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U.S. DEPARTMENT OF ENERGY (DOE) REVIEW OF U.S. NUCLEAR REGULATORY COMMISSION'S (NRC) UNSATURATED AND SATURATED FLOW UNDER ISOTHERMAL CONDITIONS ISSUE RESOLUTION STATUS REPORT, REVISION 2

DOE has reviewed Revision 2 of the Issue Resolution Status Report (IRSR) on the Key Technical Issue of Unsaturated and Saturated Flow under Isothermal Conditions. The enclosed comments are directed primarily at the acceptance criteria for the subissues associated with unsaturated and saturated flow under isothermal conditions and related discussions of the technical bases supporting those criteria.

In general, the DOE agrees with the risk-informed, performance-based approach that the NRC staff has adopted in its development of the proposed 10 CFR Part 63. However, we are concerned that some of the discussions in the subject IRSR contain implicit or explicit requirements beyond those in the acceptance criteria. A number of these requirements and some of the acceptance criteria themselves appear to be more prescriptive than is the intent of the performance-based proposed 10 CFR Part 63. They appear to remove the flexibility contained in the proposed regulations and are not clearly linked to repository performance. These concerns are noted in our comments.

DOE appreciates the opportunity to review the IRSRs and provide comments for your consideration. The enclosure contains both technical comments and editorial/information comments. We request that our comments be considered in the preparation of the next revision of the IRSR.

If you or your staff have any questions regarding our comments, please contact Russ Patterson at (702) 794-5469 or Carol Hanlon at (702) 794-1324.

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OL&RC:CLH-0900

Enclosure:
Comments on Issue Resolution Status Report,
Revision 2, Key Technical Issue:
Unsaturated And Saturated Flow Under
Isothermal Conditions

*NMS507
WM-11
Rec'd from
NMS 1/23/02*

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**COMMENTS ON ISSUE RESOLUTION STATUS REPORT,
REVISION 2, KEY TECHNICAL ISSUE:
UNSATURATED AND SATURATED FLOW UNDER
ISOTHERMAL CONDITIONS:**

Comments

1. Page 188, in the Status and path to resolution for criterion (5) of saturated zone ambient flow conditions and dilution processes (subissue 5), the text states:

“DOE should also perform downhole logging with an accelerator porosity sonde (APS) in any new Nye County wells. We believe this tool, along with other logs, would provide the best logging results for formation porosity in the valley fill, even better than that given by previously developed compensated neutron systems. The neutron logs should be appropriately calibrated, standardized, and corrected to obtain reasonable porosity estimates for the valley fill. APS logs should also be obtained for existing Nye County wells that can be reasonably re-entered. DOE should prepare a report to summarize the resulting porosity data, that also includes analysis of the physical and chemical properties of the valley fill materials sampled below the water table. Data should include conventional particle size analyses (percentages of clays, silts, sands, gravel, etc.). The report should include x-ray analyses of clay mineral types and abundances.”

The IRSR appears to indicate that resolution of this criterion is dependent upon not only much additional work (geophysical logging, determination of physical and chemical properties of valley fill materials below the water table, particle size analysis, and x-ray analysis of clay mineral types and abundances), but also upon the use of specifically mandated tools (i.e., accelerator porosity sonde). In effect, the IRSR appears to be mandating that DOE perform additional work over and above that which is currently planned by DOE and Nye County. DOE is evaluating the necessity of additional work to characterize the alluvium and plans to consider the types of work suggested by the IRSR text. However, DOE believes the mandates in this discussion are overly prescriptive and not consistent with the flexibility allowed in proposed 10 CFR Part 63. DOE recommends that this guidance be removed from the IRSR.

2. Page 180, Deep Percolation Technical Acceptance Criterion (3) states:

"For estimates of the amount of water that may contact waste packages DOE must (i) demonstrate that coupled thermal-mechanical-chemical changes in rock mass properties will not focus deep percolation into the drifts; and (ii) rigorously justify estimated diversion of deep percolation away from the waste package footprints. This must include direct observations of dripping in test drifts or tunnels under ambient (unventilated) conditions in the repository horizon, or in an analog horizon with similar characteristics. Also needed are model calculations that account for the effects of backfill (if used), drift collapse, and coupled thermal-mechanical-chemical changes to rock properties. The models have been calibrated to niche studies and tracer tests in the ESF, or using an analog with characteristics similar to the repository horizon."

DOE is evaluating the necessity of additional work to characterize ambient conditions and will consider the types of work suggested in the IRSR text. However, DOE believes the mandates in this criterion are overly prescriptive and not in keeping with the flexibility allowed in proposed 10 CFR Part 63. It should also be noted that this criterion is mandating the inclusion of "coupled thermal-mechanical-chemical" considerations in a KTI which is supposed to deal with flow under isothermal conditions. We believe such coupled effects considerations would be better addressed in the KTI specific to Evolution of the Near-field Environment and should not be included here. In keeping with the intent of proposed 10 CFR Part 63 to provide flexibility to determine how to meet the established performance criteria in a way that will encourage improved outcomes, DOE recommends that this criterion be revised to state:

"For estimates of the amount of water that may contact waste packages DOE must (i) include data related to the geology, hydrology, and geochemistry (including disruptive processes and events) of the Yucca Mountain site and information on the design of the engineered barrier system, used to define parameters and conceptual models used in the assessment, and (ii) account for uncertainties and variabilities in parameter values and provide the technical basis for parameter ranges, probability distributions, or bounding values used in the performance assessment."

In addition, the Analysis and the Status and path to resolution for this criterion state:

"Analysis: The DOE drift-scale process-level seepage model, used to calculate seepage fraction and seep flow rate for TSPA, does not include several potentially important processes, and has not been shown to yield reasonably conservative upper bounding values."

"Status and path to resolution: Open pending review of future DOE performance assessments. Prediction of capillary diversion through fracture networks and seepage into drifts is an extremely complex endeavor. It may never be possible to develop a reliable model of drift seepage. Therefore, conservative assumptions are needed."

There is no requirement in proposed 10 CFR Part 63 to incorporate conservatism. Section VIII of the Supplementary Information indicates that intentional addition of conservatism was argued to be impractical from a regulatory point of view. DOE plans to meet the requirements of proposed 10 CFR 63.114(b) and account for uncertainties and variabilities in parameter values and provide the technical basis for parameter ranges, probability distributions, or bounding values used in the performance assessment. Conservatism will be used where appropriate based on consideration of uncertainties. However, we believe it is inappropriate for the IRSR to specify one option (conservative assumptions). DOE recommends that calls for conservatism be deleted from the IRSR and this discussion be revised to be consistent with the performance-based flexibility of proposed 10 CFR Part 63.

3. On pages 36 and 179, Technical Acceptance Criterion (2) for Deep Percolation states: "To estimate deep-percolation flux, spatial and temporal variability of model parameters and boundary conditions must be considered. Model parameters must be averaged over appropriate time and space scales. DOE must also consider climate-induced change in soil depths and vegetation." DOE believes the requirement regarding time and space scale is too open to interpretation as to what "appropriate" is. We suggest that this part of the criterion be revised to state "Model parameters must be consistent with available data and current scientific understanding." Also, while we plan to consider features, events, and processes as required by proposed 10 CFR Part 63, we do not believe it appropriate for the IRSR text to specify considerations (e.g., climate-induced change in soil depths and vegetation). DOE recommends that such overly prescriptive guidance be removed from the IRSR. Furthermore, the analysis for this criterion states:

"An additional concern is that DOE has not shown that effects on deep percolation of climate-induced changes in temperature, vegetation, and soil can be neglected while still providing a conservative bound on deep percolation and seepage fluxes under future climates. This concern stems from the fact that decreases in temperature can result in increased infiltration, even when precipitation does not change. Although this effect may be limited by increased vegetation, the interplay between these factors has not been investigated. Further, observations of soil thickness and texture on YM indicate these properties have been significantly different in the past. If it can be shown that the overall impact of these effects is minor relative to changes in precipitation, then the present method is acceptable."

Calling for a "conservative bound" does not appear to be consistent with proposed 10 CFR Part 63. DOE plans, of course, to determine how to deal with uncertainties in deep percolation and seepage flux. However, for reasons discussed in comment #3 above, DOE recommends that calls for conservatism be deleted from the IRSR and this discussion be revised to be consistent with the performance-based flexibility of proposed 10 CFR Part 63. Additionally, the IRSR mentions: "Observations of soil thickness and texture on YM indicate these properties have been significantly different in the past." However, no citation is provided for where these observations are documented. DOE recommends that a citation be provided.

4. Page 186, Status and path to resolution for criterion (2) delineation of flow paths: The IRSR indicates that the delineation of flow paths is "partly resolved." However, it also notes that "Exploratory drilling and geophysical surveys should be used in addition to the Nye County wells to obtain data within the data gaps to delineate where the water table transitions from the tuff aquifer to the overlying valley-fill aquifer and reveal lengths of flow paths in the valley-fill." In effect, the IRSR appears to be mandating that DOE perform additional work over and above that which is currently planned by DOE and Nye County. DOE is evaluating the necessity of additional work to characterize ambient conditions and will determine how best to deal with uncertainties in the relevant parameters. However, we believe the recommendation in the IRSR is overly prescriptive and that it constitutes required action beyond that clearly needed to address the acceptance criterion. We therefore recommend that it be deleted.

5. On page 163, acceptance criterion (1) for matrix diffusion (subissue 6) states:

“If credit for matrix diffusion in the UZ is taken, then transport must be consistent with site geochemical and isotopic data.”

DOE believes that geochemical data are not suitable for either calibrating the transport model (as suggested on page 167, 4th paragraph) or in directly estimating matrix diffusion model parameters. Similarly, isotopic data are useful to the extent that they confirm the presence of some fast paths in the unsaturated zone (UZ) (i.e., short particle residence times in well interconnected fractures and therefore limited time for matrix diffusion to occur). However, the isotopic data cannot be directly used in adjusting the transport model parameters to reflect limited matrix diffusion as suggested in the IRSR. Consequently, we believe this acceptance criterion is inappropriately focused on certain types of data. We recommend that the acceptance criterion be revised to permit the use of other site or lab data, such as tracer test data from the alcove/niche testing, the Busted Butte experiment, and laboratory column experiments. We suggest a revision of this acceptance criterion as follows:

“If credit for matrix diffusion in the UZ is taken, then transport must be consistent with available site and/or laboratory test data on cores, site geochemical and isotope data, and data from field tracer test experiments ”

6. On page 191, in subsection 5.6.2, the narrative under “Analysis” presents a discussion of the acceptance criteria (1) for matrix diffusion. In the middle of the paragraph, the following statement is made:

“We are concerned because this modeling approach [referring to the residence time/transfer function (RTTF) model] violates an underlying assumption of the Tang et al. (1981) solution, upon which the matrix diffusion RTTF is based--that solutes enter and leave the matrix continuum through diffusion only. The result is a bias towards predicting faster diffusion from fractures into matrix, because the model allows solutes to diffuse from fractures into the immobile matrix domain, but does not allow solutes in the mobile matrix domain to diffuse into the fracture domain.”

The first sentence may point out a valid criticism. Also, if the latter statement were true, then the matrix would effectively be acting as a “trap” for mass and thereby introduce an inappropriate bias into the calculation of transport rates. In the DOE UZ transport model, however, particles advected and dispersed in the fracture continuum actually remain in the fast path. The RTTF algorithm simply adjusts the particle residence times in order to reflect, in a bulk sense, the time lag attributed to diffusion into and out of the matrix. The calculation of this matrix diffusion effect is approximate, because it is performed as if there was no advection in the matrix continuum (i.e., double porosity formulation). However, recent (as yet unpublished) computational studies have shown that the RTTF method is actually conservative in representing transport with matrix diffusion effects, relative to the more traditional model formulation of solute transport. DOE would welcome a discussion of this technical issue with NRC staff, and we recommend that the last sentence of the referenced statement be deleted.

7. On page 88 in Section 4.5.1 regarding acceptance criteria for the Saturated Zone Ambient Flow Conditions subissue, acceptance criterion #3 states that DOE should provide a hydrologic assessment to describe the likely causes of the "moderate hydraulic gradient" and the "large hydraulic gradients." There are several present hypotheses (CRWMS M&O 1998a, Section 5.3.5.1.4) regarding the possible causes of these gradients at Yucca Mountain. Additional well data are also presently being obtained to provide further insight into the cause of the large gradient. However, the actual causes of these gradients are still uncertain and may ultimately remain unresolved. Regardless of whether or not the actual causes of these hydraulic gradients are ever definitively determined, the possible consequences of the gradients on saturated flow southward under Yucca Mountain should be emphasized in this acceptance criterion. The possible consequences for repository performance are more significant than the actual causes of the gradients. DOE suggests that evaluating the consequences is more in accordance with the risk-informed, performance-based philosophy of proposed 10 CFR Part 63 and that the criterion be revised to read:

"DOE has considered alternative conceptual models of the "moderate hydraulic gradient" and the "large hydraulic gradient" that are consistent with available data and current scientific understanding, and has evaluated the effects that alternative conceptual models have on the performance of the geologic repository."

8. On page 176 in Status and path to resolution, Criterion 3 for Present-day shallow infiltration

$$p_{\frac{1}{3}} \log \frac{1}{3} + p_1 \log 1 + p_3 \log 3 = 0$$

(subissue 3) has been reopened based on NRC review of the TSPA-VA. The IRSR indicates the NRC staff agrees that the use of Mean Annual Infiltration (MAI) multipliers as in the TSPA-VA is a reasonable way to incorporate uncertainty in MAI estimates. However, the IRSR indicates that the methodology used to assign probabilities to the MAI multipliers is biased toward selecting low values for MAI. The IRSR indicates that for this criterion to be met, DOE must adopt the equation: For assigning probabilities to MAI multipliers in TSPA analyses or "... demonstrate another approach that achieves the same result." In effect, the IRSR appears to be mandating that DOE use a specific equation regardless of whether it fits the data that will be developed. DOE plans to address uncertainties in MAI. However, designating what equation must be adopted or what result must be achieved appears to be overly prescriptive and not consistent with either the less prescriptive philosophy of proposed 10 CFR Part 63 or the wording of the criterion. DOE recommends that this additional mandate beyond the scope of the criterion be revised so that the phrase "... demonstrate another approach that achieves the same result." is changed to read "... demonstrate another approach that addresses the potential bias toward the lower bound."

9. On page 179, in the Analysis section of acceptance criterion (2) for Deep Percolation (subissue 4), the text states:

“The fast-path contributions to flow, as suggested by geochemical data, are not adequately represented in the LBNL UZ Flow Model ... Additionally, the assumption of steady-state infiltration fluxes in the LBNL UZ Flow Model precludes an assessment of the impact of episodic infiltration that may bypass the PTn layer and travel quickly to the repository horizon”

Under the Status and path to resolution section, NRC recommends that:

“...the LBNL UZ Flow Model should account for heterogeneity or discrete features that result in fast flow through the PTn layer, consistent with geochemical evidence for fast transport to the repository horizon. Additionally the DOE UZ flow model should include features that allow rapid transient percolation to bypass the PTn layer...”

In both cases DOE agrees that fast paths and episodic infiltration events should be evaluated, but we believe that these should be evaluated using sensitivity studies for comparison with the base case flow field results. This can be done using sub-grid or submodel analyses. Studies are being conducted to obtain geochemical data. DOE recommends that the Path to Resolution be modified to state:

“The LBNL UZ Flow Model results should be compared with representations that include lateral heterogeneities or discrete features that result in fast flow through the PTn layer. Additionally, studies should evaluate the effect of features that allow rapid transient percolation to bypass the PTn layer...”

DOE believes that this wording is more consistent with the flexibility allowed in proposed 10 CFR Part 63.

10. Pages 21 and 173, acceptance criterion (2) indicates that models used to predict climate-induced consequences must be consistent with evidence that the water table rise during the late Pleistocene was up to 120 m. The value of 120 m for water table rise was based on an assumption of depth to water at locations of paleospring deposits, rather than being based upon measured evidence of depth to water. In multiple places, the IRSR notes that new data from Nye County wells indicate that the paleospring deposits that were the basis for the assumed 120 m value now support water table rise values of only 16 to 30 m based upon measured depths-to-water in wells. The new evidence cited in the IRSR is not reflected in this acceptance criterion. DOE recommends that the criterion be revised to simply require the consequences be consistent with available evidence regarding past water-table rises.

11. Page 187, Technical Acceptance Criterion (4) for Saturated Zone Ambient Flow Conditions and Dilution Processes states:

"DOE has provided maps of approximate potentiometric contours of the regional uppermost aquifer for an area that, at a minimum, includes wells J-11 on the east, VH-1, VH-2, and the GEXA Well on the west, UE-29a #2 to the north, and domestic and irrigation wells south of Amargosa Valley (aka Lathrop Wells). Maps of regional and site-scale recharge and discharge should be provided, along with site-scale hydrostratigraphic cross sections constructed along the paths to the accessible environment, and site-scale flow-net analysis of the SZ."

In effect, the IRSR appears to be mandating that DOE perform additional work over and above that currently planned by DOE. Specifically, DOE has no plans to develop a site-scale flow-net analysis of the saturated zone (SZ), and we do not believe one is necessary to support the repository safety case. We recommend that this criterion be revised to remove prescriptive requirements.

12. Page 179, first paragraph in Analyses for acceptance criterion (2) for subissue on Deep Percolation (subissue 5), text states: "The DOE acknowledges in their TSPA-VA report that as much as 80-90 percent of infiltration may bypass the PTn layer via fast pathways (DOE, 1998b, Volume 1, page 2-51). Flow in these fast pathways is likely to be episodic, and such transient flow is more likely to result in seepage into repository drifts."

The statement "The DOE acknowledges in their TSPA-VA report that as much as 80-90 percent of infiltration may bypass the PTn" is taken out of context, is not completely accurate, does not represent the full range of alternate hypotheses presented in the Viability Assessment (VA), and does not represent a DOE position. While page 2-51 of the VA acknowledges that a particular analysis suggests that 80 to 90 percent of total percolation flux bypasses the matrix of the PTn, other alternate hypotheses are discussed in the VA and in the Yucca Mountain Site Description, and DOE did not choose a "preferred" analysis (as discussed in the following text from the Site Description, Section 5.3.4.3.1.4 Chloride Mass Balance):

"The foregoing analysis has been based on extremely limited data and would benefit greatly from the collection of additional chloride data, particularly from the shallow saturated zone. The available chloride data can be interpreted to suggest an unsaturated-zone flow system that is dominated by fracture flow, and in which the fracture water has only limited interaction with water in the matrix pores. However, this conclusion ignores the possibilities that 1) average chloride concentrations in the PTn have been biased toward more concentrated values by siting most of the boreholes in washes, and that elsewhere, along ridges and sideslopes, the PTn chloride concentrations are much lower (Fabryka-Martin, Flint et al. 1997), and 2) the differences in PTn and perched-water chloride concentrations reflect the effects of climate change rather than preferential flow through the PTn (Sonnenthal and Bodvarsson 1997). Definitive conclusions regarding the correct conceptual model must await the results of additional sampling of pore water chloride concentrations in upland areas, as well as further analyses of the chemical

reactions that resulted in the perched-water chemistry, and the impact these reactions may have had on perched water ^{14}C ages.”

As part of demonstrating compliance with proposed 10 CFR 63.114(c), DOE plans to consider alternative conceptual models of features and processes that are consistent with available data and current scientific understanding, and we plan to evaluate the effects that alternative conceptual models have on the performance of the geologic repository. DOE recommends that the IRSR discussion not specify that any one model be given preference. DOE also recommends that the correct source document be identified, as the document cited as DOE, 1998b is the Viability Assessment and not the TSPA-VA as indicated in the quoted text from the IRSR.

13. Page 187, analysis for criterion (4): The staff has revised the IRSR text to reflect that the name of Lathrop Wells was changed to Amargosa Valley. However, as now used, the term Amargosa Valley does not differentiate between the Town of Amargosa Valley and the physiographic basin of Amargosa Valley. This can lead to confusion. For example, the analysis text states “However, the map does not include data from irrigation wells south of Amargosa Valley.” It is assumed that the wells being referred to are south of the Town of Amargosa Valley (at the intersection of highways 95 and 373) in the physiographic basin of the Amargosa Valley [so, while these wells are south of Amargosa Valley (town), they are in Amargosa Valley (basin)]. DOE recommends that the acceptance criterion be revised to differentiate between “the Town of Amargosa Valley” versus the physiographic basin “the Amargosa Valley”. Or in this particular case, the criterion could refer to “wells south of Hwy 95” or to “wells in the Amargosa Farms area.”

Editorial / Information Comments

1. Page 162, last paragraph states: “However, the sensitivity analyses by NRC/CNWRA suggest that the radionuclide dose is much more sensitive to the properties of valley fill and alluvium than it is to tuff properties.” No citation is provided for where this sensitivity analyses work is published, and DOE has been unable to identify it. We recommend that a reference be provided.
2. Beginning on page 209, Sections 6.1 and 6.2 references. It is unclear why the references are divided into two lists. This division makes identifying a reference citation more difficult. DOE recommends that the lists be combined into one list and also that the combined list be edited for accuracy as there are a number of editorial errors. For example:
 - Craig 1997 on page 221 is shown as U.S. Nuclear Regulatory Commission. The author is actually United States Geological Survey (USGS).
 - In Carr et al. 1986a on page 220 “Drill Bole” should be “Drill Hole.”
 - In Bedinger et al. 1989 on page 218 “Die Basin” should be “the Basin.”
 - Winograd et al. 1992 is cited in Sections 4.1, 4.2, and 5.1.2 of the text but is only included in the reference list “6.1 References for Sections 4.1 and 4.2.”

- “Reimus 1998” on page 237 is shown to be a draft report, thus 1998 is not correct for year of publication. It is unclear whether this document was ever published or submitted for publication.
 - Schoff and Moore 1964 and Winograd 1962a on page 247 are both listed as being Open File Reports. In fact, they are Trace-Elements Investigations (i.e., a TEI not an OFR).
 - “Elater and Nolting” on page 224 should be “Elayer and Nolting.”
 - Page 69 and Page 232: “Murphy, 1998” is cited on page 69. However, on page 232 it is listed as “in press.” If this document was published in 1998 it should not be shown “in press.”
 - The second line of page 171 cites: “Yucca Mountain Site Characterization Plan (TRW Environmental Safety Systems, Inc., 1998b),” and the reference list on page 244 lists this cited document as: “TRW Environmental Safety Systems, Inc., 1998b, Book 2 *Yucca Mountain Site Characterization Plan*, Civilian Radioactive Waste Management and Operating Contractor Report B00000000-01717-5700-00019, Rev 00, Section 4 Book 2 Las Vegas, NV, TRW Environmental Safety Systems, Inc., 1998b.” The cited document is the Yucca Mountain Site Description, not the Yucca Mountain Site Characterization Plan.
 - Page 22 cites “Morrison (1996).” This reference was a draft document that had been submitted for publication. It has since been published as part of the Geological Survey of America Special paper 333, edited by L. A. Wright and B. W. Troxel (1999). We suggest that the text citation and reference be updated.
 - A document by “Buqo” is cited in both reference lists on page 209 and page 219 for what appears to be the same document, but the citations differ markedly.
 - Multiple citations in the reference lists use “et al.” for multiple authors (e.g., Li et al. on page 212; Paces et al. on page 213; Quade, Mifflin, et al. on page 214; Szabo et al. on page 215; etc.). It would be helpful for the reference list to list all authors.
 - Page 190 cites “(Geomatrix, 1997a).” However, the reference list on page 227 shows that the Saturated Zone Expert Elicitation being referenced was published in 1998. Additionally, while Geomatrix was a contributor to this document, the document is a CRWMS M&O publication. We suggest that the text be revised to cite the *Saturated Zone Flow and Transport Expert Elicitation Project* (CRWMS M&O 1998b).
3. The statement in the first paragraph of section 2.0 on page 3 of volume 1: “ Note that since the release of the previous revision of this report, a new subissue has been added regarding matrix diffusion...” is left over from revision 1 and is no longer correct for revision 2.

References

CRWMS M&O (Civilian Radioactive Waste Management System Management and Operating Contractor) 1998a. *Yucca Mountain Site Description*. B00000000-01717-5700-00019 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981202.0492.

CRWMS M&O 1998b, *Saturated Zone Flow and Transport Expert Elicitation Project*. Deliverable No. SL5X4AM3. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980825.0008.