YMP	Model Error Resolution Document *Complete only applicable items.*	QA: QA Page 1 of 58

1. Document Number:	MDL-NBS-HS-000020	2. Revision/Addendum:	REV02 AD 02	3. ERD:	ERD 04
4. Title:	Particle Tracking Model and Abstraction of Transport Processes				
5. No. of Pages Attached:	57				

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

This ERD is prepared to evaluate the impact of changes to the thorium sorption coefficient distributions (which were recommended for the impact analysis in order to resolve CR11020 (MDL-NBS-HS-000008 REV02 AD01 ERD02, in preparation)) on the UZ transport calculations (*Particle Tracking Model and Abstraction of Transport Processes*, MDL-NBS-HS-000020 REV02 AD 02 [DIRS 184748]) that supported the TSPA-LA, and on the TSPA LA model.

CR 11020:

Condition Description:

"DTN: LA0305AM831341.001 contains classifications for some tuff samples that are internally inconsistent or inconsistent with other data. This DTN (an unqualified DTN) reports K_d values (sorption distribution coefficients) for nine elements on vitric, devitrified, and zeolitic tuff. One tuff sample (G1-2698) is classified as devitrified in the DTN. However, report LA-11669-MS [DIRS 101374], Appendix 1, p. 15 reports an XRD analysis that would make it zeolitic. Three other samples are given different classifications in different places within the DTN: Sample G1-2689 is described as both devitrified and zeolitic in the spreadsheet for U, and as zeolitic on spreadsheets for other elements. Sample JA-18 is described as zeolitic on the spreadsheet for Am, but vitric on the spreadsheets for U and Pu. Sample G1-3316 is described as devitrified on the spreadsheet for Th, but zeolitic on the spreadsheets for other elements."

Note: above condition description incorrectly refers to samples G1-2689 and G1-3316. The correct sample numbers are G1-2698 and G1-3116, respectively according to DTN: LA0803AM831341.001 which supersedes DTN: LA0305AM831341.001. Resolution of CR 11020, including corrections to the tuff sample classifications and supersession of DTNs: LA0305AM831341.001, LA0310AM831341.001, LA0407AM831341.005, is documented in MDL-NBS-HS-000008 REV 02 AD 01 ERD 02.

To resolve CR11020, a new set of sorption coefficient distributions for thorium (Th) was recommended for impact analysis (MDL-NBS-HS-000008 REV02 AD01 ERD 02, DTN: LA0809SL831341.001 [DIRS 185795]). The impact of this suggested change in the Th K_d distributions to the UZ transport model has been evaluated by rerunning the FEHM calculation using the recommended K_d distributions for Th, and developing figures and tables corresponding to and for comparison with Figures 6.6.2-5[b],6.6.2-7[b], and D.2-3[b] through D.2-9[b] and Tables 6.6.1-1, 6-7 and 8-2 of MDL-NBS-HS-000020 REV02 AD 02 [DIRS 184748]. The result of this FEHM calculation is documented in sections III.1 and III.2 of this ERD. <u>Note: these modifications and reruns are done solely for supporting the impact analysis</u>

(see attached)

7. CONCURRENCE

	Printed Name	Signature	Date
Checker	James D. Schreiber	*James D. Schreiber*	1/7/2009
QCS/QA Reviewer	Peter Persoff	*Peter Persoff*	01/07/2009

8. APPROVAL

	Printed Name	Signature	Date
Originator	Shaoping Chu/Bruce Robinson	*Shaoping Chu/Bruce Robinson*	1/7/2009
Responsible Manager	Robert MacKinnon	*Robert MacKinnon*	01/09/2009

(continued from Block 6)

discussed in this ERD, they will not result in a change to baseline documents, nor replace the feed to the TSPA LA model. All references to thorium sorption coefficient changes in this ERD refer to the suggested-for-impact-analysis thorium K_d distributions developed in MDL-NBS-HS-000008 REV02 AD01 ERD 02 (DTN: LA0809SL831341.001 [DIRS 185795]), and are only for the purpose of impact analysis in this ERD. This ERD also captures a TSPA impact analysis of K_d distributions for Th as modified for this impact analysis on dose calculations (documented in section III.3 and Appendix A, DTN: MO0810LLAMDLIA.000). These changes do not affect the conclusions of MDL-NBS-HS-000020 REV 02 AD 02 [DIRS 184748].

II Inputs and Software

Inputs to this error resolution analysis for FEHM rerun part (sections III.1 and III.2) include the following DTNs: MO0705TRANSTAT.000 REV 002 [DIRS 185512], which is a product output from MDL-NBS-HS-000020 REV02 AD 02 [DIRS 184748]); and new Th K_d DTN: LA0809SL831341.001 [DIRS 185795], which gives the recommended Th K_d range and uniform distribution for the impact analysis discussed in this ERD. Other inputs to this analysis are the same as presented in MDL-NBS-HS-000020 REV 02 AD 02 [DIRS 184748] and are not repeated here. The inputs and software for TSPA impact analysis are discussed in Section III.3 and Appendix A and are listed in section A.4 of Appendix A. For this ERD impact analysis, the only change to all the model runs inputs is thorium K_d distributions recommended by MDL-NBS-HS-000008 REV02 AD01 ERD 02 (DTN: LA0809SL831341.001 [DIRS 185795]). All other inputs were unchanged.

The software codes controlled under IM-PRO-003, *Software Management*, used in this ERD are summarized in Tables II-1. The computer software code on which the UZ transport abstraction model is based is FEHM V. 2.24-01 (STN: 10086-2.24-01-00 [DIRS 179419]). This software was developed for use in this and other YMP applications and has been tailored for this application through the formal software development process. The qualification status of this and other software is indicated in the electronic Document Input Reference System (DIRS) database. All software was obtained from Software Configuration Management and is appropriate for the application. Qualified codes were used only within the range of validation.

Table II-1. Qualified Software Used in This Report

Software Title/Version (v)	Software Tracking Number	Platform/Operating System	Code Usage	DIRS
FEHM V. 2.24-01	10086-2.24-01-00	PC/Windows 2000, 2003, & XP, Red Hat Linux 2.4.21, and SUN/OS 5.9	Simulation of particle tracking base-case runs; abstraction model simulations	[DIRS 179419]

Software Title/Version (v)	Software Tracking Number	Platform/Operating System	Code Usage	DIRS
GoldSim V. 9.60.300	10344-9.60-03	WIN 2000, WINXP, WIN2003	The TSPA-LA Model uses GoldSim, an object oriented simulation software, as a driver, or integration software, to couple the model components and submodels used to simulate the performance of the repository. Model components and submodels are implemented within the framework of the GoldSim model structure or run externally using DLLs controlled by the GoldSim model. GoldSim's Monte Carlo sampling structure is used to evaluate the influence of parameter uncertainty on repository performance.	[DIRS 184387]

Following is a list of references used for this ERD:

185795 LA0809SL831341.001. Thorium Sorption Distributions. Submittal Date: 10/03/2008

177396 SNL (Sandia National Laboratories) 2007. *Radionuclide Transport Models Under Ambient Conditions.* MDL-NBS-HS-000008 REV 02 ADD 01. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20050823.0003; DOC.20070718.0003; DOC.20070830.0005; LLR.20080324.0002.

180319 10 CFR 63. 2007. Energy: Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada. Internet Accessible.

185836 40 CFR 197. 2008. Protection of Environment: Public Health and Environmental Radiation Protection Standards for Yucca Mountain, Nevada. Internet Accessible.

177424 SNL (Sandia National Laboratories) 2007. *Radionuclide Screening.* ANL-WIS-MD-000006 REV 02, Las Vegas, Nevada.

183478 SNL (Sandia National Laboratories) 2008. *Total System Performance Assessment Model /Analysis for the License Application.* MDL-WIS-PA-000005 REV 00 AD 01, Las Vegas, Nevada.

179419 FEHM V. 2.24-01. 2007. WIN2003, 2000, & XP, Red Hat Linux 2.4.21, OS 5.9. STN: 10086-2.24-01.00.

184387 GoldSim V. 9.60.300. 2008. WIN 2000, WINXP, WIN2003. STN: 10344-9.60-03.

III Analysis and Results

To conduct the impact evaluation for CR 11020, UZ transport simulations described in Section 6.6.2.2[b] and D.2[b] of MDL-NBS-HS-000020 REV02 AD 02 [DIRS 184748] were repeated using the recommended K_d distributions for Th, but with the same methodology and all other inputs. The following subsections (III.1 and III.2) present results of these new simulations. The developed DTN includes input and output files of the new simulations. The new DTN is: MO0810UZRNTCTH.000. Subsection III.3 and Appendix A discuss TSPA impact analysis. The developed DTN for TSPA impact analysis is DTN: MO0810LLAMDLIA.000.

III.1 Thorium K_d distribution changes

1) The original Th K_d distributions presented in MDL-NBS-HS-000020 REV02 AD 02 [DIRS 184748] Table 6-7 are listed in Table III.1-1:

Table III.1-1 Original Thorium K_d distributions

Species	Rock Type	Type of Uncertainty Distribution	Coefficients Describing Distribution K_d (mL/g)
Th	Zeolitic	Uniform	Range = 1000 – 30000
	Devitrified	Uniform	Range = 1000 – 10000
	Vitric	Uniform	Range = 1000 - 10000

The recommended K_d distributions for Th to be used in this impact analysis are obtained from MDL-NBS-HS-000008 REV 02 AD 01 ERD 02 (Table B-1, DTN: LA0809SL831341.001) and are listed in Table III.1-2.

Table III.1-2 Recommended Thorium K_d distributions Used in This Impact Analysis

Species	Rock Type	Type of Uncertainty Distribution	Coefficients Describing Distribution K_d (mL/g)
Th	Zeolitic	Uniform	Range = 1000 - 30000 (no change)
	Devitrified	Uniform	Range = 900 - 4000
	Vitric	Uniform	Range = 300 - 2000

2) The thorium K_d values used for the representative-case UZ transport model presented in Table 6.6.1-1 of MDL-NBS-HS-000020 REV 02 AD 02 [DIRS 184748] were the mean values of the distributions shown in Table III.1-1, and are listed in Table III.1-3, where "Key" is representative-case K_d value for thorium in three rock groups (group1: Zeolitic; group2: Devitrified; group3: Vitric).

Table III.1-3 Original Representative-Case Thorium K_d Values Used for UZ Transport Model

Key	Parameter Type	Value, K_d (mL/g)
-95	Th in Rock Group 1	15500
-96	Th in Rock Group 2	5500
-97	Th in Rock Group 3	5500

The recommended representative-case thorium K_d values for this impact analysis are mean values of the recommended K_d distributions and are listed in Table III.1-4, where "Key" is representative-case K_d value for thorium in three rock groups (group1: Zeolitic; group2: Devitrified; group3: Vitric).

Table III.1-4 Recommended Representative-Case Thorium K_d values for UZ Transport Model Used in This Impact Analysis

Key	Parameter Type	Value, K_d (mL/g)
-95	Th in Rock Group 1	15500
-96	Th in Rock Group 2	2450
-97	Th in Rock Group 3	1150

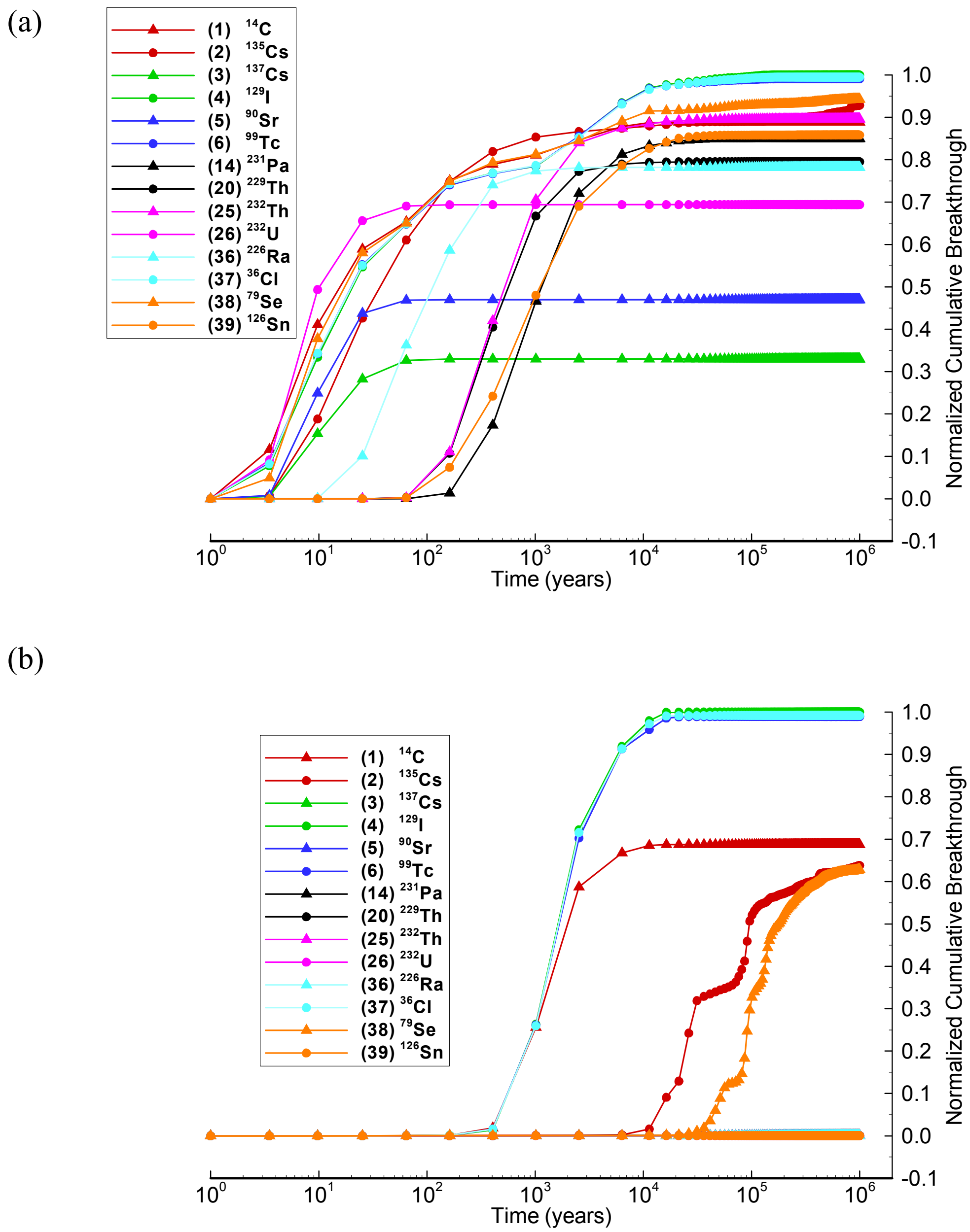
Also, the symbol for strontium in the list of radionuclides in the notes to MDL-NBS-HS-000020 REV 02 AD 02 [DIRS 184748], Table 6.6.1-1 is corrected to (Sr).

III.2 Breakthrough Curves Evaluation

This section evaluates the impact of the modified thorium K_d distributions developed for this analysis in DTN: LA0809SL831341.001 [DIRS 185795] on the representative-case UZ transport calculations.

Figure 6.6.2-5[d] shows the normalized cumulative breakthrough curves for all species modeled as simple decay radionuclides (^{14}C, ^{135}Cs, ^{137}Cs, ^{129}I, ^{90}Sr, ^{99}Tc, ^{231}Pa, ^{229}Th, ^{232}Th, ^{232}U, ^{226}Ra, ^{36}Cl, ^{79}Se, and ^{126}Sn), corresponding to Figure 6.6.2-5[b] in MDL-NBS-HS-000020 REV 02 AD 02 [DIRS 184748] and Figure 2.3.8-43 in the Safety Analysis Report (SAR). The upper figure presents breakthrough curves for the northern release location, while the lower figure shows the breakthrough curves for the southern release location.

The results using the recommended Th K_d distributions are different from the corresponding results in MDL-NBS-HS-000020 REV 02 AD 02 [DIRS 184748] (Figure 6.6.2-5[b]) in that Th breaks through approximately 500 years earlier (50% breakthrough) for the northern release with the K_d changes. The southern release results remain essentially the same with very low normalized Th breakthrough of less than 0.001. Despite the difference shown here, the conclusion reached in MDL-NBS-HS-000020 REV 02 AD 02 [DIRS 184748] still remains the same.



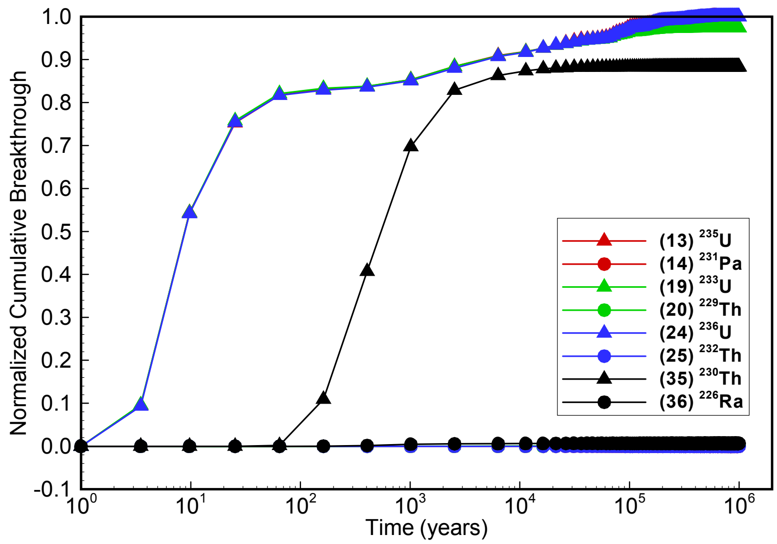
DTN: MO0810UZRNTCTH.000

NOTE: (a) Northern Release Location, (b) Southern Release Location.

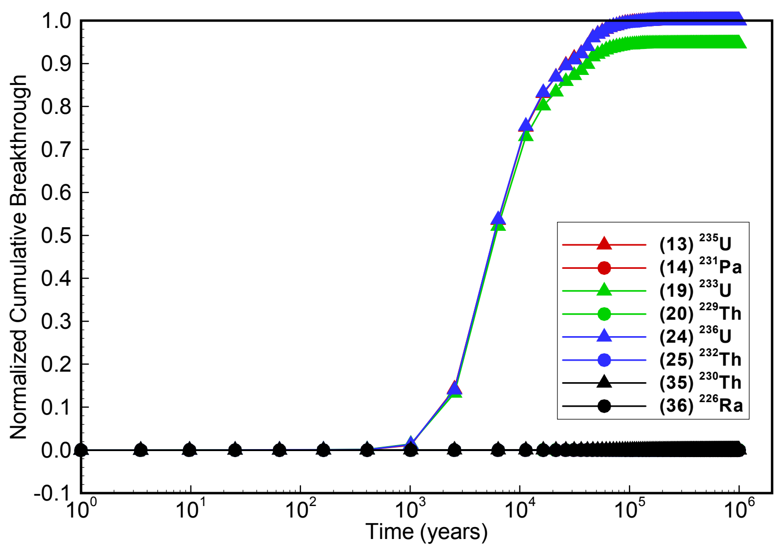
Figure 6.6.2-5[d] Normalized Cumulative Breakthrough Curves of 14 Radionuclides with Simple Decay for the Glacial-Transition 10th Percentile Infiltration Condition and Representative Parameter Values, Using the Th K_d Distributions as Recommended for This Analysis (DTN: LA0809SL831341.001[DIRS 185795]).

Figure 6.6.2-7[d], which corresponds to Figure 6.6.2-7[b] in MDL-NBS-HS-000020 REV 02 AD 02 [DIRS 184748], presents normalized breakthrough curves for radionuclide ^{235}U, ^{233}U, ^{236}U, and ^{230}Th and their daughter products ^{231}Pa, ^{229}Th, ^{232}Th, and ^{226}Ra, respectively for the two release locations. These results using the Th K_d distributions as recommended for this analysis are essentially the same as in MDL-NBS-HS-000020 REV 02 AD 02 [DIRS 184748].

(a)



(b)

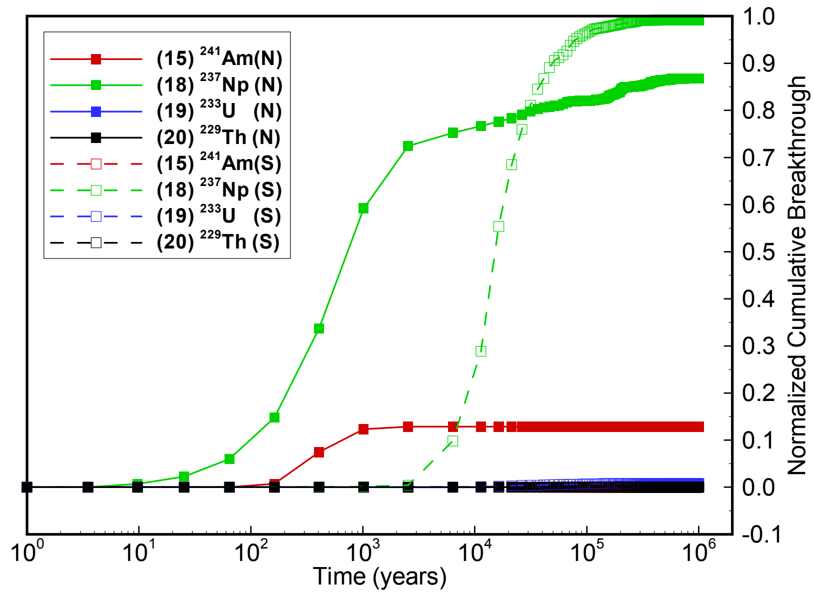


DTN: MO0810UZRNTCTH.000

NOTE: (a) Northern Release Location, (b) Southern Release Location.
^{229}Th is Hidden below the other Near-Zero Value Lines.

Figure 6.6.2-7[d] Normalized Cumulative Breakthrough Curves of Four Radionuclides (^{235}U, ^{233}U, ^{236}U, and ^{230}Th) with One Decay Chain for the Glacial-Transition 10th Percentile Infiltration Condition and Representative Parameter Values, Using the Th K_d Distributions as Recommended for This Analysis (DTN: LA0809SL831341.001[DIRS 185795]).

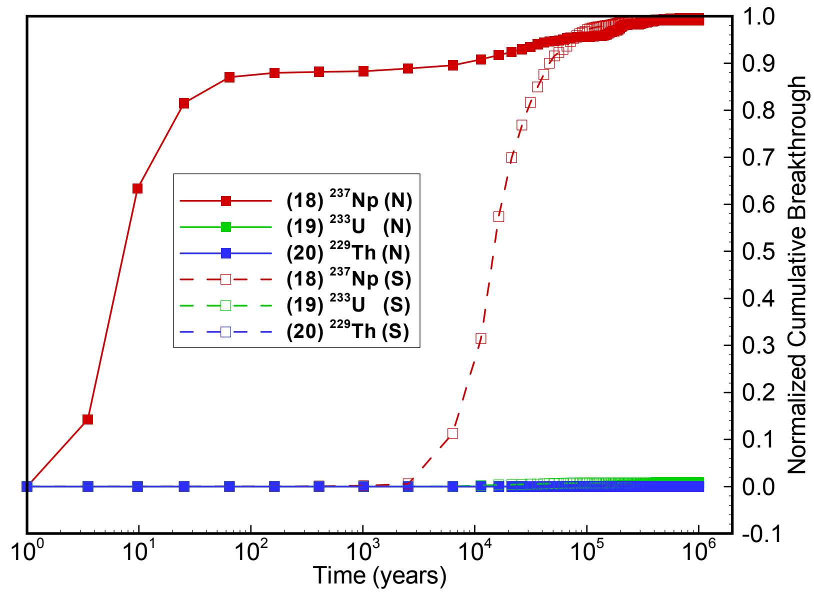
The following figures present more UZ radionuclide transport breakthrough curve simulation results for decay chains. Figures D.2-3 [d] through D.2-8[d] correspond to Figures D.2-3[b] through D.2-8[b] in MDL-NBS-HS-000020 REV 02 AD 02 [DIRS 184748] and SAR Figures 2.3.8-44(a), 2.3.8-44(b), 2.3.8-47(a), 2.3.8-45(a), 2.3.8-47(b), 2.3.8-45(b), respectively; Figure D.2-9[d] corresponds to Figure D.2-9[b] in MDL-NBS-HS-000020 REV 02 AD 02 [DIRS 184748]. The results using the Th K_d distributions as recommended for this analysis are essentially the same as in MDL-NBS-HS-000020 REV 02 AD 02 [DIRS 184748], in all cases with very low normalized Th breakthroughs of either zero or less than 0.002.



DTN: MO0810UZRNTCTH.000

NOTE: ^{229}Th is Hidden below the other Near-Zero Value Lines.

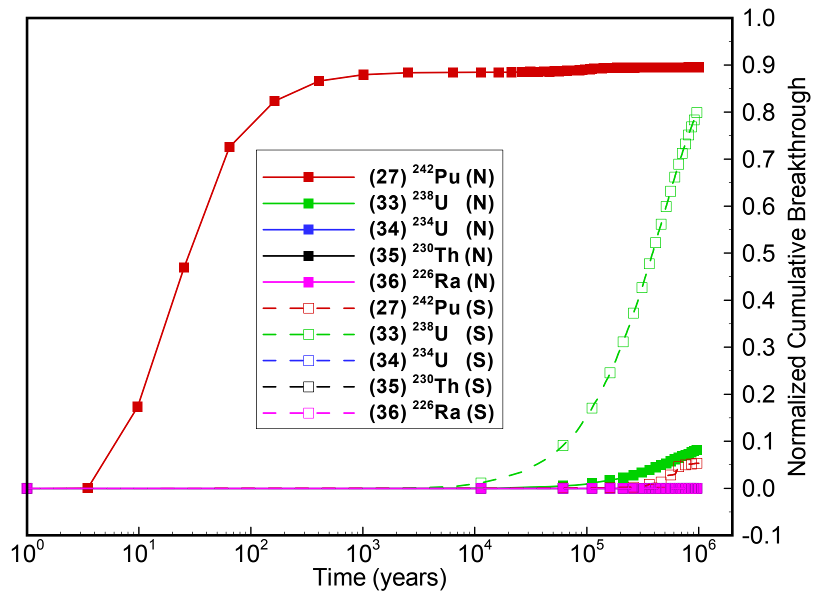
Figure D.2-3[d] Normalized Cumulative Breakthrough Curves of Decay Chain ^{241}Am→ ^{237}Np → ^{233}U → ^{229}Th for the Glacial-Transition, 10th Percentile Infiltration Condition, Representative Parameter Values, Northern and Southern Release Nodes, Using the Th K_d Distributions as Recommended for This Analysis (DTN: LA0809SL831341.001[DIRS 185795]).



DTN: MO0810UZRNTCTH.000

NOTE: ^{229}Th is Hidden below the other Near-Zero Value Lines.

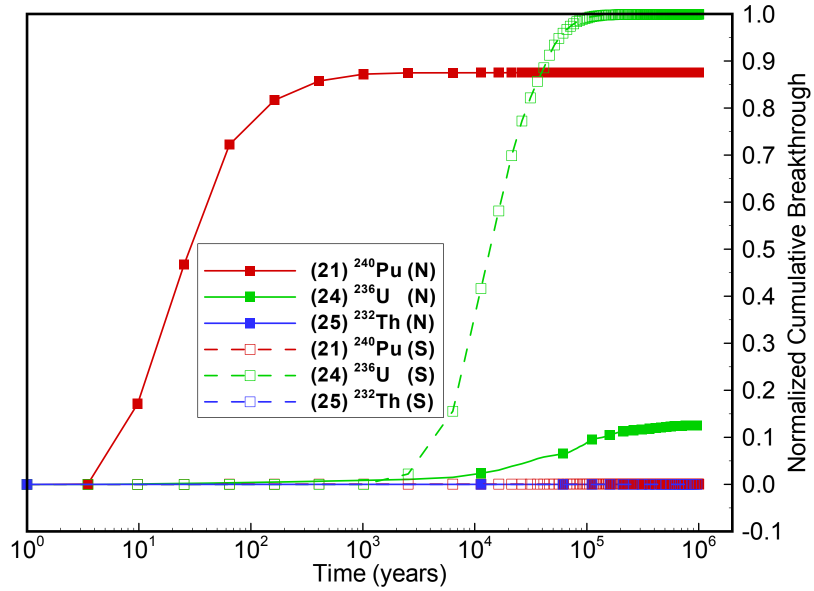
Figure D.2-4[d] Normalized Cumulative Breakthrough Curves of Decay Chain ^{237}Np→ ^{233}U → ^{229}Th for the Glacial-Transition, 10th Percentile Infiltration Condition, Representative Parameter Values, Northern and Southern Release Nodes, Using the Th K_d Distributions as Recommended for This Analysis (DTN: LA0809SL831341.001[DIRS 185795]).



DTN: MO0810UZRNTCTH.000

NOTE: ^{230}Th is Hidden below the other Near-Zero Value Lines.

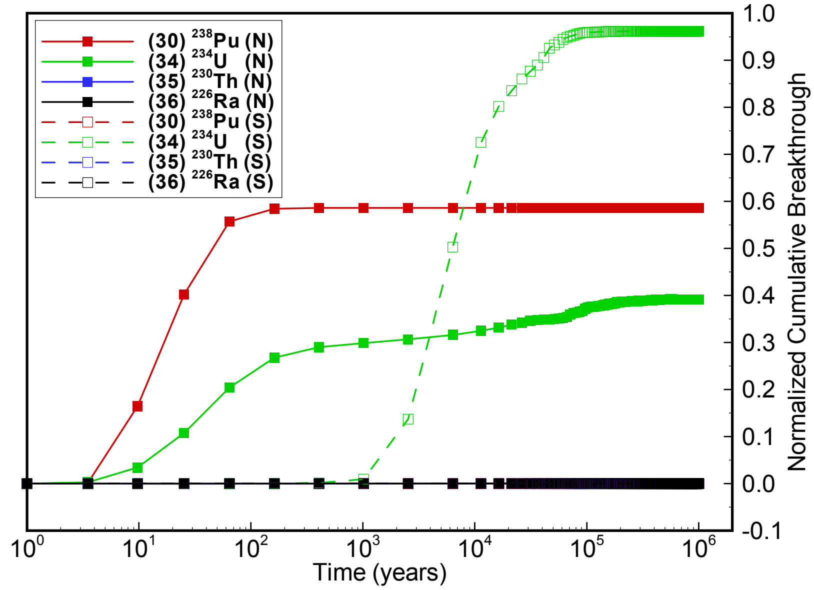
Figure D.2-5[d] Normalized Cumulative Breakthrough Curves of Decay Chain ^{242}Pu→ ^{238}U → ^{234}U → ^{230}Th→ ^{226}Ra for the Glacial-Transition, 10th Percentile Infiltration Condition, Representative Parameter Values, Northern and Southern Release Nodes, Using the Th K_d Distributions as Recommended for This Analysis (DTN: LA0809SL831341.001[DIRS 185795]).



DTN: MO0810UZRNTCTH.000

NOTE: ^{230}Th is Hidden below the other Near-Zero Value Lines.

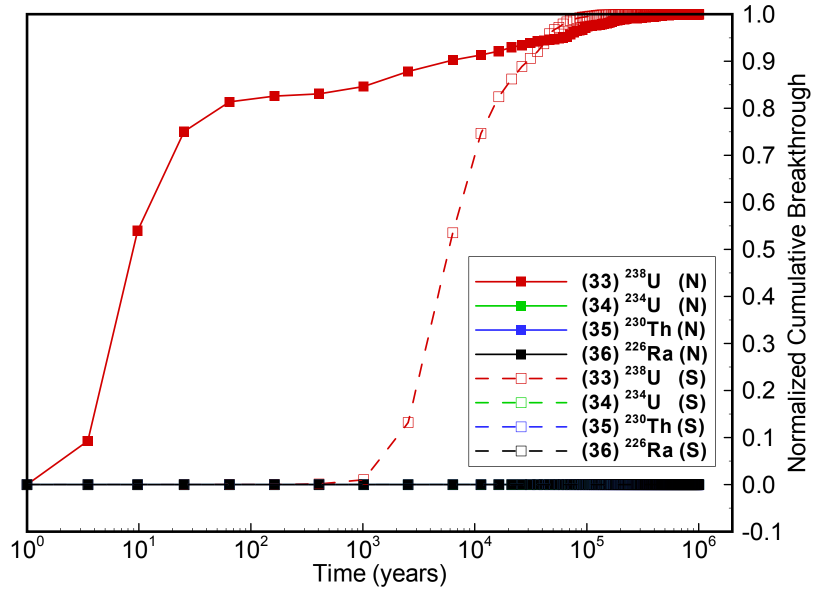
Figure D.2-6[d] Normalized Cumulative Breakthrough Curves of Decay Chain ^{240}Pu → ^{236}U→ ^{232}Th for the Glacial-Transition, 10th Percentile Infiltration Condition, Representative Parameter Values, Northern and Southern Release Nodes, Using the Th K_d Distributions as Recommended for This Analysis (DTN: LA0809SL831341.001[DIRS 185795]).



DTN: MO0810UZRNTCTH.000

NOTE: ^{230}Th is Hidden below the other Near-Zero Value Lines.

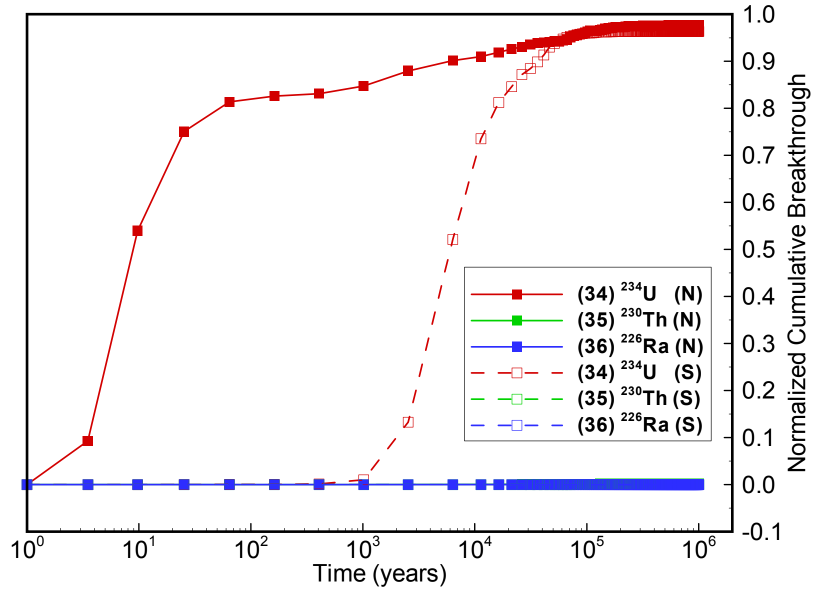
Figure D.2-7[d] Normalized Cumulative Breakthrough Curves of Decay Chain ^{238}Pu → ^{234}U→ ^{230}Th→ ^{226}Ra for the Glacial-Transition, 10th Percentile Infiltration Condition, Representative Parameter Values, Northern and Southern Release Nodes, Using the Th K_d Distributions as Recommended for This Analysis (DTN: LA0809SL831341.001[DIRS 185795]).



DTN: MO0810UZRNTCTH.000

NOTE: ^{230}Th is Hidden below the other Near-Zero Value Lines.

Figure D.2-8[d] Normalized Cumulative Breakthrough Curves of Decay Chain ^{238}U → ^{234}U→ ^{230}Th →^{226}Ra for the Glacial-Transition, 10th Percentile Infiltration Condition, Representative Parameter Values, Northern and Southern Release Nodes, Using the Th K_d Distributions as Recommended for This Analysis (DTN: LA0809SL831341.001[DIRS 185795]).



DTN: MO0810UZRNTCTH.000

NOTE: ^{230}Th is Hidden below the other Near-Zero Value Lines.

Figure D.2-9[d] Normalized Cumulative Breakthrough Curves of Decay Chain ^{234}U→ ^{230}Th →^{226}Ra for the Glacial-Transition, 10th Percentile Infiltration Condition, Representative Parameter Values, Northern and Southern Release Nodes, Using the Th K_d Distributions as Recommended for This Analysis (DTN: LA0809SL831341.001[DIRS 185795]).

III.3 TSPA Impact Analysis

As part of the resolution of CR11020 (MDL-NBS-HS-000008 REV 02 AD 01 ERD 02, in preparation) an analysis was performed to study the impact to the TSPA-LA Model of implementing suggested changes of thorium sorption coefficient in unsaturated zone units. These changes would affect both the EBS and the UZ releases of ^{229}Th, ^{230}Th, and ^{232}Th, as well as ^{226}Ra and ^{228}Ra the daughter products of ^{230}Th and ^{232}Th, respectively. In order to quantify the effect of the suggested thorium K_d changes on the TSPA results, six modeling cases were selected to compare to the original (base case) (SNL 2008 [DIRS 183478]). The selected modeling cases were:

- Igneous Intrusion (IG) modeling case for one million years
- Seismic Ground Motion (SM) modeling case for one million years
- Seismic Ground Motion (SM) modeling case for 10,000 years
- Drip Shield Early Failure (ED) modeling case for 10,000 years
- Waste Package Early Failure (EW) modeling case for 10,000 years

- Human Intrusion (HI) modeling case for one million years.

The IG and SM one-million year cases were chosen because these cases dominate the total mean dose for 1,000,000 years (SNL 2008 [DIRS 183478], Figure 8.1-3[a]). The 10,000-year modeling cases were simulated because they are used to estimate the Total Radium and Gross Alpha Emitter (excluding radon and uranium isotopes) activity concentrations in groundwater for the TSPA-LA AMR (SNL 2008 [DIRS 183478], Figure 8.1-9[a] and Figure 8.1-11[a]). Total Radium activity concentration is a function of concentrations of ^{226}Ra and ^{228}Ra which are daughter products of ^{230}Th and ^{232}Th. The HI model was also run to see the effects on the mean dose from human intrusion presented in SNL 2008 [DIRS 183478], Figure 8.1-16[a].

In addition, an evaluation of the simulations performed to support the validity of using CSNF as a surrogate for naval spent nuclear fuel (NSNF) (SNL 2008 [DIRS 183478], Section 7.5.3.2) is also presented. These simulations include the 10,000 year ED and IG Modeling Cases with sources comprising single CSNF and NSNF waste packages.

To evaluate the impact of changes in the thorium K_d distributions on the TSPA-LA, the data input file for the FEHM DLL (2007 [DIRS 179419] and SNL 2008 [DIRS 183478], Section 6.3.9), which is used in the TSPA-LA Model to simulate radionuclide transport in the UZ (SNL 2008 [DIRS 183478], Section 6.3.9), was updated. The data elements for thorium K_ds were re-sampled using the new thorium K_d distributions for devitrified and vitrified tuffs presented in Table A-2. All other sampled elements were unchanged. The results for the TSPA-LA modeling cases and for the simulations using the updated data input file were then compared to evaluate the potential impact on the TSPA-LA Model results.

The following summarizes the results of the TSPA-LA modeling cases evaluated in this analysis, and how the TSPA-LA model would be impacted by the changes in thorium K_d distributions. Additional discussion of the results of this analysis, including the EBS and UZ releases of ^{230}Th and its daughter product ^{226}Ra, are presented in Appendix A.

The results from the IG one-million-year Modeling Case are presented in Figure A-2. As can be seen in the Figure A-2, there is small difference between the mean annual dose results from the TSPA-LA simulations and those considering the new thorium K_d distributions. For the IG Modeling Case for one million years, the change in thorium K_d distributions increased the mean annual dose by 10% at the end of the simulation. The mean annual dose results from the SM one-million-year Modeling Case are presented in Figure A-11 and also show little change. For the SM one-million-year Modeling Case, the change in thorium K_d distributions increased the mean annual dose by only 3.7% at the end of the simulation. Because these two modeling cases dominate the total dose results for one million years, it can be surmised that any conclusions presented in SNL 2008 ([DIRS 183478], Section 8.1.1.2[a]) based on total dose will not change.

A similar comparison of the mean annual dose results for the HI Modeling Case is presented in Figure A-14. Little difference can be seen between the TSPA-LA modeling results and those considering the new thorium K_d distribution. Thus conclusions based on the HI results presented in the TSPA-LA AMR (SNL 2008 [DIRS 183478], Section 8.1.3.2[a]) would be unaffected by the changes in the thorium K_d distributions for devitrified and vitrified tuffs.

The mean activity concentration of radium from the TSPA-LA model was also evaluated for the impact of changing the thorium K_d distributions. As can be seen in Figure A-20, a comparison of the mean values of total radium concentration, which are based on the summation of the mean ^{226}Ra and ^{228}Ra concentrations from the 10,000-year ED, EW and SM Modeling Cases, shows that the impact of changing the thorium K_d distributions is negligible. Thus conclusions based on the mean activity concentrations of radium presented in the TSPA-LA AMR (SNL 2008 [DIRS 183478], Section 8.1.2.1[a]) would be unaffected by the changes in the thorium K_d distributions for devitrified and vitrified tuffs. Likewise, the mean activity concentration of alpha-emitters from the TSPA-LA model was also evaluated for the impact of changing the thorium K_d distributions. As can be seen in Figure A-21, a comparison of the mean values of alpha-emitter concentration, which are based on the summation of the mean alpha-emitter concentrations from the 10,000-year ED, EW and SM Modeling Cases, shows that the impact of changing the thorium K_d distributions is negligible. Thus conclusions based on the mean activity concentrations of alpha-emitters presented in the TSPA-LA AMR (SNL 2008 [DIRS 183478], Section 8.1.2.2[a]) would be unaffected by the changes in the thorium K_d distributions for devitrified and vitrified tuffs.

The impact of changes in the thorium K_d distributions on conclusions pertaining to the validity of using CSNF as a surrogate for NSNF has also been examined (Section A.3.9). This examination demonstrated that conclusions presented in SNL 2008 [DIRS 183478] (Section 7.5.3[a]) regarding the representation of NSNF would not be impacted by the described changes in thorium K_ds.

IV Impact Evaluation

The following DIRS Impact Analysis report lists documents that either reference MDL-NBS-HS-000020 (*Particle Tracking Model and Abstraction of Transport Processes*) and/or use it as input. These documents could be impacted if MDL-NBS-HS-000020 were changed.

Document Input Reference System

Impact Analysis

184748	SNL (Sandia National Laboratories) 2008. *Particle Tracking Model and Abstraction of Transport Processes.* MDL-NBS-HS-000020 REV 02 AD 02. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20080129.0008; DOC.20070920.0003; LLR.20080325.0287; LLR.20080522.0170; LLR.20080603.0082.

Controlled

ANL-NBS-HS-000039 Rev. 02
Saturated Zone In-Situ Testing

ANL-WIS-MD-000024 Rev. 01
Postclosure Nuclear Safety Design Bases

ANL-WIS-MD-000027 Rev. 00
Features, Events, and Processes for the Total System Performance Assessment: Analyses

MDL-WIS-PA-000005 Rev. 00, Addendum 01
Total System Performance Assessment Model/Analysis for the License Application

MDL-WIS-PA-000005 Rev. 00, MiscId 01
Total System Performance Assessment Model/Analysis for the License Application - Volume I

MDL-WIS-PA-000005 Rev. 00, MiscId 02
Total System Performance Assessment Model/Analysis for the License Application - Volume II

MDL-WIS-PA-000005 Rev. 00, MiscId 03
Total System Performance Assessment Model/Analysis for the License Application - Volume III
mcneishj

Under Development

DOE/EIS-0250F-S1 MiscId 18
Final Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada - Appendix F

LASAR-2.03.01
LA Safety Analysis Report Section 2.3.1

LASAR-2.03.02
LA Safety Analysis Report Section 2.3.2

LASAR-2.03.08
LA Safety Analysis Report Section 2.3.8

LASAR-2.03.09
LA Safety Analysis Report Section 2.3.9

LASAR-2.04
LA Safety Analysis Report Section 2.4

181006	SNL (Sandia National Laboratories) 2007. *Particle Tracking Model and Abstraction of Transport Processes.* MDL-NBS-HS-000020 REV 02 ADD 01. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20070823.0005.

Controlled

ANL-NBS-HS-000039 Rev. 02, ACN 01
Saturated Zone In-Situ Testing

ANL-WIS-PA-000001 Rev. 03
EBS Radionuclide Transport Abstraction

MDL-EBS-PA-000004 Rev. 03
Waste Form and In-Drift Colloids- Associated Radionuclide Concentrations: Abstraction And Summary

MDL-NBS-HS-000006 Rev. 03
UZ Flow Models and Submodels

MDL-NBS-HS-000008 Rev. 02, Addendum 01

Radionuclide Transport Models under Ambient Conditions

MDL-WIS-PA-000005 Rev. 00, MiscId 01
Total System Performance Assessment Model/Analysis for the License Application - Volume I

MDL-WIS-PA-000005 Rev. 00, MiscId 10
Total System Performance Assessment Model/Analysis for the License Application - Volume III - 7

TDR-WIS-PA-000014 Rev. 00
TSPA Information Package for the Draft SEIS

173980	BSC (Bechtel SAIC Company) 2005. *Particle Tracking Model and Abstraction of Transport Processes.* MDL-NBS-HS-000020 REV 02. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20050808.0006.

Controlled

ANL-NBS-HS-000049 Rev. 00, ACN 01
Parameter Sensitivity Analysis for Unsaturated Zone Flow

ANL-NBS-HS-000049 Rev. 00
Parameter Sensitivity Analysis for Unsaturated Zone Flow

ANL-NBS-HS-000054 Rev. 00
Data Analysis for Infiltration Modeling: Bedrock Saturated Hydraulic Conductivity Calculation

The issue identified in CR 11020 resulted in recommendation of modified K_d distributions for Th for impact analysis (see MDL-NBS-HS-000008 REV02 AD01 ERD 02). The impact evaluation to the above listed documents identified that the following documents would be affected by modifying thorium K_d distributions as described in Table III.1-2 and Table III.1-4:

1) To TSPA AMR (MDL-WIS-PA-000005):

   Table 8-2 in MDL-NBS-HS-000020 REV 02 AD 01[DIRS 181006] lists the unsaturated zone transport parameter feeds to TSPA. In Table 8-2 the source DTN for "Matrix Sorption Coefficient for Th" (item 95 through 97) (listed as "Parameter developed in SNL 2007 [DIRS 177396] from statistical data descriptors in DTN: LA0408AM831341.001 [DIRS 171584] Unsaturated Zone Distribution Coefficients (K_ds) for U, Np, Pu, Am, Pa, Cs, Sr, Ra, and Th") would be affected.

2) To SAR (LASAR-2.03.08):

   Table 2.3.8-2 in LASAR-2.03.08 lists the sorption coefficient (K_d) probability distributions for radioisotopes; the thorium K_d distributions would be affected.

   Table 2.3.8-9 in LASAR-2.03.08 lists the selected parameter values for representative-case unsaturated zone model; mean thorium K_d values (Key -95 through -97) would be affected.

Figures 2.3.8-43, 2.3.8-44, 2.3.8-45 and 2.3.8-47 in LASAR-2.03.08 show decay chain (with thorium in it) breakthrough curves (corresponding to Figures 6.6.2-5[d], D.2-3[d] and D.2-4[d], D.2-6[d] and D.2-8[d], D.2-5[d] and D.2-7[d]) and would be affected.

3) To DOE/EIS-0250F-S1 MiscId 18 and TDR-WIS-PA-000014 Rev. 00:

   In DOE/EIS-0250F-S1 MiscId 18, Appendix F (Environmental impacts of postclosure repository performance), Section F2.7 (unsaturated zone transport), sorption paragraph (page F-19): the citation to SNL 2008 [DIRS 184748], Figures 6.6.2-5[b], D.2-3[b] and D.2-6[b] would be affected.

   In TDR-WIS-PA-000014 Rev. 00, Section 6.3.9.3 (TSPA-SEIS implementation), page 6.3.9-10, third paragraph, the citation to SNL 2007 [DIRS 177396], Table 6-1[a], would be affected. Also, in Table 6.3.9-2, which lists the matrix sorption coefficient distributions for unsaturated zone units in the unsaturated zone transport submodel, the thorium K_d distributions would be affected.

Other than the four documents identified above, no other listed documents are affected by modifying thorium K_d distributions. The impact analysis from this ERD concludes that the change in thorium K_d distributions has no impact on these identified four documents; the conclusion of no impact is justified as follows:

The simulations described in Section III herein allowed for an impact evaluation of this thorium K_d distributions modification to UZ radionuclides transport. These comparisons are presented in Section III.2 above and discussed with respect to corresponding tables and figures in MDL-NBS-HS-000020 REV 02 AD 02 [DIRS 184748]. As was demonstrated in Section III.2, the updates to MDL-NBS-HS-000020 REV 02 AD 02 [DIRS 184748] described in this ERD do not impact the conclusions of that document, because the breakthrough curves using the modified K_d distributions differ only slightly from the breakthrough curves from MDL-NBS-HS-000020 REV 02 AD 02 [DIRS 184748]. Therefore, there is no detrimental impact to the conclusions of MDL-NBS-HS-000020 REV 02 AD 02 [DIRS 184748] or to any downstream technical documents.

The potential impact of the new thorium K_d distributions on the TSPA-LA dose and activity concentration calculations was also examined. Section III.3 describes the impact of changing the K_d distributions on the dose calculations for the major TSPA-LA modeling cases. Comparisons of the TSPA-LA compliance model simulations for the IG, SM and HI Modeling Cases for one million year with results from equivalent simulations with the thorium devitrified- and vitrified-tuff K_d distributions updated, indicate that changes would be small (see Figures A-2, A-11, and A-14) and conclusions presented in SNL 2008 ([DIRS 183478], Sections 8.1.1.2[a], and Section 8.1.3.2[a]) would not be impacted. Total radium activity concentration results from the TSPA-LA model were also evaluated for the impact of changing the thorium K_d distributions. As can be seen in Figure A-20, the mean values of radium activity concentrations, based on summing the ED, EW and SM Modeling Cases for 10,000 years, show negligible change which means that the results presented in the TSPA-LA AMR (SNL 2008 [DIRS 183478], Section 8.1.2.1[a]) are not affected. Likewise, as can be seen in Figure A-21, the mean values of alpha-emitter activity concentrations, based on summing the ED, EW and SM Modeling Cases for 10,000 years, show negligible change which means that the results presented in the TSPA-LA AMR (SNL 2008 [DIRS 183478], Section 8.1.2.2[a]) are not affected.

Appendix A
TSPA LA Impact Analysis of Thorium Sorption Coefficient Distributions Changes in the Unsaturated Zone

Acknowledgement: TSPA impact analysis and Appendix A are provided by Barry Lester.

The purpose of this analysis is to study the impact to the TSPA LA model of implementing alternate distributions of thorium sorption coefficients in unsaturated zone units. Sorption is important in controlling the release of thorium and its decay products. The changes to the thorium K_d distributions were recommended for the impact analysis in order to resolve CR 11020 (MDL-NBS-HS-000008 REV02 AD01 ERD 02).

The effect on the TSPA LA model from changes in thorium sorption coefficients was quantified with respect to the Postclosure Individual Protection Standards and Groundwater Protection Standards. The EPA and NRC regulations for a high-level radioactive waste (HLW) repository at Yucca Mountain require that DOE demonstrate a reasonable expectation of compliance with the applicable radiation protection standards. The EPA regulation 40 CFR Part 197 [DIRS 185836] establishes three separate and distinct radiation protection standards for the Yucca Mountain Repository as follows:

- Individual Protection Standard After Permanent Closure (10 CFR 63.311 [DIRS 180319]), which considers the required characteristics of the reasonably maximally exposed individual (RMEI), as described in 10 CFR 63.312 [DIRS 180319].
- Individual Protection Standard for Human Intrusion (10 CFR 63.321 [DIRS 180319]) according to the Human Intrusion Scenario described in 10 CFR 63.322 [DIRS 180319].
- Separate Standards for Protection of Ground Water (10 CFR 63.331 [DIRS 180319]) using the representative volume specified in 10 CFR 63.332 [DIRS 180319].

The EPA and NRC proposed regulations for Individual Protection After Permanent Closure and Human Intrusion establish two standards for annual doses to the RMEI corresponding to: (1) the time period of 10,000 years after closure, and (2) the time period after 10,000 years but within the period of geologic stability, defined as 1,000,000 years in 10 CFR 63.302 [DIRS 180319]. In contrast, the Separate Standards for Protection of Ground Water set limits for annual dose and activity concentrations (i.e., radionuclide activity per unit volume) for only the 10,000-year period following repository closure.

Per 40 CFR 197 [DIRS 185836] as amended, the postclosure individual protection standard is 15 mrem/yr, for up to 10,000 years postclosure, and 100 mrem/yr after 10,000 years, but within the period of geologic stability (1,000,000 years). Total dose results from the TSPA-LA model 10,000-year and one-million-year modeling cases are compared to the two postclosure individual protection standards. The human intrusion postclosure individual protection standard is 15 mrem/yr, for up to 10,000 years postclosure and 100 mrem/yr after 10,000 years, but within the period of geologic stability (1,000,000 years). The groundwater protection standard in the NRC Proposed Rule 10CFR63.331 [DIRS 180319] stipulates that the releases of radionuclides in groundwater at the location of the RMEI should not cause the level of radioactivity in the representative water volume of 3,000 acre-feet of water (10CFR63.332(a)(3) [DIRS 180319]) to exceed the groundwater standards. The groundwater standard for total radium is 5 pCi/L including the natural background radium. The groundwater standard for alpha-emitters is 15 pCi/L. An additional standard specifies limits for beta and photon emitters, but the standard is not relevant to this impact analysis.

A.1 Thorium K_d Changes in the Unsaturated Zone

An alternate set of distributions used for sampling thorium sorption coefficients (K_ds) in the unsaturated zone has been developed that may better reflect measured data to support the TSPA impact analysis. Figure A-1 shows the K_d distributions of zeolitic, devitrified and vitric tuff (original and alternate) together with measured data (DTN: LA0809SL831341.001). The figure shows that while the original zeolitic tuff K_d distribution reasonably reflects the measured data, the distributions for devitrified and vitric tuff needed to be modified. Tables A-1 and A-2 show the original and alternate K_d distributions for the unsaturated zone tuff units, respectively. Table A-3 shows the mean and standard deviation values of the original and alternate K_ds.

Table A-1: Original Selected Th K_d Distributions (DTN: LA0408AM831341.001 [DIRS 171584])

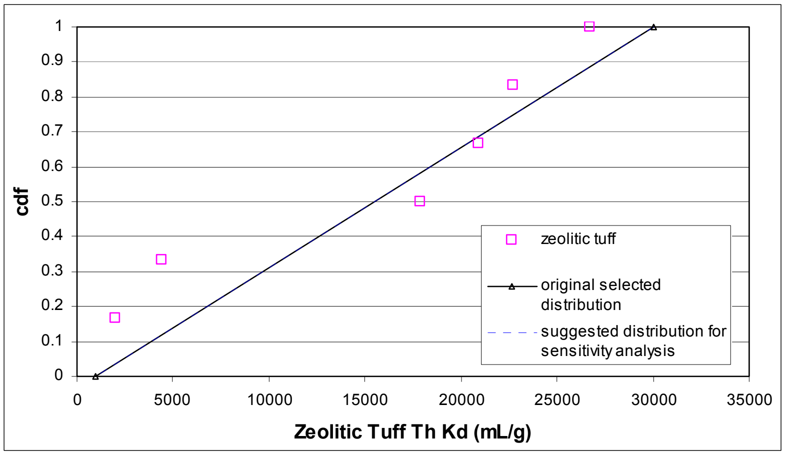
Species	Unit/Analysis	Distribution	Coefficients describing distribution (mL/g)
Th	Zeolitic	Uniform	Range = 1,000 - 30,000
	Devitrified	Uniform	Range = 1,000 - 10,000
	Vitric	Uniform	Range = 1,000 - 10,000

Table A-2: Alternate Distributions for Sensitivity Analysis Based on New DTN: LA0809SL831341.001

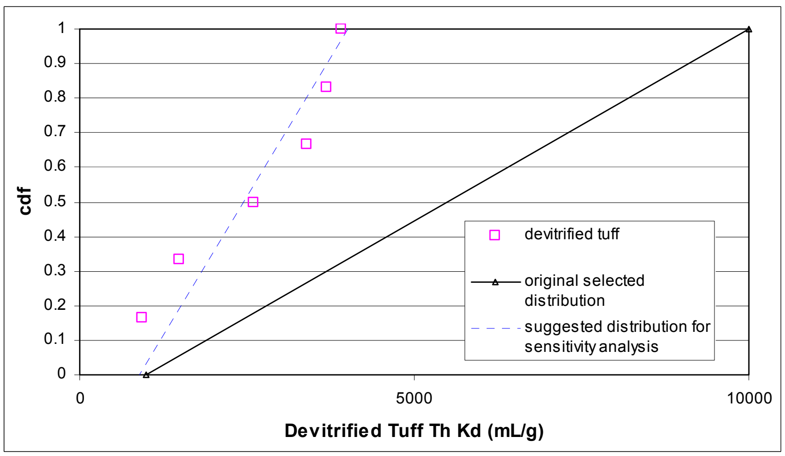
Species	Unit/Analysis	Distribution	Coefficients describing distribution (mL/g)
Th	Zeolitic	Uniform	Range = 1,000 - 30,000 (no change)
	Devitrified	Uniform	Range = 900 - 4,000
	Vitric	Uniform	Range = 300 - 2,000

Table A-3: Mean and Standard Deviation of the Original and Alternate K_ds for Devitrified and Vitric Units

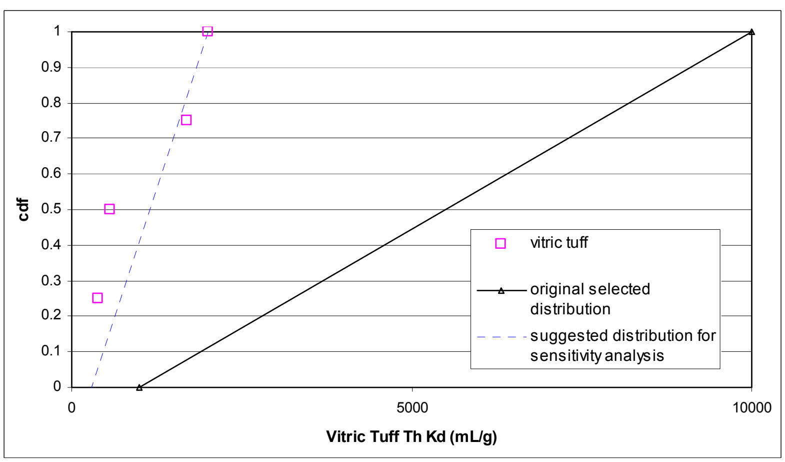
K_d	Unit/Analysis	Mean (mL/g)	Standard Deviation (mL/g)
Original	Zeolitic	15500	8371.6
	Devitrified	5500	2598.1
	Vitric	5500	2598.1
Alternate	Zeolitic	15500	8371.6
	Devitrified	2450	894.9
	Vitric	1150	490.8



a) Zeolitic Tuff



b) Devitrified Tuff



c) Vitric Tuff

Figure A-1: CDF of Uncertainty in Thorium Sorption Coefficient in the Unsaturated Zone: Original vs. Alternate (DTN: LA0809SL831341.001)

A.2 TSPA Implementation

The alternate K_ds for thorium in the devitrified and vitric units have been implemented in the TSPA model. These changes affect both the EBS and UZ radionuclide transport. In the EBS, the changes have been applied to invert transport and invert-UZ interface transport (EBS-UZ interface model). In the UZ, the changes have been applied to UZ fracture and matrix transport. Sampled thorium K_ds were first obtained by running the one-million-year Human Intrusion modeling case for 300 realizations with the alternate thorium K_d distributions applied. The model run results provided an updated UZ sampled data file with the thorium K_d changes. The sampled data file was then used as input to the FEHM dynamically linked library (DLL) (2007 [DIRS 179419]) for succeeding model runs described below.

In order to quantify the effect of the thorium K_d changes on TSPA results, six modeling cases were selected to compare the original (base case) (SNL 2008 [DIRS 183478]) and new TSPA model results. The selected modeling cases were:

- Igneous intrusion (IG) one-million-year modeling case
- Drip Shield Early Failure (ED) 10,000-year modeling case
- Waste Package Early Failure (EW) 10,000-year modeling case
- Seismic Ground Motion (SM) one-million-year modeling case
- Seismic Ground Motion (SM) 10,000-year modeling case
- Human intrusion (HI) one-million-year modeling case

The one-million-year IG and SM cases were chosen because their dose contributions dominate the total dose results presented in the TSPA-LA AMR (SNL 2008 [DIRS 183478], Figure 8.1-3[a]), which are compared to the postclosure individual protection standard for the post-10,000 years to 1,000,000 years period. The total mean annual dose results are comprised of the mean annual doses of the IG, ED, EW, SM, and Seismic Fault Displacement (SF) modeling cases, but the one-million-year SM and IG cases contribute 99% of the peak dose (2.008 mrem), with the SM case contributing 55% (1.096 mrem) and the IG case contributing 44% (0.886 mrem) (SNL 2008 [DIRS 183478], Figure 8.2-3[a] and DTN: MO0710PLOTSFIG.000 [DIRS 185207]). The HI one-million-year modeling case is also evaluated since in the TSPA-LA AMR (SNL 2008 [DIRS 183478]) its results are compared to the human-intrusion individual protection standard (10 CFR 63.321 [DIRS 180319]). The three 10,000-year modeling cases were simulated because their results are combined to generate the total radium concentrations and gross alpha activity concentrations, which are compared to the groundwater standards for total radium and alpha-emitters.

In addition to the comparisons between base case results and results based on the six new simulations performed using the updated thorium K_ds, previous simulations performed to support the validity of using CSNF as a surrogate for NSNF presented in SNL 2008 [DIRS 183478], Section 7.5.3.2) were examined to evaluate whether or not conclusions based on their results are likely to be impacted by the change in thorium K_ds. These simulations include the 10,000 year ED and IG Modeling Cases with sources comprising single CSNF and NSNF waste packages. Note that new simulations using the new thorium K_ds were not performed in this analysis since changes in the dose contributions of thorium radionuclides and their daughter products due to the updated K_ds are unlikely to have a significant impact on total doses and change any conclusions discussed in the TSPA-LA AMR (SNL 2008 [DIRS 183478]).

A.3 Discussion of TSPA Model Results

The TSPA models for the above six modeling cases were run using the software GoldSim V. 9.60.300 (SNL, 2008 [DIRS 184387]). The simulation results for these modeling cases are compared to results of the base case (version 5.005 of the compliance model) presented in the TSPA-LA AMR (SNL 2008 [DIRS 183478]). Because not all the data used in the comparisons was saved in the original base-case TSPA-LA IG and HI one-million year simulations, the TSPA-LA IG and HI base-case models were re-run for this analysis to output the additional data needed. Note that in the 10,000-year case simulations, although the transport of ^{230}Th, ^{232}Th, ^{226}Ra, and ^{228}Ra is evaluated and concentrations at the RMEI are generated, dose contributions for these species have been removed from consideration (screened out) in the TSPA-LA dose calculations since they are unlikely to significantly contribute to radiation dose to the public from the Yucca Mountain nuclear waste repository, as discussed in SNL 2007 [DIRS 177424], Table 7-1. Note that blanks in the table indicate that the species is screened out. Therefore, all dose changes in the 10,000-year dose plots reflect changes in ^{229}Th dose contributions only.

The evaluation of the simulations performed to support the validity of using CSNF as a surrogate for NSNF is based upon a review of simulations described in SNL 2008 [DIRS 183478], Section 7.5.3.2, which were also run using the software GoldSim V. 9.60.300 (2008 [DIRS 184387]. Simulations using updated thorium K_ds were not performed for this evaluation since the updated K_ds are unlikely to have a significant impact on total doses because the contribution of ^{229}Th to dose is small for release from a single CSNF waste package. The impact of the changes to the thorium K_ds are approximated using other simulations performed in this study as analogues.

A.3.1 IG One-Million-Year Modeling Case

Figures A-2 to A-10 show the impact of the thorium K_d changes on the results of the IG one-million-year modeling case. Figure A-2 shows the thorium K_d changes have a small impact on the mean annual dose. The increase in mean annual dose for the IG one-million-year modeling case, at one million years, is about 10% (from 0.8861 mrem to 0.9786 mrem). The increases in the ^{230}Th dose contribution (Figure A-3) and ^{226}Ra dose contribution (Figure A-4) at one million years are about 24% (from 0.0244 mrem to 0.0302 mrem) and 27% (from 0.2306 mrem to 0.2922 mrem), respectively. The increases in the ^{230}Th dose contribution (Figure A-3) and ^{226}Ra dose contribution (Figure A-4) basically reflect the increase in release of ^{230}Th from the EBS, as depicted in Figure A-5. How the change in thorium K_d distributions impacts the transport processes can be seen by examining the releases of ^{230}Th and ^{226}Ra from the EBS, UZ, and SZ. The increase in release of ^{230}Th from the EBS is about 25% (from 0.0530 g/yr to 0.0660 g/yr) at one million years. As can be seen in Figure A-6, this increase is associated with a slight decrease in ^{226}Ra release from the EBS, which decreases about 7% (from 0.0213 g/yr to 0.0198 g/yr) by one million years. The decrease in ^{226}Ra release is associated with the decrease in ^{230}Th within the EBS (due to the increase in release) and associated decrease in the formation of daughter product. As can be seen in Figures A-7 and A-8, the release of ^{230}Th from the UZ reflects the increase of ^{230}Th released from the EBS, and the release of ^{226}Ra from the UZ reflects the decrease of ^{226}Ra released from the EBS. Examining the ^{230}Th releases from the SZ presented in Figure A-9 shows that, as expected, the release of ^{230}Th from the SZ reflects the increase of ^{230}Th released from the EBS and UZ. Examining the releases of ^{226}Ra from the SZ presented in Figure A-10 shows that the release of ^{226}Ra from the SZ is also a function of the increase of ^{230}Th released from the EBS and UZ, as ^{230}Th decays to ^{226}Ra during transport through the SZ.

A.3.2 SM One-Million-Year Modeling Case

Figures A-11 to A-13 show plots of mean annual dose, ^{230}Th dose contribution, and ^{226}Ra dose contribution for the SM one-million-year modeling case. As shown in Figure A-11, the thorium K_d changes have a very small impact on the mean annual dose. There is an increase in the mean annual dose of approximately 3.7% (from 1.0960 mrem to 1.1365 mrem) at one million years. Note that this small increase reflects the relative unimportance of the thorium and radium radionuclides in the one-million-year SM Modeling Case compared to ^{99}Tc, ^{129}I, and ^{242}Pu, as shown in Figure 8.2-12[a] of SNL 2008 [DIRS 183478]. There are substantial changes to the dose contributions from ^{230}Th and ^{226}Ra associated with the changes in thorium K_ds, as shown in Figures A-12 and A-13, respectively. At one million years, there is an increase in the dose contribution from ^{230}Th of 61% (from 0.00859 mrem to 0.0138 mrem) and an increase in the dose contribution from ^{226}Ra of 37% (from 0.0441 mrem to 0.0603 mrem).

A.3.3 HI One-Million-Year Modeling Case

Figures A-14 to A-16 show the impact of the thorium K_d changes on the mean annual dose from HI, and the contributions to mean annual dose from ^{230}Th and ^{226}Ra. As shown in the plots, there is very little change in results due to the thorium K_d changes. Note that since the HI one-million-year model bypasses the invert and EBS/UZ interface (SNL 2008 [DIRS 183478], Section 6.7), the EBS releases would not be affected by the K_d change. The only influence on the EBS release would be in the diffusion from the borehole to the surrounding rock matrix. As discussed in SNL 2008 [DIRS 183478], Section 7.7.1.6[a] the diffusion from the borehole into the surrounding rock matrix dominates the borehole transport process for aqueous species with higher K_ds such as plutonium. In the case of ^{230}Th, which has a K_d range that is much higher than that of plutonium, only a negligible amount of ^{230}Th will exit from the borehole. This means that ^{230}Th released from the SZ is mainly the daughter product of ^{234}U transported through the SZ. For this reason, changing the thorium K_d distributions has a negligible impact on the mean dose contributions from ^{230}Th. Similarly, the ^{226}Ra release from the SZ is dominated by ^{230}Th decaying to ^{226}Ra in the SZ. Therefore, there is little change in the mean dose contributions from ^{226}Ra associated with changing the thorium K_d distributions.

A.3.4 ED 10,000-Year Modeling Case

Figure A-17 shows plots of mean annual dose for the ED 10,000-year modeling case. The thorium K_d changes have little impact on mean annual dose. As discussed above in Section A.3, for 10,000-year modeling cases, ^{230}Th, ^{232}Th, ^{226}Ra, and ^{228}Ra are not considered in dose calculations. The negligible dose changes depicted in Figure A-17 reflect changes in the dose contribution from ^{229}Th, which is a small contributor to dose as shown in SNL 2008 [DIRS 183478], Figure 8.2-4[a].

A.3.5 EW 10,000-Year Modeling Case

Figure A-18 is a plot of mean annual dose for the EW 10,000-year modeling case. As discussed above in Section A-3, for 10,000-year modeling cases, ^{230}Th, ^{232}Th, ^{226}Ra, and ^{228}Ra are not considered in dose calculations. The negligible dose changes depicted in Figure A-18 reflect changes in the dose contribution from ^{229}Th, which is a small contributor to dose as shown in SNL 2008 [DIRS 183478], Figure 8.2-6[a].

A.3.6 SM 10,000-Year Modeling Case

Figure A-19 is a plot of mean annual dose from the 10,000-year SM modeling case, showing that the thorium K_d changes have little impact on mean annual dose. As discussed above in Section A.3, for 10,000-year modeling cases, ^{230}Th, ^{232}Th, ^{226}Ra, and ^{228}Ra are not considered in dose calculations. The negligible dose changes depicted in Figure A-19 reflect changes in the dose contribution from ^{229}Th, which is a small contributor to dose as shown in SNL 2008 [DIRS 183478], Figure 8.2-12[a].

A.3.7 Total Radium Concentrations

The radium concentrations used for comparison with the total radium ground water protection standard are derived by combining the results of the ED 10,000-year modeling case, the EW 10,000-year modeling case, and the SM 10,000-year modeling case. The mean and 95th percentile results for the TSPA-LA compliance model and the model with updated thorium K_ds are presented in Figure A-20. As can be seen from Figure A-20, the mean and 95th percentile total radium concentrations show negligible impact from the change in thorium K_d distributions.

A.3.8 Gross Alpha Activity Concentrations

The gross alpha activity concentrations of all alpha emitters used for comparison with the groundwater standard for alpha-emitters are derived by combining the results of the ED10,000-year modeling case, the ED 10,000-year modeling case, and the SM 10,000-year modeling case. The mean and 95th percentile results for the TSPA-LA compliance model and the model with updated thorium K_ds are presented in Figure A-21. As can be seen from Figure A-21, the mean and 95th percentile gross alpha activity concentrations show negligible impact from the change in thorium K_d distributions.

A.3.9 Use of CSNF as a Surrogate for NSNF

In the modeled repository, there are 8,213 CSNF waste packages of which 417 represent NSNF (SNL 2008 [DIRS 183478], Section 7.5.3[a]). To evaluate the validity of using CSNF waste packages as a surrogate for NSNF, the TSPA-LA AMR includes the results of probabilistic analyses that compare the mean annual doses associated with the failure of a single waste package of CSNF to the mean annual doses associated with the failure of a single waste package of NSNF (SNL 2008 [DIRS 183478], Sections 7.5.3.2[a] and 7.5.3.3[a]). Because the change in the thorium K_ds may impact the 10,000-year ED and IG Modeling Cases, and these cases are among those used to determine the validity of using CSNF as a surrogate for NSNF, the potential impact on conclusions drawn from the analysis must be examined. As noted in Section A.3, ^{230}Th, ^{232}Th, ^{226}Ra, and ^{228}Ra have been removed from consideration (screened out) in the 10,000-year TSPA-LA dose calculations since they are unlikely to significantly contribute to radiation dose to the public, as discussed in SNL 2007 [DIRS 177424]. For this reason, the discussion below pertains to the potential impact of the change in the thorium K_ds on the dose contribution from ^{229}Th. As discussed in Sections A.2 and A.3, no new simulations were performed for this evaluation, although the simulations described in Section A.3.4 was used as analogues.

An examination of the mean annual doses of the 10,000-year ED Modeling Case presented in Figure A-22 indicates that the use of a CNSF waste package as a surrogate is a conservative choice with the mean annual dose from the surrogate waste package simulation over two orders of magnitude greater than that of the NSNF waste package simulation. Figure A-23 shows that for the NSNF waste package simulation the maximum percentage contribution of ^{229}Th (which occurs at 10,000 years) to the mean annual dose is approximately 6% (3.34×10^{-6} mrem vs. 5.51×10^{-5} mrem). Thus, for the NSNF waste package simulation, only a large change in the contribution from ^{229}Th would have a significant effect on the mean annual dose (doubling the maximum percentage contribution of ^{229}Th, at 10,000 years, would only increase the total mean annual dose by another 6%). For the CNSF waste package simulation (see Figure A-24), the maximum percentage contribution of ^{229}Th to the mean annual dose is approximately 0.008% (7.73×10^{-7} mrem vs. 9.82×10^{-3} mrem), which means that for the CNSF waste package simulation only a large change in the contribution from ^{229}Th would have a significant effect on the mean annual dose (multiplying the contribution of ^{229}Th at 10,000 years by a factor of 126 would only increase the original total mean annual dose by 1% at 10,000 years). Section A.3.4 presents a comparison of the ED 10,000-year modeling case mean annual dose results for the two different sets of thorium K_ds. Although these simulations included both CDSP and CSNF waste, it is expected that the negligible difference in mean annual dose (see Figure A-17) is indicative of the degree of change that would be seen for a single CSNF waste package release. This expectation is based on the consideration that the maximum ^{229}Th dose contribution in the 10,000-year ED Modeling Case for a single CSNF waste package (which occurs at 10,000 years) has a mean annual contribution of ^{229}Th to dose that is 0.008 % (7.73×10^{-7} mrem vs. 9.82×10^{-3} mrem) of the mean annual total dose (Figure A-24). In comparison, the maximum percentage ^{229}Th dose contribution in the 10,000-year TSPA-LA ED Modeling Case (which also occurs at 10,000 years) has a mean annual contribution of ^{229}Th to dose that is 0.006 % (3.77×10^{-9} mrem vs. 6.32×10^{-5} mrem) of the mean annual total dose (SNL 2008 [DIRS 183478], Figure 8.2-4[a] and DTN: MO0710PLOTSFIG.000 [DIRS 185207]). Since these two percentages are similar in order of magnitude the simulations described in Section A.3.4 are good analogues for the case of a single CSNF waste package. In addition, since the mean annual dose from the CSNF waste package simulation is approximately two orders of magnitude greater than the mean annual dose from the NSNF waste package simulation (Figure A-22), it is unlikely that any conclusions about the validity of using CSNF waste packages as surrogates for the NSNF waste packages will be impacted by the change in thorium K_ds.

An examination of the mean annual doses of the 10,000-year IG analysis presented in Figure A-25 shows that the use of a CNSF waste package as a surrogate is a conservative choice but not to the extent shown in the ED analysis. Figure A-26 shows that for the NSNF waste package simulation the maximum percentage contribution of ^{229}Th to the mean annual dose is approximately 0.02% (4.85 × 10^{-6} mrem vs. 2.66 × 10^{-2} mrem). This means that you would have to multiply the contribution of ^{229}Th by a factor of 51 to increase the original total dose by 1%. For the CNSF waste package simulation (see Figure A-27), the maximum percentage contribution of ^{229}Th to the mean annual dose is approximately 0.007% (3.37 × 10^{-6} mrem vs. 4.96 × 10^{-2} mrem). This means that you would have to multiply the contribution of ^{229}Th by a factor of 144 to increase the original total dose by 1%. For both the CNSF waste package and NSNF waste package simulations a change in the dose contribution from ^{229}Th would have a negligible effect on the mean annual dose results unless the increase was large. In addition, Section A.3.1 presents a comparison of the IG one-million-year modeling case mean annual dose results for the two different sets, of thorium K_ds, that can be used as an analogue for the single CSNF single waste package release. Although this is not a 10,000 year simulation, the mean annual dose results at 10,000 years for the one-million year IG base case are similar to the results for the 10,000 year base case. The total mean annual doses for the 10,000 year IG case and one-million-year IG case are 0.0661 mrem and 0.0660 mrem respectively (SNL 2008 [DIRS 183478], Figure 8.2-8[a] and DTN: MO0710PLOTSFIG.000 [DIRS 185207]). The total mean annual dose contributions of ^{229}Th for the 10,000 year IG case and one-million-year IG case are 5.7 × 10^{-6} mrem and 4.8 × 10^{-6} mrem respectively (SNL 2008 [DIRS 183478], Figure 8.2-8[a] and DTN: MO0710PLOTSFIG.000 [DIRS 185207]). Although the IG one-million-year modeling case simulations included both CDSP and CSNF waste, it is expected that the negligible difference in mean annual dose (see Figure A-28) is indicative of the degree of change that would be seen for a single CSNF waste package release. This expectation is based on the consideration that the maximum ^{229}Th dose contribution in the 10,000-year IG Modeling Case for a single CSNF waste package (which occurs at 10,000 years) has a mean annual contribution of ^{229}Th to dose that is approximately 0.007 % (3.37 × 10^{-6} mrem vs. 4.96 × 10^{-2} mrem) of the mean annual total dose (Figure A-27). In comparison, the maximum percentage ^{229}Th dose contribution in the one-million-year TSPA-LA IG Modeling Case (which also occurs at 10,000 years) has a mean annual contribution of ^{229}Th to dose that is approximately 0.007 % (4.80 × 10^{-6} mrem vs. 6.60 × 10^{-2} mrem) of the mean annual total dose (SNL 2008 [DIRS 183478], Figure 8.2-8[a] and DTN: MO0710PLOTSFIG.000 [DIRS 185207]). Since these two percentages are approximately the same, the simulations described in Section A.3.1 are good analogues for the case of a single CSNF waste package.

A.3.10 Summary of Results

Selected TSPA model runs were made to assess the impact of alternate thorium K_d distributions (Table A-2) on the TSPA LA. The alternate K_d changes were implemented in the TSPA LA model. Comparison of outputs of mean annual dose, ^{230}Th dose and ^{226}Ra dose, total radium concentrations, as well as ^{230}Th and ^{226}Ra releases from the EBS, UZ, and SZ were made. The new mean annual dose results were compared with the base case for each modeling case, and the results showed that the changes in mean annual dose were relatively small for the one-million-year IG and SM Modeling Cases and negligible for the other cases. Comparison of total radium concentration results also showed a negligible change.

The mean annual dose contribution from the IG modeling case for one million years increased approximately 10%, and the mean annual dose contribution from the SM modeling case for one million years increased approximately 3.7%. Since these modeling cases dominate the total dose results for the combined modeling cases, the increase in total dose results associated with the change in thorium K_d distributions is expected to be small. This indicates that conclusions drawn with respect to total dose calculations for the post-10,000 years to 1,000,000 years period would not be affected by use of the alternate thorium K_d distributions. The small changes in total mean annual dose from the use of the alternate thorium K_d distributions is not unexpected, because radionuclides other than ^{226}Ra and ^{230}Th are significant contributors to total mean annual dose (SNL 2008 [DIRS 183478], Figure 8.1-7[a]).

An examination of changes in dose contributions from ^{230}Th and ^{226}Ra for the one-million-year IG and SM simulations indicates that there is a sizable increase in the release of ^{230}Th and ^{226}Ra to the accessible environment. Comparisons of mean releases of ^{230}Th and ^{226}Ra from the EBS, UZ, and SZ for the one-million-year IG simulations showed a 25% increase in the EBS release of ^{230}Th that is reflected in the release of ^{230}Th from the UZ and SZ and the release of ^{226}Ra from the SZ. The correlation of the increase of the release of ^{226}Ra from the SZ with the increase in release of ^{230}Th from the UZ is a function of formation of ^{226}Ra as a daughter product of ^{230}Th. The release of ^{226}Ra from the UZ is correlated with a slight decrease in the EBS release of ^{226}Ra associated with the change in thorium K_d distributions. Comparisons of mean annual dose results from the 10,000-year simulations showed negligible changes, as expected, since ^{230}Th, ^{232}Th, ^{226}Ra, and ^{228}Ra are not included in dose calculations for the 10,000-year simulations (SNL 2007 [DIRS 177424]).

A comparison of mean annual dose results from the HI simulation associated with the change in thorium K_ds with the TSPA-LA HI model showed that the change in K_ds has a negligible impact on results of the HI model. This negligible impact is consistent with the fact that, in the HI model, the transport process in the borehole is dominated by matrix diffusion into the surrounding rock, and the thorium and radium radionuclide releases to the accessible environment are predominantly daughter and granddaughter products of ^{234}U that is released from the UZ. The negligible change in the mean annual dose results indicates that conclusions drawn with respect to comparisons of mean annual dose calculations with the human intrusion individual protection standard for the post-10,000 years to 1,000,000 years period would not be impacted by use of the alternate thorium K_d distributions.

With respect to total ^{226}Ra and ^{228}Ra concentrations for the combined 10,000-year ED, EW, and SM simulations, the comparison of the updated results with the TSPA-LA Compliance Model results indicated that the changes in the thorium K_d distributions have a negligible impact on the total radium concentrations. The small changes in the total radium concentration are reflective of the short time period of the analysis (i.e., 10,000 years). The negligible change in the total radium concentration results indicated that conclusions drawn with respect to comparisons of total radium concentration calculations with the groundwater standard for total radium for the 10,000 years after closure would not be impacted by use of the alternate thorium K_d distributions.

Examining the gross alpha activity concentrations of all alpha emitters for the combined 10,000-year ED, EW, and SM simulations, the comparison of the updated results with the TSPA-LA Compliance Model results indicated that the changes in the thorium K_d distributions have a negligible impact on the gross alpha activity concentrations. The small changes in the gross alpha activity concentrations are reflective of the short time period of the analysis (i.e. 10,000 years). The negligible change in gross alpha activity concentration results indicated that conclusions drawn with respect to comparisons of gross alpha activity concentration calculations with the groundwater standard for alpha-emitters for the 10,000 years after closure would not be impacted by use of the alternate thorium K_d distributions.

The impact of changes in the thorium K_d distributions on conclusions pertaining to the validity of using CSNF as a surrogate for NSNF has also been examined (Section A.3.9). This examination was comprised of reviewing the NSNF surrogate validation simulations presented in (SNL 2008 [DIRS 183478], Sections 7.5.3.2[a] and 7.5.3.3[a]) and evaluating how much they may be impacted based upon the percent contributions of ^{229}Th to total mean annual dose in the original simulations. Analyses performed for the TSPA-LA 10,000 ED Modeling Case and the one-million-year IG Modeling Case were also used as analogues to bound the possible impact that a change in thorium K_ds could have on the validation studies. This examination demonstrated that conclusions presented in SNL 2008 [DIRS 183478] (Section 7.5.3[a]) regarding the representation of NSNF would not be impacted by the described changes in thorium K_ds.

A.4 References

180319 10 CFR 63. 2007. Energy: Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada. Internet Accessible.

185836 40 CFR 197. 2008. Protection of Environment: Public Health and Environmental Radiation Protection Standards for Yucca Mountain, Nevada. Internet Accessible.

179419 FEHM V. 2.24-01. 2007. WIN2003, 2000, & XP, Red Hat Linux 2.4.21, OS 5.9. STN: 10086-2.24-01.00.

184387 GoldSim V. 9.60.300. 2008. WIN 2000, WINXP, WIN2003. STN: 10344-9.60-03.

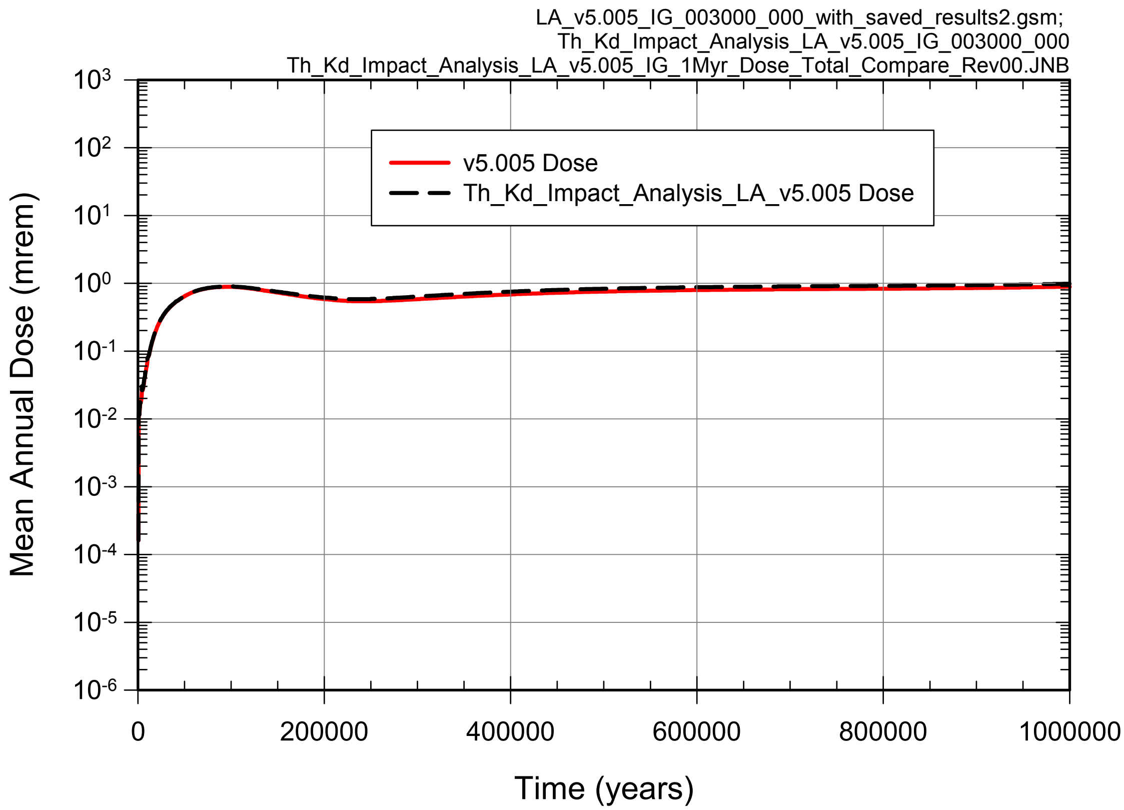
177424 SNL (Sandia National Laboratories) 2007. *Radionuclide Screening.* ANL-WIS-MD-000006 REV 02, Las Vegas, Nevada.

183478 SNL (Sandia National Laboratories) 2008. *Total System Performance Assessment Model /Analysis for the License Application.* MDL-WIS-PA-000005 REV 00 AD 01, Las Vegas, Nevada.

171584 LA0408AM831341.001. Unsaturated Zone Distribution Coefficients (K_ds) for U, Np, Pu, Am, Pa, Cs, Sr, Ra, and Th. Submittal date: 08/24/2004.

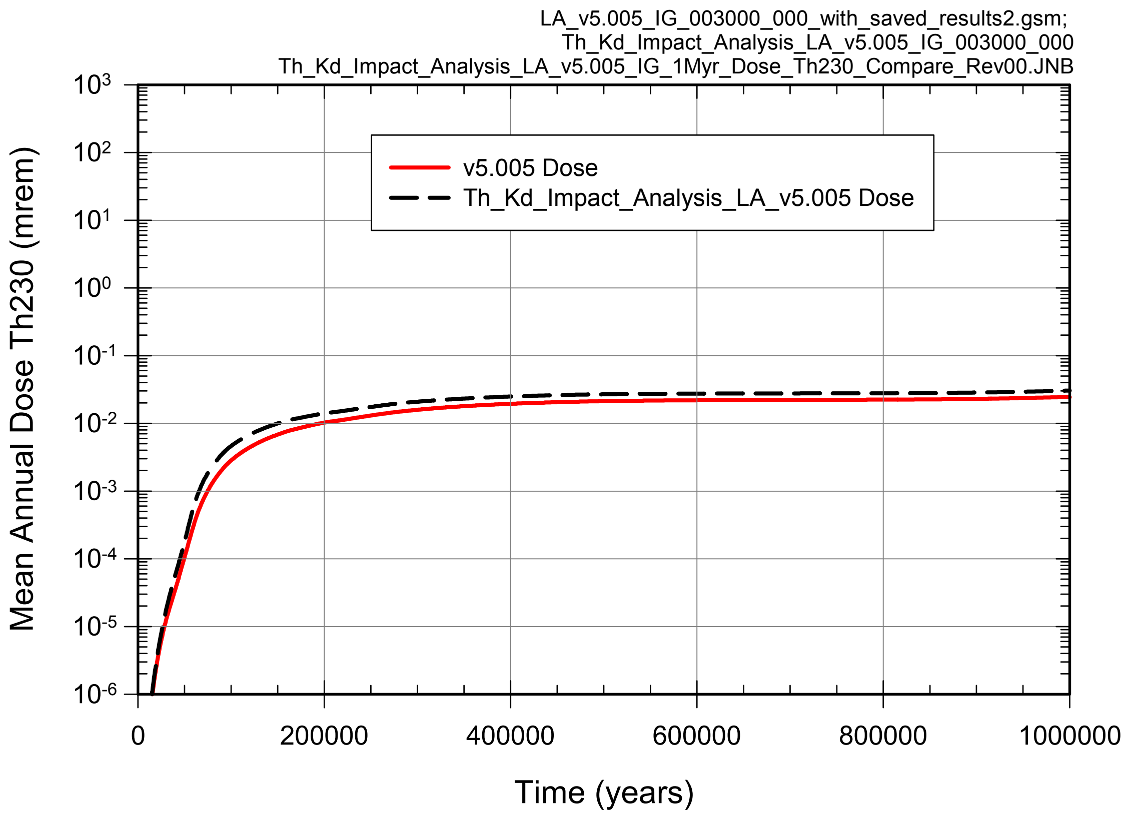
185795 LA0809SL831341.001. Thorium Sorption Distributions. Submittal Date: 10/03/2008

MO0810LLAMDLIA.000. Thorium Kd-LA Model Impact Analysis. Submittal date: 10/23/08



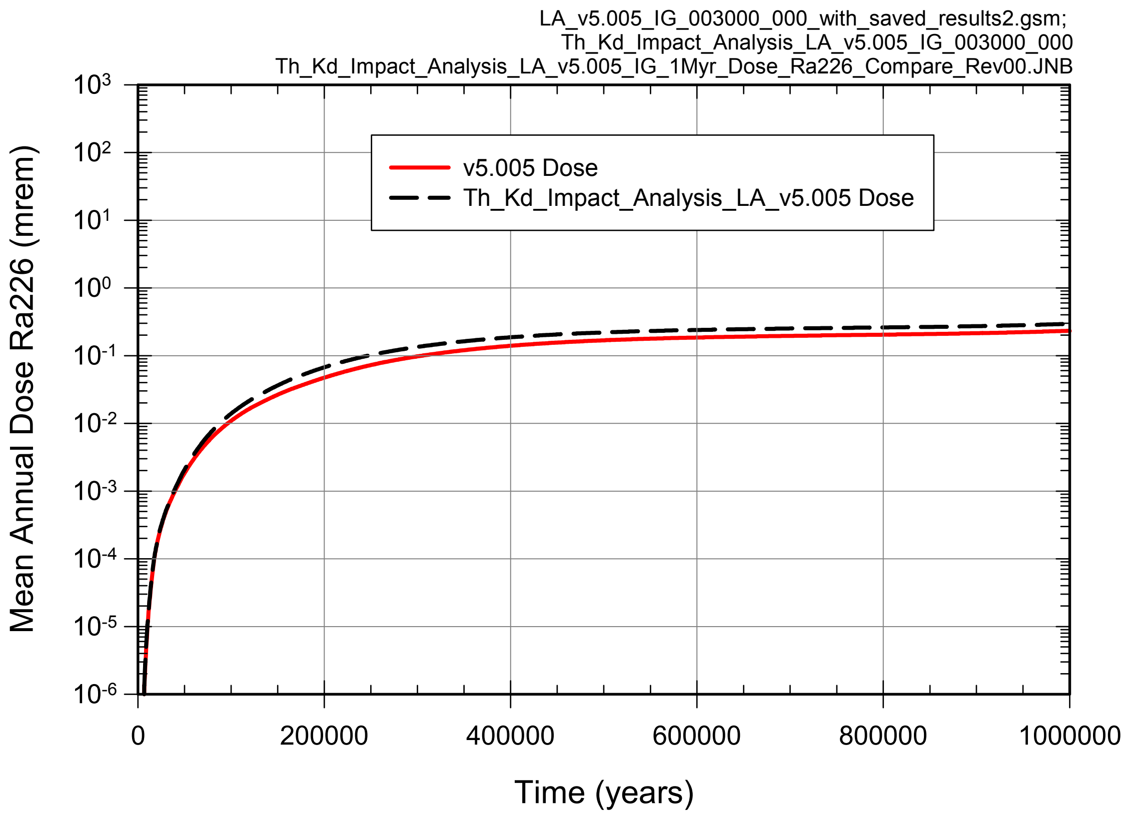
DTN: MO0810LLAMDLIA.000

Figure A-2. Comparison of the Mean Annual Dose for the TSPA-LA Model to the Thorium K_d Changed Model for the IG One-Million-Year Modeling Case. Note: the base case is red line and the sensitivity case is black dashed line.



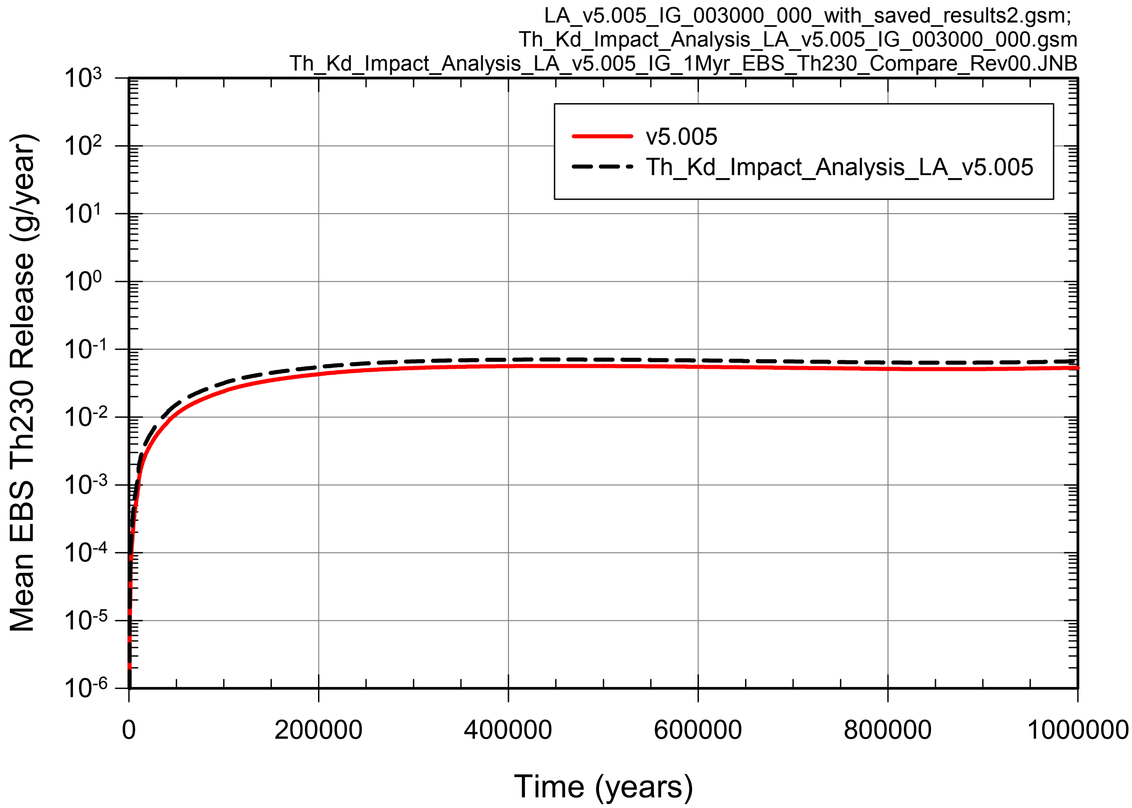
DTN: MO0810LLAMDLIA.000

Figure A-3. Comparison of ^{230}Th Mean Annual Dose for the TSPA-LA Model to the Thorium K_d Changed Model for the IG One-Million-Year Modeling Case. Note: the base case is red line and the sensitivity case is black dashed line.



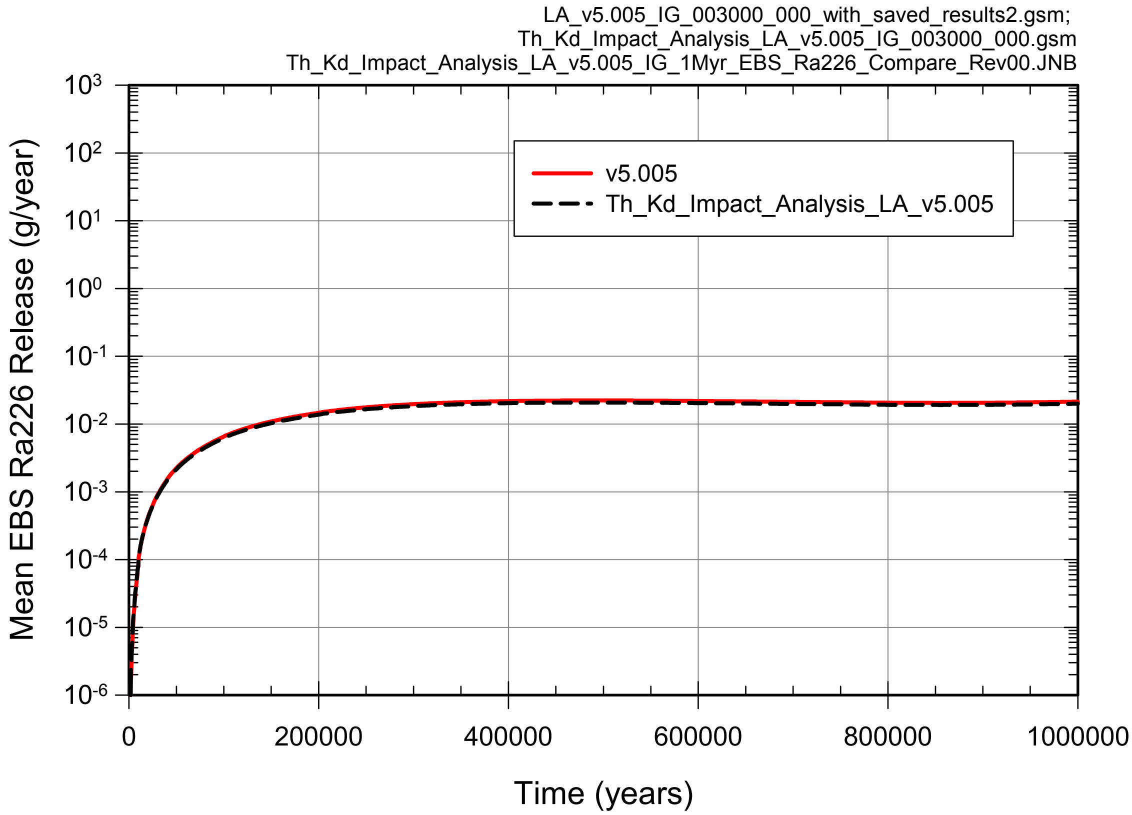
DTN: MO0810LLAMDLIA.000

Figure A-4. Comparison of ^{226}Ra Mean Annual Dose for the TSPA-LA Model to the Thorium K_d Changed Model for the IG One-Million-Year Modeling Case. Note: the base case is red line and the sensitivity case is black dashed line.



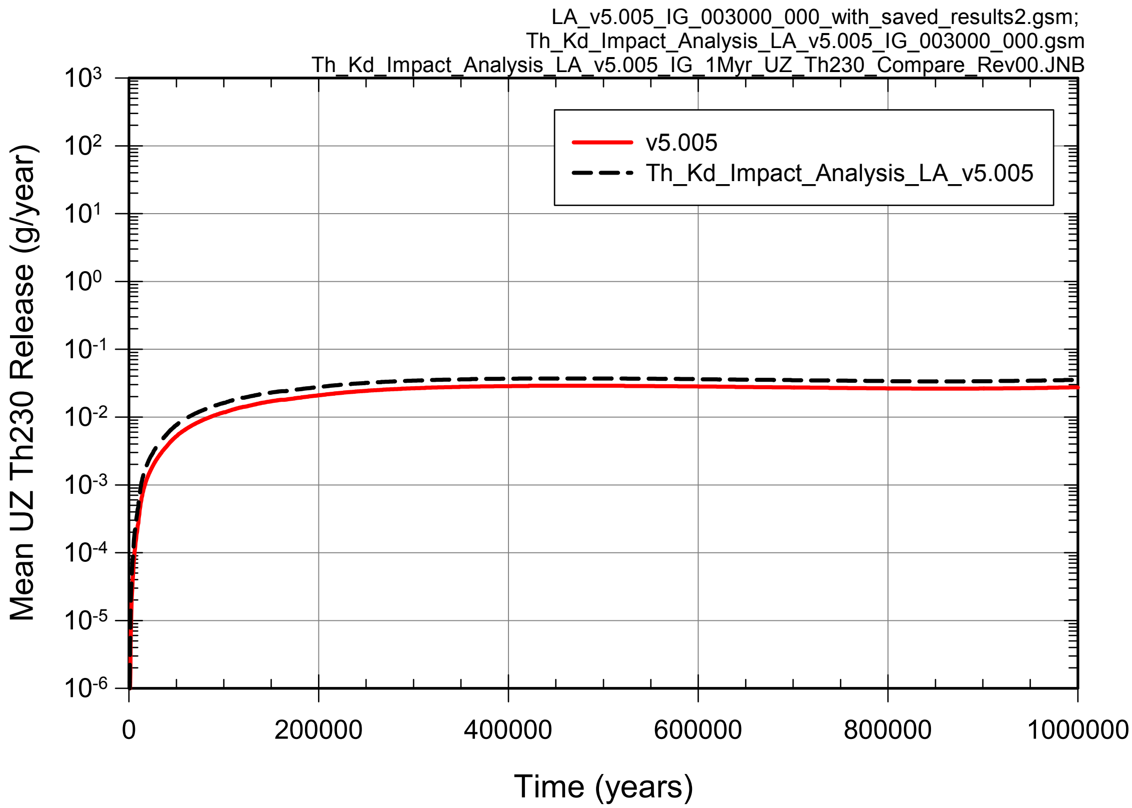
DTN: MO0810LLAMDLIA.000

Figure A-5. Comparison of Mean EBS ^{230}Th Release for the TSPA-LA Model to the Thorium K_d Changed Model for the IG One-Million-Year Modeling Case. Note: the base case is red line and the sensitivity case is black dashed line.



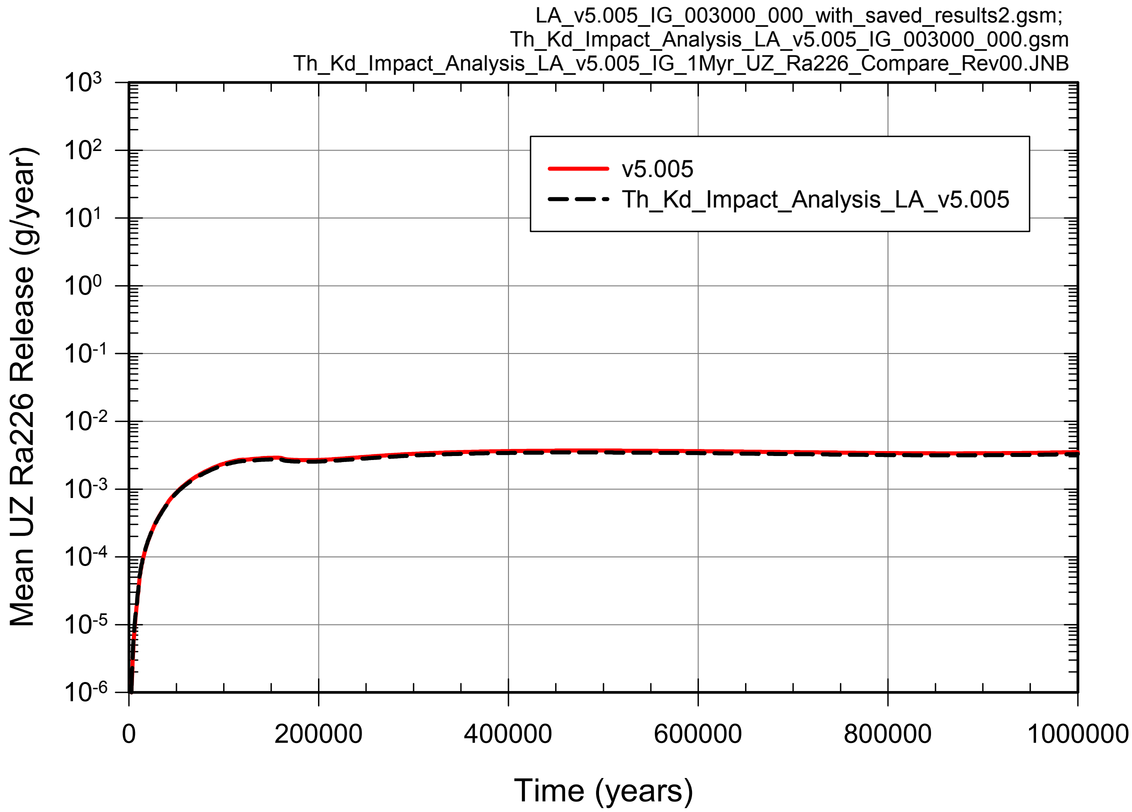
DTN: MO0810LLAMDLIA.000

Figure A-6. Comparison of Mean EBS ^{226}Ra Release for the TSPA-LA Model to the Thorium K_d Changed Model for the IG One-Million-Year Modeling Case. Note: the base case is red line and the sensitivity case is black dashed line.



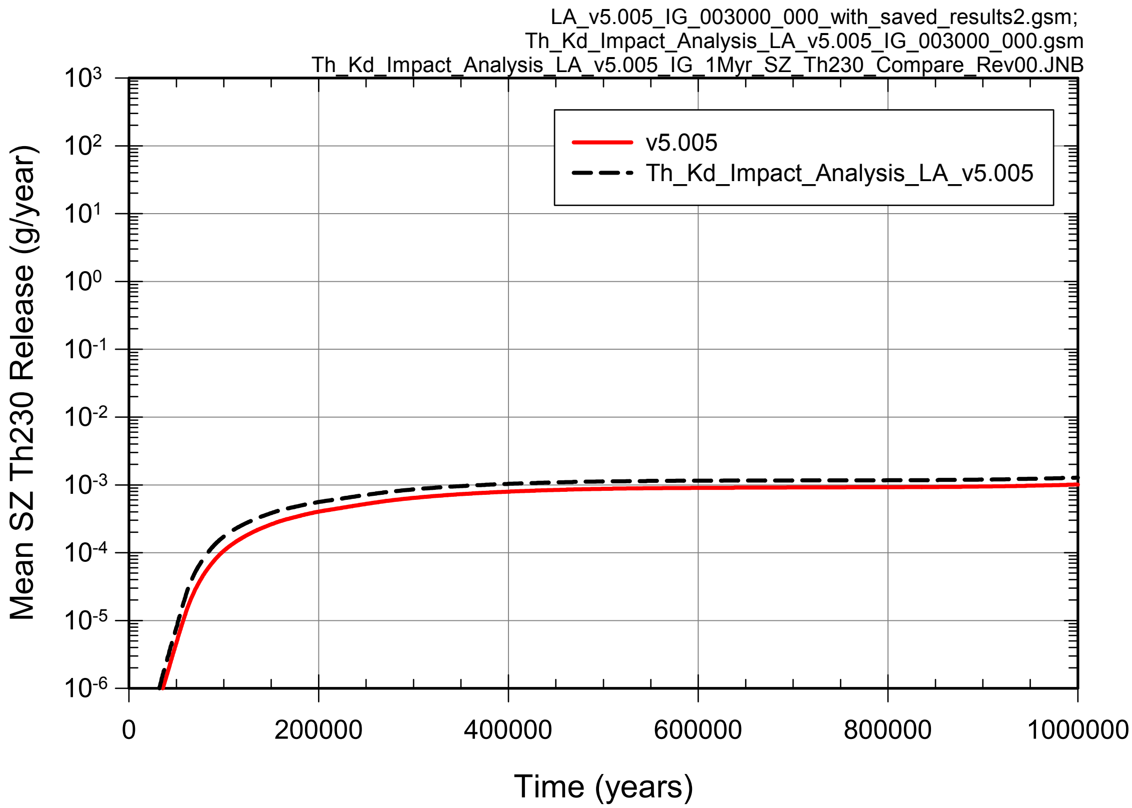
DTN: MO0810LLAMDLIA.000

Figure A-7. Comparison of Mean UZ ^{230}Th Release for the TSPA-LA Model to the Thorium K_d Changed Model for the IG One-Million-Year Modeling Case. Note: the base case is red line and the sensitivity case is black dashed line.



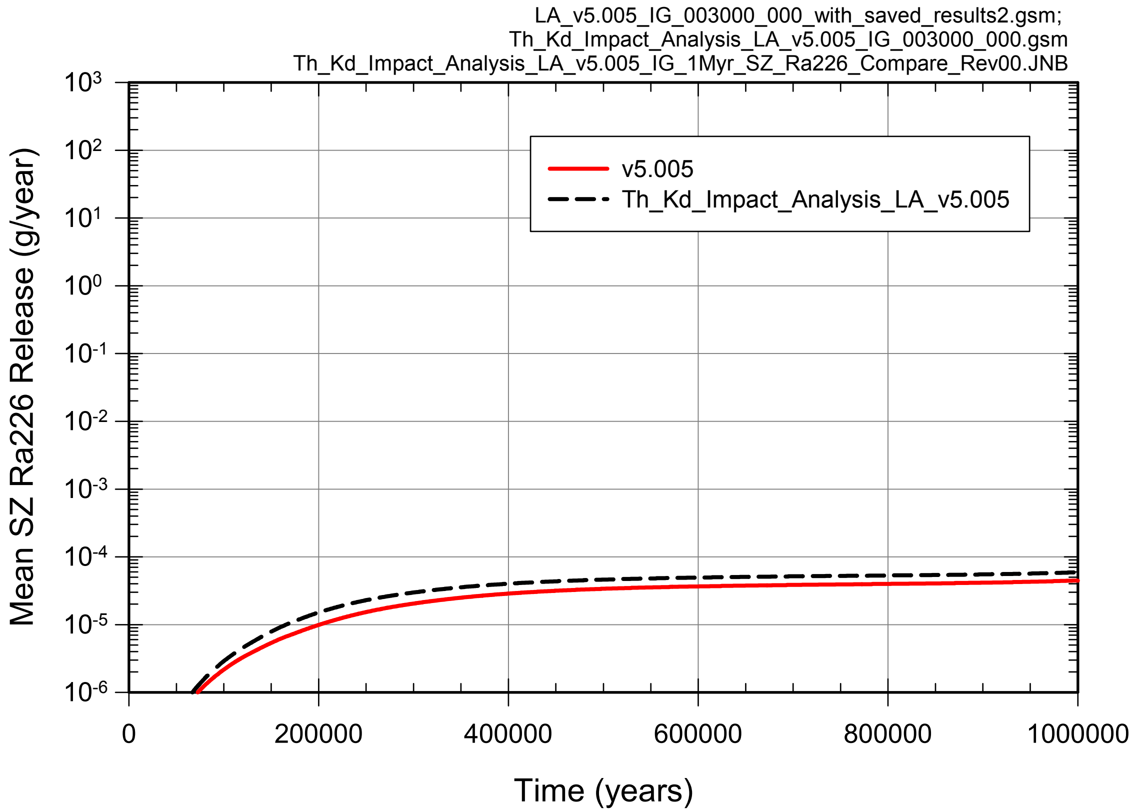
DTN: MO0810LLAMDLIA.000

Figure A-8. Comparison of Mean UZ ^{226}Ra Release for the TSPA-LA Model to the Thorium K_d Changed Model for the IG One-Million-Year Modeling Case. Note: the base case is red line and the sensitivity case is black dashed line.



DTN: MO0810LLAMDLIA.000

Figure A-9. Comparison of Mean SZ ^{230}Th Release for the TSPA-LA Model to the Thorium K_d Changed Model for the IG One-Million-Year Modeling Case. Note: the base case is red line and the sensitivity case is black dashed line.



DTN: MO0810LLAMDLIA.000

Figure A-10. Comparison of Mean SZ ^{226}Ra Release for the TSPA-LA Model to the Thorium K_d Changed Model for the IG One-Million-Year Modeling Case. Note: the base case is red line and the sensitivity case is black dashed line.

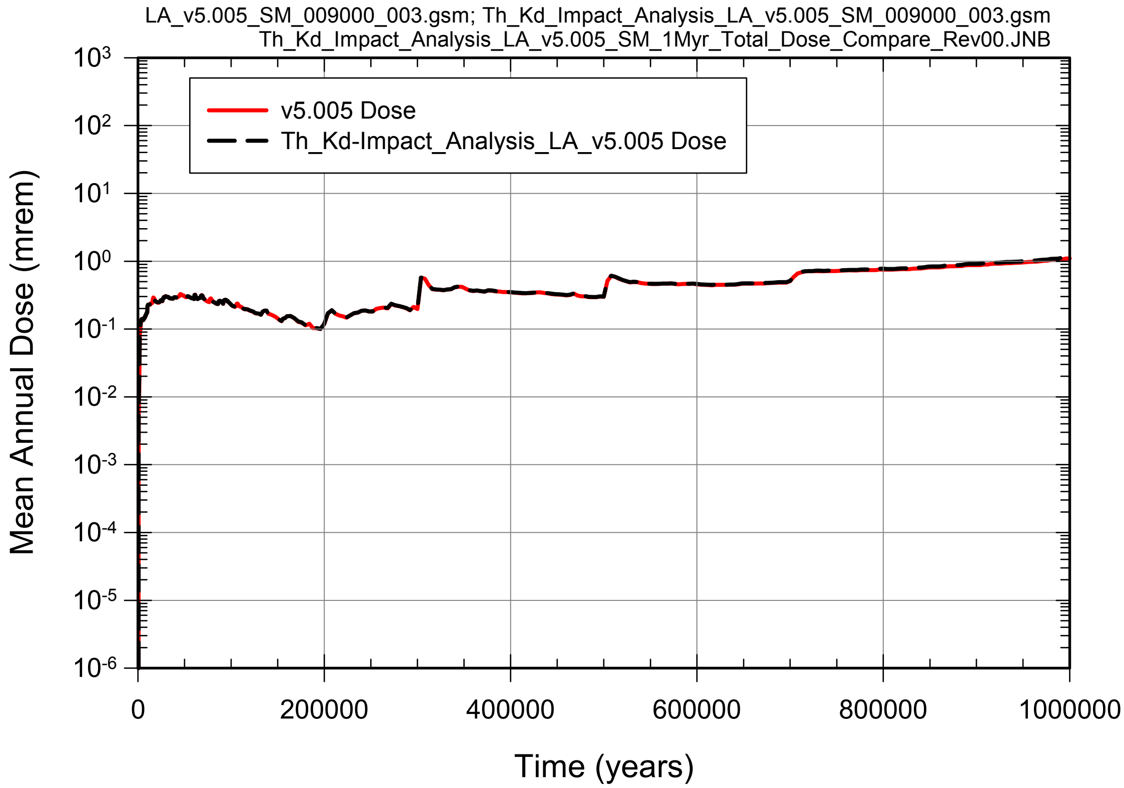


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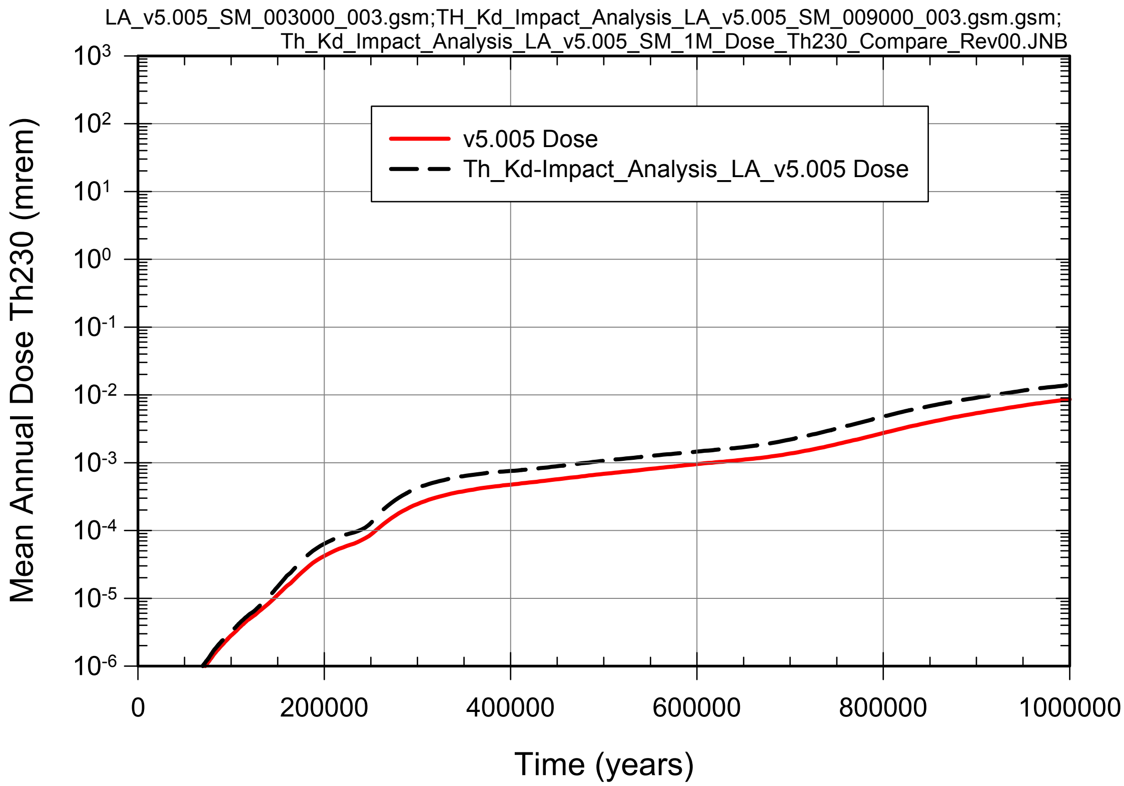
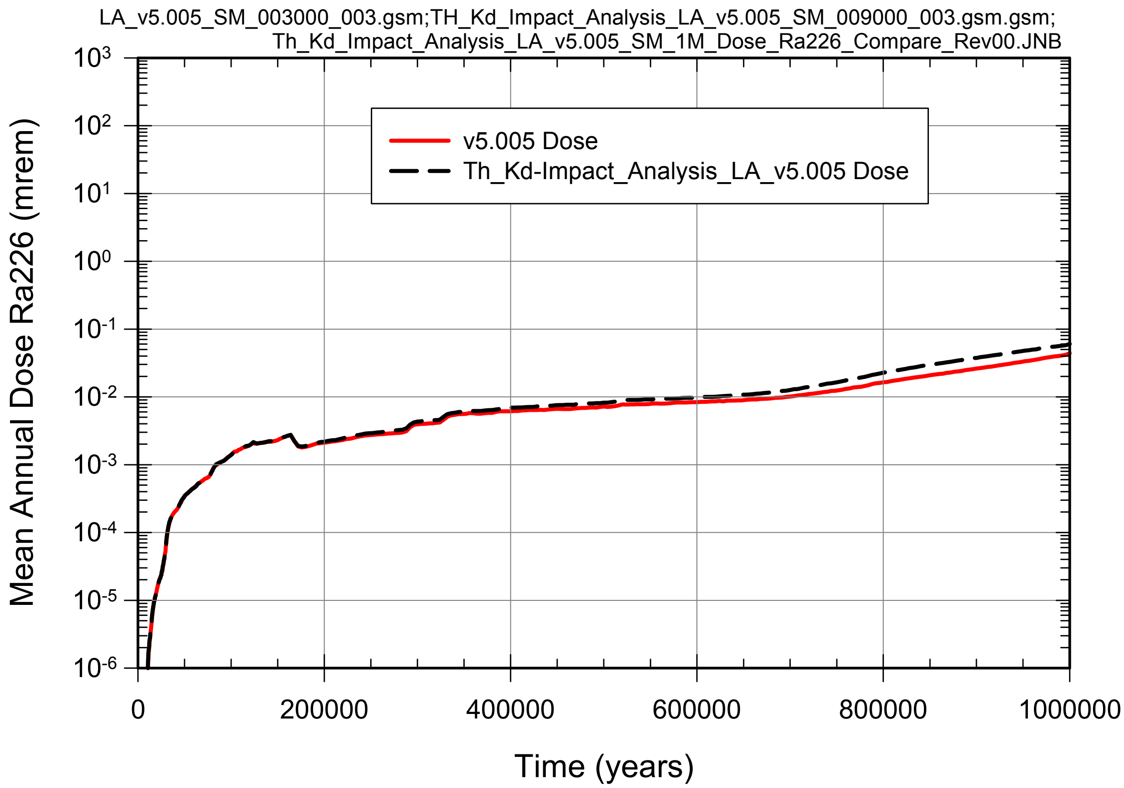
Figure A-11. Comparison of Mean Annual Dose for the TSPA-LA Model to the Thorium K_d Changed Model for the SM One-Million-Year Modeling Case. Note: the base case is red line and the sensitivity case is black dashed line.



DTN: MO0810LLAMDLIA.000

Figure A-12. Comparison of ^{230}Th Mean Annual Dose for the TSPA-LA Model to the Thorium K_d Changed Model for the SM One-Million-Year Modeling Case. Note: the base case is red line and the sensitivity case is black dashed line.



DTN: MO0810LLAMDLIA.000

Figure A-13. Comparison of ^{226}Ra Mean Annual Dose for the TSPA-LA Model to the Thorium K_d Changed Model for the SM One-Million-Year Modeling Case. Note: the base case is red line and the sensitivity case is black dashed line.

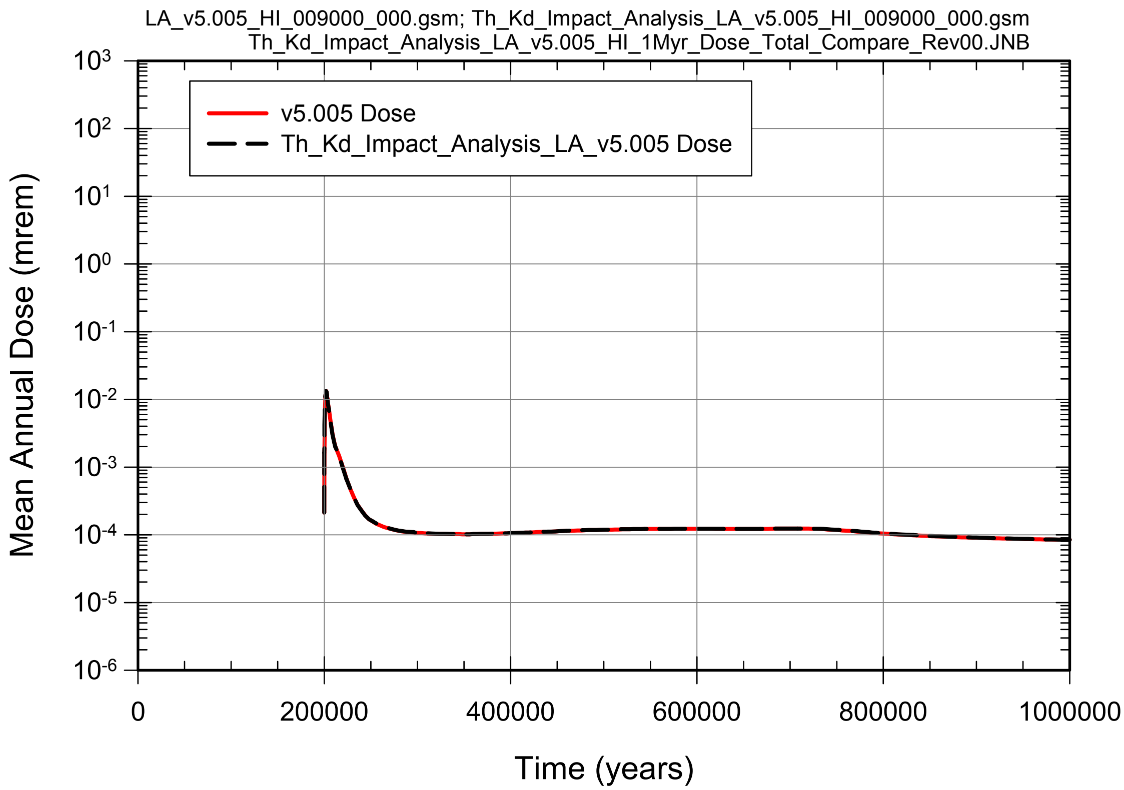


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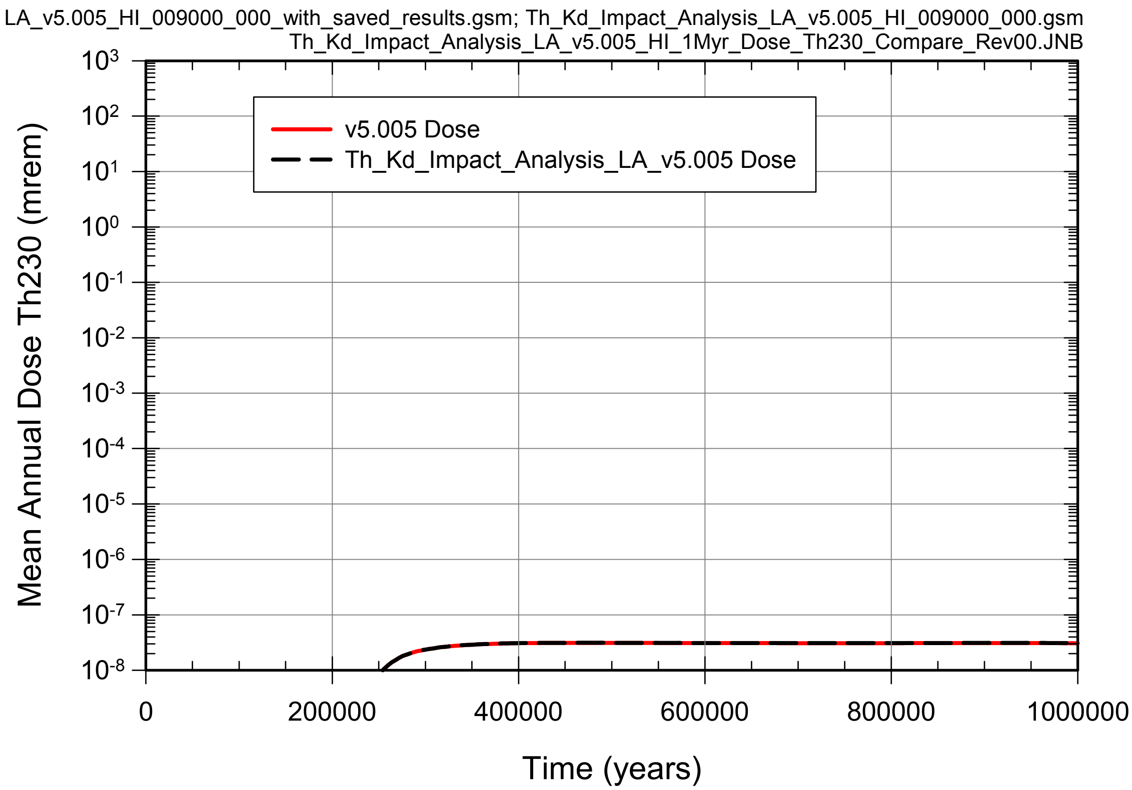
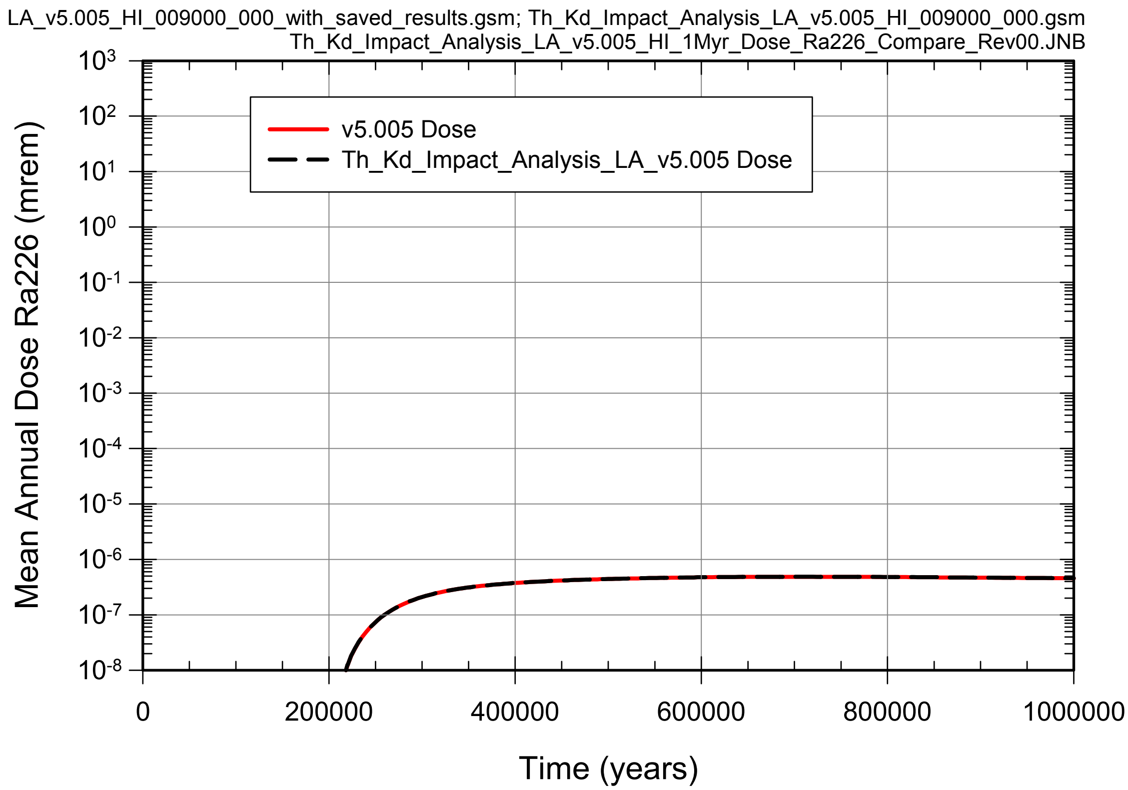
Figure A-14. Comparison of Mean Annual Dose for the TSPA-LA Model to the Thorium K_d Changed Model for the HI One-Million-Year Modeling Case. Note: the base case is red line and the sensitivity case is black dashed line.



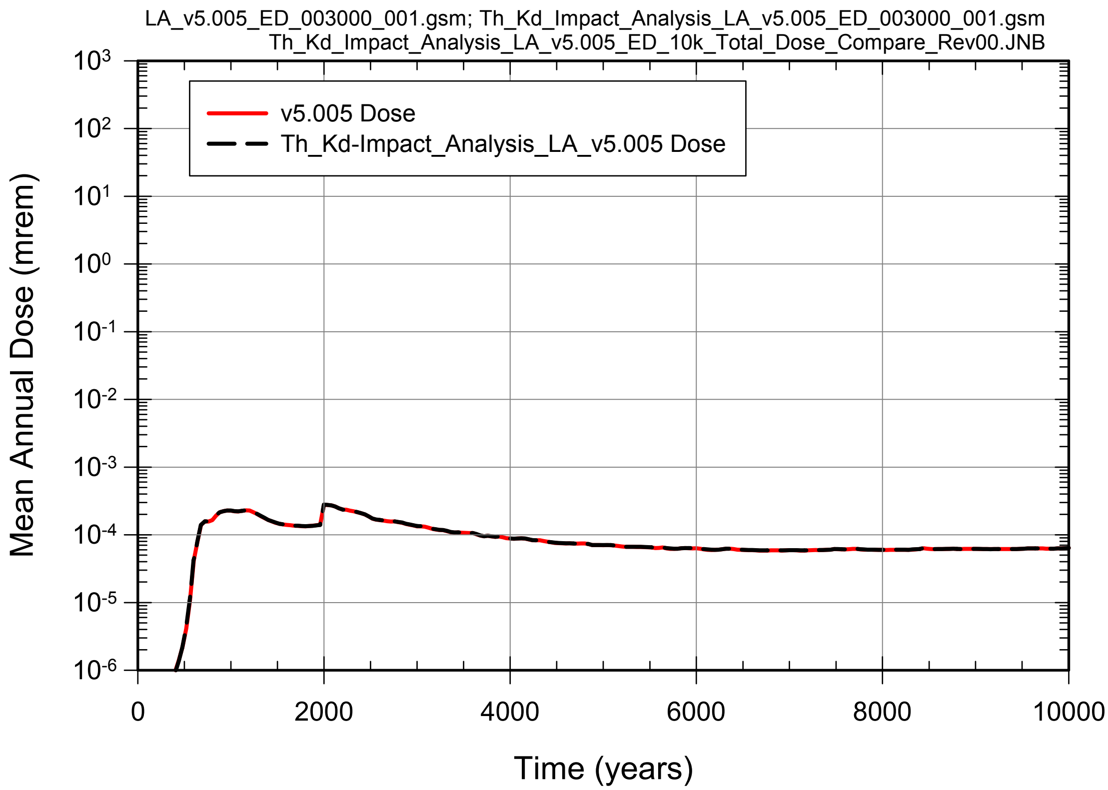
DTN: MO0810LLAMDLIA.000

Figure A-15. Comparison of ^{230}Th Mean Annual Dose for the TSPA-LA Model to the Thorium K_d Changed Model for the HI One-Million-Year Modeling Case. Note: the base case is red line and the sensitivity case is black dashed line.



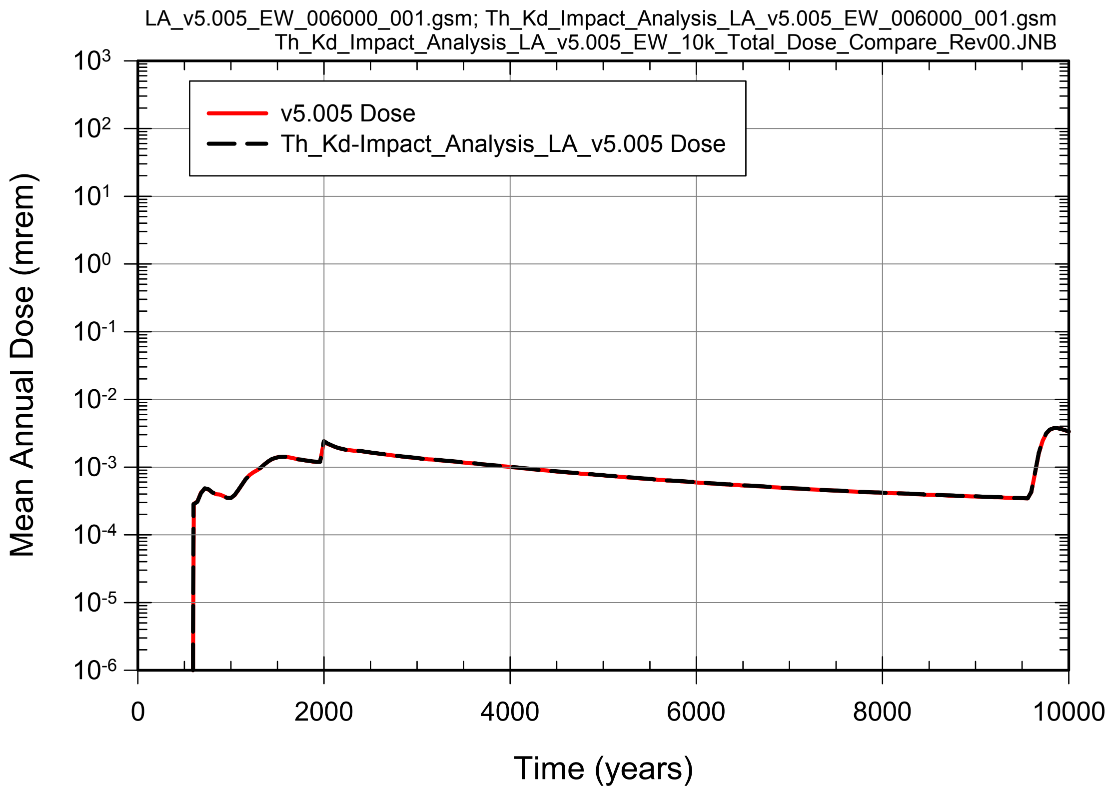
DTN: MO0810LLAMDLIA.000

Figure A-16. Comparison of ^{226}Ra Mean Annual Dose for the TSPA-LA Model to the Thorium K_d Changed Model for the HI One-Million-Year Modeling Case. Note: the base case is red line and the sensitivity case is black dashed line.



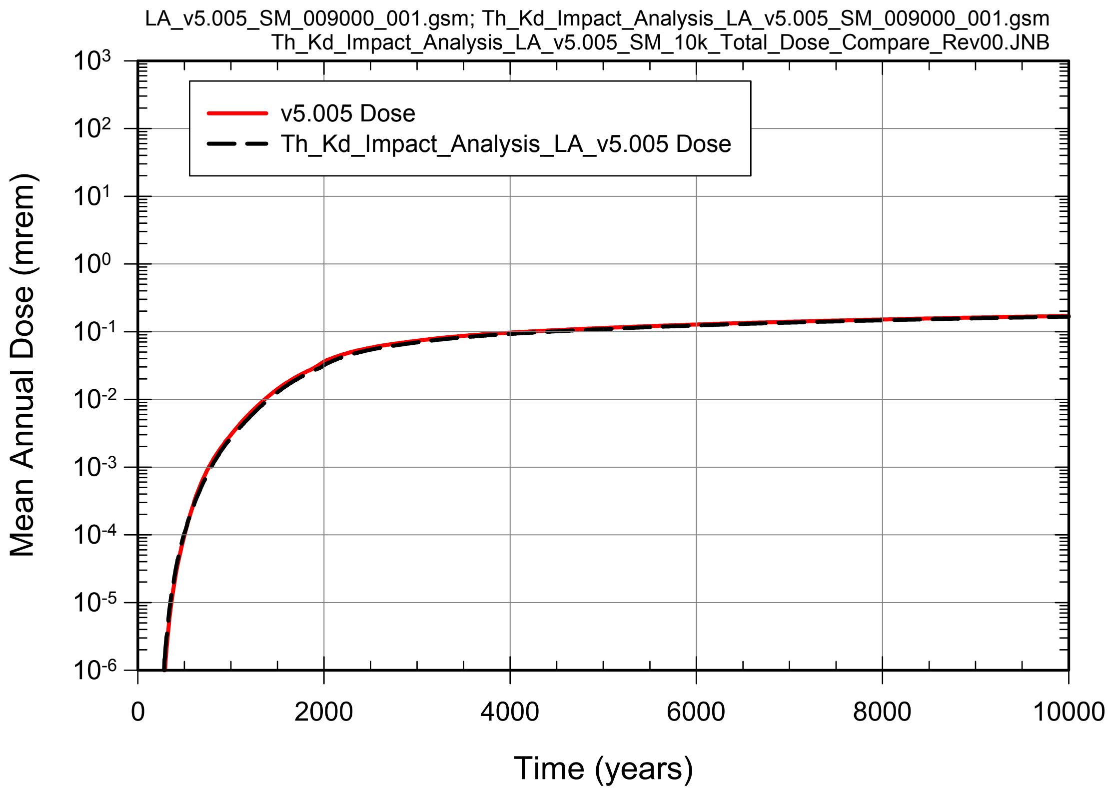
DTN: MO0810LLAMDLIA.000

Figure A-17. Comparison of Mean Annual Dose for the TSPA-LA Model to the Thorium K_d Changed Model for the ED 10, 000-Year Modeling Case. Note: the base case is red line and the sensitivity case is black dashed line.



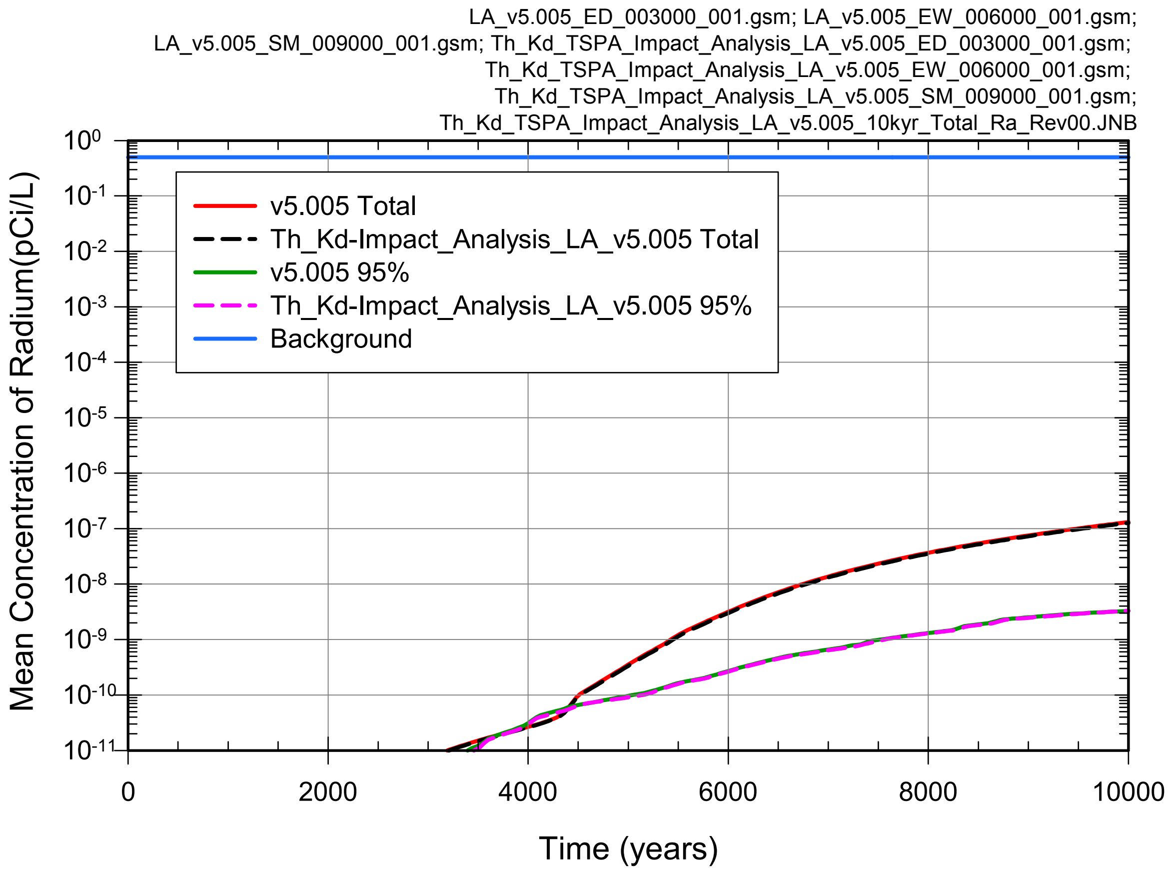
DTN: MO0810LLAMDLIA.000

Figure A-18. Comparison of Mean Annual Dose for the TSPA-LA Model to the Thorium K_d Changed Model for the EW 10, 000-Year Modeling Case. Note: the base case is red line and the sensitivity case is black dashed line.



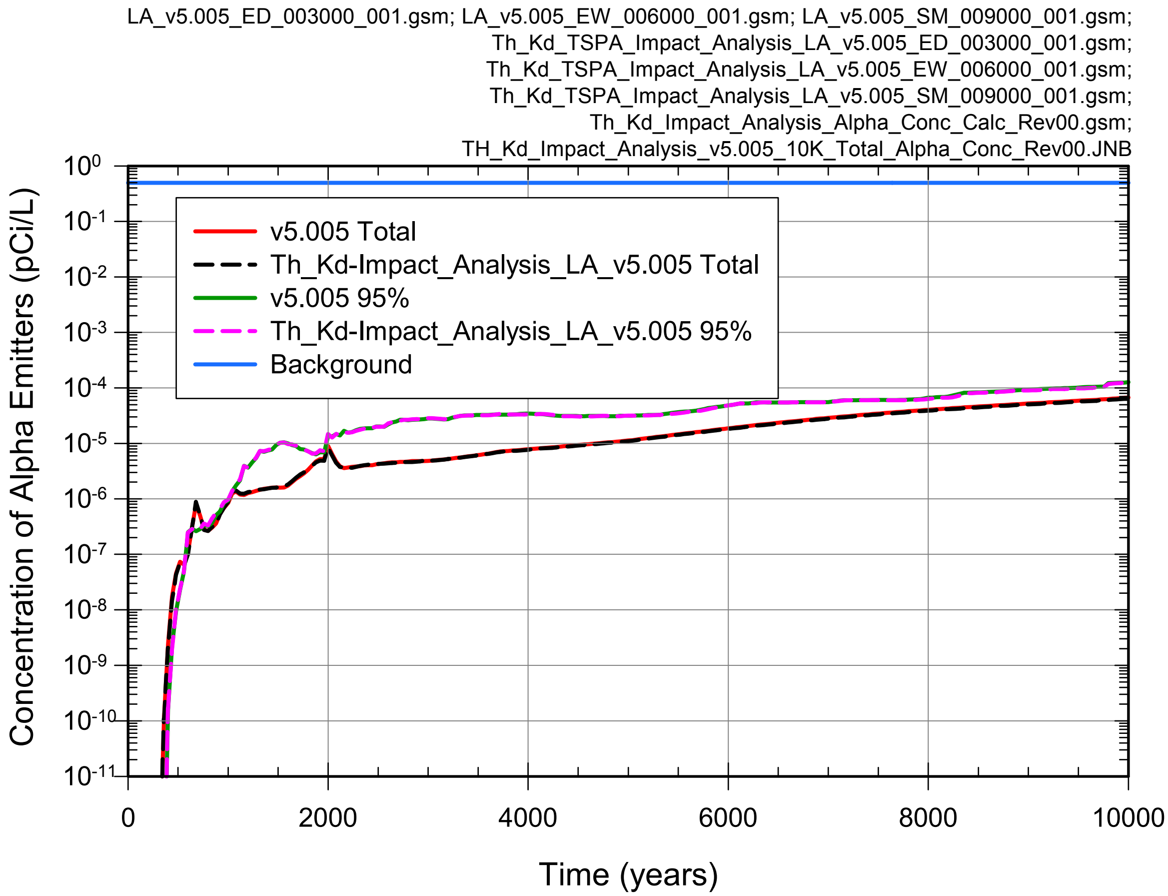
DTN: MO0810LLAMDLIA.000

Figure A-19. Comparison of Mean Annual Dose for the TSPA-LA Model to the Thorium K_d Changed Model for the SM 10, 000-Year Modeling Case. Note: the base case is red line and the sensitivity case is black dashed line.



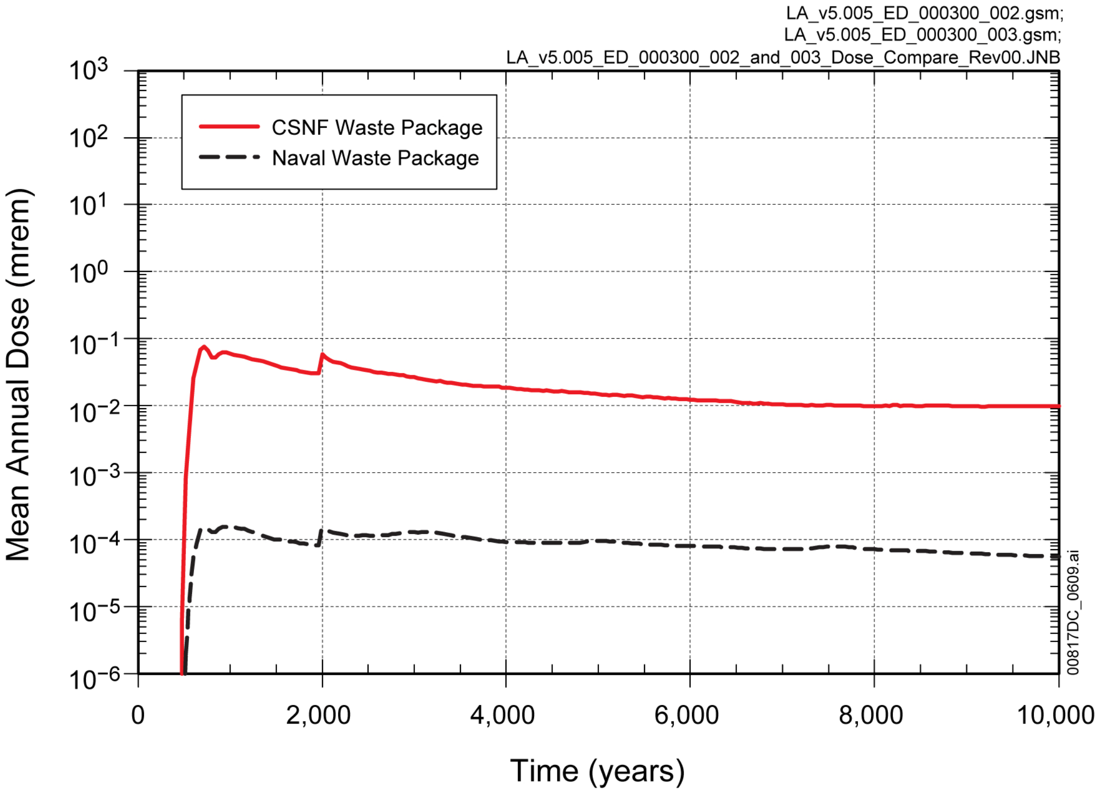
DTN: MO0810LLAMDLIA.000

Figure A-20. Comparison of combined Total Radium (^{226}Ra and ^{228}Ra) Concentrations between the TSPA-LA Model and the Thorium K_d Changed Model. Note: the base cases are solid red and green lines and the sensitivity cases are black and pink dashed lines, respectively.



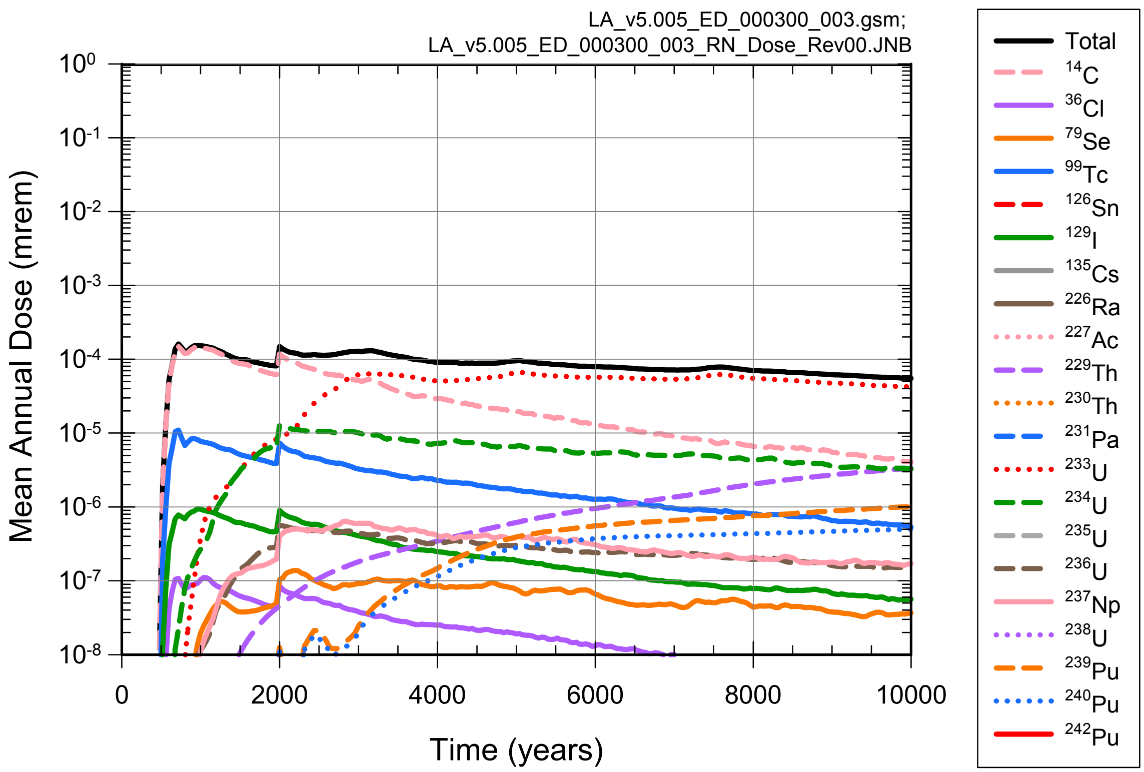
DTN: MO0810LLAMDLIA.000

Figure A-21. Comparison of Gross Alpha Activity Concentrations of All Alpha Emitters between the TSPA-LA Model and the Thorium K_d Changed Model. Note: the base cases are solid red and green lines and the sensitivity cases are black and pink dashed lines, respectively.



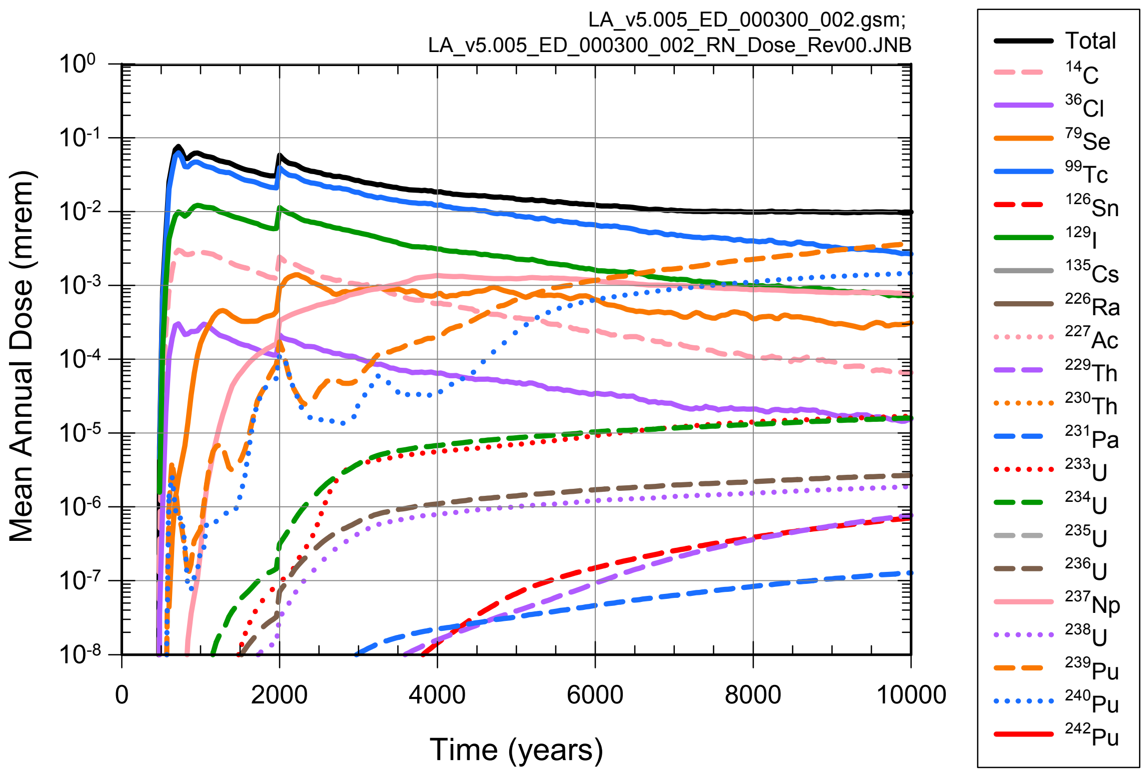
Source: Output DTN: MO0801TSPANSNF.000 [DIRS 184619].

Figure A-22. Comparison of Mean Annual Dose for a Single CSNF waste package and a Single waste package with a Naval Source Term for the ED Modeling Case (From SNL 2008 [DIRS 183478], Figure 7.5-4[a])



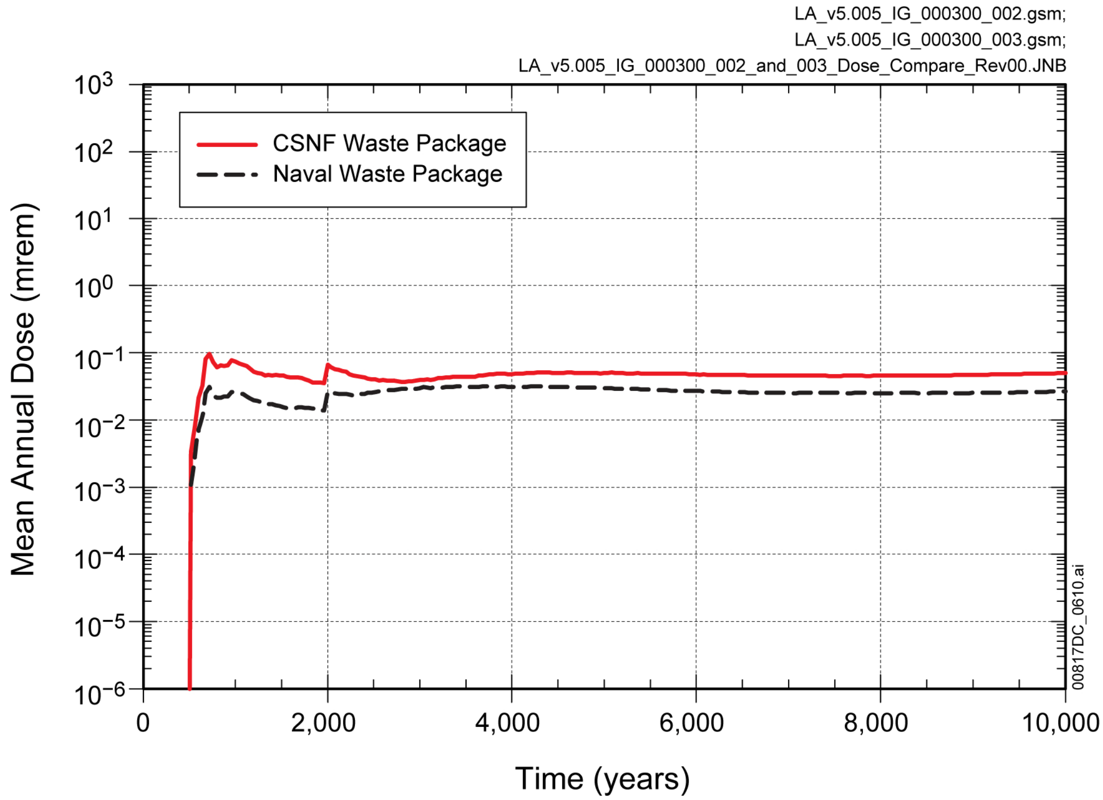
Source: Output DTN: MO0801TSPANSNF.000 [DIRS 184619].

Figure A-23. Contribution to Mean Dose from a Single waste package with a Naval Source Term for the ED Modeling Case



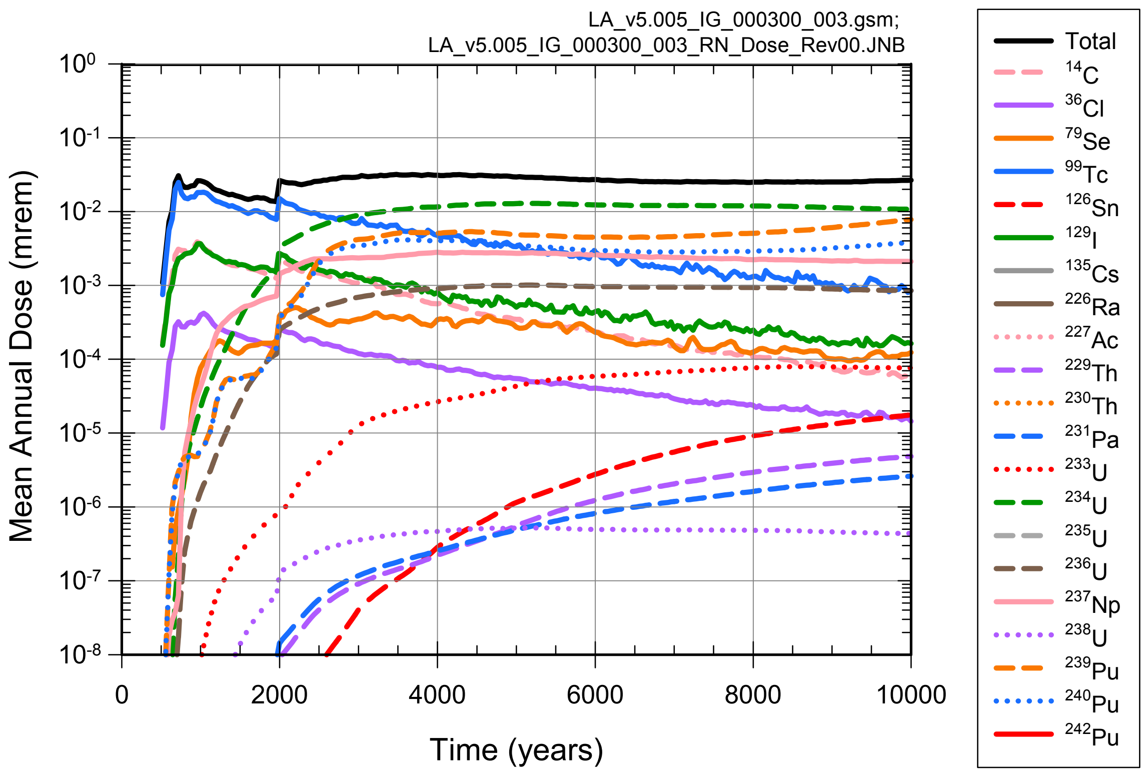
Source: Output DTN: MO0801TSPANSNF.000 [DIRS 184619].

Figure A-24. Contribution to Mean Dose from a Single CSNF waste package for the ED Modeling Case



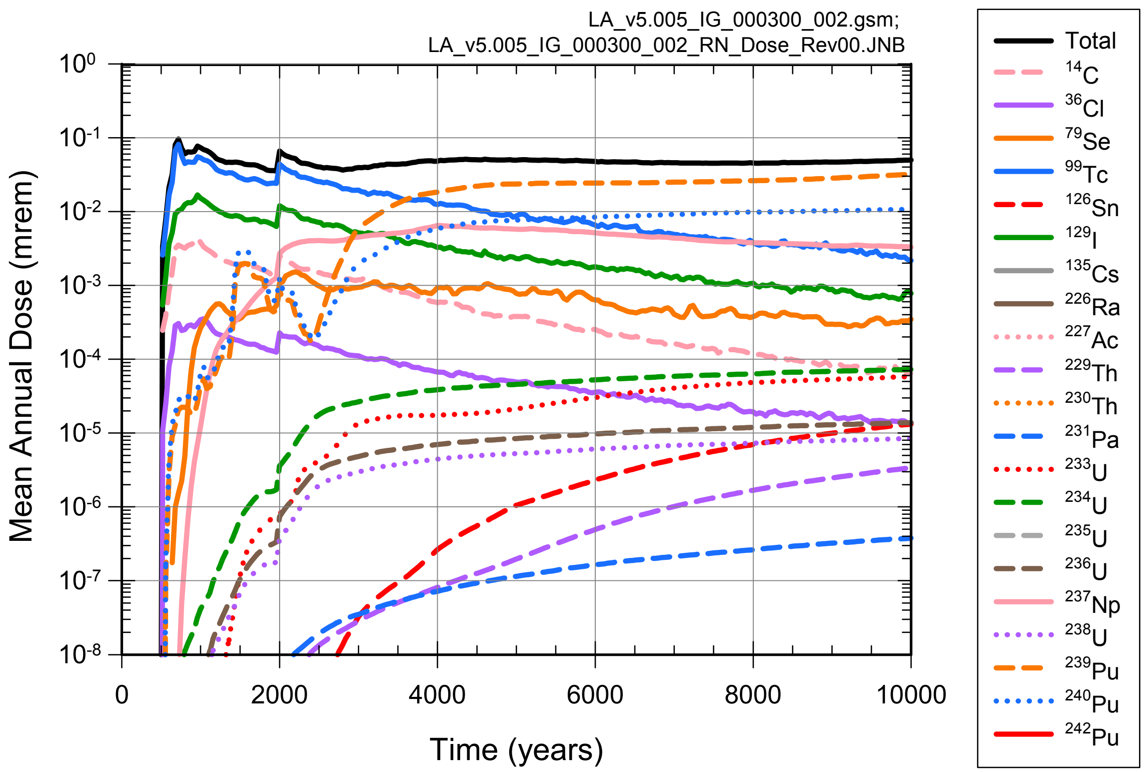
Source: Output DTN: MO0801TSPANSNF.000 [DIRS 184619].

Figure A-25. Comparison of Mean Annual Dose for a Single CSNF waste package and Single waste package with a Naval Source Term for the IG Modeling Case (From SNL 2008 [DIRS 183478], Figure 7.5-5[a])



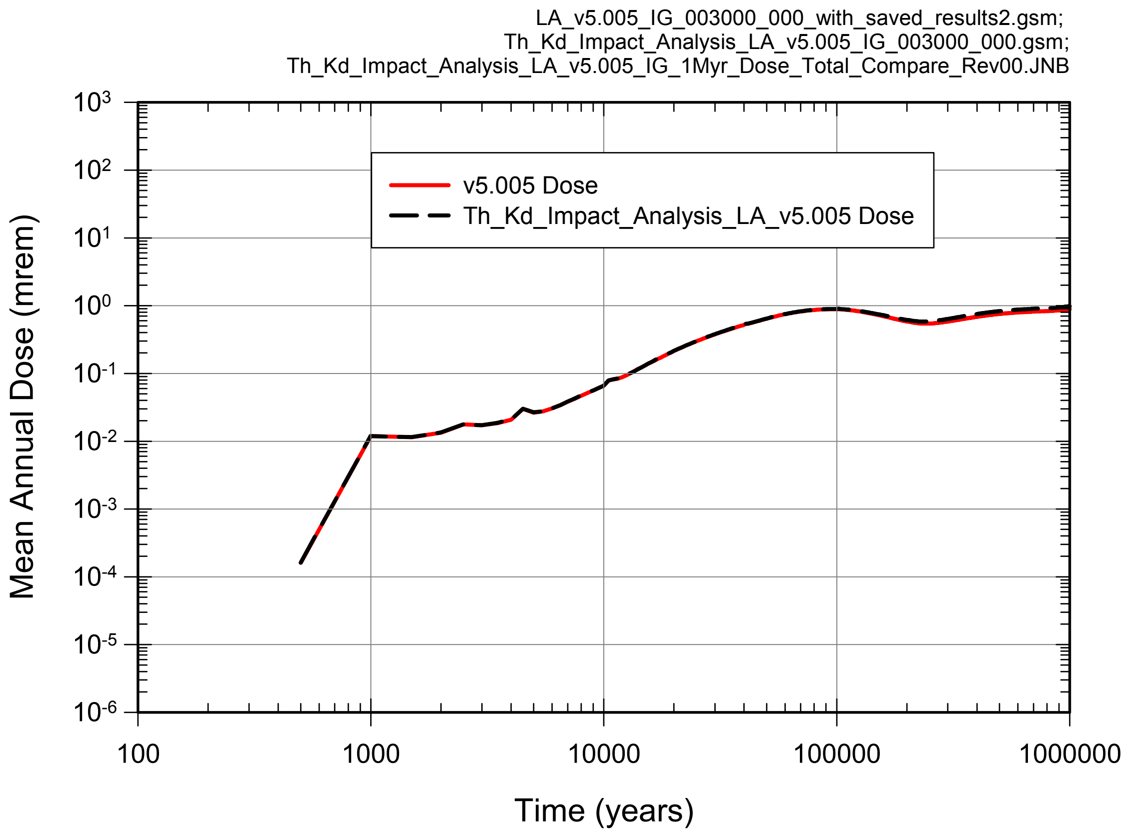
Source: Output DTN: MO0801TSPANSNF.000 [DIRS 184619].

Figure A-26. Contribution to Mean Dose from a Single waste package with a Naval Source Term for the IG Modeling Case



Source: Output DTN: MO0801TSPANSNF.000 [DIRS 184619].

Figure A-27. Contribution to Mean Dose from a Single CSNF waste package for the IG Modeling Case



DTN: MO0810LLAMDLIA.000

Figure A-28. Comparison of the Mean Annual Dose for the TSPA-LA Model to the Thorium K_d Changed Model for the IG One-Million-Year Modeling Case with the Time Scale converted to Log Base10