November 15, 2002

Joseph D. Ziegler, Acting Assistant Manager
Office of Licensing and Regulatory Compliance
U.S. Department of Energy
Yucca Mountain Site Characterization Office
P.O. Box 364629
North Las Vegas, NV 89036-8629

SUBJECT: UNSATURATED AND SATURATED FLOW UNDER ISOTHERMAL CONDITIONS AGREEMENT 6.01

Dear Mr. Ziegler:

In your letter dated July 30, 2002, the U.S. Department of Energy (DOE) enclosed a report, "Matrix Diffusion Sensitivity Analysis." The U.S. Nuclear Regulatory Commission (NRC) staff has reviewed this information, with respect to Unsaturated and Saturated Flow Under Isothermal Conditions (USFIC) Agreement 6.01, and the results of the staff's review are enclosed.

The DOE has adopted an approach for including the effects of matrix diffusion on radionuclide transport calculations. This approach uses residence time transfer functions in particle-tracking simulations to adjust particle residence times in transport model numerical grid cells to account for matrix diffusion and radionuclide sorption. Because this approach is somewhat innovative and greatly simplifies a complex process, the staff requested DOE to provide sensitivity analyses to illustrate the overall importance of matrix diffusion to performance assessment calculations.

The sensitivity analyses provided by DOE for matrix diffusion in the saturated zone provide useful insights into the potentially important natural barrier role of matrix diffusion in the saturated zone. Especially useful are the subsystem analysis results. Staff find the saturated zone analyses to be acceptable.

DOE earlier provided sensitivity analyses for matrix diffusion in the unsaturated zone in their Total-System Performance Assessment–Site Recommendation. NRC staff reviewed those analyses and provided comments to DOE. In short, NRC staff found those analyses contained adequate information. It was, however, not entirely clear to NRC staff why the risk significance of matrix diffusion in the unsaturated zone seemed moderate to high compared to the apparently low risk significance of matrix diffusion in the saturated zone. This ambiguity should be clarified when DOE provides additional information requested in other technical agreements. In addition, DOE still needs to provide independent lines of evidence to afford additional confidence in the use of the active fracture model which can influence the extent of matrix diffusion in the unsaturated zone.

USFIC Agreement 6.01 is considered complete. If there are any questions regarding this letter, please contact Hans Arlt at 301-415-5845 or by e-mail at hda@nrc.gov.

Sincerely,
/RA/

Janet R. Schlueter, Chief
High-Level Waste Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

Attachment: NRC Review of DOE Letter Pertaining to USFIC.6.01.

cc: See attached distribution list

Letter to J. Ziegler from J. Schlueter dated November 15, 2002

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J. Leeds, Las Vegas Indian Center

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D. Eddy, Jr. Colorado River Indian Tribes

G. Runkle, DOE, Washington, DC

W. Briggs, Ross, Dixon & Bell

H. Jackson, Public Citizen

USFIC Agreement 6.01 is considered complete. If there are any questions regarding this letter, please contact Hans Arlt at 301-415-5845 or by e-mail at hda@nrc.gov.

Sincerely,
/RA/

Janet R. Schlueter, Chief
High-Level Waste Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

Attachment: NRC Review of DOE Letter Pertaining to USFIC.6.01.

cc: See attached distribution list

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NRC Review of DOE Documents Pertaining to
Key Technical Issue Agreement USFIC.6.01

The U.S. Nuclear Regulatory Commission (NRC) goal of issue resolution during this interim pre-licensing period is to assure that the U.S. Department of Energy (DOE) has assembled enough information on a given issue for NRC to accept a licensing application for review. Resolution by the NRC staff during pre-licensing does not prevent anyone from raising any issue for NRC consideration during review of a license application. Just as important, resolution by the NRC staff during pre-licensing does not prejudge what the NRC staff evaluation of that issue will be after its licensing review. Issues are resolved by the NRC staff during pre-licensing when the staff has no further questions of comments about how DOE is addressing an issue. Pertinent new information could raise new questions or comments on a previously resolved issue.

This enclosure addresses agreement Unsaturated and Saturated Flow Under Isothermal Conditions (USFIC).6.01 which was reached between NRC and DOE during a technical exchange and management meeting.[1]

Wording of the Agreement: "The DOE will provide the final sensitivity analysis on matrix diffusion [for UZ (unsaturated zone)] in the TSPA-SR, Rev. 0. Due date: December 2000. The saturated zone information will be available in TSPA-SR, Rev. 1, expected to be available in June 2001."

NRC Review

Background

The DOE has adopted a rather novel approach for including the effects of matrix diffusion in radionuclide transport calculations for total-system performance assessments. This approach uses residence time transfer functions in particle-tracking simulations to adjust particle residence times in transport model numerical grid cells to account for matrix diffusion and radionuclide sorption. Because this approach is somewhat innovative and greatly simplifies a complex process, the staff requested DOE to provide sensitivity analyses to illustrate the overall importance of matrix diffusion to performance assessment calculations.

DOE earlier provided sensitivity analyses for matrix diffusion in the unsaturated zone in their Total-System Performance Assessment–Site Recommendation. NRC staff reviewed those analyses and provided comments to DOE.[2] In short, NRC staff found those analyses contained adequate information. It was, however, not entirely clear to NRC staff why the risk significance of matrix diffusion in the unsaturated zone seemed moderate to high compared to the apparently low risk significance of matrix diffusion in the saturated zone. This ambiguity should be clarified when DOE provides the additional information requested in technical agreement TSPAI.3.29. Additionally, DOE has agreed to:

[1]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Unsaturated and Saturated Flow Under Isothermal Conditions (October 31–November 2, 2000)." Letter (November 17, 2000) to S. Brocoum, DOE.

[2]Reamer, C.W. "Review of Documents Pertaining to Key Technical Issue Agreements." Letter (February 8, 2002) to S. Brocoum, DOE.

- obtain further validation of the conceptual model for matrix diffusion in the UZ through completion of tracer transport testing in the Alcove 8-Niche 3 test (see agreement USFIC.6.03), and
- provide independent lines of evidence to provide additional confidence in the use of the active fracture continuum concept in the transport model which can influence the extent of matrix diffusion in the unsaturated zone (see agreement TSPAI.3.28).

The agreement status for agreement USFIC.6.01 was left open, pending receipt of additional sensitivity analyses for matrix diffusion in the saturated zone. DOE has now provided these additional sensitivity analyses,[3] which are the subject of this review.

Review of the Analyses Provided by DOE

The DOE sensitivity analyses for saturated zone matrix diffusion are reported at both the subsystem modeling level (i.e., effects on tracer breakthrough times at the 18 km distance as predicted by the saturated zone transport model), and at the total-system performance level (i.e., effects on mean annual dose rates at the receptor location).

The subsystem sensitivity analyses (Section 3.3 of the DOE report) are especially useful for evaluating the relative importance of matrix diffusion because potential masking effects of other design components, such as a robust waste package, are not considered in these analyses. It is thus possible to evaluate the relative role of matrix diffusion in saturated zone radionuclide transport, where the saturated zone is a potential natural-system component of a multiple barrier design concept. The results of the most optimistic case subsystem analysis shows that matrix diffusion can lead to a substantial increase in saturated zone radionuclide transport times. For example, predicted breakthrough times for uranium isotopes, which sorb moderately to volcanic tuffs (K_d = 2.0 ml/g), were nearly four times as great for the optimistic matrix diffusion case than for the case with no matrix diffusion.

The expected-case results of the subsystem model analyses revealed much less benefit from matrix diffusion. For example, expected-case breakthrough time for non-sorbing Tc-99 was approximately 800 years, compared to the approximately 700 years with no matrix diffusion. Similarly, expected-case breakthrough time for moderately sorbing uranium increased less than ten percent from the case with no matrix diffusion. The small effect of matrix diffusion on the expected-case radionuclide transport time reflects relatively modest assumptions regarding flowing-fracture spacings and matrix diffusion coefficients in the saturated zone transport calculations.

The DOE report (Section 3.5) shows calculations of saturated zone transport time for what they refer to as the “nominal case” from the Total-System Performance Assessment–Site Recommendation. Calculations of median radionuclide transport time were compared to cases with essentially no matrix diffusion (diffusion coefficient reduced ten orders of magnitude) and a case with enhanced matrix diffusion (flow interval spacing reduced two orders of magnitude). The results of the comparison were similar to those of the previously discussed expected case. That is, a significant increase in radionuclide transport time is estimated for the most optimistic cases of matrix diffusion, but calculated transport times for the nominal case were not substantially greater than for the case with essentially no matrix diffusion.

[3]Ziegler, J.D. “Transmittal of Report Addressing Key Technical Issue (KTI) Agreement Item Unsaturated and Saturated Flow Under Isothermal Conditions (USFIC) 6.01.” Letter (July 30, 2002) to J. Schlueter.

Finally, the DOE report (Section 3.6) provides sensitivity analyses using the base-case scenario of the Total-System Performance Assessment–Site Recommendation. In this analysis, there were negligible differences between cases with no matrix diffusion and with enhanced matrix diffusion in the saturated zone. These results were expressed in terms of mean annual dose. The low sensitivity of dose to matrix diffusion reflects the masking effect of other components of the total-system analyses, chiefly the robustness of the waste canister. These results thus provide little insight into the importance of matrix diffusion as a natural-system barrier to radionuclide transport but do illustrate that matrix diffusion would be of no consequence if all other system components perform within their estimated ranges of model and parameter uncertainty.

Staff Comments:

Sensitivity analyses of matrix diffusion in the unsaturated zone were previously reviewed by NRC staff and deemed acceptable. The sensitivity analyses provided by DOE for matrix diffusion in the saturated zone provide useful insights into the potentially important natural barrier role of matrix diffusion in the saturated zone. Especially useful are the subsystem analysis results, which illustrate that the expected and nominal cases of matrix diffusion parameter values, as used for the Total-System Performance Assessment–Site Recommendation, do not produce overly optimistic radionuclide transport time estimates. Staff, therefore, find the saturated zone analyses to be acceptable.

It should be noted that it is not known whether the same or similar matrix diffusion parameter values will be used to support a license application. Staff will therefore remain vigilant of any changes to DOE abstractions of matrix diffusion processes in performance assessment calculations or in a demonstration of multiple barriers.

Additional information needs:

None.

Status of Agreements: Agreement USFIC.6.01 is complete.