August 20, 2002

Joseph D. Ziegler, Acting 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: UNSATURATED AND SATURATED FLOW UNDER ISOTHERMAL CONDITIONS AGREEMENT 4.07

Dear Mr. Ziegler:

During a Technical Exchange and Management Meeting held on August 16-17, 2000, the U.S. Nuclear Regulatory Commission (NRC) and the U.S. Department of Energy (DOE) reached agreement on a number of issues within the Unsaturated and Saturated Flow Under Isothermal Conditions (USFIC) Key Technical Issue (KTI). The wording and numbering of some of these agreements, including USFIC Agreement 4.07, were modified during a Technical Exchange and Management Meeting held on August 6-10, 2001. By letter dated May 30, 2002, DOE provided the Natural Analogue Synthesis Report. The NRC staff has reviewed this report as it relates to the agreement and the results of the staff's review are enclosed.

In summary, although none of the analogues closely replicate future conditions in a geologic repository at Yucca Mountain, DOE has provided an adequate description and analysis of a variety of analogue sites, with sufficient detail to meet the intent of USFIC Agreement 4.07. Therefore, USFIC Agreement 4.07 is "complete." In addition, DOE's May 30, 2002, letter also addressed General Agreement 1.01 (#75) which references USFIC Agreement 4.07. The NRC staff believes the information provided by DOE satisfactorily addresses the issue outlined in Item #75.

If you have any questions regarding this matter, please contact Mr. James Andersen of my staff. He can be reached at (301) 415-5717.

Sincerely,

/RA/

Janet Schlueter, 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 J. Ziegler from J. Schlueter dated August 20, 2002

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M. Bengochia, Bishop Paiute Indian Tribe

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NRC Review of DOE Documents Pertaining to Key Technical Issue Agreements

The U.S. Nuclear Regulatory Commission (NRC) goal of issue resolution during the 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 important, resolution by the NRC staff during pre-licensing does not prejudge what the NRC staff evaluation of that issue will be after its 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 two NRC/DOE agreements. Unsaturated and Saturated Flow Under Isothermal Conditions (USFIC) Agreement 4.07 was made during a Technical Exchange and Management Meeting held on August 16-17, 2000 (see NRC letter dated September 8, 2000, for meeting summary), and then renumbered and modified during a Technical Exchange and Management Meeting held on August 6-10, 2001 (see NRC letter dated August 23, 2001, for meeting summary). General Agreement 1.01 (#75) was made during a Technical Exchange and Management Meeting held on September 18-19, 2001 (see NRC letter dated October 2, 2001, for meeting summary). By letter dated May 30, 2002, DOE submitted a document to address both USFIC Agreement 4.07 and General Agreement 1.01 (#75). The document submitted and associated Key Technical Issue (KTI) agreements are discussed below:

Wording of USFIC Agreement 4.07 and General Agreement 1.01 (#75)

USFIC Agreement 4.07:

DOE will provide documentation of the results obtained from the Natural Analogs modeling study. The study was to apply conceptual models and numerical approaches developed from Yucca Mountain to natural analog sites with observations of seepage into drifts, drift stability, radionuclide transport, geothermal effects, and preservation of artifacts. This will be documented in the natural Analogs for the Unsaturated Zone AMR (ANL-NBS-HS-000007) expected to be available to NRC FY 2002.

General Agreement 1.01 (#75):

> NRC Concern: The cave natural analogues described on pp. 4-12 and 4-13 [of DOE's Supplemental Science and Performance Analyses report] are all examples without significant seepage flux. How do other environmental variables, such as relative humidity in the cave, near field saturation, and percolation flux, compare to Yucca Mountain? Are there examples of natural analogues that show significant seepage over time (Rainier Mesa has seepage)?
>
> DOE Response: ...[DOE] will provide documentation of the results for all relevant natural analogues that we [DOE] identify. This includes any natural analogs that may indicate significant seepage.

NRC Review of Both Agreements: In response to both agreements, DOE provided the Natural Analogue Synthesis Report (TDR-NBS-GS-000027, Rev00, ICN 02), dated May 2002. This material was sent under a DOE cover letter dated May 30, 2002. The intent of the natural analogue studies was to collect corroborative evidence from analogues to demonstrate additional understanding of processes expected to occur during postclosure at a potential Yucca Mountain repository. A second purpose of the report is to document the various

applications of natural analogues to geologic repository programs, focusing primarily on the way analogues have been used by the Yucca Mountain Project.

The report states that since no single site will be a perfect analogue to all ongoing and anticipated processes at Yucca Mountain, focus is placed on identifying sites having analogous processes rather than total system analogues. Care must also be exercised to exclude those analogues for which initial and/or boundary conditions are poorly known and where important data, such as the source term, are poorly constrained and may not be obtainable. A given site will usually only be analogous to some portion of a repository or to a subset of processes that will occur in a repository. Furthermore, additional processes will have occurred that are not characteristic of a repository. Therefore, choices must be made to select the processes of greatest relevance and the ability to isolate them for study. The long-term nature of analogues introduces some limitations and uncertainties, but analogues can still be used effectively if appropriate selection criteria are determined and applied.

Section 3.2-3.4 - (Repository Drift Stability Analogues)

There are no exact analogues to the openings that would be created for a potential repository at Yucca Mountain, but numerous examples demonstrate that both natural and man-made underground openings can exist for thousands of years in a wide variety of geologic settings, even with minimal or no engineering. The report also acknowledges an inherent bias is reflected in the studies because of the difficulty of determining the relative percent of openings that remain versus those that have collapsed. It is more difficult to evaluate the cause of collapse of such openings, whether by human interference or natural causes. However, the report does not elaborate how this bias will be accounted for in future analyses.

Section 6.2 (Preservation of artifacts)

This section presents the natural analogue studies of corrosion. It lists some of the sites where the survival of metal archaeological artifacts over prolonged periods of time is related to the corrosion-resistant properties of metals and metal alloys, the development of protective passive film coatings with the onset of corrosion, and the location of artifacts in arid- to semi-arid environments. Such features can be used to select materials and design configuration to enhance the durability of waste packages at Yucca Mountain. It also presents naturally occurring metals like Josephinite and Chromite as natural analogues. The survival for millions of years of the naturally occurring ordered nickel-iron alloy found in Josephinite (with only relatively minor amounts of surface oxidation) indicates that this material is highly resistant to oxidation and other forms of corrosion that occur in its geologic environment. While the composition of this metal differs from Alloy 22 (in that it does not contain chromium, molybdenum, and tungsten), it does provide evidence that a similar alloy can remain passive over prolonged periods of time. Another observation presented is the potential instability of chromium-bearing materials, illustrated by the observed natural release (under ambient conditions) of chromium from chromite in the Sierra de Guanajuato ultramafic rocks. Corrosion appears to be concentrated along exsolution rims, analogous to structural defects on metal surfaces. While the chromite has undergone some alteration, it has survived for over 140 million years. The report states that the corrosion behavior of this chromium oxide mineral may differ from that of the chromium-bearing metal alloys that are currently slated for use in the construction of the waste package. However, it could provide insight into corrosion processes that could potentially be associated with Alloy 22.

Section 8.2-8.4 (Seepage)

This section examines several different types of qualitative and quantitative natural analogues for seepage. For the quantitative analogues, two cases - Kartchner Caverns, Arizona, and a cave at Altamira, Spain, have been presented. Both of these examples are from natural limestone caves in fractured karst terrain. It follows from these examples that unsaturated zone (UZ) flow would be dominated by fracture flow, just as it is at Yucca Mountain. These examples are of caves where significant seepage was measured and thus address the General Agreement 1.01 comment 75. The amount of seepage observed at these analogue sites is a very small percentage of the percolation flux. However, this section does not present any anthropogenic openings that use ground support systems (mine shafts, etc). Since Yucca Mountain will have excavated tunnels that use ground support structures, the processes that control seepage could be different from natural openings like caves that have fewer asperities. These natural openings also do not account for the absence of ventilation (post closure period) on seepage and relative humidity conditions in the drift. Though the similarities of these sites to Yucca Mountain are presented, details regarding other case studies available in the literature, criteria for presenting only these two cases, and the cause for rejection of other case studies are not discussed.

Section 8.5 (Summary of Seepage Analogues)

The NRC staff recognizes the difficulty of identifying natural analogues of Yucca Mountain seepage that represent long time periods. For example, most natural caves are open to ventilation from the outside and have fewer asperities than would exist in an excavated tunnel. The roof and ceiling of the opening at Yucca Mountain will have a greater frequency of asperities than the example sites presented in the report, especially where localized drift roof collapse takes place. The analogue report states that "In the few instances where dripping has been noted in settings that are analogous to Yucca Mountain, the drips can be attributed to asperities in the surface of the roof and ceiling of the opening." (p.8-7).

The natural analogue report clearly highlights the importance of relative humidity. "One important variable for preservation in underground openings is relative humidity. It is obvious that if relative humidity in the drift is kept below 100% by ventilation, then seepage of liquid water would be reduced or completely suppressed." (p.8-6). Ventilation is the factor that prevents natural caves and man-made underground openings documented in this report from being close analogues of Yucca Mountain. The analogue report states, "These caves are naturally ventilated; thus, the amount of seepage in these caves would be expected to be low. This would also be true at Yucca Mountain while ventilation is maintained." (p.8-7) The current design schedule of a potential repository stipulates that the drifts be sealed after the pre-closure period.

Section 9 (Analogues for Unsaturated Zone Flow)

The section titled “Analogues for Unsaturated Zone Flow” mentions Apache Leap and Rainier Mesa, but does not present them as analogues. The only analogue presented is the modeling of UZ flow and tracer tests at the Radioactive Waste Management Complex at Idaho National Engineering and Environmental Laboratory (INEEL). A summary of the interpretation from the study and the relevance to the Yucca Mountain site are stated as follows, "Preliminary results indicated that while the dual-permeability conceptual model can be used to simulate unsaturated flow, it does not adequately simulate conservative transport in fractured basalt." "This conclusion is especially significant to the site-scale Yucca Mountain model, in which, the dual-permeability approach is used extensively to simulate both unsaturated flow and transport in fractured tuff." (p.9-13).

Section 10.3-10.5 (Analogues to Unsaturated Zone Transport)

This section presents updates on two recent studies examining transport of radionuclides in UZ conditions. The first is a study of migration of radionuclides at INEEL with the objective of explaining mechanisms responsible for detection of concentrations of neptunium and uranium in monitoring wells below the water table. The second study presents results of analyses and modeling of uranium systematics at Peña Blanca, Mexico, based on water sampling campaigns in 2000 and 2001. Additional insights derived from natural analogues in Steenkampskraal, South Africa, and Koongarra, Australia, on the significance of colloid transport in the UZ are also presented. The report concludes that the hydrogeologic and geochemical setting at Peña Blanca is closely analogous to that at Yucca Mountain and the INEEL site presents a far wetter environment than that of Yucca Mountain. The wetter environment at INEEL is manifested in higher infiltration at the Subsurface Disposal Area and flooding events that could have resulted in enhanced radionuclide migration beneath it. It is stated that the UZ Flow and Transport Model at Yucca Mountain considers a range of infiltration rates that are then used to bound the range of percolation flux. Because the non-welded Paintbrush unit has a damping effect on flow to the welded Topopah Spring unit, it is unlikely that the enhanced transport scenario proposed in the INEEL modeling study would occur at Yucca Mountain. It should be noted that there could be alternative flow pathways that could cause enhanced transport at Yucca Mountain and studies at INEEL can aid in understanding such scenarios. However, INEEL provided the closest similarity in that it occurs in a fractured porous medium with perched water zones and units of varying permeability. It provided the additional advantage of data sets that included radionuclides, which strengthen model testing aspects of the analogue study.

Section 11.2-11.5 (Analogues to Thermally Coupled Processes)

This section presents natural analogue sites with observations of geothermal effects. It includes the results of an extensive survey of geothermal literature for the purpose of obtaining insights from coupled processes operating in geothermal fields, a detailed examination of thermal-hydrological-chemical (THC) processes relevant to the Yucca Mountain drift-scale system observed at the Yellowstone, Wyoming, geothermal field, results of a field investigation and modeling study of evidence left in a fossil hydrothermal system at Paiute Ridge, Nevada and some examples of evidence for THC effects on transport. Geothermal systems illustrate a variety of THC processes that are relevant to Yucca Mountain. They include advective and conductive heating, fracture-dominated fluid flow, chemical transport, boiling and dryout, condensation, and mineral alteration, dissolution, and precipitation. While the amounts of heat and fluid flow at Yellowstone are orders of magnitude greater than those expected for Yucca Mountain, the link between boiling, increased silica concentrations, and resulting precipitation of amorphous silica can still be applied to the Yucca Mountain system. THC processes are expected to have a much smaller effect on hydrogeological properties at Yucca Mountain than what is observed at Yellowstone, because of unsaturated conditions, lower temperatures, and much lower fluid fluxes that will result in less extensive water-rock interaction. Field, laboratory and modeling studies at the Paiute Ridge complex offered some insights into magmatic intrusions in tuffaceous rock above the water table that are analogous to the potential Yucca Mountain high-level nuclear waste repository following emplacement of waste.

Summary: The NRC staff recognizes the difficulty of identifying natural analogues of Yucca Mountain seepage that represent long time periods and extensive fracture systems. Although none of the analogues closely replicate future conditions in a geologic repository at Yucca Mountain, DOE has provided an adequate description and analysis of a variety of analogue sites, with sufficient detail to meet the intent of USFIC Agreement 4.07 and General Agreement 1.01 (#75).

The NRC notes that natural analog studies are not specifically required by 10 CFR Part 63, but they clearly are recognized as useful approaches for providing the technical basis for performance assessment models [e.g., Part 63.114(g), 63.21(c)(15)]. The natural analog studies pertaining to USFIC Agreement 4.07 and General Agreement 1.01 (#75) deal mainly with the application of drift seepage models to performance assessment. The natural analog studies of seepage into underground openings do provide limited support to the concept that the amount of dripping from drift ceilings is expected to be significantly reduced from the percolation flux reaching the top of the drift. These studies do not, however, provide a sufficient quantitative technical basis to either support or bound estimates of seepage fractions and seepage fluxes used in the DOE performance assessment models. Thus, while DOE has provided the information requested in the subject agreements and these agreements can be considered complete, it is emphasized that additional technical basis is needed to justify the drift seepage abstraction for performance assessments (e.g., see USFIC Agreements 4.01 to 4.03 and Total System Performance Assessment and Integration Agreement 3.27).

Additional Information Needed: None at this time.

Status of Agreements: USFIC Agreement 4.07 is "complete." Comment 75 of General Agreement 1.01 has also been addressed satisfactorily.