5.2.6 Igneous-Activity Scenario

The model and parameter changes from TSPA-SR to the model configuration used in the analysis for this Letter Report for the igneous-activity scenario are described in detail in SSPA Volume 1 (BSC 2001 [DIRS 154657], Sections 13 and 14, all) and are summarized here.

Several input parameters to the TSPA models used to calculate consequences of igneous disruption were changed subsequent to the TSPA-SR and have been included in this analysis (BSC 2001 [DIRS 154657], Section 14.3.3.7, all). Consistent with new information regarding the probability of an eruption at the location of the potential repository given an igneous intrusive event (BSC 2001 [DIRS 154657], Section 14.3, all), the conditional probability of an eruption at the potential repository was revised from 0.36 (CRWMS M&O 2000 [DIRS 153246], Table 3.10-4, p. 198) to 0.77 (BSC 2001 [DIRS 154657], Section 14.3.3.1, p. 14-13). According to *Characterize Framework for Igneous Activity at Yucca Mountain, Nevada.* (CRWMS M&O 2000 [DIRS 151551], Section 6.5.3.2, all, and Table 12a, p. 130), the approach for the calculation of the conditional number of eruptive centers occurring within the repository footprint was modified by: (1) using empirical distributions for the average spacing between eruptive centers rather than the expected values for these distributions; and (2) incorporating uncertainty in the effect of the repository opening on the conditional probability of the occurrence of an eruptive center within the potential repository footprint. This modified approach resulted in the new conditional probability of 0.77 for one eruptive center to occur involving the Primary Block of the HTOM repository footprint during or coincident with an igneous-activity event. This conditional probability has also been assumed for the LTOM analyses whose results are presented below in Section 6.

Changes also were made in the probability distribution for an intrusive event, consistent with revisions in the potential repository footprint (i.e. changes related to the HTOM) since inputs were compiled for TSPA-SR. Revised distributions were provided for the number of waste packages affected by igneous-intrusion and volcanic-eruption scenarios, consistent with the revised event-probability information for the Primary Block of the HTOM. This adjusted event probability has also been assumed for the results of the LTOM analyses presented in Section 6. Changes have been made in the input data used to determine the wind speed during an eruption (BSC 2001 [DIRS 154657], Section 3.3.1.2.1, all). Additional changes in inputs to the TSPA-SR igneous-consequence model are listed in SSPA Volume 1 (BSC 2001 [DIRS 154657], Section 14.3.3.7, p. 14-24, and Tables 14.3.3.7-1 and 14.3.3.7-2, p. 14T-5 to 14T-6). Other model inputs and assumptions, including the assumption that wind direction is fixed toward the location of the receptor at all times, are the same as those used in the TSPA-SR (CRWMS M&O 2000 [DIRS 153246] Section 3.10, all).

5.2.7 Human-Intrusion Scenario

The human-intrusion scenario for the calculations in this Letter Report was developed from that in the TSPA-SR (CRWMS M&O 2000 [DIRS 153246], Section 4.4, all). The model changes implemented for the human-intrusion calculations in this Letter Report are described as follows.

Errata in the TSPA-SR human-intrusion model associated with "boosting" the inventory of certain radionuclides to account for first-generation daughter product transport through the 3-D SZ model (CRWMS M&O 2000 [DIRS 148384], Section 6.3.4.1, p. 233) were corrected.

In the TSPA-SR human-intrusion model (CRWMS M&O 2000 [DIRS 148384], Section 6.3.9.3, p. 513), for the purpose of determining thermohydrologic conditions, in-package chemistry, and in-drift chemistry, the failed waste package was placed in a specified dripping environment for a given infiltration condition. For the calculations in this Letter Report, the failed waste package for each realization of the human-intrusion scenario is randomly placed in one of several dripping environments depending on the infiltration condition.

Colloidal-facilitated transport of Am, Pu, Th, and Pa in an exploratory borehole through the UZ has been included in the human-intrusion scenario in this Letter Report. Np-237, the daughter of irreversibly sorbed Am-241, is included as an irreversibly sorbed colloidal species. Colloidal-facilitated transport is implemented by adjusting the sorption coefficients of the aforementioned nuclides according to the relationship (CRWMS M&O 2000 [DIRS 139440], p. 26):

$$K_d^{adj} = \frac{K_d^{orig}}{(1+K_c)}$$

where,

K_d^{orig} = sorption coefficient without colloidal-facilitated transport

K_d^{adj} = sorption coefficient with colloidal-facilitated transport

K_c = colloid partition coefficient

The human-intrusion scenario included in this Letter Report was simulated for a 1,000,000-year duration (as opposed to the 100,000-year duration in the TSPA-SR). To be consistent with the SSPA 1,000,000-year calculations, two additional nuclides, ^{228}Ra and ^{232}Th, are included in the inventory (BSC 2001 [DIRS 154657], Section 13.2.1.10, p. 13-9 to 13-10). The 30,000-year human-intrusion scenario is the same scenario analyzed in the SSPA (BSC 2001,Volume 1 [DIRS 154657], Appendix A, all). The information presented in this appendix addresses the issue of when a human intrusion could occur based upon the earliest time that current technology and practices could lead to a waste-package penetration without the driller noticing the waste-package penetration. The time is effectively the time to general-corrosion failure of a waste package, approximately 30,000 years. The 100-year human-intrusion scenario was developed based on NRC guidance provided at proposed 10 CFR Part 63.113d ([DIRS 107770], p. 8651 to 8652).

The assessment of the human-intrusion scenario did not combine the results of the human-intrusion scenario with the results of the disruptive igneous-activity scenario. However, combined results can be approximated by adding the results of the human-intrusion calculations to the results of the igneous-activity scenario. Whether or not the intrusion occurred at 100 years or at 30,000 years, based on the results presented in sections 6.3 and 6.4 below, the highest mean annual dose to the RMEI that would result from a human intrusion would be more than an order-of-magnitude less, or one tenth, than the dose from a disruptive igneous event.

5.3 SOURCE TERM

The source term for the calculation of the annual dose histories associated with disposal of CSNF, DSNF, and HLW waste under all scenarios in this Letter Report includes the several

waste forms that are contained in the waste packages. The descriptions of the types of waste, the packaging, the physical properties, and the dissolution models of the waste forms are presented in the TSPA-SR Rev 00 ICN 01(CRWMS M& O 2000 [DIRS 153246], Sections 3.5.3 and 3.5.4, all).

5.3.1 Radionuclide Inventories

The calculations included in this Letter Report are based on radionuclide inventories which conform to). the Nuclear Waste Policy Act of 1982, as amended (NWPA, Public Law 97-425 [DIRS 131951]) to include the total projected commercial and DOE waste. The materials comprising the 70,000-MTHM-case radionuclide inventory are described and tabulated in *Inventory Abstraction* (BSC 2001 [DIRS 154841], Table 36, p. 38). The tabulated per-package inventory used in these calculations is shown on Table 5-3. The cases analyzed, as directed by DOE, are described in Section 1. The radionuclide inventory used for Module 2 (i.e. GTCC and SPAR waste) is described and tabulated in DOE (1999 [DIRS 105155] Volume II, Appendix A, p. A-56 to A-61) and that per-package inventory is shown on Table 5-4. The details of obtaining the per-package inventory for GTCC and SPAR are described in Attachment III of this Letter Report.

Table 5-3 Per-Package Radionuclide Inventories for the CSNF and Co-Disposal Waste Packages

Isotope	CSNF Waste Packages (grams/waste package)	Co-Disposal Waste Packages (grams/waste package)	
		From DSNF	From HLW Glass
^{227}Ac	3.09E-06	1.13E-04	4.67E-04
^{241}Am	1.09E+4	1.17E+02	6.57E+01
^{243}Am	1.29E+03	1.49E+00	3.99E-01
^{14}C	1.37E+00	4.69E-02	6.43E-03
^{137}Cs	5.34E+03	1.12E+02	4.51E+02
^{129}I	1.80E+03	2.51E+01	4.80E+01
^{237}Np	4.74E+03	4.79E+01	7.23E+01
^{231}Pa	9.87E-03	3.25E-01	7.96E-01
^{210}Pb	0.00E+00	1.40E-08	1.14E-07
^{238}Pu	1.51E+03	6.33E+00	9.33E+01
^{239}Pu	4.38E+04	2.30E+03	3.89E+03
^{240}Pu	2.09E+04	4.89E+02	3.81E+02
^{242}Pu	5.41E+03	1.11E+01	7.77E+00
^{226}Ra	0.00E+00	1.87E-06	1.67E-05
^{228}Ra	0.00E+00	6.98E-06	3.19E-06
^{90}Sr	2.24E+03	5.54E+01	2.88E+02
^{99}Tc	7.68E+03	1.15E+02	7.29E+02
229Th	0.00E+00	2.66E-02	4.08E-03
230Th	1.84E-01	1.06E-02	7.82E-03
^{232}Th	0.00E+00	1.49E+04	7.31E+03
^{232}U	1.01E-02	1.47E-01	8.23E-04
^{233}U	7.00E-02	2.14E+02	1.11E+01
^{234}U	1.83E+03	5.72E+01	4.72E+01
^{235}U	6.28E+04	8.31E+03	1.70E+03
^{236}U	3.92E+04	8.53E+02	3.98E+01
^{238}U	7.92E+06	5.09E+05	2.61E+05

DTN: SN0003T0810599.010 [DIRS 151021]

Table 5-4 Per-Package Radionuclide Inventories for the GTCC and SPAR Waste

Isotope	GTCC and SPAR (grams/Waste Package)
^{227}Ac	0.00E+00
^{241}Am	4.00E+01
^{243}Am	1.51E-03
^{14}C	2.89E+01
^{137}Cs	7.71E+02
^{129}I	7.05E-04
^{237}Np	0.00E+00
^{231}Pa	0.00E+00
^{210}Pb	0.00E+00
^{238}Pu	1.56E+00
^{239}Pu	2.86E+03
^{240}Pu	1.23E-02
^{241}Pu	2.07E-02
^{242}Pu	6.14E-03
^{226}Ra	5.04E-02
^{90}Sr	8.20E-01
^{99}Tc	5.68E+02
^{229}Th	0.00E+00
^{230}Th	0.00E+00
^{232}U	2.87E-06
^{233}U	4.19E-03
^{234}U	0.00E+00
^{235}U	0.00E+00
^{236}U	0.00E+00
^{238}U	5.63E+05

See Attachment III of this Letter Report for development of the data included in this table.

5.3.2 Waste Packaging

The waste packages simulated in this Letter Report include CSNF packages and DSNF-HLW co-disposal packages as described in the *Update to the EIS Engineering File for the Waste Package in Support of the Final EIS* (CRWMS M&O 2000 [DIRS 150558], Section 4.3, all).

5.3.3 Waste Form Physical Properties

The physical properties of the various waste forms for the CSNF, DSNF, and HLW to be placed in the proposed Yucca Mountain repository are described in detail in the TSPA-SR (CRWMS 2000 [DIRS 153246], Section 3.5). The waste-form modeling consists of the in-package chemistry model, dissolution models for each waste form type (CSNF, DSNF, HLW), concentration limits for each radionuclide (representing the effect of the formation of secondary phases), and the formation and sorption of colloids (BSC 2001 [DIRS 154657], Sections 3 and 4, all).

5.3.4 Cladding Failure

The model and parameter changes from TSPA-SR to the model configuration used in this analysis for the cladding degradation are described in detail in SSPA Volume 1 (BSC 2001 [DIRS 154657], Section 9.3.3, p. 9-18 to 9-23) and are summarized here. The SSPA model was a modification of the cladding model developed in the TSPA-SR (CRWMS M&O 2000 [DIRS 148384], Section 3.5.4, p. 3-111 to 3-118).

The cladding-degradation component of the SSPA model used in the calculation presented in this Letter Report consists of six components. These components are represented by mathematical distributions covering the expected range of values of the parameters used in the calculation. The degradation components incorporated in the cladding model are:

1. The number of rods initially perforated in a CSNF waste package from reactor operation, shipping, or during dry storage,

2. The fraction of cladding perforated because of creep rupture and stress-corrosion cracking,

3. Cladding failure from localized corrosion,

4. Failure from mechanical damage, namely due to seismic events (Rock-overburden failures have been added for sensitivity calculations since the TSPA-SR model was developed.),

5. The CSNF degradation rate (intrinsic dissolution), and

6. The unzipping of the cladding, which represents the exposure of the surface area of the CSNF matrix inside the cladding and its availability for degradation.

6. RESULTS

The GoldSim simulations in support of this Letter Report estimate the dose to the RMEI for both the 70,000-MTHM-case inventory and expanded-inventory cases (119,000 MTHM plus GTCC and SPAR waste), and for igneous-activity and human-intrusion scenarios. The downgradient RMEI location, has been specified by DOE as the farthest southern point at the boundary of the controlled area and the accessible environment, as defined in 40 CFR Part 197.12 (66 FR 32074 [DIRS 155216], p. 32133). This is the location where radiological results, i.e. RMEI dose and groundwater protection, are calculated. According to 40 CFR Part 197.21 and Part 197.31 (66 FR 32074 [DIRS 155216], p. 32134 to 32135), compliance should be evaluated at the point above the highest concentration of radionuclides in the simulated plume of contamination where the plume crosses the southernmost boundary of the controlled area, at a Latitude of 36°40′13.6661″ North, and enters the accessible environment approximately 18 km downgradient from the repository. This location corresponds to where the RMEI, who lives in an average farming community, would consume and use groundwater withdrawn from wells. In accordance with 40 CFR Part 197.35 ([DIRS 155216], p. 32135), the annual dose was calculated for the period of geologic stability which is 1,000,000 years. These calculations indicate that GoldSim simulations extending from repository closure to 1,000,000 years after repository closure include both the 10,000 and 1,000,000 year performance periods specified in 40 CFR Part 197.20 and 197.35 (66 FR 32074 [DIRS 155216], p 32134 and 32135). The calculations included in this Letter Report also show the peak dose for all scenarios. The location is also the location where a

representative volume of groundwater would be withdrawn and whose radiation cannot exceed the limits of 40 CFR Part 197.30 Table 1 ([DIRS 155216] p. 32134). This Letter Report also evaluates groundwater protection at that location.

The data from the multiple realizations can be summarized by showing time versus annual dose (i.e. annual dose histories) for the 5th and 95th percentile of the output, along with the mean and median of the output. In the same manner as described for TSPA-SR (CRWMS M&O 2000 [DIRS 153246], Section 2.2.4.6, p. 2-39 to 2-40), these statistical measures are calculated for all 300 realizations of the probabilistic simulations at each time step of the dose histories. The plot of the ***mean*** represents the average of all 300 data points at each time step. For each point on the plot of the ***median*** dose, 50 per cent of the data have a value greater than the plotted point and 50 per cent have a value less that the plotted point. Likewise, for the ***95th and 5th percentiles***, the plotted data points are such that 5 percent of data are greater (or less) than the plotted point and 95 per cent of the data points are less (or greater) than the plotted points, for each point, or time step, plotted. The statistical measures are superimposed, in contrasting colors, on plots that show all 300 realizations, also known as "horsetail plots".

The data files containing all the graphical and tabular results for the calculations presented in this report have been submitted to the Records Processing Center along with a list of the files and instructions on retrieving these data. (Saulnier, G. 2001. "Delivery of Input and Output Files used in the Analyses for Disposal of Commercial and DOE Waste Inventories at Yucca Mountain - Input to Final Environmental Impact Statement and Site Suitability Evaluation." MOL.20010926.0009 [DIRS 156138], all).

6.1 WASTE PACKAGE FAILURE

Figure 6-1 shows the waste-package failure curves for the 70,000-MTHM case for the 1,000,000-year performance period for the HTOM. The figure indicates that the first waste-package failures occur at less than 10,000 years after repository closure. These early waste-package failures are due to improper heat treatment, manufacturing defects, and materials failures (Section 5.2.4). The figure shows that only from 1 to 3 waste packages incur early failure. Because waste-package failure is the first step in releasing radionuclides for groundwater flow and transport, the figure demonstrates that, for the 70,000-inventory case, the early dose to receptors before 10,000 years postclosure is orders of magnitude less than the peak dose that occurs a few hundred-thousand years after repository closure as shown in results presented in Section 6.2 below.

Figure 6-2 shows cladding perforated during the post-closure period and includes the averaged impact of seismic events. The cladding failure results presented in Figure 6-2 are essentially the same as developed in the SSPA (BSC 2001 [DIRS 154659], p.9-19 to 9-23).

6.2 ANNUAL DOSE HISTORIES FOR THE 1,000,000- YEAR PERFORMANCE PERIOD

This Letter Report presents graphical representations of annual dose histories for the inventories and scenarios described in Section 1. The performance period for the calculations in this Letter Report was generally 1,000,000 years after repository closure except in the case of the igneous-activity scenarios. The annual dose histories for the igneous-activity scenarios were calculated

for 100,000 years postclosure. In addition to the following graphical presentations, Table 6-1 shows the values of a) the peak mean annual dose (and the time of the peak dose) for all scenarios that occurs in the 10,000-year, 100,000-year, and 1,000,000-year postclosure performance periods, in accordance with 40 CFR Part 197.20, 197.25, and 1978.35 (66 FR 32074 [DIRS 155216], p. 32134 to 32135), and b) the peak 95th percentile dose for the same performance periods and scenarios.

6.2.1 Annual Dose Due to the 70,000-MTHM Inventory

6.2.1.1 Annual Dose Calculated for the High-Temperature Operating Mode

Figure 6-3 shows the mean annual dose results of the 300 probabilistic simulations for the HTOM (approximately 56 MTHM/acre) for the 70,000-MTHM inventory at the RMEI location (~ 18 km downgradient from the repository) for 1,000,000 years after repository closure. Figure 6-3 also shows the results of the TSPA-SR nominal-case results for comparison (CRWMS M&O 2000 [DIRS 153246], Figure 4.1-19a, p. F4-19). Figure 6-4 displays the relative contribution of selected radionuclides that contribute most to the total mean annual dose due to all radionuclides. Figure 6-5 displays the results of the 300 probabilistic simulations of the 70,000-MTHM inventory, HTOM, at the RMEI location (~18 km) downgradient from the repository for 1,000,000 years after repository closure. This figure displays the results for each realization and the 5th and 95th percentiles, and the mean and median of these simulations.

Table 6-1 Peak Dose and Year of Peak Dose by Scenario for Various Performance Periods: (a) Peak Mean Annual Dose; (b) Peak 95th Annual Dose

a) Peak Mean Annual Dose

Mean Annual Dose (mrem/yr)							
Case	Model File	10,000 yr Peak		100,000 yr Peak		1,000,000 yr Peak	
		Value	Year	Value	Year	Value	Year
70,000 MTHM, HTOM	SE01_006nm6	1.7E-05	4,875	1.2E-01	99,500	152.5	476,000
70,000 MTHM, LTOM	SE01_007nm6	1.1E-05	3,437.5	8.5E-02	99,500	122.2	476,000
Module 1, HTOM	SE01_010nm6	2.7E-05	4,937.5	1.6E-01	100,000	237.9	476,000
Module 2, HTOM	SE01_012nm6	6.6E-04	2,875	6.6E-04	2,875	3.3E-01	208,000
Igneous Activity, HTOM	SE01_001im5	1.0E-01	312.5	1.0E-01	312.5	N/A	
Igneous Activity, LTOM	SE01_002im5	1.0E-01	312.5	1.0E-01	312.5	N/A	
Igneous Activity, HTOM (Intrusive Only)	SE01_001im5	4.3E-04	10,000	2.1E-02	48,000	N/A	
Igneous Activity, LTOM (Intrusive Only)	SE01_002im5	5.0E-04	10,000	2.8E-02	48,000	N/A	
Igneous Activity, HTOM (Eruptive Only)	SE01_001im5	1.0E-01	312.5	1.0E-01	312.5	N/A	
Igneous Activity, LTOM (Eruptive Only)	SE01_002im5	1.0E-01	312.5	1.0E-01	312.5	N/A	
Human Intrusion 30k-yr Event, HTOM	SE01_001hm6	N/A		1.7E-03	30,562.5	2.3E-03	108,000
Human Intrusion 100-yr Event, HTOM	SE01_002hm6	4.8E-03	875	4.8E-03	875	4.8E-03	875
N/A = Not Applicable							
Note: These data are based on the same probabilistic annual water usage model used in the SR (not 3000 acre-ft/yr).							

b) Peak 95th Percentile Dose

95th Percentile Annual Dose (mrem/yr)							
Case	Model File	10,000 yr Peak		100,000 yr Peak		1,000,000 yr Peak	
		Value	Year	Value	Year	Value	Year
70,000 MTHM, HTOM	SE01_006nm6	1.2E-04	4,937.5	4.0E-02	99,500	618.0	408,000
70,000 MTHM, LTOM	SE01_007nm6	8.6E-05	5,000	3.4E-02	100,000	513.2	408,000
Module 1, HTOM	SE01_010nm6	1.8E-04	4125	7.9E-02	100,000	976.7	476,000
Module 2, HTOM[1]	SE01_012nm6	0.0E+00	N/A	1.3E-03	100,000	1.5	208,000
Igneous Activity, HTOM	SE01_001im5	4.1E-01	312.5	4.1E-01	312.5	N/A	
Igneous Activity, LTOM	SE01_002im5	4.1E-01	312.5	4.1E-01	312.5	N/A	
Igneous Activity, HTOM (Intrusive Only)	SE01_001im5	2.9E-04	9,750	5.2E-02	100,000	N/A	
Igneous Activity, LTOM (Intrusive Only)	SE01_002im5	3.1E-04	9,875	3.3E-02	48,000	N/A	
Igneous Activity, HTOM (Eruptive Only)	SE01_001im5	4.1E-01	312.5	4.1E-01	312.5	N/A	
Igneous Activity, LTOM (Eruptive Only)	SE01_002im5	4.1E-01	312.5	4.1E-01	312.5	N/A	
Human Intrusion 30k-yr Event, HTOM	SE01_001hm6	N/A		4.5E-03	38,500	4.5E-03	38,500
Human Intrusion 100-yr Event, HTOM	SE01_002hm6	8.9E-03	2,687.5	8.9E-03	2,687.5	8.9E-03	2,687.5
N/A = Not Applicable							
[1]The mean dose is driven by 3 realizations which experience early failures. No other realizations have a dose before 10,000 years. Thus the 95th highest value is 0 mrem/yr.							
Note: These data are based on the same probabilistic annual water usage model used in the SR (not 3000 acre-ft/yr).							

6.2.1.2 Annual Dose Calculated for the Low-Temperature Operating Mode

Figure 6-3 displays representations of the mean annual dose results of the 300 probabilistic simulations for the LTOM (approximately 45 MTHM/acre) for the 70,000 MTHM inventory at the RMEI location (~ 18 km downgradient from the repository) for 1,000,000 years after repository closure. Because Figure 6-3 shows little difference between the annual dose histories calculated for the HTOM and the LTOM, the remaining scenarios, other than the igneous-activity scenario, were only simulated for the HTOM.

Figure 6-6 displays the results of the 300 probabilistic simulations of the 70,000-MTHM case, LTOM, at the RMEI location (~18 km) downgradient from the repository for 1,000,000 years after repository closure. This figure displays the results for each realization and the 5th and 95th percentiles, and the mean and median of these simulations.

6.2.2 Annual Dose Due for the Module 1 Expanded Inventory, High-Temperature Operating Mode

Figures 6-7 displays the annual dose histories for the 300 probabilistic simulations of the expanded-inventory Module 1, HTOM, case (119,000 MTHM) at the RMEI location (~18 km) downgradient from the repository for 1,000,000 years after repository closure. This figure displays the results for each realization and the 5th and 95th percentiles, and the mean and median of these simulations.

6.2.3 Annual Dose Due to the Module 2 Expanded Inventory, High-Temperature Operating Mode

A GoldSim simulation was also performed for a case that included only the GTCC and SPAR components of the Module 2 inventory. The case did not include the other components of the Module 2 inventory i.e., the 119,000 MTHM of the Module 1 inventory. The GoldSim simulation for only the Module 2 GTCC and SPAR inventory, HTOM, was performed as a separate probabilistic case at the RMEI location (~18 km) downgradient from the repository. Figure 6-8 displays the annual dose histories for the 300 probabilistic simulations of the radioactive components of GTCC and SPAR components of the Module 2 inventory. The effects of non-radioactive components of this waste are not included in the analysis. This figure displays the results for each realization and the 5th and 95th percentiles, and the mean and median of these simulations.

6.2.4 Comparison of Mean Annual Dose Due to the 70,000 MTHM Inventory, the Module 1 Expanded Inventory, and the Module 2 Expanded Inventory, High-Temperature Operating Mode

Figure 6-9 is a comparison plot of the mean annual dose versus time for the 70,000 MTHM inventory, HTOM, and the expanded-inventory cases for the Module 1 and Module 2 inventories, HTOM, at the RMEI location downgradient from a repository. These results show that during the first 10,000 years, the mean annual dose due to the GTCC and SPAR components of the Module 2 inventory is greater than that calculated for the 70,000 MTHM and Module 1 inventories, but is essentially zero. After 10,000 years, the dose due to the GTCC and SPAR components of the Module 2 inventory is about two orders of magnitude less than that calculated for the 70,000 MTHM and Module 1 inventories. These results indicate that the addition of the GTCC and SPAR waste to the Module 1 inventory would not materially increase the mean annual dose. As a result of this comparison, separate probabilistic simulations were deemed to be unnecessary for Module 2, either as separate simulations of the GTCC and SPAR components of the Module 2 inventory or combined with the Module 1 inventory, i.e. as the complete Module 2 inventory.

6.3 ANNUAL DOSE FOR THE IGNEOUS-ACTIVITY SCENARIOS

The performance of a Yucca Mountain repository was evaluated for a combined igneous-activity scenario that included both an igneous event and a volcanic eruption. Probability-weighted simulations of the combined igneous-activity scenario were performed for the HTOM and LTOM for the 70,000 MTHM inventory. However, probability-weighted annual dose histories were not calculated for the igneous-activity scenario for the expanded-inventory cases.

6.3.1 Annual Dose Due to the High-Temperature Operating Mode

Figure 6-10a displays representations of the probability-weighted annual dose histories for 500 of the 5,000 probabilistic simulations for the igneous-activity scenario, HTOM (approximately 56 MTHM/acre) for the 70,000 MTHM inventory at the RMEI location (~ 18 km downgradient from the repository) for 100,000 years after repository closure. Figure 6-10a displays the 5th and 95th percentiles, and the mean and median of all 5,000 probability-weighted igneous-activity simulations. The results presented in Figure 6-10a represent the combined effect of both the igneous-intrusion and eruptive events.

Figure 6-10b displays the probability-weighted mean annual dose versus time for the igneous-activity scenario for the 70,000-MTHM inventory for the HTOM at the RMEI location downgradient from a repository. The figure also displays the mean results for both the eruptive and intrusive events. Figure 6-10c displays the probability-weighted mean annual dose versus time for the igneous-activity scenarios, which represent the sum of the igneous and eruptive events, for the TSPA-SR nominal case (CRWMS M&O 2000 [DIRS 153246], Figure 4.1-19a, p. F4-19), and the 70,000-MTHM inventory for the HTOM and LTOM at the RMEI location downgradient from a repository.

6.3.2 Annual Dose Due to the Low-Temperature Operating Mode

Figure 6-11a displays representations of the probability-weighted annual dose histories for 500 of the 5,000 probabilistic simulations for the igneous-activity scenario, LTOM (approximately 45 MTHM/acre) for the 70,000 MTHM inventory at the RMEI location (~ 18 km downgradient from the repository) for 100,000 years after repository closure. Figure 6-11a displays the 5th and 95th percentiles, and the mean and median of all 5,000 probability-weighted igneous-activity simulations. The results presented in Figure 6-11a represent the combined effect of both the igneous-intrusion and eruptive events.

Figure 6-11b displays the probability-weighted mean annual dose versus time for the igneous-activity scenario for the 70,000-MTHM inventory for the LTOM at the RMEI location downgradient from a repository. The figure also displays the mean results for both the eruptive and intrusive events.

6.4 MEAN ANNUAL DOSE CALCULATED FOR THE HUMAN-INTRUSION SCENARIO

The performance of a Yucca Mountain repository was evaluated for the human-intrusion scenario for intrusions at two different postclosure times as described in Section 5.2.7 above. The human-intrusion scenario was simulated for the HTOM for the 70,000 MTHM inventory. Annual dose histories were not calculated for the human-intrusion scenario for the expanded-inventory scenarios.

6.4.1 Annual Dose Due to Human Intrusion at 30,000 years after Repository Closure, High-Temperature Operating Mode

Figure 6-12 displays representations of the annual dose results of the 300 probabilistic simulations for the human-intrusion scenario, 30,000 years after repository closure, with a 70,000-MTHM inventory for the HTOM at the RMEI location downgradient from the repository.

Figure 6-12 displays the results for each simulation and the 5th and 95th percentiles, and the mean and median of these simulations.

6.4.2 Annual Dose Due to Human Intrusion at 100 years after Repository Closure, High-Temperature Operating Mode

Figure 6-13 displays representations of the annual dose histories of the 300 probabilistic simulations for the human-intrusion scenario, 100 years after repository closure, with a 70,000-MTHM inventory for the HTOM at the RMEI location downgradient from the repository. The figure displays the results for each simulation and the 5th, 95th, mean and median of these simulations.

6.5 COMPARATIVE RESULTS

Figure 6-14 displays four mean annual dose histories; the 70,000-MTHM inventory, HTOM, calculated for this Letter Report; the TSPA-SR (CRWMS M&O 2000 [DIRS 153246], Figure 4.1-19a, p. F4-19), and the SSPA, both LTOM, and HTOM (BSC 2001 [DIRS 154659], Figure 4.1-1, p. 4F-1).

Figure 6-15 displays the mean annual dose histories for all the calculation scenarios described in this Letter Report and the TSPA-SR case (CRWMS M&O 2000 [DIRS 153246], Figure 4.1-19a, p. F4-19).

Figure 6-16 displays a comparison of the annual dose versus time for the 70,000 MTHM inventory, (HTOM and LTOM), the igneous-activity scenario (HTOM and LTOM), and the TSPA-SR case for the 100,000-year performance period (CRWMS M&O 2000 [DIRS 153246], Figure 4.1-5, p. F4-5).

6.6 GROUNDWATER PROTECTION

An analysis of groundwater protection was conducted in accordance with the EPA Final Rule 40 CFR Parts 197.30 and 197.31 (66 FR 32074 [DIRS 155216], p. 32134 to 32135). The rule is based on meeting three groundwater radionuclide-concentration levels. The first is the maximum concentration of ^{226}Ra and ^{228}Ra in a representative volume of 3,000 acre-ft of groundwater in a release from the potential repository. The second groundwater-concentration level is for the gross alpha activity (excluding radon and uranium) in the representative volume of groundwater. Both of these calculations apply to releases from both natural sources and the potential repository at the same location as the RMEI. The third groundwater-protection calculation is the dose to the whole body or any organ of a human receptor for beta- and photon-emitting radionuclides released from the potential repository. For this calculation, the receptor would consume two (2) liters per day from the representative volume of groundwater. This groundwater is that which would be withdrawn annually from an aquifer containing less than 10,000 mg/L of total dissolved solids, and centered on the highest concentration in the plume of contamination at the same location as the RMEI. The results of the calculations for this Letter Report produced data consistent with the EPA Final Rule and are presented graphically and in tabular form.

Figure 6-17 presents the mean activity concentrations of gross alpha activity and total radium (^{226}Ra plus ^{228}Ra) in the representative volume of groundwater for the 70,000 MTHM case,

HTOM. The concentrations are calculated for a representative volume of water of 3,000 acre-feet at the same location as the RMEI at the accessible environment as described in 40 CFR Part 197.30 and Part 197.31 ([DIRS 155216], p. 32134 to 32135). Naturally occurring background radionuclide concentrations are not included because the calculated values are negligible compared to background concentrations up to 100,000 years postclosure. Figure 6-18 presents the same information for the LTOM.

Figure 6-19 presents the mean dose to critical organs for ^{99}Tc, ^{14}C, and ^{129}I, the prominent beta and photon-emitting radionuclides (CRWMS M&O 2000 [DIRS 153246], Section 4.1.5, p. 4-17) for the 70,000 MTHM inventory, HTOM, for the 1,000,000 performance period. Figure 6-20 presents the mean dose to critical organs for ^{99}Tc, ^{14}C, and ^{129}I for the 70,000 MTHM inventory, LTOM, for the 1,000,000 performance period.

The results developed for the groundwater-protection standard are tabulated in Table 6-2, which shows the peak mean gross alpha activity by scenario for various performance periods; Table 6-3 which shows peak total radium concentration by scenario for various performance periods; and Table 6-4 which shows the peak dose to critical organs in 10,000 years for ^{99}Tc, ^{14}C, ^{129}I, and the total of all beta- and photon-emitting radionuclides.

Table 6-2 Peak Mean Gross Alpha Activity by Scenario for Various Performance Periods

Mean Alpha Activity (pCi/L)							
Case	Model File	10,000 yr Peak		100,000 yr Peak		1,000,000 yr Peak	
		w/o bckgrnd	w/ bckgrnd	w/o bckgrnd	w/ bckgrnd	w/o bckgrnd	w/ bckgrnd
70,000 MTHM, HTOM	SE01_006nm6	1.8E-08	4.0E-01	1.7E-02	4.2E-01	17.7	18.1
70,000 MTHM, LTOM	SE01_007nm6	3.3E-08	4.0E-01	1.0E-02	4.1E-01	14.2	14.6
Module 1, HTOM	SE01_010nm6	3.3E-08	4.0E-01	2.3E-02	4.2E-01	27.7	28.1
Module 2, HTOM	SE01_012nm6	2.2E-10	4.0E-01	4.2E-05	4.0E-01	3.9E-02	4.4E-01
Human Intrusion 30k-yr Event, HTOM	SE01_001hm6	N/A		1.8E-04	4.0E-01	3.1E-04	4.0E-01
Human Intrusion 100-yr Event, HTOM	SE01_002hm6	3.7E-05	4.0E-01	3.6E-04	4.0E-01	3.6E-04	4.0E-01
Background Alpha Activity Concentration is 0.4 pCi/L							
Mean Gross Alpha Activity is Not Available for Volcanic Scenarios							
N/A = Not Applicable							
These data are based on an Annual Water Usage equal to 3000 acre-ft/yr							

Table 6-3 Peak Total Radium Concentration by Scenario for Various Performance Periods

Total Radium (226Ra and 228Ra) Concentration (pCi/L)							
Case	Model File	10,000 yr Peak		100,000 yr Peak		1,000,000 yr Peak	
		w/o bckgrnd	w/ bckgrnd	w/o bckgrnd	w/ bckgrnd	w/o bckgrnd	w/ bckgrnd
70,000 MTHM, HTOM	SE01_006nm6	1.1E-11	1.0	2.4E-05	1.0	3.3E-01	1.4
70,000 MTHM, LTOM	SE01_007nm6	2.4E-12	1.0	2.7E-05	1.0	2.7E-01	1.3
Module 1, HTOM	SE01_010nm6	3.3E-10	1.0	4.0E-05	1.0	6.7E-01	1.7
Module 2, HTOM	SE01_012nm6	6.7E-13	1.0	6.8E-09	1.0	1.6E-03	1.0
Human Intrusion 30k-yr Event, HTOM	SE01_001hm6	N/A		2.4E-07	1.0	3.8E-07	1.0
Human Intrusion 100-yr Event, HTOM	SE01_002hm6	4.8E-09	1.0	2.4E-07	1.0	3.8E-07	1.0
Background Radium Activity Concentration is 1.04 pCi/L							
Total Radium Concentration is Not Available for Volcanic Scenarios							
N/A = Not Applicable							
These data are based on an Annual Water Usage equal to 3000 acre-ft/yr							

Table 6-4 Maximum Dose to Critical Organs in 10,000 years for ^{99}Tc, ^{14}C, ^{129}I, and Total of All Beta- and Photon-Emitting Radionuclides

Maximum Dose to Critical Organs In 10,000 years (mrem/yr)					
Case	Model File	**Tc-99**	**C-14**	**I-129**	**Total**
70,000 MTHM, HTOM	SE01_006nm6	1.2E-05	2.4E-07	9.1E-06	2.2E-05
70,000 MTHM, LTOM	SE01_007nm6	7.0E-06	1.8E-07	7.5E-06	1.5E-05
Human Intrusion 30k-yr Event, HTOM	SE01_001hm6	N/A	N/A	N/A	N/A
Human Intrusion 100-yr Event, HTOM	SE01_002hm6	2.4E-03	8.4E-05	2.5E-03	5.0E-03
N/A = Not Applicable These data are based on an Annual Water Usage equal to 3000 acre-ft/yr					

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7.2 CODES, STANDARDS, AND REGULATIONS

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7.3 PROCEDURES

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8. ATTACHMENTS

Attachments	Title
I	Acronyms and Abbreviations
II	Extracting Repository Release Nodes
III	GTCC and SPAR Inventory

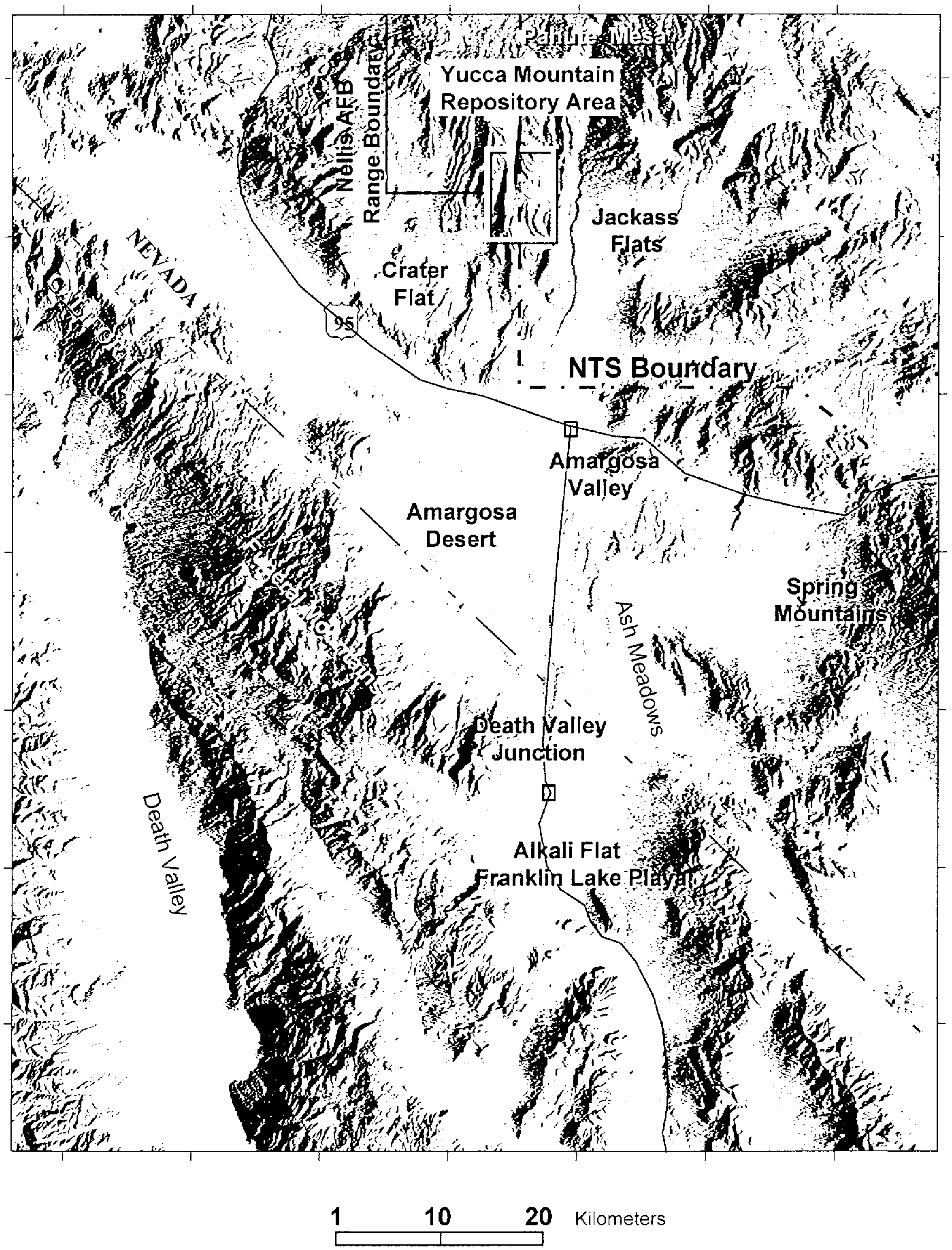


Figure 5-1 Location of a Potential Yucca Mountain Repository

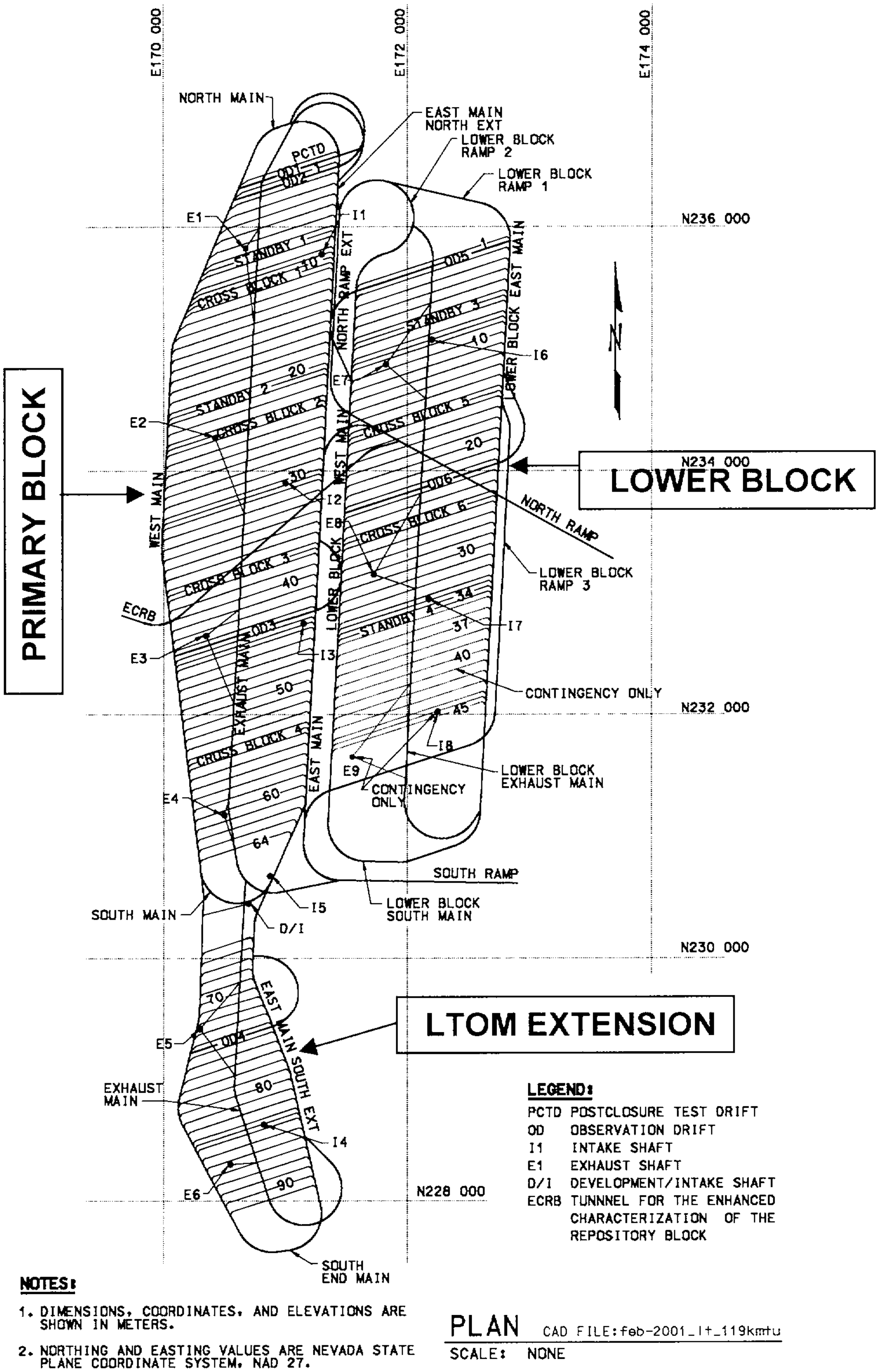
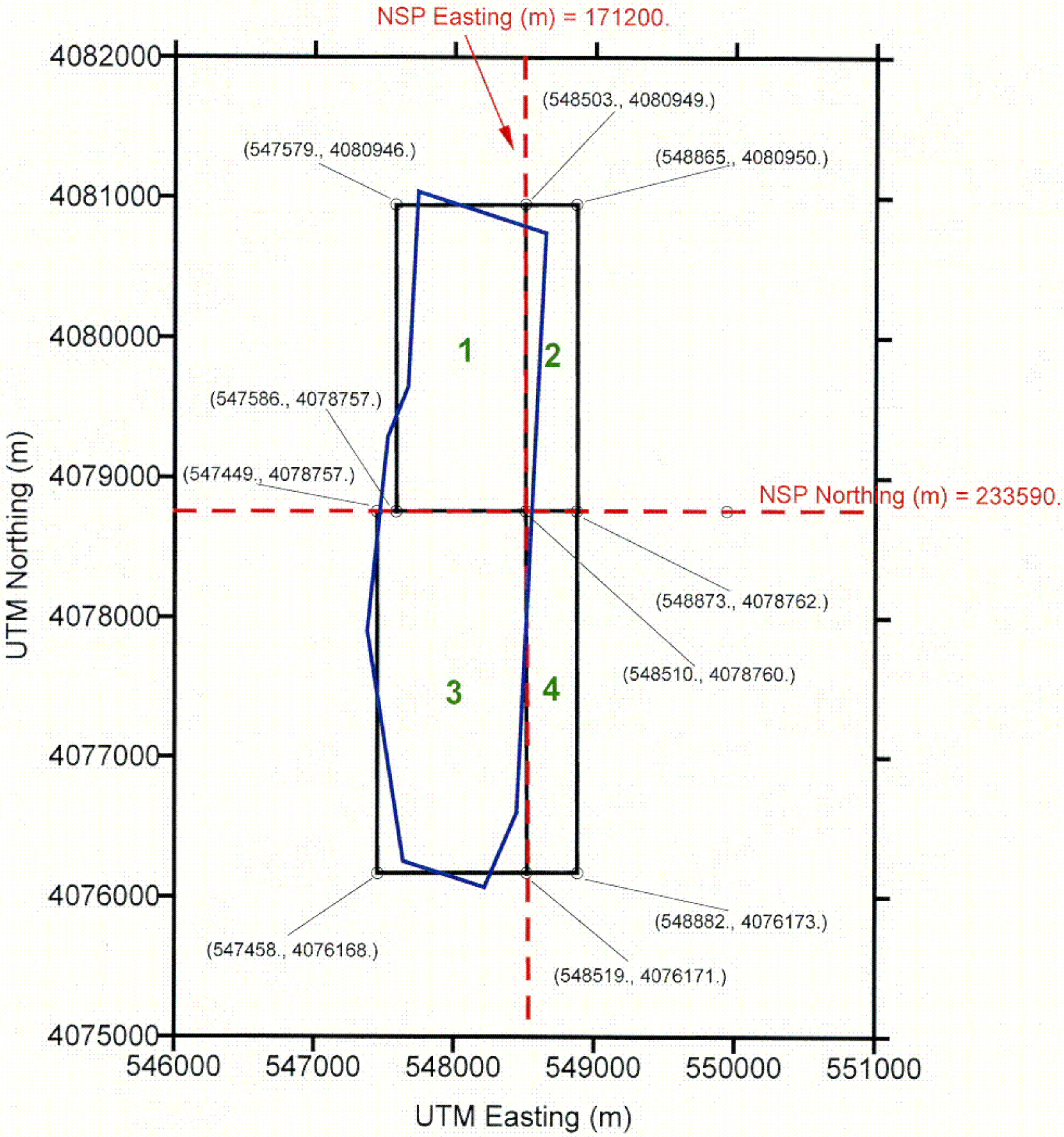


Figure 5-2 Approximate configuration of a potential Yucca Mountain Repository.

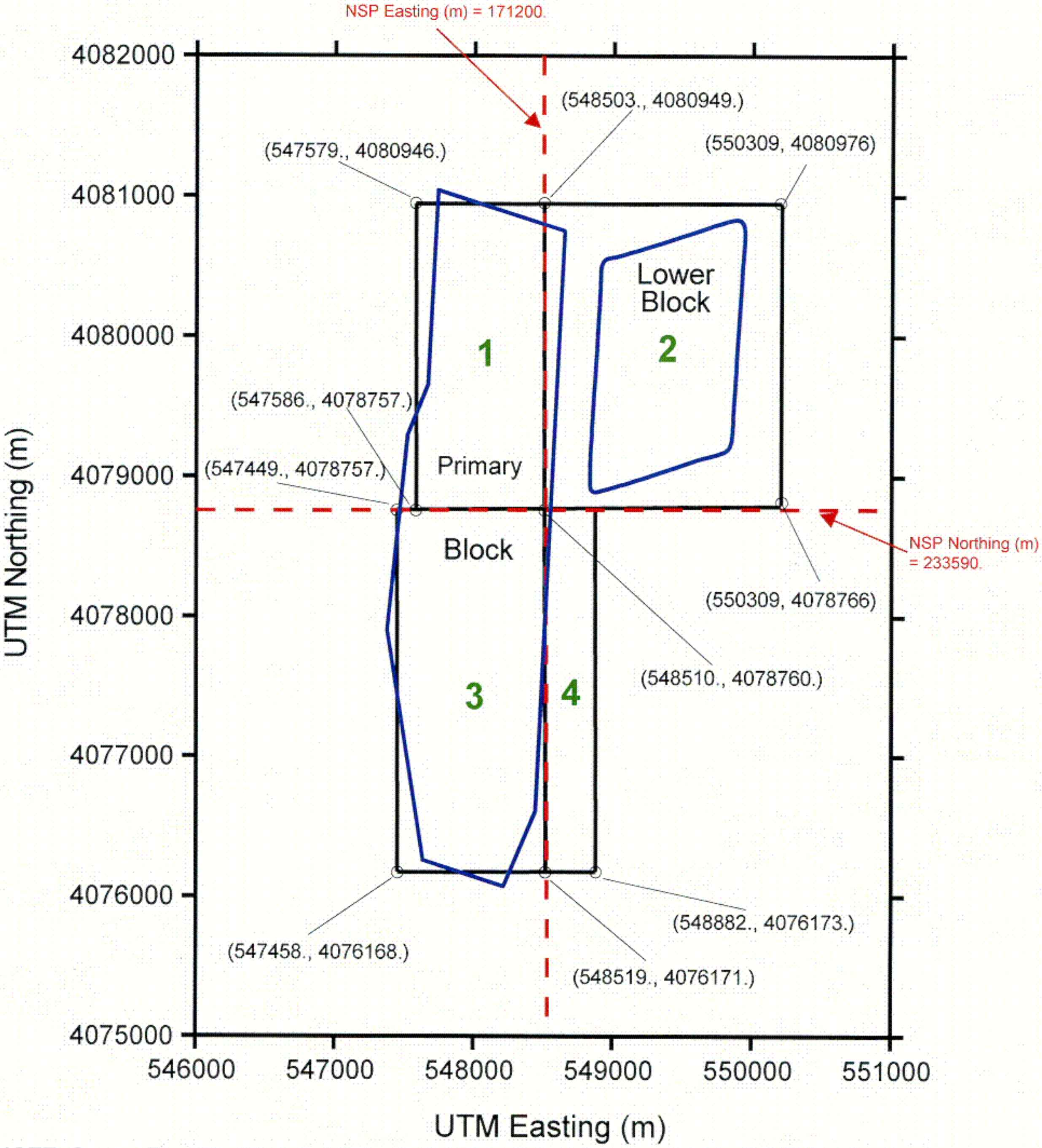
Note: Disposal for the 70,000 MTHM case under the HTOM would utilize the Primary Block. Disposal for the Expanded-inventory Case, approximately 119,000 MTHM, would utilize the Primay Block and the Lower Block. (Source BSC 2001 [DIRS 154554], Section 6.1.2.1, Figure 3, p. 43 of 126)



NOTE: Source Regions are outlined with the solid black rectangles and numbered from 1 to 4. The coordinates of the vertices of the source region rectangles are given in UTM coordinates (m). The outline of the repository is shown by the blue lines. The dashed red lines indicate the quadrants from which radionuclide arrivals from the UZ model are applied to the SZ source regions. Coordinates of the dashed red lines are given in Nevada State Plan (NSP) coordinates (m). Source TSPA-SR (CRWMS M&O 2000 [DIRS 153246], Figure 3.8-14, p. F3-117)

Figure 5-3 The Four Saturated-Zone Capture Regions in Relation to the Primary Repository Block for the 70,000-MTHM-Inventory Case

C01



NOTE: Source Regions are outlined with the solid black rectangles and numbered from 1 to 4. The coordinates of the vertices of the source region rectangles are given in UTM coordinates (m). The outline of the repository is shown by the blue lines. The dashed red lines indicate the quadrants from which radionuclide arrivals from the UZ model are applied to the SZ source regions. Coordinates of the dashed red lines are given in Nevada State Plan (NSP) coordinates (m). Source CRWMS M&O 2000 ([DIRS 155393], Figure 5-5, p. 25)

Figure 5-4 The Four Saturated-Zone Capture Regions in Relation to the Primary and Lower Repository Blocks for the Expanded-Inventory Case

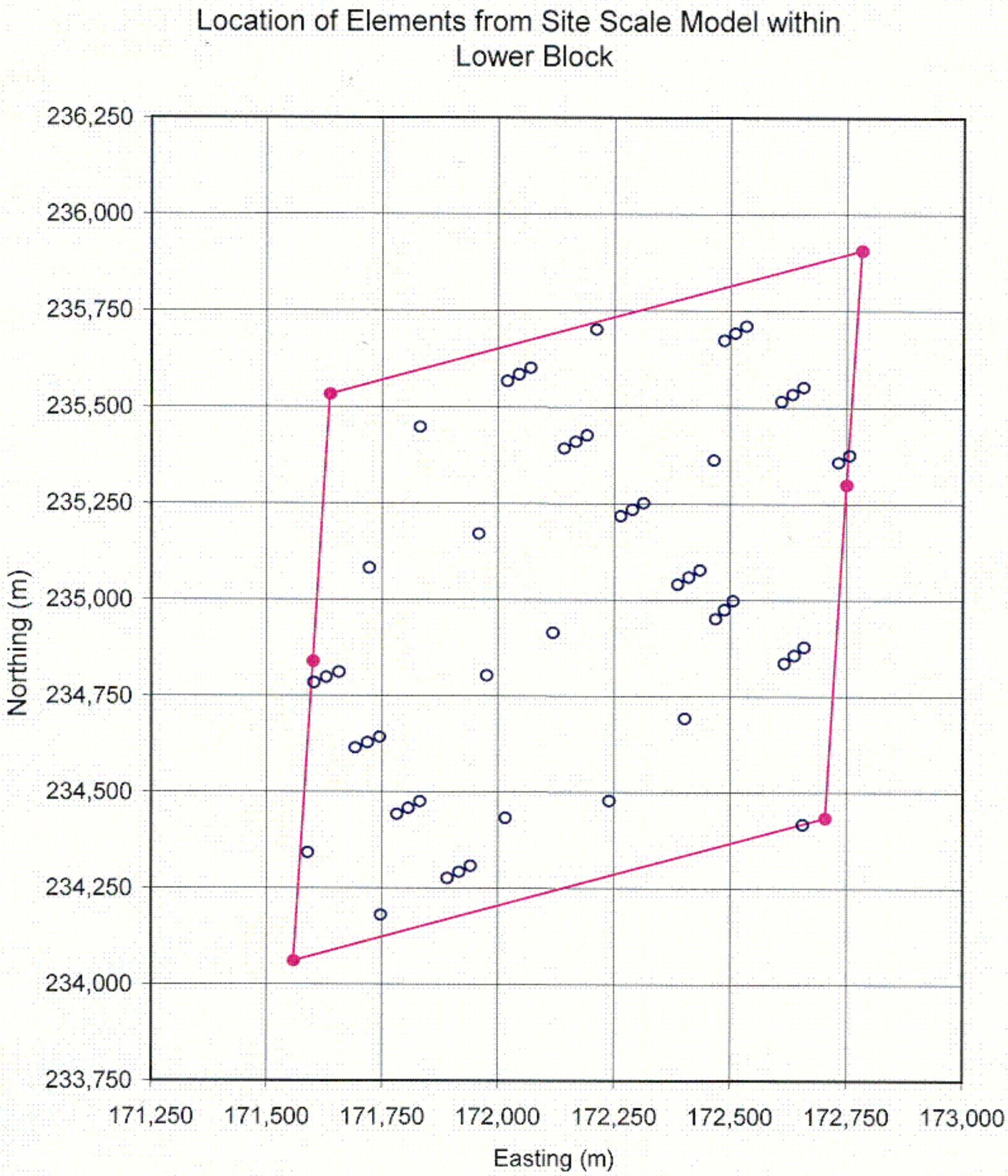
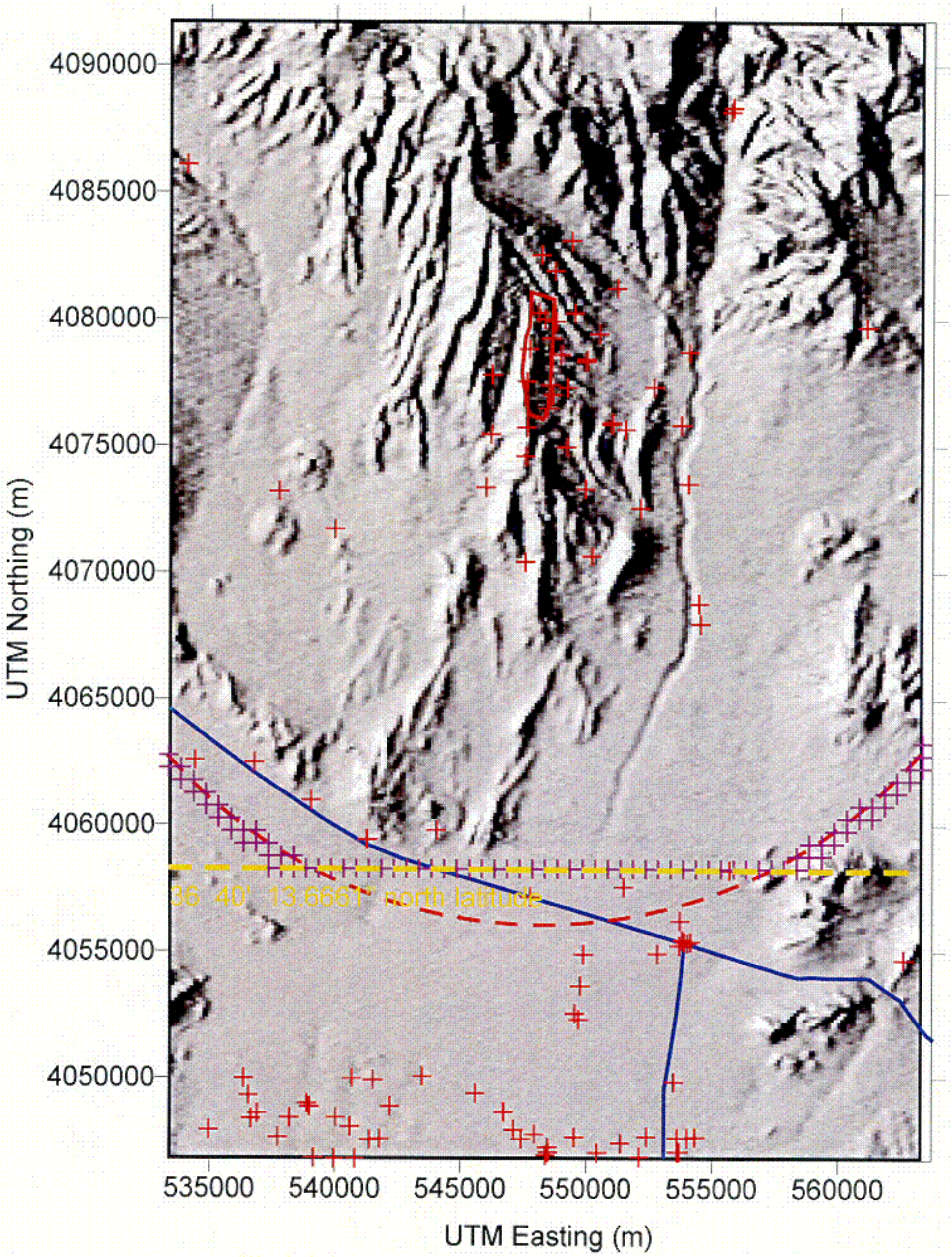


Figure 5-5 Outline of the Lower Block Showing the Locations of the 51 Particle-Tracking Nodes. Source CRWMS M&O 2000 ([DIRS 155393], Figure 5-6, p. 26)

C03



NOTE: The yellow dashed line represents the southernmost boundary between the controlled area and accessible environment (36° 40' 13.6661" North latitude as per EPA 40 CFR Part 197 (66 FR 32074 [DIRS 155216])). The red dashed line represents the 20-km fence used in TSPA-SR to evaluate compliance with proposed EPA and NRC regulations. The purple crosses represent SZ model grid cells at the intersection of the new southernmost boundary with the 20-km fence used in TSPA-SR evaluations. The red crosses are well locations, and the blue lines represent Highway 95 and Highway 373. Source BSC 2001 [DIRS 154657] Figure 12.5.3-1, p. 12F-37.

Figure 5-6 Southernmost Boundary of the Controlled Area and the Accessible Environment

C04

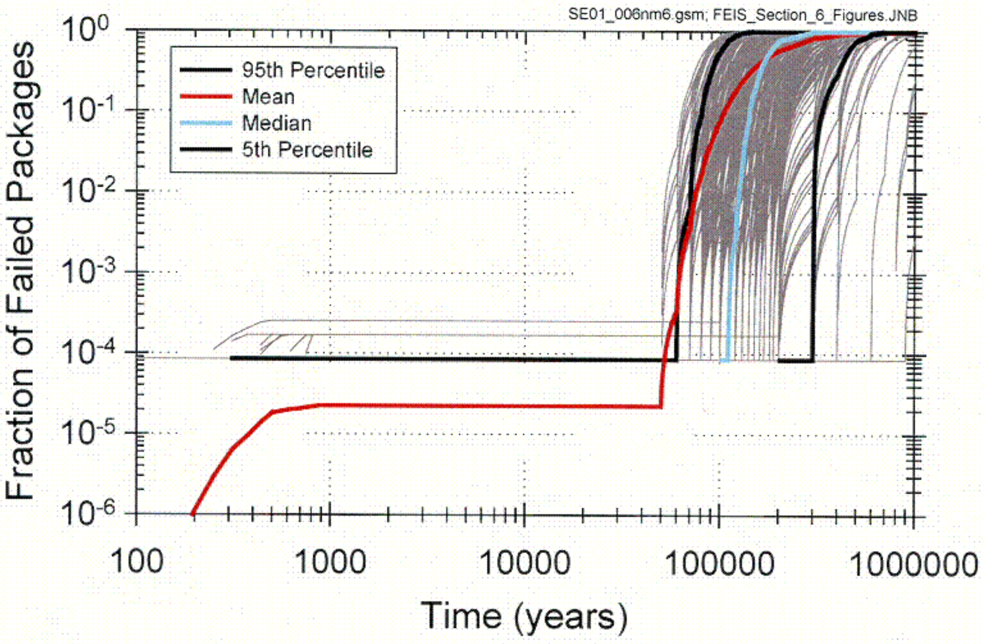


Figure 6-1 Waste-Package Failure Curves for the 70,000-MTHM Inventory and the 5th and 95th Percentiles, and the Mean and Median of these Simulations

C05

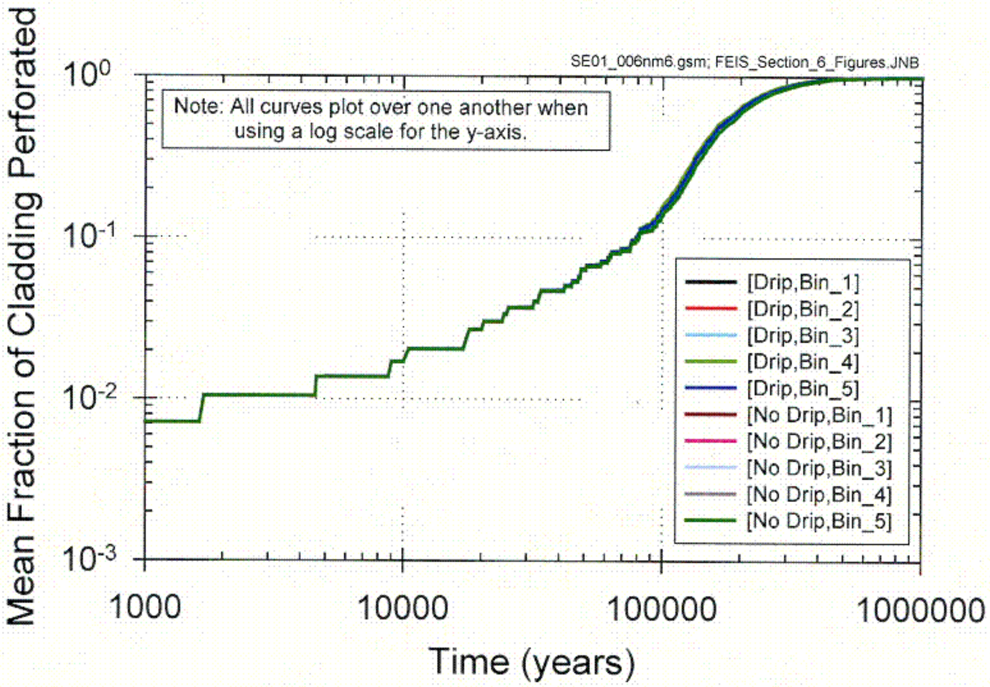


Figure 6-2 Cladding-Failure Profile for the 70,000-MTHM-Inventory Case

C06

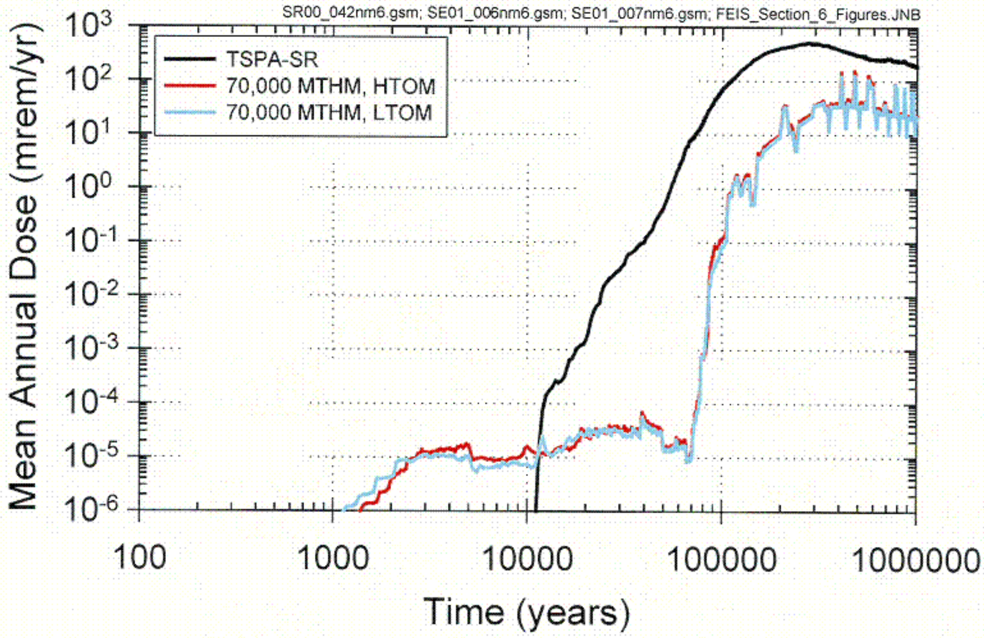


Figure 6-3 Comparison Plot of the Mean Annual Dose versus Time for the TSPA-SR Case, the High Temperature Operating Mode and the LTOM for the 70,000-MTHM Inventory at the RMEI Location Downgradient from a Yucca Mountain Repository

C07

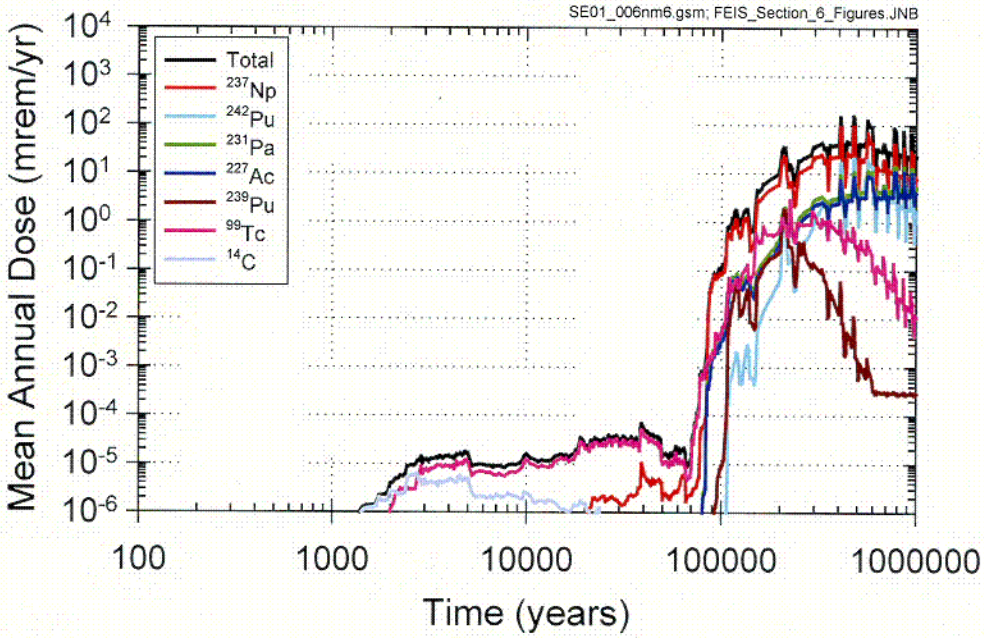


Figure 6-4 Total Mean Annual Dose and Mean Annual Dose for Radionuclides Contributing to Total Mean Annual Dose from the 300 Probabilistic Simulations for the HTOM for the 70,000-MTHM Inventory at the RMEI Location Downgradient from a Yucca Mountain Repository

C08

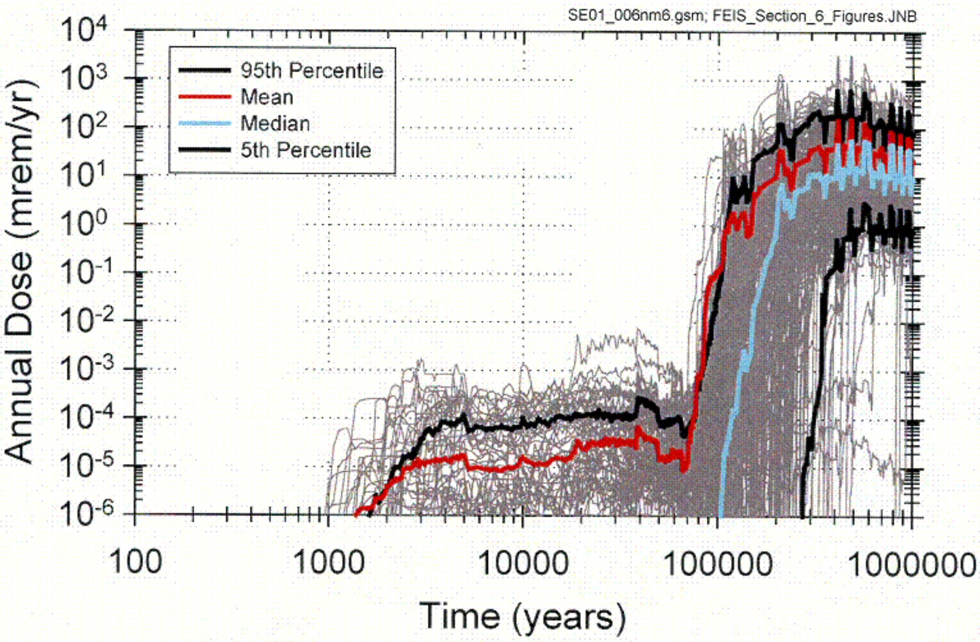


Figure 6-5 Annual Dose versus Time for 300 Probabilistic Simulations of the 70,000-MTHM Inventory for the HTOM at the RMEI Location Downgradient from a Repository. The Figure Displays the Results for Each Simulation and the 5th and 95th Percentiles, and the Mean and Median of these Simulations.

C09

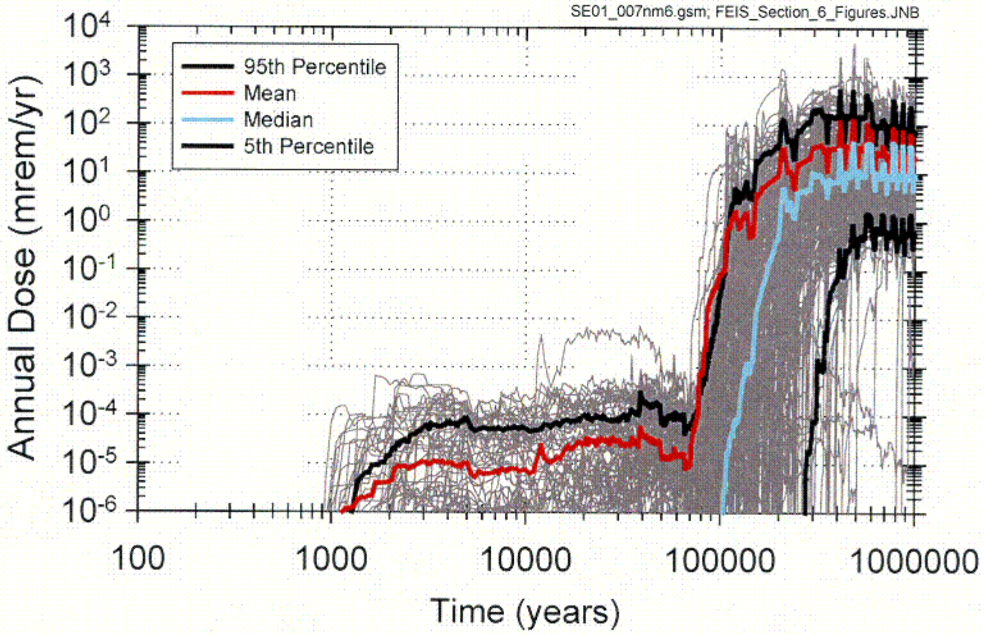


Figure 6-6 Annual Dose versus Time for 300 Probabilistic Simulations of the 70,000-MTHM Inventory for the LTOM at the RMEI Location Downgradient from a Repository. The Figure Displays the Results for Each Simulation and the 5th and 95th Percentiles, and the Mean and Median of these Simulations.

C10

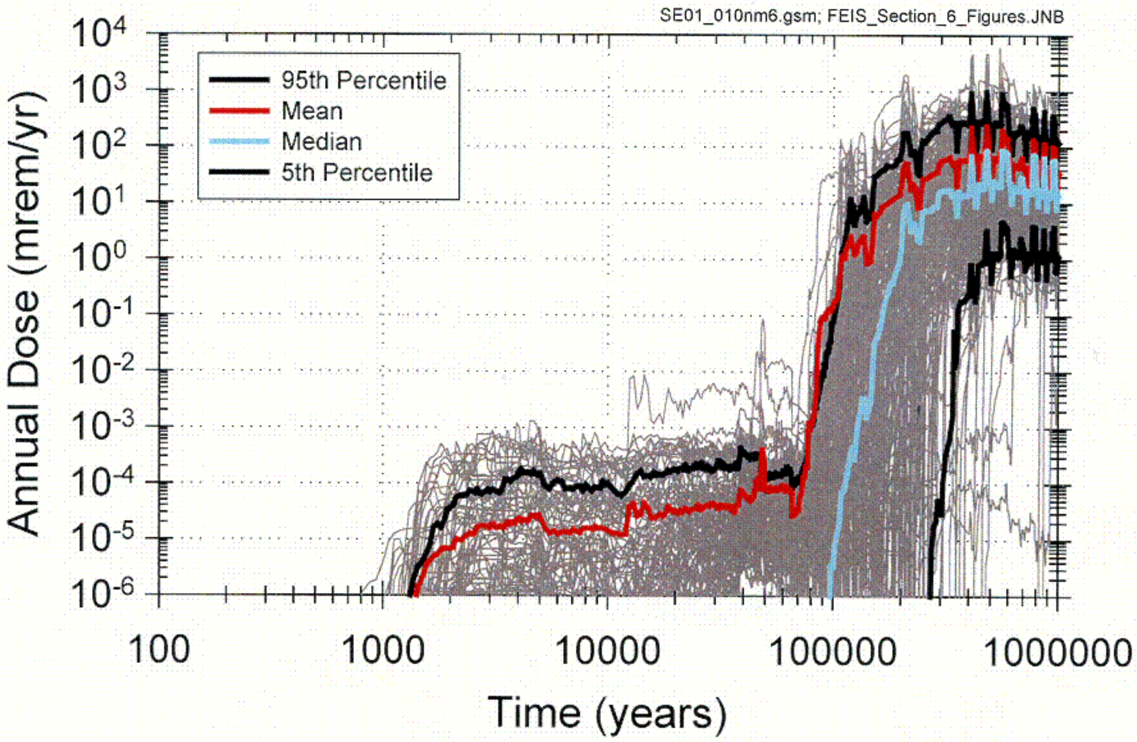


Figure 6-7 Annual Dose versus Time for 300 Probabilistic Simulations of the Module 1 Expanded Inventory for the HTOM at the RMEI Location Downgradient from a Repository. The Figure Displays the Results for Each Simulation and the 5^{th} and 95^{th} Percentiles, and the Mean and Median of these Simulations.

C11

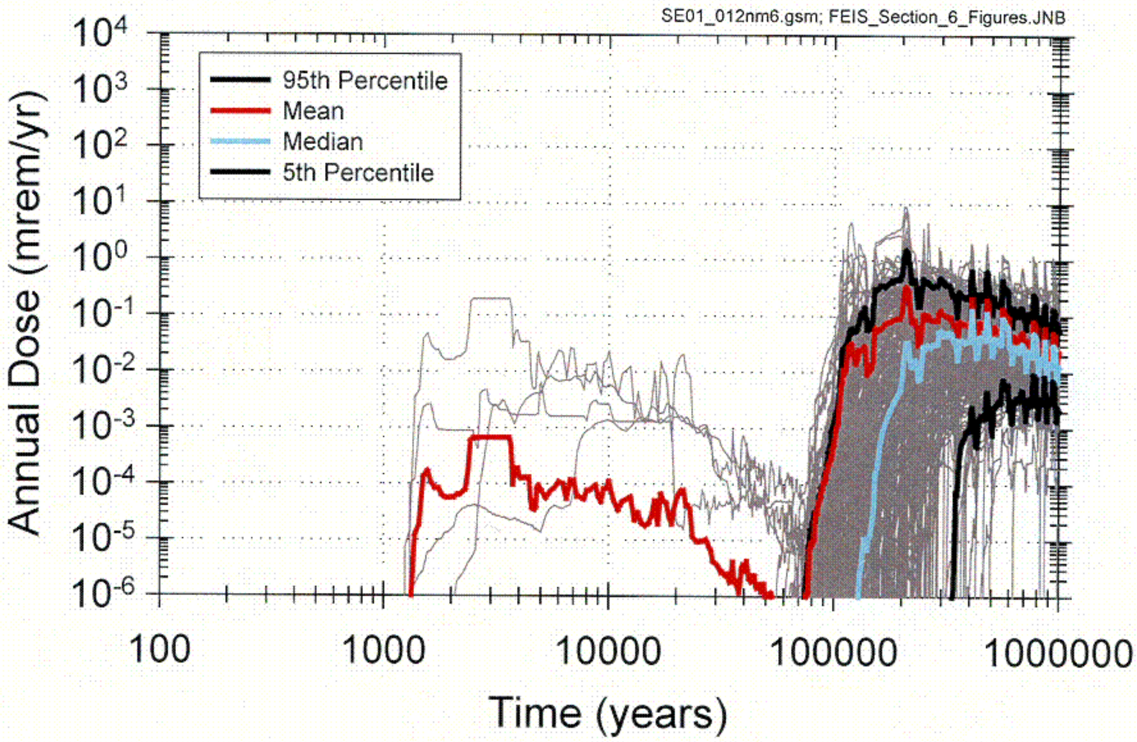


Figure 6-8 Annual Dose versus Time for 300 Probabilistic Simulations of the Module 2 Expanded Inventory for the HTOM at the RMEI Location Downgradient from a Repository. The Figure Displays the Results for Each Simulation and the 5th and 95th Percentiles, and the Mean and Median of these Simulations.

C12

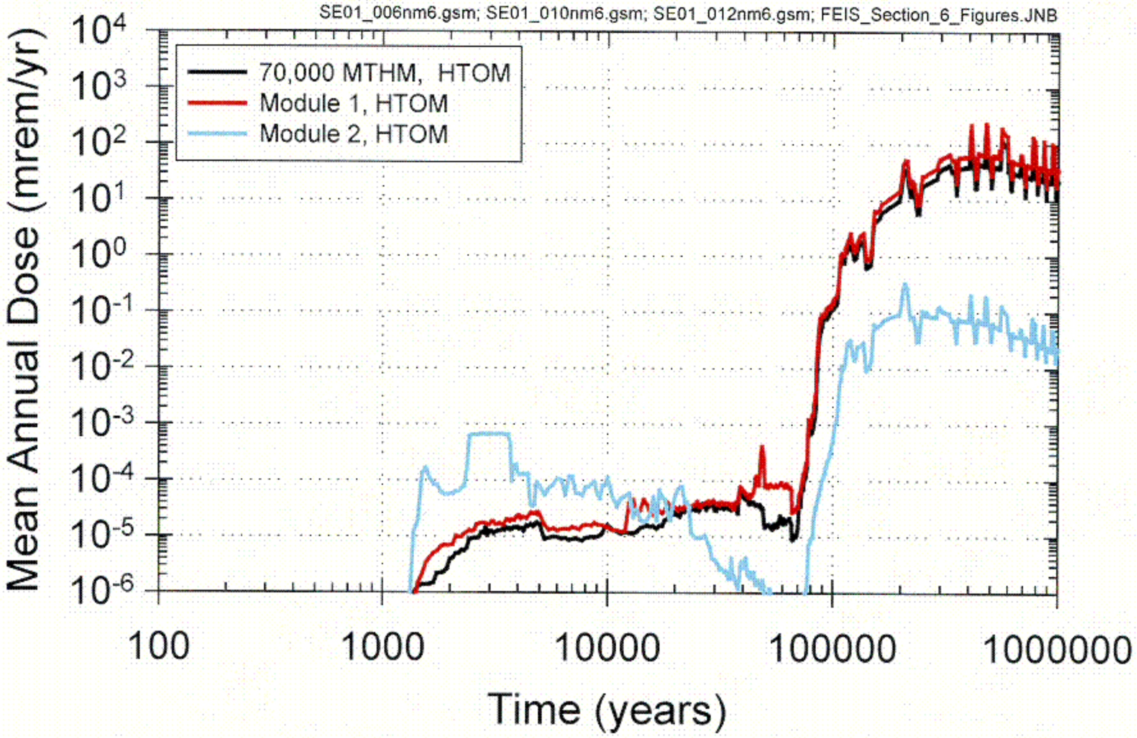


Figure 6-9 Comparison Plot of the Mean Annual Dose versus Time for HTOM for the 70,000-MTHM, Module 1 and Module 2 Inventories at the RMEI location Downgradient from a Repository

C13

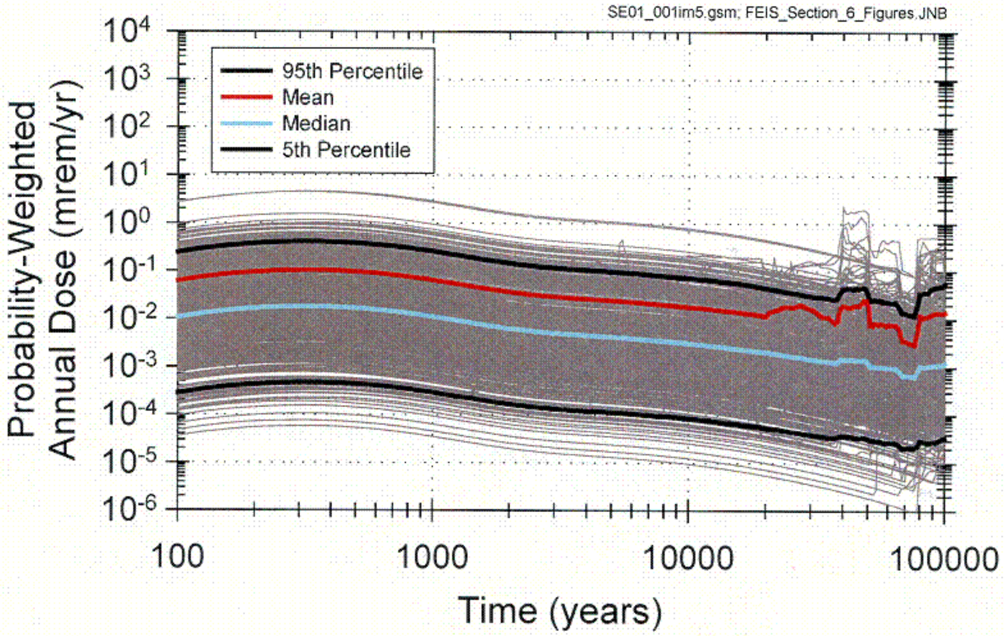


Figure 6-10a Annual Dose versus Time for 500 of 5000 Probabilistic Simulations of the Igneous Activity Scenario, including both Intrusive and Eruptive Events, for the 70,000-MTHM Inventory for the HTOM at the RMEI Location Downgradient from a Repository. The Figure Displays the Results for Each Simulation and the 5th and 95th Percentiles, and the Mean and Median of these Simulations.

C14

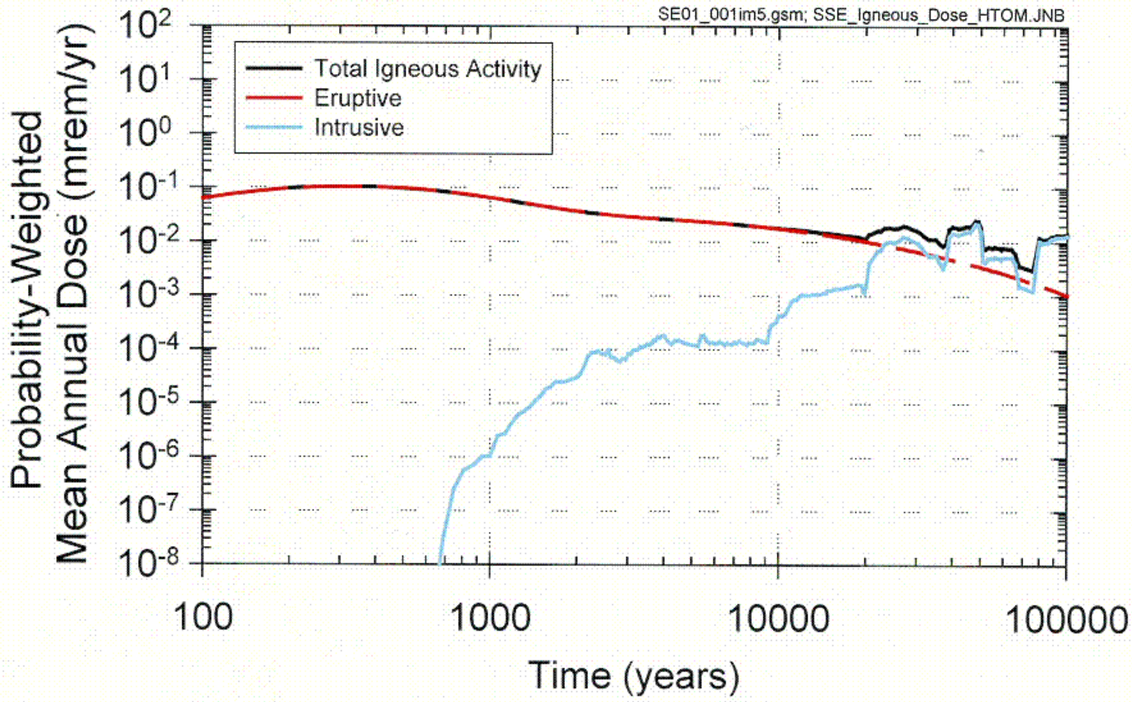


Figure 6-10b Mean Annual Dose versus Time for the Igneous Activity Scenario for the 70,000-MTHM Inventory for the HTOM at the RMEI Location Downgradient from a Repository. The Figure Displays the Mean Results for Both the Eruptive and Intrusive Events and the Sum of these Events as "Total Igneous".

C15

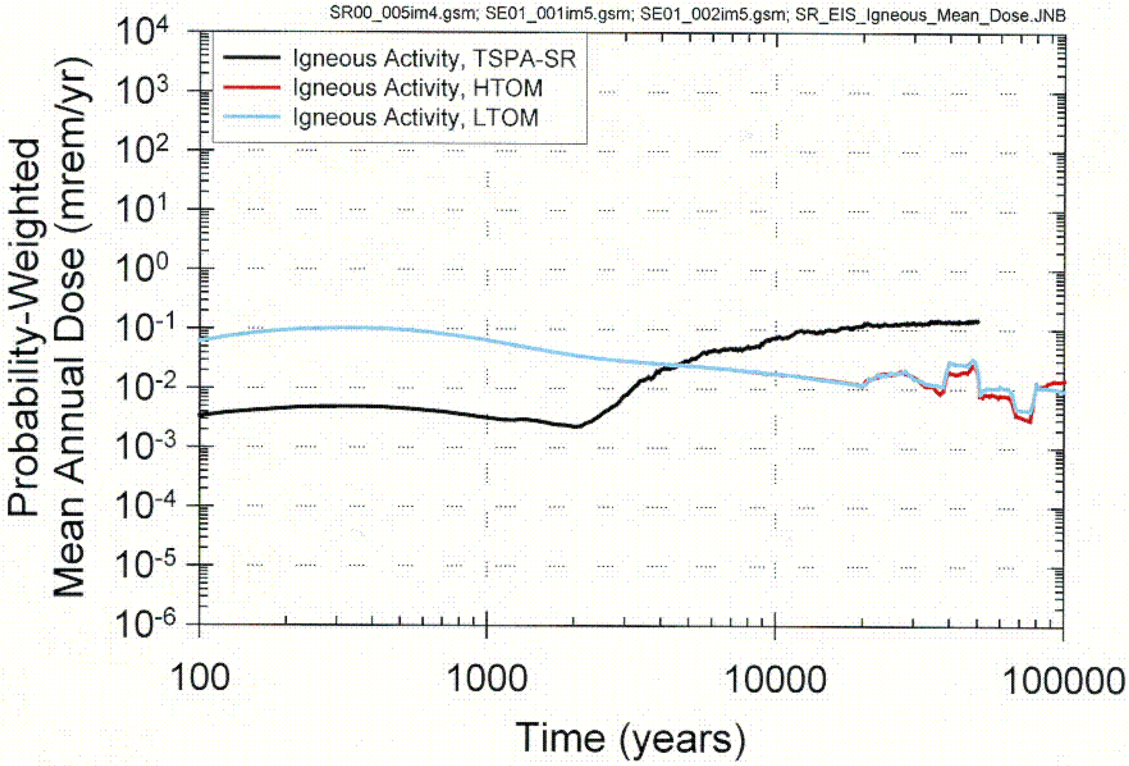


Figure 6-10c Mean Annual Dose versus Time for the Total Igneous Activity Scenario, which includes the Sum of the Igneous and Eruptive Events, for the TSPA-SR, HTOM, and the HTOM and LTOM for the 70,000-MTHM Inventory for this Letter Report at the RMEI Location Downgradient from a Repository.

C16

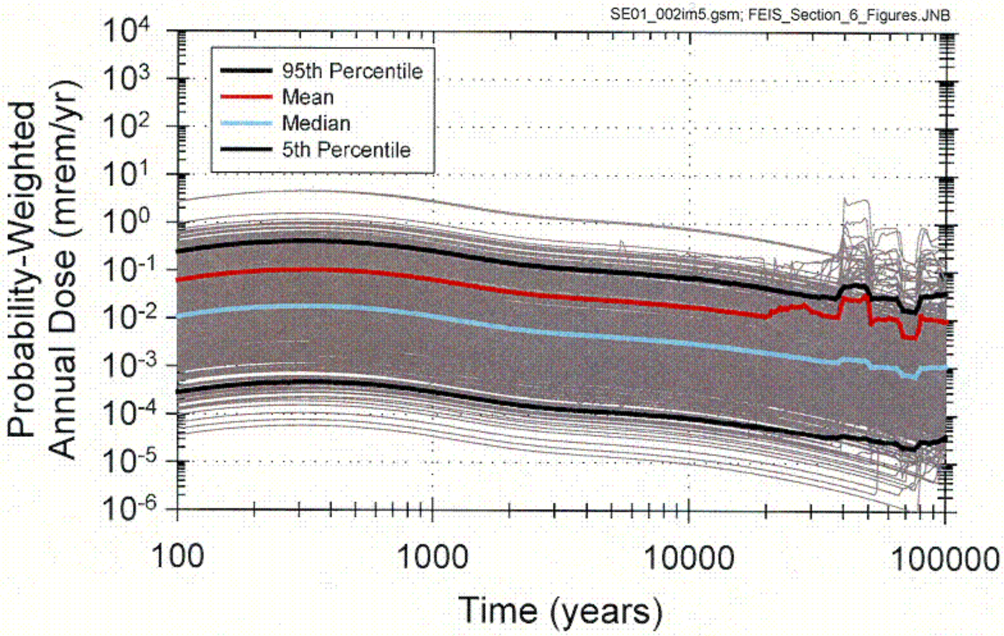


Figure 6-11a Annual Dose versus Time for 500 of 5000 Probabilistic Simulations of the Igneous Activity Scenario, including both Intrusive and Eruptive Events, for the70,000-MTHM Inventory for the LTOM at the RMEI Location Downgradient from a Repository. The Figure Displays the Results for Each Simulation and the 5th and 95th Percentiles, and the Mean and Median of these Simulations.

C17

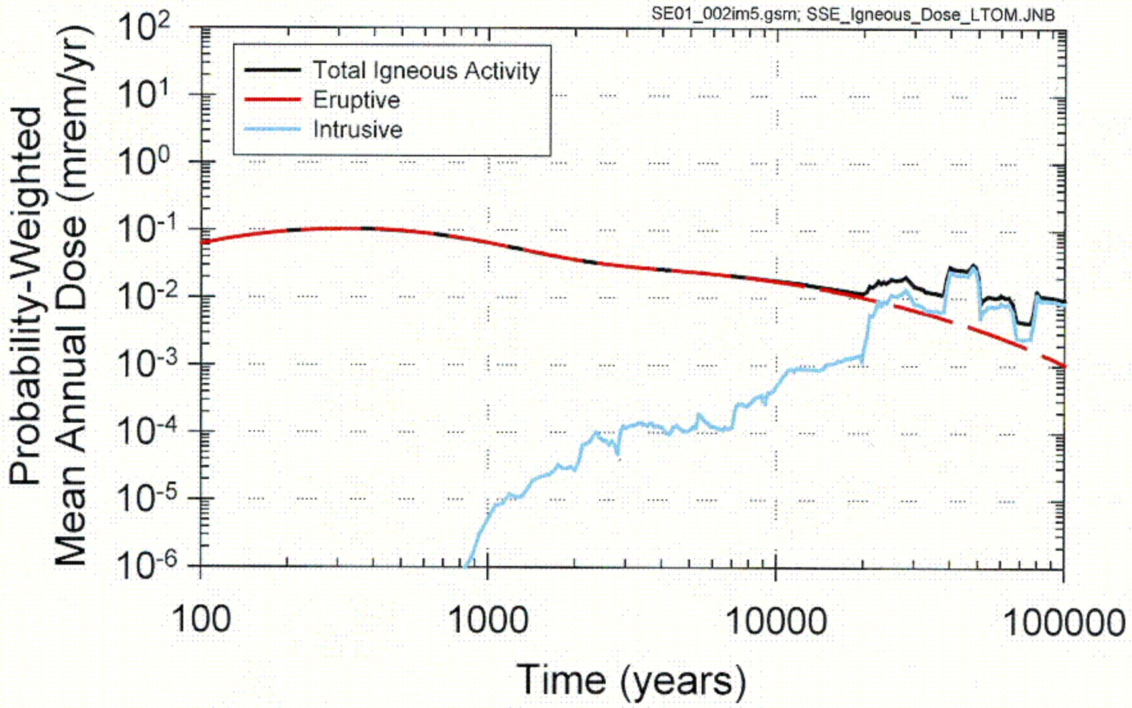


Figure 6-11b Mean Annual Dose versus Time for the Igneous Activity Scenario for the 70,000-MTHM Inventory for the LTOM at the RMEI Location Downgradient from a Repository. The Figure Displays the Mean Results for Both the Eruptive and Intrusive Events and the Sum of these Events as "Total Igneous".

C18

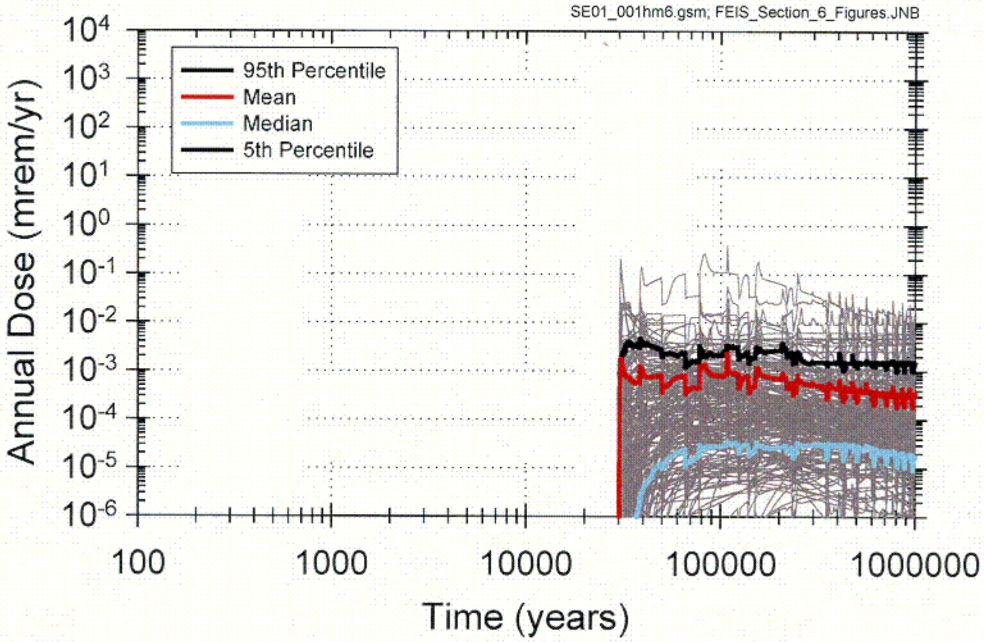


Figure 6-12 Annual Dose versus Time for the HTOM for the 30,000 year Human Intrusion Scenario for the 70,000-MTHM Inventory at the RMEI Location Downgradient from a Yucca Mountain Repository. The Figure Displays the Results of Each Simulation and the 5th and 95th Percentiles, and the Mean and Median of these Simulations

C19

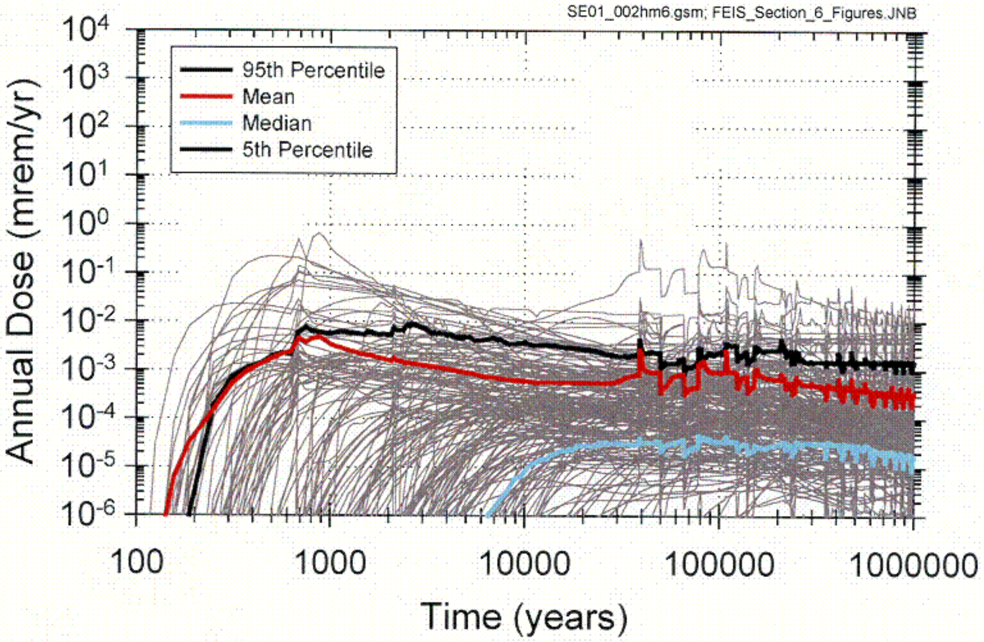


Figure 6-13 Annual Dose versus Time for 300 Probabilistic Simulations of the 100 year Human-Intrusion Scenario for the 70,000-MTHM Inventory for the HTOM at the RMEI Location Downgradient from a Repository. The Figure Displays the Results for Each Simulation and the 5th and 95th Percentiles, and the Mean and Median of these Simulations.

C20

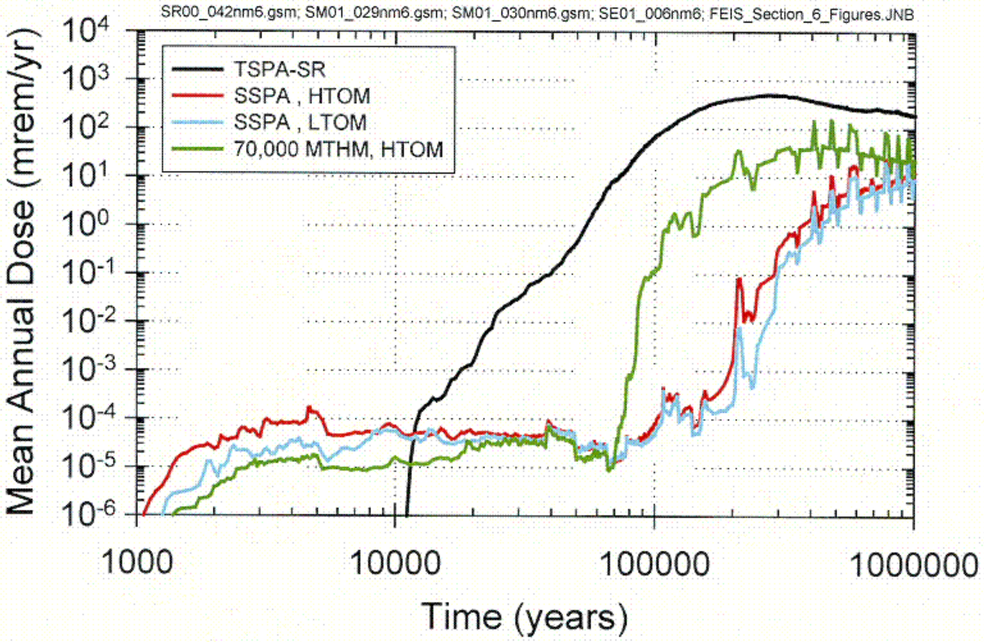


Figure 6-14 Comparison of the Mean Annual Dose versus Time for the 70,000-MTHM Inventory, the TSPA-SR Case, and the SSPA Case, both HTOM and LTOM

C21

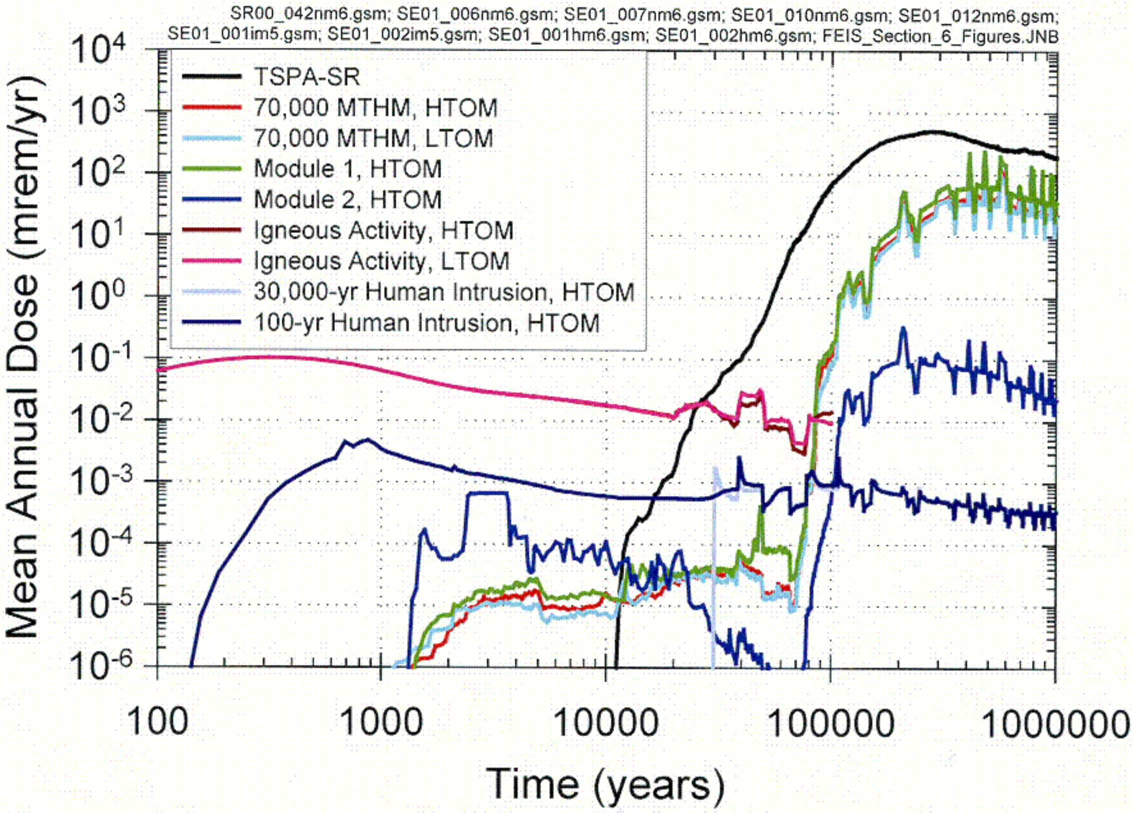


Figure 6-15 Comparison of the Annual Dose versus Time for the 70,000 MTHM Inventory, HTOM and LTOM, the Module 1 Inventory, HTOM, the Module 2 Inventory, HTOM, the Igneous-Activity Scenario, HTOM and LTOM, the 30,000-yr and 100-yr Human-Intrusion Scenarios, HTOM, and the TSPA-SR Case, HTOM

C22

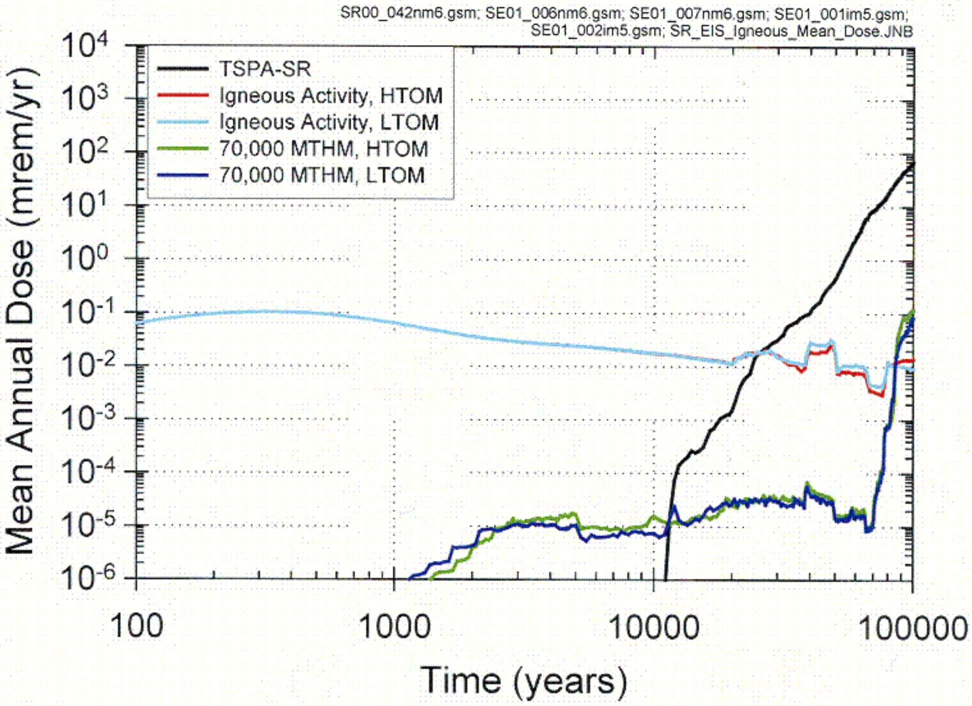


Figure 6-16 Comparison of the Annual Dose versus Time for the 70,000 MTHM Inventory, HTOM and LTOM, the Igneous-Activity Scenario, HTOM and LTOM, and the TSPA-SR Case, HTOM for the 100,000-year Performance Period

C23

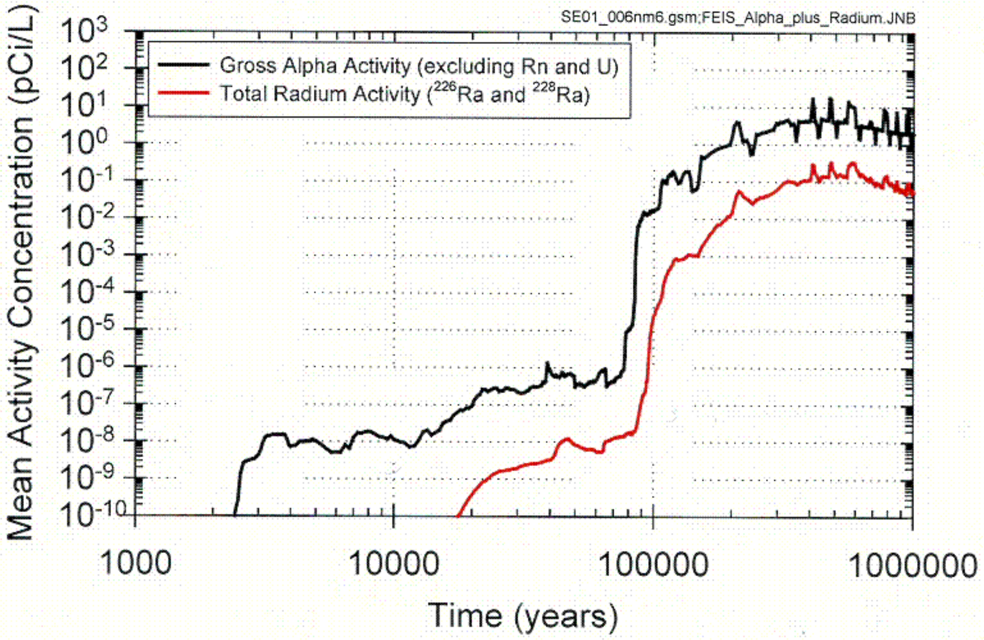


Figure 6-17 Mean Activity Concentrations of Gross Alpha Activity and Total Radium (^{226}Ra plus ^{228}Ra) for the 70,000 MTHM Inventory, HTOM. The Concentrations are Calculated for a Representative Volume of Groundwater of 3,000 acre-feet at the Accessible Environment, Which is the Same as the RMEI Location.

C24

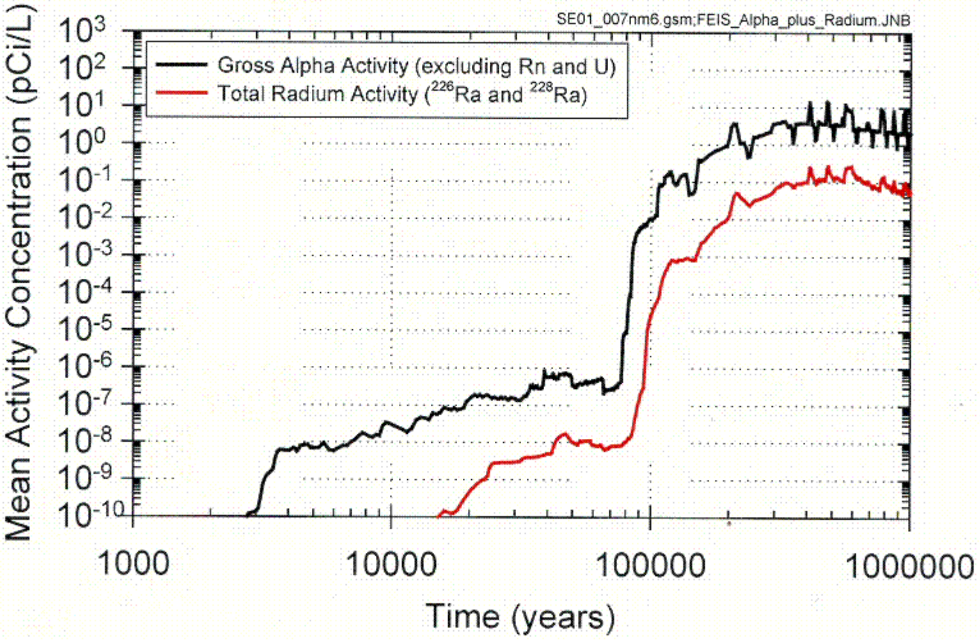


Figure 6-18 Mean Activity Concentrations of Gross Alpha Activity and Total Radium (^{226}Ra plus ^{228}Ra) for the 70,000 MTHM Inventory, LTOM. The Concentrations are Calculated for a Representative Volume of Groundwater of 3,000 acre-feet at the Accessible Environment, Which is the Same as the RMEI Location.

C25

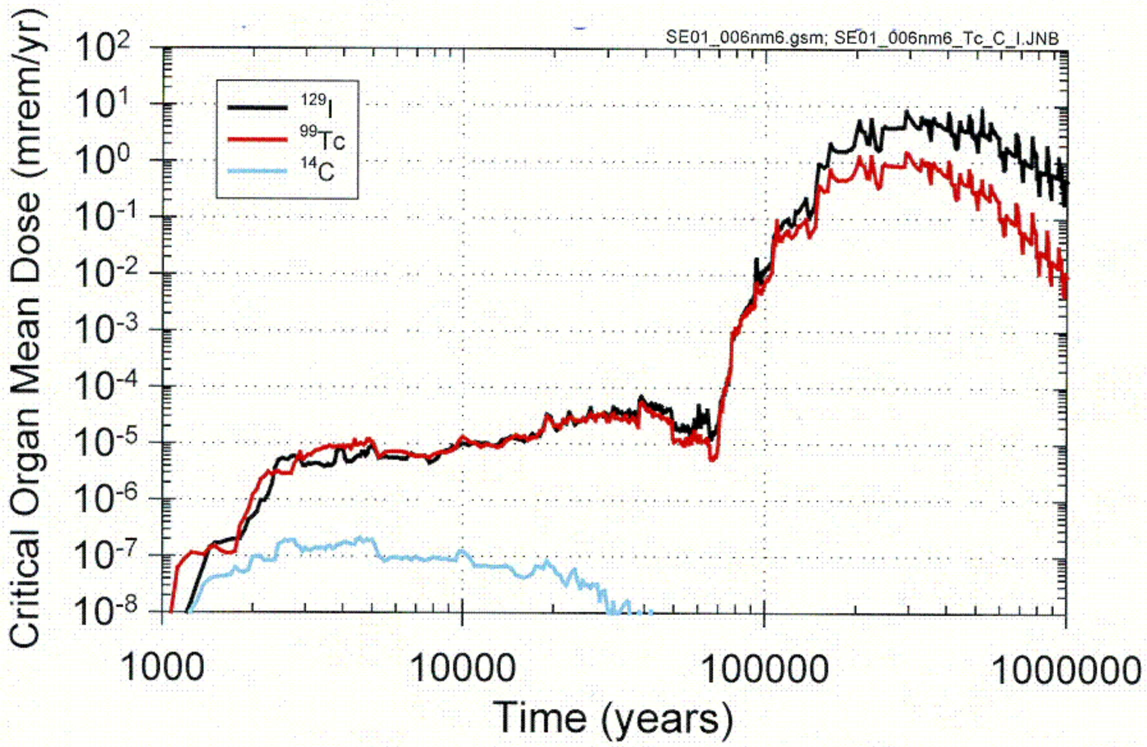


Figure 6-19 Mean Dose to Critical Organs for ^{99}Tc, ^{14}C, and ^{129}I for the 70,000 MTHM Inventory, HTOM. The Concentrations are Calculated for a Representative Volume of Groundwater of 3,000 acre-feet at the Accessible Environment, Which is the Same as the RMEI Location.

C26

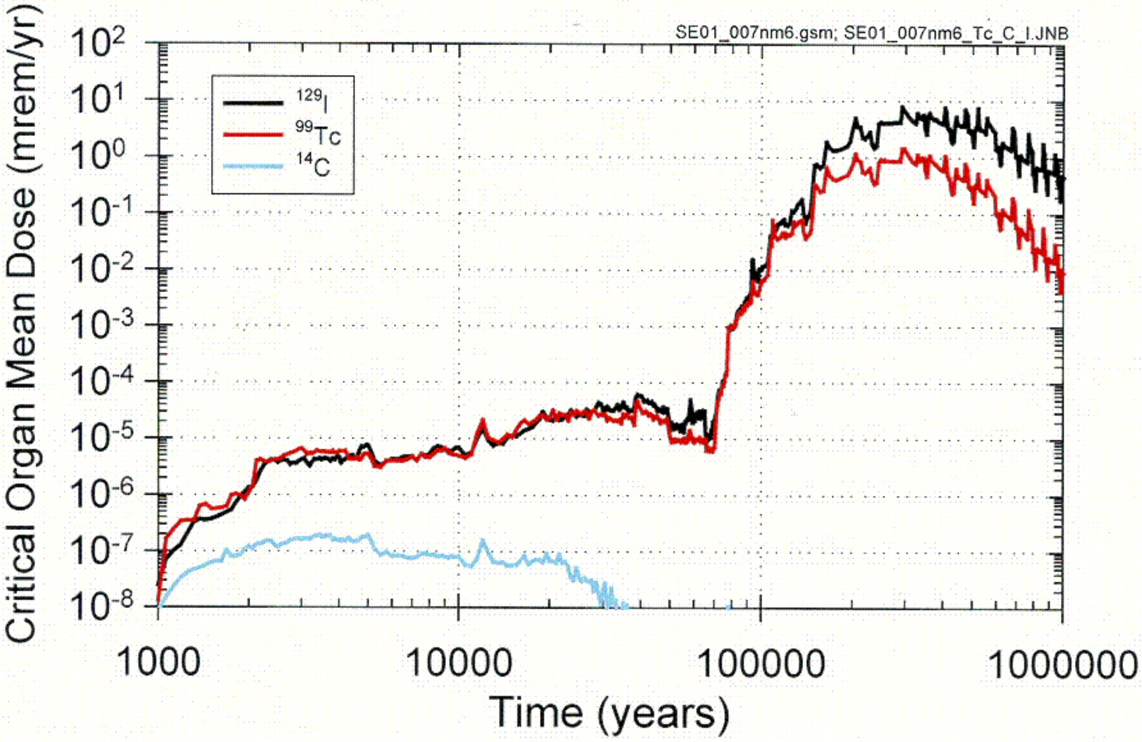


Figure 6-20 Mean Dose to Critical Organs for ^{99}Tc, ^{14}C, and ^{129}I for the 70,000 MTHM Inventory, LTOM. The Concentrations are Calculated for a Representative Volume of Groundwater of 3,000 acre-feet at the Accessible Environment, Which is the Same as the RMEI Location.

C27

ATTACHMENT I

ACRONYMS AND ABBREVIATIONS

ACRONYMS AND ABBREVIATIONS

AMCG	average member of the critical group
AMR	Analysis Model Report
BSC	Bechtel SAIC Company, LLC
CFR	Code of Federal Regulations
CRWMS	Civilian Radioactive Waste Management System
CSCI	Computer Software Configuration Item
CSNF	Commercial Spent Nuclear Fuel
DIRS	Document Input Reference System
DOE	U.S. Department of Energy
DSNF	DOE Spent Nuclear Fuel
EPA	U.S. Environmental Protection Agency
EIS	Environmental Impact Statement
FEHM	Finite Element Heat and Mass model
FEIS	Final Environmental Impact Statement
GTCC	Greater Than Class C
HLW	High-Level Waste
HTOM	high-temperature operating mode
JTC	Jason Technologies Corporation
LTOM	low-temperature operating mode
MTHM	Metric Tons Heavy Metal
M&O	Management and Operating Contractor
NRC	Nuclear Regulatory Commission
NUFT	Nonisothermal Unsaturated-saturated Flow and Transport model
NWPA	Nuclear Waste Policy Act
OCRWM	Office of Civilian Radioactive Waste Management
REV	Revision
RIP	Repository Integration Program
RMEI	reasonably maximally exposed individual
SSE	Site Suitability Evaluation

SNF	Spent Nuclear Fuel
SPAR	Special Performance Assessment Required
SR	Site Recommendation
SSPA	Supplemental Science and Performance Analysis
STN	Software Tracking Number
SZ	Saturated Zone
TSPA	Total System Performance Assessment
UZ	Unsaturated Zone

ATTACHMENT II

Extraction of Repository Release Nodes

The following describes the procedures used to calculate the new fraction of the repository area for each infiltration-rate bin for the simulation of the EIS Expanded-inventory case.

The fraction of the repository area occupied by each infiltration-ate bin for the expanded-inventory case was calculated to determine adequate area assignments. In the TSPA-SR base-case analysis, the fraction of repository area for each infiltration-rate bin is known. This information is presented in Table II-1. The data are tracked by DTN: LL000114004242.090, LL000114104242.091, and LL000113904242.089.

Table II-1 Infiltration-rate bin Fractional Areas: 70,000-MTHM Inventory

Bin Number	Low Infiltration	Mean Infiltration	High Infiltration
1	0.597	0.016	0
2	0.403	0.132	0.012
3	0	0.321	0.134
4	0	0.529	0.548
5	0	0.003	0.306
Total	1	1.001	1

For the current analysis, this information has been updated. The updated repository fractions were contained in a series of thermal hydrology files describing environmental parameters in the Near Field Environment. There were two sets of Infiltration-rate bin Fractional Areas, one for the High Temperature Operating Mode (HTOM) and one for the Low Temperature Operating Mode (LTOM). These data are presented in Tables II-2a and II-2b, respectively.

Table II-2a Infiltration-rate bin Fractional Areas: 70,000-MTHM Inventory, HTOM

Bin Number	Low Infiltration	Mean Infiltration	High Infiltration
1	0.6955	0	0
2	0.3045	0.0601	0.0104
3	0	0.3243	0.0587
4	0	0.6156	0.6687
5	0	0	0.2622
Total	1	1	1

Table II-2b Infiltration-rate bin Fractional Areas: 70,000-MTHM Inventory, LTOM

Bin Number	Low Infiltration	Mean Infiltration	High Infiltration
1	0.7441	0	0
2	0.2559	0.1451	0.0087
3	0	0.3394	0.1489
4	0	0.5155	0.6236
5	0	0	0.2188
Total	1	1	1

The number of FEHM nodes assigned to each infiltration-rate bin under each infiltration scenario is known for both the 70,000 MTHM case and expanded-inventory case. The FEHM node distribution is identical for both the HTOM and LTOM cases and no distinction is made for the thermal mode. The number of FEHM nodes assigned to each infiltration-rate bin should approximate the mass distribution among the bins. The calculation of the repository area for the simulations for the expanded-inventory case was calculated using the 70,000-MTHM-inventory repository area distribution and the FEHM node placement proportions for the two scenarios.

The number of FEHM nodes for the 70,000 MTHM case was supplied in the text files glal1_EBS.zone, glam1_EBS.zone, and glau1_EBS.zone for the low, mean, and high infiltration scenarios, respectively. The number of FEHM nodes for the low-infiltration case are found on line 3 for Bin 1, line 33 for Bin 2, line 43 for Bin 3, line 47 for Bin 4, and line 51 for Bin 5. The number of FEHM nodes for the mean-infiltration case are found on line 3 for Bin 1, line 13 for Bin 2, line 22 for Bin 3, line 35 for Bin 4, and line 51 for Bin 5. The number of FEHM nodes for the high-infiltration case are found on line 3 for Bin 1, line 12 for Bin 2, line 18 for Bin 3, line 25 for Bin 4, and line 43 for Bin 5. The number of nodes per bin for the 70,000-MTHM case inventory is presented in Table II-3a. The contribution of FEHM nodes from infiltration-rate bins that do not account for any of the fractional bin areas was removed. The adjusted number of nodes per bin for the 70,000-MTHM case is presented in Table II-3b.

Table II-3a Number of FEHM Nodes in Each Infiltration-rate bin: 70,000-MTHM Inventory

Bin Number	Low Infiltration	Mean Infiltration	High Infiltration
1	216	51	43
2	53	42	23
3	4	78	32
4	2	98	115
5	0	6	62
Total	275	275	275

Table II-3b Adjusted Number of FEHM Nodes in Each Infiltration-rate bin: 70,000-MTHM Inventory

Bin Number	Low Infiltration	Mean Infiltration	High Infiltration
1	216	0	0
2	53	42	23
3	0	78	32
4	0	98	115
5	0	0	62
Total	269	218	232

The fraction of the resulting total of FEHM nodes was calculated for each bin. The results are presented in Table II-4.

Table II-4 Fraction of FEHM Nodes in Each Infiltration-rate bin: 70,000-MTHM Inventory

Bin Number	Low Infiltration	Mean Infiltration	High Infiltration
1	0.8030	0	0
2	0.1970	0.1927	0.0991
3	0	0.3578	0.1379
4	0	0.4495	0.4957
5	0	0	0.2672
Total	1	1	1

The number of FEHM nodes for the expanded inventory was supplied in the text files glal1_EBS_EIS.zone, glam1_EBS_EIS.zone, and glau1_EBS_EIS.zone for the low-, mean-, and high-infiltration scenarios, respectively. The number of FEHM nodes for the low-infiltration case are found on line 3 for Bin 1, line 62 for Bin 2, line 73 for Bin 3, line 77 for Bin 4, and line 81 for Bin 5. The number of FEHM nodes for the mean-infiltration case are found on line 3 for Bin 1, line 17 for Bin 2, line 27 for Bin 3, line 42 for Bin 4, and line 60 for Bin 5. The number of FEHM nodes for the high-infiltration case are found on line 3 for Bin 1, line 15 for Bin 2, line 22 for Bin 3, line 30 for Bin 4, and line 49 for Bin 5. The number of nodes per bin for the expanded-inventory case is presented in Table II-5.

Table II-5 Number of FEHM Nodes in Each Infiltration-rate bin: Expanded Inventory

Bin Number	Low Infiltration	Mean Infiltration	High Infiltration
1	281	84	71
2	59	51	30
3	3	89	40
4	2	113	128
5	0	8	76
Total	345	345	345

The node assignments were adjusted for bins that do not account for any of the repository area and the fraction of the total FEHM nodes was calculated for each bin. The results are presented in Table II-6.

Table II-6 Fraction of FEHM Nodes in Each Infiltration-rate bin: Expanded Inventory

Bin Number	Low Infiltration	Mean Infiltration	High Infiltration
1	0.8265	0	0
2	0.1735	0.2016	0.1095
3	0	0.3518	0.1460
4	0	0.4466	0.4672
5	0	0	0.2773
Total	1	1	1

It was observed that the fraction of FEHM nodes in each bin is similar, so it was reasoned that the fraction of repository area should also be similar. To calculate the fraction of repository area for each infiltration bin in the expanded-inventory case, the fraction of the repository area for each bin for the 70,000-MTHM, HTOM and 70,000-MTHM LTOM cases (Tables 2a and 2b, respectively) were multiplied by the fraction of FEHM nodes for the expanded-inventory case (Table 6). This value was then divided by the fraction of FEHM nodes for the 70,000-MTHM inventory case (Table 4). This proportional calculation, based on FEHM node distribution, yielded the values presented in Table II-7a and II-7b.

Table II-7a Proportional Fraction of the Repository Area in Each Infiltration-rate bin: Expanded Inventory, HTOM

Bin Number	Low Infiltration	Mean Infiltration	High Infiltration
1	0.7159	0	0
2	0.2682	0.0629	0.0115
3	0	0.3188	0.0621
4	0	0.6116	0.6302
5	0	0	0.2721
Total	0.9840	0.9934	0.9760

Table II-7b Proportional Fraction of the Repository Area in Each Infiltration-rate bin: Expanded Inventory, LTOM

Bin Number	Low Infiltration	Mean Infiltration	High Infiltration
1	0.7659	0	0
2	0.2254	0.1518	0.0096
3	0	0.3337	0.1576
4	0	0.5122	0.5877
5	0	0	0.2271
Total	0.9913	0.9977	0.9820

The values in Tables II-7a and II-7b were normalized by dividing by the sum totals. The results yield the calculated fraction of the repository area per infiltration-rate bin for the HTOM and LTOM simulations for the expanded-inventory case. These results are presented in Table II-8a and II-8b.

Table II-8a Normalized Fraction of the Repository Area in Each Infiltration-rate bin: Expanded Inventory, HTOM

Bin Number	Low Infiltration	Mean Infiltration	High Infiltration
1	0.7275	0	0
2	0.2725	0.0633	0.0118
3	0	0.3210	0.0637
4	0	0.6157	0.6457
5	0	0	0.2788
Total	1	1	1

Table II-8b Normalized Fraction of the Repository Area in Each Infiltration-rate bin: Expanded Inventory, LTOM

Bin Number	Low Infiltration	Mean Infiltration	High Infiltration
1	0.7726	0	0
2	0.2274	0.1522	0.0098
3	0	0.3345	0.1605
4	0	0.5133	0.5985
5	0	0	0.2312
Total	1	1	1

ATTACHMENT III

GTCC and SPAR INVENTORY

The following tables were assembled in an EXCEL 97 spreadsheet. The source of the data is DOE 1999 ([DIRS 105155], Volume II, Appendix A, p. A-56 to A-61).

Table III-1 Volume of Inventory and Package Estimate

	Vol (m3)	# pkgs
SPAR	4000	400
GTCC	2010	201
Total	6010	601

Note: Conversion factor 10 m3/DPC

Table III-2 GTCC Radionuclide Inventory

Spec Act. (Ci/g)	GTCC	Comm reactor	Sealed sources	Other	Totals (Ci)	Totals (g)
3.44E+00	**Am241**		8.00E+04	2.40E+03	8.24E+04	2.40E+04
2.00E-01	**AM243**					
4.46E+00	**C14**	6.80E+04		7.70E+03	7.57E+04	1.70E+04
8.65E+01	**CS137**		4.00E+07	6.60E+01	4.00E+07	4.62E+05
1.77E-04	**I129**				0.00E+00	0.00E+00
7.06E-04	**NP237**				0.00E+00	0.00E+00
4.72E-02	**PA231**					
1.71E+01	**PU238**		1.60E+04		1.60E+04	9.36E+02
6.22E-02	**PU239**		1.07E+05		1.07E+05	1.72E+06
2.28E-01	**PU240**					
1.03E+02	**PU241**					
3.82E-03	**PU242**					
9.90E-01	**RA226**				0.00E+00	0.00E+00
6.98E-02	**SE79**					
1.37E+02	**SR90**				0.00E+00	0.00E+00
1.70E-02	**TC99**		5.80E+03	5.10E-02	5.80E+03	3.41E+05
2.20E+01	**U232**					
9.69E-03	**U233**					
6.26E-03	**U234**					
3.37E-07	**U238**		5.70E+01		5.70E+01	1.69E+08

Table III-3 SPAR Radionuclide Inventory

Spec Act. (Ci/g)	SPAR	Hanford	INEEL	ORNL	Total Ci	Total (g)
3.44E+00	**Am241**		2.40E+02		2.40E+02	6.98E+01
2.00E-01	**AM243**					
4.46E+00	**C14**		8.30E+02	1.00E+01	8.40E+02	1.88E+02
8.65E+01	**CS137**	6.00E+04	3.00E+01	1.70E-04	6.00E+04	6.94E+02
1.77E-04	**I129**			7.50E-05	7.50E-05	4.24E-01
7.06E-04	**NP237**				0.00E+00	0.00E+00
1.71E+01	**PU238**				0.00E+00	0.00E+00
6.22E-02	**PU239**		2.00E+01		2.00E+01	3.22E+02
2.28E-01	**PU240**					
1.03E+02	**PU241**					
3.82E-03	**PU242**					
9.90E-01	**RA226**		3.00E+01		3.00E+01	3.03E+01
6.98E-02	**SE79**					
1.37E+02	**SR90**	6.00E+04	7.40E+03		6.74E+04	4.92E+02
1.70E-02	**TC99**		3.30E+00	8.00E-01	4.10E+00	2.41E+02
2.20E+01	**U232**					
9.69E-03	**U233**					
6.26E-03	**U234**					
3.37E-07	**U238**		5.70E+01		5.70E+01	1.69E+08

Table III-4 Naval SPAR Radionuclide Inventory

		Naval (Ci/pkg)		Naval (Ci/pkg)			
Spec Act. (Ci/g)		**small(200)**	**Ci**	**large (100)**	**Ci**	**Total (Ci)**	**Total (g)**
3.44E+00	**AM241**	5.40E-02	1.1E+01	6.00E-02	6.00E+00	1.68E+01	4.88E+00
2.00E-01	**AM243**	5.80E-04	1.2E-01	6.50E-04	6.50E-02	1.81E-01	9.05E-01
4.46E+00	**C14**	3.2	6.4E+02	3.6	3.60E+02	1.00E+03	2.24E+02
8.65E+01	**CS137**	1.1	2.2E+02	1.3	1.30E+02	3.50E+02	4.05E+00
1.77E-04	**I129**	0.00E+00	0.0E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7.06E-04	**NP237**	0.00E+00	0.0E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4.72E-02	**PA231**	0.00E+00	0.0E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.71E+01	**PU238**	0.00E+00	0.0E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6.22E-02	**PU239**	2.10E-02	4.2E+00	2.40E-02	2.40E+00	6.60E+00	1.06E+02
2.28E-01	**PU240**	5.40E-03	1.1E+00	6.00E-03	6.00E-01	1.68E+00	7.37E+00
1.03E+02	**PU241**	4.10E+00	8.2E+02	4.60E+00	4.60E+02	1.28E+03	1.24E+01
3.82E-03	**PU242**	4.50E-05	9.0E-03	5.10E-05	5.10E-03	1.41E-02	3.69E+00
9.90E-01	**RA226**	0.00E+00	0.0E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6.98E-02	**SE79**	1.20E-05	2.4E-03	1.30E-05	1.30E-03	3.70E-03	5.30E-02
1.37E+02	**SR90**	4.20E-01	8.4E+01	4.70E-01	4.70E+01	1.31E+02	9.56E-01
1.70E-02	**TC99**	5.30E-04	1.1E-01	6.00E-04	6.00E-02	1.66E-01	9.76E+00
2.20E+01	**U232**	1.20E-04	2.4E-02	1.40E-04	1.40E-02	3.80E-02	1.73E-03
9.69E-03	**U233**	7.80E-05	1.6E-02	8.80E-05	8.80E-03	2.44E-02	2.52E+00
6.26E-03	**U234**	0.00E+00	0.0E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3.37E-07	**U238**	0.00E+00	0.0E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table III-5 Sum of GTCC and SPAR Radionuclide Inventories and Per-Package Inventory Estimate

	SPAR+GTCC	601 WP
	Totals (g)	**g per WP**
Am241	2.40E+04	4.00E+01
AM243	9.05E-01	1.51E-03
C14	1.74E+04	2.89E+01
CS137	4.63E+05	7.71E+02
I129	4.24E-01	7.05E-04
NP237	0.00E+00	0.00E+00
PA231	0.00E+00	0.00E+00
PU238	9.36E+02	1.56E+00
PU239	1.72E+06	2.86E+03
PU240	7.37E+00	1.23E-02
PU241	1.24E+01	2.07E-02
PU242	3.69E+00	6.14E-03
RA226	3.03E+01	5.04E-02
SE79	5.30E-02	8.82E-05
SR90	4.93E+02	8.20E-01
TC99	3.41E+05	5.68E+02
U232	1.73E-03	2.87E-06
U233	2.52E+00	4.19E-03
U234	0.00E+00	0.00E+00
U238	3.38E+08	5.63E+05