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NUCLEAR REGULATORY COMMISSION
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AUG 22 1994

Mr. Ronald A. Milner, Acting Director
Office of Program Management and Integration
Office of Civilian Radioactive Waste Management
U.S. Department of Energy, RW 30
1000 Independence Avenue
Washington, D.C. 20585

Dear Mr. Milner:

SUBJECT: REVIEW OF THE U.S. DEPARTMENT OF ENERGY (DOE) STUDY PLAN ON "SITE UNSATURATED-ZONE MODELING AND SYNTHESIS (REVISION 0)" (8.3.1.2.2.9)

On July 14, 1993, DOE transmitted the subject study plan to the Nuclear Regulatory Commission for review and comment. The NRC staff has completed its review of the subject study plan using the "Review Plan for the NRC Staff Review of DOE Study Plans, Revision 2," (dated March 10, 1993). Based on its review of the study plan, the staff considers the material submitted consistent, to the extent possible, at this time, with the revised NRC-DOE "Level of Detail Agreement and Review Process for Study Plans," (dated March 22, 1993).

A major purpose of the review is to identify concerns with studies, tests, or analyses that, if started, could cause significant and irreparable adverse effects on the site, the site characterization program, or the eventual usability of the data for licensing. Such concerns would constitute "objections," as that term has been used in earlier NRC staff reviews of DOE documents related to site characterization, (e.g., "Consultation Draft Site Characterization Plan") and the "Site Characterization Plan for the Yucca Mountain Site.") It does not appear that the conduct of the activities described in this study plan will have adverse impacts on repository performance and the review of this study plan identified no objections with any of the activities proposed.

As part of its study plan review, the NRC staff also determines whether or not detailed comments or questions are warranted. The NRC staff's review of the subject study plan has resulted in the identification of one comment and five questions. The enclosed comment and questions will be tracked by the NRC staff as open items similar to those previously raised by the NRC staff in its 1989 Site Characterization Analysis.

Finally, the staff's review of the activities described in this study plan indicate that much of the work appears to meet the scope of the procedure for scientific notebooks, (see YMP-USGS-QMP-5.05, Rev. 3). However, there is no information in the study plan regarding how the development of models under this study will be documented. The staff

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has recently identified an open-item comment during reviews of other related study plans, (e.g., 8.3.1.2.3.3, "Site Saturated-Zone Hydrologic System Synthesis and Modeling," dated January 1993 and 8.3.1.5.2.2, "Characterization of Future Regional Hydrology due to Climate Changes," dated December 1994.) This open item expresses the concern that the process of creating groundwater models may not be reproducible unless it is adequately documented. Unless these types of study plans contain information on how the modeling work is to be documented, then this open item applies to all modeling and synthesis studies under the DOE's high-level waste program.

If you have any questions concerning this letter, please contact Michael P. Lee at (301) 415-6677.

Sincerely,
/s/
Joseph J. Holonich, Chief
High-Level Waste and Uranium Recovery
Projects Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

Enclosure: As stated

*See Previous Concurrence

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Study Plan 8.3.1.2.2.9
Site Unsaturated-Zone Modeling and Synthesis, Revision 0

Comment 1
The list of hydrologic issues to be resolved by this study plan appears to neglect the possibility that the Solitario Canyon fault could act as a short-circuit for water to infiltrate laterally into the repository and the effect on the spatial distribution of flux by highly conductive fracture networks, which might extend from the surface, through the non-welded units, into the repository horizon and down to the water table.

Basis
In section 3.1.3.2, on pages 3.1-7 through 3.1.-10, five hydrologic issues that were previously identified in the SCP are listed. As is stated on page 3.1-6, "[r]esolution of these issues may be considered one of the principal objectives of this activity." The five issues are: (1) "the role of faults in the hydrologic system;" (2) "the role of the Paintbrush tuff non-welded unit on the hydrologic system;" (3) "investigation of the expected relative contributions of liquid-water and water-vapor fluxes to the net moisture flow within the unsaturated-zone system;" (4) "assessment of the likelihood for the occurrence of geothermally or barometrically driven convection cells involving the upward flow of water vapor with a corresponding downward return flow of water;" and (5) the "potential for downward flow to bypass the zeolitic facies of the Calico Hills unit."

However, these issues do not appear to address the possibility that the Solitario Canyon fault could act as a short-circuit for water to infiltrate laterally into the repository horizon or the effect of highly conductive fracture networks extending from the surface, to the water table, on the rate and spatial distribution of flux. Both of these issues (conceptual models) have the potential to increase the flux of water through the repository and therefore increase the rate of radionuclide release from waste packages and the rate of radionuclide transport to the accessible environment.

Recommendation
Describe how the possibility that the Solitario Canyon fault could act as a short-circuit for water to infiltrate laterally into the repository will be considered. Describe how the potential effect on the spatial distribution of flux by highly conductive fracture networks, which might extend from the land surface to the water table will be considered.

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Question 1
Will this study plan evaluate the importance of wetting front instabilities for modeling the Yucca Mountain hydrologic regime?

Basis
This study plan identifies five hydrologic issues; resolution of which is considered to be a principal objectives of this study plan. One of these issues is the "role of the Paintbrush tuff nonwelded unit (PTn)" on the hydrologic system. This issue will investigate the possibility that downward-flowing water may be diverted laterally within the Paintbrush Tuff and at the contacts with adjacent units, shedding water around the potential locations of waste-emplacement drifts.

However, the study plan appears to assume that wherever a fine-grained unit overlies a coarse-grained unit in the unsaturated regime, a capillary barrier will form which, due to the mild eastward dip of all units within Yucca Mountain, will tend to divert infiltrating water away from the repository block. In Section 3.1.3.2, on page 3.1-13, it is stated that "[w]hen materials with relatively small pores overlie material with relatively large pores, water movement into the underlying material is delayed if matrix potentials at the interface between the two materials are low and the effective hydraulic conductivity of the underlying unit is too low to accept the flux." It is asserted that "[t]his condition may exist between adjacent subunits within the PTn unit, or between the PTn unit and the fractures of the underlying welded units." Moreover it is noted that "[t]he formation of capillary barriers in layered sequences can promote the lateral spreading of localized infiltration." The study plan cites analytical studies performed by Ross, (1990) which "[suggest] that a capillary barrier capable of diverting 15 to 200 meters^3 of water per year per meter thickness along the strike of the beds may be formed between the Paintbrush nonwelded unit and the underlying fractures of the Topopah Spring hydrogeologic unit."

However, wetting front instabilities often form along capillary barriers. These wetting front instabilities produce vertically extensive wetted channels or "fingers" along which flux rates may be quite rapid. The phenomenon of wetting front instabilities as evidenced by the generation of fingers has been observed in laboratory experiments in which water is introduced at the top of a column composed of a fine-grained sand overlying a coarse-grained sand [Miller and Gardner (1962), Peck (1965), Hill and Parlange (1972), Diment and Watson (1983), Glass *et al.* (1989), and Baker and Hillel (1990)]. According to Hillel and Baker (1988) the larger air-entry value for the coarser underlying layer restricts transmission of water across the soil interface until the water pressure in the overlying layer is great enough to wet the adjacent, larger pores. However, because the spatial distribution of pore-sizes along the interface is not uniform, transmission of water across the interface will not occur simultaneously at all locations. Factors that may attenuate the growth of fingers are decreasing material pore-size and decreasing hydraulic conductivity encountered by the

fingers as they propagate. In the absence of these factors, fingers may propagate very rapidly through the medium and thus serve as fast pathways both to and from the repository. Unfortunately, unless the model explicitly incorporates lateral variations in air entry pressures along the interface of the units, standard numerical models may be unable to model the potential for wetting front instabilities to develop at the transition from a bedded tuff unit to a densely welded, highly fractured unit.

Recommendation

Explain why wetting front instabilities are not important to modeling the Yucca Mountain flow regime or explain how it will be determined if they are important or unimportant to modeling flow. If it is determined that wetting front instabilities may result in fast pathways through the repository or are significant for other reasons to modeling the Yucca Mountain hydrologic regime, it is recommended that modelling approaches be developed to incorporate this effect.

References

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Ross, B., "The Diversion Capacity of Capillary Barriers," *Water Resources Research*, 26(10):2625-2629 [1990].

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Question 2
How will hydrologic parameters which describe the hydrologic properties of fractures in the unsaturated zone, such as fracture flow as a function of water content, fracture porosity, and water movement between the fractures and the matrix be obtained from site data?

Basis
Models of ground water flow through Yucca Mountain will be dependent on site characterization activities to provide information, which can be used to derive hydrologic parameters needed by the models. Therefore, successful site characterization will be dependent on the development of techniques to both gather data and to derive hydrologic parameters from the data. Determining, under what conditions fracture flow could occur and the direction and rate of flow, will be important for calculating the anticipated performance of Yucca Mountain. However, the NRC staff is not aware of any techniques to obtain hydrologic parameters that describe the resistance to flow (hydraulic conductivity) through a fracture as a function of water content, fracture porosity, or how water moves between the fractures and the matrix (in a porous equivalent code this would be equivalent to the characteristic curves, fracture porosity, and resistance to flow between the fracture and matrix).

The staff recognizes that many models of Yucca Mountain will probably not model single fractures, but will use parameters that represent the hydrologic properties of large numbers of fractures. However, again the NRC staff is not aware of any techniques to determine for large numbers of fractures, hydrologic parameters that describe the resistance to flow (hydraulic conductivity) as a function of water content, porosity, or how water moves between the fractures and the matrix. In single continuum porous equivalent codes, this would be equivalent to the combined hydraulic conductivity characteristic curves of fractures and matrix and the combined porosities of fractures and matrix. For dual continuum porous equivalent codes this would be equivalent to the characteristic curves representing the fractures, porosities of the fractures, and a transfer term representing resistance to flow between fractures and matrix.

The staff recognizes that other modeling approaches than those mentioned above may be used to model unsaturated flow through Yucca Mountain. However, whatever the modeling approach, the ability to derive the fracture hydrologic parameters will be key to determining flow direction, flow magnitude, and when fracture flow is initiated.

Recommendation
Explain how hydrologic parameters, which describe unsaturated zone fracture hydrologic properties, will be obtained from site data.

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Question 3
How will local potential gradients of water within a fracture or a set of fractures be measured so that net moisture flux rates can be inferred?

Basis
On page 2.1-1, in the second paragraph, it is stated that "[n]et moisture flux, occurring in both liquid and vapor phases, is not accessible to direct *in-situ* measurement and, therefore, must be inferred from the local potential gradients and hydraulic conductivities or effective vapor diffusion coefficients." *In-situ* measurement of local potentials, while difficult to perform, can be obtained from the rock matrix. If water flows primarily through the rock matrix, such measurements may be sufficient for characterizing the net moisture flux through Yucca Mountain. However, using this approach, if fractures play a significant role in transporting water throughout the mountain, *in-situ* water potentials within the fractures must also be measured. At this time the NRC staff is not aware of any methods that can measure *in-situ* fracture water potentials.

Recommendation
Give a thorough description of the methods that will be used to measure water potential in fractures.

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Question 4
Which smaller-scale hydrologic sub-models will be calibrated using experimentally induced perturbations from Yucca Mountain surface and subsurface tests?

Basis
In the paragraph at the top of the page 2.1-6, it is stated that "[i]t is not expected that experimentally induced perturbations can practically be included in the calibration process because of the long time factors involved." It is probably true that the surface and subsurface tests which will be conducted at the site will not last long enough to induce changes that can be used to calibrate a large scale site model. However, these tests could still be used to calibrate smaller scale sub-models, which will be used to design the large scale site model.

Recommendation
If experimentally induced perturbations by Yucca Mountain surface and subsurface tests will be used to calibrate smaller scale sub-models, then DOE should: (1) identify those submodels relevant to this study plan that will be calibrated in this manner; and (2) generally describe how they will be used to design the large scale site model.

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Question 5
How will this study plan evaluate the importance of modeling the non-Darcian flow regime that may occur at seepage faces formed in wide, rubble-filled fault zones?

Basis
This study plan identifies five hydrologic issues; resolution of which are considered to be principal objectives of this study plan. One of these issues is the "role of faults in the hydrologic system." This issue will investigate the possibility that "if faults are open they may intercept water flowing parallel to unit contacts and redirect this flow downward" and the possibility that if fault openings are so large that they function as seepage faces, perched-water bodies may form on the up dip side of the fault.

In reviewing the study plan, it appears that Darcian or equivalent porous media codes will be used to investigate these possibilities. However, the dynamics of flow on a seepage face will be determined strongly by water viscosity and gravity. Therefore, it may be easier to analyze this as a fluid continuum problem, than to devise a defensible effective porous continuum equivalent for such a phenomenon. The fluid continuum may be coupled to the porous matrix via moisture diffusion if the seeping water encounters an unsaturated-zone.

Recommendation
Explain how it will be determined if seepage faces formed in wide rubble-filled fault zones are important to modeling the Yucca Mountain hydrologic regime. If seepage faces may be important, explain the need to consider non-darcian flow modeling approaches.