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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 "CHARACTERIZATION OF FUTURE REGIONAL HYDROLOGY DUE TO CLIMATE CHANGES" (8.3.1.5.2.2)

On December 24, 1992, 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 (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 three 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).

As part of its review (see Comment 1), 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 either of the work activities. However, it is the staff's understanding that in instances where technical procedures do not apply, scientific notebooks will be employed in their

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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 8.3.1.2.3.3 ("Site Saturated-Zone Hydrologic System Synthesis and Modeling," dated January 1993) 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 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
cc: See Attached List

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Mr. Ronald Milner

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STUDY PLAN 8.3.1.5.2.2
CHARACTERIZATION OF FUTURE REGIONAL HYDROLOGY DUE TO CLIMATE CHANGE

Comment 1
There appears to be a gap in the documentation of groundwater modeling work under this study.

Basis
In general, groundwater modeling consists of three main phases:

(1) Development and verification of software (hydrologic process codes);

(2) Creation of groundwater models using appropriate process codes -- this process includes making assumptions about the dimensionality and layering of a model, recharge and discharge boundary conditions, physical properties, and future changes to the hydrologic flow system; this phase also includes model calibration; and

(3) Peer review and approval of modeling publications.

Procedures to document Phases 1 and 3 are listed in Appendix 7.1 of the study plan. However, there appears to be no requirement to document work in progress under Phase 2, the creation of groundwater models.

Appendix 7.1 to the study plan lists quality-assurance requirements. The procedure for a scientific notebook system (YMP-USGS-QMP-5.05, Rev. 3) is not included under the requirements. Much of the work under this study meets the scope of this procedure, which states: "This QMP [procedure] applies to the YMP-USGS and supporting organizations assigned to perform the work related to quality assurance (QA) graded technical activities that produce data, maps, or other products which are the basis for the YMP site characterization, licensing, or environmental monitoring. The Scientific Notebook shall be used when scientific investigations include: (1) trial-and-error, experimental, or innovative methods; (2) emerging technologies; or (3) developmental research. Technical activities conducted as standard, routine, and/or industry accepted practices require Technical Procedures as described in QMP-5.01." With regard to the content of scientific notebooks, this procedure states that "Each entry shall provide sufficient detail to allow another scientist of appropriate experience and qualification to retrace or recreate the investigation process and to properly evaluate the original and new results, without the consultation or guidance of the original PI [Principal Investigator]." The NRC staff considers that documentation similar to that required in scientific notebooks will be required at the time of licensing for staff review of the calibration and validation of models.

In a letter dated November 3, 1993 [D. Shelor (DOE) to J. Holonich (NRC)], DOE indicated that YMP-USGS-QMP-3.03 (Rev. 3) addresses QA for computer codes. However, the staff is concerned that QMP-3.03 covers only code development, validation, and maintenance. There appears to be little documentation of the elaborate process of selecting and rejecting conceptual models and developing modeling parameters to simulate the Yucca Mountain region, based on available field data. The process includes making assumptions about the dimensionality of a model, boundary conditions, physical properties, and future changes to the hydrologic flow system. The Shelor to Holonich letter also mentions QMP-3.04 (Rev. 4) procedure for technical review, approval, and distribution of YMP-USGS publications. It documents the process for approving reports (etc.) for external publication. This procedure governs review of final draft products, but does not document the interactive and elaborate process of creating models.

Given the importance of this study with respect to scenario development and, therefore, performance evaluations and licensing of a HLW repository, it is not clear why model development work is not being documented more thoroughly. Without this kind of documentation, it may be difficult for NRC to evaluate the validity of hydrologic synthesis and modeling work. There is also the question of project continuity. If a PI for a synthesis and modeling project should depart the program, how would the new PI continue the work without documentation of work in progress?

Documentation of model development is discussed by Anderson and Woessner (1992, p. 276). They state that "Keeping a journal or a log during the modeling study is well worth some extra time because it will facilitate report preparation, allow reconstruction of the model at a later time, and also reduce calibration time." They also state that, without appropriate records, it "may be impossible for another modeler to reconstruct the original modeler's thought process." The NRC staff consider that journals or logs would also provide solid foundations for modelers to defend their work during technical audits and peer reviews.

Documentation will also be needed because site models for the unsaturated zone are proposed to be developed under another study (Study Plan 8.3.1.2.2.9 (DOE, 1993)). The surface water, unsaturated zone, and saturated zone regimes actually represent a continuum and must be treated accordingly. The documentation should show that proper coordination between studies has been performed, and ensure that the various models are compatible. For example, the net liquid flux across the earth-atmosphere interface defines the upper boundary condition for flow through the unsaturated zone. Future flux conditions will need to be estimated under the future surface water activity and applied to the unsaturated zone models developed under Study 8.3.1.2.2.9. In turn, output from these models must feed back into the regional saturated zone activity of Study 8.3.1.5.2.2.

Recommendation

The elaborate process of developing groundwater models under this study plan needs to be

Recommendation

The elaborate process of developing groundwater models under this study plan needs to be documented. DOE should describe how this work will be documented, including the relationship to the procedure for scientific notebooks (YMP-USGS-QMP-5.05, Rev. 3).

References

Anderson, M.P. and W.W. Woessner, *Applied Groundwater Modeling: Simulation of Flow and Advective Transport,* Academic Press, Inc., San Diego, CA, 381 p.

U.S. Department of Energy, "Study Plan for Study 8.3.1.2.2.9: Site Unsaturated-Zone Modeling and Synthesis," Office of Civilian Radioactive Waste Management, May 1993. [Prepared by U. S. Geological Survey.]

STUDY PLAN 8.3.1.5.2.2
CHARACTERIZATION OF FUTURE REGIONAL HYDROLOGY DUE TO CLIMATE CHANGE

Question 1
How will the work under this study (regional surface water and saturated zone modeling) be integrated with the site unsaturated zone modeling under Study 8.3.1.2.2.9 ("Site Unsaturated-Zone Modeling and Synthesis")?

Basis
The following comment appears on page 1.1-1 of the subject study plan:

> "This activity [8.3.1.5.2.2.2, "Analysis of Future Unsaturated-Zone Hydrology due to Climate Changes"] has not been included in the study plan because its scientific content has been incorporated in YMP-USGS SP 8.3.1.2.2.9 ("Site Unsaturated-Zone Modeling and Synthesis"). The logic for this change is explained in Section 1.2."

But the only references to unsaturated zone hydrology in Section 1.2 are:

> "The modeling of the site unsaturated zone under conditions of greater-than-present effective precipitation (SCP Activity 8.3.1.5.2.2.2) is not included in this study; it will be performed in Study 8.3.1.2.2.9 (YMP-USGS SP 8.3.1.2.2.9, "Site Unsaturated-Zone Modeling and Synthesis"), and this effort will be integrated as appropriate with the efforts of the present study." (page 1.2-1)

> "The unsaturated-zone modeling efforts of Study 8.3.1.2.2.9 are expected to provide a range of estimates for possible values of future infiltration, percolation, and saturation." (page 1.2-1)

Despite the reference (page 1.1-1) to the "logic for this change", no such logic for the exclusion of unsaturated zone hydrology is found in Section 1.2. Finally, Section 3.2 states that:

> "The modeling of the future unsaturated-zone hydrology due to climate changes is described in Section 3.5 ("Site Unsaturated-Zone Integration and Synthesis") of Study 8.3.1.2.2.9 (YMP-USGS SP 8.3.1.2.2.9, "Site Unsaturated-Zone Modeling and Synthesis"). Activity 8.3.1.5.2.2.2 has been omitted from the present study plan for this reason." (page 3.2-1)

These statements also do not give the logic for omitting Activity 8.3.1.5.2.2.2 from this study plan. In general, it does not seem rational to evaluate future climatic effects on the unsaturated zone separately from the effects on surface water hydrology and the saturated zone. As stated in the technical rationale for this study (page 2.1-1), "... climate changes impact surface, unsaturated-zone, and saturated zone hydrology and these impacts may affect

the performance of the repository." Crucial, and in some cases poorly understood, relationships exist between the flow of surface water and flow in the unsaturated and saturated zones. These three flow regimes are intimately linked, requiring a carefully integrated assessment.

DOE's 1988 Site Characterization Plan (p. 8.3.1.5-120) notes that a calibrated model of unsaturated-zone, present-day conditions will be developed under Activity 8.3.1.2.2.9.3. That model was intended to be used under Activity 8.3.1.5.2.2.2 to simulate transient infiltration scenarios over a 10,000 year period. The study plan under review revises this approach because it omits Activity 8.3.1.5.2.2.2 and commits to performing the work under Study 8.3.1.2.2.9. However, Study Plan 8.3.1.2.2.9 (DOE, 1993) does not list Study 8.3.1.5.2.2 under its discussion of contributions from other studies (p. 2.1-11). It should have been included because of the need to couple surface water models to unsaturated zone models. DOE (1993) does state that (p. 4.2-3) "... modeled results of the forward extrapolation of unsaturated-zone conditions may contribute to the modeling of future saturated-zone hydrology in Study 8.3.1.5.2.2 ...."

Placing the future unsaturated zone assessment in a different study plan may result in incomplete coupling between the surface water hydrologic system and the ground water components. Water that infiltrates from the surface must pass through the unsaturated zone before recharge of the saturated zone can occur. This requires proper linkages between surface water, unsaturated zone, and saturated zone models. In particular, estimation of future flux across the atmosphere-earth interface is of primary concern to repository performance. The infiltration component from surface water models needs to be coupled to unsaturated zone models of the site. While a general reference is made in Section 2.1.4 that external activities will be linked to the surface water and saturated zone studies, the manner in which this will be done is not explained. It is also not clear that output from site-scale models of the unsaturated zone will provide adequate input to support regional-scale modeling of the saturated zone.

This open item is a specific example of NRC's concern about technical integration, that was raised in the cover letter to the Site Characterization Analysis (NRC, 1989, p. xi).

Recommendations

Provide the logic for excluding Activity 8.3.1.5.2.2.2 from this study plan. Explain what advantage could accrue by analyzing physically interdependent flow regimes under separate study plans. Also, describe how site-scale models of the unsaturated zone (from Study 8.3.1.2.2.9) will adequately support the regional-scale modeling activity for the saturated zone under this study.

References

U.S. Department of Energy, "Site Characterization Plan, Yucca Mountain Site, Nevada Research and Development Area, Nevada," Office of Civilian Radioactive Waste Management, DOE/RW-0199, 9 vols. December 1988.

U.S. Department of Energy, "Study Plan for Study 8.3.1.2.2.9: Site Unsaturated-Zone Modeling and Synthesis," Office of Civilian Radioactive Waste Management, May 1993. [Prepared by U. S. Geological Survey.]

Nuclear Regulatory Commission, "NRC Staff Site Characterization Analysis of the Department of Energy's Site Characterization Plan, Yucca Mountain Site, Nevada," Office Of Nuclear Material Safety and Safeguards/Division of High-Level Waste Management, NUREG-1347, August 1989.

STUDY PLAN 8.3.1.5.2.2
CHARACTERIZATION OF FUTURE REGIONAL HYDROLOGY DUE TO CLIMATE CHANGE

Question 2
How will infiltration be simulated under the surface water modeling activity?

Basis
The identified models for predicting runoff were developed in climatic regions that are very different from the climate of the Yucca Mountain region. The models apparently do not consider the influence of macroporosity (such as fractures, soil structure, root holes, animal burrows) on the infiltration characteristics of the watershed. They were developed for agricultural lands where the macropores could be neglected because they were destroyed in the plowed soil horizon. The transfer of agricultural runoff models to field sites in natural soils in arid regions must be performed with caution, due to the different conditions present at the site. The presence of macropores can result in rapid drainage of surface water to great depths, beyond the zone of evapotranspiration. Evidence from the Apache Leap Tuff Site shows that eighty percent of the largest annual rainfall events, and higher percentages for smaller events, is diverted into fractures (Rasmussen and Evans, 1993). This significant flow into fractures will not be modeled or incorporated in the models as currently designed. Specific locations of macropores are difficult to predict and to quantify. This is especially true for open fractures that underlie channel beds. As stated on page 3.1-11 of the study plan, one of the three potential modeling problems is that "the models either do not account for or only partially account for stream losses due to channel bed infiltration..."

Recommendation
Describe how infiltration will be simulated in the surface water modeling work. Specifically address how infiltration through macropores (such as fracture zones) will be treated.

Reference
Rasmussen, T. C. and D.D. Evans, "Water Infiltration into Exposed Fractured Rock Surfaces," *Soil Sci. Soc. of Am. J.*, 57(2):324-329 [1993].

STUDY PLAN 8.3.1.5.2.2
CHARACTERIZATION OF FUTURE REGIONAL HYDROLOGY DUE TO CLIMATE CHANGE

Question 3
How will surface water models be calibrated and validated?

Basis
On page 2.2-1, it is stated that "The calculation methods for calibrating the precipitation-runoff model will use meteorology and streamflow data collected from drainages at, and peripheral to, the Yucca Mountain site. Thus, the modeling will be undertaken at full scale using data representative of the site." However, due to the limited number of storms and runoff events which can be sampled at the site, inadequate data may be available for the calibration and validation of surface water models. This is recognized in the study plan. On page 3.1-2, it is stated that "...the present streamflow gaging network (Activity 8.3.1.2.1.2.1) has been in place for too short a time to adequately establish long-range hydrologic modeling parameters." Extrapolation of limited rainfall-runoff data to changing future climatic conditions will contain high levels of uncertainty.

Section 3.1.5.1.3 of the study plan is intended to describe the kinds of data needed to calibrate a surface water model. These include: (1) slope, elevation, vegetation, and soil data to describe hydrologic response units; (2) roughness of overland flow planes; (3) physical parameters of channel beds; and (4) climatic data. The NRC staff point out that these are the kinds of data needed to design a surface water model. For calibration purposes, information is needed on the response of surface water flow to precipitation events of varying magnitudes. That kind of information is not described in Section 3.1.5.1.3.

Recommendation
Describe the approaches and assumptions that will be used to calibrate and validate surface water models in the vicinity of Yucca Mountain. This information should be incorporated in Section 3.1.5.1.3 of the study plan if a future revision of the plan is issued.