Review Plan on what constitutes sufficient supporting data, acceptable model assumptions and abstractions, and acceptable expressions of parameter uncertainty.

4. The NRC staff should be prepared to evaluate engineering designs proposed by DOE. This evaluation will require additional NRC staff with geotechnical, engineered barrier, and waste package design experience.

5. The NRC should outline steps in the licensing process between initial submission of the safety case and final closure of the repository. This recommendation could be implemented as part of the 10 CFR Part 63 rulemaking or guidance development.

6. As part of guidance development for 10 CFR Part 63, the staff needs to identify explicitly the attributes of defense in depth (DID) that apply to waste repositories.

Background

The ACNW framed its review within the overall context of Risk-Informed, Performance-Based Regulation. The foundation for licensing a repository for high-level radioactive waste and spent fuel is expected to be an Environmental Protection Agency standard based on risk (or dose) and a set of implementing NRC regulations (10 CFR Part 63 and other applicable regulations) and guidance.

Demonstrating compliance with the standard will be based principally on a PA that uses a risk-based performance measure (i.e., the expected dose to the average member of the critical group at a specified location). The results from the PA should be expressed as a risk curve (i.e., a complementary cumulative distribution function [CCDF], sometimes referred to as a risk exceedance curve), that shows the likelihood of exceeding different radiation dose levels. The PA, in principle, considers all reasonable mechanisms for failure of the repository to limit appropriately the dose of radiation to the critical group for the required time of compliance.

The VA offers the NRC a chance to assess how DOE's presentation of license supporting material may need to be improved to meet requirements of risk-informed, performance-based criteria in the regulation and how the NRC staff may have to adapt to be able to perform their mission efficiently and effectively. It is within this framework that the ACNW conducted its review.

The ACNW's review of the VA improved our understanding of DOE's approach for moving from the VA to the site recommendation and the LA for the Yucca Mountain repository. The objective of the review was to evaluate the technical capability, tools, and guidance that the NRC staff will need to conduct a defensible review of the Yucca Mountain LA.

The ACNW focused on the technical basis of the safety case made in the VA, including the ability of DOE to demonstrate the following:

- The design would limit the access of water to the waste packages;
- The waste packages (and cladding) will have long lifetimes relative to the compliance period;
- The release of radionuclides after canisters are breached would be slow;
- The transport of radionuclides in the unsaturated zone could be estimated;
- The transport and dilution of radionuclides in the saturated zone will provide significant buffering of doses; and
- The uptake of radionuclides by biota and the dose to humans could be represented in an acceptable way.
- In addition, to be credible, DOE must present a clear, integrated, probabilistic PA.

The ACNW believes that the most important issues are limiting water access to the waste packages and the need for DOE to present a clear, integrated, probabilistic PA. It is critical that considerable work be done on these issues before submitting a credible LA. The PA is the framework within which all of these issues are put in context for licensing decisionmaking; it is the logic engine for demonstrating the safety of the repository.

Observations and Recommendations

The ACNW is impressed with the improvements in-depth and presentation of the TSPA-VA over previous versions of TSPA. Continued improvements are necessary to make future TSPAs more credible. The description and PA of the geological repository system require much data and many assumptions combined into a complex set of models. The results shown in the VA are sufficiently opaque so that it is often difficult to make reasonable judgments on the adequacy of either the computations or their underlying database.

Observation

The presentation of the VA results continues to need major improvements. More emphasis is needed on a top-down presentation of the total model that clearly traces the critical path of the computation of the performance measure; namely, the radiation risk to a member of the critical group. The components of a traceable path of the radiation risk assessment that need greater visibility and discussion include the hierarchy of the total model, the model components (modules, interfaces, inputs, outputs, etc.), and clearer

visibility of the continuity and traceability of the performance measure calculation throughout the model.

The ACNW's goal of a top-down presentation is to reveal explicitly the connection and dependence between the performance measure and each component of the model (i.e., rainfall on the site, infiltration to the repository, waste package degradation, radionuclide mobilization, transport through the geosphere and the biosphere, and biological uptake). Refinements are needed in presenting the propagation of uncertainty from the component and subsystem level to total system results. To a certain extent, such results are buried in the VA, but they need to be made more visible to facilitate the mapping of component and subsystem performance to the overall performance of the repository. To be complete, the mapping must be performed in a probabilistic framework to display the role of uncertainty in the process. The Committee believes that employing such techniques will contribute greatly to increasing confidence in the TSPA as it evolves toward a licensing basis.

Recommendation

1) The NRC should require from DOE a "transparent" PA that is sufficiently clear to determine the interrelationships among all modules of the system. Requirements for such a presentation can be incorporated into guidance or made part of the 10 CFR Part 63 rulemaking.

Observation

In addition to improving the technical clarity of the PA, the linkages to the underlying supporting evidence must be presented in a way that facilitates review. The database and other supporting evidence for the VA are voluminous and include system (natural and engineered) reliability data, scientific literature, laboratory results, field studies, special analyses, the laws of physics, the principles of chemistry, the abstraction process, and the results of expert elicitation. A major contributor to technical clarity includes the process for choosing conceptual models because both information and models are major sources of analysis uncertainties.

Future TSPAs should provide the rationale for choosing conceptual models for each module, including the process of assembling the modules into the total system model. It is essential that future TSPAs also be specific about what has been synthesized from the various sources and that data and information packages be developed to facilitate the search for supporting information. This is especially true for the major contributors to the performance measures and the associated uncertainties. A special category of evidence comes from the process of expert elicitation. It is not enough to attribute a result to the judgment of an expert; it must be possible to examine the underlying evidence used by the experts in forming their judgments.

Recommendation

2) The NRC should require from DOE the traceable linkage of the supporting evidence (data and information packages) to the PA at the module level. Data references must be explicit and, preferably, have electronic links that can be followed easily. Inputs based on expert elicitation must be linked to the supporting evidence for the information provided to and by the experts. Requirements for such a presentation can be incorporated into guidance or made part of the 10 CFR Part 63 rulemaking.

Observation

The case for the safety of a geological repository over tens to hundreds of thousands of years cannot be expressed in absolute terms; as previously stated, the basis for measuring performance must be a risk curve. The ACNW is concerned that the inherent uncertainties in an analysis for such extended periods drive critics to demand that the most conservative assumptions, conceptual models, and parameters be selected at every juncture of the analysis. We very strongly disagree with such an approach. We believe that conservatism is appropriate in regulating nuclear facilities of all kinds, but the appropriate place for conservatism is in the choice of a probability of exceedance of a risk standard.

In the case of a PA for a geological repository, we believe that the analysis should be performed with as nearly realistic assumptions, models, and parameters as possible, including the uncertainty involved. The resultant CCDF derived from the PA would show explicitly the probability that a standard would be exceeded. Increased *conservatism* may be achieved by requiring that the probability of exceeding the standard be less than, say, 1 in 10^6 as opposed to a requirement that it be less than, say, 1 in 10^3. Obviously, a licensing decision would not be based exclusively on the probability (i.e., the regulation is risk-informed rather than risk-based), but the decision about conservatism is made with the clearest view of the issues after the best information available has been used in an analysis.

Recommendation

3) The NRC should provide guidance in the Yucca Mountain License Application Review Plan on what constitutes sufficient supporting data, acceptable model assumptions and abstractions, and acceptable expressions of parameter uncertainty. ACNW recommends that the guidance not require DOE's "complete understanding," but rather reflects the philosophy that even simple approaches may be realistic as long as the full range of uncertainty is captured. The guidance should allow DOE and others to establish relatively clearly when enough data or model support has been attained. The guidance would be most useful if conditions for an acceptable risk exceedance were discussed.

Observation

The VA demonstrates that the ability to restrict the amount of water contacting the waste packages is a critical part of the safety strategy. The extreme importance of limiting the contact of water with waste has led to DOE's increasing emphasis on elements of the engineered barrier system; this would include all aspects of tunnel design as well as the canisters and their contents. The ACNW remains convinced that the NRC staff must acquire expertise in engineering design.

Recommendation

4) The NRC staff should be prepared to evaluate engineering designs proposed by DOE. This step implies augmenting the NRC staff with engineers with geotechnical, engineered barrier, and waste package design experience. Part-time consultants with such design experience could be a valuable aid to NRC full-time staff in preparing for and evaluating the LA.

Observation

In listening to presentations from DOE and to some concerns expressed by the NRC staff about the time required for evaluations, the ACNW believes that a potential exists for misunderstanding among the parties. DOE has indicated that some aspects of the repository design likely will change up to and beyond the submission of the LA. An adaptive design strategy is essential to achieve the best results. NRC must be prepared to allow design flexibility and probably will have to adopt a plan of phased licensing. The preclosure period is anticipated to range from 50 to 300 years. During this entire period, the waste will be in storage underground; under active, continuous surveillance; and will be fully retrievable. The final decision on the suitability of the repository for waste disposal will not be made until the end of the preclosure period. New materials, new technical methods, and new societal needs can be expected to arise in this period.

Certain design improvements, such as drift location, support type, waste package design, water diversion strategies, and chemically tailored backfill, are all possible during the preclosure period. Active (and natural) ventilation can be used to remove heat from the waste and reduce adverse thermal effects on the rock and waste package. Also, extensive data can be gathered during the preclosure period to reduce uncertainties in the predicted performance of the repository. On the one hand, it would be irresponsible not to allow such improvements in repository safety. On the other hand, NRC cannot approve the licensing of the repository if the LA and supporting information are not sufficiently well developed to allow the NRC to make a finding of reasonable assurance of safety. A serious evaluation of the competing needs of flexibility and design stability is required.

Recommendation

5) The NRC should outline in the 10 CFR Part 63 rulemaking or guidance the steps in the licensing process between initial submission of the safety case and final

closure of the repository. Particular attention should be given to the definition of "reasonable assurance" as applied to repository licensing. This definition will provide early guidance to DOE and others on the level of completeness of design (data, model development, and confirmatory observations) that will be necessary at different phases of the project. The outline would provide guidance on the nature of the process but would not dictate how the licensing boards or the Commission would make decisions.

Observation

DOE continues to develop methods for demonstrating defense in depth (DID). The ACNW remains convinced that the key requirement for DID in a repository is an analysis that clearly quantifies the contribution of multiple barriers, including the uncertainty associated with each barrier to the containment of radionuclides (see ACNW letter of October 31, 1997, "Recommendations Regarding The Implementation of the Defense-in-Depth Concept in the Revised 10 CFR Part 60"). In particular, the multiple barriers of the engineered system and the geological system must be shown to offer protection. We note that it would be imprudent to require a specific percentile contribution from either the geological or the engineered systems because this requirement could lead to impairment of overall performance. That is, if the geological system were required to contribute a certain fraction (say 50%) of the total performance, the applicant might degrade the design of the engineered system to boost the fraction of contribution from the natural system. The ACNW maintains that the appropriate way to judge the case for repository safety is to look at overall performance, as long as there is a clear, quantitative presentation of contributions of individual barriers.

Recommendation

6) The NRC staff is committed to developing further guidance on implementing the multiple-barriers approach required in 10 CFR Part 63. As part of this guidance development, the staff should identify clearly the attributes of DID that apply to waste repositories in relation to a risk-informed strategy. In addition, DOE and NRC should develop approaches and methodologies that clearly and transparently identify the contributions of different barriers to the overall performance of the repository.

Technical Concerns About the VA

In general terms, the ACNW shares the staff's concerns on specific technical issues; that is, the adequacy of the database and models in the areas of seepage into drifts, corrosion of alloy-22, failure of fuel cladding, and dissolution of fuel. (The Committee presented details of some of these topics in its letter of September 9, 1998, on the "Issues and Recommendations Concerning the Near-Field Environment and the Performance of Engineered Barriers at Yucca Mountain.") The planned experiments by DOE on seepage into drifts are potentially important, as are continued experiments on corrosion and other phenomena. The ACNW also agrees that data are needed on the saturated zone between Yucca Mountain and Amargosa Valley for the sake of credibility.

ACNW disagrees with the staff's concern about the need for more work on Igneous Activity. The Committee has repeatedly asked the staff for analyses that justify the staff's concerns about volcanic activity as a major component of risk at Yucca Mountain, but has yet to see a detailed justification.

Summary

The Committee was impressed with the PA discussion contained in DOE's VA. The material was very professionally written in terms of both text and graphics. The Committee believes that a great deal of excellent work has been performed on the Yucca Mountain TSPA. Confidence in the results is seriously undermined, however, by TSPA's overwhelming size and complexity. ACNW hopes that the recommendations presented in this letter will assist in improving the credibility and transparency of future safety analyses.

Sincerely,

B. John Garrick
Chairman