February 6, 2002

Dr. Stephan Brocoum, Assistant Manager
Office of Licensing and Regulatory Compliance
U.S. Department of Energy
Yucca Mountain Site Characterization Office
P.O. Box 364629
North Las Vegas, NV 89036-8629

SUBJECT: RADIONUCLIDE TRANSPORT KEY TECHNICAL ISSUE AGREEMENTS

Dear Dr. Brocoum:

During a Technical Exchange and Management Meeting held on December 5-7, 2000, the U.S. Nuclear Regulatory Commission (NRC) and the U.S. Department of Energy (DOE) reached agreement on issues pertaining to the Radionuclide Transport (RT) Key Technical Issue (KTI). By letters dated February 2, March 2, March 12, March 22, March 28, and April 13, 2001, DOE provided documents pertaining to NRC/DOE agreements, including a number of documents pertaining to RT agreements. The NRC staff has reviewed these documents as they relate to the RT KTI and the results of the staff's review are enclosed.

After you have reviewed this letter, please contact Mr. James Andersen of my staff to discuss these issues further. He can be reached at (301) 415-5717.

Sincerely,

/RA/

C. William Reamer, Chief
High-Level Waste Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

Enclosure: As stated
cc: See attached distribution list

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Letter to S. Brocoum from C.W. Reamer dated: February 6, 2002

cc:

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S. Frishman, State of Nevada
L. Barrett, DOE/Washington, DC
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A. Bacock, Big Pine Paiute Tribe of the Owens Valley

R. Quintero, Inter-Tribal Council of Nevada (Chairman, Walker River Paiute Tribe)

M. Bengochia, Bishop Paiute Indian Tribe

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**NRC Review of DOE Documents Pertaining to**
**Radionuclide Transport Key Technical Issue Agreements**

The U.S. Nuclear Regulatory Commission (NRC) goal of issue resolution during this interim pre-licensing period is to assure that the U.S. Department of Energy (DOE) has assembled enough information on a given issue for NRC to accept a license application for review. Resolution by the NRC staff during pre-licensing does not prevent anyone from raising any issue for NRC consideration during the licensing proceedings. Also, and just as importantly, resolution by the NRC staff during pre-licensing does not prejudge what the NRC staff evaluation of that issue will be after it's licensing review. Issues are resolved by the NRC staff during pre-licensing when the staff has no further questions or comments about how DOE is addressing an issue. Pertinent new information could raise new questions or comments on a previously resolved issue.

This enclosure addresses several NRC/DOE agreements made during the Radionuclide Transport (RT) Technical Exchange and Management Meeting on December 5-7, 2000 (see NRC letter dated December 12, 2000, which summarized the meeting). By letters dated February 2, March 2, March 12, March 22, March 28, and April 13, 2001, DOE submitted a number of documents to address some of the RT agreements. The documents submitted and associated KTI agreements are discussed below:

**1) Radionuclide Transport Agreement 1.03**

Wording of the Agreement: Provide the screening criteria for the radionuclides selected for PA. Provide the technical basis for selection of the radionuclides that are transported via colloids in the TSPA. The screening criteria for radionuclides selected for TSPA are contained in the AMR *Inventory Abstraction*. DOE is documenting identification of radionuclides transported via colloids for TSPA in the AMR *Waste Form Colloid-Associated Concentration Limits: Abstraction and Summary*, in the TSPA-SR Technical Report, and in the TSPA-SR Model Document. These documents will be available to the NRC in January 2001.

NRC Review: The NRC staff reviewed four documents pertaining to this agreement, Inventory Abstraction (ANL-WIS-MD-000006, Rev 00, ICN 01); Waste Form Colloid-Associated Concentration Limits: Abstraction and Summary (ANL-WIS-MD-000012, Rev 00, ICN 01); TSPA Model for Site Recommendation (MDL-WIS-PA-000002, Rev 00, ICN 00); and TSPA for the Site Recommendation (TDR-WIS-PA-000001, Rev 00, ICN 01). The analysis and model report on Inventory Abstraction (ANL-WIS-MD-000006, Rev 00, ICN 01) identifies radionuclides for the total system performance assessment model abstraction based on contribution to dose, inventory, and mobility considerations. The NRC staff considers the part of this agreement concerning screening criteria for the radionuclides selected for performance assessment fulfilled. However, to the technical basis for selecting radionuclides for transport modeling via reversible and irreversible colloid attachment is not transparent and traceable in all cases. Discussions in the waste form analysis and model report (ANL-WIS-MD-000012, Rev 00) and TSPA-SR documents (MDL-WIS-PA-000002, Rev 00, ICN 00; TDR-WIS-PA-000001, Rev 00, ICN 01) do not fully consider the possibility that waste form colloids could significantly transport radioelements other than plutonium and americium or the potential contribution of reversible colloid attachment to transport of less sorbing elements such as neptunium and uranium. It is not clear if analyses have been conducted showing that the effect of colloidal attachment on transport of these other radionuclides is insignificant. For example, it may be possible that transport of moderately sorbing radioelements would be significantly enhanced by reversible sorption onto colloids. In addition, there still exists, among the cited reports, confusion about the disposition of specific radioelements in colloid modeling. For example, the Total System

Performance Assessment–Site Recommendation model report lists U-234 and Np-237 as radionuclides irreversibly attached to colloids, but the main Total System Performance Assessment–Site Recommendation report states that neptunium and uranium isotopes are not included in colloid transport models.

Additional Information Needed:

1) Provide clarification and justification of radionuclides for which reversible and irreversible colloidal transport is modeled.

Status of Agreement: RT Agreement 1.03 requires additional information to support a potential licensing review. The NRC staff notes that this agreement is also related to Evolution of the Near-Field Environment Agreement 4.05.

**2) Radionuclide Transport Agreement 2.11**

Wording of the Agreement: Provide the updated UZ Flow and Transport and the SZ Flow and Transport FEPs AMRs. DOE will provide updates to the AMRs *Features, Events, and Processes in UZ Flow and Transport* and *Features, Events, and Processes in SZ Flow and Transport*, both available in January 2001.

NRC Review: The NRC reviewed the two documents as they pertain to this agreement. These FEPs documents were discussed during the two Total System Performance Assessment and Integration (TSPAI) technical exchanges held in May and August 2001. During these technical exchanges, the NRC and DOE reached a number of separate agreements pertaining to FEPs (see TSPAI Agreements 2.01 to 2.04). With these specific TSPAI agreements in place, the NRC considers this agreement complete. Resolution of the RT subissues depends on the satisfactory resolution of the RT portion of TSPAI Agreements 2.01 through 2.04.

Additional Information Needed: None at this time

Status of Agreement: RT Agreement 2.11 has been superceded by TSPAI Agreements 2.01 through 2.04. RT Agreement 2.11 is complete.

**3) Radionuclide Transport Agreement 3.06**
**Structural Deformation and Seismicity Agreement 3.02**

Wording of the Agreement: The NRC needs DOE to document the pre-test predictions for the Alcove 8/Niche 3 work. DOE responded that pre-test predictions for Alcove 8 Niche 3 work will be provided to NRC via letter report (Brocoum to Greeves) by mid-January 2001.

NRC Review: DOE provided, and NRC has reviewed the Pre-Test Predictions for Alcove 8-Niche 3 Cross-Over Test (Pre-Test Prediction Report) as it pertains to these agreements. In the Test Plan Development section of the document, DOE stated that: (1) a small-plot test was conducted in year 2000, and (2) the small-plot tests would be followed by line-release (~ 5 m long) tests along the fault in early 2001 and by a large 3 meter by 4 meter plot for areal release tests. In summary, it is the NRC's understanding that three separate tests make up the Alcove 8-Niche 3 Crossover Test, specifically, the Small Plot Test, the Line Release (Fault) Test, and the Large Plot Test. In addition, DOE states that both the fault test sequences and the large plot tests will consider combinations of the following test components, Saturated Flow and Transport (Phase I) and Unsaturated Flow and Transport (Phase II).

Specific comments and information needs regarding the testing are discussed below. Items 1-3 request additional information be provided by DOE to fulfill the agreement, Items 4-11 are NRC comments which should be considered by DOE with regard to conducting other tests and associated pre-test predictions.

Discussion of Additional Information Needed

1) The Pre-Test Prediction Report, which DOE provided on March 12, 2001, contains Phase I pre-test predictions for the flow and transport tests in the large plot and the tracer transport tests in the small plot. Attachment II of the enclosure contains Phase I flow predictions for the small plot test. These pre-test predictions transmitted to the NRC pertain exclusively to the Phase I test components and do not address the Phase II test components. Further, the report states that since the test parameters (such as infiltration rate) to be used in other phases are related to test results from Phase I, model predictions of the test results for the other phases will be provided after values for these test parameters become available. The NRC staff needs the pre-test predictions for the Phase II test components to satisfy the intent of this agreement.

2) The NRC staff's understanding is that the Small Plot Test was aborted in favor of the Line Release (Fault) Test. Phase I (without tracers) infiltration into the small plot was abandoned due to the unexpectedly small infiltration rate. Injection with and without tracers (Phase I) at ponded influx rates was more successful for the Line Release (Fault) Test.

The Pre-Test Prediction Report mentions that tracer transport results for the small plot tests are described in the report. DOE needs to clarify if these tracer transport results and the pre-test predictions in the Attachment II, are the pre-test predictions for the Small Plot Test or the Line Release (Fault) Test or both.

3) The test objectives of the Line Release (Fault) Test are not clearly stated in the Pre-Test Prediction Report. The characterization of faults and fractures across a lithophysal-nonlithophysal interface is listed as one test objective. The NRC staff believes that more detailed objectives are required for the Line Release (Fault) Test, particularly with regard to characterizing the fault, including the effect of the smectite and the surrounding fracture zone, which has been the focus of intensive testing effort by DOE. The fault extends beyond the bulkheads and is clearly exposed in the ESF. Variability of the properties of the fault was observed (e.g., orientation, fault-zone mineralogy, and width). The nature of intersections of fractures with the fault (most clearly in the ESF) can be measured. Compiled data on the fault being tested can be used to interpret and analyze test results associated with water moving within and adjacent to the fault.

This particular concern is also related to the Structural Deformation and Seismicity (SDS) Agreement 3.01. This agreement states that the Passive Cross Drift Hydrologic test and the Alcove 8 - Niche 3 tests need to be fracture-informed.

NRC Comments Related to Phase I (Saturated) Testing and Associated Pre-Test Predictions

4) The pre-test predictions used the active fracture model to simulate wetting of the volume of rock between Alcove 8 and Niche 3. It has not yet been demonstrated that the active fracture concept can be used to accurately predict flow and transport in unsaturated fractured rock. The use of a continuum model is inappropriate when the spacing of flowing fractures exceeds the grid size. Liu, Doughty, and Bodvarsson (1998, p. 2642) correctly acknowledge this limitation in the statement, "continuum approaches are not applicable because very few fractures are active within a grid block and fracture flow can not be captured by continuum models." Figure 10 of

the Pre-Test Prediction Report illustrates the two-dimensional spatial distribution of matrix saturation increase at times of 1 year and 10 years after the test. The grid size for this simulation is one meter or less (Figure 1). However, Table 1 lists fracture spacing in TSw33 to be 1.23 m, which is greater than the grid size. Furthermore, using an active fracture model, the spacing of fractures in which water flows is expected to increase under less than fully saturated conditions. The DOE needs to justify its use of the active fracture model as a prediction tool for these tests.

This particular concern is also related to the Total System Performance Assessment and Integration (TSPAI) Agreement 3.28. This agreement states that the DOE will provide independent lines of evidence to provide additional confidence in the use of the active fracture continuum concept in the transport model documented in FY2003. Although not specifically listed as a test objective in Attachment I of the Pre-Test Prediction Report, the NRC staff considers that testing in Alcove 8 and Niche 3 could be designed to support validation of the active fracture model if the appropriate scales of the test site characterization and model are used.

5) Unsaturated and Saturated Flow Under Isothermal Conditions (USFIC) Agreement 4.01(i) states that a mass balance of water for the Alcove 8/Niche 3 test has been considered, but is not feasible due to the size of the collection system that would be required. The agreement further states that a collection system to obtain a mass balance is being developed for the Niche 5 test. It is not clear to the NRC staff how the pre-test predictions can be meaningfully compared to the test results of the Alcove 8/Niche 3 Crossover Test without a mass balance of water. Recoverability is defined in the Pre-Test Prediction Report as the total volume of water collected at Niche 3 divided by the total volume of water applied from the infiltration plot. Without considering the amount of water lost from evaporation, calculated recoverability will provide unreliable information. Furthermore, the location of the current evaporation pan is not representative of the various and diverse evaporative conditions which exist outside of Niche 3 in the exploratory studies facility (ESF). The value of the pre-test predictions would be greatly diminished if the Alcove 8/Niche 3 tests lacked a mass balance of water. For example, without an accurate water budget, the unsaturated zone constitutive relations (e.g., van Genuchten parameter values) cannot be estimated correctly.

6) The reason for using the rock property values from Table 1 (p. 11) in the Pre-Test Prediction Report is not clear. More recent and representative rock property data are available to run predictive simulations. DOE needs to clarify the basis and give the rationale for using the values listed in Table 1, rather than the more recent data derived by direct measurements from Alcove 8 and Niche 3.

This particular concern is also related to the SDS Agreement 3.01. This agreement states that the Passive Cross Drift Hydrologic test and the Alcove 8 - Niche 3 tests need to be fracture-informed.

<u>NRC Comments Related to Phase II (Unsaturated) Testing and Associated Pre-Test Predictions</u>

7) An NRC staff concern pertains to the test objective of evaluating the fracture-matrix interface area as described in the Pre-Test Prediction Report. If saturated conditions have existed prior to tracer injection, the wetted fracture-matrix interface area will be large during and immediately after saturated conditions. Fracture sheet flow may continue until the fractures begin to dry out. If unsaturated, relatively dry conditions exist prior to tracer injection, fracture sheet flow would be less likely to occur. More likely would be finger-type preferential flow paths and, therefore, a smaller wetted fracture-matrix interface area. Such preferential flow in the

fractures would lead to more rapid movement of water and tracer. By isolating flow to a small fraction of the volume of the medium, the rate of vertical movement can be significantly increased, leading to less sorption and less matrix diffusion. Clarification is needed on how the effects from previously saturated fractures will be considered when evaluating the fracture-matrix interface area, or give the rationale for why these effects need not be considered.

This particular concern is also related to the TSPAI Agreement 3.25. This agreement states that DOE will utilize field test data to either provide additional confidence in or a basis for revising the TSPA seepage abstraction and associated parameter values (e.g., flow focusing factor, van Genuchten alpha for fracture continuum, etc.), or provide technical basis for not using it.

8) An additional staff concern pertains to the Pre-Test Prediction Report assumption that fracture-matrix interaction mechanisms are the same for the water flow from the fracture continuum to the matrix continuum as they are for water flow from the matrix continuum to the fracture continuum. This issue is roughly analogous to hysteresis of unsaturated water flow in porous media. The fracture-matrix interaction mechanisms can be very different depending on if the saturation of the flow system is increasing or decreasing. Liu, Doughty, and Bodvarsson (1998, p. 2638) stated that this issue needed further study. The rationale for assuming that fracture-matrix interaction mechanisms are the same for, and independent of, a flow system which is increasing or decreasing in saturation is needed.

This particular concern is also related to the TSPAI Agreement 3.25.

9) The Pre-Test Prediction Report states that the fracture relative permeability and the fracture-matrix interface area are a function of flux for Phase II unsaturated flow and transport test components. The NRC staff concern is how DOE will determine if the fracture-matrix saturation system is in a steady state during the Phase II experiments and not in a state of disequilibrium due to the rapidity of the sequence of tests.

This particular concern is also related to the TSPAI Agreement 3.25.

<u>NRC Comments Related to Current Testing and Future Tests and Agreements</u>

10) Seepage has been collected in Niche 3 for Phase I of the Line Release (Fault) Test; however, no tracer was captured before the tracer injection was stopped. If, after a technically reasonable length of time, no tracer has been captured, then it is not clear to the NRC staff how matrix-fracture interaction will be evaluated. The utility of proceeding with stepped reductions in water injection rates if no tracer is captured from the Phase I ponded influx rate should be explained in terms of the initial test objectives. The NRC suggests that one approach might be to inject more tracer under the ponded condition until the tracer is captured, or that an alternative approach for evaluating matrix-fracture interaction be proposed by DOE. The NRC also notes that remaining tests (e.g., the large plot test) in Alcove 8/Niche 3 are not scheduled to start until the Line Release (Fault) Test is completely finished.

11) The NRC staff will review and discuss the documents pertaining to SDS Agreement 3.01 separately, including the fracture-fault representation “3D Depiction of Fractures between Alcove 8 & Niche 3." However, the work required to fracture-inform the Alcove 8/Niche 3 Crossover Test will contribute to the satisfactory completion of this test (besides that of SDS Agreement 3.01). This work needs to be done during the early stages of the test. A brief summary is presented below on the major components to be addressed in order to fracture-inform a test.

• Descriptions of obvious discrete features, such as fracture swarms, large fractures or faults, atypically large apertures, fracture interconnections, etc., which may validate the models and assumptions, or which may bias test results and violate the conceptual models and assumptions that will be used to interpret the test results. DOE would then be able to discuss how effective fracture spacings and apertures used in the solute transport models for TSPA (Table 1 of Particle Tracking and Abstraction of Transport Processes AMR) compare to apertures and spacings of flowing fractures observed during the Alcove 8/Niche 3 Crossover Test.

• Documentation of qualitative and quantitative fracture properties with respect to seepage in order to determine whether the conceptual model is supported by observations. For example, the relationship between observed seepage and the type of fracture, frequency of fracture intersections, fracture patterns, and aperture variability needs to be documented.

• Discussion on how the presence of lithophysal cavities in the area of the repository proposed to be constructed in the lower lithophysal unit of the Topopah Springs tuff, may alter the conclusion drawn from seepage tests conducted in nonlithophysal units.

• Discussion on how or whether the observed distribution of fractures and the observed distribution of seepage as a function of percolation flux can be used to infer appropriate values for the active-fracture parameter used in the flow and transport models.

Additional Information Needed:

1) Provide the pre-test predictions for the Phase II tests (flow and transport) for the Line Release (Fault) Test and the Large Plot Test. (Item #1 above)

2) Provide clarification of whether the tracer transport results for the small plot tests discussed in the Pre-Test Prediction Report, and the pre-test predictions in Attachment II, are the pre-test predictions for the Small Plot Test or the Line Release (Fault) Test or both. (Item #2 above)

3) Provide clarification on the specific test objectives of the Line Release (Fault) Test. (Item #3 above)

Status of Agreements: RT Agreement 3.06 and SDS Agreement 3.02 require additional information (Items 1-3 above) to support a potential licensing review. DOE should consider the NRC comments in Items 4-11 in future activities associated with other tests and pre-test predictions.

**4) Radionuclide Transport Agreement 3.07**

Wording of the Agreement: Provide sensitivity studies to test the importance of colloid transport parameters and models to performance for UZ and SZ. Consider techniques to test colloid transport in the Alcove 8/Niche 3 test (for example, microspheres). DOE will perform sensitivity studies as the basis for consideration of the importance of colloid transport parameters and models to performance for the unsaturated and saturated zones and will document the results in updates to appropriate AMRs, and in the TSPA-LA document, all to be available in FY 2003. DOE will evaluate techniques to test colloidal transport in Alcove 8 / Niche 3 and provide a response to the NRC in February 2001.

NRC Review: The information reviewed was a status of DOE efforts and was not intended to provide the information required to fully address this agreement. At the RT Technical

Exchange conducted on December 5-7, 2001, the NRC staff had expressed concern about the lack of field evidence for colloid transport through fractures rock in the unsaturated zone. It was agreed that DOE would consider applying techniques to test colloid transport parameters at Alcove 8 - Niche 3. In a letter dated March 28, 2001, DOE indicated that final test plans for colloids at Alcove 8/Niche 3 have not been developed, and that microsphere testing was still being considered in light of experience at the C-Wells and Busted Butte. As noted in the March 28, 2001, letter, DOE will provide a test plan, detailing the test techniques, as soon as it is developed. Since DOE is still in the process of considering techniques to test colloid transport in the Alcove 8/Niche 3 test and will provide the test plan when developed, the NRC staff considers this part of the agreement fulfilled. The concern described above, however, remains.

Additional Information Needed: None

Status of Agreement: Since additional documents are needed for this agreement, RT Agreement 3.07 will continue to be listed as “Partly Received.”