YMP	**Scientific Analysis/Calculation Error Resolution Document** *Complete only applicable items.*	QA: QA Page 1 of ~~28~~ 29 mah 2/5/09

1. Document Number: CAL-DN0-NU-000002	2. Revision/Addendum: 00C/AD01	3. ERD: 02
4. Title: Waste Package Flooding Probability Evaluation	5. No. of Pages Attached: ~~27~~ 29 mah 2/5/09	

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

Introduction:

This document is being written as an action to resolve the following CRs:

CR-12543: Salt separation error in localized corrosion initiation analysis

CR-12589: Error in probability of criticality calculations

CR-12857: Incorrect parameter in probability of criticality calculation

Background Information Summary:

CR-12543 identified an error affecting the localized corrosion initiation analysis that manifests itself in DTN: MO0709TSPALOCO.000 [DIRS 182944]. This DTN is used as an input to CAL-DN0-NU-000002 REV 00C. During an assessment of the extent of condition and the potential impacts to downstream products affected by CR-12543, an error was identified that resulted in initiation of CR-12589 and CR-12857. CR-12589 identified that in the 3D and 4D cases, the mathematical sequence was reversed. In these calculations, uncertainty in the time of seismic events was integrated first, followed by integration over the spatial variability in localized corrosion. These steps should have been performed in the reverse order (integration over spatial variability followed by integration over the time of seismic events), because seismic events are modeled as affecting the entire repository. This error is conservative and is expected to overestimate the probability by a factor of about 5. CR-12857 identifies an error in Equation B-2.3-8 which incorrectly provides the frequency of seismic events that cause rupture to drip shields, but should actually provide the frequency of seismic events with potential to cause rupture to drip shields. The conditional probability that a seismic event causes rupture is included in the calculation of the density function for the fraction of drip shields ruptured in Equation B.2.3-5.

AMR Changes:

Direct inputs replaced in Table 4-1 and Table 4-1[a] for DIRS 182994. During the update of Table 4-1 it was noticed that data in DIRS 183148 and DIRS 183156 have been revised and have more current DIRS identifiers. The actual data used as input has not changed, but these DIRS identifiers are also being updated in this ERD. In addition, parts of Appendix B and the addenda require modification to address CR-12589. Please see attached for changes listed by change number **(C#)**. In addition, as a result of a change in ANL-EBS-MD-000076 REV 00 ERD 01, the drip shield emplacement error probability has been updated for the 2D damage sequence.

Impact Evaluations/Results:

The following documents were evaluated for impact: LA-SAR, ANL-DS0-NU-000001 Rev. 00 ACN01 and ANL-WIS-MD-000027 REV 00 ACN01.

The SAR, ANL-DS0-NU-000001 Rev 00 and ANL-WIS-MD-000027 Rev 00 will be impacted (See Attachment II for impacts).

These changes in the ERD do not impact the final quoted value for the probability of criticality for the DOE SNF and CSNF waste forms (3.7×10^{-5}) identified in ANL-DS0-NU-000001 REV 00 because the probabilities that are affected are too small (several orders of magnitude) to affect the final sum.

	Printed Name	Signature	Date
7. Checker	Charles S. Henkel	Charles S. Henkel	04 Feb 2009
8. QCS/QA Reviewer	Brian T. Mitcheltree	B. Mitcheltree	2/4/09
9. Originator	John M. Scaglione	John Scaglione	2/4/2009
10. Responsible Manager	Paul R. Dixon	Paul Dixon	2-5-09

ATTACHMENT I – AMR CHANGES INCLUDING AD01

Where large portions of the report are being modified the changed portions are denoted by a black vertical line in the margin).

(C1) Throughout report and addendum, all DIRS 182994 should be replaced with DIRS 185808; all DIRS 183148 should be replaced with DIRS 185275; and all DIRS 183156 should be replaced with DIRS 185278.

(C2) Replace all occurrences of DTN: MO0712PANLNNWP.000 with DTN: MO0810PANLNNWP.001

(C3) Replace all occurrences of DTN: MO0712PBANLNWP.000 with DTN: MO0810PBANLNWP.001

(C4) Update the following sources listed in Sections 8.1 and 8.3 as follows:

Old	178765	SNL 2007. *Analysis of Mechanisms for Early Waste Package/Drip Shield Failure*. ANL-EBS-MD-000076 REV 00. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20070629.0002.
New	178765	SNL 2007. *Analysis of Mechanisms for Early Waste Package/Drip Shield Failure.* ANL-EBS-MD-000076 REV 00. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20070629.0002; DOC.20071003.0015; LLR.20080311.0094; DOC.20080918.0002; DOC.20090204.0003.
Old	183148	MO0703PASDSTAT.001. Statistical Analyses for Seismic Damage Abstractions. Submittal date: 09/21/2007.
New	185275	MO0703PASDSTAT.001. Statistical Analyses for Seismic Damage Abstractions. Submittal date: 03/17/2008.
Old	183156	MO0703PASEISDA.002. Seismic Damage Abstractions for TSPA Compliance Case. Submittal date: 09/21/2007.
New	185278	MO0703PASEISDA.002. Seismic Damage Abstractions for TSPA Compliance Case. Submittal date: 03/17/2008.
Old	182994	MO0709TSPALOCO.000. TSPA Localized Corrosion Analysis. Submittal date: 09/13/2007.
New	185808	MO0709TSPALOCO.000. TSPA Localized Corrosion Analysis. Submittal date: 10/20/2008.

(C5) Table 4-1 should be updated as follows:

Table 4-1. Direct Inputs Used in Calculation

Input Description	Data Tracking Number/Source	Value
Intersections of known faults with emplacement drifts	DTN: MO0705FAULTABS.000 [DIRS 183150], file *Fault Displacement Abstraction for Criticality.xls,* worksheet "Tables by WP Type"	Drill Hole, Pagany Wash, and Sevier Wash = 26 West Ghost Dance = 11 Sundance = 6 Total = 43

Input Description	Data Tracking Number/Source	Value
Annual exceedance probability range for TAD canister size packages	DTN: MO0705FAULTABS.000 [DIRS 183150], file *Fault Displacement Abstraction for Criticality.xls,* worksheet "Tables by WP Type"	10^{-8}/yr to 8.2 × 10^{-8}/yr
Waste packages in the repository inventory	DTN: MO0702PASTREAM.001 [DIRS 179925], worksheet "Unit Cell" in file *DTN-Inventory-Rev00.xls,* cells B15 to L15	Navy = 400 (sum of long and short) CSNF = 7,483 (sum of 21P-TAD and 44B-TAD and 12P-Long-TAD) Total = 11,162
TSPA seepage rate, seepage fraction, for five bin locations	DTN: MO0705TSPASEEP.000 [DIRS 183008], v5.005_GS_9.60.300_Seismic-FD_1Myr.zip, folder: GoldSim_Exported_Results	Seepage rates time history are in v5.005_Seismic-FD_1Myr_*CSNF_SeepRate_Bin1.txt,* v5.005_Seismic-FD_1Myr_*CSNF_SeepRate_Bin2.txt,* v5.005_Seismic-FD_1Myr_*CSNF_SeepRate_Bin3.txt,* v5.005_Seismic-FD_1Myr_*CSNF_SeepRate_Bin4.txt,* v5.005_Seismic-FD_1Myr_*CSNF_SeepRate_Bin5.txt*. Seepage fractions at five bin locations are in *v5.005_Seismic-FD_1Myr_SeepFrac.txt*
TSPA localized corrosion results	DTN: MO0709TSPALOCO.000 [DIRS 185808], folder *TSPA-LA\CM\DTN_Prep\DTNs\ MO0709TSPALOCO.000_rev001\ Files_to_TDMS\ Additional Information\ LC_for_Criticality*	Lith_Fraction_CDSP_Bin1 Lith_Fraction_CDSP_Bin2 Lith_Fraction_CDSP_Bin3 Lith_Fraction_CDSP_Bin4 Lith_Fraction_CDSP_Bin5 NonLith_Fraction_CDSP_Bin1 NonLith_Fraction_CDSP_Bin2 NonLith_Fraction_CDSP_Bin3 NonLith_Fraction_CDSP_Bin4 NonLith_Fraction_CDSP_Bin5 Lith_Fraction_CSNF_Bin1 Lith_Fraction_CSNF_Bin2 Lith_Fraction_ CSNF _Bin3 Lith_Fraction_ CSNF _Bin4 Lith_Fraction_ CSNF _Bin5 NonLith_Fraction_ CSNF _Bin1 NonLith_Fraction_ CSNF _Bin2 NonLith_Fraction_ CSNF _Bin3 NonLith_Fraction_ CSNF _Bin4 NonLith_Fraction_ CSNF _Bin5
Percolation bin fraction within each geologic unit	DTN: MO0709TSPALOCO.000 [DIRS 185808], folder *TSPA-LA\CM\DTN_Prep\DTNs\ MO0709TSPALOCO.000_rev001\ Files_to_TDMS\Additional Information Rev00\ Additional_Information\LC_Initiation_ Uncertainty_Analysis_v2_NonLith\LC _Plots_NonLith*, file *NonLith_Frac_CSNF_out.xls*	**Bin Lith Fraction Nonlith Fraction** 1 0.680982 0.319018 2 0.762546 0.237454 3 0.826923 0.173077 4 0.958537 0.041463 5 0.890244 0.109756

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Input Description	Data Tracking Number/Source	Value
Bin fractions of the waste package parsing of percolation flux	DTN: MO0505SPAROCKM.000 [DIRS 173893]; SNL 2008 [DIRS 184433], Appendix VIII	0.05, 0.25, 0.4, 0.25, 0.05
Waste package outer corrosion barrier length	SNL 2007 [DIRS 179394], Table 4-3	5,691.38 mm (5.6914 m)
Waste package outer corrosion barrier diameter	SNL 2007 [DIRS 179394], Table 4-3	1,881.60 mm (1.8816 m)
Drip shield emplacement error	SNL 2007 [DIRS 178765], Table 6-8	2.19×10^{-9} per drip shield
DOE waste forms using absorber plates for criticality control	DOE 2004 [DIRS 170071], Section 2.1.11	See Section 4.2
Hazard curve relationship to exceedance frequency and peak ground velocity	DTN: MO0703PASDSTAT.001 [DIRS 185275], file *Lith_Rubble_Abstraction.xls*, worksheet *Data for Bounded Hazard*	See Output DTN: MO0810PBANLNWP.001, file *Lith Probability of DS Failure.xmcd* in folder 4D
Regression constants and standard deviation relationships	SNL 2007 [DIRS 176828], Figure 6-56	μ_v (PGV m/s) $m^3/m = 20.307PGV^2 - 18.023PGV + 4.0102$ σ_v (PGV m/s) $m^3/m = -3.5613PGV^2 + 18.018PGV - 6.6202$
Probability that a seismic event causes drip shield damage in nonlithophysal unit and conditional probabilities for different drip shield damage states, and probabilities of drip shield plate failure	DTN: MO0703PASEISDA.002 [DIRS 185278], Tables 1-2, 1-10, and 1-11	See Mathcad files in Output DTN: MO0810PANLNNWP.001 folder 3D/CSNF and MO0810PBANLNWP.001 folder 3D
DOE HLW waste forms using absorber plates for criticality control	DOE 2004 DIRS 170071], Section 2.1.11	Mixed oxide (MOX) represented by Fast Flux Test Facility (FFTF) fuel, $UZrH_x$ represented by Training, Research, Isotopes, General Atomic (TRIGA) fuel, U/Th Oxide represented by Shippingport Light Water Breeder Reactor fuel, aluminum-based DOE-owned SNF represented by Advanced Test Reactor (ATR) fuel, and U-Zr/U-Mo represented by Enrico Fermi fuel
Number of codisposal waste packages	Wheatley (2007 [DIRS 181533], p. 2)	MOX canister count = 143 ATR canister count = 991 TRIGA canister count = 89
PGV frequency for probability of nonzero rockfall	DTN: MO0703PASEISDA.002, [DIRS 185278], Equation 1-1,	$P_{rockfall} = MIN(1.0, MAX(0.0,(1.288)PGV - 0.353))$.
Rubble volume resulting in waste package temperature increase to 300°C	MO0709HOTWASTE.000 [DIRS 184821], Folder: *Drift Collapse*, File: *Worksheet in Seismic Consequence Analysis.xls*, Worksheet: *P10L Peak T vs Vol. LKT*	$7.5\ m^3/m$
Heat of vaporization for water	Incropera and DeWitt 2002 [DIRS 163337], Physical Constants	2257 kJ/kg

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Input Description	Data Tracking Number/Source	Value
Definition of Hazard Parameters and Drip Shield Fragility for the Seismic Damage Abstractions	DTN: MO0703PASEISDA.002 [DIRS 185278], Table 1-15	Function of the value of LAMBDA for each seismic event. Use a power law (log) interpolation between points in the table. **λ (1/yr) — PGV (m/s)** 4.287×10^{-4} — 0.219 1.000×10^{-4} — 0.4019 3.826×10^{-5} — 0.6 1.919×10^{-5} — 0.8 9.955×10^{-6} — 1.05 6.682×10^{-6} — 1.2 3.812×10^{-6} — 1.4 2.136×10^{-6} — 1.6 1.288×10^{-6} — 1.8 8.755×10^{-7} — 2.0 6.399×10^{-7} — 2.2 4.518×10^{-7} — 2.44 3.504×10^{-7} — 2.6 2.507×10^{-7} — 2.8 1.731×10^{-7} — 3.0 1.137×10^{-7} — 3.2 7.168×10^{-8} — 3.4 4.362×10^{-8} — 3.6 2.508×10^{-8} — 3.8 1.319×10^{-8} — 4.0 5.967×10^{-9} — 4.2
Probability of non-zero damage to a TAD waste package with intact internals for different residual stress thresholds	DTN: MO0703PASEISDA.002 [DIRS 185278], Table 1-6	See Output DTN: MO0810PBANLNWP.001, folder C
Frequency from bounded hazard curve corresponding to a PGV of 1.05 m/s	DTN: MO0703PASEISDA.002 [DIRS 185278], Table 1-1	9.96×10^{-6} /yr
Maximum flow rate through a crack or cracks into a given waste package	DTN: SN0705WFLOWSCC.001 [DIRS 184848], Excel file: *Bounding calc for water flow through SCC cracks.xls*, Spreadsheet "Impinging drip flow rate", cell H29)	223 g
Source for indicating localized corrosion from dust deliquescence is insignificant	SNL 2007 [DIRS 181267], Section 7[a]	0
Horizontal peak ground velocity (PGV) associated with a seismic event. Obtained as a function of recurrence frequency, and called the "bounded hazard curve"	DTN: MO0501BPVELEMP.001 [DIRS 172682]	See Mathcad file in Output DTN: MO0810PBANLNWP.001, folder C
Maximum static load on drip shield range	SNL 2007 [DIRS 176828], Section 6.7.1.5	30 to 120 m^3/m

CSNF = commercial SNF

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(C6) Change Table 7-4 as follows:

Table 7-4. Failure Mode Analysis for Water Ingress to Commercial SNF and Codisposal Waste Packages

	Drip Shield Failure Mode ►			
▼Waste Package Failure Mode	**1. Early Failure (cracking)**	**2. Early Failure (misplacement)**	**3. Nonlithophysal Big Rock Rupture**	**4. Lithophysal Rubble Rupture**
A. Early Failure (cracking) All of the scenarios in this row result in an unsaturated hydrologic state inside the waste package.	Joint probability of independent early failures (combinatorial analysis). Water ingress is represented by unsaturated steady state. Analysis Result: Water entering in the vapor phase could lead to a schoepite moderated system. Ponded water is not predicted.	Joint probability of independent early failures (combinatorial analysis). Water ingress is represented by unsaturated steady state. Analysis Result: Water entering in the vapor phase could lead to a schoepite moderated system. Ponded water is not predicted.	Drip shield failure is independent of waste package early failure. Water ingress is represented by unsaturated steady state. Analysis Result: Water entering in the vapor phase could lead to a schoepite moderated system. Ponded water is not predicted.	Drip shield failure is independent of waste package early failure. Water ingress is represented by unsaturated steady state. Analysis Result: Water entering in the vapor phase could lead to a schoepite moderated system. Ponded water is not predicted.
B. SCC by Seismic Motion Impact All of the scenarios in this row result in an unsaturated hydrologic state inside the waste package.	Drip shield early failure is independent of seismic damage to waste packages. Qualitative Statement: Water entering in the vapor phase could lead to a schoepite moderated system. Ponded water is not predicted.	Drip shield early failure is independent of seismic damage to waste packages. Qualitative Statement: Water entering in the vapor phase could lead to a schoepite moderated system. Ponded water is not predicted.	Drip shield failure is independent of seismic damage to waste packages. Qualitative Statement: Water entering in the vapor phase could lead to a schoepite moderated system. Ponded water is not predicted.	Drip shield failure is independent of seismic damage to waste packages. Qualitative Statement: Water entering in the vapor phase could lead to a schoepite moderated system. Ponded water is not predicted.
C. Rupture by Seismic Ground Motion	Waste package seismic rupture requires a multi-event sequence starting with seismic motion sufficient to produce stress corrosion cracking damage to the WPOB. Waste package rupture is considered independent of drip shield early failure. Analysis Result: This failure mode requires that the waste package be damaged by SCC prior to rupture, thus the contribution to the potential for criticality is accounted for by Row B.	Waste package seismic rupture requires a multi-event sequence starting with seismic motion sufficient to produce stress corrosion cracking damage to the WPOB. Waste package rupture is considered independent of drip shield early failure. Analysis Result: This failure mode requires that the waste package be damaged by SCC prior to rupture, thus the contribution to the potential for criticality is accounted for by Row B.	Waste package seismic rupture requires a multi-event sequence starting with seismic motion sufficient to produce stress corrosion cracking damage to the WPOB. Waste package rupture is considered independent of drip shield failure. Analysis Result: This failure mode requires that the waste package be damaged by SCC prior to rupture, thus the contribution to the potential for criticality is accounted for by Row B.	Waste package seismic rupture requires a multi-event sequence starting with seismic motion sufficient to produce stress corrosion cracking damage to the WPOB. Waste package rupture is considered independent of drip shield failure. Analysis Result: This failure mode requires that the waste package be damaged by SCC prior to rupture, thus the contribution to the potential for criticality is accounted for by Row B.

Table 7-4. Failure Mode Analysis for Water Ingress to Commercial SNF and Codisposal Waste Package (Continued)

	DS Failure Mode ►			
▼Waste Package Failure Mode	**1. Early Failure (cracking)**	**2. Early Failure (misplacement)**	**3. Nonlithophysal Big Rock Rupture**	**4. Lithophysal Rubble Rupture**
D. Localized Corrosion	Leakage through cracks in the drip shield is insufficient to cause localized corrosion. Package is not predicted to breach. Analysis Result: Probability assigned a value of zero.	Drip shield early failure is independent of seepage and waste package localized corrosion (combinatorial analysis). See notes 2 and 4. **Conditions support localized corrosion. If localized corrosion penetrates WPOB, waste package could pond or fill with water.** Result: Commercial SNF Mean probability – 2.99 × 10^{-6}; Codisposal Mean probability – 1.94 × 10^{-6}	Drip shield damage is independent of seepage and waste package localized corrosion (combinatorial analysis). See notes 3 and 4. **Conditions support localized corrosion. If localized corrosion penetrates WPOB, waste package could pond or fill with water.** Result: Commercial SNF Mean probability – 1.02 × 10^{-3} Codisposal Mean probability – 7.03 × 10^{-4} for 1,223 codisposal packages	Drip shield damage is independent of seepage and waste package localized corrosion (combinatorial analysis). See notes 3 and 4. **Conditions support localized corrosion. If localized corrosiom penetrates WPOB, waste package could pond or fill with water.** Result: Commercial SNF Mean probability – 1.79 × 10^{-5} Codisposal Mean probability – 1.30 × 10^{-5} for 1,223 codisposal packages

Source: Output DTN: MO0810PANLNNWP.001

NOTES:

1. All probabilities are "per repository" that one or more waste packages will be breached as described in calculation methods discussed in Appendix B and with packages distributed uniformly in the lithophysal and nonlithophysal tuff, for the entire 10,000 year criticality screening analysis period unless otherwise noted.
2. Discrete distribution provided, based on a fixed (median) probability for DS misplacement, from ANL-EBS-MD-000076 Rev. 00, Section 6.5. Includes uncertainty associated with seepage and localized corrosion.
3. Discrete distributions provided for these cases, using a full description of uncertainties associated with the respective DS failure mode and WP localized corrosion.
4. Cumulative distribution functions for cases 2D, 3D, and 4D are contained in Output DTN MO0810PANLNNWP.001.

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(C7) Change Appendix A as follows:

APPENDIX A

LIST OF THE ELECTRONIC FILES IN OUTPUT DTNs: MO0802WPFLOODG.001, MO0810PANLNNWP.001, AND MO0810PBANLNWP.001

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This appendix contains a listing and description of the files contained in the output DTNs of this report (DTN: MO0802WPFLOODG.001, MO0810PANLNNWP.001, and MO0810PBANLNWP.001). A brief description, file names, their size in bytes, and the date and time of last update are also shown.

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OUTPUT DTN: MO0802WPFLOODG.001

Filename	File Size (bytes)	File Date	File Time	Description
Seismic-FD.zip	1,987,526	2/11/2008	4:46 PM	Archive containing Mathcad, Excel, and data files for CSNF and Navy waste packages for calculating probability of filling with water presented in Section 7

OUTPUT DTN: MO0810PANLNNWP.001

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Filename	File Size (bytes)	File Date	File Time	Description
CSNF_CDSP.zip	12,929,202	01/09/2009	9:19 AM	Archive containing Mathcad and data files for CSNF and CDSP waste package calculations presented in Table 7-4

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OUTPUT DTN: MO0810PBANLNWP.001

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Filename	File Size (bytes)	File Date	File Time	Description
Navy.zip	9,453,515	01/09/2009	9:19 AM	Archive containing Mathcad and data files for Navy waste package calculations presented in Table B-1 and Section B2.4.2

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(C8) Change Table B-1 as follows:

Table B-1. Failure Mode Analysis for Water Ingress to Naval Waste Packages

	Drip Shield Failure Mode ►			
▼Waste Package Failure Mode	**1. Early Failure (cracking)**	**2. Early Failure (misplacement)**	**3. Nonlithophysal Big Rock Rupture**	**4. Lithophysal Rubble Rupture**
A. Early Failure (cracking)	The consequence of this case is limited to an unsaturated steady state.	The consequence of this case is limited to an unsaturated steady state.	The consequence of this case is limited to an unsaturated steady state.	The consequence of this case is limited to an unsaturated steady state.
B. SCC by Seismic Motion Impact	The consequence of this case is limited to an unsaturated steady state.	The consequence of this case is limited to an unsaturated steady state.	The consequence of this case is limited to an unsaturated steady state.	The consequence of this case is limited to an unsaturated steady state.
C. Rupture by Seismic Ground Motion The cases in this row (except for 1C) may result in waste package ponding or flooding conditions.	WP seismic rupture requires a multi-event sequence starting with seismic motion sufficient to produce stress corrosion cracking damage to the WPOB. WP rupture is considered independent of DS EF. Result: The mean probability for WP rupture alone is 2.2×10^{-8}. The mean of the joint probability is $<<10^{-8}$.	WP seismic rupture requires a multi-event sequence starting with seismic motion sufficient to produce stress corrosion cracking damage to the WPOB. WP rupture is considered independent of DS EF. Result: The mean probability for WP rupture alone is 2.2×10^{-8}. The mean of the joint probability is $<<10^{-8}$.	WP seismic rupture requires a multi-event sequence starting with seismic motion sufficient to produce stress corrosion cracking damage to the WPOB. WP rupture is considered quasi-independent of DS EF. Result: The mean probability for WP rupture alone is 2.2×10^{-8}. The mean of the joint probability is $<<10^{-8}$.	WP seismic rupture requires a multi-event sequence starting with seismic motion sufficient to produce stress corrosion cracking damage to the WPOB. WP rupture is considered quasi-independent of DS rupture. Result: The mean probability for WP rupture alone is 2.2×10^{-8}. The mean of the joint probability is $<<10^{-8}$.
D. Localized Corrosion The cases in this row (except for 1D) may result in waste package ponding or flooding conditions.	Leakage through cracks in the DS is insufficient to cause localized corrosion. The consequence of this case is therefore limited to unsaturated steady state.	DS EF is independent of seepage and WP localized corrosion. **Conditions support LC. If LC penetrates WPOB, WP could pond or fill with water.** Result: Mean probability 1.59 $\times 10^{-7}$ (see text of Appendix B, and Note 2).	DS rupture is independent of seepage and WP localized corrosion. **Conditions support LC. If LC penetrates WPOB, WP could pond or fill with water.** Result: Mean probability 7.32 $\times 10^{-4}$ (see text of Appendix B, and Note 2).	DS rupture is independent of seepage and WP localized corrosion. **Conditions support LC. If LC penetrates WPOB, WP could pond or fill with water.** Result: mean probability 1.57 $\times 10^{-5}$ (see text of Appendix B, and Note 2).

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NOTES: 1. All probabilities given are “per repository” that one or more naval waste packages will be breached as described, over 10,000 years, with 400 naval SNF packages distributed randomly throughout the repository in the lithophysal and nonlithophysal tuff. 2. Probabilities for 2D, 3D, and 4D are given for illustrative purposes only, and do not reflect the full detail of the screening justifications for criticality processes for naval SNF. 3. Evaluation for cases 2C, 3C, and 4C and probability distributions for cases 2D, 3D, and 4D are discussed in Appendix B.

WP = waste package, DS = drip shield, LC = localized corrosion, WPOB = waste package outer barrier, EF = early failure, SCC = stress corrosion cracking.

(C9) On page B-9 the value of 4.36×10^{-9} should be changed to 2.19×10^{-9}.

C(10) The last paragraph on page B-10 lists a mean probability value of 1.5×10^{-7}. This value should be replaced with 1.59×10^{-7}.

(C11) The first paragraph on page B-11 states "The estimate of 1.5×10^{-7}…" This value should be replaced with 1.59×10^{-7}.

(C12) Change Section B.2.3 as follows:

B.2.3 Probabilistic Analysis of Failure Mode 3D

Mode 3D combines: 1) rupture of the drip shield from impact by a large rock block dislodged by seismic activity; and 2) resulting breach of the waste package by seepage flow through the drip shield, and localized corrosion of the waste package outer barrier (WPOB). This case is specific to the nonlithophysal tuff, because rock blocks of sufficient size to rupture the drip shield can only occur there.

This analysis develops a distribution of probability that this mode will occur for at least one waste package among those of a certain type (target group, e.g., naval SNF packages) for 10,000 years after repository closure. This analysis is implemented for the target group of waste packages in Mathcad (Output DTN: MO0810PBANLNWP.001 and MO0810PANLNNWP.001, file: *Nonlith LC Calculation Rev03.xmcd*) for each target waste package group.

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This analysis develops an estimate of the mean probability that at least one waste package in the target group (e.g., naval SNF packages) is emplaced in the nonlithophysal tuff at a location where the drip shield is ruptured by a seismically induced impact from a large rock block, and where there is seepage, and that seepage initiates localized corrosion of the WPOB, during the first 10,000 years after closure.

Description of the analysis below is written generically, such that it can be applied to calculating probabilities that one or more naval SNF waste packages, commercial SNF packages, or DOE co-disposal packages sustains localized corrosion failure from Mode 3D.

The analysis requires that the number of packages in the target group be specified (e.g., 400 naval SNF packages) out of a total of 11,162 waste packages (DTN: MO0702PASTREAM.001 [DIRS 179925], file: *DTN-Inventory-Rev00.xls*, worksheet: UNIT CELL, Row 14). If the target group contains a significant number of waste packages that are placed randomly in the repository, then the probability that at least one target-group waste package is in the nonlithophysal tuff is essentially 1. This analysis is based on waste packages in the target group being emplaced randomly throughout the repository, and that there is a one-to-one correspondence between each drip shield and the underlying waste package. The effect from drip shield general corrosion on its resistance to rupture is neglected, because the extent of such corrosion in 10,000 years is negligible for mechanical strength properties.

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The conditional distribution of probability that waste packages will undergo seepage and localized corrosion without drip shield protection, is obtained from an intermediate product of TSPA, specifically the discrete set of simulated outcomes for 300 realizations obtained by exercising the relevant parameters and their epistemic uncertainties. These results are given for CSNF and CDSP (co-disposal) packages by files from DTN: MO0709TSPALOCO.000 [DIRS 185808]). Five such sets of 300 outcomes are used, corresponding to the five percolation "bins" used in TSPA to represent variability and uncertainty in percolation flux (SNL 2007 [DIRS 184433], Section 6.2.12.1[a]). These intermediate results also represent the uncertainties associated with localized corrosion initiation, waste package temperature and relative humidity, and uncertainty in the parameters that describe seepage chemistry. The results from TSPA, which combine representative locations in the lithophysal and nonlithophysal tuff, are sorted for this analysis to include only the nonlithophysal locations.

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The number of waste packages in the target group which are emplaced in the nonlithophysal tuff, is represented using the five percolation "bins" used in TSPA (SNL 2007 [DIRS 184433], Section 6.2.12.1[a]), and the fraction of each bin that lies within the nonlithophysal tuff (see below).

Notation

nWP	The total number of waste packages in the repository ($nWP = 11162$).
$nNWPT$	The number of waste packages in the target group (e.g., for naval SNF packages, $nNWPT = 400$).
b	Percolation bin number (integers 1 through 5).
$nNWP(b)$	Number of waste packages in the target group, in the nonlithophysal tuff.
$f(b)$	Fraction of all waste packages in percolation bin b (equal to 0.05, 0.25, 0.4, 0.25, 0.05 for the five respective bins; SNL 2007 [DIRS 184433], Appendix VIII).
$f_{NL}(b)$	Fraction of percolation bin b that is in nonlithophysal tuff (equal to 0.319, 0.237, 0.173, 0.041, 0.110 for the five respective bins; from DTN: MO0709TSPALOCO.000, file: *NonLith_Frac_CSNF_out.xls*)
f_{DS}	Random variable denoting the fraction of drip shields in the nonlithophysal tuff that are ruptured given that one seismic event occurs
v	Horizontal peak ground velocity (PGV) associated with a seismic event.
$\lambda(v)$	Frequency of seismic events (yr^{-1}) as a function of PGV, described by the seismic hazard curve DTN: MO0703PASDSTAT.001 [DIRS 185275], file *Lith_Rubble_Abstraction.xls,* worksheet *Data for Bounded Hazard*.
λ_{NL}	Frequency of seismic events (yr^{-1}) with potential to cause rupture of one or more drip shields in the nonlithophysal tuff.

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r Realization of epistemic uncertainty (index for the 300 realizations used to represent outcomes that include localized corrosion).

$f_{LC}(t,b|\mathbf{r})$ Fraction of locations in percolation bin b for which localized corrosion conditions occur at or after time t in epistemic realization **r** of the localized corrosion part of the analysis. These results are given for CSNF and CDSP (co-disposal) packages by files from DTN: MO0709TSPALOCO.000 [DIRS 185808]). Separate sets of files are used for the lithophysal and nonlithophysal host rock, for each waste package type.

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p_{ACC} Probability that a randomly selected waste package exhibits a particular state corresponding to an accessory process such as thermal damage/failure, that is independent of drip shield early failure, seepage, or localized corrosion, and for which the probability of a joint outcome is to be calculated. Set $p_{ACC} = 1$ to ignore such a process.

Development

The effect from drip shield general corrosion on its resistance to rupture from falling rock blocks is neglected, because the extent of such corrosion in 10,000 years is negligible for mechanical strength properties. In addition the probability of drip shield rupture from seismically induced rockfall is considered to be independent of its location anywhere within the nonlithophysal tuff.

For this analysis the maximum frequency is $\lambda(v_{\min}) = 1 \times 10^{-4}$ yr^{-1} , because drip shield rupture is possible at PGV values exceeding 0.4 m/s (DTN: MO0703PASEISDA.002 [DIRS 185278], Table 1-11).

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Given that an event occurs at time t that ruptures a fraction f_{DS} drip shields, the probability that a ruptured drip shield coincides with a location in percolation bin b with localized corrosion conditions is estimated by the fraction of drip shields in the nonlithophysal portion of percolation bin b that are ruptured, multiplied by the fraction of locations in the nonlithophysal tuff in percolation bin b that have localized corrosion conditions at or after time t:

$$p_{LC}(f_{DS},t,b|\mathbf{r}) = f_{DS} \times f_{LC}(t,b|\mathbf{r}) \qquad \text{(Eq. B.2.3-1)}$$

The expected number of waste packages in the target group, located within the nonlithophysal tuff, in percolation bin b, is

$$nNWP(b) = f(b) \times f_{NL}(b) \times nNWPT \qquad \text{(Eq. B.2.3-2)}$$

For convenience, assume $nNWP(b)$ is an integer by use of a round function on $nNWP(b)$, implemented in Mathcad.

Denote by $NLC(f_{DS},t,b|\mathbf{r})$ the random variable that counts the number of waste packages in the target group, that are subject to the accessory process identified by p_{ACC}, in percolation bin b, in locations that lie under ruptured drip shields resulting from a seismic event at time t that ruptures

f_{DS} of the drip shields in the nonlithophysal tuff, and that have localized corrosion conditions at or after time t, in epistemic realization $\mathbf{r}$. The random variable $NLC\left(f_{DS},t,b\middle|\mathbf{r}\right)$ can be modeled with a binomial distribution with probability $p_{LC}\left(f_{DS},t,b\middle|\mathbf{r}\right)\times p_{ACC}$:

$$P\left(NLC\left(f_{DS},t,b\mid\mathbf{r}\right)=0\right)=\binom{nNWP(b)}{0}\left(1-p_{LC}\left(f_{DS},t,b\mid\mathbf{r}\right)p_{ACC}\right)^{nNWP(b)}$$
$$=\left(1-p_{LC}\left(f_{DS},t,b\mid\mathbf{r}\right)p_{ACC}\right)^{nNWP(b)} \qquad \text{(Eq. B.2.3-3)}$$
$$=\left(1-f_{DS}\times f_{LC}\left(t,b\mid\mathbf{r}\right)p_{ACC}\right)^{nNWP(b)}$$

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The probability that one or more waste packages in the target group are affected by localized corrosion given a seismic event at time t that ruptures f_{DS} of the drip shields in the nonlithophysal tuff is then given by:

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$$P\left(NLC\left(f_{DS},t\mid\mathbf{r}\right)\geq 1\right)=1-\prod_{b=1}^{5}P\left(NLC\left(f_{DS},t,b\mid\mathbf{r}\right)=0\right) \qquad \text{(Eq. B.2.3-4)}$$

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Given the occurrence of a seismic event with potential to cause rupture, the probability that the event results in rupture of f_{DS} of the drip shields in the nonlithophysal tuff is given by $d_{f_{DS}}\left(f_{DS}\right)$, the density function for f_{DS}. The density function $d_{f_{DS}}\left(f_{DS}\right)$ is computed by

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$$d_{f_{DS}}(K)=P\left(f_{DS}=K\right)$$
$$=\int_{v_{\min}}^{v_{\max}}\left(pD_{DS}(v)\times pF_K(v)\right)d_v(v)\,dv \qquad \text{(Eq. B.2.3-5)}$$

where

$pD_{DS}(v)$ — Probability that a seismic event with PGV v causes damage to one or more drip shields in the nonlithophysal tuff (DTN: MO0703PASEISDA.002 [DIRS 185278], Table 1-10)

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$pF_K(v)$ — Probability that a fraction K of drip shields in the nonlithophysal tuff are ruptured given a seismic event with PGV v that causes damage to drip shields in the nonlithophysal tuff (DTN: MO0703PASEISDA.002 [DIRS 185278], Table 1-11, for values K = 0, 0.25, 0.5, 0.75, 1.0 corresponding to States 1, 2, 3, 4, 5, respectively).

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The density function for PGV v conditional on the occurrence of a seismic event with potential to cause rupture, $d_v(v)$ is computed as

$$d_v(v) = -\left[\frac{d\lambda(v)}{dv}\right]\frac{1}{\left(\lambda(v_{\min}) - \lambda(v_{\max})\right)} = -\left[\frac{d\lambda(v)}{dv}\right]\frac{1}{\left(10^{-4} - 10^{-8}\right)} \qquad \text{(Eq. B.2.3-6)}$$

where $\lambda(v)$ is the mean seismic hazard curve defined above.

Recalling that $\lambda(v)$ is the mean seismic hazard curve, then $v_{\min} = 0.4019$ m/s and $v_{\max} = 4.07$ m/s representing the range of potentially damaging seismic motion. These PGV limits correspond to $\lambda_{\max} = 10^{-4}$ yr^{-1} and $\lambda_{\min} = 10^{-8}$ yr^{-1}, respectively.

If $K = 0$ then the event caused no drip shields to rupture. Because K assumes only the discrete values 0, 0.25, 0.5, 0.75, 1.0, and $K = 0$ corresponds to no ruptured drip shields, the nonzero values of f_{DS} are $\frac{k}{4}$ for k = 1, 2, 3, and 4. Then the probability that one or more waste packages in the target group are affected by localized corrosion given the occurrence of a seismic event at time t that results in rupture of one or more drip shields in the nonlithophysal tuff is given by

$$P(NLC(t \mid \mathbf{r}) \ge 1) = \sum_{k=1}^{4} P(NLC(k/4, t \mid \mathbf{r}) \ge 1) \times d_{f_{DS}}\left(\frac{k}{4}\right) \qquad \text{(Eq. B.2.3-7)}$$

The frequency λ_{NL} of events with potential to cause rupture to one or more drip shields in the nonlithophysal tuff is $\lambda_{NL} = \lambda_{\max} = 10^{-4}$ yr^{-1}

Divide the interval [0, 10000 years] into intervals of length Δt with endpoints $t_0 = 0, t_1, \ldots, t_k, \ldots, 10{,}000$. The probability that an event occurs in one interval $[t_k, t_{k+1}]$ is $\lambda_{NL}\Delta t$. So the probability that an event occurs in the interval $[t_k, t_{k+1}]$ which results in one or more waste packages in the target group affected by localized corrosion is

$$\lambda_{NL}\Delta t \times P(NLC(t_k \mid \mathbf{r}) \ge 1) \qquad \text{(Eq. B.2.3-8)}$$

The probability that seismic events in 10,000 years cause one or more waste packages in the target group, in the nonlithophysal tuff to be affected by the combination of drip shield rupture by seismically induced rockfall followed by localized corrosion of the WPOB is given by

$$P(NLC \ge 1 \mid \mathbf{r}) = \int_0^{10{,}000} \lambda_{NL} \times P(NLC(s \mid \mathbf{r}) \ge 1)\, ds \qquad \text{(Eq. B.2.3-9)}$$

Finally, over all epistemic realizations, the mean probability that one or more waste packages in the target group is impacted by Mode 3D is

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$d_v(v) = -\left[\frac{d\lambda(v)}{dv}\right]\frac{1}{(\lambda(v_{\min}) - \lambda}$ … $= -\left[\frac{d\lambda(v)}{dv}\right]\frac{1}{(10^{-4} - 10^{-8})}$ (Eq. B.2.3-7)¶

where $\lambda(v)$ is the mean seismic hazard curve defined above.

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$$P(NLC \ge 1) = \frac{1}{N_r}\sum_{\boldsymbol{r}}\left(P(NLC \ge 1 \mid \boldsymbol{r})\right) \qquad \text{(Eq. B.2.3-10)}$$

The epistemic uncertainty in the probability of drip shield failure and in localized corrosion results in a distribution of values for $P(NLC \ge 1 \mid \boldsymbol{r})$.

This analysis was implemented for a target number of 400 naval SNF waste packages, resulting in a mean probability of 7.32×10^{-4} that one or more naval packages will be impacted by Mode 3D in 10,000 years. This is an illustrative calculation that does not reflect the full detail of the screening justifications for criticality processes for naval SNF.

Inherent Conservatisms

The estimate of 7.32×10^{-4} provided by Equation B.2.3-10 for the probability that one or more naval SNF waste packages experiences water ingress by Mode 3D in 10,000 years after repository closure is a reasonable estimate of this value. The calculation relies on the conservative assumptions made in describing the effects of seismic ground motion on drip shields (SNL 2007 [DIRS 176828]) and the model for initiation of localized corrosion (SNL 2007 [DIRS 178519]). No additional conservative assumptions are made in this analysis.

Uncertainty in Results

The results computed from Equation B.2.3-10 reflect aleatory uncertainty in the number and nature of seismic events that can occur in 10,000 years after repository closure as well as the spatial location of navy SNF waste packages within the repository. These aleatory uncertainties are addressed by the expected values computed in Equation B.2.3-5 and Equation B.2.3-8, which yield the expected number of drip shields ruptured by rockfall and the mean frequency of events that cause rockfall in the nonlithophysal tuff, respectively, and in Equation B.2.3-2, which yields the mean number of navy SNF waste packages in the nonlithophysal tuff. The principal epistemic uncertainties that affect this calculation are the occurrence and composition of seepage waters and the processes that lead to initiation of localized corrosion on Alloy 22. These uncertainties are represented by the use of sample elements (realizations) **r**, which result in a distribution of results from Equation B.2.3-9. Because the probability of localized corrosion initiation is uncertain and is highly variable between sample elements (see analysis results in Ouput DTN: MO0810PANLNNWP.001, file: *Nonlith LC Calculation Rev03.xmcd*), the distribution of results from Equation B.2.3-9 is significantly influenced by a few sample elements in which potential for localized corrosion persists for a long period of time. Thus, the distribution of results from Equation B.2.3-9 is highly skewed, causing the mean of this distribution (Equation B.2.3-10) to be much larger than its median value.

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(C13) Change Section B.2.4 as follows:

B.2.4 Probabilistic Analysis of Failure Mode 4D

Mode 4D combines: 1) rupture of the drip shield from seismic loading after drift collapse; and 2) resulting breach of the waste package by seepage flow through the drip shield, and localized corrosion of the waste package outer barrier (WPOB). This case is specific to the lithophysal tuff, because drift collapse of sufficient extent to cause rupture of the drip shield during a seismic event, can only occur there.

This analysis develops a distribution of probability that Mode 4D will occur for at least one waste package among those of a certain type (target group, e.g., naval SNF packages) for 10,000 years after repository closure. This analysis is implemented in Mathcad (Output DTN: MO0810PBANLNWP.001 and MO0810PANLNNWP.001, file: *Lith LC Calculation Rev05.xmcd*; for each target waste package group; this file calls other Mathcad files as indicated in its internal annotations).

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Description of the analysis below is written generically, such that it can be applied to calculating probabilities that one or more naval SNF waste packages, CSNF packages, or HLW packages sustains failure from Mode 4D.

The analysis requires that the number of packages in the target group be specified (e.g., 400 naval SNF packages) out of a total of 11,162 waste packages (DTN: MO0702PASTREAM.001 [DIRS 179925], file: *DTN-Inventory-Rev00.xls*, worksheet: UNIT CELL, Row 14). If the target group contains a significant number of waste packages that are placed randomly in the repository, then the probability that at least one target-group waste package is in the lithophysal tuff is essentially 1. This analysis is based on the waste packages in the target group being emplaced randomly throughout the repository, and that there is a one-to-one correspondence between each drip shield and the underlying waste package. The effect from drip shield general corrosion on its resistance to rupture is neglected, because the extent of such corrosion in 10,000 years is negligible for mechanical strength properties.

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The conditional distribution of probability that waste packages will undergo seepage and localized corrosion without drip shield protection is obtained from an intermediate product of TSPA. Specifically, these results consist of sets of simulated outcomes for 300 realizations over a set of dominant epistemic parameters, with drip shields removed, in which the responses for a group of waste packages (e.g., localized corrosion or not) are calculated for every realization. Five sets of 300 outcomes are used, corresponding to the five percolation "bins" used in TSPA to represent variability and uncertainty in percolation flux (SNL 2007 [DIRS 184433], Section 6.2.12.1[a]). The results are given for commercial SNF and codisposal packages by files from DTN: MO0709TSPALOCO.000 [DIRS 185808]). These intermediate results also represent the uncertainties associated with localized corrosion initiation, waste package temperature and relative humidity, temperature effect from drift collapse, and uncertainty in the parameters that describe seepage chemistry. The results from TSPA, which combine representative locations in the lithophysal and nonlithophysal tuff, are sorted for this analysis to include only the lithophysal locations.

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The number of waste packages in the target group which are emplaced in the lithophysal tuff, is represented using the five percolation "bins" used in TSPA (SNL 2007 [DIRS 184433], Section 6.2.12.1[a]), and the fraction of each bin that lies within the lithophysal tuff (see below).

Notation

nWP	=	The total number of waste packages in the repository ($nWP = 11162$).
$nNWPT$	=	The number of waste packages in the target group (e.g., for naval SNF packages, $nNWPT = 400$)
b	=	Percolation bin number (integers 1 through 5).
$nNWP(b)$	=	Number of waste packages in the target group, in the lithophysal tuff in percolation bin b.
$f(b)$	=	Fraction of all waste packages in percolation bin b (equal to 0.05, 0.25, 0.4, 0.25, 0.05 for the five respective bins; SNL 2007 [DIRS 184433], Appendix VIII)
$f_L(b)$	=	Fraction of percolation bin b that is in lithophysal tuff (equal to 0.681, 0.763, 0.827, 0.959, 0.890 for the five respective bins; from DTN: MO0709TSPALOCO.000, file: *NonLith_Frac_CSNF_out.xls*)
ν	=	Horizontal peak ground velocity (PGV) associated with a seismic event.
$\lambda(\nu)$	=	Frequency of seismic events (yr^{-1}) as a function of PGV, described by the seismic hazard curve DTN: MO0703PASDSTAT.001 [DIRS 185275], file *Lith_Rubble_Abstraction.xls,* worksheet *Data for Bounded Hazard*
$\mathbf{r}$	=	Realization of epistemic uncertainty (index for the 300 epistemic realizations for each percolation bin, used to represent outcomes that include localized corrosion)
$f_{LC}(t,b\|\mathbf{r})$	=	Fraction of locations in percolation bin b for which localized corrosion conditions occur at or after time t in epistemic realization $\mathbf{r}$ of the localized corrosion part of the analysis. These results are given for commercial SNF and codisposal packages by files from DTN: MO0709TSPALOCO.000 [DIRS 185808]). Separate sets of files are used for the lithophysal and nonlithophysal host rock, for each waste package type.
p_{ACC}		Probability that a randomly selected waste package exhibits a particular state corresponding to an accessory process such as thermal damage/failure, that is independent of drip shield early failure, seepage,

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or localized corrosion, and for which the probability of a joint outcome is to be calculated. Set $p_{ACC} = 1$ to ignore such a process.

Development

In addition the probability of drip shield rupture from seismic loading with drift collapse is assumed to be independent of its location anywhere within the lithophysal tuff.

The expected number of waste packages in the target group, in the lithophysal part of percolation bin *b* is:

$$nNWP(b) = f(b) \times f_L(b) \times nNWPT \qquad \text{(Eq. B.2.4-1)}$$

For convenience, assume *nNWP*(*b*) is an integer by use of a round function on *nNWP*(*b*), implemented in Mathcad. The probability that no waste package in the target group is placed in the lithophysal region of percolation bin *b* is essentially 0 for all percolation bins, therefore this analysis assumes that at least one waste package from the target group is placed in the lithophysal region of each percolation bin.

Given that an event occurs at time *t* that fails the drip shield plates, the probability that localized corrosion will occur at or after time *t* at a random location in percolation bin *b* is estimated by the fraction of locations in percolation bin *b* that have localized corrosion conditions at or after time *t*, $f_{LC}(t, b|\mathbf{r})$.

Rockfall in the lithophysal tuff can occur for events with PGV as low as 0.274 m/s (SNL 2007 [DIRS 176828], Eq. 6.7-1), is strongly correlated with PGV, and accumulates due to multiple events. The extent of collapse depends also on the bulking factor of the collapsed rubble (SNL 2007 [DIRS 176828], Section 6.7.1). As collapse rubble accumulates in the drift, the static load on the drip shields increases, and drip shields become more susceptible to failure during subsequent seismic loading. At full (100%) collapse, drip shield plate failure may occur with a small probability, for seismic events with PGV as low as 2.44 m/s (neglecting corrosion thinning of the plates) corresponding to annual recurrence frequency of 4.518×10^{-7} yr^{-1} (SNL 2007 [DIRS 176828], Tables 6-3 and 6-36). With less collapse (e.g. 50%; same source, Table 6-36) the probability is smaller and the intensity of the required seismic event is greater. In summary, there is a small probability that drip shield failure can occur from seismic loading under drift collapse rubble, which depends on the presence of enough rubble, which may accumulate during a single seismic event or multiple seismic events over time.

To address the recursive complexity of conditions leading to drip shield rupture in the lithophysal tuff, a Monte Carlo simulation approach, implemented in Mathcad, was used to estimate λ_L as it appears in Eq. B.2.4-5 (Output DTN: MO0810PBANLNWP.001, file: *Lith Probability of DS Failure.xmcd*). This analysis is described in detail in Section B.2.4.1.

Denote by $NLC(t, b|\mathbf{r})$ the random variable that counts the number of waste packages in the target group, that are subject to the accessory process identified by p_{ACC}, in percolation bin *b* in

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$$p(x; p, n) = \binom{n}{x} \cdot p^x \cdot (1-p)^{n}$$

(Eq. B.2.4-2)¶

the random variable $nLC(t, b|\mathbf{r})$ can be modeled with a binomial distribution with probability $p_{LC}(t, b|\mathbf{r})$: ¶

$$P(nLC(t, b|\mathbf{r}) \geq 1) = 1 - \binom{nNW}{0}$$
$$= 1 - (1 - p_L$$
$$= 1 - (1 - f_L$$

(Eq. B.2.4-3)¶

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locations that have localized corrosion conditions at or after time t, in epistemic realization $\mathbf{r}$. The random variable $NLC(t,b|\mathbf{r})$ can be represented with a binomial distribution with probability $f_{LC}(t,b|\mathbf{r})\cdot p_{ACC}$, so

$$P\left(NLC\left(t,b\,|\,\boldsymbol{r}\right)=0\right)=\binom{nNWP(b)}{0}\left(1-f_{LC}\left(t,b\,|\,\boldsymbol{r}\right)p_{ACC}\right)^{nNWP(b)} = \left(1-f_{LC}\left(t,b\,|\,\boldsymbol{r}\right)p_{ACC}\right)^{nNWP(b)} \qquad \text{(Eq. B.2.4-2)}$$

The probability that one or more waste packages in the target group are affected by localized corrosion at or after time t in epistemic realization $\boldsymbol{r}$ is given by

$$P\left(NLC\left(t\,|\,\boldsymbol{r}\right)\geq 1\right)=1-\prod_{b=1}^{5}P\left(NLC\left(t,b\,|\,\boldsymbol{r}\right)=0\right) \qquad \text{(Eq. B.2.4-3)}$$

Because λ_L is defined to be the frequency of events that fail drip shields in the lithophysal region, and this failure can occur only once, the calculation only accounts for one event that causes failure of drip shields in the lithophysal unit within 10,000 years. Dividing the interval [0, 10,000 years] into intervals of length Δt with endpoints $t_0 = 0$, t_1, …, t_k, … 10,000, the probability that the event occurs in one interval $[t_k, t_{k+1}]$ is

$$\lambda_L \Delta t \cdot e^{-\lambda_L t_k}$$

So the probability that the event occurs in the interval $[t_k, t_{k+1}]$ which results in one or more waste packages affected by localized corrosion is

$$\lambda_L \Delta t \cdot e^{(-\lambda_L t_k)} P\left(NLC\left(t_k, b\,|\,\mathbf{r}\right)\geq 1\right)$$

Finally, the probability that seismic events in 10,000 years cause one or more waste packages in the lithophysal part of repository to be affected by localized corrosion is given by

$$P\left(NLC\geq 1\,|\,\boldsymbol{r}\right)=\int_{0}^{10{,}000}\lambda_L e^{(-\lambda_L s)}\times P\left(NLC\left(s\,|\,\boldsymbol{r}\right)\geq 1\right)ds \qquad \text{(Eq. B.2.4-4)}$$

The epistemic uncertainty in localized corrosion, represented by $\mathbf{r}$, results in a distribution of values for $P(NLC\geq 1\,|\,\mathbf{r})$.

This analysis was implemented for a target group of 400 naval SNF waste packages, yielding a mean probability of 1.57 × 10^{-5} that one or more naval packages will be affected by Mode 4D in 10,000 years. This is an illustrative calculation that does not reflect the full detail of the screening justifications for criticality processes for naval SNF.

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Deleted: And the probability that no waste package is affected by the combination of drip shield failure by lithophysal rockfall and localized corrosion in 10,000 years is given by¶

$P(NLC=0|\mathbf{r})=\prod_{b=1}^{5}(1-P(NL$

(Eq. B.2.4-6)¶

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B.2.4.1 Monte Carlo Analysis of Seismic Drip Shield Failure Mode 4

This analysis generates the parameter λ_L, the frequency of seismic events that rupture drip shields in the lithophysal tuff. This case is specific to the lithophysal tuff, because drift collapse of sufficient extent to cause rupture of the drip shield during a seismic event can only occur there. This analysis is used as input to the probabilistic analysis of Mode 4D for waste package failure (Section B.2.4).

In addition the probability of drip shield rupture from seismic loading with drift collapse is considered to be independent of its location anywhere within the lithophysal tuff.

Notation

n = Number of multiple seismic events simulated over 10,000 years.

E = The rockfall volume (m^3/meter of drift) required for complete drift collapse.

Development

The following process is implemented in Mathcad (Output DTN: MO0810PBANLNWP.001, file: *Lith Probability of DS Failure.xmcd*).

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1. Given an annual exceedance frequency equal to λ(0.219 m/sec) (DTN MO0703PASDSTAT.001 [DIRS 185275], file *Lith Rubble Abstraction.xls*, worksheet *Data for Bounded Hazard*) that represents the lowest PGV with potential to cause drip shield failure, use the Poisson Distribution to determine the probability of n events occurring in 10,000 years, where n ranges from 1 to 15.

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2. Calculate the conditional probability that drip shield failure occurs given that n events have occurred in 10,000 years. This conditional probability is determined by synthetic sampling of 100,000 or more realizations. For each realization perform step A below, then for each event in the realization, perform steps B and C.

   A. For each realization, sample for E, the volume of rockfall required for complete drift collapse, by sampling a uniform distribution from 30 to 120 m^3/m.

   B. For the first event in a realization, sample the annual exceedance frequency over a range corresponding to the range of PGV from 0.219 m/s to 4.07 m/s, and determine the PGV from the hazard curve. Use the PGV and a second, independent random number to determine if non-zero rockfall occurs, then independently sample the gamma distribution to determine the rockfall volume associated with that event. Calculate the fraction of drift collapse (FD) by dividing the rockfall volume by E, not to exceed 1.0.

   Given that PGV and the FD are known for this event, it is possible to determine whether drip shield failure has occurred, by calculating the probability from the interpolation function in Table 1-2 of DTN: MO0703PASEISDA.002 [DIRS 185278]). The random number used to determine if rockfall occurs is compared to the table value to determine if

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drip shield failure has occurred. If drip shield failure occurs, then the process stops. If drip shield failure has not occurred then proceed to the next step.

C. Perform the same calculation for the second, and subsequent events (up to *n* if drip shield failure does not occur). New random numbers are generated for each event. Test for drip shield failure at each event. If drip shield failure occurs, then stop.

D. For multiple realizations, compile the conditional probability of drip shield failure for *n* events, where *n* ranges from 1 to 15.

3. The results from Step 1 give the probabilities for n = 1, 2, ...15. The results from Step 2 give the conditional probability of drip shield failure. The dot product of these two vectors then gives the expected value for the probability P of drip shield failure in 10,000 years. The parameter λ_L, representing the frequency of seismic events that cause rupture to the drip shield in the lithophysal region is estimated by $\lambda_L = \frac{P}{10,000}$ = 1.8×10^{-4} in a 10,000 year period, or 1.8×10^{-8} per year (Output DTN: MO0810PBANLNWP.001, file: *Lith Probability of DS Failure.xmcd*).

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Inherent Conservatisms

The estimate of 1.57×10^{-5} provided by Equation B.2.4-4 for the probability that one or more naval SNF waste packages experiences water ingress by Mode 4D in 10,000 years after repository closure is a reasonable estimate of this value. The calculation relies on the conservative assumptions made in describing the effects of seismic ground motion on drip shields (SNL 2007 [DIRS 176828]) and the model for initiation of localized corrosion (SNL 2007 [DIRS 178519]). No additional conservative assumptions are made in this analysis.

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Uncertainty in Results

The results computed from Equation B.2.4-4 reflect aleatory uncertainty in the number and nature of seismic events that can occur in 10,000 years after repository closure as well as the spatial location of navy SNF waste packages within the repository. These aleatory uncertainties are addressed by the calculation of λ_L, the mean frequency of events that cause drip shield failure, and in Equation B.2.4-1, which yields the mean number of navy SNF waste packages in the lithophysal tuff. The principal epistemic uncertainties that affect this calculation are the occurrence and composition of seepage waters and the processes that lead to initiation of localized corrosion on Alloy 22. These uncertainties are represented by the use of sample elements (realizations) **r**, which result in a distribution of results from Equation B.2.4-4. Because the probability of localized corrosion initiation is uncertain and is highly variable between sample elements (see analysis results in Ouput DTN: MO0810PANLNNWP.001, file: *Nonlith LC Calculation Rev03.xmcd*), the distribution of results from Equation B.2.4-4 is significantly influenced by a few sample elements in which localized corrosion is highly probable. Thus, the distribution of results from Equation B.2.4-4 is highly skewed, causing the mean of this distribution to be much larger than its median value.

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B.2.4.2 PROBABILITY OF EARLY ROCKFALL SUFFICIENT TO CAUSE ELEVATED WASTE PACKAGE TEMPERATURES AND THEN FAILURE BY LOCALIZED CORROSION

This section considers drift collapse occurring in the lithophysal rock zone during the initial thermal period after closure of the repository. The rubble from seismic events could accumulate on and around the drip shield and act as a thermal blanket for the waste packages. This would result in increased waste package temperatures relative to nominal conditions (without drift collapse).

This calculation quantifies the probability that seismic activity during the first *T* years of the repository causes lithophysal rockfall sufficient to cause a thermal blanket effect in waste package temperature (300°C or more), which could alter waste forms in the target population of waste packages. Subsequent to this occurring, one or more of the waste packages of that population could fail due to DS failure followed by seepage induced localized corrosion of the waste package outer barrier. This calculation is bounding in that the probability of localized corrosion is set to one if drip shield failure occurs.

The thermal influence of a collapsed drift on waste package temperatures is discussed in the *Postclosure Analysis of the Range of Design Thermal Loadings* (SNL 2008 [DIRS 179962], Section 6.5.1). In the case of drift collapse, the probability of waste package temperatures exceeding 300 degrees C is low right after repository closure and peaks at about 25 years after closure then continues to decrease (SNL 2008 [DIRS 179962], Section 6.5.1) to a small value after 80 years. For purposes of discussion in this calculation, the value of *T* is selected at 80 years.

This calculation is implemented in MathCad and provided in Output DTN MO0810PBANLNWP.001, file *Probability of Thermal Blanket and Localized Corrosion.xmcd*. This calculation file is developed so that an impact to waste forms occurs if lithophysal rockfall equals or exceeds 7.5 m^3/m at any time in the first 80 years. The basis for establishing the 7.5 m^3/m volume is presented in DTN: MO0709HOTWASTE.000 (SNL 2007 [DIRS 184821], Folder: *Drift Collapse*, File: *Worksheet in Seismic Consequence Analysis.xls*, Worksheet: *P10L Peak T vs Vol. LKT*). This worksheet presents a chart of the relationship of waste package temperature with the volume of rockfall at various times after repository closure. The analysis was performed with the 10^{th} percentile thermal properties set for the rock mass. Use of the 10^{th} percentile values maximizes the temperature increase with the lowest amount of rockfall and is thus conservative for this application. The selected rockfall volume of 7.5 m^3/m provides a minimum volume for which a waste package temperature reaches 300°C. The use of the minimum rockfall volume will result in an overestimate of the probability of an increased temperature that could affect the waste form and is thus conservative.

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This calculation first computes the probability that a seismic event occurs in the first *T*= 80 years sufficient to cause at least 7.5 m^3/m of lithophysal rockfall. This event has two potential outcomes: 1) the DS fails due to this first event; 2) the DS does not fail because of this first event. If the DS does not fail, the calculation considers the probability that subsequent seismic events may fail the DS.

Lithophysal rockfall may occur if the PGV exceeds 0.274 m/s as shown in DTN: MO0703PASEISDA.002, [DIRS 185278], Equation 1-1. Events at this PGV occur with a frequency approximately 2.5×10^{-4} yr^{-1} as determined from the Seismic Hazard Curve in DTN MO0703PASDSTAT.001 ([DIRS 185275] Workbook: *Lith Rubble Abstraction.xls*, Worksheet: *Data for Bounded Hazard*).

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The probability of exactly one seismic event is based on the standard (Poisson) formulation (Hahn and Shapiro 1967 [DIRS 146529], Equation 4-9) for events that occur randomly over T years with a given rate, $\Delta\lambda$ per year:

$$P(1 \mid \Delta\lambda, T) = \Delta\lambda T e^{-\Delta\lambda T} \qquad \text{(Eq. B.2.4-5)}$$

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From the bounded hazard curve the exceedance frequency which corresponds to the PGV at which there is a nonzero probability of rockfall is 2.5 x 10^{-4} per year. The probability that one event occurs in T=80 years with PGV exceeding 0.274 m/s is given by:

$$2.5 \times 10^{-4} T e^{(-2.5\times 10^{-4} T)} = 0.020 \qquad \text{(Eq. B.2.4-6)}$$

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The probability that two or more events occur within T=80 years with PGV exceeding 0.274 m/s is approximately:

$$1 - e^{(-2.5\times 10^{-4} T)} - 2.5 \times 10^{-4} T e^{(-2.5\times 10^{-4} T)} = 2.0 \times 10^{-4} \qquad \text{(Eq. B.2.4-7)}$$

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Because the outcome when considering two or more events is small relative to the probability for a single event, the calculation can consider the rockfall from only a single event as long as T is relatively small (compared to the 10,000 year time frame). Given that a seismic events occurs with PGV of v, the expected volume of lithophysal rockfall is given by:

$$E\left(V\left(v\right)\right) = P_{RF}\left(v\right) \times \mu\left(v'\right) \qquad \text{(Eq. B.2.4-8)}$$

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where $P_{RF}(v) = \min[1.0, \max(0, 1.288 \cdot v - 0.353)]$ (DTN: MO0703PASEISDA.002 [DIRS 185278], Eq. 1-1) and $v' = \max\left(v, 0.4\right)$, and $\mu\left(v'\right) = 20.307\left(v'\right)^2 - 18.023v' + 4.0102$ (DTN: MO0703PASEISDA.002 [DIRS 185278], Eqs. 1-2 and 1-3) is the mean or expected rockfall volume. Table B-2 provides results for the evaluation of Equation B.2.4-8.

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Table B-2. Expected Rockfall Volumes for Various PGV Values

PGV (v) (m/s)	$P_{RF}\left(v\right)$	$E\left(V\left(v\right)\right)$ (m^3)
0.4	0.1622	0.008129

0.5	0.291	0.021956
0.6	0.4198	0.212805
0.7	0.5486	0.737609
0.8	0.6774	1.753301
0.9	0.8062	3.416813
0.95	0.8706	4.540542
1	0.935	5.885077
1.05	0.9994	7.470033
1.1	1	8.75637
1.2	1	11.62468

Source: DTN: Output DTN: MO0810PBANLNWP.001 File: *Probability of Thermal Blanket and Localized Corrosion.xmcd.*

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From Table B-2, approximately 7.5 m^3/m occurs for events with PGV of about 1.05 m/s. From *Seismic Damage Abstractions For TSPA Compliance Case* (DTN MO0703PASEISDA.002 [DIRS 185278], Table 1-2, FD_{LITH}=1.0 cases), DS failure can occur when PGV exceeds 1.05 m/s. For simplicity, this calculation considers one seismic event occurring in the first *T* years with PGV of at least 1.05 m/s, and that the rockfall from this event is sufficient to cause a thermal blanket effect. Moreover, this calculation is conservative by considering the rockfall from the first event is sufficient to impose the maximum static load on the drip shield, therefore, the fraction of the drift filled (FD) by rockfall from the first event is set to 1. This is conservative because the volume of rockfall required to impose the maximum static load on the drip shield is uncertain and is described by a uniform distribution ranging between 30 m^3/m and 120 m^3/m (SNL 2007 [DIRS 176828], Section 6.7.1.5).

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To compute the probability of DS failure, DS corrosion can be neglected as inconsequential, so the DS thickness may be assumed to be 15 mm. For each seismic event, the seismic consequences abstraction assumes that the PGV of the event, the occurrence of rockfall and the occurrence of drip shield failure are correlated. However, the volume of rockfall is independent of these correlated values (PGV, etc.). The probability of DS failure given the occurrence of a seismic event with PGV exceeding 1.05 m/s is estimated to be 1.9 × 10^{-3}, as calculated by a Monte Carlo simulation (Output DTN: MO0810PBANLNWP.001 File: *Lith Probability of DS Failure Rev01.xmcd)*

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The probability that a seismic event with PGV exceeding 1.05 m/s occurs in the first *T* years is $\left(9.96\times10^{-6}\right)\times T$ (DTN: MO0703PASEISDA.002 [DIRS 185278], Table 1-1). Given that a seismic event with PGV exceeding 1.05 m/s occurs in the first *T* years, two outcomes are possible: 1) the DS fails due to the seismic event; 2) the DS does not fail due to the seismic event. The probability that the DS fails is $\lambda_1 = 1.9\times10^{-3}$ as previously stated, and the probability that DS failure does not occur is the complement which is 0.998.

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If the DS does not fail due to the event that occurs in the first *T* years, the DS could fail from a subsequent seismic event where the dynamic load on the DS is increased due to the rockfall from the first seismic event. The calculation of the probability of DS failure from a subsequent seismic event is simplified by the conservative assumption that the rockfall from the first event is sufficient to impose the maximum static load on the drip shield. In terms of Table 1-2 of DTN MO0703PASEISDA.002 [DIRS 185278], the fraction of drift filled by the rockfall from the first event is set to 1. This assumption is conservative because the volume of rockfall required to impose the maximum static load on the drip shield is uncertain and is described by a uniform distribution ranging between 30 m^3/m and 120 m^3/m as presented in the Seismic *Consequence Abstraction* (SNL 2007 [DIRS 176828], Section 6.7.1.5,).

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The frequency of seismic events that cause failure of the DS after the drift is filled with rubble is $\lambda_2 = 4.42\times10^{-8}\ yr^{-1}$ as shown in Output DTN: MO0810PBANLNWP.001, file: *Lith Probability of DS Failure FD EQ1 Rev01.xmcd*. This probability is obtained in the same manner as the probability of seismic drip shield failure for Mode 4 presented in Section B.2.4.1 except that the two-way interpolation presented in DTN: MO0703PASEISDA.002 ([DIRS 185278], Table 1-2) is changed to a one-way interpolation with the fraction of the drift filled with rockfall set to one, (i.e., FD=1).

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Thus the probability that a seismic event occurs in the first *T* years resulting in a thermal banket effect with subsequent drip shield failure, and that one or more of the target WPs in the lithophysal region of the repository experiences water ingress is bounded by

$$
\begin{aligned}
P &= P(seismic\ event\ in\ T\ yr)\times\left[\begin{array}{l}\left(\begin{array}{l}P(DS\ fails\ from\ first\ event)\\ \times P(water\ ingress\ after\ first\ event)\end{array}\right)\\ +\left(\begin{array}{l}P(DS\ does\ not\ fail\ from\ first\ event)\\ \times P(DS\ fails\ before\ 10{,}000\ yr\ from\ later\ event)\\ \times P(water\ ingress\ after\ DS\ failure)\end{array}\right)\end{array}\right]\\
&\le (T\times9.96\times10^{-6})\times\left[\begin{array}{l}(1.9\times10^{-3})\times1\\ +(0.998)\times((4.42\times10^{-8})\times(10{,}000-T))\times1\end{array}\right]\\
&= \begin{cases}1.86\times10^{-6} & if\ T=80\\ 6.95\times10^{-6} & if\ T=300\end{cases}
\end{aligned}
$$

(Eq. B.2.4-9)

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This calculation is provided in Output DTN: MO0810PBANLNWP.001, file *Probability of Thermal Blanket and Localized Corrosion.xmcd*.

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Inherent Conservatisms

The estimate of 6.95 × 10^{-6} (associated with *T* = 300 years)provided by Equation B.2.4-9 is a bounding estimate of the probability of water ingress into one or more of the target waste packages after seismic events during the first 300 years after repository closure have caused

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rockfall sufficient to alter waste by thermal blanket effects. This bounding estimate results from several conservative assumptions: first, that any seismic event with PGV exceeding 1.05 m/s results in rockfall sufficient to completely fill the drift (an unlikely result, see Table B2.4-1); second, that subsequent to drip shield failure, the WPOB also fails without uncertainty; and third, that if rockfall occurs, then all WP in the target population are subject to the thermal blanketing effects. In actuality, WPOB failure would depend probabilistically on the occurrence of early failure, seismic damage or localized corrosion, the models for which entail significant uncertainty (as discussed in the analyses for Modes 2D, 3D and 4D). In addition, WP temperatures show wide variability between spatial locations in simulations of the repository (SNL 2008 [DIRS 184433], Section 6.3.13), so it is possible that no WP in the target group would experience temperatures sufficient to cause adverse changes in the waste. These simplifying and conservative assumptions combine to yield a bounding estimate from Equation B.2.4-9. It should also be noted that this calculation relies on the conservative assumptions made in describing the effects of seismic ground motion on drip shields (SNL 2007 [DIRS 176828]), and no credit taken for the residual performance of the emplacement drift ground support which would limit rockfall during the first 300 years after closure.

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Uncertainty in Results

The results computed from Equation B.2.4-9 reflect aleatory uncertainty in the number and nature of seismic events that can occur in 10,000 years after repository closure. These aleatory uncertainties are addressed by the calculation of $\lambda_1 = 1.9 \times 10^{-3}$, and in the calculation of $\lambda_2 = 4.42 \times 10^{-8}\ yr^{-1}$, the frequency of events that result in drip shield failure after the drift is filled with rubble. The spatial location of navy SNF waste packages within the repository is addressed by means of a conservative assumption. In addition, the epistemic uncertainties that could affect the performance of the waste package outer barrier after drip shield failure have also been addressed by means of conservative assumptions. Because of this treatment, Equation B.2.4-9 yields a bounding value rather than a distribution of results.

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Changes to addendum CAL-DN0-NU-000002 REV 00C AD01:

(C14) Change Table 4-1[a] as follows:

Table 4-1[a]. Direct Inputs Used in Calculation

Input Description	Data Tracking Number/Source	Value
Base case time period that waste package surface temperature is above 200°C	SNL 2008 [DIRS 179962], Section 6.4.2.5, Figure 6.4.2-28	300 years
TSPA localized corrosion results used in Output DTN: MO0803SUPPANWP.000, file *Lith LC Calculation Rev06.xmcd*	DTN: MO0709TSPALOCO.000 [DIRS 185808], folder *TSPA-LA\CM\DTN_Prep\DTNs\ MO0709TSPALOCO.000_rev001\ Files_to_TDMS\ Additional Information\ LC_for_Criticality*	*Lith_Fraction_LC_CSNF_Bin1.txt* *Lith_Fraction_LC_CSNF_Bin2.txt* *Lith_Fraction_ LC_CSNF_Bin3.txt* *Lith_Fraction_ LC_CSNF_Bin4.txt* *Lith_Fraction_ LC_CSNF_Bin5.txt*
Hazard curve relationship to exceedance frequency and PGV	DTN: MO0703PASDSTAT.001 [DIRS 185275], file: *Lith_Rubble_Abstraction.xls*, worksheet: *Data for Bounded Hazard*	See output DTN: MO0803SUPPANWP.000, file: *Thermal Blanket Effect in First T Years Rev01.xmcd*
Probability that a seismic event causes drip shield damage in lithophysal zone	DTN: MO0703PASEISDA.002 [DIRS 185278], Table 1-2	See output DTN: MO0803SUPPANWP.000, file: *Lith Probability of DS Failure For a Single Event Rev03.pdf*
PGV frequency for probability of nonzero rockfall in lithophysal zone	SNL 2007 [DIRS 176828], Section 6.7.1.1	$P_{rockfall} = MIN(1.0, MAX(0.0, (1.288)PGV - 0.353))$.
Regulatory limit for screening	10 CFR 63.114(d) [DIRS 180319]	One chance in 10,000 over 10,000 years

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(C15) Bottom of page 4 of AD01 should be replaced with the following:

Eq. 3[a] should be replaced with $P(1 \mid \lambda, T) = T \cdot \lambda(0.274) \cdot e^{-T \cdot \lambda(0.274)}$

$$P_E = T \cdot \lambda(0.274) \cdot e^{-T \cdot \lambda(0.274)} \cdot P_{RF} \qquad \text{(Eq. 4[a])}$$

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For T = 300 years, P_E = 0.0149 (output DTN: MO0803SUPPANWP.000, file: *Thermal Blanket Effect in First T Years Rev01.xmcd*).

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(C16) p. 5, 4th paragraph of AD01 the value $P_L = 7.42 \times 10^{-5}$ should now be 3.85×10^{-5}

(C17) Section 7[a], 1st and 2nd paragraphs value of 6.96×10^{-6} should now be 5.92×10^{-6}

(C18) Section 8.3[a] changed from

182994 MO0709TSPALOCO.000. TSPA Localized Corrosion Analysis. Submittal date: 09/13/2007.

to

185808 MO0709TSPALOCO.000. TSPA Localized Corrosion Analysis. Submittal date: 10/20/2008.

ATTACHMENT II: IMPACT EVALUATION RESULTS

The following impacts were observed:

1) LA-SAR — Some values listed in Section 2.2.1.4 will need to be updated to reflect the changes that are propagated through from this ERD. Pages 2.2-54 and 2.2-55 are affected.
2) ANL-DS0-NU-000001 Rev. 00 ACN01 – Source DTN: MO0712PANLNNWP.000 [DIRS 184480] will need to be updated as it is being superseded by DTN: MO0810PANLNNWP.001. This will result in a revision to the DTN: MO0705CRITPROB.000 and changes to values listed in Table 6.4-7 and Table 7.1-1.
3) ANL-WIS-MD-000027 REV 00 ACN01 – Source DTNs: MO0712PANLNNWP.000 and MO0712PBANLNWP.000 have been superseded and will need to be updated.

No other documents have been identified as impacted by any change from this ERD.

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Repository geographic and geologic location	SNL 2007 [DIRS 179466], Table 4-1, Item 01-01 and 01-03	15% of repository is in the nonlithophysal unit and 85% is in the lithophysal unit

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$$\begin{aligned}\lambda_{NL} &= \lambda(v_{\min}) \times (1 - P(f_{DS} = 0)) \\ &= \lambda(v_{\min}) \times \left(\sum_{1}^{4} P\left(f_{DS} = \frac{k}{4} \right) \right) \\ &= \lambda(v_{\min}) \times \left(\sum_{1}^{4} d_{f_{DS}} \left(\frac{k}{4} \right) \right)\end{aligned} \qquad \text{(Eq. B.2.3-8)}$$

λ_{NL} is small enough (~10^{-6} yr^{-1}) that only one event that causes rupture of drip shields within 10,000 years needs to be considered.

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and the probability that no waste package in the target group, in the nonlithophysal tuff, is affected by the combination of drip shield rupture by seismically induced rockfall, followed by localized corrosion of the WPOB, in 10,000 years is given by

$$P(NLC = 0 | \mathbf{r}) = \prod_{b=1}^{5} (1 - P(NLC(b | \mathbf{r}))) \qquad \text{(Eq. B.2.3-12)}$$

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the complement, or averaging the epistemic uncertainty in the probability of drip shield early failure and in localized corrosion, represented by **r**, results in a distribution of values for $P(NLC \geq 1)$.