| YMP YUCCA MOUNTAIN PROJECT | **Model Error Resolution Document** *Complete only applicable items.* | QA: QA Page 1 of 2 |
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| **1. Document Number**: | MDL-WIS-PA-000005 | **2. Revision/Addendum**: | Rev 00 and AD 01 | **3. ERD**: | ERD 05 |
|---|---|---|---|---|---|
| **4. Title**: | Total System Performance Assessment Model/Analysis for the License Application | | | | |
| **5. No. of Pages Attached**: | 24 | | | | |

**6. Description of and Justification for Change** (Identify affected pages, applicable CRs and TBVs):

This Error Resolution Document (ERD) is provided to update the *Total System Performance Assessment for the License Application* (TSPA-LA) documents, including Rev 00, the addendum (AD 01), ERD 02 and ERD 04, to correct issues identified in the following condition reports (CRs). The corrections identified are necessary to add clarity and strengthen the discussion within the suite of TSPA-LA documents. There are no impacts on results or conclusions due to the clarifications and text revisions from the CRs listed below. CR 12543, however, will have an impact on the results from the TSPA-LA localized corrosion initiation analysis (Appendix O), but will have no effect on the overall model conclusions that are based on the calculation of repository performance.

An impact analysis was performed for TSPA-LA Rev00 [DIRS 178871] and the addendum [DIRS 183478]. For Rev00, a total of 12 controlled documents were found, however, none of the documents are using the TSPA-LA as a direct input, nor do they reference any of the sections being revised in this ERD. For the Addendum, 8 controlled documents were found, of these, two use the Addendum as a direct input but are affected only by changes in this ERD related to CR 12543 (ANL-WIS-MD-0000027 Rev 00 and ANL-DS0-NU-000001 Rev 00). It should also be noted that CAL-DN0-NU-000002 Rev 00C uses the localized corrosion DTN (CR 12543) as direct input, and will also be affected. The SAR has been evaluated for changes needed due to this ERD and will require minor modifications through the LCR process. These changes will have no effect on the results and conclusions presented in the text.

**CR 12543—Salt separation error in localized corrosion initiation analysis.**

In TSPA-LA Rev00, Section 6.3.5.2 describes the model abstraction for initiation of localized corrosion on the WP outer barrier. As part of this abstraction, localized corrosion is assumed to initiate if salt-brine separation occurs during re-wetting of the WP outer barrier. TSPA implements the abstraction for initiation of localized corrosion in a set of GoldSim model files documented in output DTN: MO0709TSPALOCO.000_R0 [DIRS 182994]). However, it has been determined that localized corrosion from the occurrence of salt separation was not accounted for in these model files due to an incomplete implementation. The analysis with these model files is documented in the TSPA-LA Appendix O.

A new analysis has been completed with the appropriate implementation of localized corrosion being initiated from the occurrence of salt separation and the output DTN updated (MO0709TSPALOCO.000 [DIRS 185808]). This ERD updates the discussion presented in Appendix O of the parent document (Attachment 1), which is based on TSPA-LA Model v5.000 (output DTN: MO0709TSPAREGS.000 [DIRS 182976]) with results from the new analysis and dose histories from TSPA-LA v5.005 (output DTN: MO0710ADTSPAWO.000 [DIRS 183752]). The original dose analysis evaluating the impact of localized corrosion in the Seismic Ground Motion Modeling Case for 10,000 years (DTN: MO0708FREQCALC.000 [DIRS 183006]) presented in Section 7.3.2 of the parent document has also been updated (Attachment 2) with the corrected localized corrosion model results and TSPA-LA v5.005 dose histories from output DTN: MO0710ADTSPAWO.000 [DIRS 183752]. Attachment 2 contains a replacement for TSPA-LA Figure 7.3.2-17; however no modification to the text was required. Attachment 3 contains areas in the document which should be revised to reflect the new localized corrosion DTN.

The effect of this error is limited to three downstream users of this DTN: (1) ANL-WIS-MD-0000027 Rev 00 (CR Action 003), (2) ANL-DS0-NU-000001 Rev 00 (CR Action 004), and (3) CAL-DN0-NU-000002 Rev 00C (CR Action 005). These three documents are included in the CR and will be updated as necessary according to the actions in CR 12543. Data from this analysis was also provided to the NNPP for the screening of criticality performed by the Navy Nuclear Propulsion Program (NNPP). The Lead Lab does not have insight into the use of the data by the NNPP, but initial notification has been sent. Any potential SAR impacts have been evaluated through the normal LA Impact evaluations.

| **7. CONCURRENCE** | | | |
|---|---|---|---|
| | Printed Name | Signature | Date |
| Checker | David Mohr | David E Mohr | 12/18/08 |
| QCS/QA Reviewer | Brian Mitcheltree | Brian Mitcheltree | 12/18/08 |
| **8. APPROVAL** | | | |
| Originator | Eric Zwahlen | Eric Zwahlen | 12/18/08 |
| Responsible Manager | Jerry McNeish | Jerry A McNeish | 1.5.09 |

| | Model<br>**Error Resolution Document**<br>*Complete only applicable items.* | QA: NA<br>Page 1 of 2 |
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| **1. Document Number**: | MDL-WIS-PA-000005 | **2. Revision/Addendum**: | Rev 00 and AD 01 | **3. ERD**: | ERD 05 C |
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**4. Title**: Total System Performance Assessment Model/Analysis for the License Application

**5. No. of Pages Attached**: 24

6. Description of and Justification for Change (continued):

**CR 12801—TSPA-LA Document Opportunities for Improvement**

Several typographical errors were found during a recent review of the TSPA-LA suite of documents (Rev00, AD01, and ERD02). Attachment 4 includes the changes in regards to these typographical errors. There are no impacts on results or conclusions due to the clarifications and text revisions in CR 12801. All of these changes have either already been incorporated into the SAR as part of LCR-0061-01, or will be included in the new LCR being developed. As mentioned above, no other documents references these sections as direct inputs.

**CR 12464—Water Table Error in the Performance Margin Analysis**

A problem was identified in FEHM v2.25 in which, the water-table option incorrectly locates the unsaturated zone exit nodes at the bottom of the grid during the glacial and post-10,000 year climate states. This CR has been evaluated in accordance with MGT-PRO-004 and no impact was found. Any change as a result of this error would not be visible at the scale shown in these figures (SAR Figure 2.4-135 and TSPA Figure 7.7.4-7[a]). Therefore, no update to the document is required for this error.

**CR 12984—Revise TSPA-LA Model Report to fully address procedural requirements and correct editorial errors**

Four items were noted during the recent TSPA Audit that require further clarification. The TSPA-LA Model was not explicitly categorized as required in SCI-PRO-006. A minor update to Section 1.9 in regards to deviations from the Technical Work Plan to address this issue is included in Attachment 4. In addition, the use of exempt software was not fully documented, and therefore a description will be added to Section 3 (Attachment 4) to clarify the use of commercial, off-the-shelf software in TSPA. Further clarification is also needed in regards to non-Q software being used for corroborative purposes. Statements will be added, and references corrected in Section 7.7.2, 7.7.4, Appendix C.1 and Appendix I.1 (Attachment 4). Finally, several editorial corrections were also discovered and are corrected in the appropriate sections of the document in Attachment 4.

**CR 13004—TSPA documentation improvements**

During the recent TSPA-LA Audit, opportunities to improve the documentation of the TSPA-LA Model Report were identified. It was recommended the discussion in Section 3 (page 3-1) be expanded to address the rationale for the selection of codes that were not developed for use with the TSPA-LA Model. The updated text to clarify this issue appears in Attachment 4. It was also noted that clarification be added to clearly state in Section 6.2 that 63.111(c) is being addressed in regards to alternative conceptual models. The updated text for Section 6.2 also appears in Attachment 4.

**CR 12553—Errors in SCC AMR and DTNs**

During the extent of condition conducted for this CR, it was noted the description associated with TSPA-LA parameter name Z_OL_a was not consistent throughout the text and tables. This change will have a minor affect on the text in Sections 6.3.5, 8[a], and Appendix K and several tables (Tables 6.3.5-3, 7.4-4, K3-1, K3-2, K3-3, K9-1, and K9-1[a]). The updates to the text and tables appear in Attachment 4.

**CR 13035—Typographical Error in TSPA-LA AMR**

In the TSPA-LA Rev00 a typographical error was found in the header text in parts of Figure K6.3.2-4 (b, d, and f), which is used for internal traceability. The sigmaplot file name (.jnb) and the mView file name (.mview) located on the top of these plots indicates ESNP237C, when they should read ESPU239C. The axis labels, data, captions and all associated text remains correct. Therefore, since the results are correct, and traceability is not lost, only slightly hampered. In addition, a similar typographical error has been found in the legend of Figure K4.3-1 parts (e) and (f). In the legend, the label for the purple line should be ALPHAL, and the label for the olive line should be SEEPPRM. The axis labels, data, captions and all associated text remains correct. The necessary revisions to the figures are included in Attachment 4 and the readme file for the DTN (MO0709TSPAPLOT.000 [DIRS 183010 has been updated to inform users of these minor typographical errors.

# ATTACHMENT 1—REPLACE APPENDIX O (CR 12543)

## O1. INTRODUCTION

This appendix presents the Localized Corrosion Initiation Uncertainty Analysis, which implements the Localized Corrosion Initiation Submodel described in Section 6.3.5.2. The original Localized Corrosion Initiation Model is developed in *General Corrosion and Localized Corrosion of Waste Package Outer Barrier* (SNL 2007 [DIRS 178519], Sections 6.4.4, 6.4.4.3.1, and 6.4.4.5). The main result of this analysis is the fraction of locations in the repository that have the potential for localized corrosion initiation if the drip shield fails at a given time. This fraction is the cumulative fraction of WP locations that can potentially corrode any time after the drip shield fails. The analysis also provides support for the tables of zeros for localized corrosion in the TSPA-LA Model. The results of the Localized Corrosion Initiation Uncertainty Analysis are also used to support screening arguments that localized corrosion initiation can occur only with a low probability and only at a few locations in the repository.

Localized corrosion can be initiated as a result of two independent processes. The first process, discussed in *Engineered Barrier System: Physical and Chemical Environment* (*EBS P&CE*) (SNL 2007 [DIRS 177412], Sections 6.10 and 6.15.1.3), initiates localized corrosion because of the formation of a chloride rich brine on the waste package surface resulting from salt separation from seepage water. The second process, discussed in detail in Section 6.3.5.2, initiates localized corrosion when the open-circuit potential, or corrosion potential ($E_{corr}$), is equal to or greater than the critical threshold potential ($E_{critical}$). This appendix will discuss the implementation of these two processes in the Localized Corrosion Initiation Uncertainty Analysis.

The Localized Corrosion Initiation Uncertainty Analysis uses only a subset of the TSPA-LA Model. Specifically, it is an Engineered Barrier System (EBS) only model in which the unsaturated zone (UZ), saturated zone (SZ), biosphere, and results portions of the TSPA-LA Model have been removed. Also, the EBS has been simplified so that only seepage, thermal hydrology, drift-wall condensation, and chemistry are calculated. The epistemic sampling is identical to the TSPA-LA Model. Also, the aleatory submodels, including the seismic model, are identical. The consequences of the seismic model, specifically drift collapse and its effect on EBS temperature and relative humidity, are included in this analysis. However, the Localized Corrosion Initiation Uncertainty Analysis does not use the representative package for each percolation subregion, but instead it calculates conditions at each of the 3,264 thermal-hydrologic (TH) nodes in the repository. This gives the spatial variability that is necessary to evaluate whether localized corrosion initiates throughout the repository.

The uncertainty analysis in this appendix calculates the chemical conditions on the waste package (WP) surface to determine if the conditions for localized corrosion initiation can exist. If the drip shield (DS) is intact, localized corrosion initiation cannot occur because seepage does not contact the WP surface. However, if the DS is breached or if the DS is assumed to not perform as intended, then the chemistry on the WP surface may allow localized corrosion to initiate. In this analysis, the DS will be assumed to fail at a specified time, and then the conditions on the WP surface will be analyzed. The results and conclusions of this analysis can then be used qualitatively in the TSPA-LA Model for any cases in which the DS does not perform as intended.

The result of this analysis is the fraction of WPs that could potentially have localized corrosion initiation from either chloride rich brine resulting from salt separation or corrosion potential conditions (or both) given that the DS fails at some specified time. As will be discussed in more detail later, the conditions for salt separation only occur in this analysis within the first 1,000 years after closure so localized corrosion initiation from the formation of a chloride rich brine does not occur after 1,000 years. The conditions for localized corrosion initiation do not exist anywhere in the repository beyond 12,000 years after closure because temperatures decrease and chemical conditions become less aggressive.

## O2. MODEL ABSTRACTION

This Localized Corrosion Initiation Uncertainty Analysis implements two processes for localized corrosion initiation. This section will discuss the abstraction and implementation for localized corrosion from chloride rich brine and the corrosion potential.

As discussed in *Engineered Barrier System: Physical and Chemical Environment* (*EBS P&CE*) (SNL 2007 [DIRS 177412], Sections 6.10 and 6.15.1.3), localized corrosion can be initiated by the formation of a chloride rich brine as a result of salt separation on the surface of the WP. This is a bounding assumption because the EBS P&CE model does not evaluate the chemical conditions after salt separation occurs on the waste package and the relative humidity rises above the threshold value. Therefore, if this condition occurs after the DS fails and while seepage is occurring, localized corrosion initiation is assumed to occur on that WP.

The second potential process for localized corrosion initiation is discussed in Section 6.3.5.2. The Localized Corrosion Initiation Submodel stipulates that localized corrosion of the WP outer surface initiates when the open-circuit potential, or corrosion potential ($E_{corr}$), is equal to or greater than the critical threshold potential ($E_{critical}$); that is, when $\Delta E = E_{critical} - E_{corr} \leq 0$. This Localized Corrosion Initiation Uncertainty Analysis uses $\Delta E \leq 0$ as the condition necessary for localized corrosion to initiate. For the TSPA-LA Model, the Localized Corrosion Initiation Abstraction uses the crevice repassivation potential ($E_{rcrev}$) as the critical potential. The crevice repassivation potential for crevice corrosion on the WP outer surface is defined in terms of WP surface temperature and chemical conditions as follows:

$$E_{critical} = E_{rcrev} = a_o + a_1 T + a_2 \ln\left[Cl^-\right] + a_3 \frac{\left[NO_3^-\right]}{\left[Cl^-\right]} + a_4 T\left[Cl^-\right] + \varepsilon_{rcrev} \quad \text{(Eq. O-1)}$$

where $a_o$, $a_1$, $a_2$, $a_3$, and $a_4$ are regression constants, $T$ is the WP outer barrier surface temperature (°C), $[NO_3^-]$ is the nitrate ion molality (moles/kg water), and $[Cl^-]$ is the chloride ion molality (moles/kg water). The error term, $\varepsilon_{rcrev}$, represents data variance not explained by the fitting procedure and is modeled by a normal distribution with a mean of 0 mV versus the saturated silver chloride electrode and a standard deviation (SD) of 45.055 mV versus saturated silver chloride electrode. The Localized Corrosion Initiation Abstraction stipulates that the calculated value of $E_{rcrev}$ be constrained to the ±2 SD prediction intervals of the unconstrained model.

The long-term steady-state corrosion potential, $E_{corr}$, for the WP outer surface is expressed as:

$$E_{corr} = c_o + c_1 T + c_2 pH + c_3 \frac{[NO_3^-]}{[Cl^-]} + c_4 T \frac{[NO_3^-]}{[Cl^-]} + c_5 pH \frac{[NO_3^-]}{[Cl^-]} + c_6 pH \ln[Cl^-] + \varepsilon_{corr} \quad \text{(Eq. O-2)}$$

where $c_o$, $c_1$, $c_2$, $c_3$, $c_4$, $c_5$, and $c_6$ are coefficients of the parameters, *pH* is the calculated Pitzer pH, and the other parameters are as previously defined. The error term, $\varepsilon_{corr}$, is a term representing data variance not explained by the fitting procedure and has a normal distribution with a mean of zero mV versus saturated silver chloride electrode, and an SD of 85.265 mV versus saturated silver chloride electrode. The units of the coefficients should be consistent with $E_{corr}$ having units of mV. The calculated value of $E_{rcrev}$ should also be constrained to the ±2 SD prediction intervals of the unconstrained model.

The thermal hydrology, seepage, and chemistry submodels used in the Localized Corrosion Initiation Uncertainty Analysis differ from those in the TSPA-LA Model in that they are applied at the individual WP level. Seepage and drift wall condensation are important because localized corrosion initiation requires seepage or condensation to bring corrosive chemicals to the WP surface. The seepage calculation in the Localized Corrosion Initiation Uncertainty Analysis is similar to the TSPA-LA Model. The main difference is that the seepage calculation is implemented directly in the Localized Corrosion Initiation GoldSim model instead of as a linked external program. Also, rather than calculating the average seepage rate and seepage fraction for the percolation subregion, the seepage calculation in this Localized Corrosion Initiation Uncertainty Analysis determines the seepage rate at each WP location. The seepage calculation includes the same seismic effects as the TSPA-LA Model. The drift-wall condensation is calculated as part of the analysis. Driftwall condensation is independent of seepage and can also bring water and chemicals to the surface of the WP. Drift wall condensation is especially important for co-disposed (CDSP) WPs during Stage 2 when all CDSP WPs are assumed to have drift-wall condensation.

The Localized Corrosion Initiation Uncertainty Analysis uses a similar chemistry submodel (Section 6.3.4.3.2) as the TSPA-LA Model, accessing the same 396 chemical composition look-up tables. However, rather than calculating the *pH* and ionic strength in the invert, the chemistry submodel calculates the *pH*, $[Cl^-]$, and $[NO_3^-]$ on the WP surface

The thermal-hydrology submodel is similar to the TSPA-LA Model (Section 6.3.2) and determines the temperature and relative humidity on the WP surface. The effects on the temperature and relative humidity from rubble are included as in the TSPA-LA Model. The main difference is in how the individual locations in the repository are modeled. The repository is divided into percolation subregions, or bins with a total of 3,264 multi-scale thermal hydrology nodes distributed over all of the bins. Bin 1 has 163 nodes, bin 2 has 817 nodes, bin 3 has 1,300 nodes, bin 4 has 820 nodes, and bin 5 has 164 nodes. These nodes do not correspond exactly to the actual WP locations. The TSPA-LA Model represents each bin with a representative WP (Section 6.3.2). Unlike in the TSPA-LA Model, this Localized Corrosion Initiation Uncertainty Analysis represents the uncertainty in the thermal hydrology submodel by modeling two CDSP WPs and six commercial spent nuclear fuel (CSNF) WPs at each of the 3,264 nodes.

In summary, the Localized Corrosion Initiation Submodel samples the epistemic parameters for the 300 realizations just like the TSPA-LA Model. However, unlike TSPA-LA this submodel is run multiple times with varied drip shield failure times specified. Then at each node within each bin for every realization, specific CSNF and CDSP WPs are chosen randomly from among the six CSNF WPs and the two CDSP WPs associated with that node, using the thermal-hydrology files. The model determines the thermal conditions and the relative humidity conditions for the WPs to determine whether or not seepage is occurring on the WP, assuming that the DS does not keep water off of the WP after it has failed. Then, at every timestep, the model determines the chemical conditions on the WP surface. Finally, the model outputs the total number of nodes in each bin that have salt separation and formation of a chloride rich brine or $\Delta E \leq 0$ (or both) any time during the simulation after the assumed DS failure time. This total number of nodes is further post-processed to determine the fraction of nodes within each bin that have conditions favorable for the initiation of localized corrosion. Ultimately, the results of this Localized Corrosion Initiation Uncertainty Analysis are used to assess the effects of localized corrosion initiation and screening arguments for FEPs.

## O3. RESULTS

The Localized Corrosion Initiation Uncertainty Analysis evaluates the potential for localized corrosion initiation at each WP location in the repository for 300 epistemic realizations and a set of specified DS failure times. If seepage occurs after the DS failure time, the DS is assumed to allow water to contact the WP surface. The main result of the Localized Corrosion Initiation Uncertainty Analysis shown on Figure O-1 is the fraction of nodes for each WP type in each bin that have salt separation and formation of a chloride rich brine or $\Delta E \leq 0$ (or both) after the specified DS failure time, indicating localized corrosion could initiate on the WP surface. The time axis on Figure O-1 is the specified DS failure time. The fraction is the cumulative fraction of WP locations that could initiate localized corrosion any time after the DS fails. Each figure shows 300 curves, one for each of 300 realizations of the epistemic parameters. Each curve displays the fraction of locations within the percolation bin at which localized corrosion could potentially occur after drip shield failure, if WPs of each particular type are present at these locations. Statistics (mean, median, and 95th and 5th percentiles) are shown for the distribution of these 300 curves. In some figures, some of the 300 curves or percentiles may not be visible because they are below the scale of the graph. In addition, one realization (Realization 142) is identified for further analysis. The curves for each realization end at the last time at which localized corrosion could occur at any location. The plots of statistics end at the time when no realization shows potential for localized corrosion at any location. All of the plots end at 12,000-years, indicating conditions for WP localized corrosion initiation do not occur in the repository beyond 12,000 years even if the DS were to fail after 12,000 years.

The fraction of locations with the potential for localized corrosion initiation is highest for DS failures within the first few hundred years because both initiation processes are affected by the hot, low relative humidity conditions. As the repository initially heats up and dries out, the relative humidity drops below the salt separation threshold at many locations. The hot and relatively dry conditions also give the lowest $\Delta E$ values. These first few hundred years are also the time when Stage 2 drift-wall condensation occurs at every CDSP WP location, which gives many seeping locations. Therefore, most CDSP locations have the potential for localized corrosion initiation if the DS fails within the first few hundred years. It should be noted that the actual localized corrosion may not occur until sometime after the DS fails. The curves show the fraction of locations that could potentially initiate at any time after the given DS failure time.

In general, bins 3, 4, and 5 have higher fractions of localized corrosion because they have more locations with seepage. Before about 1,000 years, the CDSP WPs have a higher fraction of locations with potential localized corrosion initiation. This is due to the Stage 2 drift-wall condensation at every CDSP WP location. After Stage 2 ends at around 1,000-years, drift seepage dominates over drift-wall condensation and CSNF WPs have a higher incidence of localized corrosion initiation mainly because CSNF WPs have higher temperatures than CDSP WPs. Also, shown on Figure O-1 is the dominant effect of the single epistemic realization number 142, which is the only realization to have any nodes with localized corrosion after a few thousand years.

Figure O-2 shows the average fraction of all WPs that could potentially experience localized corrosion, computed by multiplying each of the mean curves on Figure O-1 by its respective bin fraction (0.05, 0.25, 0.40, 0.25, and 0.05) and its WP type fraction (3416/11629 for CDSP WP and 8213/11629 for CSNF WP). There are more CSNF WPs and they are hotter so CSNF WPs comprise a larger fraction of the total number of WPs that could experience localized corrosion. The repository total curve shows the mean fraction of WPs with potential for localized corrosion for the entire repository. The average fraction of WPs on which localized corrosion may potentially initiate peaks at about 0.34 for the first few hundred years after closure when the repository is hot, and highly concentrated solutions exist on the WP surface. Of the 0.34 fraction, about 0.1 is from the corrosion potential only and the remainder is from the chloride rich brine resulting from salt separation (or both). After a few thousand years, the fraction of WPs with the potential for localized corrosion initiation decreases to below $10^{-3}$.

As mentioned previously, only realization 142 has conditions favorable for localized corrosion initiation persisting beyond a few thousand years. This persistence is due to the combination of uncertain parameters in this realization. The coefficients in Equation O-1 and Equation O-2 are correlated within each equation, but the uncertainty terms and the coefficients are not correlated between the two equations. This allows for sampling the combination of large negative values for $a_o$ and $\varepsilon_{rcrev}$, and large positive values for $c_o$ and $\varepsilon_{corr}$. Also, the algorithm for applying uncertainty in the chemistry model essentially fixes the $[Cl^-]/[NO_3^-]$ ratio as an epistemic parameter (Section 6.3.4.3.2). These features of this analysis imply that seven of the epistemic uncertain parameters essentially combine to give a constant value for each realization.

$$\text{Constant value} = \left( a_o + a_3 \frac{[NO_3^-]}{[Cl^-]} + \varepsilon_{rcrev} \right) - \left( c_o + c_3 \frac{[NO_3^-]}{[Cl^-]} + \varepsilon_{corr} \right) \qquad \text{(Eq. O-3)}$$

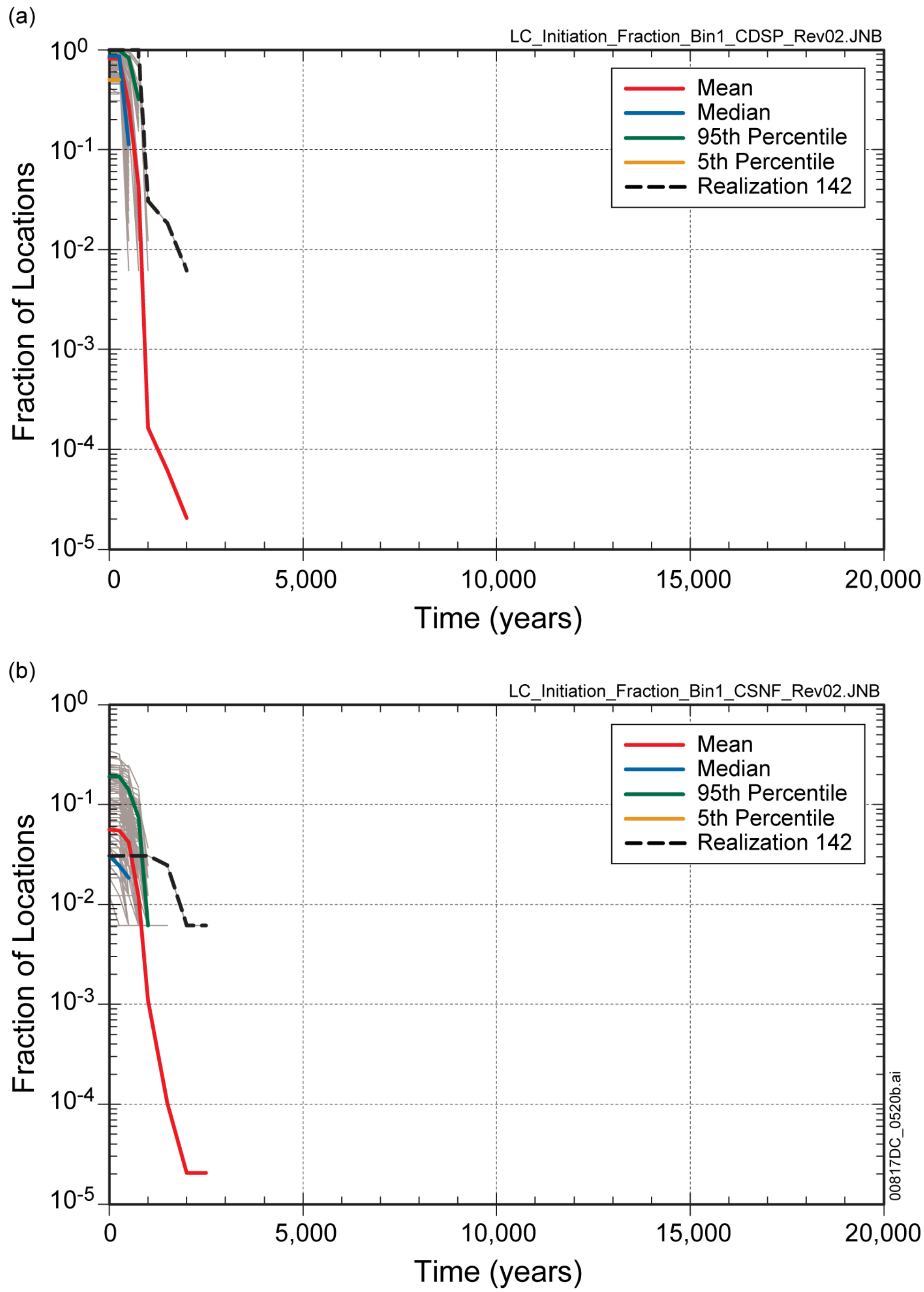
The combined value of the uncertain parameters in Equation O-3 for realization 142 is -936 mV, which is the tenth lowest of the 300 realizations. This large negative value means that the other conditions must change dramatically for the $\Delta E$ to become positive. Specifically, the temperature must cool down significantly and the $[Cl^-]$ and $[NO_3^-]$ must both become smaller. It takes a long time in realization 142 to overcome the large negative value indicated by Equation O-3.

The time histories of the chemical conditions and $\Delta E$ at every node for every realization cannot reasonably be shown. However, the time histories of the mean of all the nodes in a single bin can be shown. The values for the CSNF WPs in bin 3 are shown to represent the range of values for $\Delta E$, with Realization 142 highlighted. Figure O-3 shows the value of $\Delta E$, averaged over all of the 1,300 nodes for this bin. Notice that the mean $\Delta E$ for realization 142 is the last to go above zero. As mentioned previously, the large negative value for the parameters shown in Equation O-3 keeps $\Delta E$ low. The highest curves on Figure O-3, which have large positive values for the parameters in Equation 3, are never close to zero. Thus, localized corrosion due to $\Delta E$ never occurs in these realizations.

## O4. IMPLEMENTATION IN TSPA-LA MODEL

Localized corrosion affects only those modeling cases in which the drip shield (DS) could fail to function within 12,000 years. The events and processes that could lead to DS failure include general corrosion of the DS, igneous intrusions, and seismic events. Section 6.3.5.2.3 discusses each of the modeling cases and indicates that localized corrosion is not modeled directly in any of the cases because of the low incidence of initiation within the first 10,000 years. This Localized Corrosion Initiation Uncertainty Analysis supports the low incidence argument.

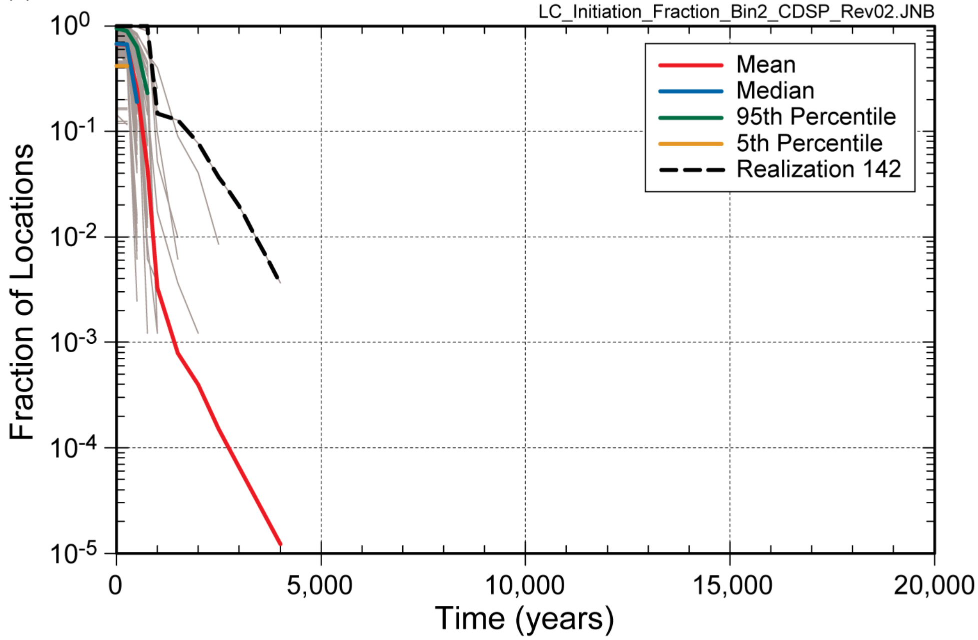
The actual results shown in Figure 8.3-7[a] and its source, LA_v5.005_SM_090000_003.gsm (DTN: MO0710ADTSPAWO.000 [DIRS 183752]) indicate that the earliest DS failure for the Seismic Ground Motion Modeling Case for 1,000,000 years is 13,762 years. This time is greater than the 12,000 years during which localized corrosion initiation can potentially occur. This conclusion supports the use of tables of zeros for the effect of localized corrosion in the TSPA-LA Model because the DS does not fail when localized corrosion could potentially occur. Section 7.3.2.6.1.3.2 and Figure 7.3.2-17 discuss why DS failure and potential localized corrosion initiation can be omitted from the 10,000-year Seismic Ground Motion Modeling Case.



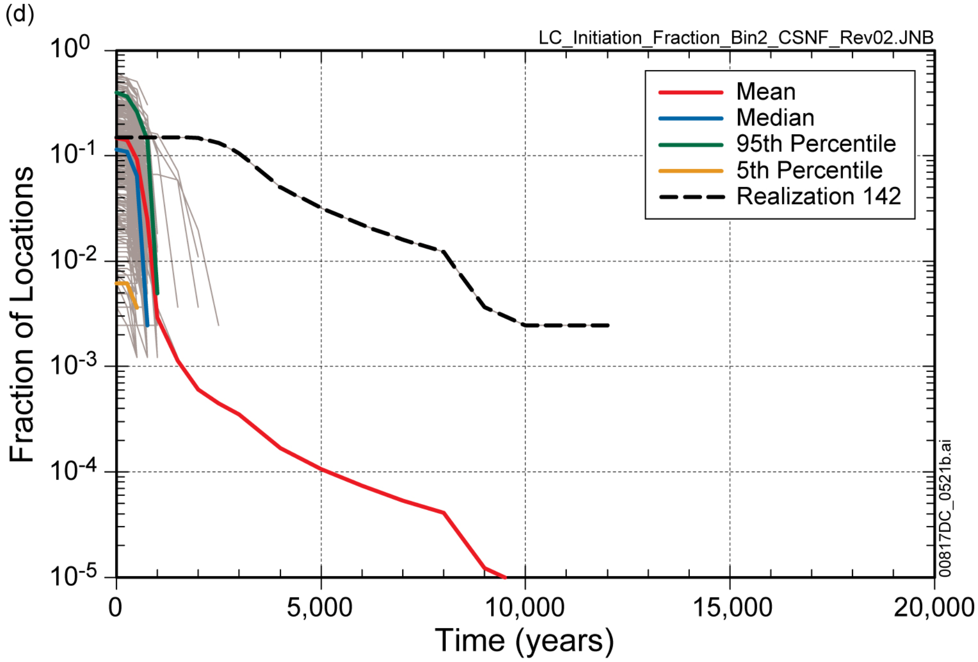

Source: Output DTN: MO0709TSPALOCO.000 [DIRS 185808].

Figure O-1. Fraction of Locations with the Potential for Localized Corrosion Initiation as a Function of Drip Shield Failure Time: (a) Bin1, CDSP; (b) Bin1, CSNF; (c) Bin2, CDSP; (d) Bin2, CSNF; (e) Bin3, CDSP; (f) Bin3, CSNF; (g) Bin4, CDSP; (h) Bin4, CSNF; (i) Bin5, CDSP; and (j) Bin5, CSNF

(c)



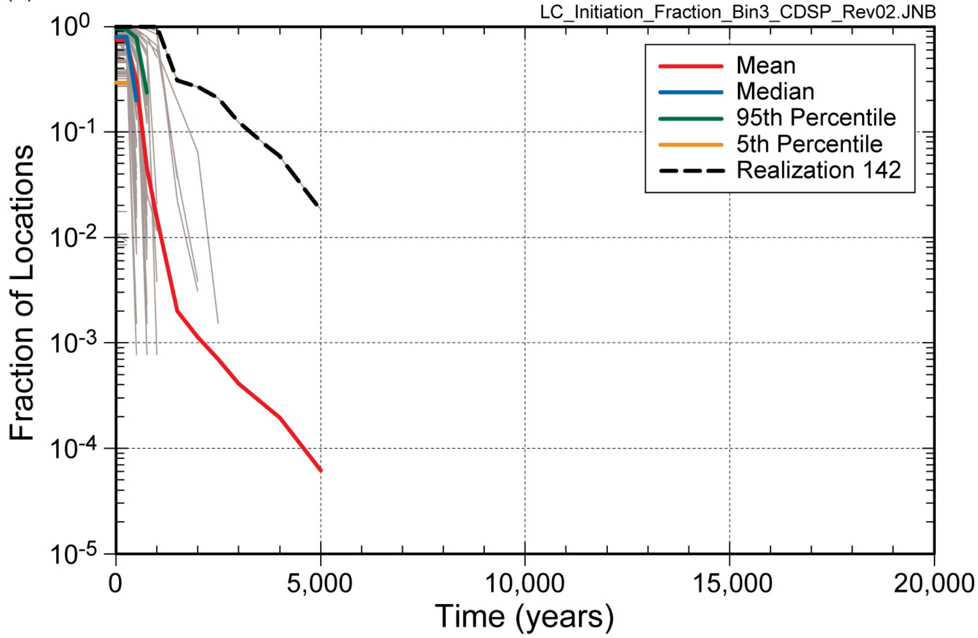

(d)



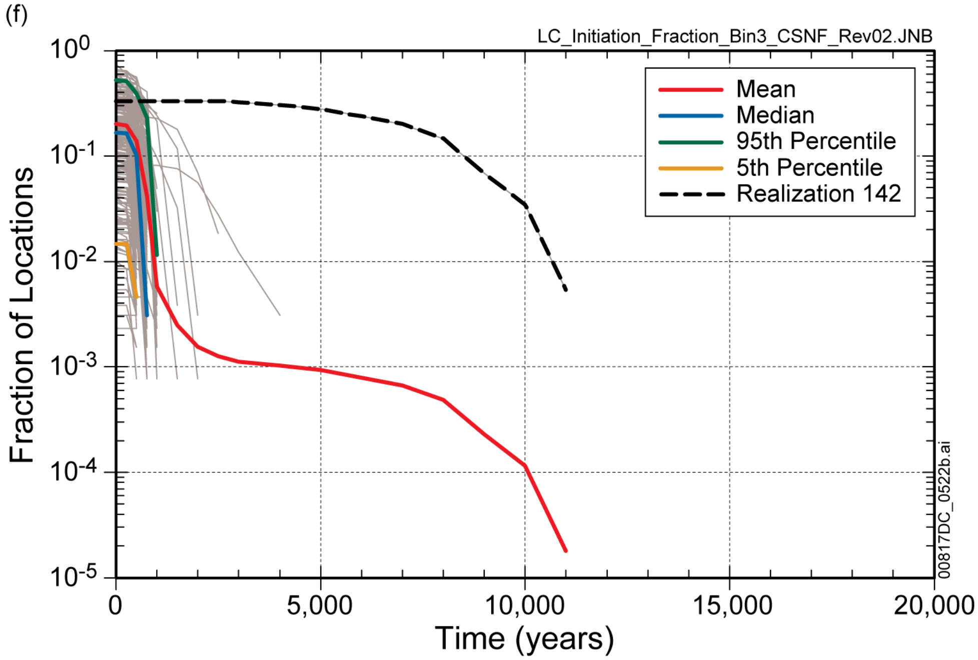

Source: Output DTN: MO0709TSPALOCO.000 [DIRS 185808].

Figure O-1. Fraction of Locations with the Potential for Localized Corrosion Initiation as a Function of Drip Shield Failure Time: (a) Bin1, CDSP; (b) Bin1, CSNF; (c) Bin2, CDSP; (d) Bin2, CSNF; (e) Bin3, CDSP; (f) Bin3, CSNF; (g) Bin4, CDSP; (h) Bin4, CSNF; (i) Bin5, CDSP; and (j) Bin5, CSNF (continued)

(e)

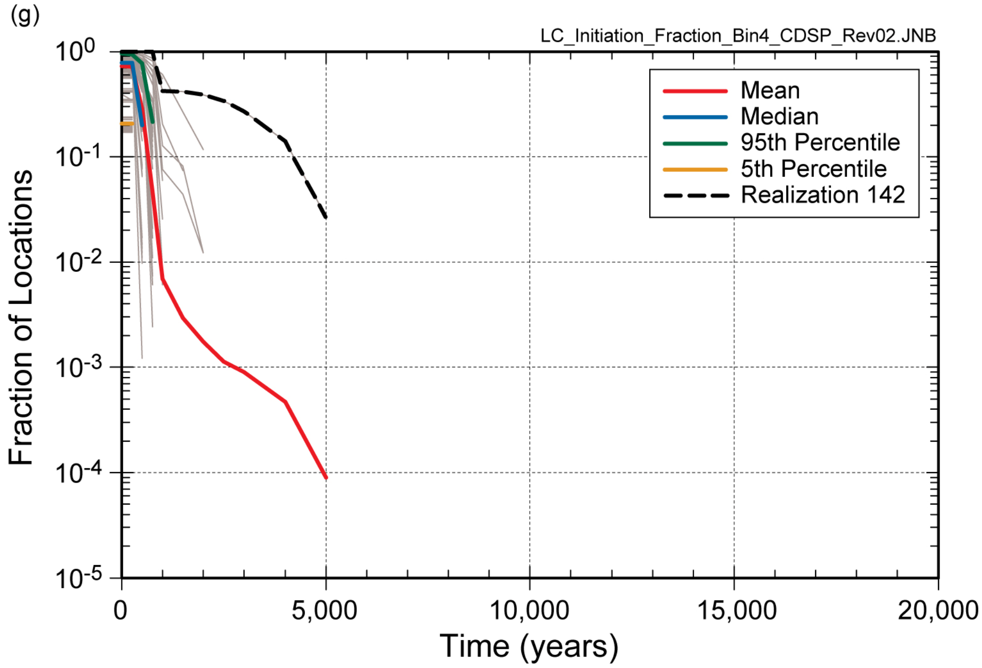


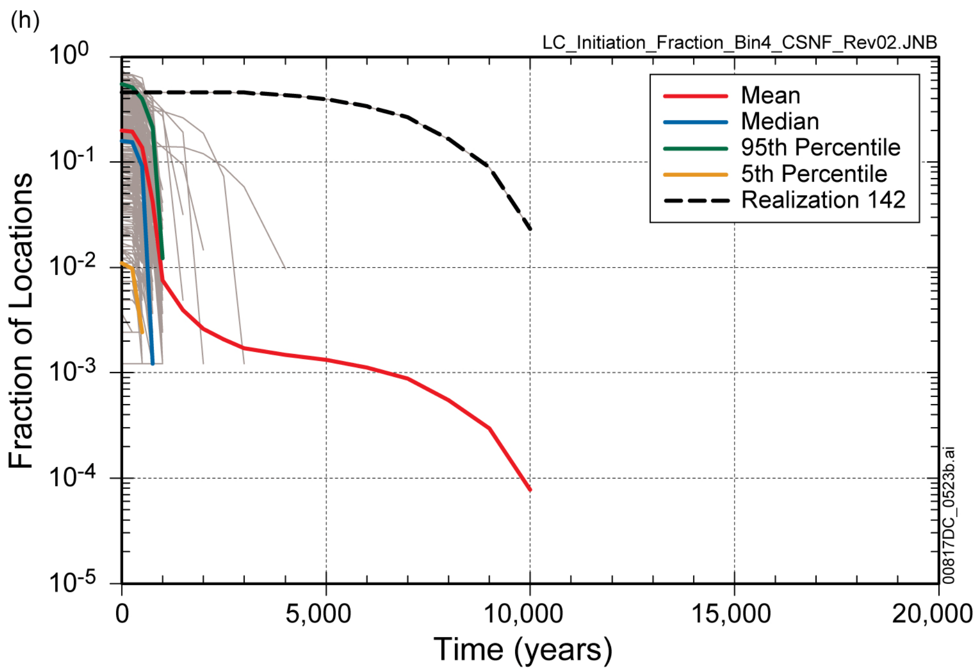

(f)




Source: Output DTN: MO0709TSPALOCO.000 [DIRS 185808].

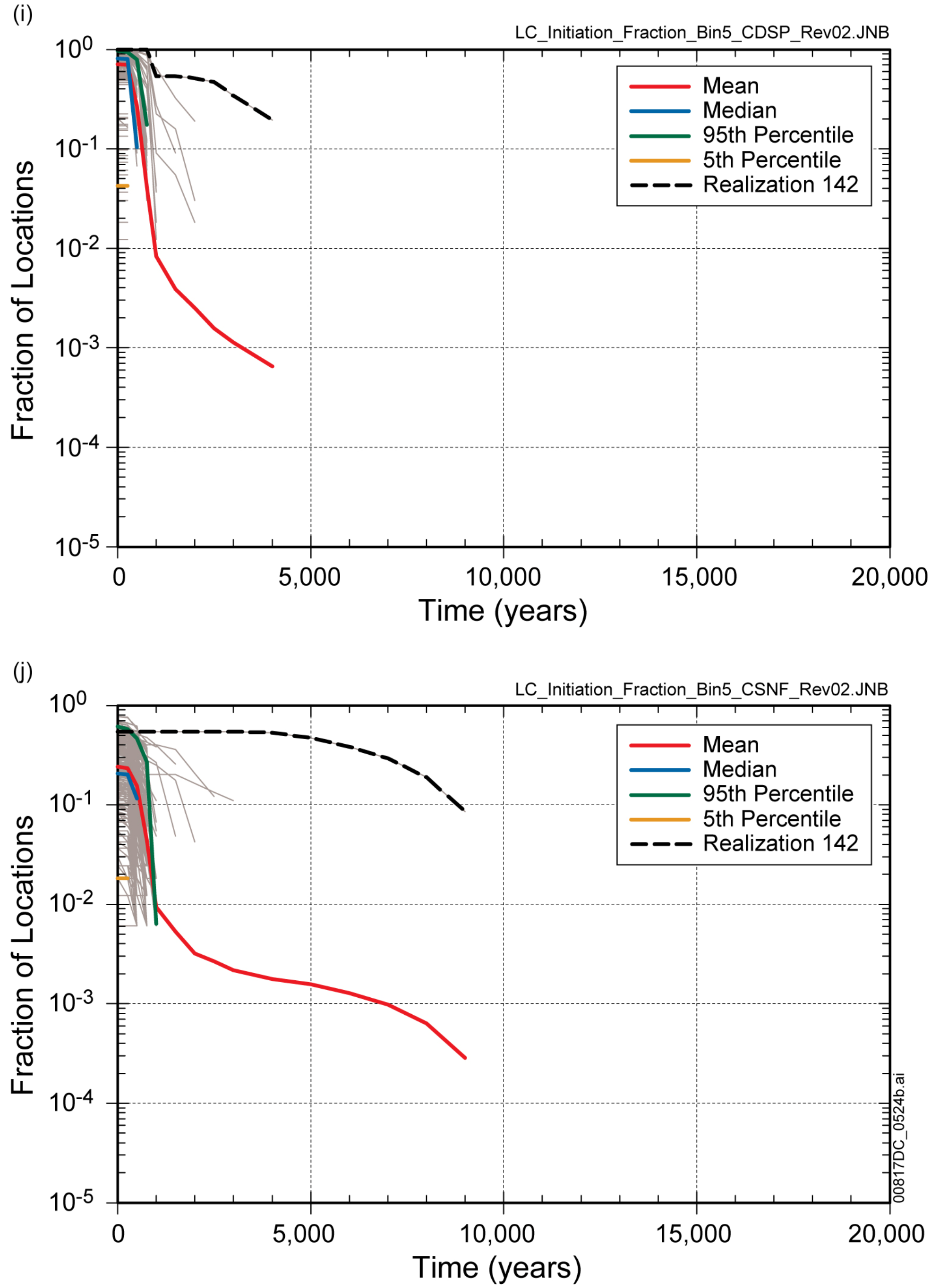
Figure O-1. Fraction of Locations with the Potential for Localized Corrosion Initiation as a Function of Drip Shield Failure Time: (a) Bin1, CDSP; (b) Bin1, CSNF; (c) Bin2, CDSP; (d) Bin2, CSNF; (e) Bin3, CDSP; (f) Bin3, CSNF; (g) Bin4, CDSP; (h) Bin4, CSNF; (i) Bin5, CDSP; and (j) Bin5, CSNF (continued)



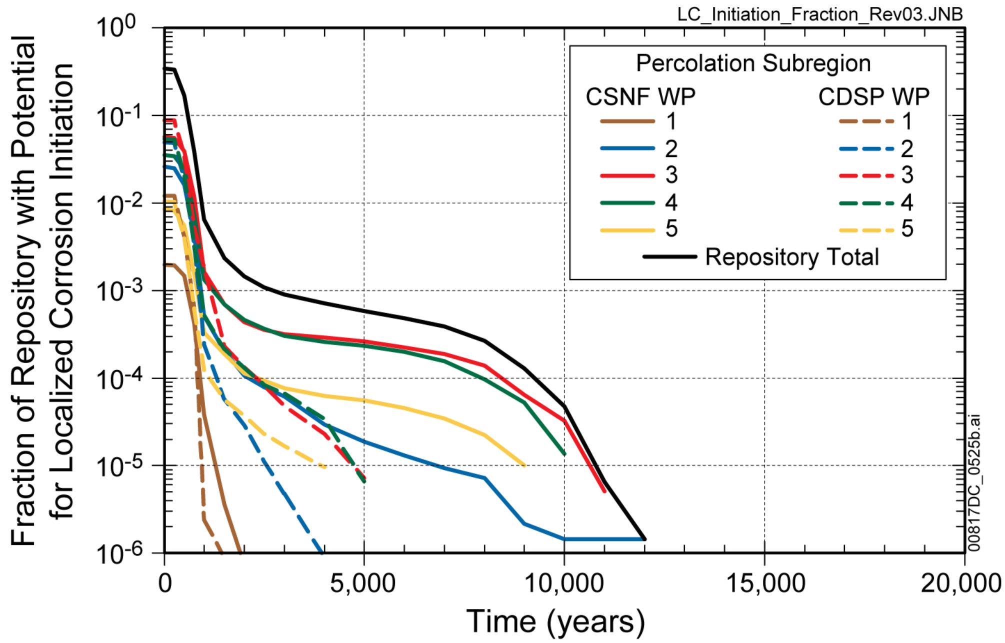

Source: Output DTN: MO0709TSPALOCO.000 [DIRS 185808].

Figure O-1. Fraction of Locations with the Potential for Localized Corrosion Initiation as a Function of Drip Shield Failure Time: (a) Bin1, CDSP; (b) Bin1, CSNF; (c) Bin2, CDSP; (d) Bin2, CSNF; (e) Bin3, CDSP; (f) Bin3, CSNF; (g) Bin4, CDSP; (h) Bin4, CSNF; (i) Bin5, CDSP; and (j) Bin5, CSNF (continued)



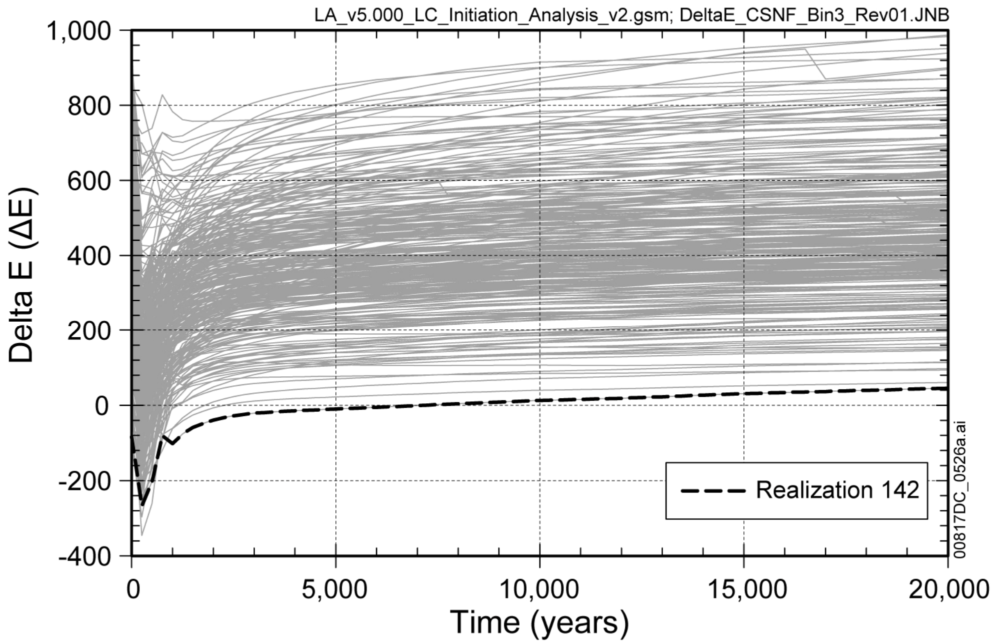

Source: Output DTN: MO0709TSPALOCO.000 [DIRS 185808].

Figure O-1. Fraction of Locations with the Potential for Localized Corrosion Initiation as a Function of Drip Shield Failure Time: (a) Bin1, CDSP; (b) Bin1, CSNF; (c) Bin2, CDSP; (d) Bin2, CSNF; (e) Bin3, CDSP; (f) Bin3, CSNF; (g) Bin4, CDSP; (h) Bin4, CSNF; (i) Bin5, CDSP; and (j) Bin5, CSNF (continued)




Source: Output DTN: MO0709TSPALOCO.000 [DIRS 185808].

Figure O-2. Fraction of Locations in Each Percolation Subregion with the Potential for Localized Corrosion Initiation after the Drip Shield Fails as a Function of Drip Shield Failure Time

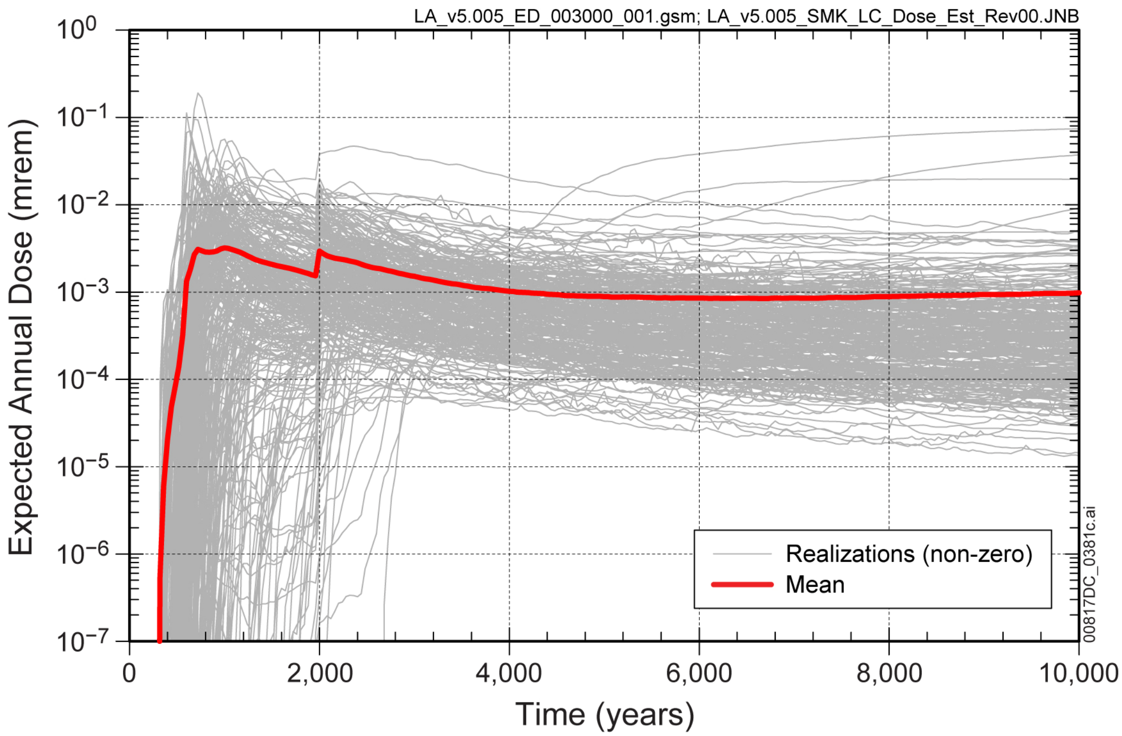



Source: Output DTN: MO0709TSPALOCO.000 [DIRS 185808].

Figure O-3. Average Delta E for Percolation Subregion 3, CSNF, for 300 Epistemic Realizations

INTENTIONALLY LEFT BLANK

## ATTACHMENT 2—REPLACE FIGURE 7.3.2-17 ON PAGE F7.3.2-17




Source: Output DTNs: MO0710ADTSPAWO.000 [DIRS 183752]; and MO0709TSPALOCO.000 [DIRS 185808].

NOTE: This figure has been updated to use dose data from v5.005 of the TSPA-LA Model.

Figure 7.3.2-17. Expected Annual Dose Over 10,000 Years from Seismic Ground Motion Events that Result in Drip Shield Plate Failure

# ATTACHMENT 3—REVISE REFERENCES TO DTN

## Rev00, Volume I, Section 6.3.5.2.3:

In the first paragraph revise the DTN reference to the following (page 6.3.5-25):

(Output DTN: MO0709TSPALOCO.000 [DIRS 185808).

In the second paragraph under TSPA-LA Modeling Cases revise the DTN reference to the following (page 6.3.5-29):

output DTN: MO0709TSPALOCO.000 [DIRS 185808).

## Rev00, Volume III, Table of Contents, Table of Figures:

In the table of contents, update the figure caption of Figures O-1 and O-2.

## Rev00, Volume III, Appendix B, Section B2.17:

In the section heading, revise the DTN reference to the following (page B-4):

OUTPUT DTN: MO0709TSPALOCO.000_R1 [DIRS 185808).

Revise the DTN description text with the following (page B-4):

**Reference Figure B-1, Block 17**—This DTN contains the GoldSim runs that are used to confirm that localized corrosion is addressed by the Compliance Model that is documented in output DTNs MO0709TSPAREGS.000 [DIRS 182976] and MO0710TSPAWO.000 [DIRS 183752].

Replace Figure B-1 in order to revise the DTN reference in Block 17 (page B-9):

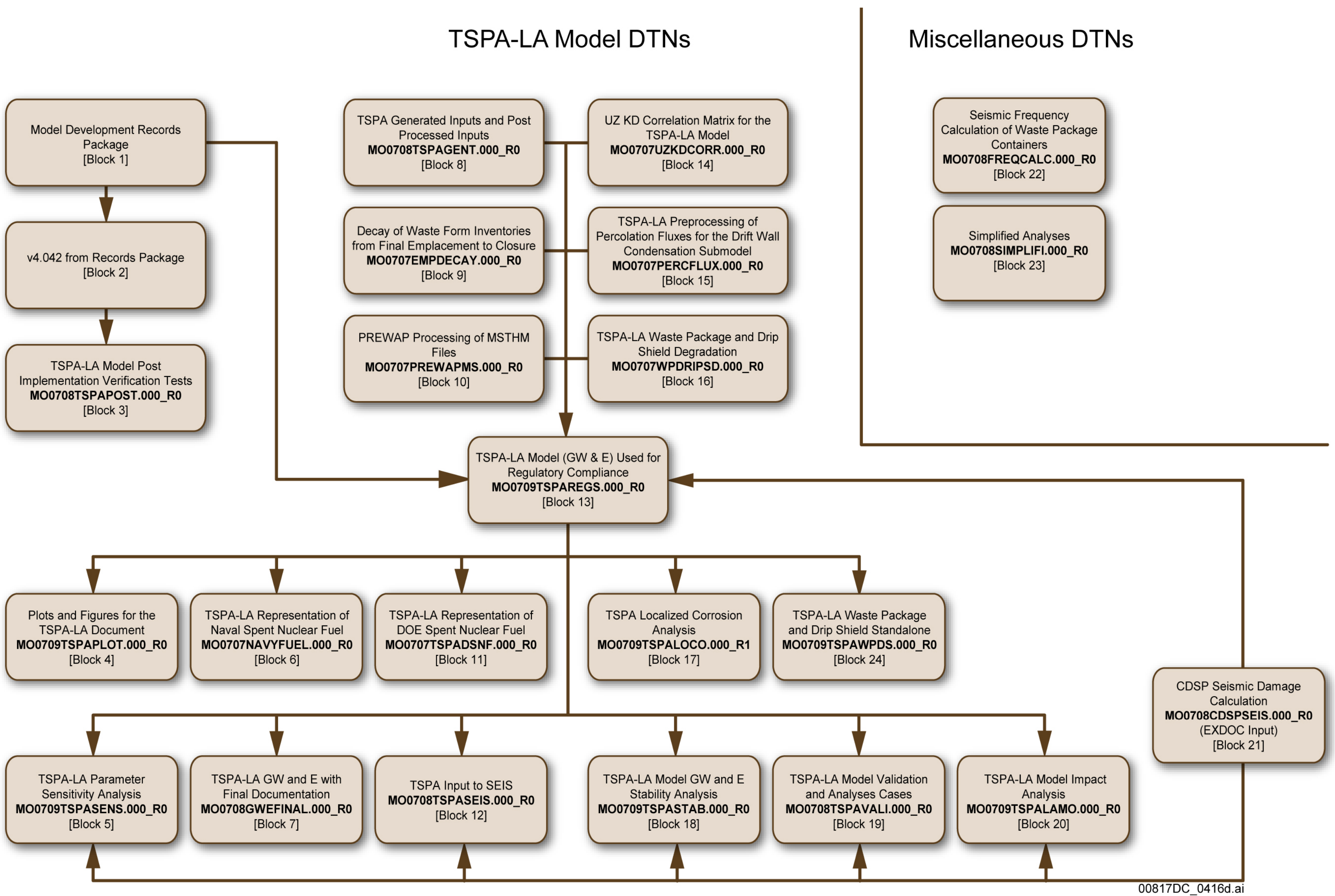



Figure B-1. Road Map of TSPA-LA Model Data Tracking Numbers

# ATTACHMENT 4—CR 12801, CR 12984, 12553, 13004 AND 13035

## Rev00, Volume I, Executive Summary:

On page ES-35, in the third sentence of Section ES8.7, **add** "(Independent Mathematical Model)" after "Electric Power Research Institute (EPRI)".

Replace the note on Figure ES-32 (page FES-32) which was added in TSPA-LA ERD 04 with the following:

Notes: Section 7.5 was omitted from the figure as it was not considered to be at the same level as the other validation activities (not required by procedure), as it was only used to confirm the surrogate waste forms appropriately represent DSNF and NSNF. Numbers located in the upper left corner of the during-development boxes, correspond to the list of Level 1 validation activities found in SCI-PRO-002.

## Rev00, Volume I, Section 1.9

Add an additional bullet to fourth paragraph of Section 1.9 as follows (page 1-49):

- Although not identified in the planning document, the TSPA-LA Model is categorized as a compliance decision model per SCI-PRO-006, Section 6.1.2.A.

## Rev00, Volume I, Section 3:

In the second paragraph of Section 3, replace the 5th sentence with the following (page 3-1):

The software codes used to support the TSPA-LA Model were either developed specifically for implementation within the model or specified to be directly used in the TSPA-LA Model by other supporting models in conjunction with their output data. The specific capabilities provided by the software are identified in the subsections below.

Insert the following to be the fourth paragraph in Section 3 (page 3-1):

Commercial, off-the-shelf software that is exempt from software qualification under IM-PRO-003 was used in the preparation of the TSPA-LA Model Report. These software products were used primarily to plot data for visualizing modeling results and perform various calculations. Standard functions within the software were used in data calculations and presentations as documented in the report or output DTNs. The formulas and algorithms, and the inputs and outputs for the calculations are included in the descriptions. No other information is required for independent reproduction or verification of the work. The software for the Microsoft Windows 2000 and 2003 operating environments used are as follows:

- Microsoft Excel 2000 and 2003
- MathCad Versions 13 and 14
- SigmaPlot Version 8

## Rev00, Volume I, Section 6.2:

In Section 6.2, replace the last sentence of the fourth paragraph with the following (page 6.2-1):

As required in 10 CFR 63.114(C) [DIRS 178394], each model component and submodel discussion in summarized in Table 6.2-1 and Sections 6.3, 6.4, 6.5, 6.6, and 6.7 includes a summary evaluation of the effects of ACMs on the performance of the geologic repository

## Rev00, Volume I, Section 6.3.5:

In Table 6.3.5-3 replace the parameter description for Z_OL_a with the following (T6.3.5-4):

Uncertainty variation in the residual stress and stress intensity factor profiles in closure weld regions (epistemic uncertainty)

## Rev00, Volume I, Section 6.7:

In the first row of Table 6.7-5, replace both references listed in the last column to the following (page T6.7-3):

(Derived in Output DTN: MO0708TSPAGENT.000 [DIRS 183000)

## Rev00, Volume II, Sections 7.1.2, 7.1.3 and 7.10:

Replace the note on Figure 7.1-2 (page F7.1-2) which was added in TSPA-LA ERD 04 with the following:

Notes: Section 7.5 was omitted from the figure as it was not considered to be at the same level as the other validation activities (not required by procedure), as it was only used to confirm the surrogate waste forms appropriately represent DSNF and NSNF. Numbers located in the upper left corner of the during-development boxes, correspond to the list of Level 1 validation activities found in SCI-PRO-002.

Replace the second to the last paragraph of Section 7.1.2.1 with the following (pages 7.1-6 and 7.1-7):

The results calculated within the TSPA-LA Model and passed from one submodel to another and/or calculated by DLLs that use abstracted models were compared to the validation results presented in the respective analysis or model reports. Small differences observed between the results from the two calculations were accounted for and typically derived from different solution techniques and/or differences in discretization, the numbers and durations of the model timesteps between the calculations, and/or differences in numerical solutions as compared to analytical solutions. A good match between the expected values and TSPA-LA Model results indicated verification of the abstracted model.

Move the last bullet of the 2nd paragraph of Section 7.1.3 (page 7.1-9) to the first paragraph of Section 7.1.2 (page 7.1-3):

4. As an additional confidence building activity, the comments and recommendations by past technical reviews, including those by the IVRT review of earlier drafts of the TSPA-LA were addressed and implemented as appropriate [During Development] (Section 7.9; Figure 7.1-2).

Replace the third bullet on page 7.10-7 of Section 7.10 with the following:

- Output of DLLs that calculate results within the TSPA-LA Model was found to be acceptable.

## Rev00, Volume II, Sections 7.4:

In Table 7.4-4 for the Nominal Modeling Case, replace the description (3rd column) of the WDZOLID parameter with the following:

Scale factor used to incorporate uncertainty into the stress intensity factor for the closure-lid weld

## Rev00, Volume II, Sections 7.7.2 and 7.7.4:

In the last sentence of the second paragraph of Section 7.7.2 (page 7.7.2-1) change Section 6.2.1.M to the following:

Section 6.2.1.N

In the last sentence of the third paragraph of Section 7.7.4 (page 7.7.4-1) add the following to the end of the sentence after PMA:

that produces unqualified data.

## Rev00, Volume II, Section 7.8.2 and ERD 02:

Replace the 4th bullet in the 3rd paragraph of Section 7.8.2 with the following (supersedes change in TSPA-LA ERD 02):

- Geochemistry—The uraninite ore at the Nopal I mine has been altered to secondary uranium minerals, such as oxyhydroxides, schoepite, and uranyl silicates, such as boltwoodite and uranophane. The SNF at Yucca Mountain will be primarily uranium oxide, which is essentially uraninite, and the fuel is also expected to be altered to schoepite and uranyl silicates (BSC 2004 [DIRS 169218], Sections 4.2).

Replace the 5th bullet in the 1st paragraph of Section 7.8.2.3 with the following (supersedes change in TSPA-LA ERD 02):

- The regional, surface-water-discharge location for the Nopal I ore deposit is approximately 10 km from the deposit, versus an approximate 60 km to 80 km travel distance to the nearest surface-water discharge for the Yucca Mountain flow system at the Franklin Lake Playa (DOE 2002 [DIRS 155970], Section 5.3, and Appendix I, Sections I.1 and I.4.5)

## Rev00 AD01, Volume II, Sections 7.7.2.2[a], 7.7.2.3[a], 7.7.4.1[a], 7.7.4.2[a], and 7.10.7[a]:

Replace the last paragraph in Section 7.7.2.2[a] with the following (page 7-85[a]):

This comparison is identical to the results documented in Section 7.7.2.2 of the parent document and shows that the general trend in the annual dose between the two models is very similar and the maximum mean annual dose calculated using the Simplified TSPA Analysis is within approximately half of an order of magnitude as that calculated by the TSPA-LA Model.

Replace the second paragraph (last) of Section 7.7.2.3[a] with the following (page 7-85[a]):

The mean annual dose results for the Simplified TSPA Analysis are similar to those from the TSPA-LA Model. Figure 7.7.2-9[a] shows a comparison of the Simplified TSPA Analysis results and the TSPA-LA Model results for the Seismic GM Modeling Case at 200,000 years; 400,000 years; 600,000 years; 800,000 years; and 1,000,000 years following repository closure. There is generally a positive trend in the annual dose for the TSPA-LA Model results whereas the Simplified TSPA Analysis is variable with time. The two models show a similar maximum mean annual dose; the Simplified TSPA Analysis is within approximately half an order of magnitude lower as that calculated by the TSPA-LA Model. However, the earlier maximum mean annual dose in the Simplified TSPA Analysis reflects the differences in the sampling technique used in the Simplified TSPA Analysis and the lower rate of general corrosion results in 40 percent of the realizations having no WP failures over the 1,000,000-year simulation period, as documented in Section 7.7.2.3 of the parent document. Another notable difference occurs at 200,000 years. Figure 7.7.2-9[a] shows a significant reduction between the TSPA-LA Model v5.005 results and the Simplified TSPA Analysis. This is a result of differences between version 5.000 and 5.005 of the TSPA-LA Model as discussed in Section 7.3.1.5.6[a] of this addendum. Overall, for all other time periods the comparison presented in this addendum is nearly identical to the comparison of results documented in Section 7.7.2.3 of the parent document.

Replace the second bullet of Section 7.7.4.1[a] on page 7-88[a] with the following:

- The maximum PMA total mean annual doses calculated over 10,000 years are lower by over an order of magnitude over the largest total mean annual dose from the TSPA-LA Model.

Replace the second bullet of Section 7.7.4.1[a] on page 7-89[a] with the following:

- The maximum PMA total mean annual doses calculated over 1,000,000 years are lower by a factor of two over the largest total mean annual dose from the TSPA-LA Model as documented in the parent document.

Replace the bullets numbered 2 and 3 of Section 7.7.4.2[a] with the following (page 7-90[a]):

2. Relative to the TSPA-LA Model results, the maximum PMA total mean annual dose is lower by over an order of magnitude for the 10,000-year time period and lower by a factor of two for the time period after 10,000 years.
3. The evaluated conservatisms did not introduce any inappropriate risk dilution in the TSPA Model results presented in support of the LA. This was demonstrated by the absence of higher maximum mean annual doses relative to the TSPA-LA Model for the PMA results for both the probabilistic projections of the total dose histories and the projected total mean dose.

Replace the paragraph labeled Performance Margin Analysis in Section 7.10.7[a] with the following (page 7-94[a] and 7-95[a]):

A comparison of TSPA-LA Model v5.005 results with the PMA was conducted to confirm the quantitative evaluation of the differences in repository performance due to significant explicit and implicit conservatisms embedded in the TSPA-LA Model submodels documented in Section 7.7.4 and Appendix C of the parent document. The conservatisms were evaluated to (1) confirm that they are conservative with respect to the mean annual dose of the TSPA-LA Model; (2) quantify the extent to which they, individually and collectively, overestimate the projected annual dose; and (3) assess that the evaluated conservatisms did not introduce any inappropriate risk dilution in the TSPA-LA Model results presented in support of the LA. The details of approach and results of the PMA are presented in Section 7.7.4 of the parent document with additional supporting material in Appendix C of the parent document. Summarizing here, the results show that the margin evaluated in the PMA as documented in the parent document are indeed conservative with respect to the total system performance measures (e.g., maximum mean annual dose) as the largest doses calculated in the PMA for 10,000 years and 1,000,000 years are lower than the doses used in the compliance demonstration presented in Section 8[a] of this addendum. The additional analyses confirm that the largest calculated PMA mean annual doses are lower by over an order of magnitude and a factor of two over the largest mean annual dose relative to the TSPA-LA Model (Section 8[a]) for the time periods of 10,000 years and 1,000,000 years, respectively. Further, this PMA confirms that the significant conservatisms did not introduce risk dilution in the TSPA-LA Model results, as demonstrated by the absence of higher maximum mean annual dose values in the comparison of the projected total mean annual dose for the PMA relative to TSPA-LA Model v5.005. The differences in the relative contributions to the total mean annual dose from each of the scenario modeling cases between the PMA and the TSPA-LA Model indicate that the reduction in the selected conservative assumptions embedded in these TSPA-LA Model components provides a performance margin in the projected annual dose predictions presented in Section 8 of the parent document and Section 8[a] of this addendum.

## Rev00 Volume III Appendix P, Volume II Addendum, Volume III Appendix P Addendum:

Table P-6 on page P-35 of Rev. 00, Section 7.2.6[a] on page 7.18[a] and Table P-6[a] on page P-18[a] of Addendum 01 was updated in TSPA-LA ERD 02 due to an error in the discussion of the uncertainty of dissolved concentrations related to temperature conditions. There is one minor parenthetical that should be updated in the ERD02, along with the sections mentioned above.

In the seventh sentence of the updated paragraph, the parenthetical should be updated in all sections from (i.e., 2) to:

(i.e., 2 standard deviations)

## Rev00 Volume III, Appendix B:

In the Section heading B2.23 change Output DTN to the following:

Corroborative DTN:

## Rev00 Volume III, Appendix C:

In the last sentence of the third paragraph of Section C.1 (page C-3) change Section 6.2.1.O to the following:

Section 6.2.1.N

In the first sentence of the first paragraph of Section C.3.4 (page C-8) change Section 6.2.1.O to the following:

Section 6.2.1.N

In the last paragraph of Section C.7 (page C-95) add the following to the end of the paragraph:

It is important to note that PMA is a corroborative analysis which utilizes unqualified software, per Section 6.2.1.N, SCI-PRO-006 and produces unqualified output.

## Rev00 Volume III, Appendix I:

In Table I-2, replace the following FEP names in the third column of the table:

Page I-50: FEP 2.1.03.02.0A should read "Stress corrosion cracking of waste packages"

Page I-54: FEP 2.1.03.11.0A should read "Physical form of waste package and drip shield"

Page I-59: FEP 2.1.02.25.0B should read "Naval SNF cladding"

Page I-66: FEP 2.1.08.07.0A should read "Unsaturated flow in the EBS"

Page I-77: FEP 2.2.08.10.0B should read "Colloidal transport in the UZ"

Page I-84: FEP 2.2.08.10.0A should read "Colloidal transport in the SZ"

## Rev00 Volume III, Appendix K:

In the fifth sentence of the fourth full paragraph of Section K4.2 on page K-12 replace the text in parenthesis associated with parameter WDZOLID with the following:

(scale factor used to incorporate uncertainty into the stress intensity factor for the closure-lid weld)

Table K3-1 has a typographical error in the distribution mean listed for the regression parameter UZTORRG2. In Table K3-1, replace the Mean: -3.62 with the following (page TK-25):

*Mean*: -1.57.

In Table K3-1, for the parameter WDZOLID, replace the description (Deviation from ….) with the following (page TK-26):

Scale factor used to incorporate uncertainty into the stress intensity factor for the closure-lid weld (dimensionless)

Table K3-1 has a typographical error in the range listed for parameter Conc_Col. In Table K3-1, replace the *Range*: −9 to −3.6 with the following (page TK-20):

*Range*: −9 to −3.7

Table K3-2 has a typographical error in the range listed for parameter Conc_Col. In Table K3-2, replace the *Range*: −9 to −3.6 with the following (page TK-28):

*Range*: −9 to −3.7

In Table K3-2, for the parameter z_OL_a, replace the description (Deviation from ….) with the following (page TK-52):

Scale factor used to incorporate uncertainty into the stress intensity factor for the closure-lid weld (dimensionless)

Table K3-3 has a typographical error in the range listed for parameter Conc_Col. In Table K3-3, replace the *Range*: −9 to −3.6 with the following (page TK-57):

*Range*: −9 to −3.7

In Table K3-3, for the parameter z_OL_a, replace the description (Deviation from ….) with the following (page TK-113):

Scale factor used to incorporate uncertainty into the stress intensity factor for the closure-lid weld (dimensionless)

In Table K9-1 for the Nominal Scenario Class, replace the description ($3^{rd}$ column) of the WDZOLID parameter with the following (page TK-157):

Scale factor used to incorporate uncertainty into the stress intensity factor for the closure-lid weld

In Figure K6.3.2-4 (b, d, and f), the sigmaplot file name (.jnb) and the mView file name (.mview) located on the top of these plots indicates ESNP237C, when they should read ESPU239C. Replace the header text in these 3 plots with the following (page FK-147):

Replace II_1M_00_T250_ESNP237C_PRCC_HT.JNB with II_1M_00_T250_ESPU239_PRCC_HT.JNB

Replace II_1M_00_T250_ESNP237C.mView with II_1M_00_T250_ESPU239.mView

In the legend of Figure K4.3-1 parts (e) and (f), the label for the purple line should be ALPHAL, and the label for the olive line should be SEEPPRM. Replace the labels with the following (page FK-10):

In the legend, replace the label for the purple line with ALPHAL.

In the legend, replace the label for the olive line with SEEPPRM.

## Rev00 Volume III, Appendix L:

In the last sentence of the first paragraph of Section L1. (page L-3) change Section 6.2.1.M to the following:

Section 6.2.1.N

In the first paragraph of Section L3.2 (page L-56) add the following to the end of the paragraph:

The Simplified TSPA is a corroborative analysis which utilizes unqualified software, per Section 6.2.1.N, SCI-PRO-006 and produces unqualified output.

## Rev00 AD01, Volume III, Section 8.2.1[a]

In the second to the last sentence of the last paragraph of Section 8.2.1[a] on page 8-28[a] replace the sentence associated with parameter WDZOLID (Several other uncertain inputs…..) with the following:

Several other uncertain inputs, such as the scale factor used to incorporate uncertainty into the stress intensity factor for the closure-lid weld, *WDZOLID*, are identified as having additional, lesser effects.

## Rev00 AD01, Volume III, Section K8.1[A]

In the process of developing this ERD, a minor editorial mistake was found in a figure call out. In the last paragraph of Section K8.1[a] on page K-29[a], the figure call out for Figure K8.1-2a, b, c[a] should be:

Figure K8.1-2b,c,d[a]

## Rev00 AD01, Volume III, Appendix K[a]:

In Table K9-1[a] for the Nominal Scenario Class, replace the description (3rd column) of the WDZOLID parameter with the following (page K-35[a]):

Scale factor used to incorporate uncertainty into the stress intensity factor for the closure-lid weld