

Summary Highlights of NRC/DOE Technical Exchange and Management Meeting on Radionuclide Transport

December 5-7, 2000
Berkeley, California

Introduction and Objectives

This Technical Exchange and Management Meeting on Radionuclide Transport (RT) is one in a series of meetings related to the U.S. Nuclear Regulatory Commission (NRC) key technical issue (KTI) and sufficiency review and the U.S. Department of Energy (DOE) site recommendation decision. Consistent with NRC regulations on preclicensing consultations and a 1992 agreement with DOE, staff-level resolution can be achieved during preclicensing consultation. The purpose of issue resolution is to assure that sufficient information is available on an issue to enable the NRC to docket a proposed license application. Resolution at the staff level does not preclude an issue being raised and considered during the licensing proceedings, nor does it prejudge what the NRC staff evaluation of that issue will be after its licensing review. Issue resolution at the staff level, during preclicensing, is achieved when the staff has no further questions or comments at a point in time regarding how the DOE is addressing an issue. The discussions recorded here reflect NRC's current understanding of aspects of radionuclide transport most important to repository performance. This understanding is based on all information available to date which includes limited, focused, risk-informed reviews of selected portions of recently provided DOE documents (e.g., Analysis and Model Reports (AMRs) and Process Model Reports (PMRs)). Pertinent additional information could raise new questions or comments regarding a previously resolved issue.

Issues are **Aclosed** if the DOE approach and available information acceptably address staff questions such that no information beyond what is currently available will likely be required for regulatory decision making at the time of any initial license application. Issues are **Aclosed-pending** if the NRC staff has confidence that the DOE proposed approach, together with the DOE agreement to provide the NRC with additional information (through specified testing, analysis, etc.) acceptably addresses the NRC's questions such that no information beyond that provided, or agreed to, will likely be required at time of initial license application. Issues are **Aopen** if the NRC has identified questions regarding the DOE approach or information, and the DOE has not yet acceptably addressed the questions or agreed to provide the necessary additional information in a potential license application.

The objective of this meeting is to discuss and review the progress on resolving the RT KTI (see Attachment 1 for the description of Subissues #1, 2, and 3). Subissue #4, "Nuclear Criticality in the Far Field," was discussed during a Technical Exchange on October 22-23, 2000, and was not discussed during this meeting. The quality assurance (QA) aspect of this KTI was determined to be outside the scope of the meeting and is being tracked in NRC's ongoing review of DOE's QA program.

Summary of Meeting

At the close of the Technical Exchange and Management Meeting, the NRC staff stated that Subissues 1, 2, and 3 were “closed-pending.” Specific NRC/DOE agreements made at the meeting are provided as Attachment 1. The agenda and the attendance list are provided as Attachments 2 and 3, respectively. Copies of the presenters=slides are provided as Attachment 4. Highlights from the Technical Exchange and Management Meeting are listed below.

Highlights

1) Opening Comments

DOE stated that the intent of the meeting is to reach agreement on the current status and path forward for each of the RT subissues (see “Radionuclide Transport” presentation given by Eric Smistad). In the RT Issue Resolution Status Report (IRSR), the NRC stated that RT Subissues 1, 2, and 3 are “open.” During this meeting, DOE stated that its presentation would focus on confirmatory and additional information, data, and analyses identified by the NRC in the IRSR and subsequent discussions. DOE stated that it felt that the details provided during the current meeting would be the basis for NRC to list Subissues 1, 2, and 3 as “closed-pending.”

2) Total System Performance Assessment

DOE provided an overview of how radionuclide transport is being incorporated into the Total System Performance Assessment (TSPA) for both the unsaturated zone (UZ) from the repository to the top of the water table and for the saturated zone (SZ) from the top of the water table beneath the repository to the 20 kilometer boundary.

Radionuclide transport processes parameters were implemented into the TSPA code using a particle tracking technique. Three-dimensional dual-continuum (fracture and matrix) flow fields (steady state flux) from the unsaturated and saturate zone process-level flow models were imported into TSPA code. The TSPA transport model incorporates probabilistically defined transport parameters in the unsaturated and saturated zone. In addition to these transport parameters, the TSPA code also varies the effective porosity of the alluvial material and the location of the alluvial boundary. The DOE provided clarifying information on the use of retardation and filtration expressions for modeling colloid transport. The DOE stated that colloid transport parameters were not as well constrained as other types of parameters.

3) Technical Discussions - Subissue #1, Radionuclide Transport Through Porous Rock

A summary of the current status of resolution was presented (see “Radionuclide Transport Key Technical Issue, Subissue 1, Radionuclide Transport in Porous Rock” presentation given by Jim Houseworth and Arend Meijer). The DOE identified the NRC information needs from Revision 2 of the RT IRSR and subsequent NRC/DOE discussions. The DOE stated that the presentations would provide the basis for going to “closed” or “closed-pending” for each of the acceptance criteria and, therefore, that it believed Subissue #1 should be listed as “closed-pending.” For transport in porous rock, the DOE considers various transport processes including hydrodynamic dispersion, matrix diffusion, sorption (solutes), filtration (colloids), and radioactive decay important to performance.

The DOE stated that all the acceptance criteria are considered “closed” with the exception of criteria 2b, 2c, and 5. The DOE stated that it believed these criteria are “closed-pending.” Additional testing is needed for Criterion 2b titled “Demonstrate evaluation of R_f ” and for Criterion 2c titled “Demonstrate assumptions for K_d approach are valid.” For Criterion 2b additional sensitivity studies and review of available data need to be done to evaluate the adequacy of sorption parameters derived from laboratory experiments. Experiments for plutonium have shown kinetic effects that make the high flow rates used for the column tests non-representative. Additional sensitivity studies and a review of available data will be used to evaluate the adequacy of the data. The sensitivity of performance assessment results to protactinium sorption will be investigated to evaluate if additional tests are needed. If protactinium is important to performance and the existing data are inadequate, additional batch sorption tests using site-specific materials will be considered. The criterion to confirm the K_d for plutonium determined in static tests that are appropriate for calculating retardation in dynamic systems has not been met. To evaluate the adequacy of the data, the DOE stated that the effect of plutonium sorption on performance will be investigated in sensitivity studies and external information on plutonium sorption will be reviewed.

For Criterion 2c, NRC staff had previously commented that batch and column experiments with plutonium indicate that retardation reactions are not instantaneous in the time scale of the experiments. The DOE plans to consider the effects of plutonium sorption on performance in sensitivity studies and will also review external information concerning plutonium sorption. These experiments will be used to evaluate the need for additional experiments with plutonium.

The NRC stated that additional documentation for Criterion 4, titled “Expert judgement/elicitation,” is needed to enable a thorough evaluation of the use of expert judgement to obtain ranges and probabilities for transport parameters used in the TSPA code. The NRC staff expressed the concern that retardation (K_d) distributions were obtained from inadequately documented expert judgments. For transport parameters derived from expert judgements, the judgements should be conducted and documented in accordance with the guidance in NUREG-1563, as applicable. For those species for which K_d s were measured or referenced, the selected ranges of K_d s used to model transport of chemical species either through porous rock or fractures should be technically supported. The DOE plans to provide additional documentation to explain how transport parameters obtained from expert judgments and used for performance assessment were derived.

As a result of additional discussions, the NRC and DOE reached five agreements for Subissue #1 (see Attachment 1). With these five agreements, the NRC stated that Subissue #1 could be listed as “closed-pending”.

4) Technical Discussions - Subissue #3, Radionuclide Transport Through Fractured Rock

A summary of the current status of resolution was presented (see “Radionuclide Transport Key Technical Issue, Subissue 3, Radionuclide Transport in Fractured Rock” presentation given by Al Aziz Eddebarh, Bo Bodvarsson, George Moridis, Paul Reimus, and Edward Kwicklis). DOE identified the NRC information needs from Revision 2 of the RT IRSR and subsequent NRC/DOE discussions. The DOE stated that the presentations would provide the basis for going to “closed” or “closed-pending” for each of the acceptance criteria and, therefore, that it believed Subissue #3 should be listed as “closed-pending.”

The DOE stated that for the unsaturated zone, the path lengths through the various units are generally the shortest distance between the potential repository and the water table. The only case where this is not true is where there is lateral diversion when downward flowing water encounters lower permeability rock such as bedded zeolitized tuff units or basal vitrophyres. The DOE stated that transport behavior in the unsaturated zone is not highly sensitive to alternative transport pathways, consistent with the data and known flow processes. Fractures are the main pathways of radionuclide transport in most units of the unsaturated zone. Diffusion from the fractures into the matrix and sorption in the matrix are the main retardation processes in radionuclide transport.

Sorption onto the matrix retards the migration of sorbing radionuclides. Flow and transport in the Calico Hills nonwelded hydrogeologic unit are strongly dependent on the spatial variability of the distribution of the vitric and zeolitic layers.

Recent unsaturated zone modeling at Yucca Mountain indicates that Topopah Spring welded units appear to be the most important for early arrival at the water table, while bedded tuff zeolitic units are more important for later arrival. In terms of relative importance to arrival times at the water table, the Topopah Spring is more important than bedded tuff zeolitic units, which in turn are more important than bedded vitric tuff units.

As discussed above, the DOE believes that all acceptance criteria for this subissue are considered "closed" or not applicable, with the exception of criteria 2a and 2b. These criteria are considered to be "closed-pending." Criterion 1c is considered to be closed by the DOE, because for the saturated zone, the uncertainty related to the lengths of flow paths in the tuff and in the alluvium was discussed at the October 31-November 2, 2000, Saturated Zone Technical Exchange. However, the DOE agreed at that technical exchange to provide additional information, including Nye County data, to further justify the uncertainty distribution of the flow path in alluvium in updates to the Uncertainty Distribution Stochastic Parameters AMR. Additional information was presented at this meeting to show how water chemistry and isotopic data are being used by the DOE to better define groundwater flow paths in the saturated zone.

Criterion 2a is titled "Demonstrate ability to predict breakthrough curves". Breakthrough curves of reactive, non-reactive, and colloidal tracers have been developed from field tests. These breakthrough curves are documented in the Saturated Zone Process Model Report, the planned C-well testing report, and the Unsaturated Zone Process Model Report. The DOE has developed breakthrough curves for nonsorbing tracer transport in fractured, welded tuff based on Alcove 1 data. Additional tests are being conducted in Alcove 8/Niche 3, which will include nonsorbing and moderately sorbing tracers. The DOE is developing predictive models for the Alcove 8/Niche 3 tests as was discussed at the October 11-13, 2000, Structural Deformation and Seismicity Technical Exchange. This was the subject of an agreement made at that exchange. DOE considers this criterion "closed-pending" pending results from Alcove 8/Niche 3 testing and predictive modeling.

The NRC previously commented on the test plans for Alcove 8/Niche 3 and recommended that slots be cut into the walls of Niche 3. The NRC stated that this would allow the capture of most of the water percolating down from infiltration beds in Alcove 8. The DOE showed simulations that suggest percolation could occur well beyond where slots can be cut, making it unlikely to achieve a full water balance. The DOE also indicated that full recovery of percolation is not

necessary to interpret the Alcove 8/Niche 3 tests. As an alternative, the DOE proposed to cut slots in Niche 5 to capture the bypass flow from seepage experiments. The injection of fluid will occur only a few meters above Niche 5, making it possible to capture all flow diverted around the niche.

Criterion 2b, titled “Demonstrate tracers are appropriate homologues for radionuclides,” states that if credit is to be taken for radionuclide attenuation in fractured rock, then the DOE should have demonstrated nonradioactive tracers used in field tests are appropriate homologues for radioelements. The DOE expects to show that non-radioactive tracers used in field tests are appropriate homologues for radioelements. Ongoing testing at Alcove 8/Niche 3 will provide transport data using a suite of tracers representative of conservative and weakly sorbing radionuclides. The DOE has completed tests at the C-well complex using pentafluorobenzoic acid, bromide, lithium, and microspheres . The DOE considers these tests to be representative of transport of conservative radionuclides, sorbing radionuclides, and colloids. For dissolved radionuclides, the DOE is using these results as a means of demonstrating the appropriateness of conceptual models rather than as a source of transport parameters for TSPA. The DOE considers this criterion “closed-pending” pending documentation of Busted Butte and C-wells data.

As a result of additional discussions, the NRC and DOE reached 10 agreements for Subissue #3 (see Attachment 1). With these 10 agreements, the NRC stated that Subissue #3 could be listed as “closed-pending”.

5) Technical Discussion - Subissue #2, Radionuclide Transport Through Alluvium

A summary of the current status of resolution was presented (see “Radionuclide Transport Key Technical Issue, Subissue 2, Radionuclide Transport Through Alluvium” presentation given by Al Aziz Eddebarh, Paul Reimus, and Arend Meijer). The DOE identified the NRC information needs from Revision 2 of the RT IRSR and subsequent NRC/DOE discussions. The DOE stated that the presentations would provide the bases for going to “closed” or “closed-pending” for Subissue #2 acceptance criteria and, therefore, that it believed Subissue #2 should be listed as “closed-pending.”

Through performance assessment the DOE has determined that for the alluvium, transport processes such as sorption, radioactive decay, and colloidal filtration are important to repository performance. On-going and planned testing at the Alluvium Testing Complex will help confirm the applicability of laboratory determined transport parameters. Testing at the Alluvium Testing Complex will also confirm whether the alluvial aquifer can be considered a single continuum porous medium. Future TSPA analyses will be revised to better incorporate the effects of heterogeneity in the alluvium. Heterogeneity in the alluvial aquifer will be incorporated into TSPA analyses by the use of effective porosity distributions. The DOE indicated that gravimeter logs will be run in addition to Nye County wells to obtain further estimates of average formation porosity.

The DOE believes that all acceptance criteria are considered “closed” with the exception of criteria 2a, 2b, 2c, and 4. These criteria are considered to be “closed-pending.”

Criterion 2a stated that for the valid application of the constant K_d approach, the DOE should demonstrate that the flow path acts as a single continuum porous medium. If the flow cannot be shown to be a single continuum porous medium, then the acceptance criteria for radionuclide transport in fractured rock apply. Evidence that the alluvium can be modeled as a single continuum porous medium will be obtained by testing at the Alluvium Testing Complex. The DOE considers this criterion “closed-pending” completion of these tests.

Criterion 2b states that for the valid application of the constant K_d approach, the DOE should demonstrate that appropriate sorption values have been adequately considered (e.g., experimentally determined or measured). The DOE is using preliminary transport parameter values derived from lab measurements in performance assessment analyses. The DOE will refine and confirm these parameter values after multiple well tracer testing of radionuclide surrogates at the Alluvium Testing Complex and after laboratory batch and column radionuclide transport studies. The DOE considers this criterion “closed-pending” the completion of the testing at the Alluvium Testing Complex to obtain hydraulic and transport parameters for the alluvium.

The DOE considers Criterion 2c “closed-pending.” The DOE cited as a basis for “closed-pending” that the following tests of alluvial aquifer samples are planned: (1) batch and column testing of alluvial aquifer material for technetium and neptunium under reducing conditions; (2) column testing to address the assumption of fast desorption kinetics; and (3) laboratory testing under reducing conditions to address the assumption of bulk chemistry.

For Criterion 4, “Expert Elicitation,” the DOE stated that it did not use expert elicitation for development of K_d s for the alluvium. Additional documentation will be provided to explain how sorption coefficient distributions used for performance assessment were derived. The DOE considers this criterion “closed-pending” additional documentation of expert judgement.

As a result of additional discussions, the NRC and DOE reached 11 agreements for Subissue #2 (see Attachment 1). With these 11 agreements, the NRC stated that Subissue #2 could be listed as “closed-pending”.

6) Features, Events, and Processes

The DOE presented Features, Events, and Processes (FEPs) for unsaturated zone and saturated zone transport (see “Features, Events, and Processes for Unsaturated Zone and Saturated Zone Transport” presentation given by Jim Houseworth). The objective of the presentation was to describe the upcoming revision to the FEPs AMRs.

Out of 128 features, events, and processes important to performance in the unsaturated and saturated zone, the DOE stated that 35 are related to unperturbed radionuclide transport. Of these, 28 are included and 7 are excluded. Included FEPs are those that are modeled in the TSPA either directly or indirectly. Excluded FEPs are not included in the TSPA. The seven excluded features, events, and processes were excluded based on low consequence.

The DOE stated that it was updating the unsaturated and saturated zone flow and transport FEPs AMRs, and that the AMRs will be provided in NRC upon completion.

7) Public Comments

The State of Nevada (Ms. Linda Lehman) provided written comments at the meeting which were read at the end of the meeting. The comments were as follows:

- 1) There may be a disconnect between unsaturated zone and saturated zone structures important to transport. For example, the Ghost Dance Fault Splay seems to be important in the unsaturated zone, but may not be explicitly gridded in the saturated zone.
- 2) Distribution of recharge in the unsaturated zone is still problematic, for example on the western slope and especially where Paintbrush Tuff non-welded is absent. (This may also be relevant to the unsaturated zone FEP AMR - infiltration and recharge).
- 3) Flow paths in the saturated zone are still of concern.
- 4) Much more work must go into defining paths and chemistry thru alluvium.
- 5) There is concern about correlated variables and their use in Monte Carlo methods for performance assessment.
- 6) The State of Nevada has a problem with the boundary conditions used for diffusion, especially in Topapah Springs.
- 7) The State of Nevada has a problem with boundary conditions with respect to saturated zone dispersion stratigraphically and laterally.

C. William Reamer
Deputy Director
Division of Waste Management
Nuclear Regulatory Commission

Dennis R. Williams
Deputy Assistant Manager
Office of Licensing & Regulatory Compliance
Department of Energy