UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

May 19, 1999

MEMORANDUM TO: C. William Reamer, Chief
HLWB, DWM/NMSS

THRU: David Brooks, Section Leader
Geosciences Section
HLWB, DWM/NMSS

FROM: Bret Leslie
Geosciences Section
HLWB, DWM/NMSS

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HLWB, DWM/NMSS

SUBJECT: IN-DRIFT GEOCHEMICAL ENVIRONMENT AND ENGINEERED BARRIER SYSTEM TRANSPORT WORKSHOP TRIP REPORT, APRIL 12-15, 1999

Bret Leslie and Bill Dam attended a U.S. Department of Energy (DOE)-sponsored performance assessment (PA) workshop on the In-Drift Geochemical Environment (IDGE) and Engineered Barrier System (EBS) Transport. The workshop addressed what work will be necessary, in this subject area, for DOE to complete a defensible PA to support both the Site Recommendation (SR) and License Application (LA) for the potential Yucca Mountain high-level waste repository. The meeting was held in Las Vegas on April 13-15, 1999. This trip report provides highlights of the meeting, including the latest repository design, and describes how NRC's program may be influenced.

BACKGROUND

This meeting was one in a series of workshops run by DOE's PA organization on abstractions to be used in the Total System PA (TSPA) SR and LA. The two primary goals for this workshop were: 1) to prioritize and plan specific work activities needed for TSPA-SR, and 2) to review a list of Features, Events, and Processes (FEPs) and assign ownership of the FEPs to individual participants. NRC staff were invited to observe the workshop and share our observations on the process and proposed work to be completed prior to SR and LA.

Approximately 50 people attended the workshop. Thirty-five presentations, including overview and technical presentations, were delivered. Small group "break-out" sessions followed the presentations. Overview presentations provided the TSPA perspective, TSPA schedule, TSPA deliverables, information on the FEP approach, quality assurance (QA) expectations, LA design, a review of the TSPA-Viability Assessment (TSPA-VA) models, the Process Model Reports (PMR) approach, and a proposed baseline approach to the TSPA-SR.

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Technical presentations summarized the status of the EBS testing program and described the IDGE and EBS process-level models. Many of the workshop technical presentations addressed design features that are not currently planned in the most recent EBS. Capillary barriers (also called Richard's barriers), for example, are currently not included in the design but research results were presented. These results may be very useful to other NRC programs such as in Uranium Recovery and Low-Level Waste involving remediation designs to control contaminant migration.

The break-out sessions served the purpose of assigning responsibility for each FEP, initial screening of FEPs, and developing work plans to complete the work for TSPA-SR. Small groups discussed aspects of emplacement drifts for hydrology, boundary conditions, EBS transport and the chemical environment for drifts, the waste-form, and in-package transport.

INSIGHTS ON DOE PROGRAM

Information gathered during the workshop provides many insights on DOE's program and how recent changes may impact NRC's program. Three issues appear to be pertinent to ongoing NRC activities. First, there are three major changes among the TSPA-VA, TSPA-SR and TSPA-LA. The difference in designs between the VA design and the design used for SR and LA are addressed on page 4. Second, the analyses in TSPA-SR and TSPA-LA will be qualified. Finally, an analysis of FEPs, as required by proposed 10 CFR Part 63, will be included in TSPA-SR (see discussion of TSPA-SR approach below). Enhancements to the model abstractions presented in the TSPA-VA analyses will be minor in the TSPA-SR.

The second programmatic insight involves the timing and scope of remaining DOE pre-licensing documents (refer to Table 1). These documents, and their timing, will impact NRC's scheduling and ability to provide effective comments on DOE's program during the pre-licensing period. There will be two revisions of the TSPA-SR. The first, TSPA-SR, Rev. 0, a Level 3 milestone by the contractor, is scheduled to be completed on July 14, 2000. This document is broadly comparable to the Technical Basis Document that formed the basis for the NRC staff comments on the TSPA-VA. Within the TSPA-SR will be the PMRs, which directly correspond to some of the chapters in the VA Technical Basis Document. DOE does not expect to release the draft SR for comment by the NRC and the public until November 13, 2000. The draft SR would include the TSPA-SR. NRC's comments on the SR would be due to DOE by May 25, 2001. The second revision of TSPA-SR, Rev. 1, will be completed by the contractor on February 28, 2001. The projected date for DOE's acceptance of the deliverable is not until April 13, 2001. The updated Rev. 1 of TSPA-SR will have less data requiring verification, will include discussions on defense-in-depth, and more sensitivity and bounding analyses. These aspects would not be covered in TSPA-SR, Rev. 0. Therefore, we recommend NRC management request all contractor Level 3 milestone reports to facilitate staff reviews.

Finally, the proposed changes in design (see next section for details) and the application of the FEP screening process may lead to post-closure criticality being screened out. This impacts the NRC program since we are currently in the process of reviewing the Disposal Criticality Analysis Methodology Topical Report and NMSS is contemplating funding some work through the Office of Research on post-closure disposal criticality. Both of these efforts assume that

there would be TSPA calculations of post-closure criticality in the LA. The preliminary projected performance for the proposed SR and LA design indicates first waste package failure due to corrosion at 100,000 years. Participants at the workshop indicated that the criticality external to the waste package has been screened out in the FEP analysis and will not be included as part of TSPA calculations. The basis for screening out external criticality will be the TPSA-VA and existing documentation, including the Disposal Criticality Analysis Methodology Topical Report, and references therein. Their case will be based on probability arguments and Part 63, which allows for screening out of FEPs. It was stated that for FEPs that are screened out for SR, there will be no further work prior to licensing. Whether all post-closure criticality scenarios, including in-package criticality will be screened out, is not yet clear. The Disposal Criticality Analysis Methodology Topical Report and NRC efforts to review this document may not be consistent with the approach to be taken by DOE for TSPA-SR.

Table 1. Schedule and Scope of Activities Supporting Yucca Mountain Site Recommendation

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NRC sufficiency comments	NRC milestone	May 25, 2001
TSPA-LA	Contractor deliverable	September 30, 2001
TSPA-LA	DOE milestone	November 15, 2001
DOE LA	Submit to NRC	March 1, 2002

REPOSITORY DESIGN ISSUES

The proposed design for SR and LA is substantially different than the VA design (refer to Table 2; see attachment for figure). On April 14, 1999, the Enhanced Design Alternative II (EDA II) was submitted to DOE as the preliminary proposed design for SR and LA. A decision on the design for SR and LA will not occur until the end of May 1999 (Table 1).

Table 2. Design Features and Predicted Performance for EDA II design and VA design

Evaluation Criteria	EDA II	VA Reference
Design Characteristics		
Areal mass loading (MTU/acre)	60	85
Drift spacing (m)	81	28
Drift diameter (m)	5.5	5.5
Emplacement drifts length (km)	54	
Access drift length (km)	33.4	
Repository area (acre)	1060	740
Ground support	Steel sets	Concrete lining
Invert	Steel with sand or gravel ballast	Concrete
Waste package loading	Line	Point
Waste package materials	2 cm Alloy-22 over 5 cm Stainless Steel (316NG)	10 cm carbon steel over 2 cm Alloy-22
Waste package capacity PWR spent fuel assemblies	21	21
Average initial waste PWR package heat output (kW)	9.3	
Peak to average heat output for PWR package	120%	195%
Drip shield (emplaced at closure)	2 cm Ti-7	None
Backfill (emplaced at closure)	Yes	No
Pre-closure period (years)	50	50
Pre-closure ventilation rate (m^3/s)	2-5	0.1
Performance (central estimate)		
First/median drip shield failure (yr)	9,000/55,000	N/A
First/median waste package failure (yr)	100,000/325,000	3,000/165,000
Peak dose rate (mrem/yr)	85	330
Time of peak dose rate (yr)	630,000	310,00
Dose rate at 10,000 yr (mrem/yr)	$< 1 \times 10^{-2}$	

The design goals of EDA II are to ensure that boiling fronts from individual emplacement drifts do not coalesce and the temperature of cladding on spent fuel remains below 350 °C. The rationale for the design is two-fold. First, the design will permit shedding of water in the rock pillars, between the emplacement drifts, during the thermal pulse. Second, the design will reduce uncertainty associated with the amount of water that enters the drifts during thermal pulse. The EDA II design features include blending of spent fuel assemblies, a dual-layer waste package with a single layer of corrosion resistant material (CRM), line-loading of waste packages, pre-closure ventilation, a drip-shield, and backfill (emplaced at closure).

Between now and the end of May 1999, DOE will perform a cost/benefit analysis of backfill materials for enhancing performance. A key consideration is the ventilation rate and duration necessary to achieve temperature goals. Other topics to be studied in May 1999 include: modular design and construction; titanium drip shield thickness and resistance to failure by rockfall; waste package size standardization; details of waste package design for Alloy 22 over stainless steel; invert design (steel with sand ballast); and the design basis heat output for waste packages.

The mass loading and footprint design for EDA II includes an areal mass loading of 60 MTU/acre; drift spacing of 81 m (center to center), about 1060 acres used for emplacement in the upper block, 54 km of emplacement drifts; 33.4 km of access drift; and a total of 10, 039 waste packages. The drift layout in EDA II includes; line loading of waste packages; a 5.5 m diameter emplacement drift; steel sets for ground support; Ti-7 drip-shield; and backfill of an unspecified material (currently assumed to be quartz sand). The proposed waste package design is a single CRM waste package, with 2 cm of Alloy 22 over 5 cm of stainless steel (316NG). The waste package is proposed to contain 21 pressurized water reactors or 44 boiling water reactor spent fuel assemblies. The average initial waste package heat output would be 9.3 kW. Blending of assemblages would ensure that the maximum initial waste package heat output is within 20 percent of the average heat output. Thermal management would include blending, pre-closure ventilation (about 2-5 cubic meters m/sec airflow in emplacement drifts over a 50-year period), and possible closure at 50 years. Two or three high velocity exhaust shafts would be required to support the proposed ventilation strategy. Several preliminary TSPA calculations for EDA II were presented. These calculations indicate the first drip-shield failure is predicted to occur after 9000 years resulting in a dose rate less than 10 µrem/yr during the first 10,000 years, and a peak dose rate of 85 mrem/yr at about 305,000 years.

TSPA-SR APPROACH

The approach that DOE will implement to document model abstractions used in the TSPA-SR will differ from previous approaches. Inclusion of the FEP analysis and the requirement that the work meet QA strictures will affect the products that NRC will review for site recommendation. The QA requirement that DOE contractors must follow for PA is called AP-3.1Q. The primary procedure that the PA groups will use to control and document their abstraction models and FEP analysis is called AP-3.10Q.

DOE will rely on PMRs to synthesize all technical and supporting information that are necessary to fully describe their models and justify their suitability for application to post-closure PA of the Yucca Mountain. The PMR chapters are comparable to the chapter of the Technical Basis Document of the VA. The eight PMRs are: 1) integrated site model; 2) unsaturated zone flow and transport model; 3) saturated zone flow and transport model; 4) near field environment (covers thermal-hydrology effects, and coupled thermal-chemical-hydrologic effects external to the emplacement drifts); 5) waste package degradation; 6) waste form degradation; 7) EBS degradation and flow/transport model; and 8) biosphere. Key items to be addressed in each PMR are the technical issues; the conceptual basis and assumptions; description of models and computer codes; verification of QA status of codes; data supporting the models; model validation; and abstraction of models into the TSPA framework. The EBS PMR is comprised of four components: 1) the physical and chemical environment model; 2) water distribution and removal model; 3) radionuclide transport model; and 4) degradation mode analysis. For each of the first three components there may be more than a single process level abstraction that is necessary to describe the model. Currently, for instance, the physical and chemical environment model will have seven different abstraction models that will support it. Each abstraction will have its own AP-3.10Q report that documents the work and the assumptions. In addition, the first three components will have an AP-3.10Q that documents and controls the integration of the abstractions into the models.

The EBS PMR will only partially address the FEPs and scenario analysis. The FEPs will be used to develop scenarios presented in the TSPA. There are five steps to scenario development and analysis. The PMR will only document the first two steps in scenario development. The first step in scenario development is to identify and classify features, events, and processes potentially relevant to the long-term performance of the disposal system. There are about 70 FEPs within the scope of the EBS PMR that were addressed in this workshop. The second step is to screen FEPs using well-defined criteria to identify those that should be included in the TSPA and those that can be excluded. The final steps in scenario analysis will be addressed elsewhere.

FEPs will be screened based on regulatory arguments (specifically addressed in proposed Part 63), probability arguments (exclude events with probability < $10^{-4}/10^{4}$ yr), and consequence arguments. DOE will exclude FEPs that do not affect overall performance by using sensitivity analyses, bounding analyses, intermediate performance measures, and reasoned arguments based on literature. The initial screening of FEPs is due at the end of April 1999. This screening will include preliminary arguments for inclusion or exclusion of FEPs. Complete FEP screening arguments for excluded FEPs will be completed by August 2, 1999 (as previously shown in Table 1). Currently, the screening arguments for individual FEPs will be documented in the relevant AP-3.10Q for the abstracted model.

The final component of the EBS PMR will be the degradation mode analysis. This analysis describes the screening of FEPs, inclusion of retai[illegible]-EPs, identifies and addresses coupling failure modes within each of the EBS models (the fi[illegible] three components of the EBS PMR described above). The degradation mode analysis was described only as an integration and re-analysis report of the retained FEPs. This means there may be over 15 places (15 AP-3.10 Q reports) where NRC staff will need to look to review the FEPs analysis for FEPs that are excluded within the EBS PRM.

SUMMARY AND PATH FORWARD

The workshop was a success. Workshop participants reviewed a list of FEPs, assigned ownership for the individual FEPs, and completed an initial screening of all the FEPs. Participants also prioritized and planned, on a general level, the work activities necessary to complete the TSPA-SR in the area of the in-drift geochemical environment and EBS transport. The technical presentations demonstrated that substantial science has been conducted since DOE VA was completed. Many of these studies were not documented in the LA Plan in DOE's VA. Equally important, deficiencies in modeling within the drift environment, recognized in the TSPA-VA, were addressed. It appears that work plans to address the deficiencies will be completed. However, given the tight time constraints, there will be substantial areas of the TSPA-SR where the status of information used in the abstractions will state "to be verified."

NRC staff were asked informally by many workshop participants for guidance on several issues. We offered to bring all the following concerns to the attention of NRC management. Many attendees wanted to know what NRC will require for defense-in-depth and its demonstration in a PA. The participants wanted to know when they will receive NRC's written comments on the VA, particularly on the TSPA-VA and its relationship to design issues. Some participants are interested in determining what will NRC require for the FEPs analysis and how best to present the information. The Yucca Mountain Projects priorities under the nuclear culture include "meeting the site recommendation schedule (July 2001) using the principle of minimal, necessary and sufficient work" (Dyer 11/25/98). Some participants inquired, "what did the NRC consider minimal, necessary, and sufficient?"

We request meeting with NRC management to discuss the above principles that are mandated by DOE. In addition, NRC staff should consider the best way to continue effectively commenting on DOE's program during the pre-licensing phase given the tight time constraints and the generation of relevant contractor documents early in their schedule for the SR and LA. The apparent dual track approach for addressing criticality needs to be discussed. Finally, we recommend having the NRC QA staff acquire the QA procedures that will be used to control the PA for the SR and LA (AP-3.1Q and AP-3.10Q). These procedures could give the reviewers early insight into whether the PMR reports would contain the information necessary to meet NRC acceptance criteria for a TSPA.

If there are any questions about the trip or the contents summarized in this trip report, Bret Leslie can be contacted at (301) 415-6652, or through e-mail (bwl). Bill Dam can be contacted at (301) 415-6710, or through e-mail (wld).

Attachment: Figure, as stated

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TSPA-SR APPROACH

The approach that DOE will implement to document model abstractions used in the TSPA-SR will differ from previous approaches. Inclusion of the FEP analysis and the requirement that the work meet QA strictures will affect the products that NRC will review for site recommendation. The QA requirement that DOE contractors must follow for PA is called AP-3.1Q. The primary procedure that the PA groups will use to control and document their abstraction models and FEP analysis is called AP-3.10Q.

DOE will rely on PMRs to synthesize all technical and supporting information that are necessary to fully describe their models and justify their suitability for application to post-cl[illegible] PA of the Yucca Mountain. The PMR chapters are comparable to the chapter of the T[illegible] Basis Document of the VA. The eight PMRs are: 1) integrated site model; 2) unsa[illegible] zone flow and transport model; 3) saturated zone flow and transport model; 4) near field environment (covers thermal-hydrology effects, and coupled thermal-chemical-hydrologic effects external to the emplacement drifts); 5) waste package degradation; 6) waste form degradation; 7) EBS degradation and flow/transport model; and 8) biosphere. Key items to be addressed in each PMR are the technical issues; the conceptual basis and assumptions; description of models and computer codes; verification of QA status of codes; data supporting the models; model validation; and abstraction of models into the TSPA framework. The EBS PMR is comprised of four components: 1) the physical and chemical environment model; 2) water distribution and removal model; 3) radionuclide transport model; and 4) degradation mode analysis. For each of the first three components there may be more than a single process level abstraction that is necessary to describe the model. Currently, for instance, the physical and chemical environment model will have seven different abstraction models that will support it. Each abstraction will have its own AP-3.10Q report that documents the work and the assumptions. In addition, the first three components will have an AP-3.10Q that documents and controls the integration of the abstractions into the models.

The EBS PMR will only partially address the FEPs and scenario analysis. The FEPs will be used to develop scenarios presented in the TSPA. There are five steps to scenario development and analysis. The PMR will only document the first two steps in scenario development. The first step in scenario development is to identify and classify features, events, and processes potentially relevant to the long-term performance of the disposal system. There are about 70 FEPs within the scope of the EBS PMR that were addressed in this workshop. The second step is to screen FEPs using well-defined criteria to identify those that should be included in the TSPA and those that can be excluded. The final steps in scenario analysis will be addressed elsewhere.

FEPs will be screened based on regulatory arguments (specifically addressed in proposed Part 63), probability arguments (exclude events with probability < $10^{-4}/10^{4}$ yr), and consequence arguments. DOE will exclude FEPs that do not affect overall performance by using sensitivity analyses, bounding analyses, intermediate performance measures, and reasoned arguments based on literature. The initial screening of FEPs is due at the end of April 1999. This screening will include preliminary arguments for inclusion or exclusion of FEPs. Complete FEP screening arguments for excluded FEPs will be completed by August 2, 1999 (as previously shown in Table 1). Currently, the screening arguments for individual FEPs will be documented in the relevant AP-3.10Q for the abstracted model.

The final component of the EBS PMR will be the degradation mode analysis. This analysis describes the screening of FEPs, inclusion of retained FEPs, identifies and addresses coupling failure modes within each of the EBS models (the first three components of the EBS PMR described above). The degradation mode analysis was described only as an integration and re-analysis report of the retained FEPs. This means there may be over 15 places (15 AP-3.10 Q reports) where NRC staff will need to look to review the FEPs analysis for FEPs that are excluded within the EBS PRM.

SUMMARY A^ PATH FORWARD

The workshop was a success. Workshop participants reviewed a list of FEPs, assigned ownership for the individual FEPs, and completed an initial screening of all the FEPs. Participants also prioritized and planned, on a general level, the work activities necessary to complete the TSPA-SR in the area of the in-drift geochemical environment and EBS transport. The technical presentations demonstrated that substantial science has been conducted since DOE VA was completed. Many of these studies were not documented in the LA Plan in DOE's VA. Equally important, deficiencies in modeling within the drift environment, recognized in the TSPA-VA, were addressed. It appears that work plans to address the deficiencies will be completed. However, given the tight time constraints, there will be substantial areas of the TSPA-SR where the status of information used in the abstractions will state "to be verified."

NRC staff were asked informally by many workshop participants for guidance on several issues. We offered to bring all the following concerns to the attention of NRC management. Many attendees wanted to know what NRC will require for defense-in-depth and its demonstration in a PA. The participants wanted to know when they will receive NRC's written comments on the VA, particularly on the TSPA-VA and its relationship to design issues. Some participants are interested in determining what will NRC require for the FEPs analysis and how best to present the information. The Yucca Mountain Projects priorities under the nuclear culture include "meeting the site recommendation schedule (July 2001) using the principle of minimal, necessary and sufficient work" (Dyer 11/25/98). Some participants inquired, "what did the NRC consider minimal, necessary, and sufficient?"

We request meeting with NRC management to discuss the above principles that are mandated by DOE. In addidon, NRC staff should consider the best way to continue effectively commenting on DOE's program during the pre-licensing phase given the tight time constraints and the generation of relevant contractor documents early in their schedule for the SR and LA. The apparent dual track approach for addressing criticality needs to be discussed. Finally, we recommend having the NRC QA staff acquire the QA procedures that will be used to control the PA for the SR and LA (AP-3.1Q and AP-3.10Q). These procedures could give the reviewers early insight into whether the PMR reports would contain the information necessary to meet NRC acceptance criteria for a TSPA.

If there are any questions about the trip or the contents summarized in this trip report, Bret Leslie can be contacted at (301) 415-6652, or through e-mail (bwl). Bill Dam can be contacted at (301) 415-6710, or through e-mail (wid).

Attachment: Figure, as stated

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