QA: NA

August 2004

# Key Technical Issue Letter Report (Response to GEN 1.01)

## Revision 1

Prepared for:

U.S. Department of Energy

Office of Civilian Radioactive Waste Management
Office of Repository Development
1551 Hillshire Drive
Las Vegas, Nevada 89134-6321

Prepared by:
Bechtel SAIC Company, LLC
1180 Town Center Drive
Las Vegas, Nevada 89144

Under Contract Number

DE-AC28-01RW12101

## Note Regarding the Status of Supporting Technical Information

This document was prepared using the most current information available at the time of its development. This Technical Basis Document and its appendices providing Key Technical Issue Agreement responses that were prepared using preliminary or draft information reflect the status of the Yucca Mountain Project's scientific and design bases at the time of submittal. In some cases this involved the use of draft Analysis and Model Reports (AMRs) and other draft references whose contents may change with time. Information that evolves through subsequent revisions of the AMRs and other references will be reflected in the License Application (LA) as the approved analyses of record at the time of LA submittal. Consequently, the Project will not routinely update either this Technical Basis Document or its Key Technical Issue Agreement appendices to reflect changes in the supporting references prior to submittal of the LA.

# CONTENTS

INTENTIONALLY LEFT BLANK

## ACRONYMS

| | |
|---|---|
| CLST | Container Life and Source Term |
| DOE | U.S. Department of Energy |
| ENFE | Evolution of Near-Field Environment |
| GEN | General Agreement |
| KTI | Key Technical Issue |
| NRC | U.S. Nuclear Regulatory Commission |
| PRE | Preclosure |
| RDTME | Repository Design and Thermal-Mechanical Effects |
| RT | Radionuclide Transport |
| SSPA | Supplemental Science and Performance Analyses |
| TBD | Technical Basis Document |
| TEF | Thermal Effects on Flow |
| THE | Tsujikawa Hisamatsu Electrochemical |
| TSPAI | Total System Performance Assessment and Integration |
| USFIC | Unsaturated and Saturated Flow Under Isothermal Conditions |

INTENTIONALLY LEFT BLANK

# KEY TECHNICAL ISSUE LETTER REPORT (RESPONSE TO GEN 1.01)

## 1. GEN 1.01

This report addresses Key Technical Issue (KTI) general agreement (GEN) 1.01. This agreement was reached during the U.S. Nuclear Regulatory Commission (NRC)/U.S. Department of Energy (DOE) Technical Exchange and Management Meeting on Range of Operating Temperatures held September 18 to 19, 2001 (Reamer 2001a). The meeting was conducted by a three-way videoconference between the NRC (Rockville, Maryland), the DOE (Las Vegas, Nevada), and the Center for Nuclear Waste Regulatory Analyses (San Antonio, Texas). This was the second of two technical exchange and management meetings on the range of operating temperatures. The first meeting was held in Rockville, Maryland, on August 2, 2001 (Reamer 2001b).

At the first meeting, DOE presented a summary of its *Supplemental Science and Performance Analyses* (SSPA) (BSC 2001a, BSC 2001b). This report was produced as a supplement to the *Yucca Mountain Science and Engineering Report* (DOE 2001), released in May 2001, that presented technical information supporting the consideration of the possible site recommendation. The studies and analyses described in the SSPA provided additional technical information on (1) quantitative uncertainty analyses, (2) updates in scientific information, and (3) lower-temperature operating mode analysis.

The second meeting focused on comments raised by the NRC regarding the SSPA. The NRC comments and DOE response to the comments are listed in Enclosure 1 (Reamer 2001a). A number of the NRC comments were determined to be concerned with issues that were already subject to existing KTI agreements. These comments were incorporated into GEN 1.01, a KTI agreement in which the DOE agreed to address the comments when the related KTI agreements were addressed. The related KTI agreements were identified in the DOE responses to NRC comments.

Wording of the agreement is as follows.

**GEN 1.01**

> For NRC comments 3, 5, 8, 9, 10, 12, 13, 15, 16, 18, 21, 24, 27, 36, 37, 41, 42, 45, 46, 50, 56, 64, 69, 75, 78, 81, 82, 83, 93, 95, 96, 97, 98, 102, 103, 104, 106, 109, 110, 111, 113, 116, 118, 119, 120, 122, 123, 124, and 126, DOE will address the concern in the documentation for the specific KTI agreement identified in the DOE response (Attachment 2). The schedule and document source will be the same as the specific KTI agreement.

## 2. RELATED KEY TECHNICAL ISSUE AGREEMENTS

Each of the comments listed in KTI agreement GEN 1.01 is related to one or more KTI agreements. The related agreements are listed in Table 1.

## 3. RESPONSE

The majority of comments in GEN 1.01 have been addressed in DOE responses to other KTI agreements, either in individual KTI letter reports or in technical basis documents.

Table 1 shows the disposition of each of the GEN 1.01 comments. The first column shows the NRC comment by number. The second column, entitled "related KTI agreements" refers to the KTI agreement(s) identified in the initial DOE response to the NRC comment. The status column indicates one of the following: (1) complete, as identified in an NRC letter issued on the date indicated; (2) submitted, indicating that the DOE response to a comment has been submitted to the NRC and no review of the response has been received from the NRC; or (3) resubmitted, indicating that a revised DOE response to a comment has been submitted following an NRC determination that the initial submittal did not contain sufficient information. The disposition column shows the document in which the DOE response has been addressed or the letter by which the NRC determined a response to be complete.

Table 1. Related KTI Agreements and Comment Disposition

| Comment | Related KTI Agreements | Status | Disposition |
|---|---|---|---|
| 3 | RDTME 3.15, 3.16, 3.17, 3.19 | Submitted | Addressed in TBD #4, Appendix C |
| 5 | TEF 2.05 | Submitted | Addressed in TBD #5, Appendix M |
| 8 | CLST 2.04,2.05, PRE 7.04,7.05 | Submitted | Addressed herein |
| 9 | CLST 1.12, 2.05 | Submitted | Addressed in TBD #6, Appendix G |
| 10 | CLST 1.12, 2.05, 6.01 | Submitted | Addressed in TBD #6, Appendix G |
| 12 | CLST 1.10 | Submitted | Addressed herein |
| 13 | TSPAI 3.07 | Submitted | Addressed in TBD #3, Appendix J |
| 15 | TEF 2.08 | Submitted | Addressed in TBD #3, Appendix A |
| 16 | TSPAI 3.07, TEF 2.05 | Submitted | Addressed in TBD #5, Appendix M |
| 18 | TSPAI 3.23 | Complete | Complete per NRC Letter of 4/22/03 |
| 21 | TSPAI 3.03, CLST 1.01, 1.02, 1.09, 1.11, 5.03, 5.06; PRE 7.04, 7.05 | Submitted | Addressed in Response to CLST 5.03, 5.04 and 5.05; ENFE 5.03 and RT 4.03 |
| 24 | TSPAI 3.23 | Resubmitted | Addressed in TBD #2, Appendix I |
| 27 | RT 1.02 | Submitted | Addressed in TBD #10, Appendix A |
| 36 | TSPAI 3.17, TEF 2.05 | Submitted | Addressed in TBD #8, Appendix F |
| 37 | ENFE 4.03, 4.06 | Submitted | Addressed in TBD #8, Appendix B |
| 41 | RT 1.05, 2.10 | Submitted | Addressed in TBD #11, Appendix K |
| 42 | RT 2.01 through 2.09 | Complete | Complete per NRC Letter of 8/30/02 |
| 45 | RT 3.08 | Submitted | Addressed in TBD #11, Appendix M |
| 46 | RT 3.07, TSPAI 3.30 | Submitted | Addressed in TBD #8, Appendix D |
| 50 | CLST 1.01, 1.10, ENFE 2.15, 2.17 | Complete | Complete per NRC Letter of 6/25/04 |
| 56 | TSPAI 4.01 | Complete | Complete per NRC Letter of 10/11/02 |

Table 1. Related KTI Agreements and Comment Disposition (Continued)

| Comment | Related KTI Agreements | Status | Disposition |
|---|---|---|---|
| 64 | TSPAI 3.03, CLST 1.01, 1.02, 1.09, 1.11, 5.03, 5.06; PRE 7.04, 7.05 | Submitted | Addressed in Response to CLST 5.03, 5.04 and 5.05; ENFE 5.03 and RT 4.03 |
| 69 | TSPAI 3.23 | Resubmitted | Addressed in TBD #2, Appendix I |
| 75 | USFIC 4.07 | Complete | Complete per NRC Letter of 8/20/02 |
| 78 | TSPAI 3.38 | Resubmitted | Addressed in Response to TSPAI 1.02, 3.37, 3.38, 3.39, 3.41, 4.01, 4.03, 4.04 and 4.06 |
| 81 | ENFE 1.05 | Submitted | Addressed in TBD #5, Appendix B |
| 82 | TSPAI 3.11 | Submitted | Addressed in TBD #3, Appendix K |
| 83 | RDTME 3.20 | Submitted | Addressed in TBD #3, Appendix G |
| 93 | ENFE 1.05 | Complete | Complete per NRC Letter of 6/25/04 |
| 95 | TSPAI 3.07 | Submitted | Addressed in TBD #3, Appendix J |
| 96 | TSPAI 4.01 | Resubmitted | Addressed in Response to TSPAI 1.02, 3.37, 3.38, 3.39, 3.41, 4.01, 4.03, 4.04 and 4.06 |
| 97 | RDTME 3.20 | Submitted | Addressed in TBD #3, Appendix G |
| 98 | ENFE 1.05 | Complete | Complete per NRC Letter of 6/25/04 |
| 122 | CLST 1.01, 6.01 | Submitted | Addressed in TBD #5, Appendix A |
| 123 | CLST 1.08 | Submitted | Addressed herein |
| 124 | CLST 1.01, 3.07 | Submitted | Addressed in TBD #5, Appendix A |
| 126 | ENFE 3.03, 3.04, CLST 3.05, 3.06, 4.05, 4.06, TSPAI 3.08, 3.14 | Submitted | Addressed in TBD #7, Appendix A |

NOTE: CLST = Container Life and Source Term; ENFE = Evolution of the Near-Field Environment; PRE = Preclosure; RDTME = Repository Design and Thermal-Mechanical Effects; RT = Radionuclide Transport; TEF = Thermal Effects on Flow, TSPAI = Total System Performance Assessment and Integration, USFIC = Unsaturated and Saturated Flow Under Isothermal Conditions. TBD #2 = *Technical Basis Document No. 2: Unsaturated Zone Flow*; TBD #3 = *Technical Basis Document No. 3: Water Seeping into Drifts;* TBD #4 = *Technical Basis Document No. 4: Mechanical Degradation and Seismic Effects;* TBD #5 = *Technical Basis Document No. 5: In-Drift Chemical Environment;* TBD #6 = *Technical Basis Document No. 6: Waste Package and Drip Shield Corrosion;* TBD #7 = *Technical Basis Document No. 7: In-Package Environment and Waste Form Degradation and Solubility;* TBD #8 = *Technical Basis Document No. 8: Colloids;* TBD #10 = *Technical Basis Document No. 10: Unsaturated Zone Transport;* TBD #11 = *Technical Basis Document No. 11: Saturated Zone Flow and Transport.*

The three remaining GEN 1.01 comments are addressed below:

**NRC Comment 8**

> The determination of the probability for improper heat treatment of the WP closure welds is not transparent. Non-destructive evaluation methods to determine if the final closure weld have been properly heat treated by induction annealing have not been identified or demonstrated.
>
> Basis:
>
> Improper heat treatment of the closure weld is considered in the SSPA. The probability of improper heat treatment is calculated to be 2.23 x 10-5 based on an event tree analyses provided in the Analyses of Mechanisms for Early Waste Package Failure AMR. This probability includes the probability of an independent

laboratory check to verify that the heat treatment was done properly (with a probability of success estimated to be 0.99 or alternatively a probability of failure of 0.01). For the final closure weld, a non-destructive assessment of the final heat treatment may not be possible. Methods to assess the final closure weld after induction annealing have not been presented in DOE documents. If the final assessment cannot be performed then the probability of improper heat treatment may increase. This may have a significant effect on dose for the early WP failures.

**Initial DOE Response to Comment 8 (from September 2001 Technical Exchange)**[1]

This study represents a sensitivity study designed to evaluate the possible effects of improper heat treatment processes. Under existing CLST KTI agreements 2.4 and 2.5, DOE plans to continue the fabrication process development program including an assessment of stress mitigation process for the end closure weld and associated probability for improper heat treatment.

Applying the Poisson distribution implicitly assumes that failures of the waste packages are independent, and is therefore an approximation that does not include consideration of common-mode failures. Future work will include development and testing of welding, heat treating and inspection equipment and processes. Data from this program will be used to evaluate the potential for common-mode failures, and to refine prediction of the failure rates to be applied in future performance assessment.

The issue of improper heat treatment for a potential LA will be addressed again when the Analyses of Mechanisms for Early Waste Package Failure AMR is revised. Work to support the revision of the AMR is covered under the preclosure KTI items PRE 7.04 and PRE 7.05.

**Response**

Induction annealing is no longer being considered by the DOE for the heat treatment of the waste package final closure weld area. Therefore, the specific issue of induction annealing is no longer applicable.

With regard to the general issue of closure weld treatment, a description of the postweld stress mitigation techniques to be used is presented in *Technical Basis Document No. 6: Waste Package and Drip Shield Corrosion*, Sections 1 and 3, with technical details contained in Appendix Q (Response to CLST 2.04, CLST 2.05, and GEN 1.01 (Comment 7)), Appendix T (Response to PRE 7.03), and Appendix U (Response to PRE 7.05).

The latter appendix specifically analyzes laser peening, the currently baselined stress mitigation method for closure welds, and controlled plasticity burnishing, a potential alternative process. It concludes that either stress mitigation process would produce a shallow near outer surface cold

---

[1] The study mentioned is in response to *Analysis of Mechanisms for Early Waste Package Failure* (CRWMS M&O 2000, Section 6.2.3.1).

work gradient and would be expected to increase strength properties, decrease ductility and toughness, and potentially accelerate thermal aging processes. The closure lid weldments are fully expected to meet the requirements used for waste package performance calculations.

An analysis of the probabilities of events leading to improper laser peening treatment is contained in *Analysis of Mechanisms for Early Waste Package/Drip Shield Failure* (BSC 2003). Event trees are developed that identify scenarios that could lead to improper laser peening of the outer lid weld of the waste package, and probabilities of event occurrence are developed.

**NRC Comment 12**

> The use of cyclic potentiodynamic polarization may not be an appropriate method to obtain critical potentials for the initiation of localized corrosion. During the anodic potential scan, transpassive dissolution may occur rather than localized corrosion. Alternative test methods that avoid high potentials and limit transpassive dissolution may result in the consistent initiation of localized corrosion as well as significantly lower critical potentials for the initiation of localized corrosion.
>
> Basis:
>
> The potential based localized corrosion initiation model is based on the initiation of localized corrosion at critical potentials obtained in cyclic potentiodynamic polarization tests. The use of potentiodynamic polarization may result in the initiation of transpassive dissolution rather than localized corrosion. If transpassive dissolution is initiated the measured current density rapidly increases as a function of potential. During the reverse scan of the potentiodynamic polarization curve, the transition from transpassive dissolution to passive dissolution will likely occur much higher potential compared to repassivation potentials if localized corrosion is initiated.
>
> Recent tests conducted at the CNWRA have shown that cyclic potentiodynamic polarization does not result in the consistent initiation of localized corrosion of Ni-Cr-Mo alloys. During the anodic scan, there is insufficient time for the initiation of localized corrosion prior to reaching high potentials where transpassive dissolution is observed. A modified test method using a combination of a potentiostatic hold at a potential where localized corrosion is initiated preferentially to transpassive dissolution, followed by a slow scan rate to reach the repassivation potential yields critical potentials for the initiation of localized corrosion that are much lower than those obtained using the cyclic potentiostatic polarization method.

**Initial DOE Response to Comment 12 (from September 2001 Technical Exchange)**

> The creviced repassivation potential may lie above either the transpassive dissolution potential or the oxygen evolution potential because of the relatively high localized corrosion resistance of Alloy 22 in YMP relevant environments. Under existing CLST KTI agreement item 1.10, DOE is developing data based on

> potentiostatic polarization tests over a range of potentials, environments and temperatures. It is planned to utilize both uncreviced and creviced specimens.

**Response**

The creviced repassivation potential may lie above either the transpassive dissolution potential or the oxygen evolution potential because of the relatively high localized corrosion resistance of Alloy 22 in relevant environments. The DOE has conducted additional critical potential measurements using other methods, such as the Tsujikawa Hisamatsu Electrochemical (THE) testing, on crevice samples. Results from these tests are in general agreement with the critical potentials obtained from the cyclic potentiodynamic polarization methods. Some of the data from the "THE" method are documented in the response to CLST 1.10 and 1.11 (*Technical Basis Document No. 6: Waste Package and Drip Shield Corrosion,* Appendix O).

While sufficient data have been developed to address this NRC comment, the DOE is continuing to develop data based on potentiostatic polarization and THE tests over a range of potentials, environments, and temperatures using both uncreviced and creviced specimens.

**NRC Comment 123**

> In p. 7-67, most of archaeological evidence came from the reducing environment? If that is the case, are the quoted examples relevant to the YM project?

**Initial DOE Response to Comment 123 (from September 2001 Technical Exchange)**

> Section 7.3.7.3 of SSPA Vol. 1 documented any existing natural and archaeological analogues that could provide additional lines of evidence for long-term degradation of waste package materials under repository relevant exposure conditions. The documented analogues, except the iron pillar of Asoka, India and iron and nickel-iron alloys from meteorites, were exposed to varying degrees of reducing environments. Although the documented analogues do not provide direct quantitative evidence of long-term waste package degradation in the potential repository, their long-term durability in their respective exposure conditions provides very useful implications to the potential longevity of waste packages in the potential repository.
>
> Additional corroborative data on the natural and industrial analogues are being obtained under existing KTI agreement CLST 1.8.

**Response**

The DOE is no longer using the SSPA approach (BSC 2001a, Section 7.3.7.3) for corroborating the long-term general corrosion of the waste package outer barrier using natural and archaeological analogs. Instead, the additional lines of evidence are obtained through experimental data on passive film characterization on Alloy 22 and other industrial analogs, such as stainless steels and other nickel alloys. Details are discussed in the responses to CLST 1.08 and 1.09 (*Technical Basis Document No. 6: Waste Package and Drip Shield Corrosion,* Appendix N).

Additional corroboration of the general corrosion rates of Alloy 22 are obtained from longer term exposures of test samples in the Long Term Corrosion Test Facility (documented in the response to CLST 1.07-AIN-1 in *Technical Basis Document No. 6: Waste Package and Drip Shield Corrosion*, Appendix A) and other short-term electrochemical testing (documented in *Technical Basis Document No. 6: Waste Package and Drip Shield Corrosion*, Appendix V).

## 4. CONCLUSIONS

Comments addressed in previous KTI agreement responses (Table 1) and in this report are responsive to agreement GEN 1.01 made between DOE and NRC. This report contains the information that DOE considers necessary for NRC review for closure of this agreement.

## 5. REFERENCES

BSC (Bechtel SAIC Company) 2001a. *FY 01 Supplemental Science and Performance Analyses, Volume 1: Scientific Bases and Analyses*. TDR-MGR-MD-000007 REV 00 ICN 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010801.0404; MOL.20010712.0062; MOL.20010815.0001.

BSC 2001b. *FY01 Supplemental Science and Performance Analyses, Volume 2: Performance Analyses*. TDR-MGR-PA-000001 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010724.0110.

BSC 2003. *Analysis of Mechanisms for Early Waste Package/Drip Shield Failure.* CAL-EBS-MD-000030 REV 00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20031001.0012.

CRWMS M&O (Civilian Radioactive Waste Management System Management and Operating Contractor) 2000. *Analysis of Mechanisms for Early Waste Package Failure.* ANL-EBS-MD-000023 REV 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001011.0196.

DOE (U.S. Department of Energy) 2001. *Yucca Mountain Science and Engineering Report*. DOE/RW-0539. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20010524.0272.

Reamer, C.W. 2001a. U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Range of Operating Temperatures (September 18-19, 2001). Letter from C.W. Reamer (NRC) to S. Brocoum (DOE) October 2, 2001, 1018010176, with enclosures. ACC: MOL.20020102.0138.

Reamer, C.W. 2001b. U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Range of Operating Temperatures (August 2, 2001). Letter from C.W. Reamer (NRC) to S. Brocoum (DOE) August 14, 2001, with enclosures. ACC: MOL.20011029.0286.

INTENTIONALLY LEFT BLANK

# ENCLOSURE 1: SUMMARY OF NRC COMMENTS AND DOE RESPONSES FROM THE SEPTEMBER 2001 TECHNICAL EXCHANGE ON RANGE OF THERMAL OPERATING MODES

INTENTIONALLY LEFT BLANK

# NRC Comments and DOE Responses

## Range of Thermal Operating Modes: Technical Exchange—September 18-19, 2001

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 1 | Inconsistent ranges of allowable waste package and drift spacings, repository footprints, SNF thermal aging, and ventilation scenarios (i.e., duration, air flow rates, and forced vs. passive) are specified and evaluated in the SDEIS, S&ER, SSPA, and Thermal Management Technical Exchange Presentations. | The ranges used in the SSPA were selected to facilitate comparisons between thermal operating modes and to examine the sensitivity of various performance metrics to key input parameters. The ranges selected for the SSPA do not necessarily need to be consistent with those in other documents mentioned. [1, 2] |
| 2 | Waste package spacing could be increased from 0.1 m to as high as 8.0 m (range given in 8/2/01 Gene Rowe Presentation) to achieve lower effective thermal line loads within the repository drifts. No discussion has been provided by the DOE as to how much waste package spacing can be allowed without negating the fundamental thermal line load assumption used in many DOE process level models and related model abstractions. | The Multi-scale Thermohydrologic (MSTH) model includes a 3D submodel that includes individual waste packages and gaps. The line-loading assumption is thus not included in the base case TSPA-SR analyses. Some simplified analyses do use the assumption.<br>The 3-D ANSYS model includes individual waste packages and gaps similar to the MSTH model and therefore does not rely on the line loading assumption. The 2-D ANSYS model assumes a constant line loading down the entire length of the drift.<br>Should a change in waste package spacing be carried forward for a potential LA, the thermal loadings in DOE process models and related model abstractions will be evaluated for impact. [1, 2] |
| 3 | None of the uncertainty and/or sensitivity analyses performed in the SSPA include the effects of drift collapse. Analyzing the potential consequences of drift collapse should be done to satisfy the basic TSPAI alternative conceptual model requirement. | The SSPA rockfall sensitivity analyses (Sect. 6.3.4) was limited to examining the potential importance of three key uncertainties on rockfall. These uncertainties included 1) multiplier of fracture trace lengths, 2) Terzaghi correction factor, and 3) number of Monte Carlo simulations. These subsystem analyses did not substantially change the results of the rockfall model from that presented in the SR wherein we concluded rockfall did not significantly impact performance. As efforts were focused on other aspects of EBS performance, DOE did not perform system level SSPA Volume 2 calculations that included rockfall. DOE is continuing to do uncertainty analyses and examining an alternative model to improve the basis for screening rockfall from performance assessment abstractions per KTI agreements RDTME 3.15, RDTME 3.16, RDTME 3.17, and RDTME 3.19. If it is determined from these additional analyses that rockfall may significantly impact repository performance then, rockfall will be evaluated for abstraction into the TSPA calculations for any potential LA. [2] |
| 4 | Table 2-14 of the S&ER clearly states that the limiting temperature exposure for instruments, monitoring equipment, and remote access equipment is 50°C, but the emplacement drift temperatures, even for the Low Temperature Operating Mode (LTOM), are well above this limit. | The temperature limits in Table 2-14 are "working temperatures" that must be met for temporary equipment inside the drift. As stated in the S&ER Section 2.3.4.3, "Since the emplacement drift exhaust air temperature peaks at 60°C (140°F), additional airflow will be required to lower the temperature below 50°C (120 °F)." |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 5 | DOE did not adequately assess the probability and effects of condensation forming under the drip shield for the LTOM. | The repository performance is not sensitive to the uncertainty in condensation under the drip shield for the current LTOM results. The effect of LTOM calculations will tend to not have a significant impact since substantial waste package failure will not occur during the period when significant evaporation and condensation will occur. In addition, the bounding model ignores several effects that will reduce the flux from condensation, such as (1) natural convection lowering the temperature difference between drip shield and invert, and (2) the potential for condensation on cooler elements of the EBS, such as the vertical sides of the drip shield or the drift walls. [1] KTI agreement TEF 2.5 and FEP 2.1.08.14.00, Condensation on the underside of the drip shield addresses this concern. [2] |
| 6 | The SSPA uses an Arrhenius fit to current densities measured in electrochemical tests for calculating an activation energy to model the effect of temperature on uniform corrosion rate of Alloy 22. The corrosion rate data obtained from the Long Term Corrosion Test Facility (LTCTF) is combined with an activation energy dependence calculated using alternative data sets (Scully et al. 2001 [DIRS 154513] Lee et al. 2001 [DIRS 154891], Lloyd et al. 2001 [DIRS 155186]). Corrosion rates calculated from the electrochemical measurements conducted by Scully et al. 2001 [DIRS 154513] and Lee et al. 2001 [DIRS 154891] are much greater than those measured in the LTCTF, however the actual values of the calculated corrosion rates reported by Scully et al. 2001 [DIRS 154513] and Lee et al. 2001 [DIRS 154891] are not used in the SSPA uniform corrosion rate model.<br>Basis:<br>In the SSPA, an activation energy of 36 kJ/mol is calculated from passive current density data obtained at several temperatures (Scully et al. 2001 [DIRS 154513], Lee et al. 2001 [DIRS 154891]). Important experimental details that are relevant to the validity of the measurements (i.e., applied potentials, deaeration of the solutions, time to reach steady state, etc) are not properly reported. An activation energy of 32 kJ/mol is calculated from another current density data set (Lloyd et al. 2001 [DIRS 155186], Lee et al. 2001 [DIRS 154891]). The activation energy of 36 KJ/mol is combined with the corrosion rate data obtained from gravimetric measurements of specimens exposed in the LTCTF. The uniform corrosion rate for Alloy 22 after 2 yr exposure was found to be independent of temperature (60 and 90°C) and chemical composition of the environment. Corrosion rate data from the LTCTF is assumed in the SSPA to be valid for 60°C. Using the LTCTF data with the 36 kJ/mol activation energy, the corrosion rate | The temperature dependent general corrosion rate model for Alloy 22 was developed for sensitivity studies to evaluate the potential effects of temperature dependent general corrosion processes. As indicated in the NRC comments, the testing conditions and measurement techniques employed in the short-term potentiodynamic polarization measurements do not result in the steady-state corrosion current density, and the current density data do not represent the passive dissolution (or general corrosion) rate of Alloy 22. Therefore the absolute values of the dissolution rate from the current density data are not suitable for the waste package performance assessment calculations. However it was assumed that the temperature dependence of the measured current density represents closely the temperature dependence of the corrosion current density (i.e., passive dissolution rate or general corrosion rate) of Alloy 22. The measured current densities for temperatures from 80 to 95°C were used to estimate only the temperature dependence term (i.e., activation energy term) assuming the temperature dependence follows the Arrhenius equation. As detailed in Section 7.3.5.3 of SSPA Vol. 1, the activation energy term (i.e., the Arrhenius slope) was combined with the Alloy 22 general corrosion rate CDF used in the TSPA-SR base case, assuming the CDF represents the rate distribution at 60C.KTI Agreements CLST 1.4 and 1.10 address the limited nature of the data available on temperature dependence and the Project is developing corrosion rate data for repository relevant conditions. If a temperature dependent general corrosion model is developed for use in a potential LA, the model will be qualified and documented. [1] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| | at 60°C is calculated to vary from 1.3 x $10^{-5}$ mm/yr at the 5th percentile to 8.0 x $10^{-5}$ mm/yr at the 95th percentile. At 125 °C the corrosion rate is calculated to vary from 1.0 x $10^{-4}$ mm/yr at the 5th percentile to 6.5 x $10^{-4}$ mm/yr at the 95th percentile. In comparison, the data from Scully et al. 2001 [DIRS 154513] indicate that the calculated corrosion rate at 95°C in an electrolyte containing 10:1 [$Cl^-$] to [$NO_3^-$] + [$SO_4^{2-}$] is 1.3 x $10^{-3}$ to 2.9 x $10^{-3}$ mm/yr. Likewise, uniform corrosion rates calculated by Lee et al. 2001 [DIRS 154891], which are provided in SSPA Volume 1 Table 7.3.5-3 p. 7T-7, show the passive dissolution rate at 65°C to be 5.2 x $10^{-4}$ mm/yr. At 85°C, the passive dissolution rate is 1.0 x $10^{-3}$ mm/yr. In summary the corrosion rates calculated from the current density data reported by Scully et al. 2001 [DIRS 154513] and Lee et al. 2001 [DIRS 154891] are as much as 40x greater than the temperature dependent corrosion rate for Alloy 22 used in the SSPA. It can be concluded that the original current density data, reported by Scully et al. 2001 [DIRS 154513], cannot be used for this calculation based on Faraday's law because the measurements conditions are not well established (i.e. non-steady state conditions, presence of oxygen, etc) and the critical determination of the activation energy has been conducted over a very narrow range of temperatures (80 to 95°C). | |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 7 | The basis for the Alloy 22 Thermal aging effect after WP emplacement which is modeled using a probability of 0.0001 and a corrosion rate of 1,000 times higher than that of the general corrosion rate is not provided.<br>Basis:<br>In the SSPA, Alloy 22 was considered to be susceptible to long-range ordering and other phase instability processes. The probability of thermal aging enhancement to the general corrosion rate was assigned a value of 0.0001 with the general corrosion rate enhancement factor of 1000 used. The basis for the probability of 0.0001 and the corrosion rate of 1,000 times higher than that of the general corrosion rate is not provided. The formation of topologically closed packed phases such as P and probably μ phase as a result of thermal aging may result in accelerated grain boundary attack. The penetration rate as a result of corrosion at grain boundaries in this case may be similar to the penetration rate for crevice or pitting corrosion. | The parameters (a probability of 0.0001 and an enhancement factor of 1,000 to the general corrosion rate) were chosen for a sensitivity study only (documented in SSPA Vol. 2) to evaluate the possible effects of an alternative modeling treatment of the effects of aging and phase stability processes. The sensitivity study was to evaluate a simple "what if" case in which the aging and phase stability processes were treated alternatively as a remotely possible case with a much greater consequence to the waste package corrosion.<br>If an Aging and Phase stability model of this type is developed for use in a potential LA, concerns such as those expressed by the NRC comments will be addressed, and the model will be based on data generated under existing CLST KTI Agreements 2.4, and 2.5. [1, 2] |
| 8 | The determination of the probability for improper heat treatment of the WP closure welds is not transparent. Non-destructive evaluation methods to determine if the final closure weld have been properly heat treated by induction annealing have not been identified or demonstrated.<br>Basis:<br>Improper heat treatment of the closure weld is considered in the SSPA. The probability of improper heat treatment is calculated to be $2.23 \times 10^{-5}$ based on an event tree analyses provided in the *Analyses of Mechanisms for Early Waste Package Failure* AMR. This probability includes the probability of an independent laboratory check to verify that the heat treatment was done properly (with a probability of success estimated to be 0.99 or alternatively a probability of failure of 0.01). For the final closure weld, a non-destructive assessment of the final heat treatment may not be possible. Methods to assess the final closure weld after induction annealing have not been presented in DOE documents. If the final assessment cannot be performed then the probability of improper heat treatment may increase. This may have a significant effect on dose for the early WP failures. | This study represents a sensitivity study designed to evaluate the possible effects of improper heat treatment processes. Under existing CLST KTI agreements 2.4 and 2.5, DOE plans to continue the fabrication process development program including an assessment of stress mitigation process for the end closure weld and associated probability for improper heat treatment. [1, 2] Applying the Poisson distribution implicitly assumes that failures of the waste packages are independent, and is therefore an approximation that does not include consideration of common-mode failures. Future work will include development and testing of welding, heat treating and inspection equipment and processes. Data from this program will be used to evaluate the potential for common-mode failures, and to refine prediction of the failure rates to be applied in future performance assessment. The issue of improper heat treatment for a potential LA will be addressed again when the *Analyses of Mechanisms for Early Waste Package Failure* AMR is revised. Work to support the revision of the AMR is covered under the preclosure KTI items PRE 7.04 and PRE 7.05 .[1, 2] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 9 | Data supporting the residual stress calculations as a result of welding, after laser peening and after induction annealing are not provided.<br>Basis:<br>The distribution of residual stresses in the waste package final closure welds is based on Finite element modeling. Details of the Model are provided in the *Stress Corrosion Cracking of the Drip Shield, the Waste Package Outer Barrier, and the Stainless Steel Structural Material* AMR. The effects of induction annealing on the residual stresses in the final closure are detailed in the *Residual Stress Minimization of Waste Packages from Induction Annealing* AMR Several assumption are made in the model that are not supported by data. These include the assumed temperature profile during welding, the cooling rates during welding and the residual stress during induction annealing. The distribution of residual stress in the inner closure weld after laser peening is estimated in the SSPA using a shot-peened Incoloy 908 specimen. The technical basis for using a shot-peened specimen is not provided. Differences in the residual stress mitigation methods (i.e. mechanical shot-peening vs. laser peening) may result in significantly different stress distributions. | This response is provided as a clarification. The residual stress profiles for the post-induction annealing conditions are based on ANSYS calculations using the induction annealing temperatures, temperature distributions and the cooling rates. These calculations are not dependent on the welding conditions and as-welded stress distributions. Preliminary measurements of residual stresses in mock-ups that have been subjected to induction annealing have confirmed the effectiveness of this process. These measurements show that the resulting surface stresses are compressive. The stress profiles for the laser-peened samples are based on actual measurements. The use of shot peening data on Incoloy 908 was only to get uncertainty distribution for the process. The actual magnitude of the stress values were not used in the analysis. Under existing CLST KTI agreements 1.12 and 2.5, DOE is in the process of generating relevant data for use in a potential LA model for SCC. [2] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 10 | The modified stress corrosion cracking parameters are based in recent tests that may not consider the range of possible environments and the effects of fabrication processes.<br><br>Basis<br>The SSPA uses modified parameters for the stress corrosion cracking including the repassivation rate for the slip dissolution model and the minimum threshold stress for stress corrosion cracking. The SSPA indicates that these new parameters are based on recent data. The particular importance is the change in the minimum threshold stress which has been increased from 20-30 to 80-90% of the yield strength. The value of this parameter which is used in the model abstraction as the critical parameter for the occurrence of SCC is likely to be dependent on several factors that have not been investigated such as chemical composition of the environment and the effects of fabrication processes (only a limited number of cold worked and welded specimens has been evaluated). | The initial threshold stress range was selected as 20-30% of yield to be conservative in the absence of significant Alloy 22 specific results. This range of threshold values was for stainless steels in boiling magnesium chloride and in a NaCl drip test on stressed specimens heated to 200°C. However, more recent Alloy 22 specific results are now available on stressed (significantly over yield) U-bends in boiling magnesium chloride and on two-year (and more limited 4-year) exposed samples in SCW, SDW and SAW at 60 and 90°C (the LTCTF tank environments) (including welded specimens). In addition, results are now available on creviced double U-bends exposed 17 months to ~50,000X J-13, pH ~13 (BSW) as well as constant load tests in ~2800X J-13, pH ~12.2 at stresses up to just below the ultimate tensile stress on annealed, welded, cold-worked and aged materials. These Alloy 22 specific results form the basis for the increase in threshold stress range to 80-90% of yield which is still well below the stress levels in the various tests with all results being positive, i.e., no SCC. The high resistance to SCC initiation in this fairly broad range of relevant and accelerated test environments is also consistent with the crack growth test results obtained on compact tension specimens in BSW, SAW and SCW where SCC is only initiated at pre-existing flaws at relatively high K values (30 and 45 MPa/m) under slow cyclic loading. When the very slow cyclic loading is changed to constant load, the crack front may continue to grow for a while at a very low rate (~1-3E-10 mm/s) but the growth generally tapers off to zero. Thus, even if SCC were to initiate, it is unlikely to continue to propagate. Thus, there is a significant basis for increasing the initiation stress threshold as done for the SSPA. This work is covered under the existing CLST KTI agreements 1.12, 2.5 and 6.1. [2] |
| 11 | The analyses of the drip shield corrosion rate and the treatment of drip shield corrosion rate uncertainty in the SSPA is not transparent.<br>Basis:<br>In the supplemental model for drip shield corrosion the uncertainty due to variability is reduced. The effect of this change is in the treatment of uncertainty is that the drip shield failure occurs at later times (failure is delayed approximately 10,000 years with respect to the TSPA-SR base case). No details are provided on how the corrosion rate uncertainty was treated. | The drip shield corrosion rate variance is considered to be 100% due to uncertainty. For each realization, one corrosion rate is sampled for outside-in corrosion and another corrosion rate is sampled for inside-out corrosion (the drip shield underside). Each drip shield in a given realization has the same two general corrosion rates. Drip shield failure times differ only by the varying times at which the relative humidity threshold for the initiation of general corrosion is satisfied. A comparison of SSPA Volume 1 Figure 7.4-14 and SSPA Volume 2 Figure 4.2.5-1 shows that the two mean drip shield failure curves are nearly identical differing only in the time of the first drip shield failure (e.g., the 5$^{th}$ percentile curves for first drip shield failure overlap). If a drip shield corrosion model is used for a potential LA, the modeling approach and rationale for the modeling approach will be qualified and documented in accordance with KTI Agreements (TSPAI 3.05 and TSPAI 4.03). [1, 2] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 12 | The use of cyclic potentiodynamic polarization may not be an appropriate method to obtain critical potentials for the initiation of localized corrosion. During the anodic potential scan, transpassive dissolution may occur rather than localized corrosion. Alternative test methods that avoid high potentials and limit transpassive dissolution may result in the consistent initiation of localized corrosion as well as significantly lower critical potentials for the initiation of localized corrosion.<br><br>Basis:<br><br>The potential based localized corrosion initiation model is based on the initiation of localized corrosion at critical potentials obtained in cyclic potentiodynamic polarization tests. The use of potentiodynamic polarization may result in the initiation of transpassive dissolution rather than localized corrosion. If transpassive dissolution is initiated the measured current density rapidly increases as a function of potential. During the reverse scan of the potentiodynamic polarization curve, the transition from transpassive dissolution to passive dissolution will likely occur much higher potential compared to repassivation potentials if localized corrosion is initiated. Recent tests conducted at the CNWRA have shown that cyclic potentiodynamic polarization does not result in the consistent initiation of localized corrosion of Ni-Cr-Mo alloys. During the anodic scan, there is insufficient time for the initiation of localized corrosion prior to reaching high potentials where transpassive dissolution is observed. A modified test method using a combination of a potentiostatic hold at a potential where localized corrosion is initiated preferentially to transpassive dissolution, followed by a slow scan rate to reach the repassivation potential yields critical potentials for the initiation of localized corrosion that are much lower than those obtained using the cyclic potentiostatic polarization method. | The creviced repassivation potential may lie above either the transpassive dissolution potential or the oxygen evolution potential because of the relatively high localized corrosion resistance of Alloy 22 in YMP relevant environments. Under existing CLST KTI agreement item 1.10, DOE is developing data based on potentiostatic polarization tests over a range of potentials, environments and temperatures. It is planned to utilize both uncreviced and creviced specimens. [2] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 13 | The SSPA argues that rockbolts will not enhance seepage, contrary to the Seepage Model for PA Including Drift Collapse AMR which indicates increased seepage due to rockbolts.<br>Basis:<br>Puddles of water were observed directly under rockbolts in Alcove 5. An explanation provided by DOE for this observation was that water was used for drilling these rockbolts in place. Dripping has been observed from rockbolts in the sealed ECRB. The explanation provided by DOE (so far) for this observation is that this is condensation. | Seepage Model for PA including Drift Collapse AMR uses a simple conceptual model in which rock bolts are represented as "needles" and rock matrix is not accounted for. It is stated in the AMR that this first model is simplistic and conservative, and that more "realism" needs to be incorporated to study the effects of rockbolts on seepage. The SSPA results are based on calculations done for the UZ "realistic case". For these calculations, both fractures and matrix are included on very fine gridding, and, even for a wide range of parameter values for hydrological properties, no enhancement to seepage results from rockbolts. As to the puddles of water observed in Alcove 5, an explanation could be that these are water release from the "doubled-wall" bolts. The dripping in ECRB behind the bulkhead is most likely due to condensation. Data to date in seepage testing in both Niches and in Systematic characterization of the ECRB have not given DOE reason to believe that rockbolts enhance seepage under the range of percolation flux encountered at Yucca Mountain. This issue is addressed in KTI agreement TSPAI 3.07. [1]Future analyses, if carried forward for a potential LA, will include field evidence for the modeling results. |
| 14 | Steady dripping of condensate in an open drift could wet the invert and shadow zone of low saturation below the drift. This could provide an avenue for advective transport through the invert and shadow zone thereby speeding transport into the UZ.<br>Basis:<br>A "shadow" zone of reduced saturation forms below drifts as a consequence of the capillary barrier created by the opening. This reduced saturation corresponds to reduced fracture fluxes and slower advective transport. Transport through the invert is treated as diffusive. However, if dripping condensate forms zones of locally higher saturations, transport through the invert could be enhanced by advective flux. These zones of higher saturation could also speed up transport through the shadow zone below the drifts. | This question is a condensation issue and will be considered with respect to the drift shadow. An important question is the likelihood for condensation to produce continuous dripping. Condensation is not likely during the thermal period because the drift-wall temperature will be high. After the thermal period, the cooler temperature on the drift wall can promote condensation on it, however, surrounding the drift wall is a dry-out region and the source of moisture has to come from outside the rock mass, hence the likelihood of condensation is also not expected to be great. Since there is little drying for the "below boiling" operating mode, there may be a greater likelihood of dripping from condensation. Should DOE pursue the drift shadow model as part of a potential license application, some additional investigation into condensation would be necessary. This issue is addressed in KTI agreement TEF 2.5. [1, 2] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 15 | The analytical approach in this section moves in the direction of resolving part of agreement TEF 2.08 that states, "The DOE will consider the NRC suggestion of comparing the numerical model results to the O.M. Phillips analytical solution". However, this approach should factor into consideration changes in water properties such as increased boiling temperatures of concentrated solutions. Also, taking *u* in this approach to be condensate drainage in the reflux zone instead of net infiltration would give a transient period of increased seepage for a few hundred years after closure.<br>Basis:<br>Increased boiling temperatures of concentrated solutions will increase the distance a liquid rivulet can flow into the above-boiling region. This would have the effect of increasing seepage into drifts during the thermal period of the HTOM as modeled using the approach developed in the section starting on page 4-58.Evidence from the DST indicates some condensate drainage could have high concentrations of dissolved solids. | The analytical approach was used as an alternative conceptual model for thermal seepage. DOE will compare the analytical model with numerical model results, consistent with existing agreement TEF 2.08.[2] The changes in water properties, such as increased boiling temperatures of concentrated solutions, may only be significant for the high temperature operating mode. Preliminary data concerning boiling temperature in the DST indicates that this effect not significant. Note that data from DST geochemical sampling have not shown high concentrations of dissolved solids. A very limited number of samples from a single borehole did show high Cl content (but low silica content). These samples were taken early in the heating cycle of the DST and are believed to be contaminated from the drilling of the sampling boreholes. This will be documented in the AMR "Unsaturated Zone Thermal Testing Analysis" which is expected to be issued in FY 2003. |
| 16 | Closed drifts will have RH close to 1.0. Small temperature gradients in this environment may result in convection, vapor transport, and dripping from condensation. This provides a pathway for water to enter the drift, by vapor exchange at the driftwall, and drip onto engineered materials. Presently the DOE considers convection and condensation in a drift cross-section but does not consider convection along the drift axis.<br>Basis:<br>Agreement TEF 2.05 addresses condensation generally under the heading of cold-trap effect. This agreement specifically addresses lateral flow of vapor along the drift axis in response to temperature gradients such as those created by the edge-effect. This process may be responsible for the dripping observed in the sealed ECRB drift. | The DOE plans to investigate the observations of moisture in the ECRB bulkhead test consistent with existing agreement TSPAI.3.07[2]. Measurements of pore-water moisture tension, relative humidity, and temperature combined with modeling will be used to help interpret the observations. Model calculations will be performed to ensure that the seepage model is consistent with observations and will be used as part of the model validation. The condensation issue will be further investigated for the lower-temperature operating mode should DOE pursue this operating mode in a potential license application (see response to comment 14). [1]Existing agreement, TEF 2.05 "Represent the cold-trap effect in the appropriate models or provide the technical basis for exclusion of it in the various scale models (mountain, drift, etc.) considering effects on TEF and other abstraction/models (chemistry). Page 11 of the Open Item (OI) 2 presentation is relevant to this question. [2] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 17 | Models of repository thermal response are sensitive to thermal conductivity of the host rock. Presently there are very few data on thermal conductivity of the lower lithophysal unit. Also the presence of large lithophysae precludes using core samples to measure thermal conductivity of this unit in the lab.<br>Basis:<br>Thermal conductivity measurements are reported to be underway in the ECRB but are not yet available. Also, for the LTOM larger repository block, more characterization of host rock thermal conductivity may be needed. | Thermal conductivity can be calculated from core sample measurements coupled with field mapping of lithophysal porosity. A laboratory test program is underway to provide input data. A field test program is underway to provide in situ measurements at a scale larger than lithophysal cavities and to check that the approach of combining core data and field mapping is appropriate. Any new information collected on thermal conductivity of lithophysal rock units will be incorporated into thermal hydrologic, thermal-hydrologic-chemical, and thermal-hydrologic-mechanical models. The effects of thermal conductivity on processes such as condensation will also be included with respect to the drift shadow and radionuclide transport for those analyses carried forward to any potential license application.[1] |
| 18 | Results of seepage into drifts shown in Table 5.3.1.4.2-2 after return to ambient conditions appear to be significantly different than results from the Seepage Model for PA Including Drift Collapse AMR and seepage abstraction. What is the reason for these differences and how will the seepage abstraction incorporate this model-predicted range of variability?<br>Basis:<br>Seepage into drifts is important to repository performance and is highly variable and uncertain. | Table 5.3.1.4.2-2 shows results from Multi-Scale Thermohydrologic Model (MSTHM). Most of the stochastic realizations of heterogeneous field that give rise to results in this table assume distributions that have a standard deviation considerably greater than that determined from air-permeability measurements in the ESF. Only realizations C-56 and C-34 have distributions that are more consistent with the air-permeability measurements, and these show no seepage. Note that the current method for abstraction of thermal seepage is presented in the SSPA section 4.3.5. In this section, seepage during the thermal period is limited to the episodic seepage (analytical model) predictions (see response to comment 15). Questions concerning the representation of heterogeneity including the stochastic analyses methods used will be addressed as part of the response to KTI agreement TSPAI 3.23. [1, 2] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 19 | Site-specific investigations of hazards and fractures will be required if DOE cannot demonstrate that existing data can be extrapolated to the expansion areas.<br>Basis:<br>In the existing Probabilistic Seismic Hazard Analysis report, seismic and faulting hazards were calculated from hypothetical “demonstration points” within the original repository block. DOE would have to recompute the hazards to show if/how the hazards would differ in the expansion areas. This information is important to review the performance assessment. | Ground motion hazard was computed for a point at UTM 547.953 km easting, 4077.750 km northing- between the Solitario Canyon and Ghost Dance faults. Fault displacement hazard was determined for 9 demonstration points that span the range of conditions existing in the repository area (i.e., from primary block bounding faults through minor intrablock faults to unfaulted rock). Because ground motion hazard reflects contributions from multiple seismic sources and because attenuation relations do not fall off quickly at less than 10 km, the ground motion hazard for the demonstration point adequately represents the ground motion hazard for the repository area, including expansion areas considered to date. Also, it is expected that expansion areas will not include any faulting conditions that fall outside of the range of conditions considered for the fault displacement hazard analysis. Thus, DOE considers that the results of its seismic hazard analysis adequately represent the hazard for repository areas currently being considered. For a potential LA, DOE will consider the need for additional geotechnical, geophysical, and geologic data based on the geographic extent of the LA repository design. [1, 2] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 20 | It appears that DOE has not properly considered the different repository footprints for the various thermal options when evaluating probabilities for an igneous event. | DOE explicitly evaluated the igneous event probability for two different HTOM repository footprints. These evaluations are discussed in SSPA Vol 1, Section 14.3.3.1. New results from *Characterize Framework for Igneous Activity at Yucca Mountain, Nevada (CRWMS M&O 2000 [DIRS 151551])* were used as input to the supplemental TSPA model presented in SSPA Vol 2, Section 4.3. In addition to the summary of new work, SSPA Vol 1, Section 14.3.3.2 discusses scaling factors that could be applied to results taken from existing work related to the impact of igneous activity on repository performance. Scaling factors related to igneous event probability were specifically addressed in Section 14.3.3.2.2. The SSPA Vol. 1 analysis of scaling factors was presented as supplementary information that could be used by decision-makers to make a qualitative evaluation of alternative repository designs. This analysis and the scaling factors identified in Section 14.3.3.2.2 – 14.3.3.2.4 were referenced, but not explicitly used in Vol 2 analyses. [1]In SSPA Vol 2, Section 4.3.1it is stated that "the probability of igneous disruption is assumed to be the same for the LTOM and HTOM cases in these analyses". It is acknowledged that increasing the area of the potential repository would proportionately change the probability of igneous disruption. In the case of the LTOM design, the repository length is 70% longer than the HTOM design. Further SSPA Vol 2, Section 4.3.1 states that "Adjusting the probability of igneous disruption for the LTOM case would result in a corresponding increase of 70% in the probability-weighted annual dose." [1]In SSPA Vol.2, Section 5.2 it stated that the Vol.2 analyses "do not include the effects of possible changes in the area of the potential repository or waste emplacement geometry associated with alternative thermal operating modes. Analysis of a representative lower-temperature design, one that increases the length of the potential repository by 3,300 m, shows a 70% increase in the probability of igneous disruption and would result in a corresponding increase of 70% in the probability-weighted annual dose for igneous disruption (BSC 2001 [DIRS 154657], Section 14.3.3.2.2)." Note that this analysis reference is for the scaling factor discussion in SSPA Vol.1. [1]For a potential LA, probabilities for an igneous event will be determined on the basis of the design repository footprint. [2] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 21 | The basis for screening criticality from the postclosure performance assessment is contained in a DOE AMR, “Features, Events, and Processes-System Level and Criticality” that references a document “Probability of Criticality Before 10,000 years.” This screening argument relies upon the conclusion that failure of waste packages due to corrosion is not credible during the 10,000 year compliance period. However, analyses in the SSPA indicate that early failure of the waste package is credible due to the possibility of improper heat treatment of the closure welds. Therefore, there isn’t a sufficient basis to screen criticality from the TSPA calculations. There are not models to evaluate the consequences of a criticality event in the TSPA. | The SSPA assumed a non-mechanistic failure mode (improper heat treatment of weld areas) that allowed for early waste package failures (SSPA, Volume 1, Section 7.3.6, 2nd paragraph, last sentence). The SSPA also noted that the postulated failure mode for the early waste package failures (e.g., cracks in the closure weld) is not sufficient for criticality to occur (SSPA Volume 1, Section 9.3, 4th paragraph, 3rd sentence). The SSPA then provided a qualitative basis for screening criticality out, even with early waste package failures. The point of the qualitative basis for screening out criticality is that, in order to have a criticality within the 10,000 year period of regulatory concern, a significant amount of water must enter the waste package (i.e., water vapor in the air is not sufficient). [1]In addition:<br>It is already in our planning to revise the “Analysis of Mechanisms for Early Waste Package Failure”.<br>It is already in our planning to revise the “Probability of Criticality Before 10,000 Years” calculation (KTI agreement CLST 5.3) - originally provided 11/2000, revision to be provided FY02.<br>The “Features, Events, and Process System Level and Criticality” AMR will be re-evaluated based on the revised inputs.<br>The “What-If” criticality evaluation, per KTI agreement CLST 5.6, will follow the Topical Report methodology after assuming an early waste package failure.<br>DOE will consider whether the formation of condensed water could allow liquid water to enter the waste package without the failure of the drip shield.<br>In the assessment of improper heat treatment, DOE will consider the potential for stress corrosion cracking initiation/arrest (KTI agreement TSPAI 3.03), possibility of patch failure (KTI agreements CLST 1.1, CLST 1.2, CLST 1.9, CLST 1.11) as a result of intergranular corrosion, and mitigation process of improper heat treatment (pre-closure agreements PRE 7.04 and PRE 7.05). |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 22 | The footprint area of the latest proposed base case repository layout (e.g., YMSER, Figure 2-38) extends substantially farther north than the repository area that appears to have been used for performance calculations in the TSPA-SR (e.g., YMSER, Figures 4-120, 4-65, and 4-60).<br><br>Basis:<br><br>The base case repository design has changed from that presented in the Viability Assessment. The shape of the layout is more elongated and extends about a km farther north. That is, the northern repository boundary has increased from a northing (m) of about 235750 to about 236750. At the northern boundary of the new proposed repository footprint, the water table is approximately 100 m higher than it is at the northern boundary of the previous design (YMSER, Figure 1-13). The integration of the UZ and SZ transport models in the TSPA abstraction assumes a flat water table at 730 masl for present-day and 850 masl for future climate (UZ PMR, Section 3.7.5.2). The significantly reduced transport distance to the water table for the northern portion of the new repository design does not appear to have been considered in the TSPA abstraction. Maps in the YMSER showing the repository footprint in relation to mapped faults at Yucca Mountain (Figure 1-14) do not use the new proposed repository footprint. The new design will intersect a greater length of the Drill Hole Wash Fault and will also intersect the Pagany Wash Fault which was not intersected by the previous repository design. Particle transport modeling to show potential transport pathways in the UZ and locations of arrival at the water table (YMSER, Figure 4-120) also use the old repository design footprint. With the new design, it is likely, given the presumed high zeolitic content of the CHn in the northern portion, that lateral diversion will result in focused flow toward the Pagany Wash Fault. This constitutes a significantly different transport pathway that is not presently considered in TSPA analyses. The grid discretization shown for the UZ transport model (YMSER, Figure 4-120) is refined in the area corresponding to the old repository design footprint. It is not clear whether the current refinement of the numerical grid for PA calculations is adequate for the footprint areas of the new base case repository layout. | The old footprint associated with the EDAII design was used for gridding and UZ flow and transport calculations that fed the TSPA-SR. For supplemental studies for the low-temperature operating mode and of uncertainty analyses that are captured in the SSPA, UZ flow and transport calculations were performed using a larger footprint. The SSPA work was developed according to AP-3.11Q and special QA controls specified in the technical work plan. Some of the SSPA work may be carried forward to a potential LA, depending on the operating mode selection to be made for LA. As noted in section 1.5 of Vol. 1, at that time, the relevant software and data (including UZ and TSPA model grids) will be updated for the selected operating mode and will be fully qualified and documented.<br><br>Future AMRs that will be used to document unsaturated zone flow and transport associated with any given potential LA design footprint are: [1, 2]<br>Simulation of Net Infiltration for Modern and Potential Future Climates (U0010) (ANL-NBS-HS-000032)<br><br>Analysis of Infiltration Uncertainty (U0095) (ANL-NBS-HS-000027)<br><br>Development of Numerical Grids for UZ Flow and Transport Modeling (U0000) (ANL-NBS-HS-000015)<br><br>Calibrated Properties Model (U0035) (MDL-NBS-HS-000003)<br><br>UZ Flow Models and Submodels (U0050) (MDL-NBS-HS-000006)<br><br>Mountain-Scale Coupled Processes (TH/THM/THC) Models (U0105) (MDL-NBS-HS-000007)<br><br>Radionuclide Transport Models under Ambient Conditions (U0060) (MDL-NBS-HS-000008) |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 23 | DOE is considering five lower-temperature operating mode alternatives, a Full Inventory Repository Layout and an Expanded Repository Capacity (YMSER, p. 2-85). Some of these alternative modes have substantially expanded repository footprint areas compared to the base case design (YMSER, Table 2-2 and Figure 2-10). In addition, options identified in the *Lower-Temperature Subsurface Layout and Ventilation Concepts* (BSC 2001 [DIRS 154554]) and the *Design Input for the Engineered Barrier System Environment and Barriers* (BSC 2001 [DIRS 154548]) will be considered during the selection of the design and operating modes for the potential repository (SSPA, Vol. 1, p. 2-5 and Fig. 3.3.4-7). Only one repository layout mode option has been modeled and evaluated with an extended model grid (SSPA, Vol. 1, p. 3-33). It is not clear whether the current UZ flow and transport process model domains, grid discretization, and supporting characterization data are adequate for robust TSPA analyses of these expanded-repository design alternatives.<br>Basis:<br>Some of the alternative thermal loading designs include construction of an extended repository area to the south in the Abandoned Wash area and a "lower block" covering a large area east of the Ghost Dance fault (YMSER, Figures 2-6 and 2-10). These southern block and lower block areas come quite close to the boundaries of the current site-scale UZ flow model. If TSPA predictions are made for these design alternatives, DOE will need to demonstrate that flow and transport calculations for these model areas are not biased by boundary effects. The southern block in the Abandoned Wash area that is proposed for some of the alternative thermal loading designs lies in an area that is not as well characterized as the area west of the ESF. This southern block lies to the south of the Rock Properties Model boundaries. Faulting in around the southern block extension appears to be more intense based on maps by Simonds et al. (1995) and Day et al. (1998). Fracturing associated with the faulting would also likely be more intense than the area to the north. It is not clear how or whether the coupling between the UZ and SZ flow and transport models in the TSPA abstraction will be modified to allow consideration of performance of the new design and alternative thermal loading design footprints. That is, different source area locations for contaminants reaching the water table result in different SZ transport paths. The grid discretization shown for the UZ transport model (YMSER, Figure 4-120) is refined in the area corresponding to the old repository design footprint. It is not clear | See response to comment 22 for the unsaturated zone. Analyses completed with different source area locations for contaminants reaching the water table did not result in different SZ transport paths as documented in the SSPA chapter 12. [1, 2] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| | whether the current refinement of the numerical grid for PA calculations is adequate for the footprint areas of the alternative thermal loading designs (e.g., east of the Ghost Dance Fault). | |
| 24 | No data to support the conclusion that sublayers in the PTn might act as laterally continuous capillary barriers.<br>Basis:<br>In the SSPA, the UZ flow model domain has been extended to allow consideration of one of the low-temperature operating mode designs -- the one with the pork-chop shaped repository extension to the south. This extended model domain also has a modified grid refinement that is consistent with the most recently proposed "footprint" area for the main repository block, which addresses the earlier criticism that the repository footprint modeled in the flow and transport abstraction for TSPA-SR was not consistent with the most recent design description. An new concern is raised, however, by the grid refinement for the extended UZ flow model domain: it appears that the PTn hydrostratigraphic layer in the flow model has been refined to include two sublayers that act as homogenous, laterally continuous capillary barriers that act to laterally divert more than 20% of deep percolation above the repository toward faults. Such lateral diversion would be beneficial to repository performance, provided that waste packages are not placed in fault zones. There is, however, insufficient data to support the conclusion that sublayers in the PTn that might act as laterally continuous capillary barriers. | The conceptual model for the mountain scale UZ flow and transport is a layer model. Issues of small scale-spatial heterogeneity within each layer are addressed in sub models. That the two sublayers in PTn act as capillary barrier is a result of the calibrated properties model based on inputs of hydrological properties from laboratory measurements. The effects of heterogeneity in modeling PTn flow behavior will be addressed as part of TSPAI agreement 3.23. Future analyses, if carried forward for a potential license application, will include field evidence for the modeling results. Capillary flow and rock-fluid interactions are addressed in “Capillary Barriers in Unsaturated Fractured Rocks of Yucca Mountain, Nevada” by Wu, Y.-S.; Zhang, W.; Pan, L.; Hinds, J.; Bodvarsson, G.S., October 2000. This document presents modeling studies investigating the effects of capillary barriers on fluid-flow and tracer-transport processes in the unsaturated zone of Yucca Mountain. These studies are designed to identify factors controlling the formation of capillary barriers and to estimate their effects on the extent of possible large-scale lateral flow in unsaturated fractured rocks. |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 25 | The "flow splitting algorithm" in the EBS flow and transport model assumes a uniformly wetted WP surface. In this way all WP defects are contacted by some water, but no defects experience very low or very high flow. This assumption may reduce the predicted mean flow rates and will narrow the model uncertainty by reducing the range of expected flow rates experienced by a WP defect.<br>Basis:<br>The DOE justifies the uniform wetting assumption by stating that "the seepage flux is conceptualized to vary spatially over the approximately 10,000 WPs in the repository so that it is not always a single point source at a fixed location throughout time" (ANL-WIS-PA-000001, Rev00). The first part of this statement, that the seepage locations will vary spatially, appears to be intuitively correct. However, the conclusion that the locations will vary temporally is not intuitive and is arguable. The location of particular seepage sources are not random, but are present at a particular location due to some physical anomaly (i.e., crack, fissure, fault, rock bolt, or surface imperfection such as a bulge or depression). The DOE does not specify a driving force that will move the locations of these seepage initiators and thus the seepage locations. An inherent part of the DOE's uniform wetting assumption is that the two events: (i) the location of seepage and (ii) the location of a drip shield and/or waste package defect, are independent events. This is not intuitive and will require further justification by the DOE. The location of a drip and the location of a defect would appear to be highly correlated events. The DOE model does not include such a correlation and thus may underestimate the dripping influx to the WP. The DOE model assumes that only a portion of the water reaching the WP (ratio of the sum of defect lengths and the total length of the WP) enters the WP and thus does not allow the possibility that a large portion of the water reaching the WP can enter the WP. A large portion of the water entering the WP would have a higher likelihood than predicted by the DOE if (i) the seepage locations do not move temporally and (ii) the seepage location and defect location are highly correlated. | The SSPA calculations assumed that seepage location and engineered barrier breach locations were randomly correlated. This is based on the nature of failure from general corrosion and on deliquescence of water into dust on the engineered barrier surfaces. If this assumption is carried forward to a potential LA, evaluation of the importance of the degree of correlation between seepage and EBS breach locations will also be considered. [1]The question of time-variations in flow patterns and local anomalies that could lead to temporal variations in seepage locations will be evaluated for importance to performance for analyses carried forward to a potential license application. [1] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 26 | The MINC is asserted to be better than the DKM and to produce "relatively conservative results". This has not been supported in the SSPA, nor does the referenced AMR provide any more detailed comparison of the two numerical approaches. Furthermore, the referenced AMR (Conceptual and Numerical Models for UZ Flow and Transport) indicates that "the dual-continua approach is expected to give conservative predictions of radionuclide transport in the unsaturated zone." The matrix saturation levels beneath the repository identified in Subsection 11.3.5 seem to be much lower than those discussed in Subsection 11.3.1 (Compare Figures 11.3.1-6 and 11.3.5-2).<br>Basis:<br>The MINC is asserted to be better than the DKM and to produce "relatively conservative results". This has not been supported in the SSPA, nor does the referenced AMR provide any more detailed comparison of the two numerical approaches. Furthermore, the referenced AMR (Conceptual and Numerical Models for UZ Flow and Transport) indicates that "the dual-continua approach is expected to give conservative predictions of radionuclide transport in the unsaturated zone." Matrix saturation levels beneath the repository seem to be much lower than those discussed in Section 11.3.1 (Compare Figures 11.3.1-6 and 11.3.5-2).<br>Recognizing that these analyses were performed for different purposes, they will need to be reconciled once DOE chooses its modeling approach for TSPA-LA. This comment can be addressed by Agreement RT 1.01: Provide the basis for the proportion of fracture flow through the Calico Hills non-welded vitric. DOE will revise the AMR UZ Flow Models and Submodels and the AMR Calibrated Properties Model to provide the technical basis for the proportion of fracture flow through the Calico Hills Nonwelded Vitric. These reports will be available to the NRC in FY 2002. In addition, the field data description will be documented in the AMR In Situ Field Testing of Processes in FY 2002. | It has been found in UZ flow and transport modeling that DKM produces more conservative results in terms of radionuclide travel times to the water table, while MINC provides a more realistic representation of the UZ flow and transport system. TSPA-SR employed the DKM approach, thus yielding a more conservative estimate of UZ performance. DOE acknowledges the need to reconcile the differences should MINC be chosen as the modeling approach to be used in a potential LA. [1, 2] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
| --- | --- | --- |
| 27 | There appears to be conflicting evidence with regard to matrix flow and transport at Busted Butte and Pena Blanca. Although qualitative information is provided, the DOE does not clearly establish how information from anthropogenic and natural analogue sites (Pena Blanca, Oklo, INEEL) are being used to verify/validate conceptual models, numerical models, and data/model uncertainty with regard to Performance Assessment. Uncertainty introduced by the lack of characterization of the larger repository footprint (southern extension) considered in the lower temperature operating mode is not characterized.<br>Basis:<br>There appears to be conflicting evidence at Busted Butte and Pena Blanca (Section 11.3.2.7). Matrix flow and transport is reported to dominate tracer tests at Busted Butte. However, geochemical information appears to be limited at Pena Blanca. The differences between the two sites that might explain this difference are not explored, and the way that these results support the analysis of the effects of matrix block discretization on UZ transport is not discussed. The effect of the uncertainty resulting from the lack of characterization for the proposed larger repository footprint, particularly the southern extension, is not addressed. Unit thickness and mineralogy in particular may have an effect on transport through the unsaturated zone. These comments fall under Agreement RT.1.02: Provide analog radionuclide data from the tracer tests for Calico Hills at Busted Butte and from similar analog and radionuclide data (if available) from test blocks from Busted Butte. DOE will provide data from tracers used at Busted Butte and data from (AECL) test blocks from Busted Butte in an update to the AMR In Situ Field Testing of Processes in FY 2002. | Transport at Busted Butte is dominated by matrix flow because the nonwelded vitric Calico Hills formation is basically a porous medium system, whereas the Pena Blanca site is a welded fractured system. Therefore, it would not be surprising that the two systems have different transport characteristics. In addition, data collected from natural analogue studies, with the exception of INEEL, have been used so far only for qualitative comparison to the UZ model results. Limited numerical modeling was performed using the INEEL data. Analog test data from tracer tests at Busted Butte and data from (AECL) test blocks from Busted Butte will be provided in an update to the AMR In Situ Field Testing of Processes before LA, per KTI agreement RT 1.02. [1, 2]Flow in the CHn vitric is represented with the same dual-permeability flow and transport models used for other units. Existing project documentation concerning the Busted Butte field tests indicate that flow and transport in this unit is almost entirely in the matrix. This model can be easily calibrated to results that include more fracture transport if results from Busted Butte or other relevant information should indicate that a greater degree of transport occurs in the fractures. |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 28 | The different analyses in the SSPA use different values and distributions for Np sorption. This type of inconsistency makes it difficult to compare the results of the different types of analyses and their effects on repository performance. Also, the effects of coupled thermal-hydrological-chemical effects on transport parameters are not considered.<br>Basis:<br>Sections 11.3.1.5.3 and 11.3.4.5 use different values and distributions for Np sorption in the analyses presented in the SSPA. This type of inconsistency makes it difficult to compare the results of the different types of analyses and their effects on repository performance. Also, although the effects of coupled thermal-hydrological-chemical effects on permeability are considered (Section 11.3.5.4.2), the effects of temperature on sorption parameters are not addressed directly. These comments fall under Agreement RT.1.05: Provide additional documentation to explain how transport parameters used for performance assessment were derived in a manner consistent with NUREG-1563, as applicable. Consistent with the less structured approach for informal expert judgment acknowledged in NUREG-1563 guidance and consistent with DOE procedure AP-3.10Q, DOE will document how it derived the transport parameter distributions for performance assessment, in a report expected to be available in FY 2002. | Section 11.3.1.5.3 of SSPA Volume 1 used a single, conservative value of $K_d$ (0.3 mL/g) for Np in illustrating the effects of drift shadow zone.<br>Section 11.3.4.5 used a range of Kds (1-3 mL/g) for Np-237 that was selected based on AMR UZ & SZ Transport Properties (ANL-NBS-HS-000019) Rev 00. The difference will be reconciled should any one of these analyses be carried forward into a potential LA. [1, 2]With regard to sorption in the EBS, partition coefficients are anticipated to vary from those in the UZ because of the large mass of iron-based corrosion products and other materials in the waste package and in the invert. The rationale for the ranges of partition coefficients in the EBS is discussed in Section 10.3.4 with final values defined in Table 10.4.4-1 of Section 10.4.4. If sorption in the EBS is carried forward to a potential LA, rationale for selected ranges for sorption coefficients will be provided per KTI agreements RT 1.5 and RT 2.10. [1] |
| 29 | The text of the SSPA suggests that inclusion of drift shadow effects will be strongly considered as an addition to the UZ transport conceptual model and abstraction. The inclusion of this model will impact results not only for UZ transport but also EBS transport. The drift shadow model will result in a majority of radionuclides entering the natural system into the matrix rather than fractures below the repository. The diffusion gradient across the drift invert will also be altered, increasing transport times through the drift invert. This model will place an even heavier burden on UZ seepage and flux models and their uncertainties. | DOE acknowledges that models carried forward to support a potential LA will be qualified and documented and may require supplemental justification or analysis. [1] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 30 | Disparities in calculated results of different radionuclide transport models that could be used for UZ transport have been identified in previous sensitivity studies that support the TSPA-SR. The SSPA outlines a proposal to use a different transport model (DCPT v2.0) than has been used in previous TSPAs (FEHM v2.0). This would result in a need to thoroughly re-examine the technical basis and applicability if the new approach. | DOE acknowledges the necessity to reconcile the differences between DCPT v2.0 and FEHM v2.0 for those analyses carried forward to a potential LA. [1] |
| 31 | Comparisons to results of unsaturated flow experiments using blocks taken from the Busted Butte study area show qualitative agreement with expected behavior of sorbing radionuclides, but the results are preliminary and may be influenced by unquantified microbial processes. | DOE acknowledges the NRC comment on this issue. AECL laboratory tests related to the Busted Butte block tests were recently received (July 2001). DOE has not had an opportunity to evaluate the effects of microbial processes suggested by these tests. |
| 32 | Several examples of discrepancies between model results and field data are identified in Chapter 11 of the SSPA with accompanying notes that further work is necessary. Little if any of this work is 'officially' planned within the DOE program. Nearly all the arguments and analyses presented for both the UZ and SZ reflect adjustments to models that reduce the conservativeness of assumptions used in previous models. The effect is to enhance the delay of radionuclides transported through both the UZ and SZ. Unfortunately, many of the adjustments have little technical basis and are not adequately supported by field data. This is especially true for the SZ analyses, which require significantly more data than is presented in the document. | The SSPA document did not contain the detail of analysis and field data support. Some SSPA analyses were performed as sensitivity analyses in an effort to quantify uncertainties in TSPA-SR, and hence may not be fully consistent due to the use of different conceptual models, assumptions, and input data. For those analyses carried forward that will require model enhancements for supporting a potential LA, DOE will revisit the analyses to resolve any discrepancies with the data. [1] |
| 33 | The dissolved concentration limits of four radionuclides--thorium, neptunium, plutonium, and technetium--were reevaluated in the SSPA. In all cases, the minimum solubility limits were lowered by several orders of magnitude compared to TSPA-SR. However, insufficient technical bases are provided for the revised abstraction of dissolved concentration limits of those radionuclides. | DOE acknowledges the NRC comment on this issue and the necessity to further develop strong technical bases for any changes in dissolved concentration limits, if these revised limits are carried forward to a potential TSPA-LA. |
| 34 | If radionuclide retardation is to be modeled in the EBS, sorption coefficient distributions will need to be justified in a manner consistent with existing agreements RT.1.05 and RT.2.10. For example, non-zero $K_d$ values for technetium and iodine have not been used previously in TSPA; any future adoption of such values, as were used in the SSPA, will require stronger technical bases. | DOE understands that a strong technical basis must be provided for sorption coefficient distributions for all radionuclides that are important to performance. If retardation in the EBS is carried forward to the potential LA, implementation of KTI agreements RT 1.05 and 2.10 will provide justification for the use of radionuclide transport parameters in the performance assessment. [2] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 35 | The SSPA recommends new values for EBS colloid transport parameters. If these are adopted by TSPA in the future, the technical bases for the new distributions will require close scrutiny. Relevant KTI agreements are RT.3.07, ENFE.4.03, ENFE.4.04, and ENFE.4.06. | The new values for EBS colloidal transport parameters were designed to evaluate unquantified uncertainty for the SSPA. DOE understands that prior to any potential LA, a stronger technical basis must be provided for EBS colloidal transport parameter values carried forward to the base case analysis. [1] |
| 36 | The discussion of uncertainty in the saturation level of the invert does not consider the possibility of higher saturation. This comment is related to KTI agreement TSPAI.3.17. | Studies with the MSTH model, as reported in Chapter 5 of the SSPA Volume 1, investigated the sensitivity of invert liquid saturation to a variety of repository parameters. These parameters included bulk permeability, host-rock thermal conductivity, lithophysal porosity, and invert thermal conductivity. Predicted liquid saturation remained within a narrow range, between 4% and 10%, for all parameter variations. In addition, the diffusive breakthrough time for the invert is already relatively rapid, so any increase in saturation levels is expected to have a negligible impact. DOE will provide an uncertainty analysis of diffusion in the invert. This analysis will include uncertainty in invert saturation per KTI agreements TEF 2.05 and TSPAI 3.17. [2] |
| 37 | The discussion of THC effects on UZ transport does not address chemical effects of the repository. This concern is related to KTI agreements ENFE.4.03 and ENFE.4.06, and TSPAI FEPs item J-8. | DOE acknowledges this comment and notes that some limited studies were documented in Section 11.3.5.4.2 of SSPA Volume 1. Work is underway, consistent with the cited agreements, to study the effects of alkaline plumes generated by the cement-seepage interactions on rock properties (such as porosity and permeability) and thereby effects on radionuclide transport from the waste placement drifts, with preliminary results expected in FY03. [1, 2] |
| 38 | The effect of the drift shadow assumption on invert transport needs to be evaluated. Also, as mentioned in the chapter, any adoption of a drift shadow model will require additional justification. This concern may be related to agreement TSPAI.3.17. | The invert transport abstraction does not incorporate any direct assumptions related to a drift shadow effect. The hydrologic inputs to the invert transport calculation come primarily from the MSTH model that tracks water and gas within the near-field rock and the drift. The specific inputs from the MSTH model to invert transport are the temperature of the invert and liquid saturation of the invert. DOE acknowledges that models carried forward to support a potential license application will be qualified and documented, and may require supplemental justification or analysis. [1, 2] Also, see response to comment 29. |
| 39 | There appears to be inconsistency in natural analog interpretations presented in Subsection 11.3.2.7. Nopal evidence points to large radionuclide gradients at the fracture-matrix interface, but it may also point to little matrix diffusion having occurred. These observations seem to argue both for and against the importance of matrix diffusion. | DOE acknowledges the necessity to reconcile data inconsistencies if the data from the Nopal analog site are carried forward in analyses used to support a potential TSPA-LA. [1] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 40 | In the discussion of Nopal water data (Subsection 11.3.4.8.2), there appears to be some inconsistency between DOE's interpretation of seep water stable isotope data and their model of water-rock interaction. The seep water oxygen and hydrogen isotope data, which are interpreted to reflect an origin from condensation of water vapor, have not yet been reconciled with interpretation of uranium data as reflecting rapid transit of the seep waters through the tuff. | There are currently limited isotope data from the Nopal analog site. In DOE's interpretation of the uranium data, there was not an indication of rapid seepage through the tuff. It was clarified that the rapid seepage was concluded by a separate SWRI study. |
| 41 | The new Np sorption coefficient distribution for the SZ used in the uncertainty analysis needs further analysis. Any future adoption of this distribution in TSPA will require a technical basis consistent with agreements RT.1.05 and RT.2.10. | Alluvium Kd distribution is based on data obtained using EWDP-3S water and alluvium from 3S, 9Sx, and 2D. However, DOE acknowledges that 3S water was contaminated with a polymer/surfactant used during well development. The effect of this polymer/surfactant on Kd values is being investigated by repeating some experiments using some of the same alluvium samples with 19D water, which was not contaminated. The technical basis for sorption coefficients will be provided consistent with the cited agreements for data used in any potential license application. [1] |
| 42 | DOE is aware that much more transport-relevant alluvium characterization needs to be done, so no specific comments are needed on the discussions of alluvium Np and U sorption coefficients, bulk density, and effective porosity. Alluvium characterization is the subject of agreements RT.2.01 through RT.2.09. | Np and U sorption experiments in the alluvium are in progress (19D water, 19D alluvium). Results will appear in a revision of the Transport Properties AMR consistent with existing agreements. [1, 2] |
| 43 | The SSPA presents a new distribution for retardation of colloids with irreversibly-attached radionuclides. The distribution takes into account new site-specific alluvium data. However, any future use of this distribution in TSPA will require comparison with results of field and laboratory tests. This concern is indirectly related to agreement TSPAI.3.30. | DOE acknowledges that any future use of this distribution in TSPA will require comparison with results of field and laboratory tests [1,2]. This concern is indirectly related to KTI agreements RT 3.07 and RT 3.08. Laboratory testing of microsphere and silica colloid retardation in alluvium-packed columns is in progress. Microspheres will be used as colloid tracers in ATC cross-hole tracer testing. |
| 44 | The discussion of mill tailings site analogs concludes that "some fraction of the total uranium inventory appears to transport as a nonsorbing to weakly sorbing contaminant." However, in applying the observations to YM, no consideration is given to the possibility of a "nonsorbing" fraction at YM. In addition, no quantitative comparisons are made. | Natural and anthropogenic analogues sites have their own complexities and challenges in term of analyzing transport behavior of a given contaminant. In order to fully analyze the transport behavior, assumptions are made about parameters that don't have actual data. The difference between the transport rate of a non-sorbing constituent (Chloride) and a poorly sorbing one (Uranium) may not be quantifiable with the available data. The uncertainty distribution used in the SZ transport simulation of uranium includes Kd values of zero. |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 45 | In discussing preliminary microsphere transport tests at the Alluvial Testing Complex, it is mentioned that flow transients can remobilize microspheres. Is such a process possible in the repository system? If so, how can it be accommodated in models? These questions may be addressed under agreement RT.3.08, although that agreement specifically discusses fractured rock rather than alluvium. | Flow transients are likely to occur, but it is unlikely that they will be as rapid or extreme as the transients associated with stopping and starting the pump at ATC during single-well testing. However, it may be important to incorporate sudden transients associated with seismicity into models (it is well known that earthquakes can turn well water turbid for a while). Transients in water chemistry could also result in some remobilization of colloids. This issue is related to KTI agreement RT 3.08 and will address both fractured rock and alluvium. [1, 2] |
| 46 | The analysis of sensitivity to increased uncertainty in the reversible colloid parameter Kc (section 12.5.2.4) yielded somewhat longer transport times in the SZ. This analysis does not illustrate the effect of possibly underestimating $K_c$, because it is not clear that the mean value of $K_c$ is significantly different from the base case. This concern is related to agreements RT.3.07 and TSPAI.3.30. | This issue will be handled as part of agreements RT.3.07 and TSPAI.3.30. [1, 2] |
| 47 | The DOE should fully document all observational and experimental data used to validate models, and provide an analysis on the reliability of these data.<br>Basis:<br>Evaporation studies performed at LLNL and water and gas data from the Drift Scale Heater Test, for example, are used to support model validation of the DOE's Coupled THC models and Salts/Precipitates Analyses, but analytical uncertainties and data interpretation efforts were not adequately described in Chapter 6. | Should the observational and experimental data be carried forward to the base case analyses, additional uncertainty information and data analyses will be documented to support further validation of future EBS precipitates/salts models prior to any potential LA, as documented in KTI agreement ENFE 2.17. [1, 2] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 48 | It is not clear that THC model has been properly tested.<br>On page 6-16 of SSPA Vol 1 it is stated that "Because ambient simulations in the revised THC simulations predict water compositions more consistent with the initial (measured) water composition, it is expected that the overall uncertainty of the revised THC seepage models (BSC 2001 [DIRS 154677]) has been reduced (at least to a range within the uncertainty of input pore water and infiltration water compositions)." A similar statement is made on page 6-32.The uncertainty is not within the uncertainty of input pore water and infiltration water compositions. On pages 6-14 and 6-15 it is explained that the model is consistent with the initial pore water composition at ambient temperature because of calibration. Thus, it is expected that the model should yield consistent results in a neighborhood of conditions similar to those yielding the initial water composition. Extrapolation to other conditions is suspect, given the statement on page 6-11 that small changes in the Gibbs free energy of formation translate into orders of magnitude changes in the solution compositions. Confidence in the model could be gained if model results are consistent with experimental data and input conditions very different to those used in the calibration. On page 6-17 some model validation efforts are discussed; however, it is stated that the model results included assumptions on various reaction rates and sets of reacting minerals. It seems that the assumed valued were selected so that adequate calibration to the experimental results would be accomplished. If that is the case, the effort is of little value as validation scheme. DOE needs to clarify the approach. | A few chemical parameters input into the THC seepage models were calibrated to a given ambient water composition (i.e. shift in initial Gibbs free energies for a few aluminum silicate minerals, well within determination error), such that this ambient water composition could be reproduced fairly steadily over a long period of time under ambient conditions. Assumptions regarding the precipitation rate of some of the minerals were also made such that the ambient water composition could be reproduced. The ambient water composition has a large uncertainty, and this directly impacts the parameters calibrated/assumed from this ambient composition. As stated on p. 6-33, it would appear that "with respect to predicting the composition of fluids that may enter drifts, the uncertainty in the composition of initial infiltration water input into the THC seepage models may largely overwhelm other uncertainties". Therefore, what is meant in the statements on p. 6-16 and 6-32 referred to in the above comment, is that even though calibration narrowed the possible range of some of the input parameters, the model is still largely uncertain because of the uncertainty in the water composition used for calibration. Only a few of the input data related to computing chemical reactions needed to be calibrated or assumed to reproduce the ambient water composition. The parameters calibrated/assumed under ambient conditions were input into simulations of experimental tests (Drift Scale test and laboratory experiments) under heating conditions very different from the ambient conditions under which some of those data were derived (see page 6-17: "These analyses [the validation simulations] also use the same revised thermodynamic data for clays and zeolites and assumed calcite supersaturation gap as in the THC seepage models..."). Without further adjustment of these data, the simulations of these experiments yielded water compositions that matched reasonably well the measured compositions and, therefore, were used to conclude that the model and its input parameter were reasonably validated. The sentence in the last paragraph of the comment "It seems that the assumed values were selected so that adequate calibration to the experimental results...." is not accurate. In summary, the drift-scale THC model was calibrated to pre-test, ambient conditions, and then was validated using data collected from the DST under thermal conditions. |
| 49 | With respect to Figure 4.3.6-3 of SSPA Vol 1: Why the Ca and Cl concentrations derived from the model have an abrupt change at 16 months? These results do not seem consistent with the experimental data.<br>Clarifying question. | During the DST, heating resulted in boiling followed by evaporation of porewater initially present in the rock. In borehole 60-3 shown in Figure 4.3.6-3 of SSPA Volume 1, the dry-out period started at approximately 16 months after heating started. The THC model predicted a rapid increase in Ca and Cl concentrations following the dry-out. Water samples were not available for the dry-out period. |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 50 | What is the probability of the formation of sufficient conditions leading to localized corrosion? If none, then- Which solution compositions hitting the WP and evaporating could lead to sufficient environmental conditions for the onset of localized corrosion?- What is the probability that such initial solution compositions could be established?<br>Basis:<br>The uncertainty in the compositions of the solutions contacting the WP and DS is not acknowledged in the WP and DS analyses reported in Chapter 7 of the SSPA Vol 1. It is stated multiple times in this Chapter that localized corrosion of the WPs is not feasible as nitrates and sulfates are more abundant than chloride ions. Based on information in Chapter 6 (pages 6-8, 6-62, and 6-63), it is evident that there is high uncertainty in the solutions that could develop after evaporation.<br>These solutions are dependent on the initial solution composition. There is a high possibility of formation of solutions highly concentrated in chloride and fluoride. It is necessary to achieve better integration between the coupled THC, evaporation and salt formation models of Chapter 6 and the WP degradation analyses of Chapter 7.On page 7-59 of SSPA Vol 1 it is stated that " ... the potential for the development of environments leading to localized corrosion of Alloy 22 is unlikely." Additional technical basis are needed to support this statement. | Electrochemical studies are being employed to determine the aqueous solution compositions that could lead to conditions necessary for localized corrosion. The range of water chemistries that could contact the waste packages and drip shields is being determined. This considers a range of sources of soluble ions including seepage waters, particulate matter contained in the ventilation air, drift dust, and other engineered barrier system component interactions contributions to water chemistry. The determination of the range of water chemistries is covered in the key technical issue (KTI) agreements for Container Life and Source Term (CLST 1.1) and for Evolution of the Near Field Environment (ENFE 2.15 and 2.17). [1, 2]The studies environmental conditions on localized corrosion are covered under CLST agreement 1.10. [1, 2] |
| 51 | Is there agreement between the corrosion potential inputs to WAPDEG and those computed using Digby Macdonald's model (MPM Model) discussed in Chapter 7 of SSPA Vol 1?<br>Clarifying question. It is expected that these two independent models should be consistent. | There is no relationship between the inputs to the WAPDEG analysis and the corrosion parameters (i.e., corrosion potentials and corrosion current densities) estimated with the deterministic general corrosion model (GCM) described in Section 7.3.4 of SSPA Vol. 1. As discussed in that section, the GCM is a conceptual model and the model outputs are only to illustrate the model's features and capability and not intended for input to the waste package performance assessment. If the GCM is carried forward to LA, the corrosion process model parameters will be updated based on additional data. This work is covered under the existing CLST KTI Agreements 1.8 [1, 2] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 52 | It is not clear that the activation energy to define the temperature dependence of the corrosion rates is well established.<br>On page 7-56 of SSPA Vol 1, it is concluded that one of the points used to derive a temperature dependence is an outlier and that should not be used in the derivation of the activation energy. The following observations apply:<br>- Statistics computed on the basis of 4 points are suspect (i.e., statistical population is not large enough). It is not possible to disregard one of the points as an outlier.<br>- The point argued to be an outlier indeed corresponds to a series of measurements, not only to a single measurement.<br>- Confidence intervals for the activation energy were not derived. Selection of different activation energies has a major impact in the SSPA computations. | It should be noted that temperature dependent corrosion rate correlation was developed only as a sensitivity study. In addition, DOE recognizes that the available data on temperature dependence is very limited. Arguments presented on Pages 7-56 to 57 and 7-81 to 82 of SSPA Vol. 1 provide technical basis that the data point in question is a true outlier. Additionally, Table 7.3.5-1 indicates the outlier data point was obtained from a tightly creviced material, polarized to an applied potential of +50 mV vs. Ag/AgCl, pH 2.75, 95EC, and a $Cl^-$ to ($SO_4^{-2}$ + $NO_3^-$) ratio of 100. Therefore, the apparent higher corrosion rate indicated by the outlier may be more representative of a mix of general and localized corrosion. Because the analysis was meant to elucidate the temperature dependence for general corrosion only (not localized corrosion), exclusion of the outlier data from the analysis is appropriate. Figures 7.3.5-1 and 7.3.5-3 show the derived general corrosion temperature dependence models with and without the outlier considered, respectively. Also in the figures are shown the ∀1 and ∀2 standard deviation prediction estimates which can be considered confidence intervals. WAPDEG results using both general corrosion models (i.e., with and without the outlier) are shown in SSPA Volume 1 Figures 7.4-18 through 7.4-25.The Project is developing corrosion rate data for repository relevant conditions in accordance with KTI agreements CLST 1.4 and CLST 1.10. If a temperature dependent general corrosion model is developed for use in a potential LA, the model will be updated/improved as additional data and analysis become available, and will be qualified and documented. [1, 2] |
| 53 | Page 1-3: 'The primary goals of this effort were to provide insights into the significance of the unquantified uncertainties and the degree of conservatism in the overall assessment of repository performance in the TSPA-SR.' If the uncertainty is 'unquantified' how does assignment of a new distribution or bound provide any information about the degree of conservatism beyond the subjective interpretation of the analyst?<br>Clarifying question. | Many of the uncertainties that were not quantified in the TSPA-SR Rev.00 ICN 01 were quantified in the supplemental TSPA model described in the SSPA. The inclusion of these uncertainties and calculation of the resulting mean total system results allows a comparison of expected performance for the two models. This comparison of means and the associated implications to the conservatism in the TSPA-SR model are presented in Section 4.1 of Volume 2 of the SSPA. |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 54 | Page 1-3: ' which requires models of flow and transport that are more complex - and possibly more uncertain - than models at lower temperatures.' In the assessment that was done, how are the flow and transport models more complex for higher temperatures compared to lower?<br>Clarifying question | Implementation of flow and transport models for the HTOM are more complex than for the LTOM for two reasons: 1) the hydrologic and geochemical processes occur over a greater range of temperatures, and 2) the HTOM may lead to local boiling. Where boiling occurs, the difference between the HTOM and LTOM is not merely a matter of degree--qualitatively different system occurs in the two cases. The above boiling conditions associated with the HTOM require that models treat two phase water flow (liquid and vapor) to a greater extent and to extrapolate geochemical (both thermodynamic and kinetic) properties to temperatures that in some cases are above those for which experimental data exists. The HTOM simulations must also represent processes such as heat pipe behavior to a greater extent than do the LTOM simulations. Boiling is also likely to lead to much more significant local deposition of minerals (especially salts) which, upon subsequent dissolution, can lead to the formation of highly concentrated brines which may enhance the rate of corrosion of the waste package. In addition, the enhanced mineral precipitation associated with boiling and the HTOM may lead to local permeability change, a process which is still poorly understood. This combination of additional processes plus additional uncertainty with respect to some input data has led some observers to conclude that uncertainties are greater for the HTOM, even if these uncertainties are not apparent quantitatively in the dose consequences calculated by TSPA-SR. It should be noted that the same computer codes have been used to evaluate the processes in the HTOM & LTOM, and the differences in implementation are due to differences in initial conditions. |
| 55 | Page 1-12: Considering less than 50% of the SSPA analyses is a result of new information, it is important to distinguish to what degree new information has resulted in changes to TSPA outcomes and to what degree reinterpretation of 'old' information has influenced the outcomes. This would help define where emphasis should be placed (interpretation of data or collection of data) to evaluate unquantified uncertainties.<br>Comment only. | The assessment of uncertainties for the SSPA did not distinguish between “old data and new data.” The process modelers used all available information to provide an assessment of the uncertainties. |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 56 | Page 2-1: 'There are also cases where more than one conceptual model may be consistent with available data and observations. In the absence of definitive data or compelling technical arguments for a specific conceptual, process, or abstracted model, a conservative representation was chosen.' It is unclear what the criteria were to determine when a conservative selection was necessary. In the saturated zone modeling, there is evidence to suggest anisotropy and isotropic conditions. These states were equally weighted in the TSPA model which is inconsistent with the language highlighted above.<br>Clarification of the DOE position on alternative conceptual models needed. | The statement is generally true across inputs to the performance assessment. In most cases, the implications of alternative conceptual models are evaluated using "one-off" sensitivity analyses, presented in Section 3 of Volume 2 of the SSPA. In a few cases, alternative conceptual models are propagated through the performance assessment. Note that Agreement TSPAI 4.01 covers treatment of alternative conceptual models. [2]Alternative conceptual models are screened out during the process model calibration. Sensitivity analysis are completed to investigate the effects of alternative models on the SZ flow field, specific discharge and radionuclides transport. In addition alternative conceptual models are documented in the SZ PMR and its revisions. |
| 57 | Page 2-3: Without an independent organization evaluating the amount of conservative or nonconservative bias in parameters or models, it is unclear how independence and therefore the ability to achieve an 'unbiased' estimate was achieved in the project<br>Basis:<br>The influence of bias in interpretation of information or selection of parameter distributions or models can in many instances be as large as the technical content. | It is recognized that the TSPA-SR Rev. 00 ICN 01 contained many inputs that were believed by the process modelers to represent conservative or bounding assessments. The focus of the SSPA analyses was to gain insights into the degree of conservatism or nonconservatism in the TSPA-SR performance assessment as a whole (i.e., at the total system level). To do so, many of the key inputs to the analyses were reassessed using "unbiased" representations of uncertainty (i.e., representations that were neither conservative nor nonconservative). The resulting supplemental TSPA model analyses provide a basis for comparison with the TSPA-SR mean results. Expert Elicitation performed in support of a potential LA will comply with applicable project procedures including AP-AC.1Q, "Expert Elicitation". |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 58 | Page 2-5: As currently represented, the HTOM and the LTOM performance assessments show very little difference. Why is emphasis placed on these different design options then and what would be design differences that would materially affect risk?<br>Clarifying question. | Currently, the DOE is considering a range of design/operating mode options that could affect the performance of the repository during both the preclosure and postclosure periods. Until the analyses of the lower temperature operating mode in the SSPA were completed, the DOE could not fully anticipate the magnitude of the differences in the results between LTOM and HTOM; therefore the emphasis on performing these particular analyses to evaluate the relative risks is justified. As the reviewer has noted, the performance assessment results described in the SSPA do not indicate significant differences over the long term between the LTOM and HTOM. This is primarily because there are very low projected releases during the first few thousand years after the repository is closed, and the thermal environment in the repository is similar for the two cases after that time. Although it is not apparent in the current analyses, some reviewers believe that the degree of uncertainty associated with performance analyses during the first few thousand years may be greater for the HTOM case than for the LTOM (see question 54). If this was true, it is possible that the risk to public health and safety (or at a minimum, the uncertainty in risk analyses), could vary between different design/operating mode options. For this reason, the DOE is continuing to investigate the sensitivity and uncertainty of performance analyses to design and operating mode decisions. All decisions about design and operating mode will consider the potential impact on postclosure repository performance as well as other engineering criteria. [1]The SSPA analyses were designed to provide insight into the relative performance of the repository over a range of thermal operating conditions. As noted in the comment, the analyses do indeed show that the differences between the HTOM and LTOM models in terms of expected annual dose are small compared to the differences between the TSPA-SR and SSPA models due to the availability of new models and data and the more realistic treatment of uncertainty in the SSPA. The SSPA analyses were not intended to provide insight into design options outside the range of those considered, and further discussion of this comment would be speculative. |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 59 | Page 5-21: It is very difficult to evaluate uncertainties locally. It is acknowledged that the amount of uncertainties investigated is a big improvement, however the conclusions of 'no impact' for many are severely limited by the piecewise (local) analysis.<br>Basis<br>DOE should reevaluate conclusions of "no impact" when addressing uncertainties. | The results of the sensitivity studies are based on a "one-off" approach in which one independent parameter is varied across its range of uncertainty or variability. This approach is suitable for screening, to determine which parameters are the most significant contributors to the output (dependent variable). For most of the Chapter 5 sensitivity calculations, the peak postclosure temperature was used as an output variable, because it either influences dose rate or may be a specification for some designs or operating modes. DOE acknowledges that performance metric sensitivity to independent parameters may require an approach that samples a number of the parameters, to capture synergistic or coupled effects.[1] |
| 60 | Page 14-26: The logic tree approach may be considered in other areas of the TSPA where alternative conceptual models exist.<br>Comment only. | DOE acknowledges that this approach may be considered in other areas where alternative conceptual models exist. Note that Agreement TSPAI.4.01 covers treatment of alternative conceptual models. [1,2] |
| 61 | It is not clear whether the DOE properly tracks the condensation of water that evaporates within the EBS in their model.<br>Basis:<br>From page 8-10, where does evaporated water end up in the model? Evaporated water will condense again somewhere. | The seepage evaporation model was implemented in the SSPA for the purpose of making a first-order assessment of the potential benefit of seepage evaporation on repository performance. DOE recognizes that condensation may be an important process and it may reduce the benefit of seepage evaporation. However, this process did not have to be considered for the first-order assessment. The MSTH model also tracks water, including seepage evaporation. The vapor condenses primarily in the NFE rock. If DOE decides to carry the seepage evaporation model forward to LA, the model will be qualified and documented per KTI agreement TEF 2.5. [1, 2] |
| 62 | DOE does not appear to account for damage to the drip shield from rockfall in the discussion of flow on the inner surface of the drip shield.<br>Basis:<br>The discussion of film flow on the inner surface of the drip shield ignores the possibility of drip shield denting due to rock fall or other seismic influences (page 8-20). | Damage to the drip shield due to rock fall and other processes may influence film flow on the inner surface of the drip shield and ultimately how much water may contact the waste package, both from condensate and seepage flow. The parameter PFOWP (probability of flow directly onto the waste package) was introduced in the SSPA to account for these influences. However, this parameter was introduced in a conceptual manner only. In SSPA Volume 2, DOE assumed that the parameter PFOWP value was equal to one. That is, it was assumed that all seepage penetrating the drip shield dropped directly onto the waste package. If DOE carries this approach into a potential LA, and condensation on the underside of the drip shield is found to be important, this parameter (PFOWP) will be characterized and accounted for in the drip shield and waste package flux models for the LA which will be qualified and documented. Related KTI agreements include TEF 2.5, RDTME 3.19, and EBS FEP YMP 2.1.08.14.00. [1, 2] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 63 | The analysis of the drift shadow effect reported here may be highly unrealistic and nonconservative.<br>Basis:<br>Chemical diffusion will occur out of the matrix to the fractures. The discussion ignores sources of condensate in the drifts that can be as large or larger than the amount of seepage (page 11-4). All of the water vapor has to condense somewhere. Also (page 11-7), radionuclides will diffuse in all directions determined by the concentration gradients. If the connections are not provided in the model, then the true behavior cannot be represented. The model (FEHM v2.10) does not allow diffusion from matrix elements back to fracture elements that may be transmitting advective flow, especially at the edges of the tunnel. SSPA, Ch. 11 | DOE acknowledges that additional technical bases may be required, and that analyses that are to be carried forward to a potential LA will be qualified and documented. [1] |
| 64 | Criticality has been screened from the SSPA, without an appropriate technical basis.<br>Basis:<br>The DOE screening argument in the System Level and Criticality FEPs AMR was based on the conclusion that no waste packages would fail in the first 10,000 years except as a result of igneous events. The SSPA identifies the possibility of early waste package failure due to improper heat treatment of the closure lid, but does not provide an appropriate screening argument for criticality given this failure. | Refer to the response to Comment #21. |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 65 | The analysis of groundwater pumping rates under future wetter and cooler climates does not seem to be properly justified.<br>Basis:<br>The DOE uses a formula based on the annual evapotranspiration, rainfall, and overwatering requirements to determine the amount of irrigation that is needed to support an acre of alfalfa under future climates. This irrigation rate is used to calculate the dilution volume for radionuclide releases. However, when the results of this formula are compared to 1997 irrigation rates supplied by the State of Nevada, the formula overpredicts actual groundwater usage by about 60%. Instead of investigating why current usage may be lower than predicted based on the evapotranspiration formula (such as farmers do not utilize fields year-round or they do not always overwater sufficiently to avoid salt build-up) DOE simply assumes that the methodology that they use to determine current pumping rates is conservative and continues to use the same formula for future pumping estimates. | In TSPA-SR the DOE used the annual irrigation rate (5 acre-feet per year per acre) published by the state in their "pumpage inventory." During AMR revisions it was found for current conditions, this value used by the state is too low to satisfy the annual watering requirements of the prime crop (alfalfa) despite periods of relative dormancy (winter months). The actual requirement of alfalfa (ET) is documented in ANL-MGR-MD-000009 Rev. 01 Attachment III. When this information on ET became known, it was apparent that the correct basis for the community annual water usage was too low for current climatic conditions and was therefore conservative. However, calculations for the annual water requirement for alfalfa in the cooler and wetter climate projects showed that the irrigation requirement would be below the 5 acre-feet per year per acre used in SR and that the total annual usage would be reduced. Estimates of the changes in water usage (and, as an inverse, concentration) are presented in Section13 of the Vol. 1 of the SSPA. |
| 66 | An inherent part of the DOE's uniform wetting assumption is that the two events: (i) the location of seepage and (ii) the location of a drip shield and/or waste package defect, are independent events. This is not intuitive and will require further justification by the DOE.<br>Basis<br>The location of a drip and the location of a defect would appear to be highly correlated events. The DOE model does not include such a correlation and thus may underestimate the dripping influx to the WP. The DOE model assumes that only a portion of the water reaching the WP (ratio of the sum of defect lengths and the total length of the WP) enters the WP and thus does not allow the possibility that a large portion of the water reaching the WP can enter the WP. A large portion of the water entering the WP would have a higher likelihood than predicted by the DOE if (i) the seepage locations do not move temporally (see previous comment) and (ii) the seepage location and defect location are highly correlated. | The SSPA calculations assumed that seepage location and engineered barrier breach locations were randomly correlated. This is based on the nature of failure from general corrosion and on deliquescence of water into dust on the engineered barrier surfaces. If this assumption is carried forward to a potential LA, evaluation of the importance of the degree of correlation between seepage and EBS breach locations will also be considered. [1] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 67 | The DOE does not have a basis for the distribution selected to represent the uncertainty associated with the evaporation rate.<br>Basis<br>To account for uncertainties in the implementation of the seepage evaporation model (page 8-10) the DOE modifies the expression for the evaporation rate by multiplying it by a random number from zero to one ($f_{evap}$) to quantify the fraction of potential evaporation that may occur. The DOE does not provide a technical basis for the distribution used for $f_{evap}$. | The distribution associated with uncertainty in the condensation rate was selected to evaluate unquantified uncertainty for the SSPA. At the low end of the distribution, the condensation rate is zero. At its upper end, all of the evaporation from the invert condenses on the drip shield and is assumed to fall on the waste package. Thus, this distribution spans the full range of possible outcomes for the SSPA. If the seepage evaporation model is carried forward to a potential LA an improved technical basis for the evaporation rate distribution will be provided.[1] |
| 68 | The DOE does not appear to have sufficient justification for the assumption that water flows on the drip shield and waste package will form thin films.<br>Basis:<br>On page 8-20 the DOE discusses simulation testing that showed that no drip water was observed under the drip shield or on the waste package and states that "while this observation does not apply in general to corrosion crevices and the narrow range of test conditions in the EBS Pilot Scale Test #3, it nevertheless shows that water flows are anticipated to dominantly form thin films." It is not clear that this deduction can be made since the simulation used smooth machined surface interfaces. It seems possible that a corrosion crevice with rougher surfaces may act differently and act as a drip initiator. | With respect to seepage flow in the EBS, the SSPA does not take credit for water flow in thin films. For example, all seepage water that penetrates breaches on top of the drip shield (breaches that overlay the plan view of the waste package) is assumed to fall on the waste package (Section 8.3.3.3.1). Flow of water in thin films does have the potential to reduce water contacting the waste package and this phenomenon is discussed to provide further basis that the current flux models tend to be bounding. Note that thin films within the waste package are considered with respect to transport from within waste packages that do not see seeps (Section 10.3.1). |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 69 | The alternative modeling of flow through the Ptn as discussed on p. 3-25 is based on the capillary pressure data of a single borehole. It seems that the conclusions use the implicit assumption that this single borehole (point) data is valid across the entire Ptn layer. Spatial variability of this capillary pressure distribution could lead to very different modeling results. In particular, unless the spatial distribution of capillary pressures is not supported, the strong lateral flow component and resulting damping function of the PTn is not supported. On the contrary, lateral flow could be limited in scale, and result in localized flow focusing. The conclusion in section 3.3.3.5 on p. 3-27, that the TSPA abstraction is conservative, is not supported. It is only conservative with respect to the presented simulation including lateral Ptn flow over the entire layer. It could be non-conservative if lateral flow were found to be spatially limited, thus leading to a flow focusing within the PTn layer. | DOE acknowledges this concern about the validity of the modeling work supporting significant PTn lateral flow. Additional study is planned for FY02 to further investigate this issue consistent with TSPAI 3.23. The capillary effects and effects of microfaults will be examined using field geochemical data. The effects on UZ flow are currently studied in FY01, which will be followed by a study of the transport effects in FY02. [1,2]Future analyses, if carried forward for a potential license application, will include field evidence for the modeling results. Capillary flow and rock-fluid interactions are addressed in "Capillary Barriers in Unsaturated Fractured Rocks of Yucca Mountain, Nevada" by Wu, Y.-S.; Zhang, W.; Pan, L.; Hinds, J.; Bodvarsson, G.S., October 2000. This document presents modeling studies investigating the effects of capillary barriers on fluid-flow and tracer-transport processes in the unsaturated zone of Yucca Mountain. These studies are designed to identify factors controlling the formation of capillary barriers and to estimate their effects on the extent of possible large-scale lateral flow in unsaturated fractured rocks. |
| 70 | How is the 10 meter deep negative capillary pressure gradient shown in Figure 3.3.3-3 on p. 3F-5 explained? Is it related to a continuous desaturation with depth, or to gradually increasing pore sizes? | The figure shows about 10 m (or 1bar)/m vertical capillary gradients at the exact interface between TCw and PTn units. This is due to dramatic change in both fracture and matrix properties at the unit interface. Across this interface downward, matrix becomes much more permeable and fractures become less permeable into the PTn. As a result of contrast in rock properties, the model predicts a large capillary gradient existing at the interface. There was a typographical error in the figure: the figure presents modeled results instead of measured pressure differences. Future analyses, if carried forward for a potential license application, will include field evidence for the modeling results. Capillary flow and rock-fluid interactions are addressed in "Capillary Barriers in Unsaturated Fractured Rocks of Yucca Mountain, Nevada" by Wu, Y.-S.; Zhang, W.; Pan, L.; Hinds, J.; Bodvarsson, G.S., October 2000. This document presents modeling studies investigating the effects of capillary barriers on fluid-flow and tracer-transport processes in the unsaturated zone of Yucca Mountain. These studies are designed to identify factors controlling the formation of capillary barriers and to estimate their effects on the extent of possible large-scale lateral flow in unsaturated fractured rocks. |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 71 | Figure 3.3.3-2 shows an estimate of the present-day mean net infiltration based on chloride data. Small scale spatial heterogeneities in infiltration as shown in Figure 3.3.3-1 are entirely suppressed by this approach. Since one would expect such small scale heterogeneity to exist, this puts into doubt either the quality or the interpretation of the Cl data used to support modeling efforts. | The Cl data were used to validate the UZ flow model as illustrated in Figure 3.3.3-2. The data reflect percolation rather than infiltration. The existing chloride data is not adequate to evaluate small-scale spatial heterogeneity in chloride concentrations. The important finding from the chloride data is that the average chloride content is in agreement with modeling results. |
| 72 | The "Multiple Lines of Evidence" described on pp. 3-27 and 3-28 are related to C14 data. At the end of the section, it is concluded that this data is not sensitive enough to detect lateral diversion in the Ptn. It thus seems there is no additional line of evidence. | There is indication that data discussed on p. 3-27 and 3-28 might have been compromised by drilling activities, and therefore are not reliable to draw a definite conclusion concerning lateral flow in the PTn. Additional isotopic data are planned to be collected in FY02 to validate the numerical study of PTn lateral flow as described in the SSPA. [1] |
| 73 | The statement on p. 3-40 that the representation of the 3D flow fields in the TSPA is "representative (or conservative)" is difficult to support. The models can not be more detailed than available data, and it would be appropriate to refer to a best possible, but limited knowledge. The same applies to the statement on p. 3-44, that the "flow field provides parameters and bounding conditions for subsequent modeling studies and analyses". | The statements regarding representative and conservative TSPA-SR flow fields are based on many considerations and assessments of field data and modeling results. First, the flow fields are dependent on estimated future infiltration rates (which are much higher than present-day or maybe future rates). Second, these flow models do not take into account that potential lateral flow effects within PTn, which may reduce percolation fluxes with the repository footprint significantly. Therefore, the TSPA-SR models predict much shorter groundwater travel times or conservative results. [1, 2] |
| 74 | Seepage flux is estimated as an average over 5 m segments (p. 4-8). If seepage is highly localized, say is concentrated at a cm scale, then this averaging would significantly reduce the peak flux estimate, while spreading it over a much larger area. Can this lead to an underestimation of local dripping onto Wps? How is this integrated with the choice of patch distributions used in the WP corrosion abstraction? | Reported seepage rates are averaged for a drift segment with the length of a waste package (5.23 m). Flow focusing is accounted for on the intermediate scale through the application of flow focusing factors during seepage abstraction, and on the scale of a waste package through heterogeneity built into the AMR Seepage Model for PA. This approach accounts for potential increases in average seepage as a result of flow focusing effects. However, no information is provided on the distribution of seepage within a drift segments. Local seepage rates would be obtained by multiplying the average seepage rate with a factor A/a, where A is the area of the drift segment (5.23x5.5=28.8 m2) and a is the cross-sectional area of the local seep. See the response to Question 66. The SSPA supplemental calculations assumed that seepage location and engineered barrier breach locations were randomly correlated. This is based on the nature of failure from general corrosion and on deliquescence of water into dust on the engineered barrier surfaces. If this assumption is carried forward to a potential LA, evaluation of the importance of the degree of correlation between seepage and EBS breach locations. [1] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 75 | The cave natural analogues described on pp. 4-12 and 4-13 are all examples without significant seepage flux. How do other environmental variables, such as RH in the cave, near field saturation, and percolation flux, compare to YM? Are there examples of natural analogues that show significant seepage over time (Rainier Mesa has seepage)? | Hydrologic data are available for some of the caves reported in Section 4.3.1.7.1, e.g., Altamira (Stuckless 2000, p.6), the caves studied by Davis (1990), and Karchner caverns (Buecher, 1999). See discussion in Section 4.3.1.7.1 and cited references for details. Rainier Mesa shows seepage; it is included in the discussion (see Section 4.3.1.7.4). As stated before, data collected from natural analog sites have only been qualitatively compared to the Yucca Mountain seepage models. DOE continues to evaluate seepage analogs, both those that indicate little seepage and those with more seepage, in environments similar to Yucca Mountain; and will consider the issue in further analyses of natural analog data carried forward to any potential license application. [1]USFIC KTI agreement 4.07 states:<br>Provide documentation of the results obtained from the Natural Analogs modeling study. The study was to apply conceptual models and numerical approaches developed from Yucca Mountain to natural analog sites with observations of seepage into drifts, drift stability, radionuclide transport, geothermal effects, and preservation of artifacts. Our interpretation of this agreement is that we will provide documentation of the results for all relevant natural analogs that we identify. This includes any natural analogs that may indicate significant seepage. |
| 76 | The results shown in Figure 4.3.2-4 and described on p. 4-22 show that for a given permeability field, increasing infiltration rates yield statistically similar flux distributions. It is not clear that this comparison includes the influence of changing saturation distribution in the UZ and resulting changes in permeabilities. If the permeability field remains unchanged, then it is not clear why statistically different distributions should be expected. | The changes in saturation with different infiltration rates were incorporated into the simulations presented. |
| 77 | The assertion of a "conservative estimate" on p. 4-37 only holds with respect to the sample degradation scenarios considered. Given the uncertainties in drift degradation scenarios and in resulting degraded drift configurations, it seems difficult to identify a conservative bound. | The initial analyses documented in AMR Seepage Model for PA including Drift Collapse Rev 00 supporting TSPA-SR used a simple "worst-case" conceptual model in which rock bolts were represented as "needles" and rock matrix was not accounted for. This simplistic and conservative model predicted some seepage enhancement due to drift collapse. In comparison, the new results of SSPA are based on simulations of a more realistic case in which both fractures and matrix are included on very fine gridding. The new model shows that even for a wide range of parameter values for hydrological properties no enhancement to seepage results from rockbolts. It is therefore, concluded that the TSPA-SR analyses represent conservative estimates of the drift degradation effects. |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 78 | Page 3-6: "Uncertainties are addressed by bounding and sensitivity studies as discussed in DOE 2001…" Sensitivity studies can be an effective mechanism to assess uncertainties, however if the uncertainties show up as contributing to the output then they must be represented in the abstraction to the TSPA. | DOE acknowledges this concern, and will address specific, relevant issues according to KTI agreement TSPAI 3.38. [2] |
| 79 | **Comments on model validation and calibration:**<br>Page 3-23 Section 3.3.3.4 describes better calibration. It is unclear how better calibration increases confidence in the model without model validation.<br>Page 3-29: "These data are used to calibrate and validate the flow model ..." The same data can't be used for calibration and validation. Is there unique data used for validation? Clarification needed.<br>Page 3-59: Wouldn't the fact that the simple and extended THC models calibrate to some observed variables well but not others suggest that the model isn't calibrated well yet and therefore how is it valid for prediction?<br>Page 3-68: "The model has been calibrated and partly validated." There seems to be a misunderstanding about validation, unless some information that was not used to calibrate the model was used to validate it.<br>Page 4-61: From the description of the THC modeling it appeared that parameters in the model were adjusted (calibrated) to provide a better representation of the Drift Scale Test, therefore it is unclear how the model can be validated from the same source.<br>Page 6-9: In the second paragraph, statements are made that the THC seepage models are validated and calibrated, but it appears the same set of data was used. It is unclear from the description how you can both calibrate and validate a model from the same set of data | These are only general statements made to reflect the continuous efforts to improve the UZ flow and transport models, since it is a common practice in groundwater and oil/gas engineering to increase confidence on model outcome through model calibration and history matching. It should also be clarified that DOE did not use the same set data for calibration and validation, i.e., data used for calibration were not used for validation. Some data (e.g., those collected under ambient conditions from the pre-heating phase of the DST) were used for model calibration, and others (e.g., the heating data from the DST) for its validation. Also see the response to comment 48 for more details on the calibration vs. validation of the THC model. |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 80 | **Comments on the abstraction of uncertainty:**<br>Page 3-35: "The presence of fractures within the CHn and their potential to serve as pathways for flow and transport is not well understood, and thus adds significant uncertainty to the modeling studies." Is this uncertainty represented in the abstracted TSPA model? Page 3-36: "Currently, this uncertainty is unconstrained, ." So how is it represented in the TSPA, no sorption in the Chn? Page 3-40: "Therefore, any future changes in model abstractions for this component will not diminish the potential repository's performance as represented in the total system performance baseline." This statement does not seem to make sense. Pages 3-35, 3-36, and 3-42 list significant uncertainties. | Since the SSPA is a collection of the work of multiple project participants, DOE acknowledges that there are some inconsistencies resulted from lack of integration. The statement on p. 3-35, for instance, reflects a narrower perspective provided by the individual investigator. In general, however, the uncertainty associated with the CHn properties is well bounded through sensitivity analyses of this unit. As for the conservatism of the 3-D flow fields used in TSPA-SR compared to the SSPA flow fields, see response to comment 73. |
| 81 | **More comments on the abstraction of uncertainty:**<br>Page 3-57: It is unclear how the mountain-scale THC model can address uncertainties in the drift-scale THC seepage models. If the mountain-scale models predict bulk changes to some things, like large-scale gas convection or lateral flow, this would change the boundary conditions to the THC seepage models. If the THC seepage models are not run with the altered boundary conditions, it is unclear how they would evaluate the impact. Page 3-66 "The ranges in water and gas compositions are wider than those predicted by the drift-scale THC models at a given time as a direct result of edge effects". Page 3-70: The argument that THM processes result in a change to permeability fields that are within the original uncertainty distribution, and are therefore unimportant needs quantification. The process would likely result in a shifting of the mean or median of the distribution and changes to its shape. Having a broad uncertainty distribution may not encompass this effect. | KTI agreement ENFE 1.05 will address these issues. [2] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 82 | **More comments on the abstraction of uncertainty:**<br>Page 4-6: "Uncertainties regarding evaporation effects were addressed by selecting conservative parameter sets in the seepage abstraction." This type of procedure to address uncertainty is problematic at best and typically a source of great error. To address uncertainty in this manner, suggests one knows what the impact of the uncertainty being addressed is. If the seepage experiments are significantly in error due to this type of bias, addressing uncertainty in this manner is unlikely to capture the impact. [Page 4-8, "Remaining unquantified uncertainties (specifically regarding spatial variability of seepage-relevant rock properties, local percolation flux distribution, and the impact of design decisions regarding ventilation, thermal loading, repository extent, and drift orientation) were addressed through appropriately broadened uncertainty distributions and conservative modeling in the abstraction."]<br>Page 4-38: "In addition, the calculated seepage increases are small enough that they are well within the ranges of variability and uncertainty in seepage, as determined in the seepage abstraction for TSPA-SR." The increases may be within the original range of uncertainty and variability, but the changes would influence the mean result, therefore a quantitative comparison is warranted. | This issue has been recognized as "to be verified" in AMR Seepage Calibration Model & Testing Data. DOE will address the issue consistent with KTI agreement TSPAI 3.11. [2] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 83 | **More comments on the abstraction of uncertainty:**<br>Page 4-58: It appears that the different conceptual models or analytical techniques are the biggest source of uncertainty, but it isn't discussed in the summary. Page 4-62: 'However, because the initial water and gas compositions are only known approximately, and their spatial distributions unknown, a quantitative evaluation of the uncertainties associated with the predictions are not feasible. Yet the range of predicted and measured compositions in the drift-scale test for waters that may potentially seep into drifts are not extremely great and the model results generally capture this range.' These two sentences do not appear to be consistent. If a quantitative evaluation of uncertainties is not feasible, how can one have confidence in the predicted ranges?<br>Page 4-65: 'This localized permeability reduction tends to cause some additional flow focusing, but the changes are considerably less than the initial range in permeability.' This is another example of a problem area mentioned previously. In addition, local arguments such as this can't be made in an integrated system.<br>Page 4-86: 'The HTOM case predicted a decrease of 6 orders of magnitude in permeability for most vertical fractures during the period from 55 yrs to more than 1,000 yrs after emplacement.' It is not obvious how this amount of change would be included in the original distribution of permeability. | See comment 106 for uncertainties in THC models. RDTME agreement 3.20 will address reconciliation of the differences in THM simulations using the discrete fracture model (3DEC) and the continuum model (TOUGH2-FACL). Preliminary evaluations indicate that the discrepancies may be associated with the manner in which displacements are treated in the two models. [1, 2] |
| 84 | Page 4-78: Simulations of Nitao and Glassley predict significant fracture sealing. Why is this alternative modeling not represented in the performance assessment? What are the differences in this modeling and the current modeling of the Yucca Mountain Project that results in the substantially different outcomes? This is an important type of uncertainty that is not represented in the performance assessment. The DST can't tell you anything about fracture sealing. If Nitao and Glassley's results indicate sealing in 1400 years, an 8 yr DST would only produce a fraction of the potential total sealing that could occur and therefore shouldn't be observable in the main output of the DST. | The differences between Nitao and Glassley and TSPA-SR are caused by the fact that the former assumed a much lower fracture porosity that is not supported by field measurements. The earlier simulations by Nitao and Glassley used an initial fracture porosity about 30x smaller than the ~1% value used in the TSPA-SR and SSPA supplemental analyses. The increase in fracture porosity in the technical database since the Nitao and Glassley calculations has been a result of additional data collected in the ESF. Both models were discussed in the NFE PMR. The SSPA calculations in Chapter 4 of Volume 1 indicate that about 1% of the 1% would be filled with precipitates due to THC effects. If the initial porosity were 30x smaller, the same amount of precipitation would be about 1/3 of the available volume, with some potential local sealing. Thus, the two independent analyses have similar THC precipitation results, with the difference in conclusions primarily being attributable to the initial conditions in the calculations. |
| 85 | Page 3-23 Section 3.3.3.4.1. Is there a unique conceptual model to calibrate the observations? Does pore water evaporate, increasing chloride concentrations and therefore decreasing calibrates estimates of infiltration? | As a sensitivity analysis of the UZ flow model that supports TSPA-SR, the measured Cl data were used to adjust the PTn anisotropy of hydrogeologic properties, which may not be unique. Pore water evaporation would increase Cl concentrations and therefore decrease calibrated estimates of infiltration. However, the rate of porewater evaporation is expected to be small during the |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| | | short duration of sampling. These uncertainties will be further investigated prior to LA, if the Cl-data based infiltration rates are carried forward into a potential TSPA-LA. [1] |
| 86 | Page 3-31: One of the goals of the UZ flow model is listed as quantifying the flow of gas through the UZ. Have estimates of gas flow been compared to observations from boreholes, etc.? Page 3-46: What are gas fluxes in the near and far fields constrained by? | So far only gas pressure data have been compared to the models. There have not been measurements of gas fluxes through the UZ due to technical limitations, and therefore, no effort on the suggested comparison. |
| 87 | Page 3-39: "Thus, the increased lateral flow seen in the extended model is a reflection of the numerical resolution applied." Is the refinement stable? | The numerical solution was found stable in a preliminary study conducted with a fine grid of multi-million cells. This analysis, if carried forward for a potential LA, will be documented in the AMR UZ Flow Models and Submodels (U0050) (MDL-NBS-HS-000006). |
| 88 | Page 3-50: If the water table reaches 67-68 °C, do you have convection cells develop in the SZ which would possibly change the GW chemistry? | Since heating is from the top, convection cells do not develop. |
| 89 | Page 3-T5, Table 3.3.2.1: Why is infiltration less for the intermediate lower bound (compared to the monsoon lower bound) when precipitation is higher for the intermediate lower bound (compared to the monsoon lower bound)?<br>Clarifying question. | These are other factors such as vegetation, evapotranspiration, and runoff that would determine the infiltration rate. For the cooler intermediate state, the effect of vegetation would lead to stronger evaporation which in turn will result in less infiltration. |
| 90 | Page 3T-9, Table 3.3.4-1: How can the average percolation flux be larger than the average surface infiltration rate (as indicated by OIS 16 lower bound #1)? Also, why is the %matrix flow 7% for the mean-monsoon state and only 5% for the lower bound monsoon state, when the opposite trend is seen for the interglacial and intermediate states?<br>Clarifying question. | Average percolation fluxes are calculated for a smaller area within repository footprints, while average surface infiltration rates are for the entire UZ model area which is much larger. The larger percolation fluxes within repository footprint than surface infiltration indicate certain lateral flow occurring, focusing more water into repository areas. The lower percentage of matrix flow for the mean-monsoon state than the lower bound scenario is due to: (1) the infiltration rate for the lower-bound monsoon state is much higher than the two other scenarios (4.6 vs. 1.3 or 2.5 mm/yr, see Table 3.3.2-1); and (2) the parameter set used for the lower-bound simulations corresponds to the lower-bound present-day infiltration scenario, which is different from that for the mean infiltration scenarios. |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 91 | Page 3F-3 and 3F-4: The figures seem to be in agreement about the magnitude but are in significant disagreement about the heterogeneity. Therefore it is unclear how chloride information can be used to support the contention that heterogeneity effects are not occurring and are not important. A calibrated UZ model should be able to give reasonable agreement for the amount of heterogeneity compared to alternate sources of information. | See response to comment 71. |
| 92 | Page 3F-9: What is the significance that the models predict very high $Cl^-$ in the PTn and above that is not observed in the field data? What is the potential error involved with using this model? What would you have to do to the model to get the Cl- in the PTn to match the field observations? | This might have been an anomaly in the measured data. Only UZ-16, which was compared to in this figure, showed lower measured Cl concentrations; while all other boreholes showed higher measured concentrations. The AMR “Analysis of Geochemical Data for the Unsaturated Zone” (U0085) (ANL-NBS-HS-000017) contains information on the chloride content in the PTn for other boreholes. |
| 93 | Page 3F-43: Chloride reaches 100,000 mg/L for an extent of 200 m. Wouldn’t sorption be potentially a lot different here, compared to ambient chemistry? What about carrier plume effects? | DOE will address this issue consistent with KTI agreement ENFE 1.05. [1,2] |
| 94 | Page 4-21: All fracture properties other than permeability are modeled as constant over each hydrogeologic unit within the entire model domain. This seems to not represent the discussion earlier which described $\alpha_f$ as being important. | For the unsaturated zone, fracture permeability was varied because it is expected to have the greatest impact on flow focusing behavior for a heterogeneous system. Future analyses, if carried forward for a potential license application, will consider the effects of the capillary parameter. [1] |
| 95 | Page 4-31: The explanation of the observed seepage enhancement in the ESF and associated tunnels appears to be speculation that is not supported by any concrete evidence. | There is no indication that rockbolts will lead to seepage enhancements in field measurements or recent numerical modeling results as documented in SSPA volume 1. See response to comment 13. The explanation that the apparent enhanced seepage observed in the ESF is a result of construction water will be confirmed through geochemical measurements. |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 96 | Page 4-56: The analytical work is an excellent example of alternative methods that can be pursued as multiple lines of evidence. However, in this case it does raise additional technical questions. For example, would the chemistry of the solution in the above boiling region influence the behavior? In particular, if the solution were a chloride-brine would it have different physical characteristics than dilute water? Secondly, if 15% of the realizations predicted penetration, then roughly 1600+ waste packages (on average) should experience these conditions. Finally, where is the support for the original modeling result if the analytical result contradicts the conclusions made with the original model?<br>Page 4-57 describes "more extreme conditions", but it was not obvious that the conditions were more extreme in the analytical work, rather it appeared that the analytical work evaluated processes on a scale that the numerical model can not evaluate. | See response to comment 15.Although the asperity-induced episodic infiltration model provides convenient analytical expressions for the episodicity and water-penetration distances, it also includes a number of important assumptions (consistent with KTI agreement TSPAI 4.01):<br>Although the configuration of the infiltrating weeps is three-dimensional, the flow of water through the fractures is modeled as one-dimensional in the downward direction. Water accumulation and drainage is governed by a weep width that constrains the physical boundaries of accumulation and drainage in the lateral direction.<br>All fluid and material properties are modeled as constant over time. In the application presented here, properties were averaged over temperature ranges from ambient (20°C) to boiling (96°C for Yucca Mountain). Distributions were obtained from previous Yucca Mountain reports, as summarized in Table 4.3.5-3.<br>Fracture-matrix interaction (e.g., imbibition) is ignored in this analysis. If a significant amount of matrix imbibition exists, the water-penetration distance into the superheated distance will be less. |
| 97 | Page 4-97: ' there are apparent contradictory results at the drift wall: there is an increase in permeability in the distinct element analysis, but there is a decrease in permeability in the continuum analysis.' This appears to be the area of the problem that one should be most concerned about, due to the influence on seepage. | RDTME agreement 3.20 will address reconciliation of the differences in THM simulations using the discrete fracture model (3DEC) and the continuum model (TOUGH2-FACL). Preliminary evaluations indicate that the discrepancies may be associated with the manner in which displacements are treated in the two models. [1, 2] |
| 98 | Page 4F-34: It is not obvious that the results shown on this page demonstrate good predictability. | DOE understands that this NRC concern is related to the seemingly discrepancy between the modeled and measured concentrations for borehole 60-3. This may be a visual artifact resulting from the lack of water samples during the rapid dry-out period as discussed in the response to comment 49. [1] This issue is addressed in KTI agreement ENFE 1.5. |
| 99 | Page 4F-41: Why are only simulation results of an experiment shown? Why not provide a comparison of pertinent experimental results to the model results as a source of model confidence building? | DOE will consider plotting comparison of measured data with model results in future documentation. [1]The results for silica precipitation in the model has been verified through the single-fracture experiment discussed in this question and will be further analyzed for multi-fracture system in the planned cubic meter block test. The single-fracture and multi-fracture test results will be documented in the UZ Thermal Testing AMR and the "Drift Scale Coupled Processes – THC Effects on Hydrological Properties (MDL-NBS-HS-00001), Rev. 2, both of which are scheduled to be completed in CY 2003. |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 100 | A multiplier factor with values ranging from 0 to 1 is used in the HLW glass dissolution abstraction, where 0 indicates no dissolution of the HLW glass. Insufficient technical basis is provided for the use of the multiplier factor, specifically the minimum value of 0. | DOE acknowledges the necessity to further develop strong technical bases for any changes in glass dissolution rates, if these changes are carried forward to a potential TSPA-LA. [1] |
| 101 | Sensitivity analyses performed for section 12 of the SSPA are not sufficiently documented. The DOE states in section 12 (p. 12-4) that many sensitivity analyses will not be carried forward to baseline project documents and that a fully-documented basis for the assumptions used in these calculations and analyses has not been developed. It appears that these sensitivity analyses have been used for examination of previously unquantified uncertainty, scoping calculations, and additional conceptual models. If these sensitivity analyses are used to make decisions related to the direction of the site-characterization studies, those analyses should be documented, even if a decision is made not to pursue an area of study (i.e. sensitivity analyses indicate that a topic of interest is not important to safety). | The discussion regarding not carrying the sensitivity analyses "forward to the SSPA Volume 2 calculations" was intended to convey that there were sub-system sensitivity analyses which were not included in the TSPA calculation. Sub-system sensitivity analyses will be documented in project documents (such as revisions to AMRs) as deemed necessary to support an assumption or as a confidence building/multiple lines of evidence exercise. To ensure sufficient documentation, sub-system sensitivity analyses will be documented in accordance with appropriate procedures. |
| 102 | The DOE states in section 12 (p. 12-4) that "new data from column and batch experiments have been used to define the $K_d$ estimate for neptunium-237." Previous work used uranium $K_d$ values to characterize the $K_d$ values for $^{237}Np$. Has this been improved by using neptunium studies? | Kd values obtained directly from neptunium sorption measurements are superior to assuming that uranium Kd values also apply to neptunium. A description of column and batch Neptunium 237 experiments and results will be provided in the next revision of the transport properties AMR, per KTI agreements RT 1.05 and RT 2.10. [2] |
| 103 | The DOE mentions that an alternative study was performed to investigate the appropriateness of the treatment of anisotropy in the parameterization of the Solitario Canyon fault within the site-scale SZ flow model. However, no reference is made to this study. | The study is mentioned briefly in the SSPA. Detail of the study will be documented in a subsequent revision of the SZ calibrated flow AMR consistent with USFIC 5.11. [2] |
| 104 | The DOE has not adequately addressed the possibility that edge effects predicted by the 3-D mountain scale TH model (Section 3.3.6) could influence results from the coupled THC models (Section 4.3.6). | Duplicate with 81, refer to Comment 81 response. |
| 105 | Additional clarification and technical bases are required for the DOE's assertion on page 6-16 that thermodynamic data for clays and zeolites used in the THC seepage model are 'better constrained'. | Figures 6.3.1.4-1 and 6.3.1.4-2 show trends of increased pH, as well as Ca depletion and large Na increase for Rev 00 and Rev 01 ambient simulations. The computed Rev 00 trends are not substantiated by field data, and apparently result from clays and zeolites being somewhat too stable in the Rev 00 simulations. By shifting the Gibbs free energies of these minerals by a small amount (well within the determination error of these values), trends consistent with measured concentrations were calculated (Rev 01). Because the free energies were adjusted within their error margins, and the adjusted values more closely reflect field data, the model calibration is improved |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 106 | The DOE needs to provide additional technical bases for excluding uncertainties in infiltrating water compositions that are associated with the coupled THC model from TSPA analyses. The DOE has not adequately demonstrated that the initial water compositions used in sensitivity studies in the coupled THC models are appropriate and bounding (Chapters 3 & 6). What are the technical bases for selecting these particular water compositions selected for the analysis? Do they differ from one another in significant ways? Do they represent the full range of ground water compositions that have been collected and measured from Yucca Mountain and vicinity? How do variations in infiltrating water composition influence the In-Drift salts/evaporation models? | As stated on page 6-15, the Alcove-5 water compositions selected for most of the THC seepage modeling work were "the only available nearly full suites of analyses from a repository host unit" at the time the modeling work was initiated. In Section 6.3.1.5.3, additional simulations using UZ-14 perched water are presented. The UZ-14 perched-water composition is a good example of a reliable analysis significantly different from the Alcove-5 pore-water analyses. Additional work is planned for the next couple of years to collect additional porewater samples from the TSw in the ESF, analyze the data, and use the data to improve the THC seepage model to better predict seepage chemistry consistent with TSPAI 3.24. [1, 2]Sensitivity to starting water composition on evaporative chemical evolution is documented in section 6.3.3.5.1.1 of SSPA Vol 1. These studies take 7 different known water compositions and evaporate them using the In-drift precipitates salts model. The results of these sensitivities indicate that for 7 waters there are three possible chemical divides that the brine generation follows. The first representing waters like J-13, perched water, water from the single heater test and water from the drift scale test evolve to a sodium nitrate brine. The second set representative of the Topopah Spring pore water takes the brine towards calcium (or magnesium) chloride brine. The third set derived from the Rev 00 DST THC seepage abstraction results and associated grout modified waters that contain more sulfates than calcium. These three different brines would give different RH thresholds for brine formation on the waste package and have different boiling point elevations for any brine associated with the waste package. |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 107 | What are the uncertainties in F- and Cl- concentrations predicted by the coupled THC models, and how are these uncertainties abstracted into the TSPA and propagated into down-stream models? | As mentioned on p 6-25, "Because of the large number and variability of input parameters, as well as the complexity of modeled THC processes, a rigorous quantification (in a statistical sense) of the uncertainty of the THC seepage predictions is not achievable". Therefore, the uncertainty in predicted concentrations of chemical species, including F- and Cl-, cannot be exactly quantified. In the case of F-, a range of concentrations is predicted depending on whether the mineral fluorite is present or not in the repository host rock units (Tptpll vs. Tptpmn models, see Figure 6.3.1.4-3). Because Cl- is essentially conservative, its predicted concentration is only affected by the amount of dilution or evaporative concentration taking place in the modeled system (Figures 6.3.1.4-3 and 6.3.1.5-2). The values selected for any given abstraction period as documented in section 6.3.1.6 of SSPA Vol 1 are directly associated with a given THC process model result in that time period. Therefore, the abstraction results carry with them the assumptions, caveats and limitations of the THC and DST seepage model. For SSPA volume 1 models, uncertainty and or variability directly associated with three parameters: soil zone PCO2 (high or Low), thermal operating mode (high T or Low T), and drift location (either crown seepage or Invert imbibition) were propagated into the TSPA model. |
| 108 | Additional technical bases are needed to justify the appropriateness of the base case mineral assemblage in the coupled THC model for comparisons against drift scale heater test data. The model results are compared against analytical pCO2 data, but one mineral in the base case, calcite, is largely responsible for controlling the predicted values of pCO2, and the highly uncertain parameters describing the kinetic behavior of calcite appear to have been adjusted to obtain the desired model results. | As mentioned in the response to comment no. 48, no input parameters were calibrated to experimental data (i.e., DST or laboratory work). The kinetic behavior of calcite was dictated from published reaction rates and/or assumption of equilibrium, and from an assumption (supersaturation gap) drawn from simulations of ambient conditions, thus under conditions very different than for the DST. The relatively good agreement between calculated and measured CO2 concentrations in the DST were not the result of calibration to DST data. |
| 109 | Page 6T-15 provides an example of using average values in a model and not propagating uncertainty/variability through the coupled models. | Uncertainty is propagated to SSPA Volume 2 by providing several such tables that span salts/precipitates model calculations based on abstractions of several THC calculations. The THC calculations span a range of inputs that represent the major source of uncertainty. See the source document, Jolley 2001 [DIRS 154762] under Table 6.3.3-1 (page 6T-15) for the other tables of results from the salts/precipitates model calculations. See also response to Item 50 above and KTI agreements ENFE 2.15 and ENFE 2.17. [2] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 110 | Page 6T-12: Capillary pressure effect on chemical potentials of reacting species. It is unclear how this is taken into account because calibration of thermodynamic data result in reproduction of ambient water compositions. The ambient pore waters are at high saturations which result in relatively low capillary forces. When the rock dries out, the capillary forces may because extremely large. Therefore, it would appear that a calibrated model for a given state of the system is being argued to address an uncertainty for which the calibrated model is likely not valid. | The effect of capillary pressure would be larger in the rock matrix upon near complete dryout than under ambient conditions. However, most of the fluid transport takes place in fractures where the capillarity is minimal. In addition, the potential for water-rock interactions and fluid movement is larger in zones of large liquid saturations (reflux zone) than in nearly dried-out areas (thus, under liquid saturation/capillary pressure conditions closer to those in the ambient system than in the nearly-dry system). This uncertainty is not addressed for the case of high capillary pressures under nearly dry conditions in the rock matrix. In this case, this uncertainty may not have a significant impact on predicted seepage water compositions given the low mobility of waters at small residual saturation in the rock matrix. Reasonable model validation against field and experimental data (Section 6.3.1.4.5) would seem to indicate that this capillary effect does not need to be taken into account. This aspect of model uncertainty will be addressed as part of KTI agreement ENFE 1.05.[2] |
| 111 | Page 6F-3: The information presented in figure 6.3.1.4-2 potentially indicates that the time-steps utilized for the THC simulations may be too coarse and therefore important information may be eliminated. The liquid saturation is shown to go from 0.0 to 0.10 in one time step, whereas the rewetting process would be expected to be a gradual process. | The interval between points at 0.0 and 0.10 liquid saturation in Figure 6.3.1.4-2 is not the time step utilized for the THC simulations. This is only the printout interval of data calculated in the model (here several hundred years) (i.e., the first point shown after rewetting is the first output non-zero saturation). The actual simulation time step is much smaller (1 to 2 years). Therefore, the actual simulated rewetting is more gradual than the data shown on these graphs. As far as which output data should be used to feed downstream models (i.e. data for which time step(s) should be used to characterize the rewetting period) this question is more an abstraction question than a THC modeling question. First output saturations after rewetting (at a given time) also depend on rock properties. In other simulations presented in Section 6.3.1.5 for a different rock unit (Tptpll instead of Tptpmn), the first output fracture saturations are around 0.022 (e.g. Figure 6.3.1.5-2). In any case, these data were abstracted and averaged over a large time interval (e.g. from 1501 to 4000 yr in Table 6.3.1.6-2). Liquid saturations were not taken into account in the averaging process, which was reasonable because saturation values do not change much during the averaged time interval (by a factor of approximately 2 or less). One could argue that if concentrations at earlier, very small liquid saturations were included in the averaging process, then one would have to weight these concentrations in function of their corresponding liquid saturations. In this case, the resulting effect would be minimal on the averaged values. In this respect, we believe that the current abstracted data and abstraction method are reasonable. The question concerning time-stepping in the THC abstraction used in TSPA will be addressed as part of KTI agreement TSPAI 4.04. [2] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 112 | Page 7-16: The paragraph about the amount of water needed to supply the magnesium ion content is misleading. The amount of magnesium needed doesn't need to be supplied for 1-L of solution, it needs to be supplied for the water film covering the waste packages. The volume of the water film is much less than 1-L. Comment only. No response required. | No response required per NRC. |
| 113 | Page 7T-1: Does the pore water compositions shown in Table 7.3.1-2 suggests that the waters in the Yucca Mountain system already exhibit evidence of evolving to a Ca-Mg-Cl type system, thereby making the evolution of the waters due to thermal influences more likely to end up in the Ca-Mg-Cl system (the concentration factors of Ca, Mg, and Cl from fracture to pore water are much larger than for $NO_3$)? | The compositions of the waters shown in Table 7.3.1-2 are examples of waters that have been sampled at Yucca Mountain. Under CLST KTI agreement 1.1, testing and modeling for a potential TSPA-LA is being performed in order to determine the expected compositions of waters that will be in contact with the waste packages and drip shields. These activities consider seepage water compositions, particulate matter in the ventilation air, and dust that may be deposited on these components. [1, 2] |
| 114 | Page 9-12: It is unclear why the solubility of Tc is lowered from previous values to take into account reducing conditions, when oxidizing conditions are highly likely (due to the large gas flows) and other models don't evaluate reducing conditions. | As part of the ongoing refinement of dissolved concentration limits for a potential LA, the dissolved concentrations AMR will expand the technical bases for supporting lower Tc values. [1] |
| 115 | Page 9-15: Why is plutonium solubility evaluated over a range of pH of 5.0 to 9.8 when previous modeling suggests pH may go from 2.0 to 3.0 as a minimum for in-package chemistry? | The abstraction for Pu solubility extends to pH 2. Pu solubilities were not calculated for individual pH's at low pH's because of instability in the EQ3 program. For this reason, at low pH, the Pu solubility abstraction was set to uniformly high values that are conservative. |
| 116 | Page 10-22: What does the calculation that shows the rate of water consumption is 27 times greater than the diffusional inflow suggest about the chemical conditions inside the package? Are the simulations for in-package chemistry assuming a bathtub model appropriate? | The mass balance considerations in Section 10.3.1.3.4 make the following observations:<br>If diffusion of water vapor through stress corrosion cracks limits mild steel corrosion, then it will take approximately 4,600 years for all A516 steel components to degrade (page 10-22).<br>If diffusion of oxygen through stress corrosion cracks limits steel corrosion, then it will take approximately 1,100 years for all A516 steel components to degrade (page 10-23).<br>If both water vapor and oxygen diffuse through stress corrosion cracks, then it will take approximately 800 years for all A516 steel components to degrade (page 10-24). It follows that the mass balance considerations can "dry out" a package for a relatively limited period of time following formation of stress corrosion cracks, limiting any impacts for this effect on chemical conditions inside the package. KTI agreement TSPAI 3.14 addresses this issue. |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 117 | Page 10-58: 'The tolerance interval is appropriate in estimating the range of variability of the underlying population.' Wouldn't this statement only be true for a given population (e.g., certain materials and conditions) and not for a combination of populations that is being evaluated here? | The tolerance interval approach is only one facet in the development of distributions of partition coefficients for SSPA. The development proceeded with the following steps: (1) Review a range of Kd values from several literature surveys and for a variety of materials that are relevant to the degraded materials in the EBS,<br>(2) Use the tolerance interval method on a limited portion of this data, that is for sand, loam and clay from Sheppard and Thibault (1990).<br>(3) Pick conservative maximum values from the data in step 1, and<br>(4) Use the tolerance interval approach to provide an estimate of minimum Kd values at the 95% confidence level. Therefore, the tolerance interval approach was applied only to the data from Sheppard and Thibault (1990) for sand, loam and clayey soils. These materials might represent possible end states for the degraded materials in a waste package, which were conceptualized as iron-rich soils (see Section 10.3.4.3.1). The appropriate means and standard deviations are defined on pages 10-59 and 10-60 for this mixed data set. This approach is reasonable technically and still retains the advantage of the tolerance interval approach (providing a less subjective estimate of the lowest values for partition coefficients at 95% confidence limits). [1, 2]<br>[See related response to comment # 34.] |
| 118 | DOE's assessment of deliquescence humidity did not consider the mixed salt effect. Mixed salts may lower the delinquency points below that of pure salts. | The deliquescence of mixed salts will be addressed experimentally in FY02. This work is covered under the CLST KTI agreement 1.1. [2] |
| 119 | In p. 7-9 DOE claimed that NRC accepted the slip dissolution model. The DOE must supply the reference for this acceptance. | DOE recognizes that the slip dissolution (GE PLEDGE) model has been used for stainless steels and the model needs to be validated for Alloy 22 and titanium, for the environmental conditions relevant to the repository. Data generated under existing KTI agreements CLST 1.12 and CLST 1.15 will provide the basis for this validation. |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 120 | Page 7-11, The use of a triangular distribution for the residual stress uncertainty dictates that the endpoints of the distribution are well known. Showing the data compared to the distribution would support the selection of a triangular distribution. | A triangular distribution is used to represent uncertainty in the residual stress and stress intensity factor profiles in the weld regions of the outer and inner closure lids of the waste package Alloy 22 outer barrier. The triangular distribution was used because the uncertainty bounds used are conservative, considering the strict process control and inspections that will be implemented during the waste package manufacturing process. If the data currently being obtained under existing CLST KTI agreements 1.12 and 1.13 warrant a change in the assumed distribution, this would be carried forward into a potential TSPA-LA in accordance with KTI agreement TSPAI 3.41. [1, 2] |
| 121 | In figure 7.3. 4-4, the corrosion potential is very high in a thin film of ground water. Provide the basis for this behavior with supporting experimental evidence. How was this extreme value sampled in calculating the container life? | As discussed in the response to Comment No. 51, the deterministic general corrosion model (GCM) described in Section 7.3.4 of SSPA Vol. 1 is a conceptual model. The model outputs presented in that section are presented to illustrate the model's features and capability and are not intended for input to the waste package performance assessment. If the GCM is carried forward to a potential LA, the corrosion process model parameters will be updated based on additional data. This work is covered under the existing CLST KTI Agreement 1.8. [1, 2] |
| 122 | In p.7-58, fluoride mitigates corrosion. Provide the basis for this mitigation. | Fluoride ions have an inhibiting effect for some metals under certain situations. A general reference on corrosion inhibitors was cited for this effect (J.G.N. Thomas in *Corrosion: Corrosion Control*, Vol. 2, Chap. 17.3, L.L. Shreir, R.A. Jarman, and G.T. Burstein, eds. Butterworth-Heinemann, Woburn, Massachusetts, 1994.) An inhibiting effect of fluoride ions for Ti and Alloy 22 corrosion has not been established. DOE will provide the basis for this mitigation in accordance with KTI agreements CLST 1.1 and 6.1 |
| 123 | In p. 7-67, most of archaeological evidence came from the reducing environment? If that is the case, are the quoted examples relevant to the YM project? | Section 7.3.7.3 of SSPA Vol. 1 documented any existing natural and archaeological analogues that could provide additional lines of evidence for long-term degradation of waste package materials under repository relevant exposure conditions. The documented analogues, except the iron pillar of Asoka, India and iron and nickel-iron alloys from meteorites, were exposed to varying degrees of reducing environments. Although the documented analogues do not provide direct quantitative evidences to long-term waste package degradation in the potential repository, their long-term durability in their respective exposure conditions provides very useful implications to the potential longevity of waste packages in the potential repository. Additional corroborative data on the natural and industrial analogues are being obtained under existing KTI agreement CLST 1.8. |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 124 | In p. 7-74, Ferric Chloride generation is very remote spatially. Provide the basis for the hypothesis. NRC Clarification: Correct page number is 7-64, Section 7.3.7.1:<br>"...Although useful in ranking a range of alloys, these standard tests utilize aggressive environments (in particular, a ferric chloride solution) that are not directly relevant to expected waste package surface environments because the potential for ferric chloride generation is very remote. ..."The NRC expressed a concern that DOE models might neglect the potential accelerating effect of ferric chloride on corrosion/degradation of waste package materials and fuel cladding materials. NRC requested clarification about DOE's intent to evaluate the potential role of ferric chloride in waste package and fuel cladding degradation. | Electrochemical corrosion testing is determining the effect that minor constituents will have on the waste package corrosion processes. This will include the effects of ferric ion in the aqueous test solutions. Activities will also determine the extent that minor constituents can concentrate in the aqueous solutions. This work is covered under existing KTI agreement CLST 1.1. [1, 2] Per existing KTI agreement CLST 3.7, a ferric-chloride local clad corrosion model is being developed that will be documented in a future revision of the *Clad Degradation Summary Abstraction* AMR. [2] |
| 125 | In p.7-58, Mg/Ca chloride will result in high corrosion. Does Ca chloride result in high corrosion too? Provide the basis for this hypothesis. | $MgCl_2$ and $CaCl_2$ have similar hygroscopic properties (low deliquescence points and the consequent high boiling points for saturated solutions). Both salts are very soluble. For example at 100°C, $MgCl_2$ and $CaCl_2$ have aqueous solubilities of 7.6 and 14.3 molal, respectively. Because of the high chloride content and high boiling points of the saturated solutions of these salts they will have similar effects on corrosion. |
| 126 | In chapter 9, the assessment of in-package chemistry did not consider the spatial heterogeneity. Provide the rationales for the homogeneity. | This issue is covered under KTI agreements ENFE 3.03 and ENFE 3.04 with additional support from KTI agreements CLST 3.05, CLST 3.06, CLST 4.05, CLST 4.06, TSPAI 3.08, and TSPAI 3.14. [1, 2] |
| 127 | In chapter 10, it is unclear why the diffusional flux is faster than the advectional flux. Provide justification. <<NRC clarified that “faster” should be interpreted as “larger”>> | Diffusive transport is dominant in the EBS when stress corrosion cracks are the only breaches of the waste package. Diffusive transport is the only viable transport mechanism at these times because the advective flux of liquid water through stress corrosion cracks is assumed to be negligible. Once patches form by general corrosion, both advective and diffusive transport can occur in the EBS and advective transport becomes the dominant transport mechanism (if seepage into the emplacement drift occurs). |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 128 | NRC questions the statement in Section 7.3.6 (estimation of number of affected waste packages) that affected waste packages are independent. Basis for comment: The conclusion is based on the assumption that improper heat treatment of the WP was caused by a non-detected equipment malfunction and non-reported operator error. It seems plausible that such equipment and operator error could occur for WPs fabricated at about the same time, leading to a common-cause failure. Please explain why this is not likely to be the case. | The SSPA treatment of the probability of improper heat treatment is based on the event tree analysis documented in the *Analysis of Mechanisms for Early waste Package Failure*. This analysis was based on handbook data for industrial applications. Current assumption of independent events resulting in improper heat treatment allows for the use of Poisson's distribution to evaluate the effects on waste package performance Applying the Poisson distribution implicitly assumes that failures of the waste packages are independent, and is therefore an approximation that does not include consideration of common-mode failures. Future work will include development and testing of welding, heat treating and inspection equipment and processes. Data from this program will be used to evaluate the potential for common-mode failures, and to refine prediction of the failure rates to be applied in future performance assessment. If the improper heat treatment issue is carried forward to a potential LA, based on the work being performed under PRE 7.04 and 7.05, DOE will update the *Analysis of Mechanisms for Early waste Package Failure* AMR and reevaluate the potential causes of improper heat treatment and the effects on waste package performance. [1, 2] |

| No. | Comment/Question/Basis | Response to Comment/ Question |
|---|---|---|
| 129 | Volume 1, section 10.3.1.3.4 - The quantity of water vapor entering the WP used to limit the steel corrosion rate does not include potentially important transport mechanisms. DOE should consider other mechanisms than binary diffusion that transport water vapor and oxygen into the WP. Basis for Comment: DOE shows that the degradation of steel components within the WP is likely to be limited by the rate that oxygen and water vapor enter the WP through the stress corrosion cracks. This is a useful analysis, but it depends only on binary molecular diffusion, and does not take into account potentially important transfer mechanism such as: a) Lower pressure within WP caused by consumption of water vapor and oxygen by the corrosion process; b) Lower pressure within WP caused by dropping temperature; and c) Barometric pumping caused by fluctuations of atmospheric pressure. NRC has performed an approximate calculation with hourly atmospheric pressure fluctuations (not at the Yucca Mountain site, but likely to be within reason). NRC determined that barometric pumping would lead to approximately the same transport rate of water vapor into the WP as diffusion, provided that pressure fluctuations were the same as at the surface and the cracks were large enough that there was no appreciable resistance to air flow. | Water vapor and oxygen entering the waste package through stress corrosion cracks are unlikely to limit the steel corrosion process. No limitation of the steel corrosion process has been included in the SSPA analyses. The DOE's conclusion from the binary diffusion analysis in Section 10.3.1.3.4 is that the binary diffusion rates are approximately equal to the rates of consumption of water vapor and oxygen by corrosion. In this situation, no limitation is placed on corrosion rate. In addition, thin films of liquid water are assumed to exist within the waste package so there is no limitation on diffusive transport from in-package dryout (see page 10-24). The three mechanisms identified by the NRC, particularly the potential for barometric pumping, reinforce this viewpoint. The additional transport mechanisms discussed by the NRC will be included if the model is carried forward to a potential LA. [1, 2] |

NOTE: The information presented herein does not, at this time, represent a commitment to perform additional work. DOE is currently considering and scoping the appropriateness of a lower temperature operating mode for potential LA, should the site be approved. Should the site be approved, DOE will, as appropriate, re-evaluate the impact of a lower temperature operating mode upon existing KTIs, which were established on the basis of the higher temperature operating mode.