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NUCLEAR REGULATORY COMMISSION
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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 SATURATED-ZONE HYDROLOGIC SYSTEM SYNTHESIS AND MODELING, REVISION 0" (8.3.1.2.3.3)

On January 28, 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 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, 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 (SCP) 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 six 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 (SCA). (An number of editorial corrections were also identified; see Enclosure 2.)

As part of its review, the staff have recently identified a concern, in this and other synthesis and modeling study plans, regarding documentation of DOE modeling efforts. For example, this study plan states that technical procedures do not apply to any of the three work activities. However, it is the staff's understanding that in instances where technical procedures do not

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apply, scientific notebooks will be employed in their place. Based on the staff's review of the activities described in this study plan, much of the work does appear to meet the scope of the procedure for scientific notebooks (see YMP-USGS-QMP-5.05, Rev. 3). Therefore, there appears to be a gap in the documentation of the modeling work. (The NRC staff have also identified a similar gap as part of its on-going review of Study Plans 8.3.1.5.2.2 ("Characterization of Future Regional Hydrology due to Climate Changes," dated December 1992) and 8.3.1.2.2.9 ("Site Unsaturated-Zone Modeling and Synthesis," dated July 1993).) For each of these synthesis and modeling study plans, and perhaps others under the Yucca Mountain project, DOE should describe how in-progress work will be documented. The relationship of the study plans to scientific notebook procedures should also be described.

Finally, the NRC staff wishes to note that in its transmittal letter, DOE did not identify any SCA open items related to this study plan. The NRC staff considers that several SCA open items are directly related to development of conceptual models under this study plan, and to the related SCP Study 8.3.1.2.3.1.1-6, "Characterization of the Site Saturated-Zone Groundwater Flow System" (Revision 0) (dated May 1990). For example, SCA Comment 19 states that activities for the study of the saturated zone are not adequate to characterize hydrologic boundaries, flow directions and magnitudes, and flow paths. One of the recommendations made under Comment 19 was that one or more additional multiple-well sites (similar to the C-hole site) should be constructed. Moreover, SCA Comment 20 states that the potentiometric surface in the controlled area is not adequately defined by existing well locations, and will not be adequately defined by proposed additional well sites. This study, therefore, does not make progress toward resolution of these two SCA open items.

If you have any questions concerning this review, 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
cc: See Attached List

OFC	HLUR	E	HLUR		PAHB	E	[illegible]	E	PAHB	N
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cc: List for Milner Letter Dated: AUG 22 1994

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STUDY PLAN 8.3.1.2.3.3
SITE SATURATED-ZONE HYDROLOGIC SYSTEM SYNTHESIS AND MODELING

Comment 1
Hydrochemical data should be used to support conceptual and numerical groundwater models for the saturated zone. This is an important element in the synthesis of these models.

Basis
Section 3.1.3.2 discusses the development and validation of conceptual and numerical models. The only reference to using geochemical data occurs in the last paragraph on page 3.1-10. "Matching of simulated versus observed hydraulic heads, fluxes, gradients, and possibly geochemistry, and comparison of model results with past data will constitute the calibration process. Closeness of the simulated model results to the observed data will be judged by the investigators and by the methods discussed in Section 2.1.6." Section 2.1.6 refers to geochemical data only once: "In addition, the calibration process will involve an examination of the observed versus predicted water levels, gradients, fluxes, and possibly geochemistry produced from the flow model."

The plan does not state whether conceptual or numerical groundwater models will be evaluated by comparing them with hydrochemical data that can provide insight about recharge sources, discharge areas, flow paths, the degree of mixing between hydrologic units, groundwater ages, and groundwater travel times. This would consist of a broad range of hydrochemical information from the saturated and unsaturated zones, including data on stable and radioactive isotopes (i.e., environmental tracers such as tritium, chlorine-36, carbon-14, iodine-129, oxygen-18, and deuterium)((Pearson and White, 1967; Bath *et al.*, 1979; Freeze and Cherry, 1979; Fritz and Fontes, 1980; Kyser, 1987). The geochemistry of minerals within fractures and general alteration of rock chemistry may also provide insights about flow conditions.

Several DOE studies will evaluate hydrochemistry at the site. These include Study 8.3.1.2.3.2 ("Characterization of the Yucca Mountain Saturated-Zone Hydrochemistry") and Study 8.3.1.2.2.7 ("Hydrochemical Characterization of the Unsaturated Zone"). These plans are not referenced in the study plan, and only one of these appears in Figure 1.1-1, which shows the position of Study 8.3.1.2.3.3 within the overall saturated-zone hydrology investigation. Most importantly, these two hydrochemical studies are not cited in Section 2.1.7, which describes contributions to this study from other studies.

Recommendation
The Study Plan should explicitly describe how hydrochemical data will be used to help develop and substantiate conceptual and numerical models. Other study plans related to hydrochemical characterization should be referenced in this study plan. Specifically, Studies 8.3.1.2.3.2 and 8.3.1.2.2.7 should be added to Section 2.1.7 of this study plan.

References

Bath, A.H., W.M. Edmunds, and J.N. Andrews, "Paleoclimatic Trends Deduced from the Hydrochemistry of a Triassic Sandstone Aquifer, United Kingdom," *Isotope Hydrology 1978*, Vienna, Austria, International Atomic Energy Agency, 2:545-568 [1979].

U.S. Department of Energy, "Hydrochemical Characterization of the Unsaturated Zone," Office of Civilian Radioactive Waste Management, Study Plan 8.3.1.2.2.7 (Rev. 0), September 1990. [Prepared by the U.S. Geological Survey.]

U.S. Department of Energy, "Characterization of the Yucca Mountain Saturated-Zone Hydrochemistry," Office of Civilian Radioactive Waste Management, Study Plan 8.3.1.2.2.7 (Rev. 0), April 1992.

Freeze, R.A., and J.A. Cherry, *Groundwater*, Englewood Cliffs, NJ, Prentice-Hall, Inc, 1979.

Fritz, P., and J.Ch. Fontes, "The Terrestrial Environment," in *Handbook of Environmental Isotope Geochemistry*, 1(A):66-67 [1980].

Kyser, T.K., "Short Course in Stable Isotope Geochemistry of Low Temperature Fluids," Mineralogical Association of Canada, vol. 13, 1987.

Pearson, F.J., and D.E. White, "Carbon-14 Ages and Flow Rates of Water in Carrizo Sand, Atascosa County, Texas," *Water Resources Research*, 3(1):251-261 [1967].

STUDY PLAN 8.3.1.2.3.3
SITE SATURATED-ZONE HYDROLOGIC SYSTEM SYNTHESIS AND MODELING

Question 1
Under this study plan, which hydrologic codes may be used to simulate complex heterogeneities in the saturated zone? Are stochastic or geostatistical simulation techniques being considered?

Basis
In Section 3.3.3.2, page 3.3-11, it is stated as hypothesis 1 that "three-dimensional numerical models capable of reproducing complex heterogeneity may be needed." However, it is not clear which existing codes may be used under this study plan, and whether they will incorporate stochastic or geostatistical techniques.

Three-dimensional geostratigraphic models provide a framework for representing complex heterogeneities, which include the structural and stratigraphic elements of a natural system. However, these models typically assume homogeneous structural units, which may lead to non-conservative estimates of groundwater velocities.

Gelhar (1993) provided an excellent discussion on the stochastic approach. In many applications, the goal of modeling subsurface hydrological processes is, according to Gelhar, "... to develop methods that can be used to quantify large-scale flow and transport in complex, naturally variable, subsurface flow systems...." The mean behavior of such flow systems, as estimated by stochastic approaches, is often in agreement with the classical deterministic model results. However, Gelhar considers estimating the degree of variability in a predicted quantity to be an important issue. According to Gelhar, this is because "... local variations in hydraulic properties can have an important influence ..." and, therefore, should be accounted for when attempting to "... have some quantitative measure of the degree of variability around the predicted large-scale mean behavior ...."

Others have also recognized the importance of local variability in hydraulic properties. Gotway (1994) presented an overview of the geostatistical simulation approach and summarized some results of efforts associated with the Waste Isolation Pilot Plant (WIPP). In these modeling efforts, GWTT estimates are characterized by cumulative distribution functions ranging from 10,000 to 35,000 years. Similarly, Bagtzoglou and Baca (1994) presented an analysis of GWTT for a system analogous to Yucca Mountain. According to their analyses, a mild heterogeneity (as inferred by the variance of the logarithm of hydraulic conductivities being less than unity) reduces the GWTT estimate by 30 percent when stochastic heterogeneities are included. Even though these findings are preliminary, they demonstrate the non-conservative nature of deterministically-calculated flow and transport processes.

Geologically-based stratigraphic models of the saturated zone at Yucca Mountain need to be enhanced by intra-layer heterogeneity (stochastically or deterministically generated) if a conservative estimate of groundwater velocities is required.

Recommendation
Clarify which hydrologic codes may be used to simulate complex heterogeneities. Describe the

manner in which each code incorporates these heterogeneities. Identify any stochastic or geostatistical simulation techniques that are being considered.

References

Bagtzoglou, A.C., and R.G. Baca, "Probabilistic Calculations of Groundwater Travel Time in Heterogeneous Three-Dimensional Porous Media," *Materials Research Society Symposium Proceedings*, 333:849-854 [1994].

Gelhar, L.W., *Stochastic Subsurface Hydrology*, Prentice Hall, Englewood Cliffs, NJ, 1993.

Gotway, C.A., "The Use of Conditional Simulation in Nuclear-Waste-Site Performance Assessment," *Technometrics*, 36(2):129-141 [1994].

STUDY PLAN 8.3.1.2.3.3
SITE SATURATED-ZONE HYDROLOGIC SYSTEM SYNTHESIS AND MODELING

Question 2
What methods will be used to incorporate "soft" information in the analysis of hydrologic parameters? Will indicator kriging be used, or perhaps more exotic techniques (e.g., Journel, 1983; 1986)?

Basis
In Section 3.1.3.1, page 3.1-7, the study plan suggests that in order to compensate for the sparsity of data, methods "to incorporate soft information into the analysis" can be implemented. Various types of soft data are suggested (i.e., results from geologic and seismic work) as useful sources of information, yet no specific technique of performing such a procedure is mentioned.

Recommendation
State what method(s) this study will use to incorporate "soft" information into the conceptual and numerical models.

References
Journel, A.G. "Non-Parametric Estimation of Spatial Distributions," *Mathematical Geology* 15(3):445-468 [1983].

Journel, A.G., "Constrained Interpolation and Qualitative Information -- The Soft Kriging Approach," *Mathematical Geology*, 18(3):269-286 [1986].

STUDY PLAN 8.3.1.2.3.3
SITE SATURATED-ZONE HYDROLOGIC SYSTEM SYNTHESIS AND MODELING

Question 3
The integration of this study with other planned site characterization activities is not clear and does not appear to be complete. How will this integration be assured?

Basis
On page 2.1-14, this study plan refers to other studies that will be providing contributions. Not present within the list is Study Plan 8.3.1.4.3.1 "Systematic Acquisition of Site-Specific Subsurface Information." While data from Study Plan 8.3.1.4.3.1 will be incorporated into many of the modeling studies, it would appear to be a key data source for this study plan.

On page 3.2-7, this study plan indicates that "stiffness theory" is described in Study Plan 8.3.1.4.2.2 ("Characterization of Structural Features in the Site Area"). Stiffness theory is only briefly mentioned in Study Plan 8.3.1.4.2.2 and the key reference, Schoenberg (1980), is not included in Study Plan 8.3.1.4.2.2.

On page 3.2-7, this study plan indicates that the construction of a geophysical model of fracture-network geometry using seismic tomography performed under Study Plan 8.3.1.4.2.2 is a key component. Study Plan 8.3.1.4.2.2 refers to the seismic tomography study at the C-hole locations as a test and that "it is hoped" that details of fracturing (such as orientation and density) can be defined.

Recommendation
Clarify what appears to be incomplete integration between this study plan and Study Plans 8.3.1.4.2.2 and 8.3.1.4.3.1, and recognize that the geophysical models of fracture network geometry are dependent on the results of the planned tests in Study Plan 8.3.1.4.2.2.

STUDY PLAN 8.3.1.2.3.3
SITE SATURATED-ZONE HYDROLOGIC SYSTEM SYNTHESIS AND MODELING

Question 4
What is meant by "actual results should be bounded in a statistical sense by predicted results."

Basis
In Section 3.2.3.2.2, page 3.2-17, it is stated "If the models are valid representations of the actual system, actual results should be bounded in a statistical sense by predicted results." In the preceding paragraph, it is stated that "...predictions probably will be expressed statistically, either as a range of probable results or as a best estimate of results and associated confidence regions." The statistical methods to be used in this process are not identified.

Recommendation
Provide an explanation of the statistical methods that will be used.

STUDY PLAN 8.3.1.2.3.3
SITE SATURATED-ZONE HYDROLOGIC SYSTEM SYNTHESIS AND MODELING

Question 5
How will upper and lower boundary conditions be selected for a three-dimensional groundwater model at the scale of the controlled area? Will the Paleozoic aquifer system be included in the model?

Basis
On page 3.1-2 it is stated that boundary and initial conditions for site-scale numerical modeling will be derived from studies of Quaternary regional hydrology and regional hydrologic synthesis and modeling. "Physical boundaries will be selected specific to this study, but fluxes across those boundaries will be calculated from the regional models." The current regional model is the base-case model of Czarnecki (1985), which is a vertically integrated, two-dimensional model of the Alkali Flat-Furnace Creek Ranch subbasin. In that model, Czarnecki assumed a uniform thickness of 1000 meters for the unconfined aquifer. No upward recharge from lower depths was considered.

It is understood that a three-dimensional (3-D), regional groundwater model is under development by the DOE, and that methods to estimate regional boundary conditions have been evaluated (Downey *et al.*, 1990). However, the NRC staff previously developed an open item regarding 3-D regional modeling (see NRC, 1993). One of the staff's recommendations was that DOE should be able to demonstrate that sufficient data have been obtained to support planned 3-D regional modeling, particularly for the Paleozoic carbonate aquifer. This concern exists because of a statement contained in the study plan to characterize the regional flow system (DOE, 1991, p. 3.1-6):

> "Little is known about the distribution of hydraulic head with depth within the flow system. Hydraulic-head data in the vertical dimension are critical for calibrating three-dimensional models of ground-water flow. At present, only a handful of points exist where hydraulic head has been determined at various depths."

In the site vicinity, only one borehole penetrates the Paleozoic aquifer system. As described on page 3-201 of the Site Characterization Plan (DOE, 1988), drillhole UE-25p#1 penetrated the Paleozoic aquifer, revealing that the hydraulic head in that aquifer is about 19 meters higher than in the overlying tuffs. Head data from drillholes USW H-1 and USW H-3 indicate an upward hydraulic gradient in tuff units well below the proposed repository horizon. These vertical hydraulic gradients suggest that an upward gradient at depth may exist over a large area. However, it is not known whether the vertical hydraulic characteristics of the deep rocks allow an upward flux to occur that is large enough to influence the shallower flow regime.

With respect to the upper model boundary, Czarnecki (1985, p. 21) performed a hydraulic-head sensitivity analysis of his steady-state, regional model. The result was that changes made to fluxes from the northern boundary (Timber Mountain) and from Forty Mile Wash "had the greatest effect on the water-table position in the vicinity of the primary repository area." This suggests that the site-scale model will need to include recharge from Forty Mile Wash. If the

regional model showed great sensitivity to the assumed recharge along the wash, then the site-scale model should be even more sensitive to this parameter. Czarnecki (1985) had assumed an average annual (steady-state) recharge rate of 410 mm/yr for Forty Mile Wash. This relatively high recharge rate was assumed because the wash becomes a zone of enhanced recharge during major precipitation and runoff events.

Recommendation
Provide a rationale for selecting upper and lower boundary conditions for a three-dimensional, site-scale groundwater model.

References
Czarnecki, J. B., "Simulated Effects of Increased Recharge on Ground-Water Flow System of Yucca Mountain and Vicinity, Nevada-California," U.S. Geological Survey, Water-Resources Investigations Report 84-4344, 1985.

Downey, J. S., K. E. Kolm, and E. D. Gutentag, "Selection of Geohydrologic Boundaries for Ground-Water Flow Models, Yucca Mountain, Nevada," in *Waste Management '90, Proceedings of the Symposium on Waste Management*, Tucson, Arizona, Vol. 2, p. 725-734, 1990.

Holonich, J.J., U.S. Nuclear Regulatory Commission/Division of High-Level Waste Management, Letter to D.E. Shelor, U.S. Department of Energy/Office of Civilian Radioactive Waste Management, [Subject: "NRC Staff Review of Study Plan for Regional Hydrologic System Synthesis and Modeling"], April 6, 1993.

U.S. Department of Energy, "Chapter 3 (Hydrology)" in "Site Characterization Plan, Yucca Mountain Site, Nevada Research and Development Area, Nevada," Office of Civilian Radioactive Waste Management, DOE/RW-0199, Vol. II, December 1988.

U.S. Department of Energy, "Characterization of the Yucca Mountain Regional Ground Water Flow System," Office of Civilian Radioactive Waste Management, Study Plan 8.3.1.2.1.3 (Rev. 0), 1991. [Prepared by the U.S. Geological Survey.]

STUDY PLAN 8.3.1.2.3.3
SITE SATURATED-ZONE HYDROLOGIC SYSTEM SYNTHESIS AND MODELING

Question 6
If additional multiple-well sites are not constructed, how will DOE demonstrate that fracture-network models represent the saturated groundwater system in portions of the controlled area beyond the vicinity of the C-well complex?

Basis
On page 3.2-16 of the study plan, it is stated that the plan for site characterization includes an option to drill and test other multiple-well sites. The decision to do so "will depend on success in developing reliable conceptual models at the C-well complex and the ability of the single-well tests to give reliable estimates of hydraulic properties as compared to tests at the C-well complex." It is further stated that "In addition to providing site-characterization data, the purpose of drilling and testing other multiple-well locations is to validate geophysical and hydrologic models."

This question is related to an existing open item. In SCA Comment 19 (NRC, 1989), the staff questioned the ability of single-well tests to adequately characterize hydraulic properties of the site saturated-zone groundwater flow system. The staff recommended that one or more additional multiple-well sites be constructed.

Recommendation
Describe how verification of fracture-network models can be performed based on data from only one multiple-well site. Also describe how DOE would demonstrate whether the models are representative of the controlled area.

References
U.S. Nuclear Regulatory Commission, "NRC Staff Site Characterization Analysis of the Department of Energy's Site Characterization Plan, Yucca Mountain, Nevada," Office of Nuclear Material Safety and Safeguards, NUREG-1347, 1988.

STUDY PLAN 8.3.1.2.3.3
EDITORIAL COMMENTS

The following editorial corrections were noted during the review and should be addressed in future revisions of the study plan.

- In Section 3.1.3.2, page 3.1-10, Study 8.3.1.2.2.9 is misidentified as 8.3.1.2.9.9.
- Table 2.1-1 is misidentified as Table 2.3-1 in Section 1.3, page 1.3-2.
- Table 1.1-1 has no caption on page 1.3-1.
- In the captions for Table 3.3-1 (pages 3.3-15 and 3.3-16), the SCP section number should be changed to "(SCP 8.3.1.2.3.3.3)."
- Table 3.3-1, page 3.3-15, "Ground-water flux velocities" should read "Ground-water flow velocities."
- Table 3.3-1, page 3.2-19, "multiple-sell" should read "multiple-well."
- Page 3.2-13, Geldon (in press) should have a date.