WSRC-TR-2004-00300
REV. 0

Key Words:
Vadose Zone
PORFLOW
Timed Sum-of-Fractions

Retention:
Permanent

SPECIAL ANALYSIS:

2004 GENERAL REVISION OF SLIT AND ENGINEERED TRENCH LIMITS

Prepared by:

Leonard B. Collard
Robert A. Hiergesell

June 14, 2004

Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808

Prepared for the U.S. Department of Energy Under Contract Number DE-AC09-96SR18500

SRS savannah river site ™

THIS PAGE INTENTIONALLY LEFT BLANK

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

µCi	microcuries
Ci	curie
CIG	Components-in-Grout
DOE	U.S. Department of Energy
ETF	Effluent Treatment Facility
ft	feet
g	gram
JCW	Job Control Waste
K_d	sorption coefficient
L	liters
Log	logarithm
m	meters
MCL	maximum contaminant level
ml	milliliters
PA	performance assessment
PD	post-drilling
pCi	picocuries
SA	Special Analysis
SOF	Sum-of-Fractions
SS	Special Study
UDQ	Unreviewed Disposal Question

THIS PAGE INTENTIONALLY LEFT BLANK

1 EXECUTIVE SUMMARY

This Special Analysis revises the Slit Trench and Engineered Trench inventory limits. Changes have been made in the methods of analyses and in the implementation of those methods. The most important changes are discussed in this section.

This report provides limits for each nuclide for each pathway/scenario in a single table to help implement the approach introduced in the "timed sum-of-fractions" report [1,2]. The pathways/scenarios include the following:

1. Groundwater
   a) 0-12 years
   b) 12-100 years
   c) 100-1000 years
2. Inadvertent Intruder
   a) Agriculture
   b) Resident
   c) Post-Drilling
3. Air
4. Radon

In the timed sum-of-fractions report, the time intervals were selected to be 0-100 years, 100-1000 years, and 1000-10,000 years. The time intervals for this report were refined to 0-12 years, 12-100 years, and 100-1000 years to account for the separation of the tritium groundwater peak from those of other radionuclides (e.g., Tc-99, I-129).

The first general change was to implement the 1000-year time of compliance[3] specified in DOE Order 435.1. The second general change that affects multiple pathways was to modify the closure cap[4] and assumptions associated with its performance. The new closure cap eliminates the agriculture intruder scenario by introducing an erosion barrier. The new closure cap also reduces the sharp spike in infiltration water at the end of institutional control.

This report includes nuclides not previously analyzed in the PA[5]. Some of these nuclides are included because they have been disposed in Slit or Engineered Trenches and the latest screening analysis[6] indicates that they survived the screening process. Other nuclides are only included because they survived the screening process and they have been disposed in other disposal units.

The PA considered a set of five slit trenches that were 20 ft wide with a 10-ft wide space between adjacent trenches as a disposal unit. Solid Waste is considering using a set of three slit trenches that are 40 ft wide with a 15-ft wide space between adjacent trenches as a disposal unit. This report also includes Engineered Trenches that are 157 ft wide. Because of these various trench set configurations individual inventory limits could be developed for each configuration. However, the inventory limits for different configurations are bounded by the original Slit Trench configuration (assuming that a smaller waste configuration is not selected) and the Engineered Trench configuration. The effects of these configurations are discussed in each pathway/scenario section below as horizontal geometry changes.

The contaminant transport at the water table (from the vadose zone transport analyses) was injected into 5 aquifer source cells, rather than 6 as was done in the PA. These 5 cells better approximated the footprint of two sets of Slit Trenches (see Figure 4).

Only H-3 has a fraction (inventory divided by its inventory limit) during the first time interval that exceeds 0.1 for Slit Trench 1 with an inventory on April 5, 2004. Only the groundwater pathway showed an isotope with a fraction greater than 0.1. Some recommendations for modeling changes and/or operation changes to mitigate these results are provided in the Conclusions.

2 INTRODUCTION

This Special Analysis revises the Slit Trench and Engineered Trench inventory limits. Changes have been made in the methods of analyses and in the implementation of those methods. General changes applicable to multiple pathways/scenarios are discussed in this section, while changes specific to individual pathways/scenarios are discussed in their applicable sections.

This report provides limits for each nuclide for each pathway/scenario in a single table to help implement the approach introduced in the "timed sum-of-fractions" report[1,2]. The pathways/scenarios include the following:

1. Groundwater
   a) 0-12 years
   b) 12-100 years
   c) 100-1000 years
2. Inadvertent Intruder
   a) Agriculture
   b) Resident
   c) Post-Drilling
3. Air
4. Radon

In the timed sum-of-fractions report, the time intervals were selected to be 0-100 years, 100-1000 years, and 1000-10,000 years. The time intervals for this report were refined to 0-12 years, 12-100 years, and 100-1000 years to account for the separation of the tritium groundwater peak from those of other radionuclides (e.g., Tc-99, I-129).

The first general change was to implement the 1000-year time of compliance[3] specified in DOE Order 435.1. Previously the time of compliance was at 10,000 years. This change tends to increase inventory limits. Thus the groundwater pathway limit from 1000 to 10,000 years was eliminated.

The second general change that affects multiple pathways was to modify the closure cap[4] and assumptions associated with its performance. The new closure cap contains an erosion barrier that is assumed to exist for the entire duration of the analysis. The erosion barrier protects the underlying material from erosion and preserves the thickness of the clean material over the waste.

The erosion barrier eliminates the agriculture scenario, because the depth of excavation of a standard basement is less than the non-eroded thickness of the clean material over the waste. The erosion barrier increases inventory limits for the resident scenario because the non-eroded clean material over the waste provides substantially more shielding than with the original cover design. The new closure cap generally tends to increase inventory limits for the groundwater pathway, because the closure cap is assumed to gradually degrade over time. The amount of infiltration water that penetrates the waste is gradually increased, which in turn gradually increases the groundwater concentrations, whereas a sudden cap failure (as assumed in the PA[5]) results in a sudden increase in infiltration water and a sudden and typically higher increase in groundwater concentrations.

In addition to the changes in the methods of analysis, this report supercedes many previous Unreviewed Disposal Question Evaluations (UDQEs) and Special Analyses. In other cases this document only supercedes the portion of some reports that address Slit Trenches or Engineered Trenches. A separate section in this report discusses the affected UDQEs and Special Analyses.

This report includes nuclides not previously included in the PA. Some of these nuclides are included because they have been disposed in Slit or Engineered Trenches and the latest screening analysis[6] indicates that they survived the screening process. Other nuclides are only included because they survived the screening process and they have been disposed in other disposal units.

To date, a Slit Trench disposal unit has been defined as a set of five slit trenches with each trench being 20 feet wide with a 10-ft space between trenches. Solid Waste is considering using a set of three slit trenches that are 40 ft wide with a 15-ft wide space between adjacent trenches as a disposal unit. This report also includes Engineered Trenches that are 157 ft wide. Because of these various trench set configurations individual inventory limits could be developed for each configuration. However, the inventory limits for different configurations are bounded by the original Slit Trench configuration (assuming that a smaller waste configuration is not selected) and the Engineered Trench configuration (that has the maximum footprint because it encompasses the entire LAW vault footprint). The effects of these configurations are discussed in each pathway/scenario section below as horizontal geometry changes.

3 GROUNDWATER PATHWAY ANALYSIS

To be consistent with the PA analysis, two Slit Trench disposal units (i.e., ten slit trenches) were analyzed.

The groundwater pathway analysis for a single radionuclide consists of a vadose zone analysis followed by an aquifer analysis. The vadose zone analysis estimates the contaminant flux that crosses the water table. That contaminant flux subsequently is applied as a source term for the aquifer analyses.

Each of the vadose zone analyses and aquifer analyses consisted of two parts, the flow analysis and the contaminant transport analysis. The flow analysis produced a set of steady-state flow fields. Those steady-state flow fields described the water movement that transported the contaminants. The contaminant transport analysis then employed the steady-state flow fields to help estimate the fate and transport of contaminants to either the water table or a hypothetical 100-m well.

The vadose zone model is a two-dimensional cross-section of one twenty foot wide slit trench. Each modeling analysis commenced with an inventory of 1 Ci of the parent and zero Ci for every other nuclide in the chain. The contaminant fluxes at the water table are expressed in terms of the initial inventory by dividing by 1 Ci, thus they are also fractional contaminant fluxes.

It was assumed that the contaminant flux through each cross-section of the trench was equal (thus end effects were ignored). Consequently, the contaminant flux through the modeled cross-section was multiplied by the entire length of 10 slit trenches to calculate the total flux to the water table for the two Slit Trench disposal units. The inventory was also multiplied by the entire length of 10 slit trenches to calculate the total inventory.

The fractional contaminant flux at the water table needed to be assigned to the appropriate set of aquifer modeling cells, called the aquifer source cells. Each of the aquifer cells had a footprint that was 200 ft wide by 200 ft long in plan view, which replicated the sizes used in the PA. The footprint of the set of 10 slit trenches was overlaid on the aquifer modeling grid and the appropriate columns of aquifer source cells were selected to best match the footprint of the two sets of 5 slit trenches. This topic is discussed in more detail in the section below on aquifer modeling changes.

Because the aquifer model extended to the ground surface, the appropriate source cell within the column needed to be selected. The criterion was to select the aquifer source cell in a column as the uppermost cell that was 100 percent saturated.

The aquifer model was executed with the fractional contaminant flux as a source that changed with respect to time. However, the fractional contaminant flux was the amount of flux that a single set of Slit Trenches would produce, while the aquifer model spread that contaminant flux over two sets of Slit Trenches. Consequently, all well concentrations produced by the model were multiplied by two to boost the contaminant flux to the amount that would be produced by two sets of 5 Slit Trenches.

The time intervals for reporting maximum well concentrations was modified from the “timed sum-of-fractions” report[1,2]. In that report the time intervals were selected from 0-100 years, 100-1000 years and 1000-10,000 years. In this report, after examining preliminary results, the time intervals were selected

from 0-12 years, 12-100 years and 100-1000 years to account for the separation of the tritium groundwater peak from those of other radionuclides (e.g., Tc-99, I-129).

.

Modeling changes consisted of both changes to the method and implementation changes. The most important implementation changes that could significantly affect limits are presented immediately below along with method changes. Other implementation changes that are primarily of interest to modelers are presented in Appendix A.

3.1 Vadose Zone Modeling Changes

The only conceptual changes for models were for the vadose zone analyses (see Table 1). Probably the most significant change was based on changes in the closure cap[4]. A cap with geotextiles replaced the kaolin cap, intrusion of pine trees was introduced and gradual degradation of the cap (after the end of institutional control) replaced instant failure. Infiltration rates through the new cap are shown in Figure 1. In the PA, three steady-state flow fields were developed to represent the 25-year operational stage, the 100-year institutional control stage, and the 9875-year post-institutional control stage. In the current revision, multiple steady-state flow fields were developed. The major difference is the gradual degradation of the new cap, such that the rate of infiltration through the cap is only about 0.41 inches/year[4] for the first 200 years after the end of institutional control versus about 15.7 in/year in the PA model. For the PA, the cap was combined with the waste in a single model, while in the current revision, the infiltration through the cap was independently simulated with the HELP[52] model.

Table 2 shows the modeled infiltration rates and the time intervals over which they were applied. The applied infiltration rates are the highest value shown over that interval. This approach produces a total infiltration that is slightly higher than what would be obtained if the average infiltration rate were applied.

The second conceptual change relates to new materials for the waste and the four feet of backfill placed directly over the waste. In the PA, both the waste and the four feet of backfill were simulated as "native soil," a synthesized or hybrid soil with properties between topsoil and other backfill materials. The four feet of backfill for the current analysis generally was assumed to have the same properties as the backfill used in the PA (see Table 3). However, the saturated hydraulic conductivity (Ksat) for the four feet of backfill initially was assumed to be 1E-3 cm/s[7], because that backfill is not compacted initially. After compaction a value of 1E-4 cm/s was assigned.

Table 1. Conceptual and implementation modeling changes

Type	Title	Analysis	Description
Conceptual (1)	Closure cap	Vadose zone	Interim cap followed by gradually degrading final cap. Cap was independently simulated with the HELP model
Conceptual (2)	Materials	Vadose zone	New waste material and 4 feet of backfill material
Conceptual (3)	Dynamic compaction	Vadose zone	Waste zone thickness changed when dynamic compaction occurs
Conceptual (4)	Cellulose Degradation Products	Vadose zone	Explicitly modeled
Conceptual (5)	Width of trenches	Vadose zone	Two widths for Slit Trenches addressed and Engineered Trench addressed
Implementation (1)	Footprint	Aquifer	Contaminant flux at water table spread over five aquifer source cells vs. six aquifer source cells in the PA
Implementation (2)	Source cell vertical locations	Aquifer	Source cells adjacent to each other
Implementation	Limits for	Aquifer	Limits for chains are calculated by considering the

Type	Title	Analysis	Description
(3)	chains		combined effect of all nuclides in the chain

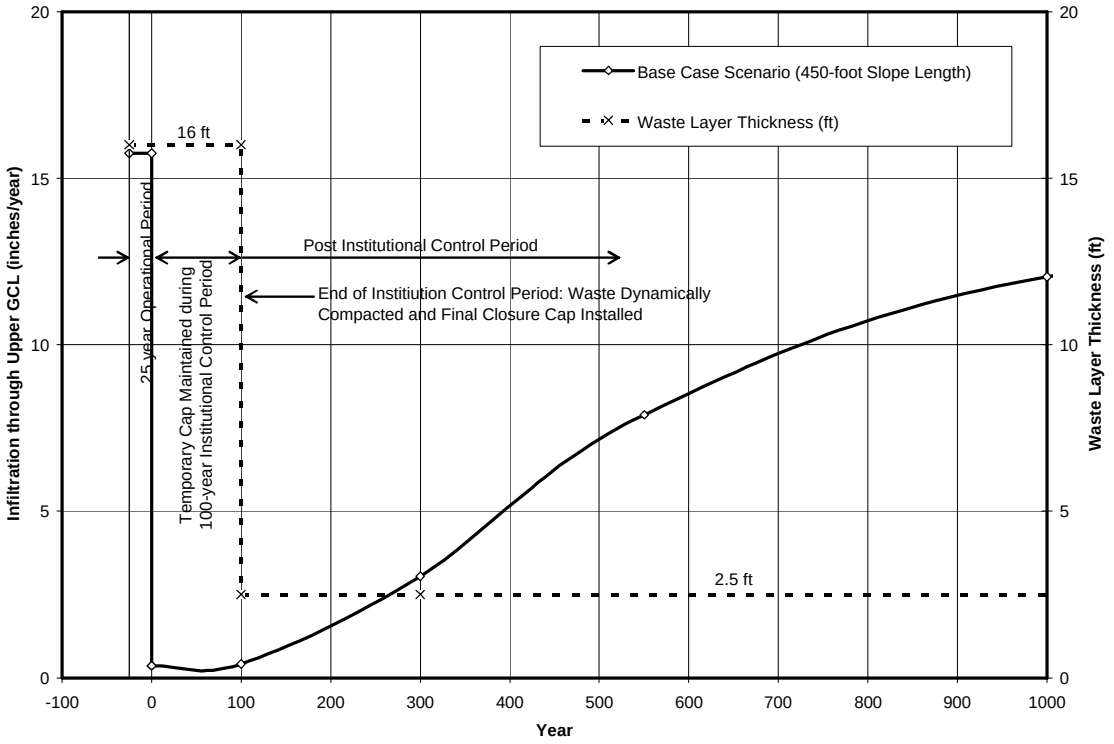

Figure 1. Infiltration through the new cap with a geotextile[4]

Table 2. Modeled infiltration rates and time intervals

Infiltration rate (in/yr)	Time interval from Figure 1 (years)		Time interval in model (years)	
	Low	High	Low	High
15.748	-25	0	0	25
0.41	0	100	25	125
3.05	100	300	125	325
7.90	300	550	325	575
12.04	550	1000	575	1025
14.10	1000	9975	1025	10000

Table 3. Physical material properties for vadose zone flow analyses

Material	Particle Density (g/cc)	Porosity (cc/cc)		Saturated Hydraulic Conductivity (cm/yr: cm/s)		Moisture Characteristic Curve Type	
		Initial	After compaction	Initial	After compaction	Initial	After compaction
4 feet of backfill above waste	2.65	0.51	0.51	3.154E4 (1E-3)	3.154E3 (1E-4)	backfill	backfill
top 13.5 ft of waste zone	2.65	0.38	0.51	3.154E5 (1E-2)	3.154E3 (1E-4)	topsoil	backfill
bottom 2.5 ft of waste zone	2.65	0.38	0.38	3.154E5 (1E-2)	6.3072E3 (2E-4)	topsoil	topsoil

"native" soil	2.65	0.42	0.42	315.4 (1E-5)	315.4 (1E-5)	native soil	native soil

The waste was expected to be more sand-like than the native soil, thus topsoil properties were assigned to the waste for the current revision, although the Ksat was assigned unique values. The waste (especially in an Engineered Trench) is extremely loose in general[8]. Based on this knowledge, the Ksat for the waste was assigned an initial value that was one order of magnitude greater than for the modeled backfill.

The third conceptual change was to incorporate some of the effects of dynamic compaction and subsidence. The metal containers (B-25 and B-12 boxes and Sealand containers) initially will support the overlying four feet of backfill and the waste should exhibit minimal subsidence). However, the metal containers will gradually corrode. The corrosion will reduce their strength and ultimately they will subside and the waste will also subside. Dynamic compaction is planned to hasten that subsidence, so that the subsidence after placement of the final cap will be greatly reduced. Because the thickness of the waste zone is expected to be greatly reduced (from about 16 feet thick to potentially about 2.5 feet thick[4,8], – see Figure 2), the waste zone thickness was modeled as a variable. Because there is tremendous uncertainty in how the waste zone thickness will change over time, only two states were modeled, the initial state (16 feet thick) and the potential final state (2.5 feet thick). The potential final state was assumed to occur at the time of the dynamic compaction, slated for the end of the institutional control period that is 100 years after the end of the operational period.

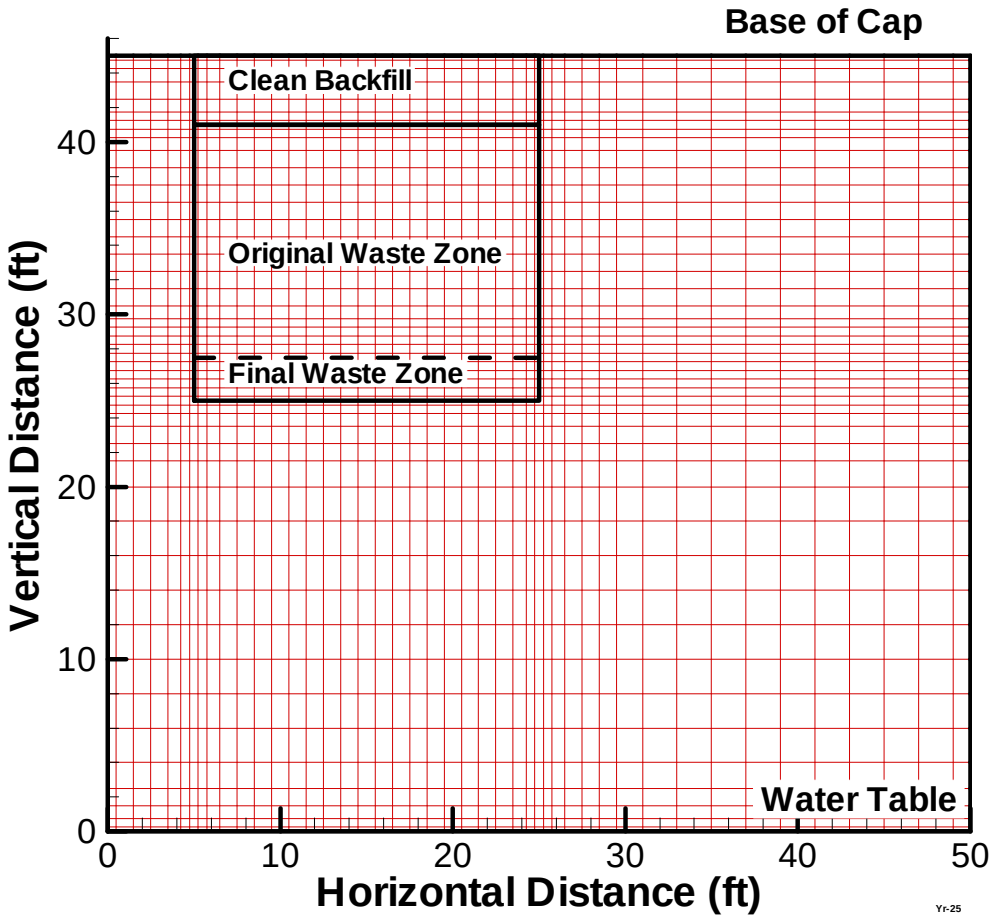

Figure 2. Vadose zone model showing mesh and waste zone before and after dynamic compaction

For the period after dynamic compaction, the top 13.5 ft of the initial waste zone was replaced with new backfill material also compacted to a Ksat of 1E-4 cm/s. Compaction was assumed to be less effective on the lower 2.5 ft of the initial waste zone such that a Ksat of 2E-4 cm/s was attained. The moisture characteristic information for the three material types is shown in Figure 3. Red lines show properties for "native soil," blue lines show properties for backfill and green lines show properties for waste.

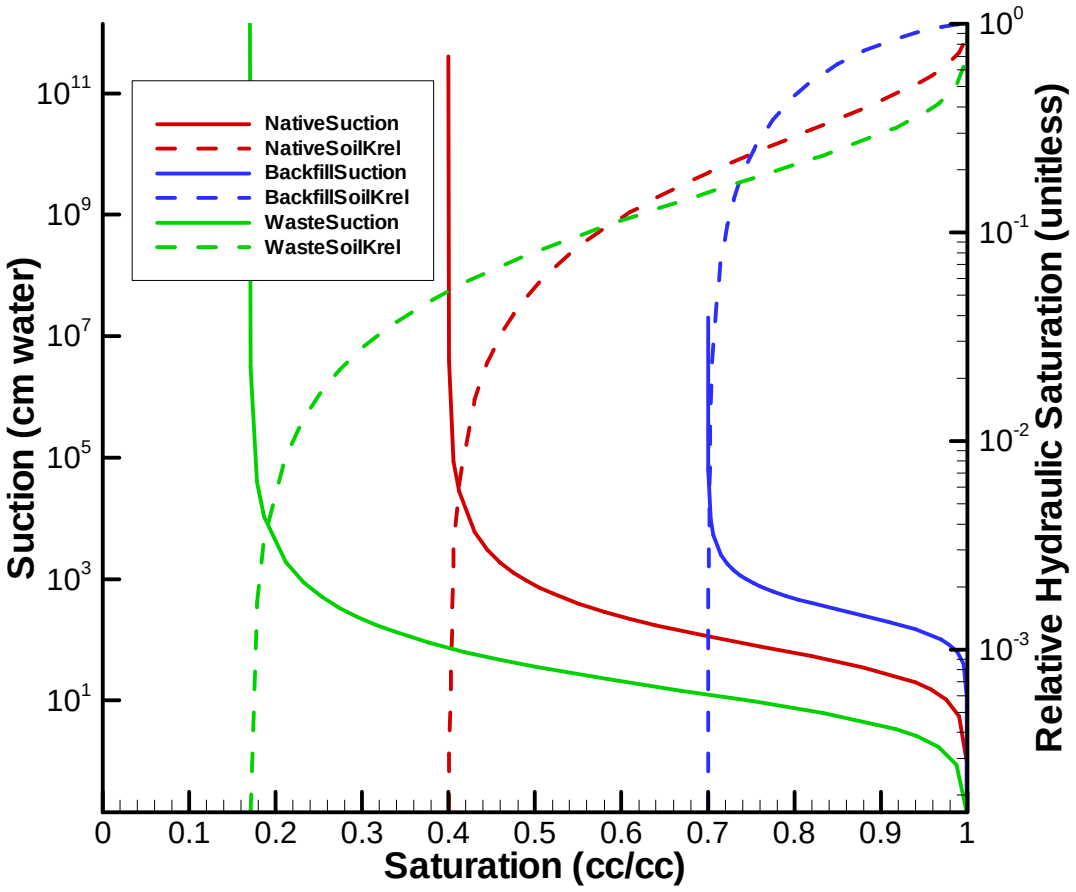

Figure 3. Moisture characteristic information for three material types

For the transport analysis, dynamic compaction had two effects. First the porosity of the top 13.5 ft of the initial waste zone was changed as new backfill was assumed to replace the waste material (see Table 4). Additionally the contaminants in the upper 13.5 ft were immediately moved to the lower 2.5 ft of the waste zone and added to the amount of contaminants already there.

Table 4. Physical material properties for vadose zone transport analyses

Material	Particle Density (g/cc)	Porosity (cc/cc)		Diffusion Coefficient (cm^2/s)		Longitudinal dispersivity (cm)	Transverse dispersivity (cm)
		Initial	After compaction	Initial	After compaction	Initial	After compaction
4 feet of backfill above waste	2.65	0.51	0.51	5E-6	5E-6	0	0
top 13.5 ft of waste zone	2.65	0.38	0.51	5E-6	5E-6	0	0

bottom 2.5 ft of waste zone	2.65	0.38	0.38	5E-6	5E-6	0	0
"native" soil	2.65	0.42	0.42	5E-6	5E-6	0	0

The fourth conceptual change was to model the effects of the cellulose (from paper and wood, etc.) degradation products explicitly. Previously, the effects of cellulose degradation products were captured by post-processing modeling results[9]. The post-processing consisted of effectively multiplying the peak well concentration by the ratio of the "average Kd" for the model (without the cellulose degradation products) divided by the "average Kd" if the cellulose degradation products had been considered. (The "average Kd" values were weighted by the path length over which they applied.) For example, if the cellulose degradation products would cause the "average Kd" to drop to half of its original value, the peak concentration would double, which would cause the inventory limit to be halved.

The effects of cellulose degradation products were explicitly modeled in this report using a surrogate. Degradation of cellulose would produce dissolved organic carbon, which in turn would affect the pH. Therefore pH expressed as a hydrogen ion concentration was used as the surrogate.

The hydrogen ion concentration was initially modeled to establish profiles of hydrogen ion concentrations in each model cell as a function of time. A table of Kd values expressed as a function of hydrogen ion concentration was produced for each contaminant (see Table 23 in Appendix A). At any point in time, the hydrogen ion concentration in each model cell was used with the table of Kd values to select the appropriate Kd value for modeling.

To align with the steady-state flow stages, a single pH value was selected for each cell for each steady-state flow stage. The pH value that produced the most mobile (lowest Kd) contaminant for that flow stage was selected.

The effects of the cellulose degradation products were only applied to the vadose zone models, because the aquifer provides substantial dilution of the dissolved organic carbon. For the purposes of this report, the hydrogen ion concentration only within the actual waste zone was fixed for the entire duration of the analysis. The actual waste zone was initially 16 ft thick, but after dynamic compaction, it was compressed to 2.5 ft.

The fifth conceptual change was to address two widths for the Slit Trenches and the full width for the Engineered Trench. The PA[5] considered a set of five Slit Trenches, each with a width of 20 feet and approximately 10 feet separating each pair of Slit Trenches (an overall width of 140 feet). This SA also considers a set of three Slit Trenches, each with a width of 40 feet and approximately 15 feet separating each pair of Slit Trenches (an overall width of 150 feet). This SA considers an Engineered Trench with a width matching the width of a LAW vault footprint[10] or 157 feet.

3.2 Aquifer Modeling Changes

The most important implementation modeling changes were designed to more accurately represent the locations in the aquifer where the contamination from the vadose zone would first enter. The first step was to better represent the footprint of the waste by using only five aquifer source cells rather than the 6 aquifer source cells that were analyzed in the PA. A comparison of the waste footprint and the footprint for the aquifer source cells is presented in Table 5, Figure 4 and Figure 5. Even with the 5 cell model for the aquifer, the footprint in the aquifer exceeds the footprint in the vadose zone for two sets of Slit Trenches, while being smaller than the footprint for the two sets of Engineered Trenches by about 3 percent.

Figure 4 shows the zoomed-in model that was used wherever possible to reduce computer execution times. In Figure 4 and Figure 5 the following legend applies:

- wide black line outlines the zoomed-in modeling domain

- wide pink lines outline aquifer source cells
- wide blue lines are streamtraces
- red circles on streamstraces are 5-year pore velocity markers that start from 4 corners of 10-trench footprint
- narrow horizontal and vertical orange lines are aquifer cell outlines (this figure is a subset of the overall General Separations Area model, so some outlines for aquifer cells outside the zoomed-in model are shown)
- green curves are seeplines only shown in Figure 5

The modeling domain partially shown in Figure 5 was used for the highly mobile nuclides (see Table 6). Highly mobile contaminants typically generated high early peaks and the center of the contaminant mass would move beyond the boundaries of the zoomed-in model in less that 100 years. In order to observe the concentration peaks after 100 years, the region being monitored had to extend further, thus the full model for the General Separations Area (GSA) was adopted for those nuclides.

Table 5. Waste footprint and aquifer source cell footprint comparison

	Length (ft) X Width (ft) Area (ft^2)		
	Vadose Zone	Aquifer	
Disposal Unit	Outline of waste for 2 sets of trenches	5 Aquifer source cells	6 Aquifer source cells
5 Slit Trenches 20 ft wide 10 ft spacing	(656 X 140) X 2 183,680	(200 X 200) X 5 200,000	(200 X 200) X 6 240,000
3 Slit Trenches 40 ft wide 15 ft spacing	(656 X 150) X 2 196,800		
Engineered Trench 157 ft wide	(656 X 157) X 2 205,984		

Table 6. List of highly mobile nuclides requiring use of full GSA model

Al-26
Cl-36
H-3
H-3-ETF-Carbon
I-129
Tc-99
All sensitivity study nuclides

The second important implementation modeling change was to force all the aquifer source cells to be adjacent to each other. The contaminant flux crossing the water table from the vadose zone model was input as a source term into the aquifer model. The water table likely does not have jumps in its vertical location, thus the source term should be applied similarly with respect to the vertical location of aquifer source cells. The PA used a simple approach that produced nonadjacent aquifer source cells. That approach has been improved to force all aquifer source cells to be adjacent to each other.

The third important implementation modeling change was to calculate limits for chains by considering the combined effect of all nuclides in the chain. In the PA, each nuclide in the chain was considered independently and the lowest limit from among all the nuclides was selected as the limit to impose. The combined effect of all nuclides in the chain can be calculated by summing the impact from each nuclide and comparing the sum to the maximum allowable impact. To account for different performance measures for the nuclides in a chain (e.g., the MCL for beta and gamma-emitting radionuclides and 25 mrem/year for alpha-emitting radionuclides); the calculated radionuclide groundwater concentration was divided by the

nuclide's performance measure. The sum-of-fractions for all nuclides in the chain was calculated. The multiplicative inverse of the sum-of-fractions was the inventory limit.

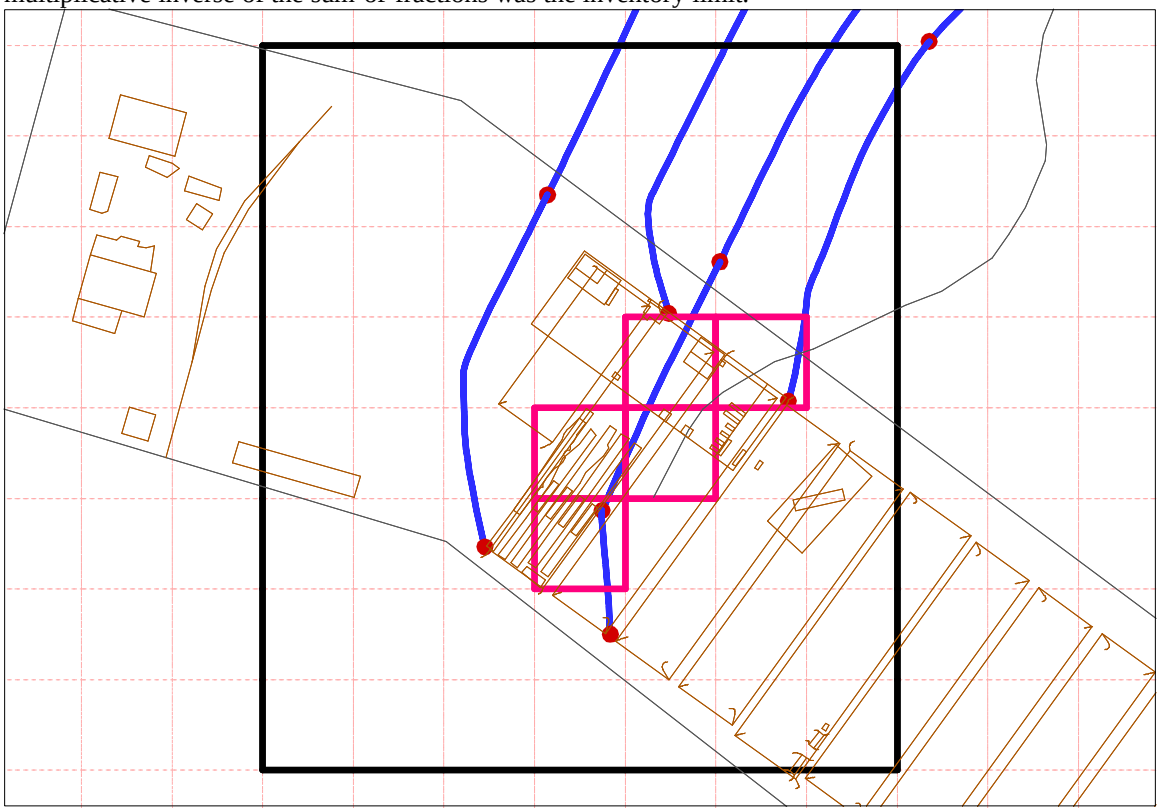

Figure 4. Plan view of aquifer node cells and Slit Trenches for zoomed-in model

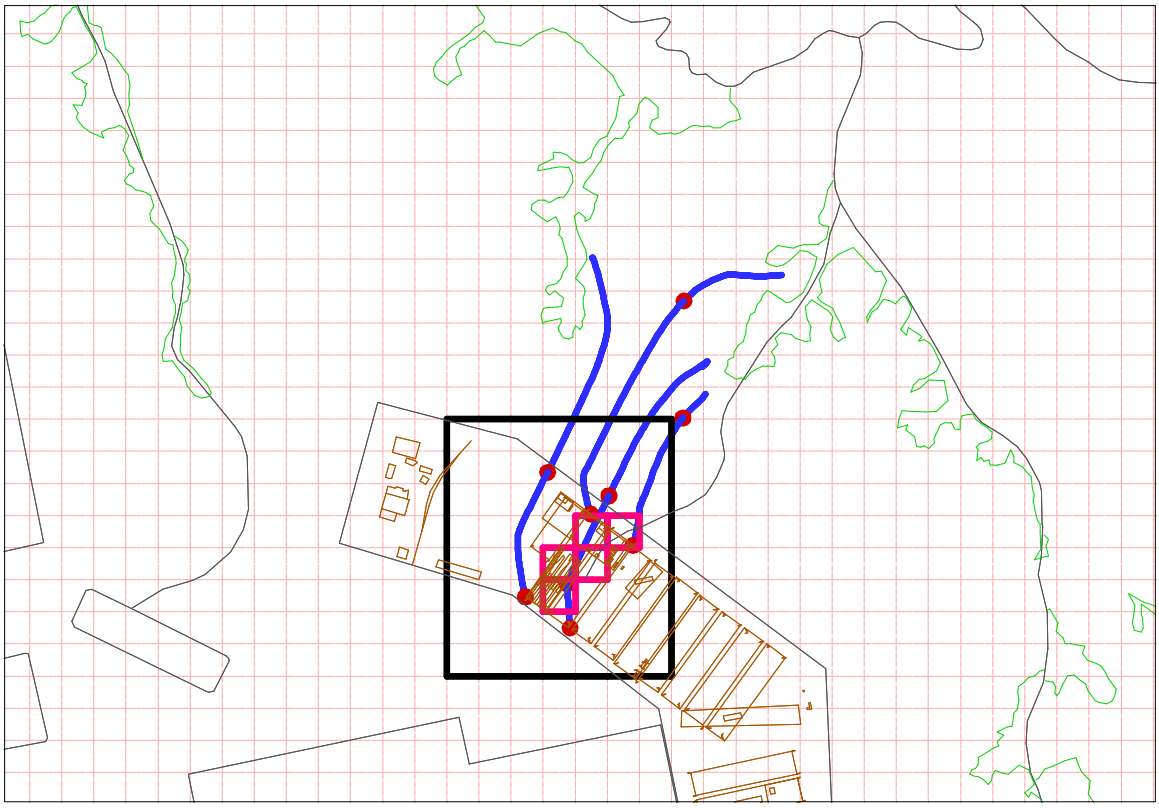

Figure 5. Partial plan view of aquifer node cells and Slit Trenches for full GSA model

Method for analyzing Pu colloids

In the Special Analysis for Pu new chemistry[43] Pu colloids were independently analyzed based on a field investigation[51]. The field investigation measured Pu concentrations of about 0.339 pCi/L on colloids in a well about 550 m from a source. The source consisted of a seepage basin that had a Pu concentration of about 308 pCi/L. The ratio of the colloid concentration at the 550-m well to the source concentration (C_{well}/C_{source}) thus was 1.1E-3 (0.339/308). The Pu new chemistry SA[43] applied a Kd of 88,000 ml/g in the waste zone. The ratio of the concentration in the waste zone liquid for the Pu colloids to the concentration in the waste zone liquid for generic Pu (based on a Kd of 370 ml/g for Pu non-colloids) approximated the C_{well}/C_{source} found in the field. The Kd outside the waste zone was set to 0 ml/g for the colloids. That approach forced a very slow release of Pu colloids from the waste zone, when the Pu colloids would actually move at the same speed as the water. Also, when the colloids finally arrived at the 550-m well the concentrations would be less than at the waste zone, thus the modeled C_{well}/C_{source} would be less than the field C_{well}/C_{source}.

An improved method was developed. The modeled C_{well}/C_{source} was set at the field C_{well}/C_{source} at time zero, then radioactive decay and conversion between oxidation states were allowed to occur without any transport away from the well. The colloid concentration at the theoretical 100-m well was based on the field measurement at the 550-m well[51]. The Pu colloid concentrations at the 550-m well were increased by a factor of 550m/100m to reflect the higher concentrations that would be expected for a well closer to the source. A new model was implemented that only included a well with an initial concentration of C_{well}/C_{source} (the vadose zone and surrounding aquifer cells were not modeled).

In actuality the Pu colloid concentration at the 550-m well would start at zero, then quickly increase because the colloids would travel faster than the non-colloids. The non-colloidal Pu would tend to produce a typical breakthrough curve, while potentially continuously spawning colloids from multiple locations and at multiple times. The mechanisms for producing the colloids are not well understood, nor are the rates of production. The colloids could be produced solely in the waste zone, solely in the surrounding sediments or in both the waste zone and in the surrounding sediments and likely at different rates. Because of the lack of a complete understanding, the following assumptions were made:

1. the observed field ratio represented a steady-state condition. (As the concentrations at the source changed, the concentrations at the 100-m well would change in a similar manner such that the ratio would be maintained.)
2. the observed field ratio is independent of the size of the source

The first assumption neglects the initial time required to establish the “steady-state” ratio. If the field measurements occurred prior to this initial time lag, then the ratio would be too small.

The second assumption reflects a limited source and instant transport. A very large source volume would continue to provide colloids at a high rate for a very long time. In that case, the maximum concentration of the colloids at the well would remain high for a long duration and would not decrease significantly for that duration. Adopting this assumption allows an initial well concentration to be applied and then to only consider radioactive decay and conversion between oxidation states.

The decay at the well approximates the decay of the original source material. While the colloids observed at the well will be transported away by the water, they will be replaced by other colloids arriving from the original source contaminants. If instantaneous transport is assumed, then the original colloids in the well will be completely removed and will be replaced by colloids from the decayed source contaminants. This removal and replacement is equivalent to merely allowing the original well colloids to decay in place.

A candidate for a sensitivity study would be to consider a higher initial maximum well concentration in case the field measurements were made before a “steady-state” ratio could be fully established. Another

candidate would be to hold the initial peak well concentration constant for several years in case the source is very large and can sustain the peak well concentration for a long duration.

This improved method makes full use of the available information. More complex modeling would have to make the same assumptions that were made for this simplified approach. Additionally, more complex modeling would have to be calibrated to match the field observations at an assumed time, which is what this simplified modeling accomplishes.

3.3 Modeling Results

Peak values for the fractional contaminant flux at the water table generated by the vadose zone model and peak values for the concentration at the hypothetical 100-m well are shown in Table 7. This table serves to replace Table 4.3-5 in the PA for fluxes and Table 5.1-4 in the PA for peak well concentrations. The table contains only the fluxes and groundwater concentrations for the non-colloid modeling, because vadose zone modeling was not performed for the colloids. The individual inventory limits for the colloids and the non-colloids are provided in the appendices. The results are based on the assumption that the waste is uniformly distributed.

The columns for each groundwater pathway interval are based on the results that 1 Ci of the parent would produce if distributed throughout 1 set of Slit Trenches. Results from each analysis of a parent nuclide are separated by a blank row in the table. The nuclides in the table represent the chain that was modeled, e.g., for Am-243, the chain consisted of Am-243, Np-239, Pu-239 and Pu5-239. Pu-239 represents Pu-239 (III/IV), while Pu5-239 represents Pu-239 (V/VI). The table presents by nuclide, its flux, the time when that peak flux occurred, the peak concentration, the fraction of its performance measure for that concentration, and the time when that peak concentration occurred. All concentrations less than 1E-99 were set to 1E-100.

The effect of horizontal geometry changes for trenches does not affect groundwater pathway inventory limits when applying the current method of analysis. Because all the contaminant flux is dumped into 5 aquifer source cells, the model is incapable of recognizing differences at a smaller scale. If waste is confined into a smaller horizontal space, then the waste concentration increases and the contaminant fluxes at the water table per waste footprint and the well concentrations per waste footprint should tend to increase. However, because the aquifer cell footprint does not adjust to match the waste footprint, the increased concentrations per waste footprint are diluted by the aquifer cell footprint back to the original values.

Table 7. Peak contaminant fluxes and well concentrations for groundwater pathway modeled for non-colloidal species

	Peak Flux		Peak Conc. 0-12 yr			Peak Conc. 12-100 yr			Peak Conc. 100-1000 yr		
Isotope	**Flux (fraction)**	**Time (yr)**	**Conc1 (pCi/L)**	**Frac1 (fraction)**	**Time1 (yr)**	**Conc2 (pCi/L)**	**Frac2 (fraction)**	**Time2 (yr)**	**Conc3 (pCi/L)**	**Frac3 (fraction)**	**Time3 (yr)**
Al-26	2.98E-01	5.10E+00	5.15E-02	1.29E-04	1.19E+01	1.16E+01	2.90E-02	9.99E+01	8.50E+01	2.13E-01	3.25E+02
Am-243	1.09E-02	6.05E+02	4.29E-55	5.65E-56	1.10E+01	2.23E-43	2.93E-44	9.93E+01	1.23E-03	1.62E-04	9.99E+02
Np-239	7.78E-08	6.06E+02	1.08E-43	3.60E-46	1.10E+01	1.01E-40	3.35E-43	9.93E+01	4.64E-01	1.55E-03	9.99E+02
Pu-239	1.27E-05	3.74E+03	3.07E-44	3.78E-45	1.10E+01	4.20E-36	5.19E-37	9.93E+01	6.85E-04	8.46E-05	9.99E+02
Pu5-239	5.28E-09	3.74E+03	4.10E-44	5.06E-45	1.10E+01	1.79E-39	2.21E-40	9.93E+01	2.56E-07	3.17E-08	9.99E+02
Bi-210	2.99E-76	2.01E+00	4.12E-87	4.57E-90	1.01E+00	2.36-195	2.62-198	1.20E+01	0.00E+00	0.00E+00	0.00E+00
Po-210	1.30E-46	8.01E+00	8.92E-52	5.95E-53	1.00E+01	5.78E-52	3.85E-53	1.20E+01	1E-100	1.E-100	1.00E+02
C-14	7.26E-03	1.98E+02	7.00E-06	3.50E-09	1.10E+01	4.45E+01	2.23E-02	5.72E+01	4.25E+02	2.13E-01	2.39E+02
Cf-249	2.61E-02	5.78E+02	2.57E-43	3.48E-44	1.10E+01	3.80E-32	5.13E-33	9.93E+01	1.13E-02	1.52E-03	9.99E+02
Cm-245	1.89E-03	6.21E+02	1.70E-48	2.24E-49	1.10E+01	7.57E-36	9.96E-37	9.93E+01	2.69E-05	3.55E-06	9.99E+02
Pu-241	3.09E-07	6.54E+02	7.45E-43	2.48E-45	1.10E+01	1.24E-34	4.12E-37	9.93E+01	3.68E-04	1.23E-06	9.99E+02
Pu5-241	1.23E-10	6.54E+02	1.20E-42	4.00E-45	1.10E+01	5.62E-38	1.87E-40	9.93E+01	1.40E-07	4.67E-10	9.99E+02
Am-241	1.20E-04	6.09E+02	2.71E-46	3.57E-47	1.10E+01	7.10E-37	9.34E-38	9.93E+01	3.01E-05	3.96E-06	9.99E+02
Np-237	1.10E-04	5.76E+02	2.36E-25	2.65E-26	1.10E+01	1.72E-14	1.94E-15	9.93E+01	3.81E-04	4.28E-05	9.99E+02
Cl-36	2.98E-01	5.10E+00	1.48E+04	2.11E+01	7.11E+00	3.08E+03	4.40E+00	1.20E+01	4.51E+01	6.44E-02	1.00E+02
Cm-245	2.60E-03	8.21E+02	3.92E-62	5.16E-63	1.10E+01	3.04E-50	4.01E-51	9.93E+01	3.35E-05	4.41E-06	9.99E+02
Pu-241	4.45E-07	8.42E+02	6.50E-43	2.17E-45	1.10E+01	9.27E-37	3.09E-39	9.93E+01	1.64E-03	5.46E-06	9.99E+02
Pu5-241	1.78E-10	8.42E+02	9.29E-43	3.10E-45	1.10E+01	7.95E-40	2.65E-42	2.51E+01	6.74E-07	2.25E-09	9.99E+02
Am-241	2.10E-04	6.15E+02	2.54E-46	3.34E-47	1.10E+01	1.67E-38	2.20E-39	9.93E+01	5.72E-04	7.52E-05	9.99E+02
Np-237	2.63E-04	5.76E+02	3.38E-21	3.80E-22	1.10E+01	7.48E-11	8.40E-12	9.93E+01	1.50E-02	1.68E-03	6.68E+02
Cm-246	2.47E-03	8.20E+02	3.92E-62	5.16E-63	1.10E+01	3.02E-50	3.98E-51	9.93E+01	3.14E-05	4.13E-06	9.99E+02

	Peak Flux		Peak Conc. 0-12 yr			Peak Conc. 12-100 yr			Peak Conc. 100-1000 yr		
Isotope	**Flux (fraction)**	**Time (yr)**	**Conc1 (pCi/L)**	**Frac1 (fraction)**	**Time1 (yr)**	**Conc2 (pCi/L)**	**Frac2 (fraction)**	**Time2 (yr)**	**Conc3 (pCi/L)**	**Frac3 (fraction)**	**Time3 (yr)**
Cm-247	2.78E-03	8.23E+02	3.93E-62	4.73E-63	1.10E+01	3.07E-50	3.70E-51	9.93E+01	3.64E-05	4.38E-06	9.99E+02
Am-243	2.15E-07	6.13E+02	4.03E-59	5.30E-60	1.10E+01	6.04E-47	7.94E-48	9.93E+01	7.85E-05	1.03E-05	9.99E+02
Np-239	1.54E-12	6.13E+02	3.04E-47	1.01E-49	1.10E+01	2.74E-44	9.13E-47	9.93E+01	2.97E-02	9.91E-05	9.99E+02
Pu-239	2.63E-10	1.37E+03	5.59E-48	6.90E-49	1.10E+01	1.15E-39	1.42E-40	9.93E+01	3.91E-05	4.83E-06	9.99E+02
Pu5-239	1.09E-13	1.40E+03	8.88E-48	1.10E-48	1.10E+01	4.91E-43	6.06E-44	9.93E+01	1.47E-08	1.81E-09	9.99E+02
Cm-248	2.78E-03	8.23E+02	3.93E-62	1.87E-62	1.10E+01	3.07E-50	1.46E-50	9.93E+01	3.63E-05	1.73E-05	9.99E+02
Pu-244	4.33E-07	3.87E+03	1.46E-49	1.69E-50	1.10E+01	1.31E-41	1.52E-42	9.93E+01	3.59E-08	4.18E-09	9.99E+02
Pu5-244	1.79E-10	3.88E+03	1.96E-49	2.28E-50	1.10E+01	5.58E-45	6.49E-46	9.93E+01	1.36E-11	1.58E-12	9.99E+02
Cs-135	7.72E-03	5.76E+02	7.57E-21	8.41E-24	1.10E+01	6.93E-10	7.70E-13	9.93E+01	1.71E+02	1.89E-01	7.29E+02
H-3	2.26E-01	5.00E+00	9.98E+03	4.99E-01	6.91E+00	1.58E+03	7.89E-02	1.20E+01	1.64E-01	8.21E-06	1.00E+02
H-3_ETF-Carbon	1.28E-04	1.33E+02	0.00E+00	0.00E+00	0.00E+00	4.34E-01	2.17E-05	9.99E+01	6.99E+00	3.49E-04	1.35E+02
I-129	9.31E-02	1.62E+01	5.33E+01	5.33E+01	1.19E+01	3.58E+03	3.58E+03	2.71E+01	1.09E+02	1.09E+02	1.00E+02
I-129_10	2.89E-02	2.50E+01	1.57E+00	1.57E+00	1.10E+01	1.09E+03	1.09E+03	3.10E+01	3.97E+02	3.97E+02	1.74E+02
I-129_ETF-Carbon	2.01E-04	1.03E+03	4.16E-35	4.16E-35	1.10E+01	2.05E-09	2.05E-09	9.93E+01	1.11E+01	1.11E+01	6.05E+02
I-129_ETF-GT-73	1.50E-04	1.03E+03	1.60E-03	1.60E-03	1.10E+01	1.11E+00	1.11E+00	3.10E+01	8.25E+00	8.25E+00	6.05E+02
I-129_F-Carbon	1.15E-05	1.03E+03	1.21E-04	1.21E-04	1.10E+01	8.41E-02	8.41E-02	3.10E+01	6.27E-01	6.27E-01	6.05E+02
I-129_F-CG-8	7.48E-03	3.26E+02	3.20E-01	3.20E-01	1.10E+01	2.22E+02	2.22E+02	3.10E+01	3.56E+02	3.56E+02	2.52E+02

	Peak Flux		Peak Conc. 0-12 yr			Peak Conc. 12-100 yr			Peak Conc. 100-1000 yr		
Isotope	**Flux (fraction)**	**Time (yr)**	**Conc1 (pCi/L)**	**Frac1 (fraction)**	**Time1 (yr)**	**Conc2 (pCi/L)**	**Frac2 (fraction)**	**Time2 (yr)**	**Conc3 (pCi/L)**	**Frac3 (fraction)**	**Time3 (yr)**
I-129_F-Dowex-21K	2.19E-04	1.03E+03	2.36E-03	2.36E-03	1.10E+01	1.64E+00	1.64E+00	3.10E+01	1.21E+01	1.21E+01	6.05E+02
I-129_F-Filtercake	8.03E-03	3.26E+02	2.82E-01	2.82E-01	1.10E+01	1.96E+02	1.96E+02	3.10E+01	3.73E+02	3.73E+02	3.45E+02
I-129_H-Carbon	2.61E-05	1.03E+03	2.76E-04	2.76E-04	1.10E+01	1.92E-01	1.92E-01	3.10E+01	1.43E+00	1.43E+00	6.05E+02
I-129_H-CG-8	2.47E-03	3.27E+02	4.22E-02	4.22E-02	1.10E+01	2.93E+01	2.93E+01	3.10E+01	1.47E+02	1.47E+02	3.58E+02
I-129_H-Dowex-21K	9.67E-05	1.03E+03	1.03E-03	1.03E-03	1.10E+01	7.14E-01	7.14E-01	3.10E+01	5.30E+00	5.30E+00	6.05E+02
I-129_H-Filtercake	1.87E-03	5.76E+02	2.47E-02	2.47E-02	1.10E+01	1.71E+01	1.71E+01	3.10E+01	1.08E+02	1.08E+02	6.02E+02
K-40	1.02E-02	3.26E+02	4.03E-08	1.34E-10	1.10E+01	3.62E+00	1.21E-02	9.93E+01	3.69E+02	1.23E+00	3.76E+02
Mo-93	1.09E-02	3.26E+02	1.04E-08	2.60E-12	1.10E+01	1.65E+00	4.13E-04	9.93E+01	3.87E+02	9.68E-02	3.73E+02
Nb-93m	2.39E-04	3.26E+02	5.35E-12	5.35E-15	1.10E+01	2.60E-02	2.60E-05	9.93E+01	6.98E+00	6.98E-03	3.94E+02
Nb-94	4.31E-04	3.45E+03	2.67E-44	2.67E-47	1.10E+01	2.42E-32	2.42E-35	9.93E+01	8.52E-10	8.52E-13	9.99E+02
Nb-95m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb-95	1.54E-59	3.00E+00	1.12E-66	3.73E-69	3.01E+00	3.91E-79	1.30E-81	1.20E+01	1.28-234	4.27-237	1.00E+02
Ni-59	9.91E-02	5.78E+02	4.92E-41	1.64E-43	1.10E+01	5.96E-30	1.99E-32	9.93E+01	1.60E-01	5.34E-04	9.99E+02
Np-237	2.02E-02	3.42E+02	5.35E-10	6.02E-11	1.10E+01	2.40E-01	2.69E-02	9.93E+01	4.97E+02	5.59E+01	4.12E+02
Pd-107	1.22E-01	5.76E+02	6.42E-25	1.60E-29	1.10E+01	4.78E-15	1.20E-19	9.93E+01	6.31E+01	1.58E-03	9.99E+02
Pu-238	2.27E-13	1.81E+03	2.89E-45	3.24E-46	1.10E+01	3.16E-39	3.55E-40	9.93E+01	1.77E-16	1.99E-17	9.99E+02

	Peak Flux		Peak Conc. 0-12 yr			Peak Conc. 12-100 yr			Peak Conc. 100-1000 yr		
Isotope	**Flux (fraction)**	**Time (yr)**	**Conc1 (pCi/L)**	**Frac1 (fraction)**	**Time1 (yr)**	**Conc2 (pCi/L)**	**Frac2 (fraction)**	**Time2 (yr)**	**Conc3 (pCi/L)**	**Frac3 (fraction)**	**Time3 (yr)**
Pu5-238	9.29E-17	1.81E+03	7.80E-46	8.77E-47	1.10E+01	1.33E-42	1.50E-43	9.93E+01	7.02E-20	7.88E-21	9.99E+02
U-234	5.19E-02	5.82E+02	1.09E-50	8.36E-53	1.10E+01	5.10E-41	3.92E-43	9.93E+01	7.74E-06	5.96E-08	9.99E+02
Pu-239	3.01E-04	4.56E+03	3.14E-45	3.88E-46	1.10E+01	6.96E-39	8.60E-40	9.93E+01	4.72E-13	5.82E-14	9.99E+02
Pu5-239	1.21E-07	4.57E+03	8.49E-46	1.05E-46	1.10E+01	2.94E-42	3.63E-43	9.93E+01	1.87E-16	2.30E-17	9.99E+02
U-235	6.77E-04	5.83E+02	4.05E-54	6.24E-56	1.10E+01	1.80E-44	2.78E-46	9.93E+01	1.37E-08	2.10E-10	9.99E+02
Pu-240	2.13E-04	4.48E+03	3.14E-45	3.88E-46	1.10E+01	6.91E-39	8.53E-40	9.93E+01	4.37E-13	5.39E-14	9.99E+02
Pu5-240	8.56E-08	4.48E+03	8.48E-46	1.05E-46	1.10E+01	2.92E-42	3.60E-43	9.93E+01	1.73E-16	2.13E-17	9.99E+02
U-236	2.44E-03	5.83E+02	1.22E-52	8.70E-55	1.10E+01	5.42E-43	3.87E-45	9.93E+01	4.00E-07	2.86E-09	9.99E+02
Pu-241	4.85E-31	6.86E+02	1.87E-45	6.23E-48	1.10E+01	5.54E-41	1.85E-43	9.93E+01	1.17E-32	3.91E-35	7.50E+02
Pu5-241	2.26E-34	6.82E+02	5.07E-46	1.69E-48	1.10E+01	2.85E-44	9.49E-47	2.51E+01	4.95E-36	1.65E-38	7.46E+02
Am-241	4.50E-03	6.05E+02	1.46E-48	1.92E-49	1.10E+01	1.12E-42	1.47E-43	9.93E+01	9.33E-06	1.23E-06	9.99E+02
Np-237	8.80E-03	3.52E+02	1.17E-19	1.31E-20	1.10E+01	7.17E-10	8.06E-11	9.93E+01	1.54E-03	1.73E-04	4.29E+02
Pu-242	3.40E-04	4.60E+03	3.14E-45	3.79E-46	1.10E+01	6.98E-39	8.41E-40	9.93E+01	4.84E-13	5.84E-14	9.99E+02
Pu5-242	1.37E-07	4.59E+03	8.49E-46	1.02E-46	1.10E+01	2.95E-42	3.55E-43	9.93E+01	1.92E-16	2.31E-17	9.99E+02
U-238	4.40E-05	5.83E+02	6.39E-55	6.39E-56	1.10E+01	2.84E-45	2.84E-46	9.93E+01	2.17E-09	2.17E-10	9.99E+02
Pu-244	3.43E-04	4.59E+03	3.14E-45	3.65E-46	1.10E+01	6.98E-39	8.12E-40	9.93E+01	4.85E-13	5.64E-14	9.99E+02
Pu5-244	1.38E-07	4.61E+03	8.49E-46	9.88E-47	1.10E+01	2.95E-42	3.43E-43	9.93E+01	1.92E-16	2.23E-17	9.99E+02
Ra-226	6.13E-02	5.79E+02	5.45E-43	1.09E-43	1.10E+01	8.26E-32	1.65E-32	9.93E+01	5.55E-02	1.11E-02	9.99E+02
Rb-87	4.60E-02	5.76E+02	1.29E-25	4.30E-28	1.10E+01	2.47E-15	8.25E-18	9.93E+01	6.43E+01	2.14E-01	9.99E+02
Se-79	2.14E-03	1.11E+03	3.18E-30	4.54E-33	1.10E+01	1.31E-18	1.87E-21	9.93E+01	3.88E+00	5.55E-03	9.99E+02

	Peak Flux		Peak Conc. 0-12 yr			Peak Conc. 12-100 yr			Peak Conc. 100-1000 yr		
Isotope	**Flux (fraction)**	**Time (yr)**	**Conc1 (pCi/L)**	**Frac1 (fraction)**	**Time1 (yr)**	**Conc2 (pCi/L)**	**Frac2 (fraction)**	**Time2 (yr)**	**Conc3 (pCi/L)**	**Frac3 (fraction)**	**Time3 (yr)**
Sn-126	2.74E-01	5.76E+02	1.31E-31	4.38E-34	1.10E+01	3.44E-21	1.15E-23	9.93E+01	7.61E+00	2.54E-02	9.99E+02
Sr-90	5.62E-06	3.44E+02	4.32E-13	5.40E-14	1.10E+01	4.15E-05	5.19E-06	9.93E+01	9.00E-03	1.13E-03	4.10E+02
Tc-99	1.28E-01	1.18E+01	1.30E+03	1.44E+00	1.19E+01	5.16E+03	5.73E+00	1.91E+01	1.89E+01	2.10E-02	1.00E+02
Th-228	9.48E-49	2.50E+01	6.97E-62	4.64E-63	1.10E+01	2.86E-56	1.91E-57	3.01E+01	1.01E-63	6.74E-65	1.00E+02
Ra-224	6.45E-48	2.50E+01	5.22E-61	3.48E-62	1.10E+01	1.90E-55	1.26E-56	3.01E+01	6.53E-63	4.35E-64	1.00E+02
Th-229	3.30E-03	7.32E+02	4.43E-60	4.61E-61	1.10E+01	3.16E-48	3.29E-49	9.93E+01	1.16E-04	1.21E-05	9.99E+02
Ra-225	2.00E-02	7.33E+02	6.14E-59	3.07E-60	1.10E+01	2.06E-47	1.03E-48	9.93E+01	7.47E-04	3.74E-05	9.99E+02
Ac-225	2.64E-02	7.32E+02	1.13E-58	7.53E-60	1.10E+01	2.31E-47	1.54E-48	9.93E+01	8.32E-04	5.54E-05	9.99E+02
Th-230	3.51E-03	7.33E+02	4.43E-60	2.96E-61	1.10E+01	3.18E-48	2.12E-49	9.93E+01	1.27E-04	8.46E-06	9.99E+02
Ra-226	1.50E-02	5.80E+02	1.57E-46	3.14E-47	1.10E+01	7.13E-35	1.43E-35	9.93E+01	2.02E-02	4.05E-03	9.99E+02
Pb-210	3.54E-02	5.77E+02	1.50E-42	1.50E-42	1.10E+01	5.69E-32	5.69E-32	9.93E+01	4.35E-02	4.35E-02	9.99E+02
Po-210	2.88E-04	5.78E+02	1.01E-41	6.75E-43	1.10E+01	1.07E-31	7.11E-33	9.93E+01	7.87E-02	5.25E-03	9.99E+02
Th-232	3.53E-03	7.33E+02	4.43E-60	3.41E-61	1.10E+01	3.19E-48	2.45E-49	9.93E+01	1.28E-04	9.85E-06	9.99E+02
Ra-228	2.03E-02	7.00E+02	1.18E-44	2.37E-45	1.10E+01	1.50E-36	3.00E-37	4.82E+01	1.14E-03	2.29E-04	9.99E+02
Th-228	3.34E-03	7.00E+02	3.65E-46	2.43E-47	1.10E+01	2.44E-37	1.63E-38	5.12E+01	1.79E-04	1.19E-05	9.99E+02
Ra-224	2.03E-02	7.00E+02	2.34E-45	1.56E-46	1.10E+01	1.56E-36	1.04E-37	5.12E+01	1.15E-03	7.64E-05	9.99E+02
U-232	1.50E-04	5.82E+02	3.99E-47	1.53E-48	1.10E+01	4.00E-36	1.54E-37	9.93E+01	1.92E-06	7.40E-08	7.84E+02
Th-228	3.32E-05	5.84E+02	2.11E-48	1.41E-49	1.10E+01	9.24E-37	6.16E-38	9.93E+01	4.84E-07	3.23E-08	7.86E+02
Ra-224	2.01E-04	5.84E+02	1.37E-47	9.16E-49	1.10E+01	5.91E-36	3.94E-37	9.93E+01	3.10E-06	2.07E-07	7.86E+02
U-233	5.19E-02	5.82E+02	4.47E-47	3.44E-49	1.10E+01	1.10E-35	8.47E-38	9.93E+01	2.16E-02	1.66E-04	9.99E+02
Th-229	2.76E-04	6.17E+02	7.72E-52	8.05E-53	1.10E+01	5.56E-39	5.79E-40	9.93E+01	1.04E-04	1.08E-05	9.99E+02

	Peak Flux		Peak Conc. 0-12 yr			Peak Conc. 12-100 yr			Peak Conc. 100-1000 yr		
Isotope	**Flux (fraction)**	**Time (yr)**	**Conc1 (pCi/L)**	**Frac1 (fraction)**	**Time1 (yr)**	**Conc2 (pCi/L)**	**Frac2 (fraction)**	**Time2 (yr)**	**Conc3 (pCi/L)**	**Frac3 (fraction)**	**Time3 (yr)**
Ra-225	1.67E-03	6.17E+02	5.28E-51	2.64E-52	1.10E+01	3.56E-38	1.78E-39	9.93E+01	6.63E-04	3.31E-05	9.99E+02
U-234	5.19E-02	5.82E+02	4.47E-47	3.44E-49	1.10E+01	1.10E-35	8.47E-38	9.93E+01	2.16E-02	1.66E-04	9.99E+02
Th-230	2.74E-05	6.18E+02	7.52E-53	5.01E-54	1.10E+01	5.42E-40	3.61E-41	9.93E+01	1.03E-05	6.84E-07	9.99E+02
Ra-226	4.07E-05	5.80E+02	2.40E-51	4.80E-52	1.10E+01	3.42E-39	6.83E-40	9.93E+01	8.07E-05	1.61E-05	9.99E+02
Pb-210	8.99E-05	5.77E+02	1.09E-47	1.09E-47	1.10E+01	1.32E-36	1.32E-36	9.93E+01	1.73E-04	1.73E-04	9.99E+02
Po-210	7.41E-07	5.78E+02	8.11E-47	5.41E-48	1.10E+01	2.47E-36	1.65E-37	9.93E+01	3.13E-04	2.09E-05	9.99E+02
U-234_MGlass	5.74E-05	5.83E+02	5.15E-53	3.96E-55	1.10E+01	3.87E-41	2.98E-43	9.93E+01	3.37E-05	2.60E-07	9.99E+02
Th-230	6.35E-08	1.00E+04	8.28E-59	5.52E-60	1.10E+01	1.87E-45	1.25E-46	9.93E+01	1.43E-08	9.55E-10	9.99E+02
Ra-226	2.41E-08	5.80E+02	2.85E-57	5.70E-58	1.10E+01	1.23E-44	2.46E-45	9.93E+01	6.94E-08	1.39E-08	9.99E+02
Pb-210	5.23E-08	5.77E+02	1.46E-53	1.46E-53	1.10E+01	5.53E-42	5.53E-42	9.93E+01	1.50E-07	1.50E-07	9.99E+02
Po-210	8.69E-10	1.00E+04	1.21E-52	8.06E-54	1.10E+01	1.04E-41	6.92E-43	9.93E+01	2.71E-07	1.81E-08	9.99E+02
U-235	5.20E-02	5.82E+02	4.47E-47	6.88E-49	1.10E+01	1.10E-35	1.69E-37	9.93E+01	2.17E-02	3.34E-04	9.99E+02
Pa-231	2.60E-03	5.76E+02	1.22E-46	3.93E-47	1.10E+01	1.90E-35	6.11E-36	9.93E+01	1.28E-03	4.11E-04	9.99E+02
Ac-227	1.81E-03	5.76E+02	2.35E-46	2.35E-46	1.10E+01	3.57E-35	3.57E-35	9.93E+01	1.58E-03	1.58E-03	9.99E+02
Th-227	2.24E-04	5.76E+02	2.97E-47	1.98E-48	1.10E+01	5.00E-36	3.33E-37	9.93E+01	2.22E-04	1.48E-05	9.99E+02
Ra-223	1.36E-03	5.76E+02	1.89E-46	1.26E-47	1.10E+01	3.20E-35	2.13E-36	9.93E+01	1.42E-03	9.48E-05	9.99E+02
U-235_MGlass	5.74E-05	5.83E+02	5.15E-53	7.93E-55	1.10E+01	3.87E-41	5.96E-43	9.93E+01	3.38E-05	5.20E-07	9.99E+02
Pa-231	1.78E-06	5.76E+02	1.45E-52	4.68E-53	1.10E+01	7.26E-41	2.34E-41	9.93E+01	1.26E-06	4.07E-07	9.99E+02
Ac-227	1.20E-06	5.77E+02	2.70E-52	2.70E-52	1.10E+01	1.36E-40	1.36E-40	9.93E+01	1.55E-06	1.55E-06	9.99E+02
Th-227	1.50E-07	5.77E+02	3.39E-53	2.26E-54	1.10E+01	1.91E-41	1.27E-42	9.93E+01	2.18E-07	1.45E-08	9.99E+02
Ra-223	9.12E-07	5.77E+02	2.15E-52	1.43E-53	1.10E+01	1.22E-40	8.16E-42	9.93E+01	1.40E-06	9.31E-08	9.99E+02
U-236	5.20E-02	5.82E+02	4.47E-47	3.20E-49	1.10E+01	1.10E-35	7.87E-38	9.93E+01	2.17E-02	1.55E-04	9.99E+02
U-236_MGlass	5.81E-06	4.06E+02	1.47E-51	1.05E-53	1.10E+01	5.34E-40	3.81E-42	9.93E+01	5.13E-05	3.66E-07	9.99E+02

	Peak Flux		Peak Conc. 0-12 yr			Peak Conc. 12-100 yr			Peak Conc. 100-1000 yr		
Isotope	**Flux (fraction)**	**Time (yr)**	**Conc1 (pCi/L)**	**Frac1 (fraction)**	**Time1 (yr)**	**Conc2 (pCi/L)**	**Frac2 (fraction)**	**Time2 (yr)**	**Conc3 (pCi/L)**	**Frac3 (fraction)**	**Time3 (yr)**
U-238	5.20E-02	5.82E+02	4.47E-47	4.47E-48	1.10E+01	1.10E-35	1.10E-36	9.93E+01	2.17E-02	2.17E-03	9.99E+02
Th-234	1.22E-02	5.82E+02	9.94E-48	2.49E-50	1.10E+01	2.74E-36	6.86E-39	9.93E+01	5.42E-03	1.36E-05	9.99E+02
U-234	8.53E-05	5.82E+02	1.28E-51	9.88E-54	1.10E+01	3.09E-39	2.38E-41	9.93E+01	6.12E-05	4.71E-07	9.99E+02
U-238_MGlass	5.74E-05	5.83E+02	5.15E-53	5.15E-54	1.10E+01	3.87E-41	3.87E-42	9.93E+01	3.38E-05	3.38E-06	9.99E+02
Th-234	1.35E-05	5.83E+02	1.14E-53	2.85E-56	1.10E+01	9.65E-42	2.41E-44	9.93E+01	8.46E-06	2.11E-08	9.99E+02
U-234	5.88E-08	5.82E+02	1.41E-57	1.08E-59	1.10E+01	1.07E-44	8.23E-47	9.93E+01	6.47E-08	4.98E-10	9.99E+02
Zr-93	7.76E-02	5.79E+02	1.54E-44	7.70E-48	1.10E+01	2.86E-33	1.43E-36	9.93E+01	5.09E-02	2.54E-05	9.99E+02
Nb-93m	9.42E-04	5.86E+02	3.75E-37	3.75E-40	1.10E+01	4.99E-27	4.99E-30	9.93E+01	2.51E-01	2.51E-04	9.99E+02
Zr-95	4.56E-52	5.00E+00	4.67E-60	2.33E-62	6.02E+00	2.09E-63	1.05E-65	1.20E+01	4.37-163	2.18-165	1.00E+02
Nb-95	1.77E-47	4.01E+00	1.53E-54	5.09E-57	4.01E+00	1.24E-60	4.14E-63	1.20E+01	3.75-162	1.25-164	1.00E+02

4 INTRUDER ANALYSIS

The intruder analysis was performed with a newly completed tool for automated analyses[11]. This tool eliminates the use of extensive spreadsheets that required extensive design checks.

The first important change in the method of analysis was to decouple the intruder analyses from the groundwater pathway analysis by neglecting leaching and only considering decay for the amount of contaminant remaining at the time of intrusion. The groundwater pathway typically used a distribution coefficient (Kd) that was conservative for its own pathway by enhancing the release slightly. However, that Kd typically was slightly unconservative for the intruder pathways because too much release meant that too little contaminant remained for the intruder to encounter. That unconservatism has been removed with the revised method.

The second important change in the method of analysis was to introduce a transient analysis for each type of intrusion, rather than selecting a fixed time. The decay process continually changes the amount of contaminant present in the waste zone that the intruder can encounter. While the amount of parent monotonically decreases, the amount of each progeny initially increases and ultimately decreases. At the same time as the decay process, sediments and engineered materials can erode and degrade. It is impossible to determine the time when the most conservative impact on the intruder can occur unless a rigorous examination is conducted with calculus or a transient analysis is performed. The new method selected a transient analysis that is valid across the spectrum of disposal units and does not require extensive calculations by the analyst, rather it requires the analyst to define the geometry and processes, then relies on the computer model to perform the analysis.

The first change in the implementation was selection of a new closure geometry that includes a 12 inch thick erosion barrier near the top of the cap[4]. Because the erosion barrier is assumed to never erode and all the layers between the waste and the erosion barrier always remain in place at their design thickness, about 10.4 ft[11] of material always exists above the waste. That thickness is greater than the depth of a typical basement (3 m or 9.8 ft) and the agriculture scenario can never occur, because the agriculture scenario relies on a basement extending into the waste zone.

For the resident scenario, the erosion barrier greatly increases the amount of material above the waste that serves to shield the resident intruder. For the post-drilling scenario, the erosion barrier does not prevent drilling through the waste.

The second change in the implementation was to consider different trench configurations (horizontal geometry changes) within a trench set boundary. The PA considered a set of 5 Slit Trenches, a trench set boundary that approximated the footprint for a single LAW vault. The PA reported different sizes for the LAW-vault footprint, so a UDQ-E was developed[10] that recommended a single size (656 ft by 157 ft) for the trench set boundary.

The PA states “the geometrical correction factor, G, in Eq. 6.3-1 takes into account that a large-scale excavation into disposal units, as assumed in the agriculture and resident scenarios, would involve exposure to uncontaminated material between individual disposal units as well as disposed waste itself.” “Therefore, the geometrical correction factor is given by the fraction of the land area encompassed by the disposal units of a particular type that contains waste.” ([5] page 6-20). (Simply stated, the “geometry factor” equals the footprint of the trenches divided by the LAW vault footprint.) On the other hand, for the post-drilling scenario where mixing would be less likely to occur the “geometry factor” was set to unity.

For the agriculture and resident scenarios, if the horizontal waste area increases, the geometry factor will increase by exactly the same amount (on a percentage basis), because the horizontal waste area is the numerator of the geometry factor. The inventory limit is calculated by multiplying a concentration limit by the horizontal waste area and dividing by the geometry factor. Thus an increase in the horizontal waste area is exactly offset by the increase in the geometry factor. Therefore the inventory limits for the agriculture and resident scenarios are independent of the trench configurations. This effect for the

agriculture and resident scenarios was verified by executing the intruder program for multiple trench configurations.

However, the post-drilling "geometry factor" does not include the trench area hence the inventory limits for the post-drilling scenario will directly vary with the trench area. The concentration limits will be the same for different trench configurations, but the greater the trench area is, the greater the inventory limit will be. This effect for the post-drilling scenario was verified by executing the intruder program for multiple trench configurations.

Selecting the minimum trench area will produce the minimum inventory limit that can be applied for all trench configurations. The trench areas (assuming trenches extend for the full length of the trench set boundary) for Slit Trenches and Engineered Trenches are shown in Table 8 with the associated geometry factors. The PA Slit Trench configuration has the smallest total area, which will produce the smallest inventory limit for the post-drilling scenario.

Table 8. Trench areas and geometry factors

Disposal unit	Length (ft)	Width (ft)	Area (ft^2)	Agriculture and Resident geometry factor	Post-drilling geometry factor
5 trenches	656	20	65,600	0.63694	1.0
3 trenches	656	40	78,720	0.76433	1.0
1 trench	656	157	102,992	1.0	1.0

The results of the resident intruder analyses are provided in Table 9 (that replaces Table 6.3-14 in the PA) for all sets of Slit Trenches that have a minimum combined waste width of 100 ft. The results of the post-drilling intruder analyses are provided in Table 10 (that replaces Table 6.3-18 in the PA) for all sets of Slit Trenches that have a minimum combined waste width of 100 ft. The results of the resident intruder analyses are provided in Table 11 (that supplements Table 6.3-14 in the PA) for Engineered Trenches. The results of the post-drilling intruder analyses are provided in Table 12 (that supplements Table 6.3-18 in the PA) for Engineered Trenches.

In these tables, the concentration limit is provided for 1 m^3 of waste and the inventory limit is provided for the entire volume of the trenches, i.e. disposal unit. Limits of "---"signify values that are greater than 1E20.

Table 9. Intruder-Based Radionuclide Disposal Limits for Slit Trenches – Resident Scenario with Transient Calculation for 1000 Years

Radionuclide	Time of Limit (Years)	Concentration Limit ($\mu Ci/m^3$)	Inventory Limit (Ci/Unit)
Ag-108m	760	1.31E+03	3.90E+01
Al-26	760	1.33E+02	3.95E+00
Am-241	760	2.11E+07	6.26E+05
Am-242m	760	5.50E+06	1.64E+05
Am-243	760	1.33E+04	3.95E+02
Ba-133	100	1.44E+11	4.28E+09
Bi-207	100	3.69E+06	1.10E+05
Bk-249	760	4.82E+06	1.43E+05
C-14	---	---	---
Cd-113m	---	---	---
Cf-249	760	1.25E+04	3.70E+02
Cf-250	1000	1.28E+15	3.81E+13
Cf-251	760	4.64E+04	1.38E+03

Table 9. Intruder-Based Radionuclide Disposal Limits for Slit Trenches – Resident Scenario with Transient Calculation for 1000 Years

Radionuclide	Time of Limit (Years)	Concentration Limit ($\mu Ci/m^3$)	Inventory Limit (Ci/Unit)
Cf-252	1000	2.55E+13	7.57E+11
Cl-36	---	---	---
Cm-242	1000	9.00E+10	2.67E+09
Cm-243	760	1.38E+09	4.09E+07
Cm-244	760	1.48E+13	4.40E+11
Cm-245	760	7.99E+04	2.37E+03
Cm-246	1000	3.51E+12	1.04E+11
Cm-247	1000	2.67E+03	7.94E+01
Cm-248	1000	1.87E+08	5.55E+06
Co-60	100	6.87E+10	2.04E+09
Cs-135	---	---	---
Cs-137	100	7.16E+07	2.13E+06
Eu-152	100	7.67E+07	2.28E+06
Eu-154	100	1.38E+09	4.09E+07
Eu-155	100	---	3.97E+18
H-3	---	---	---
I-129	760	2.49E+11	7.41E+09
K-40	760	2.27E+03	6.75E+01
Kr-85	100	3.26E+12	9.70E+10
Mo-93	760	---	---
Na-22	100	9.32E+16	2.77E+15
Nb-93m	760	---	---
Nb-94	760	3.26E+02	9.70E+00
Ni-59	---	---	---
Ni-63	---	---	---
Np-237	1000	5.66E+03	1.68E+02
Pb-210	100	4.70E+12	1.40E+11
Pd-107	---	---	---
Pu-238	1000	4.57E+08	1.36E+07
Pu-239	760	1.29E+08	3.82E+06
Pu-240	760	4.10E+10	1.22E+09
Pu-241	760	6.31E+08	1.88E+07
Pu-242	1000	2.36E+10	7.01E+08
Pu-244	760	1.49E+03	4.43E+01
Ra-226	760	3.10E+02	9.20E+00
Ra-228	100	4.44E+09	1.32E+08
Rb-87	---	---	---
Sb-125	100	1.69E+18	5.01E+16
Se-79	---	---	---
Sm-151	760	---	---
Sn-121m	---	---	---
Sn-126	760	2.95E+02	8.78E+00
Sr-90	---	---	---
Tc-99	760	3.55E+10	1.05E+09
Th-228	100	---	6.69E+18

Table 9. Intruder-Based Radionuclide Disposal Limits for Slit Trenches – Resident Scenario with Transient Calculation for 1000 Years

Radionuclide	Time of Limit (Years)	Concentration Limit ($\mu Ci/m^3$)	Inventory Limit (Ci/Unit)
Th-229	760	3.06E+03	9.08E+01
Th-230	1000	6.37E+02	1.89E+01
Th-232	760	1.49E+02	4.42E+00
U-232	100	1.08E+05	3.20E+03
U-233	1000	3.16E+04	9.39E+02
U-234	1000	1.29E+05	3.83E+03
U-235	1000	1.71E+04	5.09E+02
U-236	1000	9.44E+08	2.81E+07
U-238	1000	3.30E+04	9.80E+02
Zr-93	760	---	---

Table 10. Intruder-Based Radionuclide Disposal Limits for Slit Trenches – Post-Drilling Scenario with Transient Calculation for 1000 Years

Radionuclide	Time of Limit (Years)	Concentration Limit ($\mu Ci/m^3$)	Inventory Limit (Ci/Unit)
Ag-108m	100	7.85E+04	2.33E+03
Al-26	100	5.42E+04	1.61E+03
Am-241	100	4.73E+04	1.40E+03
Am-242m	100	4.70E+04	1.40E+03
Am-243	100	3.88E+04	1.15E+03
Ba-133	100	2.74E+08	8.16E+06
Bi-207	100	8.72E+05	2.59E+04
Bk-249	100	1.66E+07	4.93E+05
C-14	100	6.72E+04	2.00E+03
Cd-113m	100	1.01E+06	3.00E+04
Cf-249	100	4.28E+04	1.27E+03
Cf-250	100	8.80E+06	2.61E+05
Cf-251	100	3.95E+04	1.17E+03
Cf-252	100	1.81E+09	5.39E+07
Cl-36	100	8.54E+02	2.54E+01
Cm-242	100	2.37E+07	7.06E+05
Cm-243	100	7.33E+05	2.18E+04
Cm-244	100	3.38E+06	1.01E+05
Cm-245	1000	2.60E+04	7.72E+02
Cm-246	100	4.98E+04	1.48E+03
Cm-247	1000	4.28E+04	1.27E+03
Cm-248	100	1.34E+04	3.97E+02
Co-60	100	2.81E+10	8.37E+08
Cs-135	100	8.26E+05	2.46E+04
Cs-137	100	8.12E+05	2.41E+04
Eu-152	100	2.19E+07	6.51E+05
Eu-154	100	3.76E+08	1.12E+07
Eu-155	100	7.79E+12	2.32E+11
H-3	100	7.00E+07	2.08E+06
I-129	100	1.29E+04	3.82E+02
K-40	100	1.73E+04	5.16E+02
Kr-85	100	3.81E+10	1.13E+09
Mo-93	100	1.61E+07	4.78E+05
Na-22	100	2.03E+16	6.03E+14
Nb-93m	100	4.24E+09	1.26E+08
Nb-94	100	9.28E+04	2.76E+03
Ni-59	100	1.41E+07	4.20E+05
Ni-63	100	1.03E+07	3.05E+05
Np-237	100	3.69E+03	1.10E+02
Pb-210	100	7.21E+04	2.14E+03
Pd-107	100	2.96E+07	8.81E+05
Pu-238	100	1.21E+05	3.61E+03
Pu-239	100	4.99E+04	1.48E+03
Pu-240	100	5.03E+04	1.50E+03

Table 10. Intruder-Based Radionuclide Disposal Limits for Slit Trenches – Post-Drilling Scenario with Transient Calculation for 1000 Years

Radionuclide	Time of Limit (Years)	Concentration Limit ($\mu Ci/m^3$)	Inventory Limit (Ci/Unit)
Pu-241	100	1.39E+06	4.13E+04
Pu-242	100	5.25E+04	1.56E+03
Pu-244	1000	4.31E+04	1.28E+03
Ra-226	130	2.42E+03	7.20E+01
Ra-228	100	8.38E+08	2.49E+07
Rb-87	100	5.18E+05	1.54E+04
Sb-125	100	2.50E+16	7.44E+14
Se-79	100	8.01E+05	2.38E+04
Sm-151	100	2.02E+08	6.00E+06
Sn-121m	100	3.98E+07	1.18E+06
Sn-126	100	7.03E+04	2.09E+03
Sr-90	100	5.63E+04	1.67E+03
Tc-99	100	8.26E+04	2.45E+03
Th-228	100	---	3.46E+18
Th-229	100	1.70E+04	5.05E+02
Th-230	1000	6.49E+03	1.93E+02
Th-232	180	5.03E+03	1.49E+02
U-232	100	3.19E+04	9.47E+02
U-233	1000	7.47E+04	2.22E+03
U-234	1000	1.16E+05	3.44E+03
U-235	1000	7.50E+04	2.23E+03
U-236	100	1.33E+05	3.96E+03
U-238	1000	1.36E+05	4.03E+03
Zr-93	250	3.22E+07	9.56E+05

Table 11. Intruder-Based Radionuclide Disposal Limits for Engineered Trenches – Resident Scenario with Transient Calculation for 1000 Years

Radionuclide	Time of Limit (Years)	Concentration Limit ($\mu Ci/m^3$)	Inventory Limit (Ci/Unit)
Ag-108m	760	8.35E+02	3.90E+01
Al-26	760	8.47E+01	3.95E+00
Am-241	760	1.34E+07	6.26E+05
Am-242m	760	3.51E+06	1.64E+05
Am-243	760	8.46E+03	3.95E+02
Ba-133	100	9.18E+10	4.28E+09
Bi-207	100	2.35E+06	1.10E+05
Bk-249	760	3.07E+06	1.43E+05
C-14	---	---	---
Cd-113m	---	---	---
Cf-249	760	7.94E+03	3.70E+02
Cf-250	1000	8.17E+14	3.81E+13
Cf-251	760	2.96E+04	1.38E+03
Cf-252	1000	1.62E+13	7.57E+11
Cl-36	---	---	---
Cm-242	1000	5.73E+10	2.67E+09
Cm-243	760	8.77E+08	4.09E+07
Cm-244	760	9.43E+12	4.40E+11
Cm-245	760	5.09E+04	2.37E+03
Cm-246	1000	2.24E+12	1.04E+11
Cm-247	1000	1.70E+03	7.94E+01
Cm-248	1000	1.19E+08	5.55E+06
Co-60	100	4.38E+10	2.04E+09
Cs-135	---	---	---
Cs-137	100	4.56E+07	2.13E+06
Eu-152	100	4.89E+07	2.28E+06
Eu-154	100	8.76E+08	4.09E+07
Eu-155	100	8.50E+19	3.97E+18
H-3	---	---	---
I-129	760	1.59E+11	7.41E+09
K-40	760	1.45E+03	6.75E+01
Kr-85	100	2.08E+12	9.70E+10
Mo-93	760	---	---
Na-22	100	5.94E+16	2.77E+15
Nb-93m	760	---	---
Nb-94	760	2.08E+02	9.70E+00
Ni-59	---	---	---
Ni-63	---	---	---
Np-237	1000	3.61E+03	1.68E+02
Pb-210	100	3.00E+12	1.40E+11
Pd-107	---	---	---
Pu-238	1000	2.91E+08	1.36E+07
Pu-239	760	8.19E+07	3.82E+06
Pu-240	760	2.61E+10	1.22E+09

Table 11. Intruder-Based Radionuclide Disposal Limits for Engineered Trenches – Resident Scenario with Transient Calculation for 1000 Years

Radionuclide	Time of Limit (Years)	Concentration Limit ($\mu Ci/m^3$)	Inventory Limit (Ci/Unit)
Pu-241	760	4.02E+08	1.88E+07
Pu-242	1000	1.50E+10	7.01E+08
Pu-244	760	9.49E+02	4.43E+01
Ra-226	760	1.97E+02	9.20E+00
Ra-228	100	2.83E+09	1.32E+08
Rb-87	---	---	---
Sb-125	100	1.07E+18	5.01E+16
Se-79	---	---	---
Sm-151	760	---	---
Sn-121m	---	---	---
Sn-126	760	1.88E+02	8.78E+00
Sr-90	---	---	---
Tc-99	760	2.26E+10	1.05E+09
Th-228	100	---	6.69E+18
Th-229	760	1.95E+03	9.08E+01
Th-230	1000	4.06E+02	1.89E+01
Th-232	760	9.48E+01	4.42E+00
U-232	100	6.85E+04	3.20E+03
U-233	1000	2.01E+04	9.39E+02
U-234	1000	8.21E+04	3.83E+03
U-235	1000	1.09E+04	5.09E+02
U-236	1000	6.01E+08	2.81E+07
U-238	1000	2.10E+04	9.80E+02
Zr-93	760	---	---

Table 12. Intruder-Based Radionuclide Disposal Limits for Engineered Trenches – Post-Drilling Scenario with Transient Calculation for 1000 Years

Radionuclide	Time of Limit (Years)	Concentration Limit ($\mu Ci/m^3$)	Inventory Limit (Ci/Unit)
Ag-108m	100	7.85E+04	3.66E+03
Al-26	100	5.42E+04	2.53E+03
Am-241	100	4.73E+04	2.21E+03
Am-242m	100	4.70E+04	2.19E+03
Am-243	100	3.88E+04	1.81E+03
Ba-133	100	2.74E+08	1.28E+07
Bi-207	100	8.72E+05	4.07E+04
Bk-249	100	1.66E+07	7.73E+05
C-14	100	6.72E+04	3.14E+03
Cd-113m	100	1.01E+06	4.70E+04
Cf-249	100	4.28E+04	2.00E+03
Cf-250	100	8.80E+06	4.11E+05
Cf-251	100	3.95E+04	1.84E+03
Cf-252	100	1.81E+09	8.46E+07
Cl-36	100	8.54E+02	3.98E+01
Cm-242	100	2.37E+07	1.11E+06
Cm-243	100	7.33E+05	3.42E+04
Cm-244	100	3.38E+06	1.58E+05
Cm-245	1000	2.60E+04	1.21E+03
Cm-246	100	4.98E+04	2.32E+03
Cm-247	1000	4.28E+04	2.00E+03
Cm-248	100	1.34E+04	6.23E+02
Co-60	100	2.81E+10	1.31E+09
Cs-135	100	8.26E+05	3.86E+04
Cs-137	100	8.12E+05	3.79E+04
Eu-152	100	2.19E+07	1.02E+06
Eu-154	100	3.76E+08	1.75E+07
Eu-155	100	7.79E+12	3.64E+11
H-3	100	7.00E+07	3.26E+06
I-129	100	1.29E+04	6.00E+02
K-40	100	1.73E+04	8.09E+02
Kr-85	100	3.81E+10	1.78E+09
Mo-93	100	1.61E+07	7.50E+05
Na-22	100	2.03E+16	9.47E+14
Nb-93m	100	4.24E+09	1.98E+08
Nb-94	100	9.28E+04	4.33E+03
Ni-59	100	1.41E+07	6.60E+05
Ni-63	100	1.03E+07	4.80E+05
Np-237	100	3.69E+03	1.72E+02
Pb-210	100	7.21E+04	3.37E+03
Pd-107	100	2.96E+07	1.38E+06
Pu-238	100	1.21E+05	5.66E+03
Pu-239	100	4.99E+04	2.33E+03
Pu-240	100	5.03E+04	2.35E+03

Table 12. Intruder-Based Radionuclide Disposal Limits for Engineered Trenches – Post-Drilling Scenario with Transient Calculation for 1000 Years

Radionuclide	Time of Limit (Years)	Concentration Limit ($\mu Ci/m^3$)	Inventory Limit (Ci/Unit)
Pu-241	100	1.39E+06	6.48E+04
Pu-242	100	5.25E+04	2.45E+03
Pu-244	1000	4.31E+04	2.01E+03
Ra-226	130	2.42E+03	1.13E+02
Ra-228	100	8.38E+08	3.91E+07
Rb-87	100	5.18E+05	2.42E+04
Sb-125	100	2.50E+16	1.17E+15
Se-79	100	8.01E+05	3.74E+04
Sm-151	100	2.02E+08	9.43E+06
Sn-121m	100	3.98E+07	1.86E+06
Sn-126	100	7.03E+04	3.28E+03
Sr-90	100	5.63E+04	2.62E+03
Tc-99	100	8.26E+04	3.85E+03
Th-228	100	---	5.43E+18
Th-229	100	1.70E+04	7.92E+02
Th-230	1000	6.49E+03	3.03E+02
Th-232	180	5.03E+03	2.35E+02
U-232	100	3.19E+04	1.49E+03
U-233	1000	7.47E+04	3.49E+03
U-234	1000	1.16E+05	5.40E+03
U-235	1000	7.50E+04	3.50E+03
U-236	100	1.33E+05	6.21E+03
U-238	1000	1.36E+05	6.33E+03
Zr-93	250	3.22E+07	1.50E+06

5 RADON ANALYSIS

The scope of the investigation for this report involved defining a decay chain of parent radioisotopes to evaluate with a 1D vertical numerical model. The model was customized to represent the thickness of the waste zones and cover material over the facilities. The instantaneous Radon-222 flux at the land surface was evaluated at the Performance Assessment compliance period of 1000 years. This flux was then compared to the standard identified of 20 pCi/m2-s of Rn-222 in 40 CFR Part 61 to develop the inventory limits. Disposal limits for each of the precursor parent isotopes of Rn-222 were calculated for the disposal units identified in Table 5, based on the peak flux encountered in the 1000-year performance period. These limits are listed in Table 13. Additional details of the radon analysis are provided in Appendix A.

Table 13. 1000-Year Trench Unit Disposal Limits for SA scenarios, non-compaction case.

Parent Isotope	Limit for 5 Trenches, each 656 ft x 20 ft (Ci/disposal unit)	Limit for 3 Trenches, each 656 ft x 40 ft (Ci/disposal unit)	Limit for 1 Trench 656 ft x 157 ft (Ci/disposal unit)
Pu-238	4.60E+06	5.52E+06	6.62E+06
U-238	1.21E+06	1.45E+06	1.74E+06
U-234	1.33E+03	1.60E+03	1.92E+03
Th-230	7.47E+00	8.96E+00	1.08E+01
Ra-226	2.84E-00	3.40E-00	4.09E-00

6 AIR ANALYSIS

Air analysis results are based on the report for the Cement-Stabilized-Encapsulated Waste (CSEW also referred to as Components-in-Grout) trenches[12]. The only difference between the CSEW trenches and the Slit Trenches is the assumption that the outer foot of waste was replaced by grout, although no special credit was taken for the grout. Because the size of the CSEW trenches is assumed to match the size of Slit Trenches, and no special credit was taken for the grout, the air analyses for each type of disposal unit are identical.

The CSEW Trench report examined two cases. The first case is for the first 125 years from the start of operations through the end of institutional control where the public can receive a dose at the SRS site boundary. The second case is at 125 years when a member of the public could be located 100 m from the waste. Dose factor results for the air analyses are presented in Table 14 that replaces the Slit Trench portion of Table 4.2.2 in the PA. Doses for a unit release are presented in Table 15 that replaces the Slit Trench portion of Table 4.3-2 in the PA. Results for the radon pathway were removed from the tables because more nuclides than U-234 were analyzed, so results are presented in separate tables. Inventory limits for the air pathway are presented in
Table 16 that replaces the Slit Trench portion of Table 5.2-1 in the PA.

Table 14. Dose Factors for the Air Pathway

Disposal Unit	Radionuclide	100 m Location (mrem/Ci Released)	Site Boundary Location (mrem/Ci Released)
All Slit Trenches and Engineered Trenches			
	^{3}H	3.0E-03	2.4E-05
	^{14}C	1.4E-01	1.2E-03

Table 15. Doses for a unit release for the air pathway

Disposal Unit	Radionuclide	Dose for Unit Release (mrem/Ci) 100 meters	SRS Boundary
All Slit Trenches and Engineered Trenches			
	^{3}H (oxide)	3.0E-03	2.4E-05
	^{14}C	1.4E-01	1.2E-03

Table 16. Inventory limits for the air pathway

	Inventory Limit Based on Location 100 m from Waste after 100 Year Institution Control Period (Ci/disposal unit)	Inventory Limit Based on Location at SRS Boundary before 100 year Institution Control Period (Ci/disposal unit)	Inventory Limit Based on Air Pathway (Ci/disposal unit)
H-3			
1 Set of Slit Trenches	9.0E+05	4.1E+05	4.1E+05
1 Engineered Trench	9.0E+05	4.1E+05	4.1E+05
C-14			
1 Set of Slit Trenches	7.0E+01	8.7E+03	7.0E+01
1 Engineered Trench	7.0E+01	8.7E+03	7.0E+01

7 SUPERCEDING PREVIOUS UNREVIEWED DISPOSAL QUESTION EVALUATIONS (UDQ-E'S) AND SPECIAL ANALYSES

UDQ-E's either recommend that Special Analyses be performed or explain why the current Performance Assessment and Special Analyses bound the condition, new information, or new waste form, thus allowing the existing inventory limits to apply. Special Analyses provide the vehicle to establish new inventory limits. For purposes of this report, UDQ-E's and Special Analyses will be referred to as Limit Reports.

The current report can supercede, partially supercede or not change previous Limit Reports. The current report supercedes a previous Limit Report only if that report applies strictly to Slit Trenches and/or Engineered Trenches. Furthermore the analyses in the current report must examine, as a minimum, all the topics addressed in the Limit Report. The current report typically only partially supercedes a previous Limit Report when that Limit Report includes other disposal units.

Table 17 lists the previous Limit Reports that dealt with Slit/Engineered Trench operations. Those reports which have been partially or fully superceded, along with any operational restrictions that must remain in force, are identified.

Table 17. Superceding previous UDQ-E's and Special Analyses

Topic	Superceded	Discussion	UDQ-E / SA/SS	Reference
GENERAL				
PA	Partial	Only for disposal units in current report	PA	5
Interim Measures –2003	Partial	Included applicable analyses recommended in previous report	UDQ-E	13,14
Timed Sum-of-Fractions	Partial	Applied same methods, but previous report included other disposal units	SA	1,2
First Engineered Trench	Yes	Applied limits from Slit Trenches, but did not explicitly analyze	UDQ-E	15,16 mega
Time of Compliance	No	Referenced	SS	17
New Trench Locations	No	Separate flow analysis not performed in this report for all trench locations even though flow model changed.	UDQ-E	18,19
Job Control Waste, etc.	Yes	Current model applied to multiple waste types	UDQ-E	20
Program to manage trench models	No	Referenced	SS	21
GEOMETRY				
Size of LAW Vault Footprint	Yes	Selected recommended size from previous report	UDQ-E	10
Shallow Trenches	No	Groundwater analysis did not confirm conclusions in UDQ-E. See sensitivity/uncertainty section.	UDQ-E	22
Trench As-Built Anomalies	Yes	Prior operational restriction remains in effect: That portion of Slit Trench #1 currently unavailable for use (blocked by lay down yard) must be made available for use prior to closure and considered an integral part of this disposal unit. With this provision, additional waste may be disposed of in this area of Slit Trench #1 as long as the SOFs remains below 1.0.	UDQ-E	23
Short/long or Narrow/Wide Trenches	No	Groundwater analysis did not confirm conclusions in UDQ-E. See sensitivity/uncertainty section. Reduction in managed sum-of-fractions was included.	UDQ-E	24,25 slit width
Aquifer Source Node Location	Yes	New selection made	SS	26
Dynamic Compaction	Referenced	Some effects explicitly modeled	SS	8
Subsidence	Referenced	Some effects explicitly modeled		27
Large Components	No	Groundwater analysis did not confirm conclusions in UDQ-E. See sensitivity/uncertainty section.		28
NO LEACHING				
331-M Standards	Yes	Required no leaching thus matches this report	UDQ-E	29
Beneficial Reuse Containers	Partial	Required no leaching thus matches this report. Previous report includes other disposal	UDQ-E	30

Topic	Superceded	Discussion	UDQ-E / SA/SS	Reference
		units.		
Cesium Source	Yes	Required no leaching thus matches this report	UDQ-E	31
Paducah Cask	Yes	Required no leaching and applied newer Kd for U that both match this report	UDQ-E	32
Paducah Cask	Yes	Required no leaching and newer Kd for U that both match this report. Prior operational restriction remains in effect: No concrete or cellulose-containing waste materials should be placed within 20 feet of the cask within the same trench.	SA	33
LLW Sources	Yes	Required no leaching and newer Kd for U that both match this report		34
No Dose/Low Dose Scrap	Yes	Required no leaching and newer Kd for U that both match this report		35
HIGH Kd				
High-Concentration I-129 Waste Forms	Yes	Required waste-specific Kd that matches this report	SA	36
SPECIAL RELEASE				
ETF-Carbon I-129 and H-3	Yes	Required waste-specific Kd for I-129 and 25-year delayed release for welding. Both aspects match this report. Prior operational restriction remains in effect: Dynamic compaction is prohibited before the end of the 25-year operational period.	UDQ-E	37
ETF-Carbon I-129 and H-3	Yes	See UDQ-E discussion	SA	38
M-Area Glass	Yes	Required special release rate and special agriculture scenario treatment. Special release rate matches this report (with update to zero Kd in waste zone). Special agriculture scenario matches this report, because there is no agriculture scenario.	UDQ-E	39
M-Area Glass	Yes	See UDQ-E discussion. Prior operational restriction remains in effect: No concrete or cellulose-containing waste materials should be disposed in the vicinity of M-Area Glass.	SA	40
M-Area Glass Sequel	Yes	See UDQ-E discussion	UDQ-E	41
SPECIATION				
Pu New Chemistry	Yes	Applied same methods, but used more recent transformation rates treated colloids differently. Extended analysis to include ancestors that produce Pu	UDQ-E	42
Pu New Chemistry	Yes	See UDQ-E discussion	SA	43
WOOD PRODUCTS				
	Yes	Effects of dissolved organic carbon modeled explicitly	SS,SA	44,45

Topic	Superceded	Discussion	UDQ-E / SA/SS	Reference
INFILTRATION				
	No	Referenced		4
MISCELLANEOUS				
Area-wide Air Analysis	Yes	Slit Trenches and Engineered Trenches match size of CIG trenches	SA	12
Correction and Update	Partial	Previous report included other disposal units	UDQ-E SA UDQ-E	46,47,48
Lead	No	Referenced	SA	49
Uncertainty	No	Model changes mean previous uncertainty results likely no longer apply	SS	50
Uncontaminated lifting bail	No	Referenced	UDQ-E	56
PCB Waste with unanalyzed radionuclides	Yes	Current report includes the unanalyzed radionuclides	UDQ-E	57

8 SENSITIVITY/UNCERTAINTY

Three sensitivity/uncertainty cases were analyzed for the groundwater pathway. The first case was to verify the UDQ-E for shallow trenches. The second case was to verify the UDQ-E for shorter trenches. The third case was to determine the potential effect of varying the operational duration.

For the first case of a shallow trench, Cl-36 was selected as a surrogate for a conservative species. Cl-36 is fully mobile with a Kd of 0 ml/g[53]. It has a halflife of 3.010E+05 years, which given its early peak essentially generates no decay. The entire inventory of 1 Ci was placed in the uppermost row of waste cells that extended from 40.5 ft to 41.0 ft above the water table.

For the second case of a shorter trench, Cl-36 was selected as a surrogate for a conservative species. The entire inventory of 1 Ci was placed in a center column of waste cells that had a width of 1 ft. This model actually analyzes a narrower trench, but its results should be applicable to a shorter trench because a two-dimensional vadose analysis was conducted.

For the third case, varying the duration of the operational period could affect the well concentrations for highly mobile species. Placing an interim cap over the disposal unit greatly reduces the amount of infiltration water available to transport highly mobile contaminants. For contaminants that achieve early peak well concentrations slightly after cap placement, delaying cap placement could allow the peak well concentrations to more fully develop at higher levels. On the other hand, early cap placement could reduce the peak well concentrations. I-129 was selected for this sensitivity case, because its peak in the PA occurred slightly after the end of the operational period.

Results from the sensitivity/uncertainty simulations are presented in Table 18. Peak fluxes and times are presented for the base case and for the sensitivity/uncertainty cases. Both the shallow and narrow trenches show higher peak fluxes than for the standard case. Special waste forms with Kds that are higher than the surrounding sediments may produce different results.

The UDQ-E for shallower trenches[22] stated the following:

> "The shallow trench segments will impact the groundwater pathway by increasing the distance between the bottom of the waste layer and the top of the water table by 5 feet. This greater distance will increase the travel time for radionuclides in the waste, and thus the time for radioactive decay. If all other factors remain the same, the shallower trenches will result in lower concentrations and doses at the compliance well 100 meters from the edge of the waste."

Modeling results may be higher because the waste is more concentrated.

The UDQ-E for shorter trenches[24] referred to the proposed set of Slit Trenches to occupy the LAW Vault 10 footprint. That UDQ-E stated the following:

> "For the proposed set of slit trenches, the available disposal volume will be 948,416 ft^3. This is 90.4% of the disposal capacity assumed in the PA.
>
> If the radionuclide inventory limits developed in the PA (Table 7.1-3[3]) were to be applied to the proposed set of slit trenches, the average radionuclide concentration of the trenches would be 11% greater than that analyzed in the PA. Even though parameters, such as disposal unit dimensions, used in the PA are considered nominal (i.e., having an acceptable tolerance of about 10%), since this is a new set of slit trenches, they should be managed so that no more than 90% of the PA-derived radionuclide inventory limits may be disposed (i.e., the sum-of-fractions of the individual radionuclide limits is managed to be no more than 0.9 rather than 1.0)."

While this case was not directly modeled, adjustments were made in the UDQ-E and in this SA to the sum-of-fractions to account for the reduction in disposal capacity.

The standard I-129 actually peaks before the end of the 25-year operations, hence waiting for 30 years to place an interim cap should have no effect. However, placing an interim cap much earlier could decrease the peak fluxes.

I-129 was selected for the sensitivity/uncertainty study, because in previous analyses it typically contributed significantly to the sum-of-fractions and its peak concentration appeared to be sensitive to the selection of the duration of operations. For Slit Trenches in the PA, I-129 had a peak flux at the water table at 22.4 years and a peak well concentration at 29 years. However, in the current analysis, the peak flux occurs much earlier.

Selection of a 25-year period of operations versus say 20 years or 30 years could have an impact on isotopes that attain peak fluxes during that time interval. A better candidate would have been Th-228 with a peak flux at 25 years, but if it does not contribute significantly to the sum-of-fractions, then changing its limit of 1E20 Ci would not impact operations.

Table 18. Peak fluxes for sensitivity/uncertainty cases

Description	Flux (fraction)	Time (yr)
Cl-36 standard	0.274	6
Cl-36 shallow	0.299	6
Cl-36 narrow	0.294	5
I-129 standard	0.092	17
I-129 30-year operations	0.092	17

9 RESULTS

The full list of limits for all pathways/scenarios is presented in Table 19 along with comparisons to the inventory in the first set of Slit Trenches as of April 5, 2004. The full descriptions of the abbreviated titles in Table 19 are as follows:

Res: Resident scenario
PD: Post-drilling scenario
GW1: Groundwater pathway during the first time interval from 0 to 12 years
GW2: Groundwater pathway during the second time interval from 12+ to 100 years
GW3: Groundwater pathway during the third time interval from 100+ to 1000 years.
Inv: Actual inventory for Slit Trenches set 1 on 4/5/04

In Table 19 only H-3 has a fraction (0.42) that exceeds 0.1.

Application of the limits provided in Table 19 can be simplified by applying the assumption in the screening analysis[6] that the inventory for any specific isotope in a specific disposal unit cannot exceed 1E7 Ci. A partial sum-of-fractions for multiple isotopes of less than about 0.0001 (0.01%) is insignificant. Assuming about 100 isotopes that could have insignificant fractions, the fraction for each isotope should not exceed 1E-6 (0.0001 / 100). For a maximum inventory of 1E7 and a maximum fraction of 1E-6, the minimum limit would be 1E13 (1E7 / 1E-6). Therefore, limits of at least 1E13 can be considered as "No Limit" cases.

The list of isotopes for which inventories are maintained and fractions are calculated can further be reduced if the worst case is accepted and the fraction for the worst case is entered as a constant (or alternatively by reducing the maximum sum-of-fraction). For example, if Solid Waste is willing to accept a 0.001 fraction as the worst case for a set of relatively insignificant isotopes, then it would only have to track other isotopes with limits less than 1E12 (based again on 100 isotopes filling the class of relatively insignificant isotopes, but the smaller the list of isotopes, the larger the minimum limit can be).

Table 19. Comparison of limits to inventory of Slit Trench 1by pathway/scenario

	Inventory Limits (Ci)								Fractions						
Nuclide	**Res**	**PD**	**Air**	**Radon**	**GW1**	**GW2**	**GW3**	**Inv**	**Res**	**PD**	**Air**	**Radon**	**GW1**	**GW2**	**GW3**
Ag-108m	3.9E+01	2.3E+03													
Al-26	4.0E+00	1.6E+03			7.8E+03	3.5E+01	4.7E+00								
Am-241	6.3E+05	1.4E+03			8.2E+13	1.8E+05	8.9E+01	3.7E-02	5.9E-08	2.7E-05			4.5E-16	2.1E-07	4.2E-04
Am-242m	1.6E+05	1.4E+03						7.4E-03	4.6E-08	5.3E-06					
Am-243	4.0E+02	1.2E+03			1.3E+06	1.4E+05	5.4E+02	6.1E-05	1.5E-07	5.1E-08			4.7E-11	4.4E-10	1.1E-07
Ba-133	4.3E+09	8.2E+06													
Bi-207	1.1E+05	2.6E+04													
Bi-210					1.0E+20	1.0E+20	1.0E+20	1.9E-04					1.9E-24	1.9E-24	1.9E-24
Bk-249	1.4E+05	4.9E+05			2.4E+10	2.8E+08	2.5E+05								
C-14	1.0E+20	2.0E+03	7.0E+01		2.9E+08	4.5E+01	4.7E+00	6.1E-02	6.1E-22	3.1E-05	8.7E-04		2.1E-10	1.4E-03	1.3E-02
Cd-113m	1.0E+20	3.0E+04													
Cf-249	3.7E+02	1.3E+03			6.0E+07	7.0E+05	6.3E+02	6.7E-06	1.8E-08	5.1E-09			1.1E-13	9.5E-12	1.1E-08
Cf-250	3.8E+13	2.6E+05			1.0E+20	1.0E+20	8.7E+07								
Cf-251	1.4E+03	1.2E+03						6.6E-05	4.7E-08	5.5E-08					
Cf-252	7.6E+11	5.4E+07			5.8E+14	6.5E+13	7.4E+09	1.4E-06	1.9E-18	2.6E-14			2.5E-21	2.2E-20	1.9E-16
Cl-36	1.0E+20	2.5E+01			4.7E-02	2.3E-01	1.6E+01								
Cm-242	2.7E+09	7.1E+05			8.7E+04	9.6E+04	1.9E+05	6.1E-05	2.2E-14	8.5E-11			7.0E-10	6.3E-10	3.2E-10
Cm-243	4.1E+07	2.2E+04						6.9E-06	1.7E-13	3.1E-10					
Cm-244	4.4E+11	1.0E+05			1.5E+05	1.5E+05	1.5E+05	3.8E-02	8.7E-14	3.8E-07			2.6E-07	2.6E-07	2.6E-07
Cm-245	2.4E+03	7.7E+02			2.6E+04	2.7E+03	2.7E+02	2.7E-07	1.1E-10	3.6E-10			1.1E-11	1.0E-10	1.0E-09
Cm-246	1.0E+11	1.5E+03			1.0E+20	1.0E+20	2.4E+05	1.5E-06	1.5E-17	1.0E-09			1.5E-26	1.5E-26	6.4E-12
Cm-247	7.9E+01	1.3E+03			2.5E+09	3.0E+07	8.2E+03	1.4E-06	1.8E-08	1.1E-09			5.7E-16	4.8E-14	1.7E-10
Cm-248	5.6E+06	4.0E+02			4.5E+09	5.0E+08	5.8E+04	1.4E-06	2.6E-13	3.6E-09			3.2E-16	2.9E-15	2.5E-11
Co-60	2.0E+09	8.4E+08						4.7E+00	2.3E-09	5.6E-09					
Cs-135	1.0E+20	2.5E+04			1.0E+20	1.3E+12	5.3E+00	7.1E-08	7.1E-28	2.8E-12			7.1E-28	5.5E-20	1.3E-08
Cs-137	2.1E+06	2.4E+04						7.1E+00	3.4E-06	3.0E-04					
Eu-152	2.3E+06	6.5E+05						3.0E-04	1.3E-10	4.6E-10					

	Inventory Limits (Ci)								Fractions						
Nuclide	**Res**	**PD**	**Air**	**Radon**	**GW1**	**GW2**	**GW3**	**Inv**	**Res**	**PD**	**Air**	**Radon**	**GW1**	**GW2**	**GW3**
Eu-154	4.1E+07	1.1E+07						1.0E-03	2.4E-11	9.1E-11					
Eu-155	4.0E+18	2.3E+11						2.0E-05	5.1E-24	8.9E-17					
H-3	1.0E+20	2.1E+06	4.1E+05		2.0E+00	1.3E+01	1.2E+05	8.5E-01	8.5E-21	4.0E-07	2.1E-06		4.2E-01	6.5E-02	7.1E-06
H-3_ETF-Carbon	1.0E+20	2.1E+06	4.1E+05		1.0E+20	4.6E+04	2.9E+03								
I-129	7.4E+09	3.8E+02			1.9E-02	2.8E-04	9.2E-03	2.0E-05	2.7E-15	5.2E-08			1.0E-03	7.1E-02	2.2E-03
I-129_10	7.4E+09	3.8E+02			6.4E-01	9.2E-04	2.5E-03								
I-129_ETF-Carbon	7.4E+09	3.8E+02			1.0E+20	4.9E+08	9.0E-02								
I-129_ETF-GT-73	7.4E+09	3.8E+02			6.2E+02	9.0E-01	1.2E-01								
I-129_F-Carbon	7.4E+09	3.8E+02			8.3E+03	1.2E+01	1.6E+00								
I-129_F-CG-8	7.4E+09	3.8E+02			3.1E+00	4.5E-03	2.8E-03								
I-129_F-Dowex-21K	7.4E+09	3.8E+02			4.2E+02	6.1E-01	8.3E-02								
I-129_F-Filtercake	7.4E+09	3.8E+02			3.5E+00	5.1E-03	2.7E-03	8.1E-05	1.1E-14	2.1E-07			2.3E-05	1.6E-02	3.0E-02
I-129_H-Carbon	7.4E+09	3.8E+02			3.6E+03	5.2E+00	7.0E-01								
I-129_H-CG-8	7.4E+09	3.8E+02			2.4E+01	3.4E-02	6.8E-03								
I-129_H-Dowex-21K	7.4E+09	3.8E+02			9.7E+02	1.4E+00	1.9E-01								
I-129_H-Filtercake	7.4E+09	3.8E+02			4.1E+01	5.8E-02	9.2E-03	2.8E-07	3.7E-17	7.3E-10			6.8E-09	4.8E-06	3.0E-05
K-40	6.8E+01	5.2E+02			7.4E+09	8.3E+01	8.1E-01	4.3E-03	6.3E-05	8.2E-06			5.8E-13	5.2E-05	5.3E-03
Kr-85	9.7E+10	1.1E+09						7.8E-05	8.0E-16	7.1E-14					
Mo-93	1.0E+20	4.8E+05			3.8E+11	2.3E+03	9.7E+00	1.2E-05	1.1E-25	2.4E-11			3.0E-17	5.0E-09	1.2E-06
Na-22	2.8E+15	6.0E+14						7.9E-07	2.8E-22	1.3E-21					
Nb-93m	1.0E+20	1.3E+08						7.4E-02	7.4E-22	5.7E-10					
Nb-94	9.7E+00	2.8E+03			1.0E+20	1.0E+20	1.2E+12	1.1E-03	1.1E-04	3.9E-07			1.1E-23	1.1E-23	9.0E-16
Nb-95m					1.0E+20	1.0E+20	1.0E+20								
Ni-59	1.0E+20	4.2E+05			1.0E+20	1.0E+20	1.9E+03	2.2E-02	2.2E-22	5.3E-08			2.2E-22	2.2E-22	1.2E-05
Ni-63	1.0E+20	3.0E+05						1.6E+00	1.6E-20	5.3E-06					
Np-237	1.7E+02	1.1E+02			1.7E+10	3.7E+01	1.8E-02	1.1E-03	6.5E-06	1.0E-05			6.5E-14	3.0E-05	6.1E-02
Pb-210	1.4E+11	2.1E+03						1.9E-04	1.4E-15	9.2E-08					
Pd-107	1.0E+20	8.8E+05			1.0E+20	8.4E+18	6.3E+02	1.1E-07	1.1E-27	1.2E-13			1.1E-27	1.3E-26	1.7E-10
Pu-238	1.4E+07	3.6E+03		4.6E+06	4.4E+02	4.9E+02	9.8E+02	2.4E-01	1.7E-08	6.7E-05		5.2E-08	5.5E-04	4.9E-04	2.4E-04

	Inventory Limits (Ci)								Fractions						
Nuclide	**Res**	**PD**	**Air**	**Radon**	**GW1**	**GW2**	**GW3**	**Inv**	**Res**	**PD**	**Air**	**Radon**	**GW1**	**GW2**	**GW3**
Pu-239	3.8E+06	1.5E+03			4.0E+02	4.0E+02	4.0E+02	2.5E-02	6.5E-09	1.7E-05			6.2E-05	6.2E-05	6.2E-05
Pu-240	1.2E+09	1.5E+03			4.0E+02	4.0E+02	4.1E+02	6.8E-03	5.7E-12	4.5E-06			1.7E-05	1.7E-05	1.7E-05
Pu-241	1.9E+07	4.1E+04			1.3E+04	1.2E+04	4.0E+03	2.1E-01	1.1E-08	5.2E-06			1.6E-05	1.8E-05	5.3E-05
Pu-242	7.0E+08	1.6E+03			4.1E+02	4.1E+02	4.1E+02	1.1E-04	1.6E-13	6.9E-08			2.7E-07	2.7E-07	2.7E-07
Pu-244	4.4E+01	1.3E+03			4.3E+02	4.3E+02	4.3E+02	2.3E-15	5.3E-17	1.8E-18			5.5E-18	5.5E-18	5.5E-18
Ra-226	9.2E+00	7.2E+01		2.8E+00	1.0E+20	1.0E+20	9.0E+01	3.4E-03	3.7E-04	4.7E-05		1.2E-03	3.4E-23	3.4E-23	3.7E-05
Ra-228	1.3E+08	2.5E+07						2.6E-03	2.0E-11	1.1E-10					
Rb-87	1.0E+20	1.5E+04			1.0E+20	1.2E+17	4.7E+00	8.6E-14	8.6E-34	5.7E-18			8.6E-34	7.2E-31	1.8E-14
Sb-125	5.0E+16	7.4E+14						4.6E-02	9.2E-19	6.2E-17					
Se-79	1.0E+20	2.4E+04			1.0E+20	1.0E+20	1.8E+02	2.0E-04	2.0E-24	8.3E-09			2.0E-24	2.0E-24	1.1E-06
Sm-151	1.0E+20	6.0E+06						1.3E-04	1.3E-24	2.2E-11					
Sn-121m	1.0E+20	1.2E+06													
Sn-126	8.8E+00	2.1E+03			1.0E+20	1.0E+20	3.9E+01	1.8E-04	2.1E-05	8.7E-08			1.8E-24	1.8E-24	4.7E-06
Sr-90	1.0E+20	1.7E+03			1.9E+13	1.9E+05	8.9E+02	3.2E+00	3.2E-20	1.9E-03			1.7E-13	1.7E-05	3.6E-03
Tc-99	1.0E+09	2.4E+03			6.9E-01	1.7E-01	4.8E+01	5.1E-03	5.1E-12	2.1E-06			7.3E-03	3.0E-02	1.1E-04
Th-228	6.7E+18	3.5E+18			1.0E+20	1.0E+20	1.0E+20	2.6E-03	3.9E-22	7.5E-22			2.6E-23	2.6E-23	2.6E-23
Th-229	9.1E+01	5.0E+02			1.0E+20	1.0E+20	9.5E+03								
Th-230	1.9E+01	1.9E+02		7.5E+00	1.0E+20	1.0E+20	1.9E+01	4.8E-04	2.5E-05	2.5E-06		6.4E-05	4.8E-24	4.8E-24	2.5E-05
Th-232	4.4E+00	1.5E+02			1.0E+20	1.0E+20	3.1E+03	2.6E-03	6.0E-04	1.8E-05			2.6E-23	2.6E-23	8.5E-07
U-232	3.2E+03	9.5E+02			1.0E+20	1.0E+20	3.2E+06	1.2E-06	3.7E-10	1.2E-09			1.2E-26	1.2E-26	3.7E-13
U-233	9.4E+02	2.2E+03			1.0E+20	1.0E+20	4.8E+03	6.2E-03	6.6E-06	2.8E-06			6.2E-23	6.2E-23	1.3E-06
U-234	3.8E+03	3.4E+03		1.3E+03	1.0E+20	1.0E+20	2.7E+03	7.7E-02	2.0E-05	2.3E-05		5.9E-05	7.7E-22	7.7E-22	2.9E-05
U-234_MGlass	3.8E+03	3.4E+03		1.3E+03	1.0E+20	1.0E+20	2.3E+06								
U-235	5.1E+02	2.2E+03			1.0E+20	1.0E+20	4.1E+02	6.1E-03	1.2E-05	2.8E-06			6.1E-23	6.1E-23	1.5E-05
U-235_MGlass	5.1E+02	2.2E+03			1.0E+20	1.0E+20	3.9E+05								
U-236	2.8E+07	4.0E+03			1.0E+20	1.0E+20	6.5E+03	3.3E-03	1.2E-10	8.2E-07			3.3E-23	3.3E-23	5.0E-07
U-236_MGlass	2.8E+07	4.0E+03			1.0E+20	1.0E+20	2.7E+06								
U-238	9.8E+02	4.0E+03		1.2E+06	1.0E+20	1.0E+20	4.6E+02	1.5E-01	1.5E-04	3.7E-05		1.2E-07	1.5E-21	1.5E-21	3.2E-04
U-238_MGlass	9.8E+02	4.0E+03		1.2E+06	1.0E+20	1.0E+20	2.9E+05								

	Inventory Limits (Ci)								Fractions						
Nuclide	**Res**	**PD**	**Air**	**Radon**	**GW1**	**GW2**	**GW3**	**Inv**	**Res**	**PD**	**Air**	**Radon**	**GW1**	**GW2**	**GW3**
Zr-93	1.0E+20	9.6E+05			1.0E+20	1.0E+20	3.6E+03	2.7E-05	2.7E-25	2.8E-11			2.7E-25	2.7E-25	7.5E-09
Zr-95					1.0E+20	1.0E+20	1.0E+20	4.5E-03					4.5E-23	4.5E-23	4.5E-23
Sum									1.4E-03	2.5E-03	8.8E-04	1.3E-03	4.3E-01	1.8E-01	1.2E-01

10 CONCLUSIONS

Inventory limits for Slit Trenches and Engineered Trenches were recalculated while imposing a multitude of changes. The most important changes both tended to increase limits, such as changing the time of compliance from 10,000 years to 1000 years and tended to decrease limits, such as modifying the aquifer source node selection. The net effect for the groundwater pathway reduced some limits for nuclides that dominate the sum-of-fractions. The set of inventory limits for Slit Trenches and Engineered Trenches is presented in Table 20. In that table all limits greater than 1E20 Ci are removed as fractions for those isotopes cannot contribute a significant amount to the sum-of-fractions, because the inventory for any single isotope cannot exceed 1E7 Ci based on an assumption in the screening analysis. Bi-210, Nb-95m and Zr-95 appear in Table 19, but do not appear in Table 20 because all their limits are 1E20 or greater.

Table 20. Inventory limits (Ci) for Slit Trenches and Engineered Trenches*

Nuclide	Res	PD	Air	Radon	GW1	GW2	GW3
Ag-108m	3.9E+01	2.3E+03					
Al-26	4.0E+00	1.6E+03			7.8E+03	3.5E+01	4.7E+00
Am-241	6.3E+05	1.4E+03			8.2E+13	1.8E+05	8.9E+01
Am-242m	1.6E+05	1.4E+03					
Am-243	4.0E+02	1.2E+03			1.3E+06	1.4E+05	5.4E+02
Ba-133	4.3E+09	8.2E+06					
Bi-207	1.1E+05	2.6E+04					
Bk-249	1.4E+05	4.9E+05			2.4E+10	2.8E+08	2.5E+05
C-14		2.0E+03	7.0E+01		2.9E+08	4.5E+01	4.7E+00
Cd-113m		3.0E+04					
Cf-249	3.7E+02	1.3E+03			6.0E+07	7.0E+05	6.3E+02
Cf-250	3.8E+13	2.6E+05					8.7E+07
Cf-251	1.4E+03	1.2E+03					
Cf-252	7.6E+11	5.4E+07			5.8E+14	6.5E+13	7.4E+09
Cl-36		2.5E+01			4.7E-02	2.3E-01	1.6E+01
Cm-242	2.7E+09	7.1E+05			8.7E+04	9.6E+04	1.9E+05
Cm-243	4.1E+07	2.2E+04					
Cm-244	4.4E+11	1.0E+05			1.5E+05	1.5E+05	1.5E+05
Cm-245	2.4E+03	7.7E+02			2.6E+04	2.7E+03	2.7E+02
Cm-246	1.0E+11	1.5E+03					2.4E+05
Cm-247	7.9E+01	1.3E+03			2.5E+09	3.0E+07	8.2E+03
Cm-248	5.6E+06	4.0E+02			4.5E+09	5.0E+08	5.8E+04
Co-60	2.0E+09	8.4E+08					
Cs-135		2.5E+04				1.3E+12	5.3E+00
Cs-137	2.1E+06	2.4E+04					
Eu-152	2.3E+06	6.5E+05					
Eu-154	4.1E+07	1.1E+07					
Eu-155	4.0E+18	2.3E+11					
H-3		2.1E+06	4.1E+05		2.0E+00	1.3E+01	1.2E+05
H-3_ETF-Carbon		2.1E+06	4.1E+05			4.6E+04	2.9E+03
I-129	7.4E+09	3.8E+02			1.9E-02	2.8E-04	9.2E-03
I-129_10	7.4E+09	3.8E+02			6.4E-01	9.2E-04	2.5E-03
I-129_ETF-Carbon	7.4E+09	3.8E+02				4.9E+08	9.0E-02
I-129_ETF-GT-73	7.4E+09	3.8E+02			6.2E+02	9.0E-01	1.2E-01

Nuclide	Res	PD	Air	Radon	GW1	GW2	GW3
I-129_F-Carbon	7.4E+09	3.8E+02			8.3E+03	1.2E+01	1.6E+00
I-129_F-CG-8	7.4E+09	3.8E+02			3.1E+00	4.5E-03	2.8E-03
I-129_F-Dowex-21K	7.4E+09	3.8E+02			4.2E+02	6.1E-01	8.3E-02
I-129_F-Filtercake	7.4E+09	3.8E+02			3.5E+00	5.1E-03	2.7E-03
I-129_H-Carbon	7.4E+09	3.8E+02			3.6E+03	5.2E+00	7.0E-01
I-129_H-CG-8	7.4E+09	3.8E+02			2.4E+01	3.4E-02	6.8E-03
I-129_H-Dowex-21K	7.4E+09	3.8E+02			9.7E+02	1.4E+00	1.9E-01
I-129_H-Filtercake	7.4E+09	3.8E+02			4.1E+01	5.8E-02	9.2E-03
K-40	6.8E+01	5.2E+02			7.4E+09	8.3E+01	8.1E-01
Kr-85	9.7E+10	1.1E+09					
Mo-93		4.8E+05			3.8E+11	2.3E+03	9.7E+00
Na-22	2.8E+15	6.0E+14					
Nb-93m		1.3E+08					
Nb-94	9.7E+00	2.8E+03					1.2E+12
Ni-59		4.2E+05					1.9E+03
Ni-63		3.0E+05					
Np-237	1.7E+02	1.1E+02			1.7E+10	3.7E+01	1.8E-02
Pb-210	1.4E+11	2.1E+03					
Pd-107		8.8E+05				8.4E+18	6.3E+02
Pu-238	1.4E+07	3.6E+03		4.6E+06	4.4E+02	4.9E+02	9.8E+02
Pu-239	3.8E+06	1.5E+03			4.0E+02	4.0E+02	4.0E+02
Pu-240	1.2E+09	1.5E+03			4.0E+02	4.0E+02	4.1E+02
Pu-241	1.9E+07	4.1E+04			1.3E+04	1.2E+04	4.0E+03
Pu-242	7.0E+08	1.6E+03			4.1E+02	4.1E+02	4.1E+02
Pu-244	4.4E+01	1.3E+03			4.3E+02	4.3E+02	4.3E+02
Ra-226	9.2E+00	7.2E+01		2.8E+00			9.0E+01
Ra-228	1.3E+08	2.5E+07					
Rb-87		1.5E+04				1.2E+17	4.7E+00
Sb-125	5.0E+16	7.4E+14					
Se-79		2.4E+04					1.8E+02
Sm-151		6.0E+06					
Sn-121m		1.2E+06					
Sn-126	8.8E+00	2.1E+03					3.9E+01
Sr-90		1.7E+03			1.9E+13	1.9E+05	8.9E+02
Tc-99	1.0E+09	2.4E+03			6.9E-01	1.7E-01	4.8E+01
Th-228	6.7E+18	3.5E+18					
Th-229	9.1E+01	5.0E+02					9.5E+03
Th-230	1.9E+01	1.9E+02		7.5E+00			1.9E+01
Th-232	4.4E+00	1.5E+02					3.1E+03
U-232	3.2E+03	9.5E+02					3.2E+06
U-233	9.4E+02	2.2E+03					4.8E+03
U-234	3.8E+03	3.4E+03		1.3E+03			2.7E+03
U-234_MGlass	3.8E+03	3.4E+03		1.3E+03			2.3E+06
U-235	5.1E+02	2.2E+03					4.1E+02
U-235_MGlass	5.1E+02	2.2E+03					3.9E+05

Nuclide	Res	PD	Air	Radon	GW1	GW2	GW3
U-236	2.8E+07	4.0E+03					6.5E+03
U-236_MGlass	2.8E+07	4.0E+03					2.7E+06
U-238	9.8E+02	4.0E+03		1.2E+06			4.6E+02
U-238_MGlass	9.8E+02	4.0E+03		1.2E+06			2.9E+05
Zr-93		9.6E+05					3.6E+03

* Based on an earlier UDQ-E[24] the sum-of-fractions for Slit Trenches occupying Low Activity Waste Vault footprint number 10 must be managed to be no more than 0.9 rather than 1.0.

New inventory limits are compared against old inventory limits (from the "timed sum-of-fraction" report) in Table 21 for all pathways except the groundwater pathway. The ratio of the new limit to the old limit is shown for each pathway. Increases of limits by more than a factor of 10 are highlighted by expressing the ratio in green. Decreases of limits by more than a factor of 10 are highlighted by expressing the ratio in red.

Table 22 provides information for changes in inventory limits for the groundwater pathway. Because the current analysis has two intervals for the first 100 years, the table contains a column title of "Min12New" for the minimum of limits for these first two time intervals to allow comparison with the old limit.

The agriculture scenario has no new limits. For the resident scenario some limits decreased by more than a factor of 10 because leaching was ignored. Most M-Area glass limits increased because leaching was ignored for both the old and new limits and the new cap provides more cover. The U-234_MGlass limit decreased because the old limit was calculated at 100 years, while the new transient limit occurred at 1000 years thus allowing more Bi-214 to grow in. The C-14 air limit increased by a factor of 26 because an area source was analyzed rather than a point source. For the radon analysis, the old limit for U-234 was established for a much longer time period of 10,000 years, while the new limit was established for 1,000 years, thus the limit increased significantly. Some of the post-drilling limits decreased for highly mobile nuclides because the new limits do not consider leaching. Most of the groundwater pathway limit increases for U occurred because its Kd increased from 35 ml/g to 800 ml/g in the aquifer where the Kd was not modeled as a function of pH.

Because of the plethora of changes it would be difficult to pinpoint the cause(s) for all complex changes. However, one isotope, Ni-59, was selected for investigation for the groundwater pathway. Its limit increased from 150 Ci to 1E20 Ci for the first 100 years.

The Ni-59 peak flux to the water table in the PA was calculated as 1.98E-4 Ci/yr at 6850 years. The PA analysis focused on identifying the peak aquifer concentration over 10,000 years hence it placed little emphasis on early fluxes that would not significantly affect that peak. For Ni-59, the PA selected the first two flux values as 0 Ci/yr at 17.9 years and 1.575E-6 Ci/yr at 2955 years, hence all intermediate values would be linearly interpolated between those two values. At 100 years, the flux would have been about 4.40E-08 Ci/yr.

On the other hand, the new analysis needed to provide information for early time intervals, thus it more carefully recorded the fluxes. For the new analysis, the Ni-59 flux at 100 years was 1.9E-28 Ci/yr. This value is about 20 orders of magnitude less than the PA value, while the ratio of the limits is about 18 orders of magnitude. In the "timed sum-of-fractions" report the PA limit at the peak at about 7000 years was extended to the first 100 years. This extension of the limit likely explains the difference between the peak flux and the ratio.

It is likely that this pattern holds true for most of the nuclides that exhibited very late peaks. Also, nuclides that exhibited very early peaks would have poor representations in the later time intervals in the "timed sum-of-fractions" report, because there was little value to the PA to more accurately analyze that time interval and because results likely would have to be extended to the later time intervals.

Table 21. Comparison of new versus old inventory limits for non-groundwater pathways

Nuclide	AgNew	AgOld	AgRatio	ResNew	ResOld	Ratio	PdNew	PdOld	Ratio	AirNew	AirOld	Ratio	RadonNew	RadOld	Ratio
Ag-108m				3.9E+01			2.3E+03								
Al-26				4.0E+00			1.6E+03								
Am-241		2.7E+02		6.3E+05			1.4E+03	9.9E+02	1.4E+00						
Am-242m		1.3E+03		1.6E+05			1.4E+03	8.1E+02	1.7E+00						
Am-243		2.9E+01		4.0E+02			1.2E+03	7.2E+02	1.7E+00						
Ba-133				4.3E+09			8.2E+06								
Bi-207				1.1E+05			2.6E+04								
Bi-210															
Bk-249		2.8E+04		1.4E+05			4.9E+05								
C-14		6.2E+17					2.0E+03	1.9E+04	1.1E-01	7.0E+01	2.7E+00	2.6E+01			
Cd-113m		1.0E+16					3.0E+04	2.4E+04	1.2E+00						
Cf-249		6.9E+01		3.7E+02			1.3E+03	1.1E+03	1.2E+00						
Cf-250		4.8E+04		3.8E+13			2.6E+05	2.2E+05	1.2E+00						
Cf-251		5.2E+01		1.4E+03			1.2E+03	1.1E+03	1.1E+00						
Cf-252		4.5E+06		7.6E+11			5.4E+07	3.9E+07	1.4E+00						
Cl-36							2.5E+01								
Cm-242		1.6E+08		2.7E+09			7.1E+05								
Cm-243		7.8E+08		4.1E+07			2.2E+04	1.8E+04	1.2E+00						
Cm-244		1.2E+06		4.4E+11			1.0E+05	7.6E+04	1.3E+00						
Cm-245		3.7E+01		2.4E+03			7.7E+02	6.7E+02	1.1E+00						
Cm-246		1.4E+02		1.0E+11			1.5E+03	7.9E+02	1.9E+00						
Cm-247		1.1E+01		7.9E+01			1.3E+03	7.8E+02	1.7E+00						
Cm-248		3.6E+01		5.6E+06			4.0E+02	2.2E+02	1.8E+00						
Co-60				2.0E+09	2.1E+09	9.5E-01	8.4E+08	7.3E+08	1.2E+00						
Cs-135		1.1E+04					2.5E+04	2.1E+04	1.2E+00						
Cs-137		6.0E+07		2.1E+06	2.2E+06	9.5E-01	2.4E+04	2.1E+04	1.1E+00						
Eu-152				2.3E+06			6.5E+05								
Eu-154				4.1E+07	3.6E+07	1.1E+00	1.1E+07	8.1E+06	1.4E+00						
Eu-155				4.0E+18			2.3E+11								

Nuclide	AgNew	AgOld	AgRatio	ResNew	ResOld	Ratio	PdNew	PdOld	Ratio	AirNew	AirOld	Ratio	RadonNew	RadOld	Ratio
H-3							2.1E+06		2.1E-14	4.1E+05	3.2E+05	1.3E+00			
H-3_ETF-Carbon							2.1E+06			4.1E+05					
I-129		9.8E+19		7.4E+09			3.8E+02	4.4E+07	8.6E-06						
I-129_10				7.4E+09			3.8E+02								
I-129_ETF-Carbon				7.4E+09			3.8E+02								
I-129_ETF-GT-73		5.7E+01		7.4E+09			3.8E+02	3.2E+02	1.2E+00						
I-129_F-Carbon		5.7E+01		7.4E+09			3.8E+02	3.2E+02	1.2E+00						
I-129_F-CG-8		5.7E+01		7.4E+09			3.8E+02	3.2E+02	1.2E+00						
I-129_F-Dowex-21K		5.7E+01		7.4E+09			3.8E+02	3.2E+02	1.2E+00						
I-129_F-Filtercake		5.7E+01		7.4E+09			3.8E+02	3.2E+02	1.2E+00						
I-129_H-Carbon		5.7E+01		7.4E+09			3.8E+02	3.2E+02	1.2E+00						
I-129_H-CG-8		5.7E+01		7.4E+09			3.8E+02	3.2E+02	1.2E+00						
I-129_H-Dowex-21K		5.7E+01		7.4E+09			3.8E+02	3.2E+02	1.2E+00						
I-129_H-Filtercake		5.7E+01		7.4E+09			3.8E+02	3.2E+02	1.2E+00						
K-40				6.8E+01			5.2E+02								
Kr-85				9.7E+10			1.1E+09								
Mo-93							4.8E+05								
Na-22				2.8E+15			6.0E+14								
Nb-93m							1.3E+08								
Nb-94				9.7E+00			2.8E+03								
Nb-95m															
Ni-59		7.1E+04					4.2E+05	3.6E+05	1.2E+00						
Ni-63		3.3E+06					3.0E+05	2.8E+05	1.1E+00						
Np-237		9.1E+07		1.7E+02			1.1E+02	2.1E+02	5.2E-01						
Pb-210				1.4E+11			2.1E+03								
Pd-107		5.6E+06					8.8E+05	8.9E+05	9.9E-01						
Pu-238				1.4E+07			3.6E+03						4.6E+06		
Pu-239				3.8E+06			1.5E+03								
Pu-240				1.2E+09			1.5E+03								
Pu-241				1.9E+07			4.1E+04								

Nuclide	AgNew	AgOld	AgRatio	ResNew	ResOld	Ratio	PdNew	PdOld	Ratio	AirNew	AirOld	Ratio	RadonNew	RadOld	Ratio
Pu-242				7.0E+08			1.6E+03								
Pu-244				4.4E+01			1.3E+03								
Ra-226				9.2E+00			7.2E+01						2.8E+00		
Ra-228				1.3E+08			2.5E+07								
Rb-87		1.9E+05					1.5E+04	1.5E+04	1.0E+00						
Sb-125				5.0E+16			7.4E+14								
Se-79		9.5E+04					2.4E+04	2.2E+04	1.1E+00						
Sm-151		1.0E+08					6.0E+06	6.1E+06	9.8E-01						
Sn-121m		6.0E+06					1.2E+06	1.2E+06	1.0E+00						
Sn-126		5.6E+01		8.8E+00	5.7E+04	1.5E-04	2.1E+03	1.9E+03	1.1E+00						
Sr-90		1.3E+10					1.7E+03	2.1E+03	8.1E-01						
Tc-99				1.0E+09			2.4E+03	7.4E+10	3.2E-08						
Th-228				6.7E+18			3.5E+18								
Th-229				9.1E+01			5.0E+02								
Th-230				1.9E+01			1.9E+02						7.5E+00		
Th-232		1.4E+00		4.4E+00			1.5E+02	4.4E+02	3.4E-01						
U-232		1.3E+05		3.2E+03	3.2E+03	1.0E+00	9.5E+02	1.5E+03	6.3E-01						
U-233		9.8E+02		9.4E+02	1.5E+07	6.3E-05	2.2E+03	4.1E+03	5.4E-01						
U-234		6.2E+03		3.8E+03	1.9E+08	2.0E-05	3.4E+03	4.4E+03	7.7E-01				1.3E+03	4.9E+01	2.7E+01
U-234_MGlass				3.8E+03	4.3E+04	8.8E-02	3.4E+03	4.4E+03	7.7E-01				1.3E+03	4.9E+01	2.7E+01
U-235		1.4E+03		5.1E+02	6.5E+08	7.8E-07	2.2E+03	3.9E+03	5.6E-01						
U-235_MGlass				5.1E+02	3.7E+01	1.4E+01	2.2E+03	3.9E+03	5.6E-01						
U-236		3.8E+04		2.8E+07			4.0E+03	4.6E+03	8.7E-01						
U-236_MGlass				2.8E+07	1.3E+05	2.2E+02	4.0E+03	4.6E+03	8.7E-01						
U-238		1.0E+04		9.8E+02	1.9E+06	5.2E-04	4.0E+03	4.8E+03	8.3E-01				1.2E+06		
U-238_MGlass				9.8E+02	2.0E+02	4.9E+00	4.0E+03	4.8E+03	8.3E-01				1.2E+06		
Zr-93		1.2E+05					9.6E+05	8.3E+05	1.2E+00						
Zr-95															

Table 22. Comparison of new versus old inventory limits for groundwater pathways

Nuclide	GW1New	GW2New	Min12New	GW1Old	Ratio		GW3New	GW2Old	Ratio		GW3Old
Ag-108m											
Al-26	7.8E+03	3.5E+01	3.5E+01				4.7E+00				
Am-241	8.2E+13	1.8E+05	1.8E+05	8.0E+05	2.3E-01		8.9E+01	2.4E+02	3.7E-01		2.4E+02
Am-242m											
Am-243	1.3E+06	1.4E+05	1.4E+05	8.2E-01	1.7E+05		5.4E+02	8.2E-01	6.6E+02		8.2E-01
Ba-133											
Bi-207											
Bi-210											
Bk-249	2.4E+10	2.8E+08	2.8E+08	2.6E+09	1.1E-01		2.5E+05	2.6E+09	9.6E-05		2.6E+09
C-14	2.9E+08	4.5E+01	4.5E+01	1.7E+03	2.6E-02		4.7E+00	4.6E+00	1.0E+00		4.6E+00
Cd-113m											
Cf-249	6.0E+07	7.0E+05	7.0E+05	1.3E+03	5.4E+02		6.3E+02	1.3E+03	4.8E-01		1.3E+03
Cf-250				5.2E+10	1.9E+09		8.7E+07	5.2E+10	1.7E-03		5.2E+10
Cf-251											
Cf-252	5.8E+14	6.5E+13	6.5E+13	1.5E+08	4.3E+05		7.4E+09	1.5E+08	4.9E+01		1.5E+08
Cl-36	4.7E-02	2.3E-01	4.7E-02				1.6E+01				
Cm-242	8.7E+04	9.6E+04	8.7E+04	1.7E+05	5.1E-01		1.9E+05	1.7E+05	1.1E+00		1.7E+05
Cm-243											
Cm-244	1.5E+05	1.5E+05	1.5E+05	3.9E+02	3.8E+02		1.5E+05	3.9E+02	3.8E+02		3.9E+02
Cm-245	2.6E+04	2.7E+03	2.7E+03	4.0E+01	6.8E+01		2.7E+02	4.0E+01	6.8E+00		4.0E+01
Cm-246				1.4E+08	7.1E+11		2.4E+05	1.4E+08	1.7E-03		1.4E+08
Cm-247	2.5E+09	3.0E+07	3.0E+07	6.5E-01	4.6E+07		8.2E+03	6.5E-01	1.3E+04		6.5E-01
Cm-248	4.5E+09	5.0E+08	5.0E+08	1.2E+03	4.2E+05		5.8E+04	1.2E+03	4.8E+01		1.2E+03
Co-60											
Cs-135		1.3E+12	1.3E+12	1.6E+01	8.1E+10		5.3E+00	1.6E+01	3.3E-01		1.6E+01
Cs-137											
Eu-152											
Eu-154											

Nuclide	GW1New	GW2New	Min12New	GW1Old	Ratio		GW3New	GW2Old	Ratio		GW3Old
Eu-155											
H-3	2.0E+00	1.3E+01	2.0E+00	6.3E+00	3.2E-01		1.2E+05	7.7E+02	1.6E+02		7.7E+02
H-3_ETF-Carbon		4.6E+04	4.6E+04				2.9E+03				
I-129	1.9E-02	2.8E-04	2.8E-04	1.0E-03	2.8E-01		9.2E-03	3.4E-03	2.7E+00		3.4E-03
I-129_10	6.4E-01	9.2E-04	9.2E-04				2.5E-03				
I-129_ETF-Carbon		4.9E+08	4.9E+08				9.0E-02				
I-129_ETF-GT-73	6.2E+02	9.0E-01	9.0E-01	1.0E+01	9.0E-02		1.2E-01	7.5E-01	1.6E-01		6.2E-01
I-129_F-Carbon	8.3E+03	1.2E+01	1.2E+01	1.4E+02	8.6E-02		1.6E+00	1.0E+01	1.6E-01		1.0E+01
I-129_F-CG-8	3.1E+00	4.5E-03	4.5E-03	5.0E-02	9.0E-02		2.8E-03	3.2E-03	8.8E-01		4.4E+19
I-129_F-Dowex-21K	4.2E+02	6.1E-01	6.1E-01	6.8E+00	9.0E-02		8.3E-02	5.1E-01	1.6E-01		4.2E-01
I-129_F-Filtercake	3.5E+00	5.1E-03	5.1E-03	5.0E-02	1.0E-01		2.7E-03	3.2E-03	8.4E-01		4.4E+19
I-129_H-Carbon	3.6E+03	5.2E+00	5.2E+00	5.9E+01	8.8E-02		7.0E-01	4.5E+00	1.6E-01		4.2E+00
I-129_H-CG-8	2.4E+01	3.4E-02	3.4E-02	3.8E-01	8.9E-02		6.8E-03	2.3E-02	3.0E-01		3.6E-02
I-129_H-Dowex-21K	9.7E+02	1.4E+00	1.4E+00	1.6E+01	8.7E-02		1.9E-01	1.2E+00	1.6E-01		1.0E+00
I-129_H-Filtercake	4.1E+01	5.8E-02	5.8E-02	6.6E-01	8.8E-02		9.2E-03	4.0E-02	2.3E-01		4.0E-02
K-40	7.4E+09	8.3E+01	8.3E+01				8.1E-01				
Kr-85											
Mo-93	3.8E+11	2.3E+03	2.3E+03				9.7E+00				
Na-22											
Nb-93m											
Nb-94							1.2E+12				
Nb-95m											
Ni-59				1.5E+02	6.7E+17		1.9E+03	1.5E+02	1.3E+01		1.5E+02
Ni-63											
Np-237	1.7E+10	3.7E+01	3.7E+01	1.6E+02	2.3E-01		1.8E-02	4.8E-02	3.7E-01		4.8E-02
Pb-210											
Pd-107		8.4E+18	8.4E+18	4.4E+01	1.9E+17		6.3E+02	4.4E+01	1.4E+01		4.4E+01
Pu-238	4.4E+02	4.9E+02	4.4E+02				9.8E+02				
Pu-239	4.0E+02	4.0E+02	4.0E+02				4.0E+02				
Pu-240	4.0E+02	4.0E+02	4.0E+02				4.1E+02				

Nuclide	GW1New	GW2New	Min12New	GW1Old	Ratio		GW3New	GW2Old	Ratio		GW3Old
Pu-241	1.3E+04	1.2E+04	1.2E+04				4.0E+03				
Pu-242	4.1E+02	4.1E+02	4.1E+02				4.1E+02				
Pu-244	4.3E+02	4.3E+02	4.3E+02				4.3E+02				
Ra-226							9.0E+01				
Ra-228											
Rb-87		1.2E+17	1.2E+17	3.5E-01	3.4E+17		4.7E+00	3.5E-01	1.3E+01		3.5E-01
Sb-125											
Se-79				1.2E+02	8.3E+17		1.8E+02	1.2E+02	1.5E+00		1.2E+02
Sm-151											
Sn-121m											
Sn-126				4.0E+01	2.5E+18		3.9E+01	4.0E+01	9.7E-01		4.0E+01
Sr-90	1.9E+13	1.9E+05	1.9E+05	4.2E+05	4.5E-01		8.9E+02	5.1E+02	1.7E+00		5.1E+02
Tc-99	6.9E-01	1.7E-01	1.7E-01	6.1E-01	2.8E-01		4.8E+01	1.8E+01	2.7E+00		1.8E+01
Th-228											
Th-229							9.5E+03				
Th-230							1.9E+01				
Th-232				7.2E+05	1.4E+14		3.1E+03	7.2E+05	4.3E-03		7.2E+05
U-232				5.9E+01	1.7E+18		3.2E+06	5.9E+01	5.4E+04		5.9E+01
U-233				1.9E+00	5.3E+19		4.8E+03	1.9E+00	2.5E+03		1.9E+00
U-234				1.1E+02	9.1E+17		2.7E+03	1.1E+02	2.5E+01		1.1E+01
U-234_MGlass				8.2E+02	1.2E+17		2.3E+06	8.2E+02	2.8E+03		8.2E+02
U-235				5.7E+01	1.8E+18		4.1E+02	5.7E+01	7.2E+00		8.0E+00
U-235_MGlass				1.0E+02	1.0E+18		3.9E+05	1.0E+02	3.9E+03		1.0E+02
U-236				2.0E+00	5.0E+19		6.5E+03	2.0E+00	3.2E+03		2.0E+00
U-236_MGlass				1.8E+04	5.6E+15		2.7E+06	1.8E+04	1.5E+02		1.8E+04
U-238				8.7E+00	1.1E+19		4.6E+02	8.7E+00	5.3E+01		7.4E+00
U-238_MGlass				1.3E+03	7.7E+16		2.9E+05	1.3E+03	2.2E+02		1.3E+03
Zr-93				2.6E+01	3.8E+18		3.6E+03	2.6E+01	1.4E+02		2.6E+01
Zr-95											

11 RECOMMENDATIONS

Several alternatives exist to try to mitigate the most important changes that tended to lower limits, ranging from revising the analyses to changing field operations. The waste in all trenches was assumed to be compacted to a final depth of about 2.5 feet. For the Slit Trenches, this assumption is overly conservative. However, modifying the analysis to accommodate less compaction will not affect nuclides that produce peak well concentrations before the compaction would occur, such as H-3. If an interim cover is constructed over the waste zone before the planned end of operations at 25 years, the amount of infiltration would be dramatically reduced and should lead to higher limits.

The models included the assumption that the dissolved organic carbon concentrations would be fed by an infinite supply of cellulose[53]. If that assumption were modified, limits for nuclides that have Kds that are affected by cellulose degradation products would tend to increase. Alternatively, creating trenches without cellulose degradation products would increase limits for those nuclides that are affected by the cellulose degradation products.

More careful examination of the Kds combined with some experiments would provide some relief in certain cases. The effect of pH was applied to the Kds originally listed in the PA. Further investigation could result in important changes, such as the U Kd jumping from 35 ml/g to 800 ml/g.

12 REFERENCES

[1]Collard, L. B. 2002. *Evaluation Of A Method To Calculate The Sum-Of-Fractions For Multiple Radionuclides That Uses Aquifer Concentrations Of Radionuclides That Change With Respect To Time,* WSRC-TR-2002-00430, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, September 30.

[2]Collard, L. B. 2003. *Special Analysis: Implementation of Sum-of-Fractions for Multiple Pathways Including Select Groundwater Pathway Time Intervals,*WSRC-TR-2003-00438, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, September 15.

[3]Wilhite, E. L. 2003. *Performance Assessment Position Paper: Time for compliance,* WSRC-RP-2003-00390, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, October 23.

[4]Phifer, M. A. 2004. *Preliminary E-Area Trench Closure Cap Closure Sequence, Infiltration, and Waste Thickness (U),* WSRC-TR-2004-00119, Rev. 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, March 12.

[5]McDowell-Boyer, L., A. D. Yu, J. R. Cook, D. C. Kocher, E. L. Wilhite, H. Holmes-Burns, and K. E. Young, 2000. *Radiological Performance Assessment For The E-Area Vaults Disposal Facility,* WSRC-RP-94-00218, Revision 1, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, January 31.

[6]Cook, J. R. and E.L. Wilhite 2004. *Special Analysis: Radionuclide Screening Analysis for E Area,* WSRC-TR-2004-00294, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, June 1.

[7]Phifer, M. A. and L. B. Collard 2003. *Unreviewed Disposal Question Evaluation: Backfill Soil Compaction Requirements,* WSRC-TR-2003-00081, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, February 6.

[8]Phifer, M. A., and E. L. Wilhite, 2001. *Waste Subsidence Potential Versus Supercompaction,* WSRC-RP-2001-00613, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, September 27.

[9]Cook, J. R. 2000. *Special Analysis: Updated Analysis of the Effects of Wood Products on Trench Disposal Limits at the E-Area Low-Level Waste Facility,* WSRC-RP-2000-00523, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, July 31.

[10]Collard, L. B. 2003. *Evaluation Of Variation in Size of LAW Vault Footprint Used for PA Trench Analyses* , WSRC-TR-2002-00543, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, October 30.

[11]Koffman, L. D. 2004. *An Automated Inadvertent Intruder Analysis Application,* WSRC-TR-2004-00293, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, July 16.

[12]Collard, L. B. and J. R. Cook 2003. *Special Analysis: Update of Disposal of Cement-Stabilized Encapsulated Waste at the E-Area Low-Level Waste Facility* , WSRC-TR-2003-00318, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, May 21.

[13]Collard, L. B. 2003. *Estimated Impacts For Performance Assessment Modeling Changes Planned For 2003 For E-Area Low Level Waste Facility Disposal Units,* WSRC-TR-2003-00193, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, May 2.

[14]Wilhite, E. L., and B. T. Butcher, 2003. *E Area Performance Assessment Interim Measures Assessment,* WSRC-RP-2003-00436, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, July 15.

[15]Wilhite, E. L. 2000. *Evaluation of Proposed New LLW Disposal Activity: Disposal of LLW in a Engineered Trench rather than in Slit Trenches,* WSRC-RP-2000-00217, Revision 1, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, December 18.

[16]Wilhite, E. L. and J. R. Cook 2000. *Alternative Trench Disposal Concepts,* WSRC-RP-2000-00737, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, August 30.

[17]Wilhite, E. L. 2003. *Performance Assessment Position Paper: Time of compliance,* WSRC-RP-2003-00390, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, October 23.

[18]Flach, G. P., and Millings, M. R. 2003. *Unreviewed Disposal Question Evaluation Of Unanalyzed Slit And Engineered Trench Locations,* WSRC-TR-2003-00432, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, September.

[19]Flach, G. P., and M. R. Millings, 2003. *Evaluation Of E Area Slit Trench Performance Under As Filled Conditions,* WSRC-TR-2003-00265, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, June.

[20]Wilhite, E. L. 2000. *Evaluation of Proposed New LLW Disposal Activity: Disposal of Compacted Job Control Waste, Non-compactible, Non-incinerable Waste, and Other Wasteforms in Slit Trenches,* WSRC-RP-2000-00218, Revision 1, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, December 18.

[21]Collard, L. B. 2002. *Program for Managing the E-Area Performance Assessment Models for Slit Trenches and Engineered Trenches,* WSRC-TR-2002-00544, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, December 3.

[22]Cook, J. R. 2002. *Discovery Of Disposal Of Low-Level Waste In Slit Trench Segments Shallower Than Analyzed In Performance Assessment,* WSRC-TR-2002-00249, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, May 29.

[23]Cook, J. R. 2001. *Discovery of Operational Anomalies in Slit Trench Disposal Operations,* WSRC-RP-2001-00946, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, October 15.

[24]Wilhite, E. L. 2001. *Evaluation Of Proposed New LLW Disposal Activity Disposal Of Low Level Waste In Slit Trenches Shorter Than Analyzed In Performance Assessment,* WSRC-RP-2001-00947, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, October 15.

[25]Cook, J. R. 2004. *Evaluation of Proposed New LLW disposal Activity: Variations in Slit Trench Dimensions,* WSRC-TR-2004-00085, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, February 17.

[26]Flach, G.P. and L.B. Collard, 2003. *An Evaluation of Aquifer Source Node Location Alternatives for E-Area Slit Trench Performance Assessment,* WSRC-TR-2003-00123, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, March 28.

[27]Collard, L. B. 2000. *Subsidence Sensitivity Study for Low-Level Waste in Slit Trenches,* WSRC-RP-2000-00524, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, August 3.

[28]Cook, J. R. 2003. *Variations In Slit Trench Dimensions To Allow Disposal Of Large Components,* WSRC-RP-2003-00473, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, June 10.

[29]Collard, L. B. 2003. *Evaluation of Proposed Disposal of 331-M Standards in Trenches,* WSRC-TR-2003-00473, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, October 12.

[30]Collard, L. B. 2003. *Evaluation of Proposed New LLW Disposal Activity: Disposal of Beneficial Reuse Containers Manufactured from Activated Metals,* WSRC-TR-2003-00058, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, January 27.

[31]Wilhite, E. L. 2001. *Evaluation Of Proposed New LLW Disposal Activity Disposal Of SREL Cesium Irradiation Source Containing Lead As Low Level Waste,* WSRC-RP-2001-00703, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, June 22.

[32]Hiergesell, R. A., and J. R. Cook, 2003. *Evaluation Of Proposed New LLW Disposal Activity: Disposal Of Radioactive Slugs In Paducah Demonstration Cask,* WSRC-RP-2003-00545, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, September 17.

[33]Hiergesell, R. A. 2004. *Special analysis: Re-evaluation of the Slit Trench Uranium Disposal-Limits with implications for disposal of the Paducah Demonstration Cask,* WSRC-TR-2003-00521, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, January.

[34]Cook, J. R. 2004. *Evaluation of Proposed New LLW disposal Activity: Disposal of LLW Sources,* WSRC-TR-2004-00158, Revision 1, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, March 17.

[35]Cook, J. R. 2003. *Evaluation of Proposed New LLW disposal Activity: Disposal of No Dose/Low Dose Scrap Metal in Slit Trenches,* WSRC-TR-2003-00562, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, December 16.

[36]Collard, L. B. 2001. *Special Analysis For Disposal Of High Concentration I-129 Waste In Slit Trenches At The E Area Low Level Waste Facility,* WSRC-TR-2001-00021, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, August 15.

[37]Collard, L. B. 2002. *Evaluation Of Proposed New LLW Disposal Activity Disposal Of ETF Activated Carbon Vessels In Trenches,* WSRC-TR-2002-00339, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, September 3.

[38]Collard, L. B. 2003. *Special Analysis Disposal of ETF Activated Carbon Vessels In Slit Trenches At The E Area Low Level Waste Facility,*WSRC-TR-2003-00255, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, June 13.

[39]Cook, J. R. 2002. *Evaluation of Proposed New LLW Disposal Activity: Disposal Of M-Area Glass In Slit Trenches,* WSRC-TR-2002-00245, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, May 23.

[40]Cook, J. R., and A. D. Yu, 2002. *Special Analysis Disposal Of M-Area Glass In Trenches,* WSRC-TR-2002-00337, Revision 1, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, August 21.

[41]Wilhite, E. L. 2003. *Unreviewed Disposal Question Evaluation: Discovery of Apparent Omission of Miscellaneous Glass Forms in M-Area Glass Special Analysis ,* WSRC-TR-2002-00581, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, January 7.

[42]Kaplan, D. I., and E. L. Wilhite, 2001. *Discovery of New Plutonium Chemistry and its Potential Effect on LLW Disposal at SRS*, WSRC-RP-2000-00980, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, January 22.

[43]Cook, J. R. 2002. *Special Analysis: Effect of New Plutonium Chemistry on SRS Trench Disposal Limits*, WSRC-TR-2002-00154, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, September 30.

[44]Serkiz, S. M. 2000. *Recommended Partition Coefficient (Kd) Values For Nuclides Partitioning In The Presence Of Cellulose Degradation Products*, WSRC-TR-2000-00262, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, July 28.

[45]Cook, J. R 2000. *Special Analysis: Updated Analysis Of The Effect Of Wood Products On Trench Disposal Limits At The E-Area Low-Level Waste Facility*, WSRC-RP-2000-00523, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, July 31.

[46]Cook, J. R. 2001. *Unreviewed Disposal Question Evaluation Correction And Update Of E Area Disposal Limits*, WSRC-TR-2001-00614, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, December 19.

[47]Wilhite, E. L. 2002. *Unreviewed Disposal Question Evaluation Discovery Of Error In E-Area Disposal Limits Documentation*, WSRC-TR-2002-00190, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, May 2.

[48]Cook, J. R. 2002. *Special Analysis Correction And Update Of E-Area Disposal Limits*, WSRC-TR-2002-00047, Revision 2, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, May 2.

[49]Cook, J. R., and E. L. Wilhite, 2002. *Analysis Of Disposal Of Lead In The E-Area Low Level Waste Facility*, WSRC-TR-2002-00101, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, February 20.

[50]Cook, J. R., L. B. Collard, G. P. Flach, and P. L. Lee, 2002. *Development of Probabilistic Uncertainty Analysis Methodology For SRS Performance Assessments Maintenance Plan Activities*, WSRC-TR-2002-00121, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, March 8.

[51]Kaplan, D.I., P.M. Bertsch, D.C. Adriano, and K.A. Orlandini, 1994. Actinide Association with Groundwater Colloids in a Coastal Plain Aquifer. *Radiochimica Acta* 66/67, p. 181 (1994).

[52]USEPA 1994. *The Hydrologic Evaluation of Landfill Performance (HELP) Model User's Guide for Version 3*. Office of Research and Development, EPA/600/R-94/168a. United States Environmental Protection Agency, Washington, DC. September.

[53]Kaplan, D.I. 2004. *Recommended Geochemical Input Values for the Special Analysis of the Slit/Engineered Trenches and Intermediate Level Vault*, WSRC-RP-2004-00267, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, May 30.

[54]Runchal, A. 2004. Personal communication, July 2004.

[55]Jagdish K. Tuli National Nuclear Data Center 2000. *Nuclear Wallet Cards, Sixth Edition*, Brookhaven National Laboratory, Upton, New York, http://www.nndc.bnl.gov/wallet/nwc6.html, January.

[56]Phifer, M.A. 2004. *Unreviewed Disposal Question Evaluation: Uncontaminated Lifting Attachments and Rigging within Four-foot Slit Trench "Clean Backfill"*, WSRC-TR-2004-00139, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, March 8.

[57]Wilhite, E. L. 2004. *Evaluation of Proposed New LLW Disposal Activity: Disposal of PCB Waste Containing Unanalyzed Radionuclides*, WSRC-RP-2004-00434, Revision 0, Westinghouse Savannah River Company, Aiken, South Carolina, 29808, June 8.

13 APPENDIX A. IMPLEMENTATION CHANGES FOR MODELS

Groundwater Analysis

Several differences exist between the PA models for the groundwater pathway and the current model. In addition to selection of a different set of aquifer source cells that was described earlier, the models were improved by eliminating the lateral shift in waste zone geometry between steady-state flow stages. The initial waste zone thickness was increased from 15 feet to 16 feet. The distance from the bottom of the waste zone to the simulated water table was reduced from 26 feet to 25 feet.

Fluxes and concentrations were recorded for finer time slices of 0.1 years for those nuclides that are highly mobile. The highly mobile nuclides included Al-26, I-129, Tc-99, Cl-36, all the H-3 and all the sensitivity case nuclides. All analyses for highly mobile nuclides were terminated at 325 years. The full GSA aquifer model was employed only for these nuclides.

The boundary conditions for the vadose zone were changed by commenting one of the inputs. That change allows contamination to move with the liquid flow, because the implementation of the boundary conditions by PORFLOW was changed from earlier versions of PORFLOW. (Previously, a zero concentration specified for the boundary would sweep away all contaminants that exited the boundary. However, in the new PORFLOW version, a zero concentration for a boundary condition prevents contaminants from being transported out of the domain by advection. The condition was changed to allow modeling of filters that allow liquids to pass through, but that do not allow contaminants to pass through, such as for desalinization.)

It was discovered that in some low flow cases that the boundary condition for the vadose zone did not allow advection to carry contamination across the boundary. Inspection of intermediate results indicated that contamination in the interior of the model was moving via both advection and diffusion. A conversation with the PORFLOW author[54] indicated that PORFLOW was assigning the most appropriate boundary condition depending on the Peclet number (indicating whether advection or diffusion dominated) and that contamination arriving at the boundary should cross the boundary within one or two time steps, thus the results were deemed acceptable. The boundary condition for the aquifer was set to allow advection only, which could slightly increase the concentrations at the boundary potentially leading to slightly higher well concentrations.

Kd values were changed from constant values to functions of pH[53] to allow the effects of dissolved organic carbon (DOC) to be modeled. DOC was assumed to reduce the pH from a background level of 5.5 to 4.5 within the waste zone. That 4.5 pH level in the waste zone was held constant throughout the analysis. pH levels were explicitly modeled (as hydrogen ion concentrations) and the lowest values obtained at the end of a steady-state flow stage were applied throughout the flow stage.

For the hydrogen ions a Freundlich isotherm was assigned as $S = kC^n$,

where

S = sorbed phase concentration,
k = Freundlich absorption constant,
C = aqueous phase concentration, and
n = Freundlich exponent.

the value for n[53] is 0.38 and the value for k[53] is 396 $L^{0.38}\mu g^{0.62}/kg$.

Kd values as functions of pH are provided in Table 23. No Kd values were found for Al-26 as a function of pH, therefore all values were set to zero in the vadose zone. Pu represents Pu in the oxidation states of +3 and +4. Pu5 represents Pu in the oxidation states of +5 and +6.

Table 23. Kd values (ml/g) as a function of pH in the vadose zone and for sand and clay in the aquifer

Isotope	Vadose zone pH					Aquifer	
	5.50	5.25	5.00	4.75	4.50	Sand	Clay
Ac	4.50E+02	8.00E+01	1.30E+01	4.00E+00	2.00E+00	4.50E+02	2.40E+03
Al	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.00E+01	1.20E+04
Am	1.90E+03	3.38E+02	5.50E+01	1.80E+01	1.00E+01	1.90E+03	8.40E+03
Bi	4.50E+02	8.00E+01	1.30E+01	4.00E+00	2.00E+00	4.50E+02	1.20E+03
C	2.00E+00	2.00E+00	2.00E+00	2.00E+00	2.00E+00	2.00E+00	1.00E+00
Cf	5.10E+02	9.10E+01	1.50E+01	5.00E+00	3.00E+00	5.10E+02	8.40E+03
Cl	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cm	4.00E+03	7.12E+02	1.15E+02	3.80E+01	2.20E+01	4.00E+03	6.00E+03
Cs	1.80E+01	1.20E+01	5.00E+00	5.00E+00	5.00E+00	1.80E+01	1.90E+03
H	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I	6.00E-01	6.00E-01	6.00E-01	6.00E-01	6.00E-01	6.00E-01	1.00E+00
K	3.00E+00	3.00E+00	3.00E+00	2.00E+00	2.00E+00	3.00E+00	3.00E+00
Mo	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00
Nb	1.60E+02	1.60E+02	1.60E+02	1.60E+02	1.60E+02	1.60E+02	9.00E+02
Ni	4.00E+02	1.63E+02	8.00E+00	3.80E+00	2.20E+00	4.00E+02	6.50E+02
Np	5.00E+00	3.00E+00	1.00E+00	1.00E+00	1.00E+00	5.00E+00	5.50E+01
Pa	5.50E+02	3.00E+00	1.40E+00	1.40E+00	1.40E+00	5.50E+02	2.70E+03
Pb	2.70E+02	1.10E+02	5.00E+00	3.00E+00	1.00E+00	2.70E+02	5.50E+02
Pd	5.50E+01	2.23E+01	1.10E+00	5.27E-01	3.01E-01	5.50E+01	2.70E+02
Po	1.50E+02	1.50E+02	1.50E+02	1.50E+02	1.50E+02	1.50E+02	3.00E+03
Pu	3.70E+02	3.50E+02	3.10E+02	2.70E+02	2.20E+02	3.70E+02	6.50E+03
Pu5	1.50E+01	9.00E+00	8.00E+00	8.00E+00	8.00E+00	1.50E+01	5.00E+01
Ra	5.00E+02	2.03E+02	1.00E+01	4.80E+00	2.74E+00	5.00E+02	9.10E+03
Rb	5.50E+01	3.00E+00	1.00E+00	1.00E+00	1.00E+00	5.50E+01	2.70E+02
Se	3.60E+01	3.60E+01	3.60E+01	3.60E+01	3.60E+01	3.60E+01	7.40E+02
Sn	1.30E+02	5.28E+01	2.60E+00	1.25E+00	7.12E-01	1.30E+02	6.70E+02
Sr	1.00E+01	4.00E+00	2.00E-01	1.00E-01	1.00E-01	1.00E+01	1.10E+02
Tc	3.60E-01	3.60E-01	3.60E-01	3.60E-01	3.60E-01	3.60E-01	1.00E+00
Th	3.20E+03	5.70E+02	9.20E+01	3.10E+01	1.80E+01	3.20E+03	5.80E+03
U	8.00E+02	3.25E+02	1.60E+01	8.00E+00	4.00E+00	8.00E+02	1.60E+03
Zr	6.00E+02	1.07E+02	1.70E+01	6.00E+00	3.00E+00	6.00E+02	3.30E+03

Half-lives were revised from the PA[5] by using the Brookhaven National Laboratory nuclear wallet cards[55]. Values for all half-lives were converted to years and are presented in Table 24.

Other data required for transport modeling included the rate of conversion between Pu (III/IV) and Pu (V/VI) in both directions. The decay rates[53] used for the model were

Reaction	Decay rate (1/hr)	Decay rate (1/yr)
Pu (V/VI) to Pu (III/IV)	1.E-3	8.766
Pu (III/IV) to Pu (V/VI)	1.5E-8	1.314E-4

Table 24. Half-lives for isotopes

Isotope	Half-life (years)	Isotope	Half-life (years)
Ac-227	2.18E+01	Nb-94	2.03E+04
Al-26	7.17E+05	Ni-59	7.60E+04
Am-241	4.32E+02	Ni-63	1.00E+02
Am-242m	1.41E+02	Np-237	2.14E+06
Am-243	7.37E+03	Np-239	6.46E-03
Bk-249	8.77E-01	Pa-231	3.28E+04
C-14	5.73E+03	Pb-210	2.23E+01
C-14_KB	5.73E+03	Pd-107	6.50E+06
Cd-113m	1.41E+01	Po-210	3.79E-01
Cf-249	3.51E+02	Pu-238	8.77E+01
Cf-250	1.31E+01	Pu-239	2.41E+04
Cf-251	8.98E+02	Pu-240	6.56E+03
Cf-252	2.65E+00	Pu-241	1.44E+01
Cl-36	3.01E+05	Pu-242	3.73E+05
Cm-242	4.46E-01	Pu-244	8.08E+07
Cm-244	1.81E+01	Pu-Col	1.00E+30
Cm-245	8.50E+03	Ra-223	3.13E-02
Cm-246	4.73E+03	Ra-224	1.00E-02
Cm-247	1.56E+07	Ra-225	4.08E-02
Cm-248	3.40E+05	Ra-226	1.60E+03
Co-60	5.27E+00	Ra-226	1.60E+03
Cs-135	2.30E+06	Ra-228	5.75E+00
Cs-137	3.01E+01	Rb-87	4.75E+10
Eu-152	1.35E+01	Se-79	1.10E+06
Eu-154	8.59E+00	Sm-151	9.00E+01
H-3	1.23E+01	Sn-121m	5.50E+01
I-129	1.57E+07	Sn-126	1.00E+05
I-129_10K	1.57E+07	Sr-90	2.88E+01
I-129_ETF-GT-73	1.57E+07	Tc-99	2.11E+05
I-129_F-Carbon	1.57E+07	Th-227	5.13E-02
I-129_F-CG-8	1.57E+07	Th-228	1.91E+00
I-129_F-Dowex-21K	1.57E+07	Th-229	7.34E+03
I-129_F-Filtercake	1.57E+07	Th-230	7.54E+04
I-129_H-Carbon	1.57E+07	Th-232	1.41E+10
I-129_H-CG-8	1.57E+07	Th-234	6.60E-02
I-129_H-Dowex-21K	1.57E+07	U-232	6.89E+01
I-129_H-Filtercake	1.57E+07	U-233	1.59E+05
I-129_KB	1.57E+07	U-234	2.46E+05
I-129_SIR-1200	1.57E+07	U-235	7.04E+08
K-40	1.28E+09	U-236	2.34E+07
Mo-93	4.00E+03	U-238	4.47E+09
Nb-93m	1.61E+01	Zr-93	1.53E+06

When a specific Pu isotope “decayed” two products were generated. The first product was its progeny that was generated from radioactive decay. The second product was the same Pu isotope but with a different

oxidation state. For the model, the sum of these two decay rates was assigned to the specific Pu isotope as its total decay rate. The regeneration of each of the products was assigned as the respective fraction of that total decay rate.

The final physical properties needed to perform the transport analyses were the particle densities, porosities, diffusion coefficients, and dispersivity coefficients. For the aquifer transport model, only sand and clay were considered. Values for the rest of the physical properties are presented in Table 25. The values are those that were used in the PA. The dispersivities were set to zero because numerical dispersion was expected. While the zero dispersivities could delay some early arrivals, in general it would reduce stretching of the contaminant front leading to slightly higher well concentrations.

Table 25. Miscellaneous physical properties for the aquifer transport model

Sediment	Particle density (g/cc)	Porosity (cc/cc)	Diffusion Coefficient (cm^2/s)	Longitudinal dispersivity (cm)	Transverse dispersivity (cm)
Sand	2.65	0.25	5E-6	0	0
Clay	2.65	0.25	1.5E-6	0	0

Details of implementation of colloid modeling

The initial well concentration for colloids was calculated using the field ratio C_{well}/C_{source} but with C_{source} set to the concentration of non-colloids in the modeled waste zone. To determine the C_{source} in the modeled waste zone, 1 Ci of contaminant (the inventory for non-colloids that was separately modeled) was uniformly distributed throughout the 2D waste zone and the initial concentration reported by PORFLOW was recorded. Because the 1 Ci of inventory should be distributed throughout the volume of 1 set of 5 slit trenches, the recorded initial concentration was divided by the length of 1 slit trench (600 ft) and was further divided by 5 for the 5 slit trenches. The recorded initial concentration was in units of Ci/cm^2, so units conversions included changing the length to cm to obtain Ci/cm^3, then multiplying by 1000 to produce Ci/L, and finally multiplying by 1E12 to produce pCi/L. The calculations were as follows:

Initial Waste Conc = [2.04E-8 Ci/cm^2 / (600 ft * 30.48 cm/ft * 5 trenches)] * 1000 cm^3/L * 1E12 pCi/Ci
Initial Waste Conc = 223 pCi/L

The modeling concentration (223 pCi/L) was about 72% of the concentration measured at the field source location (308 pCi/L).

The colloid modeling only depends on the activity and not on the volume, because the adjustment for the source would be exactly offset by the adjustment for the results. For example, if the model spread the 223 pCi of activity over 10 L, then the source should be multiplied by 10 to reflect the correct concentration. The total activity for the results would be summed over the same 10 L volume, thus those results should be divided by 10 to reflect the activity present in 1 L of water. The combined effect is to multiply by 10, then divide by 10 producing no net change.

Colloid modeling used 1 atom of the parent per cm^3 as the initial concentration at the 100-m well. The actual value should have been the number of atoms that would produce 4.5E-5 * 223 pCi/L (where 4.5E-5 was the ratio of the well concentration to the source concentration), thus an adjustment factor was required. Also, PORFLOW results in terms of atoms for each chain member need to be converted to activities. The two adjustment factors are defined below.

1. adjustment factor for number of atoms that have an activity of 4.5E-5 * 223 pCi
   $A^0 = \lambda_p N_p^0$
   where λ_p is disintegrations per second for 1 atom of the parent
   N_p^0 is the number of atoms of the parent at time zero
   3.7E10 disintegrations per second = 1 Ci

1E12 pCi = 1 Ci

$A^0 = \lambda_p N_p^0 * [1 Ci / (3.7E10 disintegrations/second)] * [1E12 pCi / 1 Ci]$

Therefore $N_p^0 = A^0 / \lambda_p * [(3.7E10 disintegrations/second) / 1 Ci] * [1 Ci / 1E12 pCi]$
where $A^0 = 4.5E-5 * 223 pCi$

thus $N_p^0 = (4.5E-5 * 223 pCi) / \lambda_p * [(3.7E10 disintegrations/second) / 1 Ci] * [1 Ci / 1E12 pCi]$

2. adjustment factor to express results at well as an activity in pCi
$A^t_C = \lambda_C N_C^t$
where λ_C is disintegrations per second for 1 atom of the chain member
N_C^t is the number of atoms of the chain member at time t

A^t_C is expressed in disintegrations per second of the chain member and must be converted to pCi as follows:
$A^t_C = \lambda_C N_C^t * [1 Ci / (3.7E10 disintegrations/second)] * [1E12 pCi / 1 Ci]$

The final results must be multiplied by each of the factors above, or

Final $A^t_C = \lambda_C N_C^t * [1 Ci / (3.7E10 disintegrations/second)] * [1E12 pCi / 1 Ci] *$
$(4.5E-5 * 223 pCi) / \lambda_p * [(3.7E10 disintegrations/second) / 1 Ci] * [1 Ci / 1E12 pCi]$

Final $A^t_C = N_C^t * (223 pCi * 4.5E-5) * \lambda_C / \lambda_p$

Each decay rate is ln(2) / half-life (seconds), hence
$\lambda_C / \lambda_p = [ln(2) / T_{½C}] / [ln(2) / T_{½p}]$
$\lambda_C / \lambda_p = T_{½p} / T_{½C}$, and the final equation may equivalently be expressed as

Final $A^t_C = N_C^t * (4.5E-5 * 223 pCi) * T_{½p} / T_{½C}$

Calculating and combining limits for non-colloids and colloids

For a single parent isotope (without a decay chain), the inventory limit for the non-colloids was calculated by scaling the modeled aquifer concentrations to match the allowable aquifer concentrations then multiplying this scaling factor by the inventory of non-colloids modeled (1 Ci). In symbolic notation, the modeled inventory (I_m in Ci) was multiplied by the allowable aquifer concentration (C_{all} in pCi/L) and divided by the peak modeled aquifer concentration (C_m in pCi/L) or

$L^{NC} = I_m^{NC} * C_{all} / C_m^{NC}$

The limit for the colloids was similarly calculated as

$L^C = I_m^{NC} * C_{all} / C_m^C$

(In both cases the modeled inventory for the non-colloids was 1 Ci, thus I_m^{NC} could be eliminated from the equations. The inventory of non-colloids was assumed to produce both colloids and non-colloids which produced a slight excess of 4.5E-5 Ci. (No adjustment was made for the slight excess versus 1 Ci.)

The combined limit was calculated by using the sum of the peak aquifer concentrations for non-colloids and colloids.

$L = I_m^{NC} * C_{all} / (C_m^{NC} + C_m^C)$

An equivalent expression is $L = 1 / (1/L^{NC} + 1/L^C)$.

For a parent isotope with a decay chain the previous equation was used. However, L^{NC} and L^{C} were independently calculated at the time when the maximum sum-of-fractions (for a 1 Ci inventory of the parent) including all isotopes in the decay chain.

Groundwater pathway limits for non-colloids are presented in Table A- 1 and for colloids in Table A- 2. These limits were combined to develop the final limits presented in Table 19.

Table A- 1. Groundwater pathway limits and time of peak aquifer concentration for non-colloids

Time interval (years)	0-12	12-100	100-1000	0-12	12-100	100-1000
	Limit	Limit	Limit	Peak Time	Peak time	Peak Time
Nuclide	Ci	Ci	Ci	year	year	year
Al-26	3.0E-02	1.7E-01	1.8E+03	7	12	100
Am-243	1.0E+20	1.0E+20	5.6E+02	11	99.3	999.2
Bi-210	1.0E+20	1.0E+20	1.0E+20	10	12	100.3
C-14	2.9E+08	4.5E+01	4.7E+00	11	57.2	239.2
Cf-249	1.0E+20	5.2E+14	6.5E+02	11	99.3	999.2
Cl-36	5.3E-02	3.0E-01	3.1E+03	7	12	100
Cm-245	1.0E+20	1.2E+11	5.9E+02	11	99.3	668.2
Cm-246	1.0E+20	1.0E+20	2.4E+05	11	99.3	999.2
Cm-247	1.0E+20	1.0E+20	8.4E+03	11	99.3	999.2
Cm-248	1.0E+20	1.0E+20	5.8E+04	11	99.3	999.2
Cs-135	1.0E+20	1.3E+12	5.3E+00	11	99.3	729.2
H-3	2.0E+00	1.3E+01	1.2E+05	6.9	12	100
H-3_ETF-Carbon	1.0E+20	4.6E+04	2.9E+03	0	99.9	134.9
I-129	1.9E-02	2.8E-04	9.2E-03	11.9	27.1	100
I-129_10	6.4E-01	9.2E-04	2.5E-03	11	31	174.1
I-129_ETF-Carbon	1.0E+20	4.9E+08	9.0E-02	11	99.3	605.2
I-129_ETF-GT-73	6.2E+02	9.0E-01	1.2E-01	11	31	605.2
I-129_F-Carbon	8.3E+03	1.2E+01	1.6E+00	11	31	605.2
I-129_F-CG-8	3.1E+00	4.5E-03	2.8E-03	11	31	252.2
I-129_F-Dowex-21K	4.2E+02	6.1E-01	8.3E-02	11	31	605.2
I-129_F-Filtercake	3.5E+00	5.1E-03	2.7E-03	11	31	345.2
I-129_H-Carbon	3.6E+03	5.2E+00	7.0E-01	11	31	605.2
I-129_H-CG-8	2.4E+01	3.4E-02	6.8E-03	11	31	358.2
I-129_H-Dowex-21K	9.7E+02	1.4E+00	1.9E-01	11	31	605.2
I-129_H-Filtercake	4.1E+01	5.8E-02	9.2E-03	11	31	602.2
K-40	7.4E+09	8.3E+01	8.1E-01	11	99.3	376.2
Mo-93	3.8E+11	2.3E+03	9.7E+00	11	99.3	374.2
Nb-94	1.0E+20	1.0E+20	1.2E+12	11	99.3	999.2
Nb-95m	1.0E+20	1.0E+20	1.0E+20	3	12	100.3
Ni-59	1.0E+20	1.0E+20	1.9E+03	11	99.3	999.2
Np-237	1.7E+10	3.7E+01	1.8E-02	11	99.3	412.2
Pd-107	1.0E+20	8.4E+18	6.3E+02	11	99.3	999.2
Pu-238	1.0E+20	1.0E+20	1.7E+07	11	99.3	999.2
Pu-239	1.0E+20	1.0E+20	4.8E+09	11	99.3	999.2
Pu-240	1.0E+20	1.0E+20	3.5E+08	11	99.3	999.2
Pu-241	7.6E+19	1.2E+10	5.8E+03	11	99.3	429.2
Pu-242	1.0E+20	1.0E+20	4.6E+09	11	99.3	999.2
Pu-244	1.0E+20	1.0E+20	1.8E+13	11	99.3	999.2
Ra-226	1.0E+20	1.0E+20	9.0E+01	11	99.3	999.2

Time interval (years)	**0-12**	**12-100**	**100-1000**	**0-12**	**12-100**	**100-1000**
	Limit	**Limit**	**Limit**	**Peak Time**	**Peak time**	**Peak Time**
Nuclide	**Ci**	**Ci**	**Ci**	**year**	**year**	**year**
Rb-87	1.0E+20	1.2E+17	4.7E+00	11	99.3	999.2
Se-79	1.0E+20	1.0E+20	1.8E+02	11	99.3	999.2
Sn-126	1.0E+20	1.0E+20	3.9E+01	11	99.3	999.2
Sr-90	1.9E+13	1.9E+05	8.9E+02	11	99.3	410.2
Tc-99	6.9E-01	1.7E-01	4.8E+01	11.9	19.1	100
Th-228	1.0E+20	1.0E+20	1.0E+20	11	30.1	100.3
Th-229	1.0E+20	1.0E+20	9.5E+03	11	99.3	999.2
Th-230	1.0E+20	1.0E+20	1.9E+01	11	99.3	999.2
Th-232	1.0E+20	1.0E+20	3.1E+03	11	49.2	999.2
U-232	1.0E+20	1.0E+20	3.2E+06	11	99.3	786.2
U-233	1.0E+20	1.0E+20	4.8E+03	11	99.3	999.2
U-234	1.0E+20	1.0E+20	2.7E+03	11	99.3	999.2
U-234_MGlass	1.0E+20	1.0E+20	2.3E+06	11	99.3	999.2
U-235	1.0E+20	1.0E+20	4.1E+02	11	99.3	999.2
U-235_MGlass	1.0E+20	1.0E+20	3.9E+05	11	99.3	999.2
U-236	1.0E+20	1.0E+20	6.5E+03	11	99.3	999.2
U-236_MGlass	1.0E+20	1.0E+20	2.7E+06	11	99.3	999.2
U-238	1.0E+20	1.0E+20	4.6E+02	11	99.3	999.2
U-238_MGlass	1.0E+20	1.0E+20	2.9E+05	11	99.3	999.2
Zr-93	1.0E+20	1.0E+20	3.6E+03	11	99.3	999.2
Zr-95	1.0E+20	1.0E+20	1.0E+20	4	12	100.3
Nuclides analyzed assuming instant decay of parent to a progeny						
Am-241	8.2E+13	1.8E+05	8.9E+01	11	99.3	412.2
Bk-249	1.0E+20	2.1E+17	2.6E+05	11	99.3	999.2
Cf-250	1.0E+20	1.0E+20	8.7E+07	11	99.3	999.2
Cf-252	1.0E+20	1.0E+20	7.4E+09	11	99.3	999.2
Cm-242	1.0E+20	1.0E+20	3.3E+09	11	99.3	999.2
Cm-244	1.0E+20	1.0E+20	1.3E+11	11	99.3	999.2

Table A- 2. Groundwater pathway limits and time of peak aquifer concentration for colloids

Time interval (years)	0-12	12-100	100-1000	0-12	12-100	100-1000
	Limit	Limit	Limit	Peak Time	Peak time	Peak Time
Nuclide	Ci	Ci	Ci	year	year	year
Am-243	1.3E+06	1.4E+05	1.5E+04	11	99.3	999.2
Cf-249	6.0E+07	7.0E+05	1.8E+04	11	99.3	999.2
Cm-245	2.6E+04	2.7E+03	4.9E+02	11	99.3	999.2
Cm-247	2.5E+09	3.0E+07	3.1E+05	11	99.3	999.2
Cm-248	4.5E+09	5.0E+08	5.0E+07	11	99.3	999.2
Pu-238	4.4E+02	4.9E+02	9.8E+02	0	12	100.3
Pu-239	4.0E+02	4.0E+02	4.0E+02	0	12	100.3
Pu-240	4.0E+02	4.0E+02	4.1E+02	0	12	100.3
Pu-241	1.3E+04	1.2E+04	1.3E+04	11	44	100.3
Pu-242	4.1E+02	4.1E+02	4.1E+02	0	12	100.3
Pu-244	4.3E+02	4.3E+02	4.3E+02	0	12	100.3

Time interval (years)	0-12 Limit	12-100 Limit	100-1000 Limit	0-12 Peak Time	12-100 Peak time	100-1000 Peak Time
Nuclide	Ci	Ci	Ci	year	year	year
Nuclides analyzed assuming instant decay of parent to a progeny						
Bk-249	2.4E+10	2.8E+08	7.1E+06	11	99.3	999.2
Cf-252	5.8E+14	6.5E+13	6.4E+12	11	99.3	999.2
Cm-242	8.7E+04	9.6E+04	1.9E+05	0	12	100.3
Cm-244	1.5E+05	1.5E+05	1.5E+05	0	12	100.3

Radon Analysis

INTRODUCTION

This section describes the investigation conducted to evaluate the potential for radon release from the E-Area Slit and Engineered Trenches over the 1,000-year performance assessment period of interest. The permissible radon flux for DOE facilities is addressed in USDOE 1999a (DOE Order 435.1). This order states that the release of radon, either as a constituent of waste at the time of disposal or produced by radioactive decay following disposal, should not be released from the disposal facility at a rate that would exceed the limit established in 40 CFR Part 61. From this statute, the standard identified for radon release is stated as "No source at a Department of Energy facility shall emit more than 20 pCi/m^2-s of Radon-222 as an average for the entire source, into the air". No other Radon isotopes are identified in this guidance. The USDOE Order 435.1 indicates that the radon release projected for a specific facility at the land surface should be compared to the 20 pCi/m^2-s standard.

This guidance forms the basis for the investigation to evaluate radon flux above the Engineered Trenches at the SRS. The scope of the investigation involved defining a decay chain of parent radioisotopes to evaluate with a 1D vertical numerical model. The model was customized to represent the thickness of the waste zones and cover material over the facilities. The instantaneous Radon-222 flux at the land surface was evaluated at the Performance Assessment compliance period of 1,000 years. This flux was then compared to the standard identified in 40 CFR Part 61.

The potential parent radioisotopes that can contribute to the creation of Rn-222 are illustrated in Figure 1. The diagram indicates the specific decay chains that lead to the formation of Rn-222, as well as the half-lives of each radioisotope. The extremely long half-lives of Pu-242 and U-238 (375,500 and 4,500,000 years respectively) cause the other radioisotopes higher up on the chain of parents to be of little concern with regard to their potential to contribute significantly to the Rn-222 flux at the land surface in the period of interest. The only other radon isotope that is mentioned in DOE Order 435.1 is "Rn-220 from Thorium". This decay chain was screened out as a part of this investigation due to its extremely short half-life of 55.6 seconds.

TRENCH CLOSURE CONSIDERATIONS

The concepts for closure of the E-Area Slit and Engineered Trenches are relevant to the determination of the radon flux at the land surface during the PA compliance period (1,000 years). These concepts are described in Phifer, 2004, *Preliminary E-Area Trench Closure Cap, Closure Sequence, Infiltration and Waste Thickness (U)*. The specific design is presented below. It is assumed that there will be a 25-year operations period during which the unit is loaded with waste. This is followed by a 100-year period of institutional control during which a temporary

surface runoff cover will be placed over the trench and maintained. Following the institutional control period the trench unit will be prepared for final closure. Specific information with regard to the construction of the final closure cap is presented below. The final closure cap will exist far into the future and is the configuration that must be considered in evaluating the long-term radon release at the land surface.

Trench closure configuration

During the operational period, a typical 20-foot deep trench will be filled with 16 ft. (4.9 m) of waste material and at least 4 ft. (1.2 m) of soil cover. At the end of the 25-year operational period, the trench will be covered

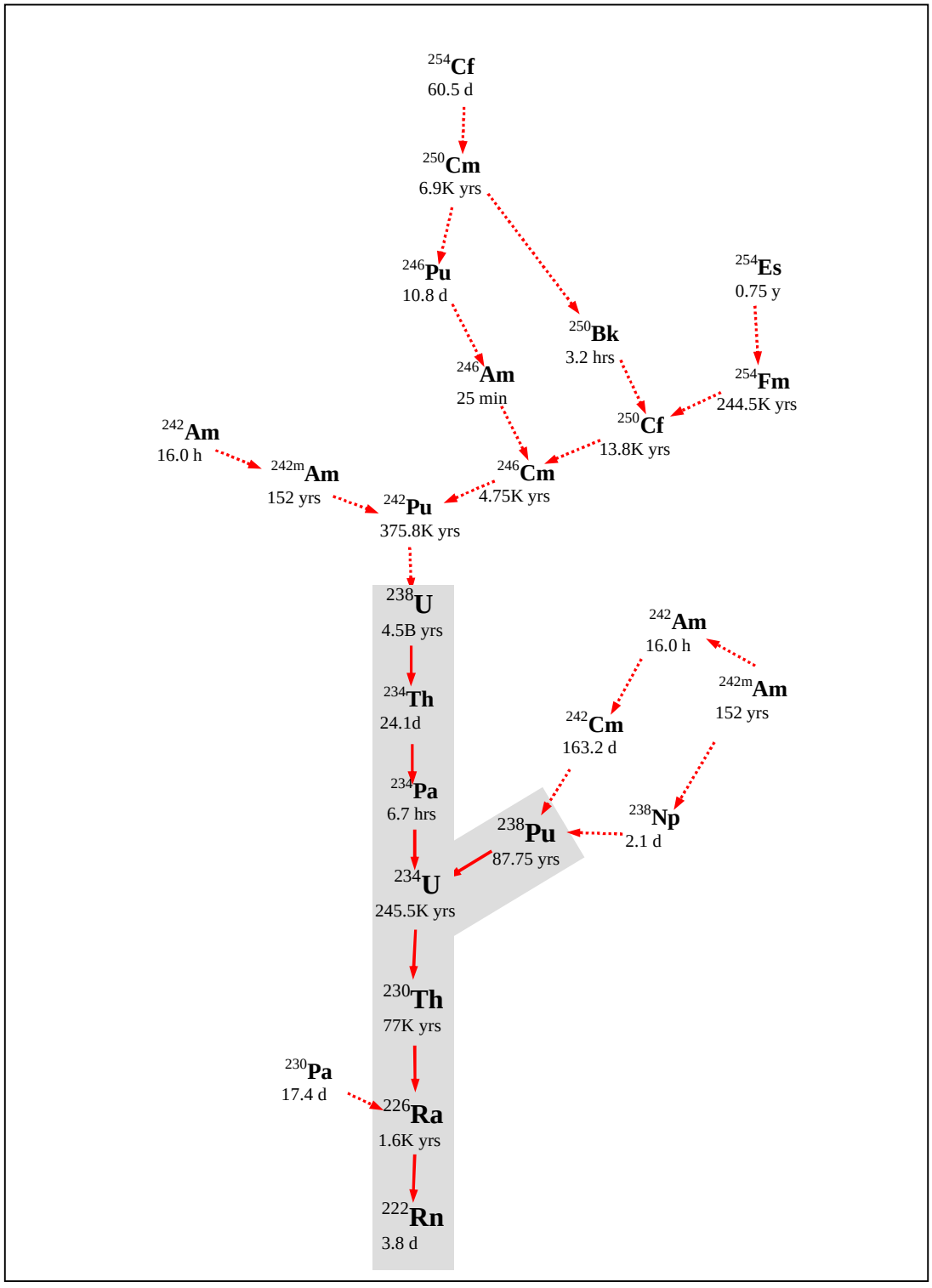

Figure 1. Decay chain of parent radioisotopes leading to Rn-222 formation.

with a temporary surface runoff cover. Maintenance of this cover will continue throughout the subsequent 100-year institutional control period.

At the end of the 100-year institutional control period, dynamic compaction of the trench fill will be performed. It is estimated in Phifer and Wilhite, 2001, that the potential for subsidence for a 16-foot (4.9 m) waste thickness was approximately 13.5 feet (4.1 m). It is therefore assumed that dynamic compaction will compress the waste into a 2.5-foot (0.8 m) zone at the base of the trench. As dynamic compaction progresses, soil fill will be added to maintain grade at land surface.

A final closure cap will be placed over the compacted and filled trench as described in Phifer, 2004. Table 1 below describes the individual components of that cap, compacted soil fill and waste material and indicates the thickness of each component in inches, cm and m.

Table 1. Vertical layer sequence and associated thickness for Trench cover material. (adapted from Phifer, 2004)

Layer	Thickness (inches)	Thickness (cm)	Thickness (m)
Topsoil	6	15.2	0.15
Upper Backfill	30	76.2	0.76
Erosion Barrier	12	30.5	0.30
Middle Backfill	12	30.5	0.30
Geotextile Filter Fabric	0.1	0.3	0.00
Upper Drainage Layer	12	30.5	0.30
Upper GCL	0.2	0.5	0.01
Lower Backfill	59	149.9	1.50
Geotextile Filter Fabric	0.1	0.3	0.00
Lower Drainage Layer	24	61.0	0.61
Lower GCL	0.2	0.5	0.01
Compacted Soil Fill	162	411.5	4.11
Compacted Waste Zone	30	76.2	0.76

The components of concern for the long-term radon performance calculation are those that will persist over the 1000-year PA evaluation period and probably for > 10,000 years. These components are situated below the top of the Erosion Barrier. The composite thickness of the non-waste material below the top of the Erosion Barrier is 23.5 ft. (7.15 m).

MODEL DEVELOPMENT

Conceptual Model

The Rn-222 flux at the land surface above an E-Area trench was evaluated for its specific closure configuration. Rn-222 is generated within the waste zones of each disposal unit by radioactive decay of different parent isotopes following along the decay chains that lead to the formation of Rn-222. The decay chains for all possible parent isotopes of Rn-222 are shown in Figure 1. In Figure 1 the part of the decay chain that was simulated is indicated with the gray shaded area (i.e.

beginning with U-238 and Pu-238 and proceeding to Rn-222). Rn-222 generated within the waste zone is in the gaseous form and diffuses outward from this zone into the air-filled pore space surrounding the waste zone, eventually resulting in some of the radon emanating at the land surface. As such, air is the fluid through which Rn-222 diffuses, although some Rn-222 may dissolve in the residual pore water. Advective transport of Rn-222 in air-filled soil pores is not considered to be a significant process when compared to air diffusion. The parent isotopes exist in the solid phase and therefore do not migrate upward through the air-filled pore space, although they could be leached and transported downward from the waste zone by pore water.

The time period of interest for which Rn-222 flux at the land surface was evaluated is 1,000 years, as specified in DOE Order 435.1. An additional 125 years were added to this to account for any possible Rn-222 buildup during the 25-year operational period and 100-year institutional control period. In addition, an evaluation was conducted for 10,000-years so that results could be compared to those formerly obtained in the E-Area Low Level Waste Facility Performance Assessment, which was evaluated for 10,000 years.

Numerical Model

The mathematical model utilized in this report is provided by the PORFLOW™ simulation package. PC-based PORFLOW™ Version 5.97.0 was used to conduct a series of simulations. PORFLOW™ is developed and marketed by Analytic & Computational Research, Inc. to solve problems involving transient and steady-state fluid flow, heat and mass transport in multi-phase, variably saturated, porous or fractured media with dynamic phase change. PORFLOW™ has been widely used at the SRS and in the DOE complex to address major issues related to the ground water and nuclear waste management.

The governing equation for mass transport of species *k* in the fluid phase is given by

$$\frac{\partial C_k}{\partial t} + \frac{\partial}{\partial x_i}(V_i C_k) = \frac{\partial}{\partial x_i}(D_{ij}\frac{\partial C_k}{\partial x_j}) + \mathrm{g}_k$$

Where

C_k	concentration of species *k* [Activity]/[L]^3
V_i	fluid velocity in the ith direction [L]/[t]
D_{ij}	effective diffusion coefficient for the species [L]^2/[t]
$\bullet_k$	net decay of species *k* [m]/[L]^3 [t]
i, j	direction index
x	direction coordinate [L]
t	time [t]

This equation is solved using PORFLOW to evaluate transient Rn-222 transport through the soil cover above the Slit and Engineered Trenches to evaluate Rn-222 flux at the land surface over time. The units utilized within the numerical model to define the terms of this equation were grams, meters and years while activity, in Ci, was utilized. Boundary conditions for application of this equation are discussed in the section below.

Model Development and Assumptions

The numerical representation of the conceptual model is as a 1-dimensional vertical stack of elements configured to represent the thickness of the waste zone and overlying cover material for typical Slit and Engineered trench construction. The conditions and assumptions of this model are:

Decay chains evaluated were U-238 à Th-234 à Pa-234 à U-234 à Th-230 à Ra-226 à Rn-222 and Pu-238 à U-234 à Th-230 à Ra-226 à Rn-222. These chains are shaded solid gray in Figure 1. Each parent in these chains, except Th-234 and Pa-234, were simulated separately as the starting point of the decay chain. Th-234 and Pa-234 have extremely short half-lives compared to the other parent isotopes in these chains.

In soils, it has been shown that only a fraction of the Rn-222 generated by the decay of radium is available for migration away from its source and into open pore space. A radon emanation coefficient is used to approximate the percentage of radon escaping its source location to the pore space of the host medium. Observed values range from 0.01 to 0.8 and a typical value for soils with low moisture content is 0.2. Experimental data also indicates that the moisture content tends to reduce the percentage of radon that reaches open pore space. The 0.2 value is the default for the analytical model, RESRAD, developed for DOE (Yu, et. al, 2001). The waste sources to be disposed in the Engineered and Slit Trenches are not contaminated soils but will be surrounded and covered with soil. This model to approximate the effective release of radon from the source into the open pore space (use of an emanation coefficient) is regarded as valid for this analysis and a value of 0.25 was utilized for each parent isotope that was evaluated. The emanation coefficient was incorporated into model simulations by use of an effective source term, 0.25 Ci of parent isotope, for each 1 Ci disposed within the facility.

Since Rn-222 exists primarily in the gaseous state, air was taken to be the fluid within which radon transport occurs. Air-diffusion was the only transport mechanism simulated in the model and advective air-transport is assumed to be negligible. Some radon dissolves in pore water but since diffusion proceeds more slowly in that fluid, air-diffusion is the only transport process by which Rn-222 can reach the land surface when it is originates in the waste zone. Transport was allowed to proceed only through air-filled pore space and, therefore, residual pore water was treated as if it was part of the solid matrix material within the flow field. No credit was taken for airborne radon dissolving in pore water as it proceeds from a Trench to the land surface although it has been observed to partition between air and water in the ratio of 4 to 1, respectively, at 20 C (Nazaroff and Nero, 1988).

The boundary conditions imposed on the domain included:

- No-flux specified for Rn-222 along sides and bottom of the domain
- Rn-222 concentration set to 0 at the top of the domain (land surface)
- No-flux specified for all other parent isotopes at perimeter of the domain

Simulations were conducted in transient mode for diffusive transport, with results being obtained at 1,125 years for all parent isotopes and a single simulation for U-234 extending to 10,125 years.

Measures implemented to assure conservative results

In this analysis, several conditions introduce a significant measure of conservatism into the calculations; these include:

- The use of no-flow boundary conditions on the sides and base of the model which force all of the Rn-222 to move upward from the waste disposal zone to the land surface. In reality, some of the Rn-222 diffuses sideways and downward in the air-filled pores surrounding the waste zone, hence ignoring this has the effect of increasing the radon flux at the land surface.

- No accounting for the removal of either Rn-222 or of the parent isotopes by pore water moving vertically downward through the model domain. This mechanism would likely carry off some dissolved Rn-222 in addition to the parent isotopes, and therefore its omission has the effect of increasing the estimate of instantaneous Rn-222 flux at the land surface in simulations conducted as a part of this investigation.

- The addition of an extra 125 years to the required 1,000-year evaluation period to account for any Rn-222 generated during the operations and institutional control period, thus incrementally increasing the instantaneous Rn-222 flux. The extra time means slightly higher instantaneous fluxes for all parent isotopes except Ra-226.

- No accounting for the compaction that is planned following 100-years of institutional control. The non-compacted waste zone sits closer to the land surface and therefore Rn-222 has a shorter distance to diffuse to the land surface, resulting in a higher instantaneous flux at the land surface over the 1,000-year evaluation period.

- No accounting for the partitioning of Rn-222 between water and air, either in the waste zone or in the overlying soil cover. This ratio is reported to be 4:1 between air and water (Nazaroff and Nero, 1988).

Grid Construction

The model grid was constructed as a node mesh 3 nodes wide by 38 nodes high. This mesh creates the vertical stack of 36 model elements. An illustration of this node and element configuration is presented below in Figure 2, which also indicates the correspondence of model zones with the revised closure configuration for a typical trench, as presented in Phifer, 2004. The grid extends upward only as far as the erosion barrier, anticipating that it will perform as expected in terms of halting erosion over the entire 1,000-year PA compliance period. Soil cover above that point is ignored as a measure of conservatism. A set of consistent units were employed in the simulations for length, mass and time, these being meters, grams and years, respectively.

Material zones

The model domain was divided into two zones, the Compacted Waste Zone occupying the lower 2.5 ft. (0.76 m) of the domain and the Soil Cover Zone, extending ~23.5 ft. (~7.1 m) above the Waste Zone to the top of the domain. The Soil Cover Zone includes the soil fill that will be added to maintain grade as compaction proceeds as well as the different closure cap layers. The top of the domain is scaled to correspond to the geometry of the trench disposal configuration with the top of the erosion resistant layer being regarded as the land surface.

Material zone properties and other input parameters

Material properties utilized within the 1-D numerical model are summarized in Table 2. Properties for both the Compacted Waste Zone and the Soil Cover Zone were represented identically. Each of these material zones were assigned values for tortuosity, total porosity, residual saturation, air-filled porosity, matrix density, air density, and diffusivity

The rock (matrix) density was selected based on the density of quartz, and is regarded to be representative of most soils. Tortuosity was assigned based on the commonly used value associated with a spherical particle tortuosity equation developed by Nielson and Rogers, 1982. Total porosities for soil materials were selected based on the typical values for soil materials found at the SRS. A typical value for residual moisture content in SRS soil material (0.6) was utilized and is consistent with simulated steady-state values that persist after the degradation of the closure cap (Flach and Hiergesell, 2004). The density of air was obtained from the Bolz, et. al., CRC Handbook of tables for Applied Engineering Science. The Rn-222 diffusivity value was selected based on the value for coefficient of diffusion of Rn-222 in open air, as reported in Rogers, et. al., 1984.

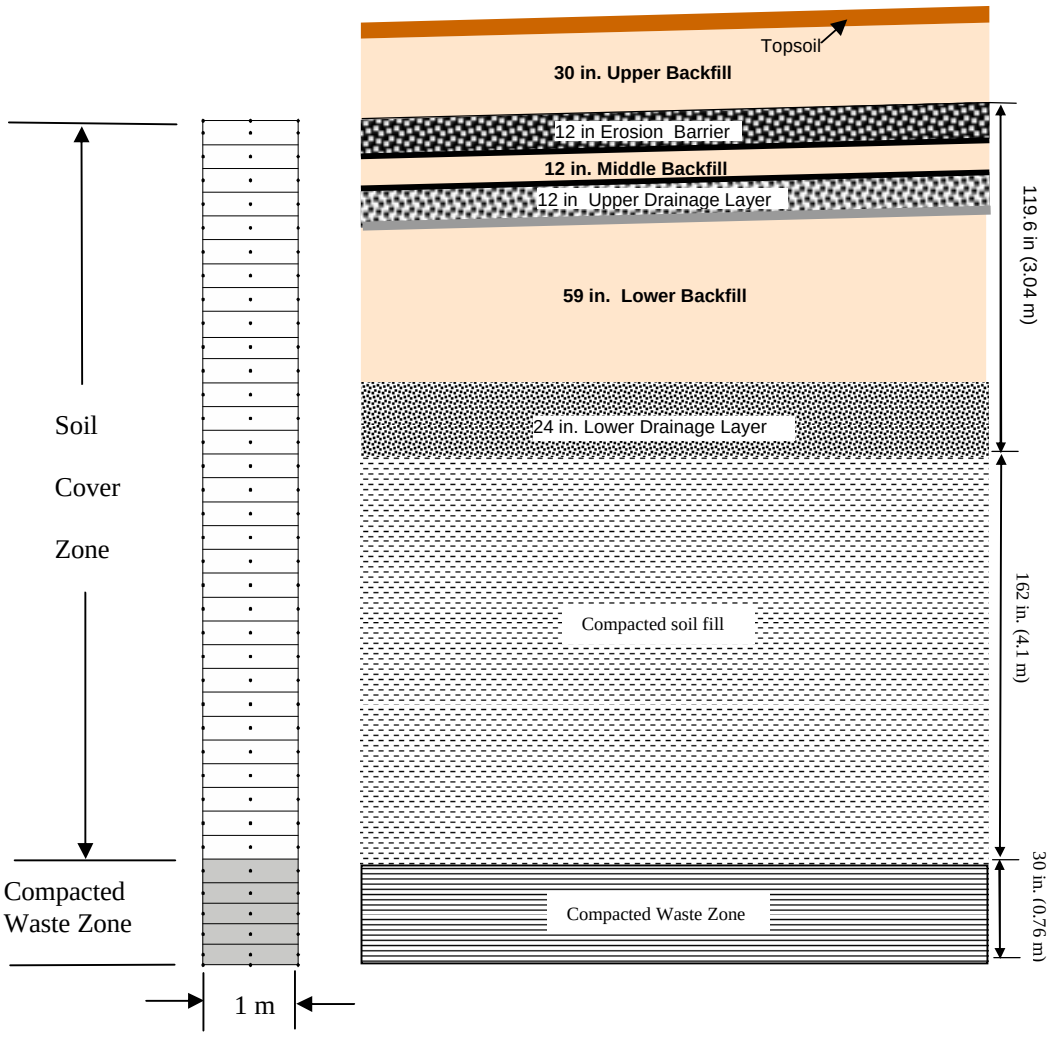

Figure 2. Model grid and associated trench closure configuration.

Table 2 Matrix and fluid properties utilized within the numerical model.

Property	Compacted Waste Zone	Soil Cover Zone
Tortuosity	0.66	0.66
Total Porosity	0.3	0.3
Residual Saturation	0.6	0.6
Air-filled Porosity	0.12	0.12
Matrix Density (g/m^3)	2.65E+06[a]	2.65E+06[a]
Air Density (g/m^3)	1.24E+03[b]	1.24E+03[b]
Molecular Diffusivity (m^2/yr)	3.47E+02[c]	3.47E+02[c]

a. CRC Handbook of Applied Engineering Science, 2'nd Ed. Table 1-2, pg. 11
b. CRC Handbook of Applied Engineering Science, 2'nd Ed. Table 1-121, pg.192
c. Rogers, et. al., 1984.

The Soil Cover Zone is treated as a single homogenous zone within this simulation, despite the layering of the closure cap. This simplification is justified for this type conceptual model where radon is simulated as diffusing only through the air filled pores. Total porosities of the separate materials undoubtedly range from a high in the gravel drain layers (up to 0.4) to a low in the compacted soil layers (<0.1) a single value of 0.3 for porosity is regarded to be a representative value for a composite of all the materials. Since radon diffuses only through the air-filled pore space, the porosity value was multiplied by (1- relative moisture content) to obtain the air filled porosity. A residual moisture content of 0.6 was assumed to prevail over the period of interest, therefore (1- 0.6) x 0.3 = 0.12.

A typical model input file is presented in the ATTACHMENT showing the specific PORFLOW commands used to implement the numerical model.

MODEL RESULTS

Model simulations were conducted to evaluate the peak instantaneous Rn-222 flux at the land surface over the 1,125 year period. This time period includes the 25-year operations cycle, 100-years of institutional control and 1,000-year PA compliance period identified in DOE Order 435.1. Model results were output in Ci/m^2-yr, consistent with the set of units employed in the model. The results were then converted into pCi/m^2-sec, which are the units used to define the regulatory flux limit in 40 CFR Part 61, Rev. 4. The results represent the peak Rn-222 flux per square meter at the top of the closure cap erosion barrier and are listed below in Table 3. The top of the erosion barrier is expected to represent the land surface 1,000 years in the future. Also shown in Table 3 are disposal limits associated with each parent isotope, expressed in Ci of parent isotope permitted per square meter of surface area of the disposal facility.

Peak instantaneous Rn-222 fluxes and associated parent disposal limits are indicated for two cases, the first is when the parent isotope is contained entirely within the waste zone following dynamic compaction, and the second case where it is assumed no dynamic compaction occurs. In the latter case the parent isotopes were entrained within the original (non-compacted) trench waste-disposal zone. The non-compacted case is the bounding case which produces a slightly higher Rn-222 flux at the land surface and a correspondingly lower disposal limit. In this

scenario, the entire inventory was placed uniformly within the model elements adjacent to the zone indicated as the "compacted soil fill" in Figure 2.

Table 3. Simulated peak instantaneous Rn-222 flux over 1,000 years at the land surface and the associated trench disposal limits.

Parent Isotope	Peak Instantaneous Rn-222 Flux at land surface (with compaction)	Parent Isotope Disposal Limit per 1 m^2 surface area (with compaction)	Peak Instantaneous Rn-222 Flux at land surface (without compaction)	Parent Isotope Disposal Limit per 1 m^2 surface area (without compaction)
	(pCi/m^2-s)	(Ci)	(pCi/m^2-s)	(Ci)
Pu-238	1.04E-02	1.93E+03	2.65E-02	7.54E+02
U-238	3.95E-02	5.06E+02	1.01E-01	1.98E+02
U-234	3.57E+01	5.60E-01	9.14E+01	2.19E-01
Th-230	6.37E+03	3.14E-03	1.63E+04	1.23E-03
Ra-226	1.68E+04	1.19E-03	4.30E+04	4.65E-04

The peak instantaneous Rn-222 flux simulated for 4 of the 5 parent isotopes occurs at t = 1,125 years, or at the end of the PA period of interest. These parent isotopes are Th-230, U-234, U-238 and Pu-238. The other parent isotope, Ra-226 has its peak at approximately 64.2 days after disposal and slowly declines after that. The instantaneous flux rates at the land surface versus time are shown below in Figure 3 for all 5 parent radioisotopes.

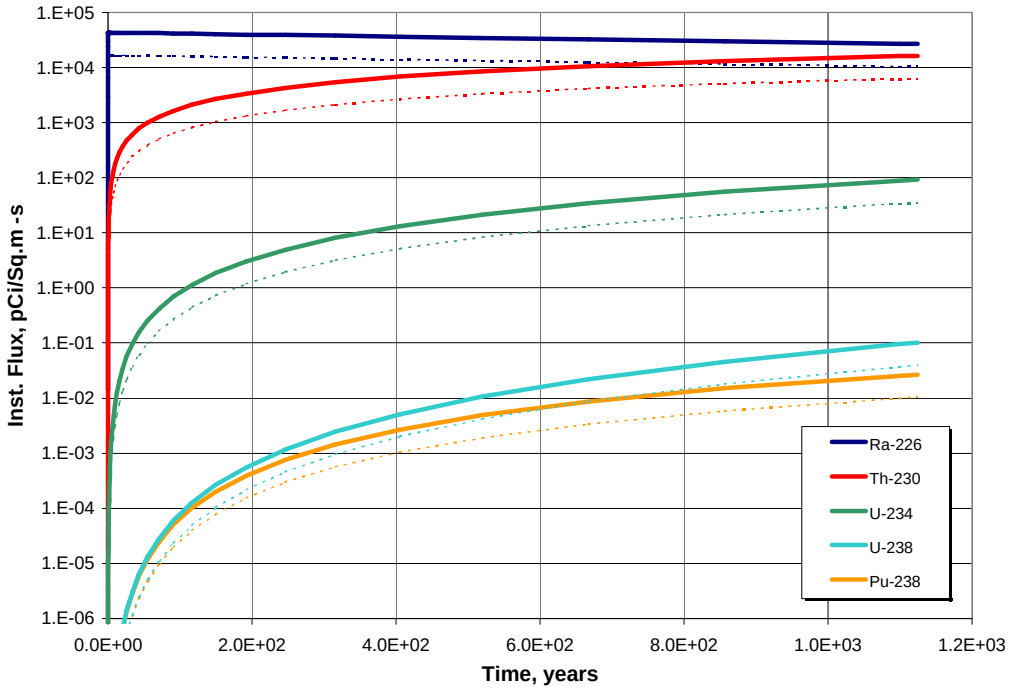

Figure 3 Simulated instantaneous Rn-222 flux versus time.

The bold lines represent fluxes for the non-compacted scenario (Bounding Case) whereas the lighter weight dashed lines of the same color represent fluxes for the compacted scenario for the same isotope.

The equation used to convert the simulated peak Rn-222 activity flux associated with each parent isotope to determine the associated disposal limit is:

Disposal Limit (in Ci/m^2 of disposal facility footprint) = (20 pCi/m^2-sec) / (simulated Rn-222 instantaneous flux, in pCi/m^2-sec).

In this equation the 20 pCi/m^2-sec is the Rn-222 flux limit applicable to the disposal facility at the land surface 1,000 years after facility closure (40 CFR Part 61, Rev 4). The Rn-222 instantaneous flux is the simulated flux associated with 1 Ci of each parent isotope evaluated in this investigation.

DISPOSAL IMPLICATIONS

Several scenarios for the number of trenches and the dimensions of each trench are under consideration in this SA as the preferred configuration. To accommodate this, the unit disposal limits (i.e. Ci of parent isotope per m^2) indicated in Table 3 were applied to each trench configuration. The different configurations are identified as Scenarios 1 through 3 and are defined as follows:

Scenario 1: a disposal unit = 5 trenches, each 656 ft. (200 m) long by 20 ft. (6 m) wide
Scenario 2: a disposal unit = 3 trenches, each 656 ft. (200 m) long by 40 ft. (12 m) wide
Scenario 3: a disposal unit = 1 trench, 656 ft. (200 m) long by 157 ft. (47.9 m) wide

The disposal limits for the non-compacted case (see Table 3) were applied to each of the 3 disposal scenarios. These resulting disposal unit limits are presented below in Table 4, and represent the limits that are applicable for the 1,000-year PA compliance period for the non-compacted, bounding case.

Table 4. 1,000-Year Trench Unit Disposal Limits for SA scenarios, non-compaction case.

Parent Isotope	Limit for 5 Trenches, each 656 ft x 20 ft (Ci/disposal unit)	Limit for 3 Trenches, each 656 ft x 40 ft (Ci/disposal unit)	Limit for 1 Trench 656 ft x 157 ft (Ci/disposal unit)
Pu-238	4.60E+06	5.52E+06	7.22E+06
U-238	1.21E+06	1.45E+06	1.89E+06
U-234	1.33E+03	1.60E+03	2.09E+03
Th-230	7.47E+00	8.96E+00	1.17E+01
Ra-226	2.84E-00	3.40E-00	4.45E-00

Because the potential for disposal of multiple parent isotopes for Rn-222 is possible within the same trench, a Sum of Fractions (SOF) approach to determining how much of each source can be disposed within that trench disposal unit is applicable.

A direct comparison with Rn-222 disposal limits identified in the original Radiological Performance Assessment for the E-Area Low-Level Waste Facility (McDowell-Boyer, et. al. 1994) is possible only for U-234. This was the only isotope analyzed in that investigation with respect to the applicable radon emanation standard (40 CFR Part 61). Since the compliance period at the time of that investigation was 10,000 years, additional simulations were conducted in this investigation to obtain the data needed to make the comparison. The original PA identified a limit of 8.8 Ci/trench unit. In this investigation the limit for a single disposal unit (5 trenches, 656 ft. x 20 ft.) was determined to be 4.15E+01Ci/trench unit for the 10,000-year compliance period. This represents an increase by a factor of 4.7.

REFERENCES

Bolz, R.E. and G.L. Tuve, (Editors), 1973. *Handbook of tables for APPLIED ENGINEERING SCIENCE, 2'nd Edition*. CRC Press, 18901 Cranwood Parkway, Cleveland, OH.

Flach, G.P., and R.A. Hiergesell, 2004. Special Analysis: Revision of Intermediate Level Vault Disposal Limits (U). WSRC-TR-2004-00346, Rev. 0, Westinghouse Savannah River Company, Aiken, South Carolina.

McDowell-Boyer, L., A.D. Yu, J.R. Cook, D.C. Kocher, E.L. Wilhite, H. Holmes-Burns, K.E. Young, 1994, *Radiological Performance Assessment for the E-Area Low Level Waste Facility*. WSRC-RP-94-218, Westinghouse Savannah River Company, Aiken, South Carolina.

Nazaroff, W.W., and A.V. Nero (editors), 1998, Radon and its Decay Products in Indoor Air, John Wiley & Sons, New York, N.Y.

Nielson, K.K., and V.C. Rogers, 1982. A Mathematical model for radon diffusion in earthen materials. NUREG/CR-2765. U.S. Nuclear Regulatory Commission, Washington, D.C.

Phifer, M. A., 2004. *Preliminary E-Area Trench Closure Cap Closure Sequence, Infiltration, and Waste Thickness (U),* WSRC-TR-2004-00119, Rev. 0, Westinghouse Savannah River Company, Aiken, South Carolina, March 12, 2004.

Phifer, M. A., and E.L. Wilhite, 2001. *Waste Subsidence versus Supercompaction*. WSRC-RP-2001-00613, Westinghouse Savannah River Company, Aiken, South Carolina.

Rogers, V.C., K.K. Nielson, and D.R. Kalkwarf. 1984. *Radon Attenuation Handbook for Uranium Mill Tailings Cover Design*, prepared for U.S. Nuclear Regulatory Commission, Washington, D.C., NUREG/CR-3533.

USDOE, 1999a. Radioactive Waste Management. USDOE Order 435.1, Office of Environmental Management, United States Department of Energy, Washington, D.C.

40 CFR Part 61 Rev. 4, 1991. National Emission Standards for Hazardous Air Pollutants, Subpart Q, National Emission Standards for Radon Emissions From Department of Energy Facilities.

Yu, C., A.J. Zielen, J.J. Cheng, D.J. LePoire, E. Gnanapragasam, S. Kamboj, J.Arnish, A. Wallo III, W.A. Williams, and H. Peterson, 2001. *Users Manual for RESRAD Version 6*, Environmental Assessment Division, Argonne National Laboratory. Chicago, Illinois.

ADDENDUM

Example input code for trench simulation

```
/*****************************************************************************
/Title E-Area Trench Diffusion for Rn-222
/1-D Vertical Column w/ 1 Ci U-234 Source
/7.04 m of soil on top of .76 m of waste
/BOUNDING CASE - NO COMPACTION OF WASTE ACHIEVED
/Simulation Length - 1,125Yrs
/DECAY CHAIN is U-234-->Th-230-->Ra226-->Rn222
/SIMULATION UNITS: length = m, mass = g, time = years
/R. A. Hiergesell
/Date 7/14/2004
/*****************************************************************************
GRID 3 by 38
ALLOcate C2
ALLOcate C3
ALLOcate C4
SCALE  1.0000
COORDINATE X:
        0.0        1.0
SCALE 1.0000
COORDINATE Y:
        0. .19 .38 .57 .76 .98 1.20 1.42 1.64 1.86 2.08 2.30 2.52 2.74 2.96
        3.18 3.40 3.62 3.84 4.06 4.28 4.50 4.72 4.94 5.16 5.38 5.60 5.82 6.04
        6.26 6.48 6.70 6.92 7.14 7.36 7.58 7.80  !!! element interfaces
DATUM = 0. 0.
DENSity = 1.24e+3    $ fluid density (air) in g/m^3
/
MATErial type 1 from  1   1  to  3 24          $ WASTE
MATErial type 2 from  1  25  to  3 38          $ SOIL
FOR 1 thru 2
MATErial DENSity = 2.65e+6                     $ particle density in g/m^3
MATErial POROsity = 0.12  0.12  0.12           $ air-filled porosity ((1-0.6) x 0.3)
MATErial TORTuosity = 0.67 0.67
/
LOCAte subregion ( 1,   1) to ( 3, 24) with ID = WASTE
LOCAte subregion ( 1,  25) to ( 3, 38) with ID = SOIL
/
SET INVentory for C to 0.25 in ID=WASTE   $ 1 Ci of U-238 w/ emanation coef = 0.25
/
TRANsport for C4  kd =  0.00, dm = 3.47e+2   $ C4 is Rn-222, dm = mol. diff. in air
/
BOUN C  X-   FLUX = 0.              $ U234
BOUN C  X+   FLUX = 0.
BOUN C  Y-   FLUX = 0.
BOUN C  Y+   FLUX = 0.
/
BOUN C2 X-   FLUX = 0.              $ Th230
BOUN C2 X+   FLUX = 0.
BOUN C2 Y-   FLUX = 0.
BOUN C2 Y+   FLUX = 0.
/
BOUN C3 X-   FLUX = 0.              $ Ra226
BOUN C3 X+   FLUX = 0.
```

```
BOUN C3 Y-   FLUX = 0.
BOUN C3 Y+   FLUX = 0.
/
BOUN C4 X-   FLUX = 0.            $ Rn222
BOUN C4 X+   FLUX = 0.
BOUN C4 Y-   FLUX = 0.
BOUN C4 Y+   VALU = 0.
/
DECAy half LIFE for C  is 2.455e+05 years    $ U-234          from Nuclear Wallet Cards, BNL
DECAy half LIFE for C2 is 7.538e+04 years    $ Th-230         "
DECAy half LIFE for C3 is 1.620e+03 years    $ Ra-226         "
DECAy half LIFE for C4 is 1.047e-02 years    $ Rn-222         "
/
REGEnerate  C2 from C     3.257E+00        $  C/C2
REGEnerate  C3 from C2   4.653E+01        $  C2/C3
REGEnerate  C4 from C3   1.547E+05        $  C3/C4
/
PROPerty for C C2 C3 C4 is GEOM mean
MATRIX in Y direction in 3 sweeps using ADI
/
DIAGnostic node for C4 at ( 2, 38) every 100 steps
/
FLUX for C4 in 'run.flx' every 50 stps   $1K-yr Simulation
/
TIME = 0.
/
CONV C4 REFE GLOBal resid = 1.0e-04,  max_iter 10,  min_iter 2,   F_threshold = 1.e-5
//////////////
DISAble FLOW
////////////
/SOLV  C C2 C3 C4 10125 yrs, init 1.e-5, inc 1.005, max 10.0          $10K-yr Simulation
SOLV  C C2 C3 C4 1125 yrs, init 1.e-5, inc 1.005, max 10.0            $1K-yr Simulation
OUTPut C C2 C3 C4 NOW
/
/SAVE  C C4  in 'run.arc'
END
```

14 APPENDIX B. PLOTS OF CONTAMINANT FLUXES AT THE WATER TABLE AND GROUNDWATER CONCENTRATIONS

Single nuclides

Plots of groundwater concentrations for nuclides modeled without a chain were developed for the time intervals presented in Table B- 1. These groundwater concentrations and contaminant fluxes at the water table are shown in figures grouped in Table B- 2. All information for a single nuclide is presented in a single figure. The contaminant flux at the water table for a 1 Ci inventory of the nuclide is shown as a dashed line.

Table B- 1. Time interval plots for single nuclides

Interval ID	Time interval (years)	Plot color
1	0-12	Red
2	12-100	Green
3	100-1000	Blue

Four plots in one figure are shown for aquifer concentrations at a hypothetical 100-m well. Multiple locations (i.e., aquifer cells) were monitored. The location with the maximum concentration for a specified time interval was plotted in the figures grouped in Table B- 2, with the aquifer concentrations shown for that specified time interval. The time intervals selected and plotted and their associated colors are shown in Table B- 1 at the end of this appendix.

The location (aquifer cell) with the maximum concentration for the first time interval sometimes differed from the location with the maximum concentration for the second or subsequent time intervals. If the concentration front passed completely through one location during the first time interval, then it would appear at another location further away from the source during the second time interval, although its magnitude likely would be reduced.

Chains

Plots of contaminant fluxes at the water table and groundwater concentrations for nuclides modeled with a chain are shown in figures grouped in Table B- 3.

Because information is presented for multiple nuclides, each time interval is plotted in its own figure, as is the flux information. Legends are provided for each figure with varying colors, line thicknesses and line patterns to uniquely identify each curve.

For chains, the maximum concentration for any single nuclide provides only part of the picture. The total dose that a potential receptor would receive is the most important factor for a chain. The total dose is directly related to the sum-of-fractions for the modeled inventory. The fraction for each nuclide in the chain is calculated as its aquifer concentration divided by its performance measure. The performance measure generally is the MCL specified by EPA. For alpha emitters the performance measure was either the MCL or the value calculated for an all-pathways dose of 25 mrem per year for drinking two liters of water each day for one year, whichever was smaller. For non-alpha emitters without an MCL, a quasi-MCL was calculated based on a groundwater pathway dose of 4 mrem per year, a member of the public drinking two liters of water each day for one year and current dose conversion factors.

The fractions and sum-of-fractions for a chain are calculated at each time step for multiple locations representing potential 100-m wells. The location with the maximum sum-of-fractions dictates the inventory limit (which is the inverse of the sum-of-fractions multiplied by the modeled inventory of 1 Ci). Adjustment are made to convert the concentrations from Ci/ft^3 to pCi/L and to double them to account for the fractional flux that would be produced by two sets of Slit Trenches.

Plots for aquifer concentrations at a hypothetical 100-m well in separate figures in Table B- 3. Each figure represents one time interval from Table B- 1. Information from the location with the maximum sum-of-fractions during the specified time interval is plotted in the appropriate figure. That information includes the aquifer concentration and the fraction for each nuclide in the chain. Additionally, the sum-of-fractions is plotted. The concentrations are plotted (versus the Y1 axis) as solid lines, while the fractions and sum-of-fractions are plotted (plotted versus the Y2 axis) as wider dashed lines. For each nuclide, the color of the solid concentration curve and the dashed fraction curve match.

Plots for fluxes show a different color for each nuclide in the chain. In some cases, the range of the X-axis was shortened if all the peaks that would appear in the figure occurred early. The maximum range of the Y-axis (concentrations) was specified as the maximum concentration for any nuclide in the chain for the location with the maximum sum-of-fractions during the time interval being considered. The minimum range of the Y-axis was set at that maximum concentration divided by 1E4. The maximum range of the Y2-axis (fractions) was specified in the same manner as that for the Y-axis, except that the maximum fraction was used. Similarly the minimum range of the Y2-axis was the maximum divided by 1E4. All values that were below the low threshold did not appear in the figure.

The text in the figure shows the peak concentrations for the respective time interval regardless of the location. In many cases one of the nuclides had a higher peak concentration at a location other than where the maximum sum-of-fractions occurred.

As was the case for the single nuclides, the location of the maximum sum-of-fractions often changed from one time interval to the next. The plotted curves were obtained by requesting that PORFLOW monitor a limited set of locations and record that information. A tool available with PORFLOW (the STATISTICS command) allowed all locations beyond the 100-m buffer zone to be monitored continuously, but only reported for the location with the maximum concentration at any time. That information was used to check that the limited set of locations included the location with the maximum concentration during each time interval.

Table B- 2. Plots of contaminant fluxes at the water table and groundwater concentrations for nuclides modeled without a chain

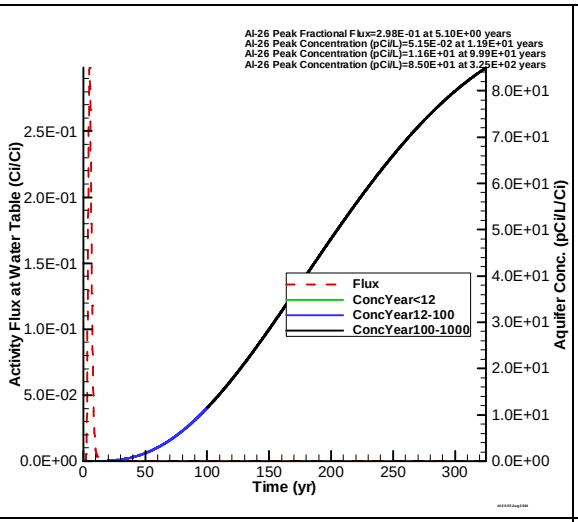

Figure A-1. Fluxes and Concentrations for Al-26

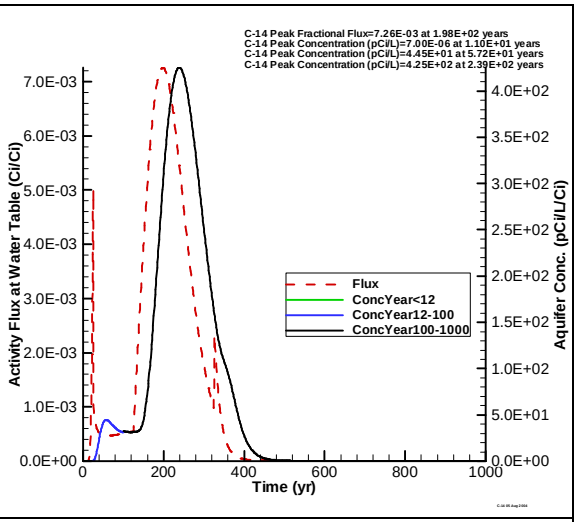

Figure A-2. Fluxes and Concentrations for C-14

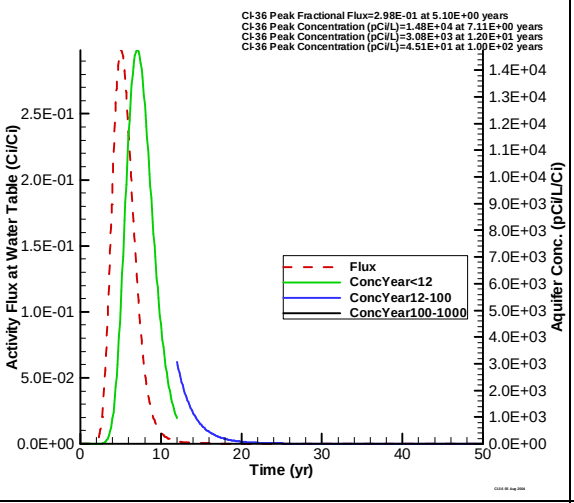

Figure A-3. Fluxes and Concentrations for Cl-36

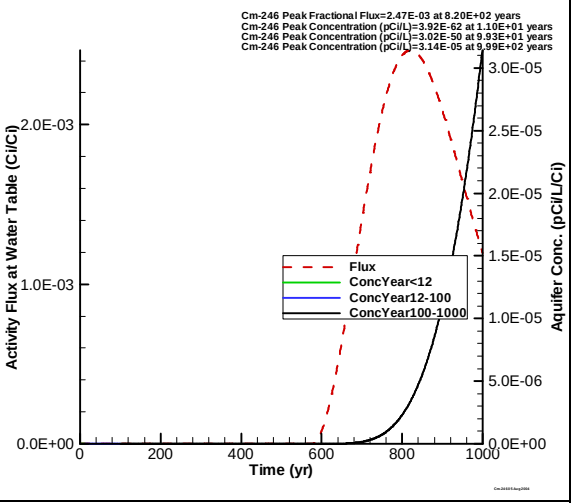

Figure A-4. Fluxes and Concentrations for Cm-246

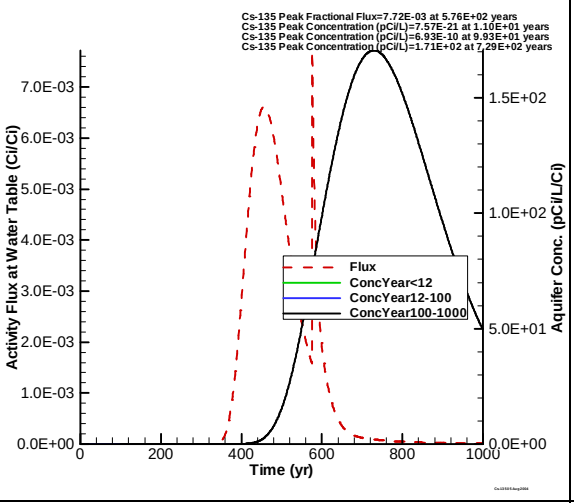

Figure A-5. Fluxes and Concentrations for Cs-135

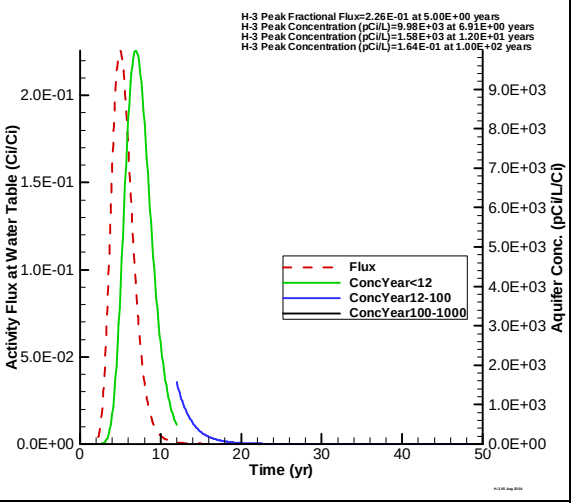

Figure A-6. Fluxes and Concentrations for H-3

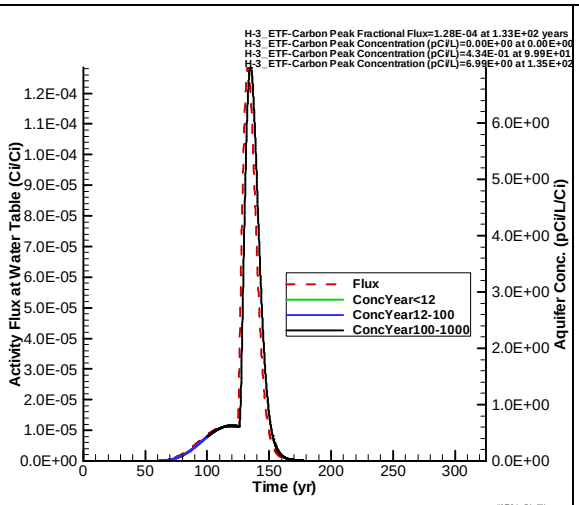

Figure A-7. Fluxes and Concentrations for H-3_ETF-Carbon

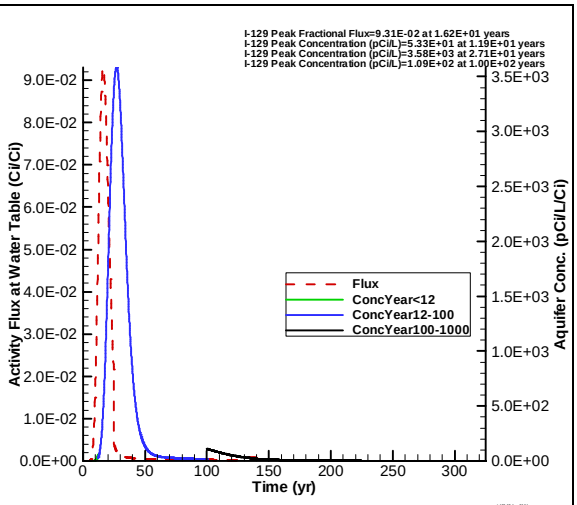

Figure A-8. Fluxes and Concentrations for I-129

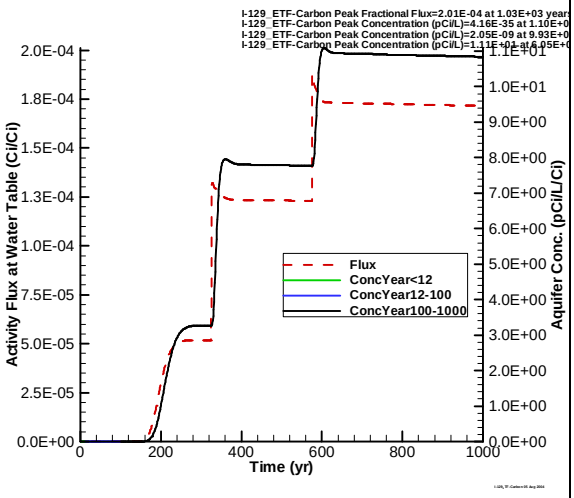

Figure A-9. Fluxes and Concentrations for I-129_ETF-Carbon

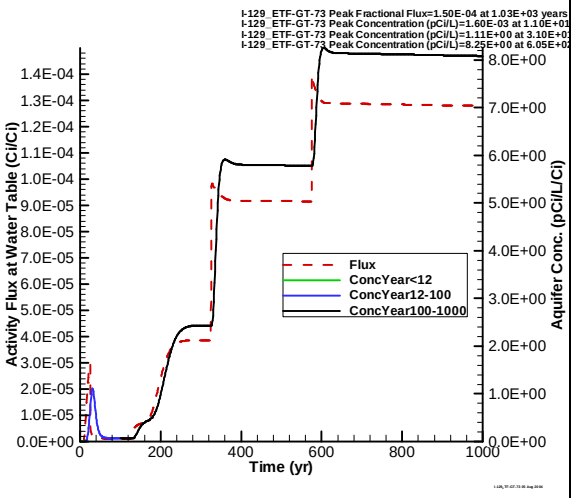

Figure A-10. Fluxes and Concentrations for I-129_ETF-GT-73

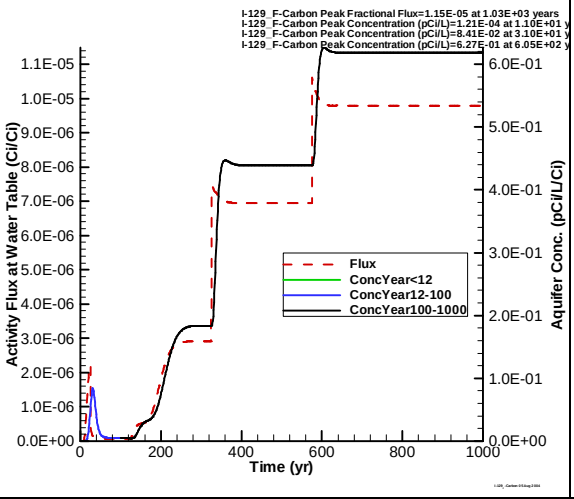

Figure A-11. Fluxes and Concentrations for I-129_F-Carbon

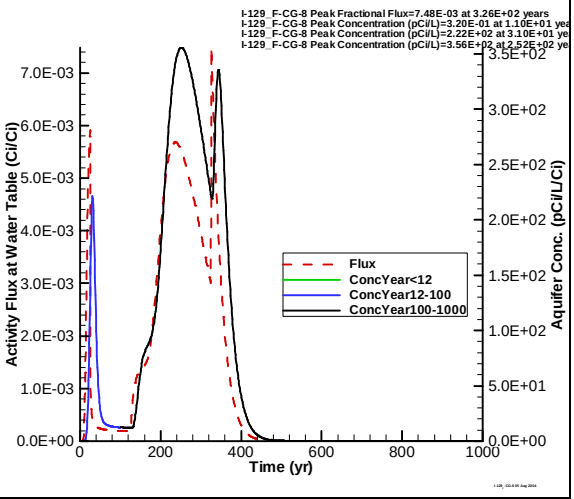

Figure A-12. Fluxes and Concentrations for I-129_F-CG-8

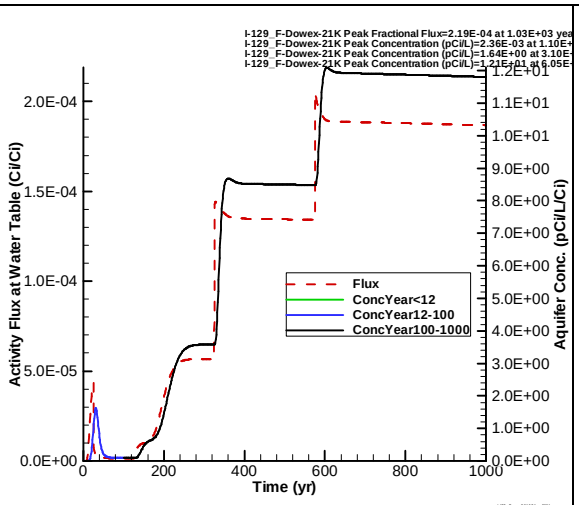

Figure A-13. Fluxes and Concentrations for I-129_F-Dowex-21K

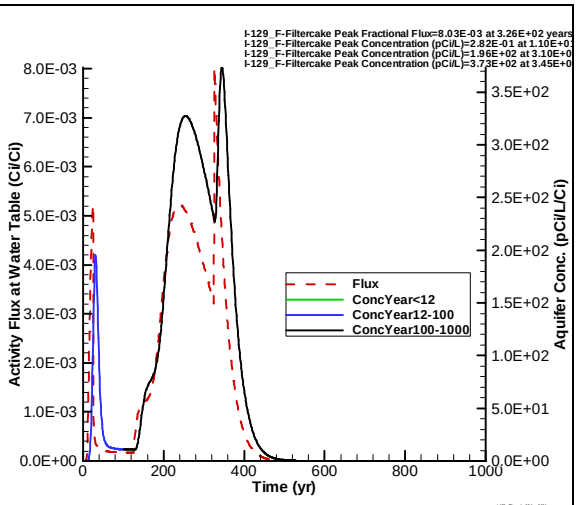

Figure A-14. Fluxes and Concentrations for I-129_F-Filtercake

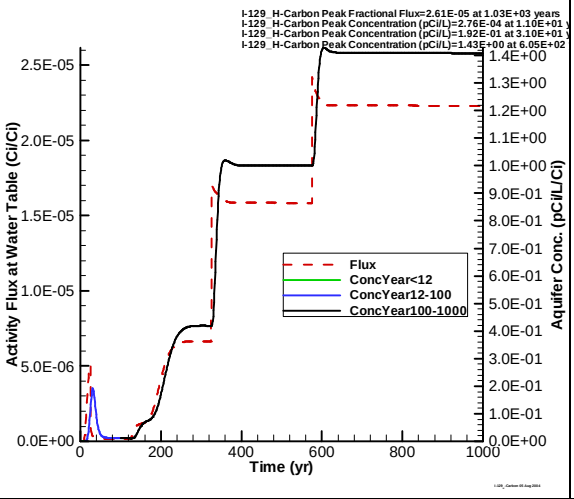

Figure A-15. Fluxes and Concentrations for I-129_H-Carbon

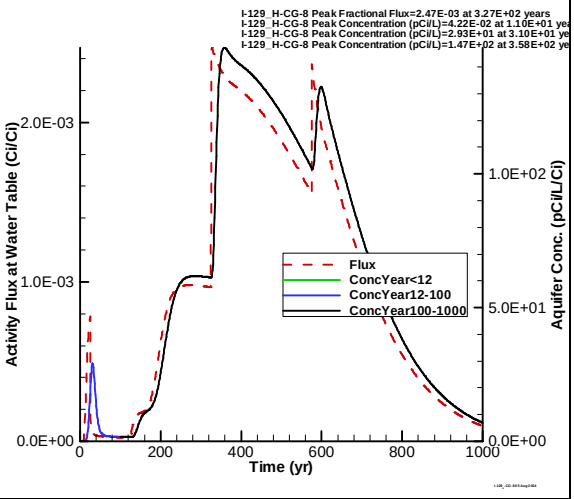

Figure A-16. Fluxes and Concentrations for I-129_H-CG-8

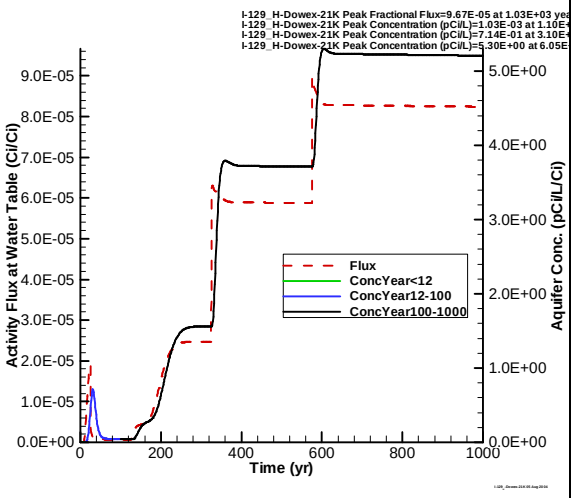

Figure A-17. Fluxes and Concentrations for I-129_H-Dowex-21K

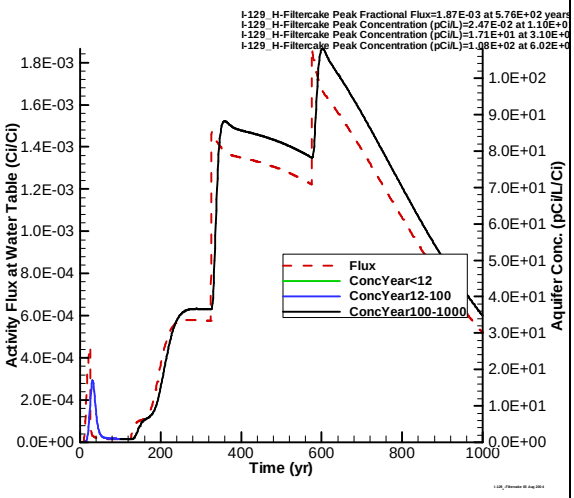

Figure A-18. Fluxes and Concentrations for I-129_H-Filtercake

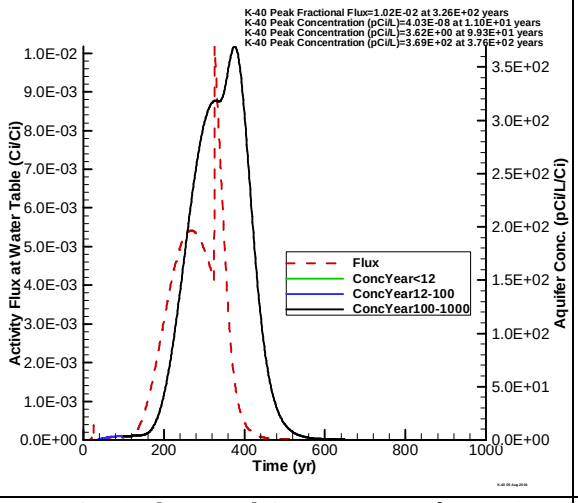

Figure A-19. Fluxes and Concentrations for K-40

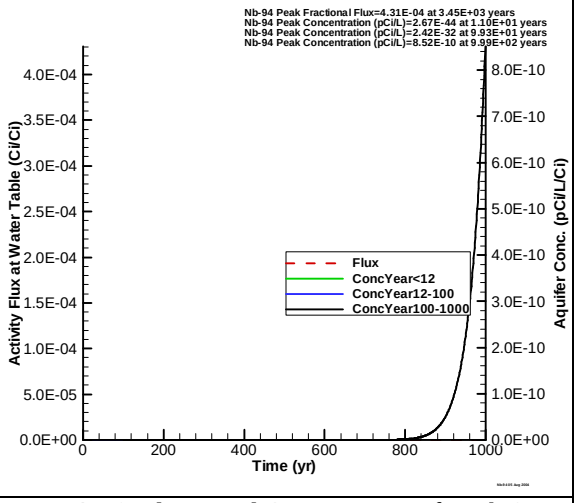

Figure A-20. Fluxes and Concentrations for Nb-94

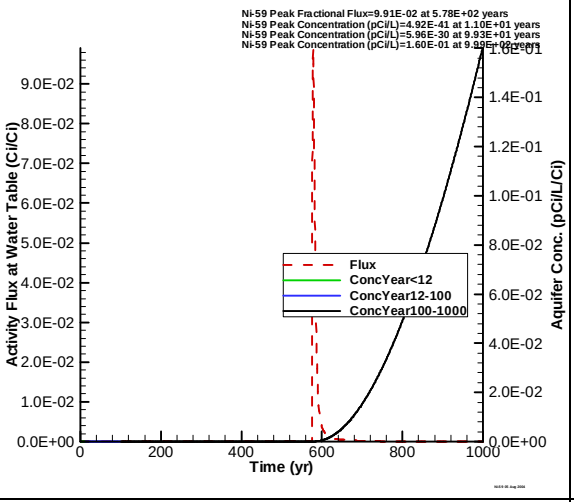

Figure A-21. Fluxes and Concentrations for Ni-59

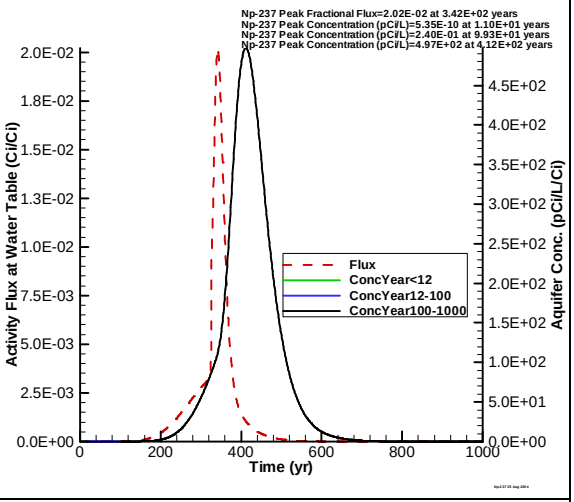

Figure A-22. Fluxes and Concentrations for Np-237

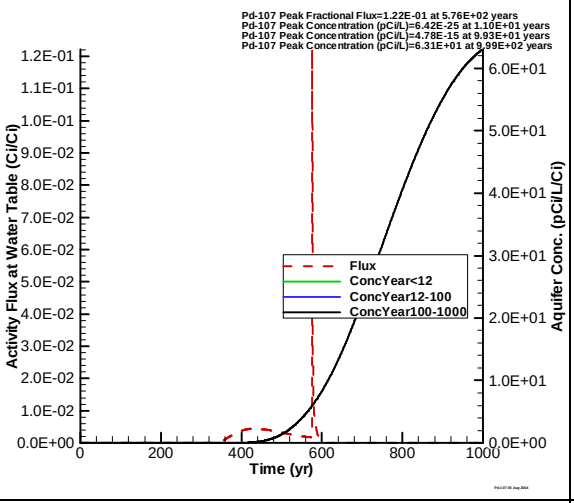

Figure A-23. Fluxes and Concentrations for Pd-107

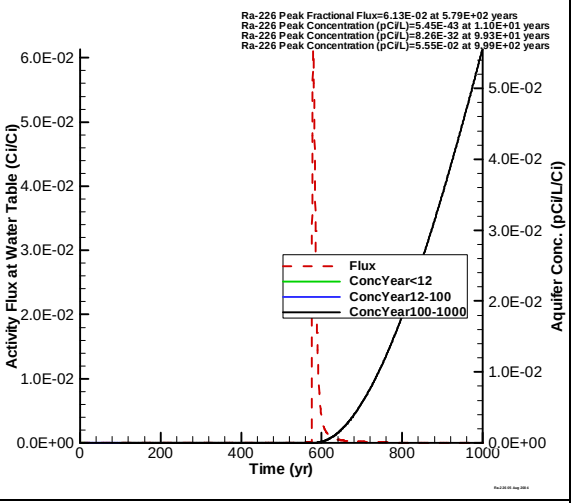

Figure A-24. Fluxes and Concentrations for Ra-226

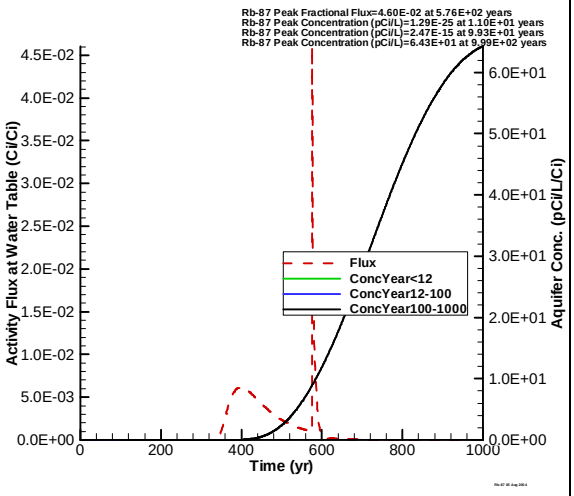

Figure A-25. Fluxes and Concentrations for Rb-87

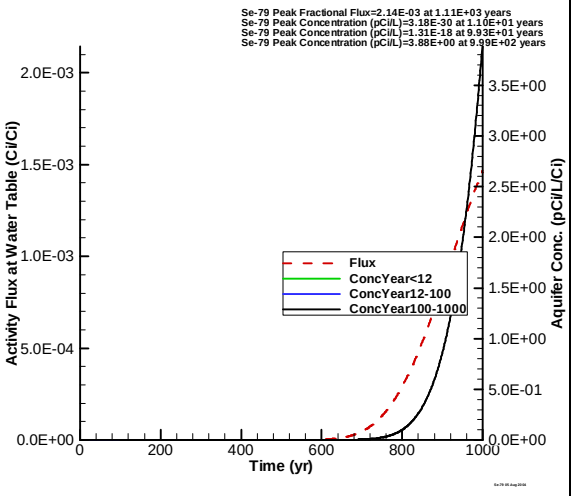

Figure A-26. Fluxes and Concentrations for Se-79

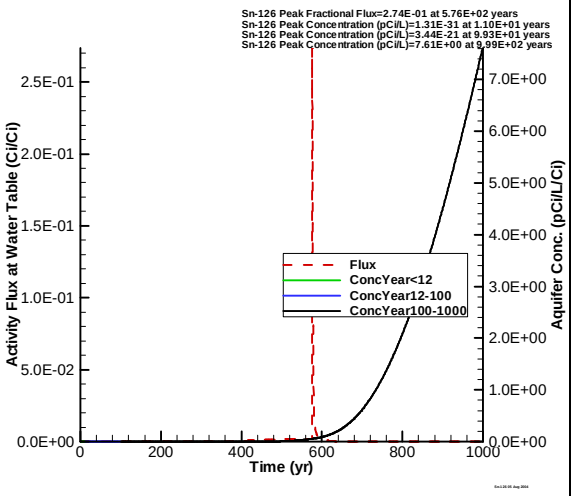

Figure A-27. Fluxes and Concentrations for Sn-126

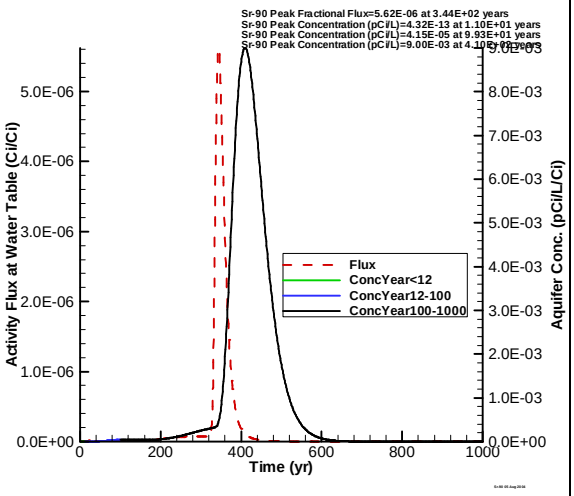

Figure A-28. Fluxes and Concentrations for Sr-90

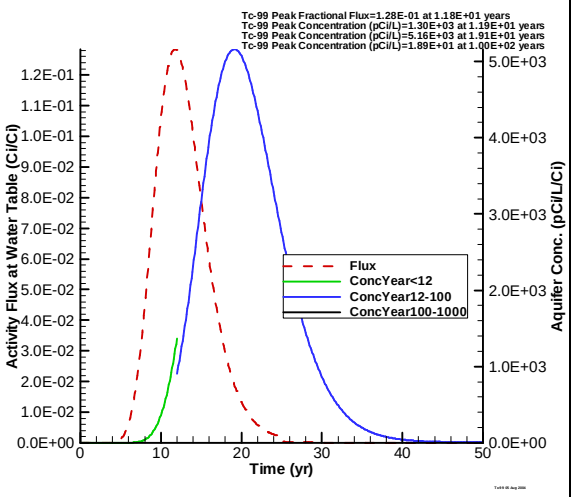

Figure A-29. Fluxes and Concentrations for Tc-99

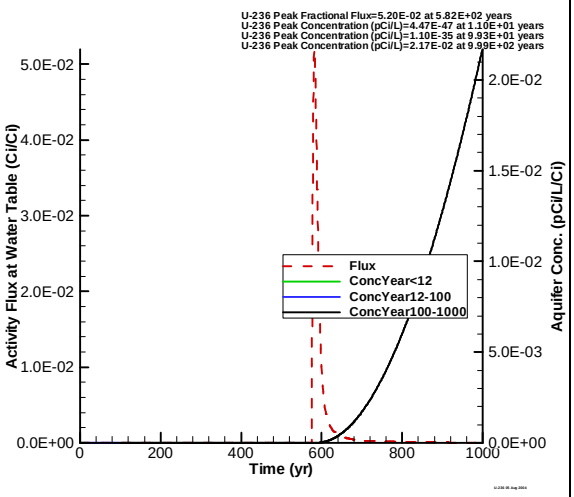

Figure A-30. Fluxes and Concentrations for U-236

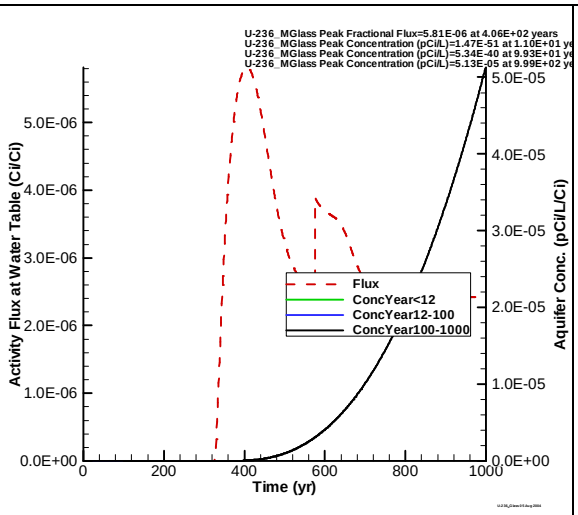

Figure A-31. Fluxes and Concentrations for U-236_MGlass

Table B- 3. Plots of contaminant fluxes at the water table and groundwater concentrations for nuclides modeled with a chain

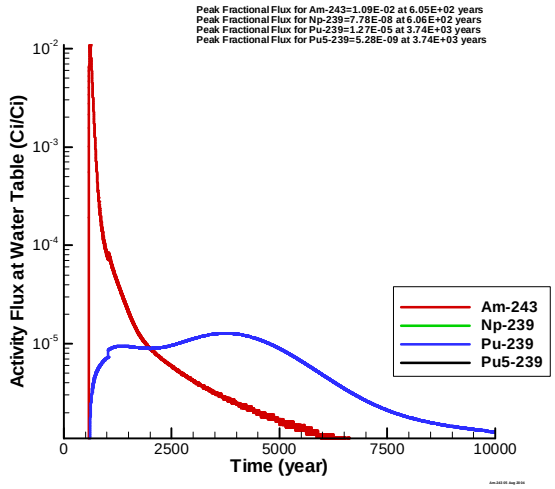

Figure A-32. Fluxes for Am-243

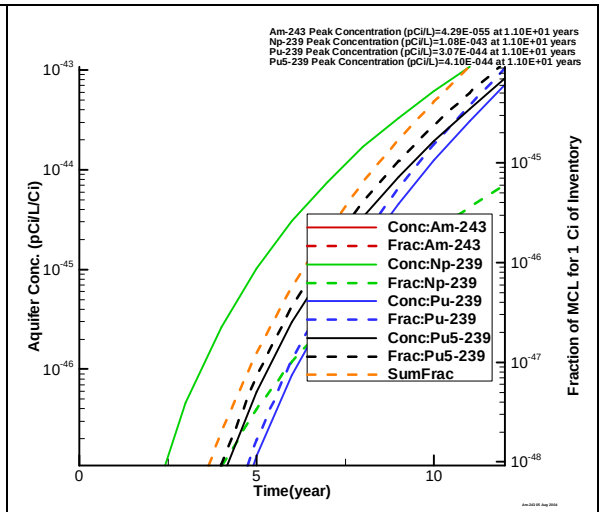

Figure A-33. Concs 0-12 years for Am-243

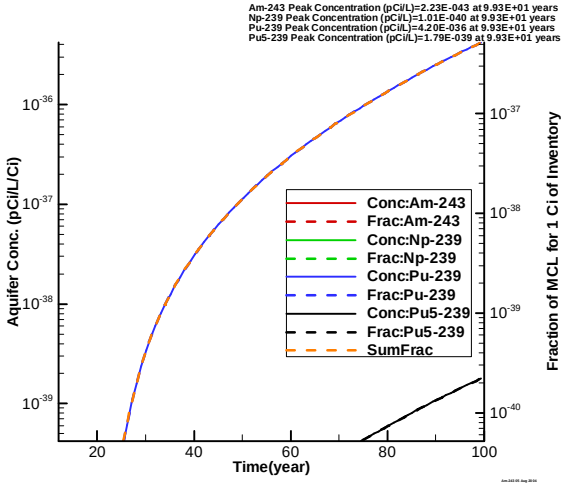

Figure A-34. Concs 12-100 years for Am-243

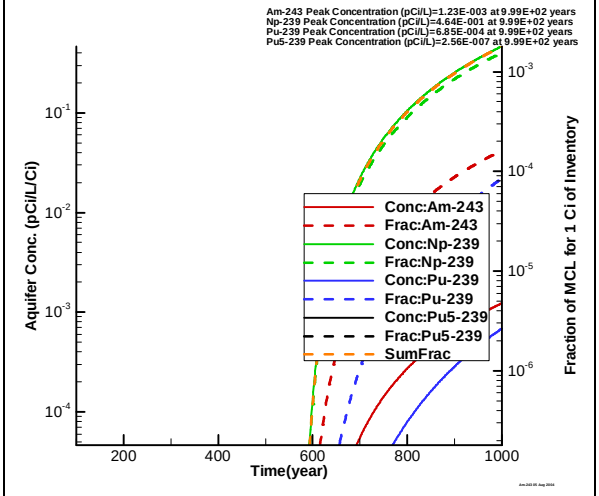

Figure A-35. Concs 100-1000 years for Am-243

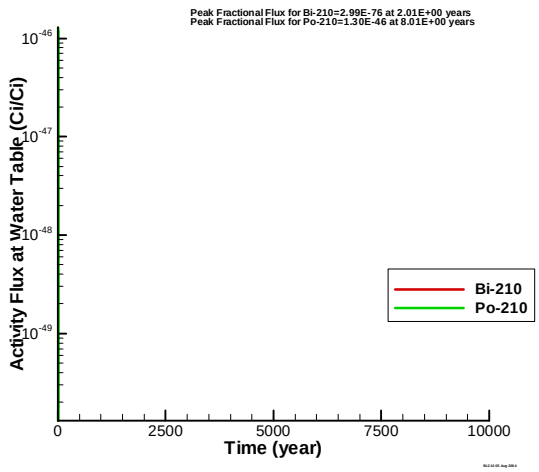

Figure A-36. Fluxes for Bi-210

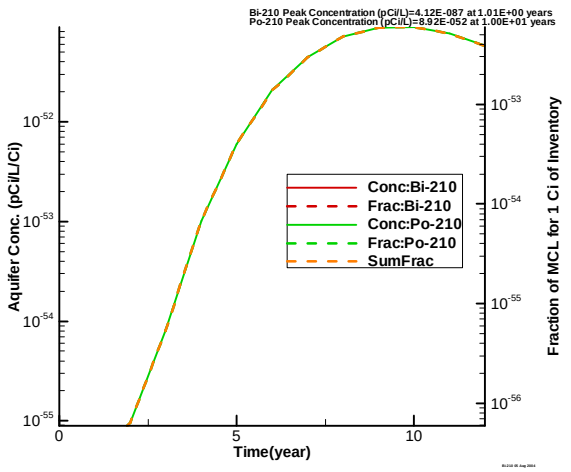

Figure A-37. Concs 0-12 years for Bi-210

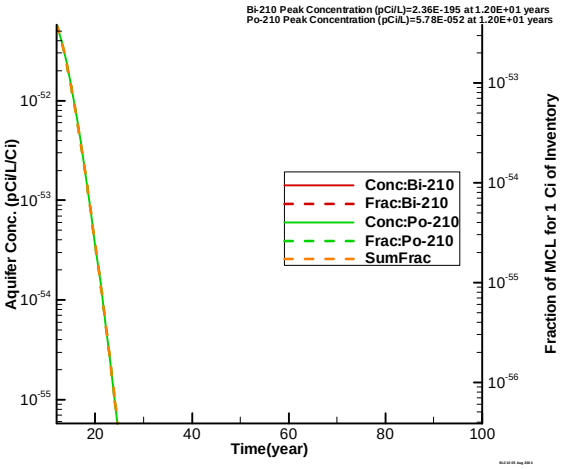

Figure A-38. Concs 12-100 years for Bi-210

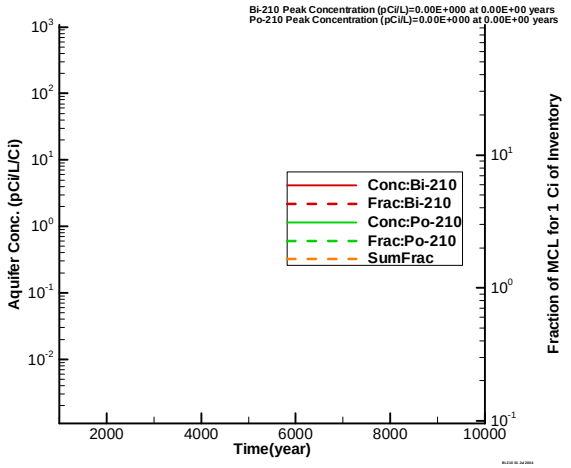

Figure A-39. Concs 100-1000 years for Bi-210

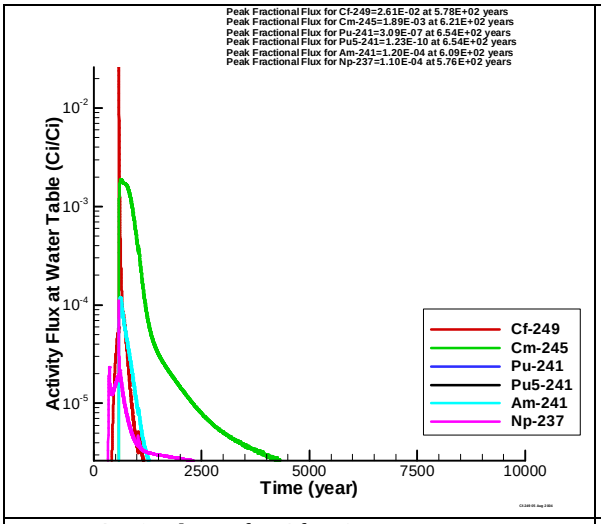

Figure A-40. Fluxes for Cf-249

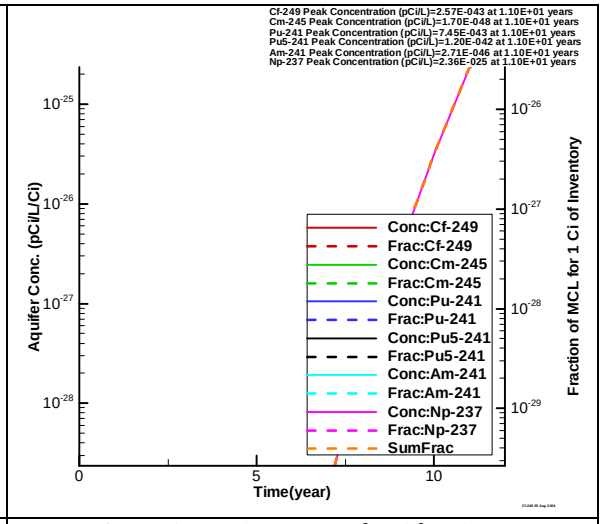

Figure A-41. Concs 0-12 years for Cf-249

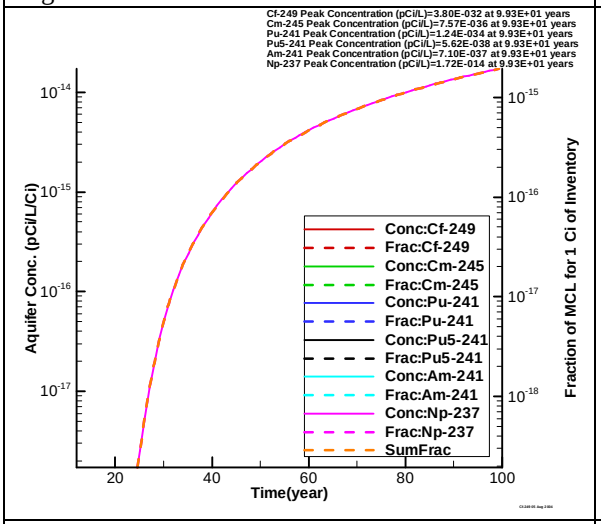

Figure A-42. Concs 12-100 years for Cf-249

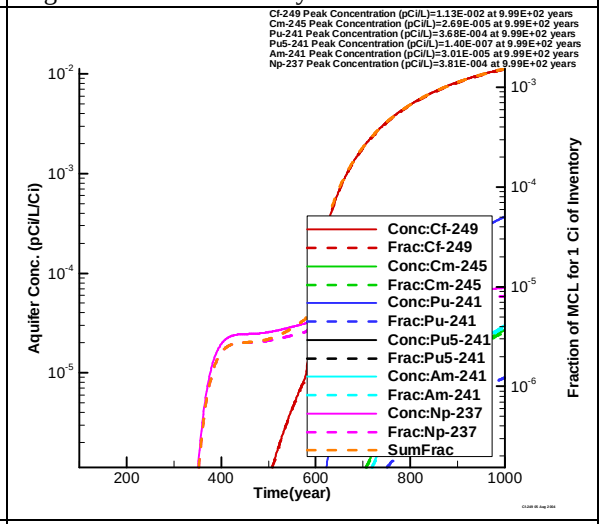

Figure A-43. Concs 100-1000 years for Cf-249

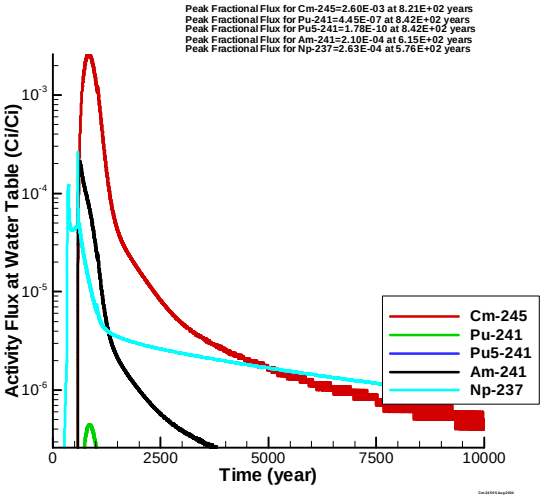

Figure A-44. Fluxes for Cm-245

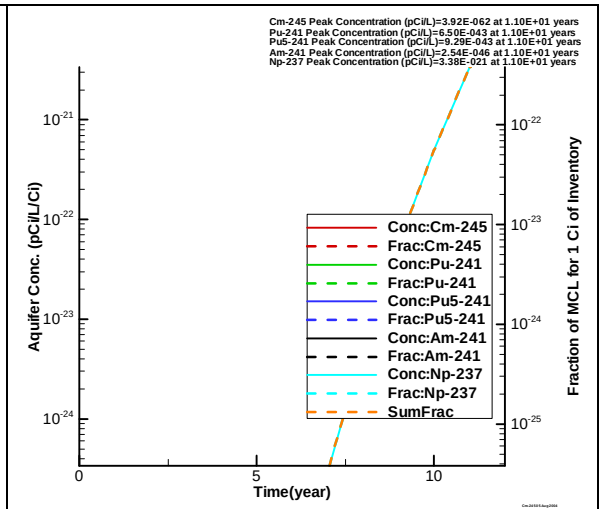

Figure A-45. Concs 0-12 years for Cm-245

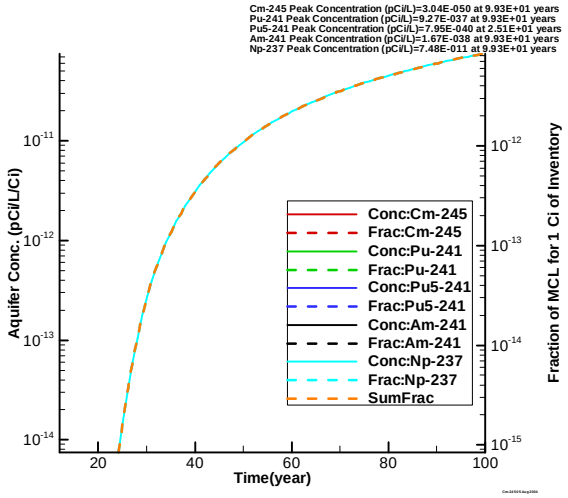

Figure A-46. Concs 12-100 years for Cm-245

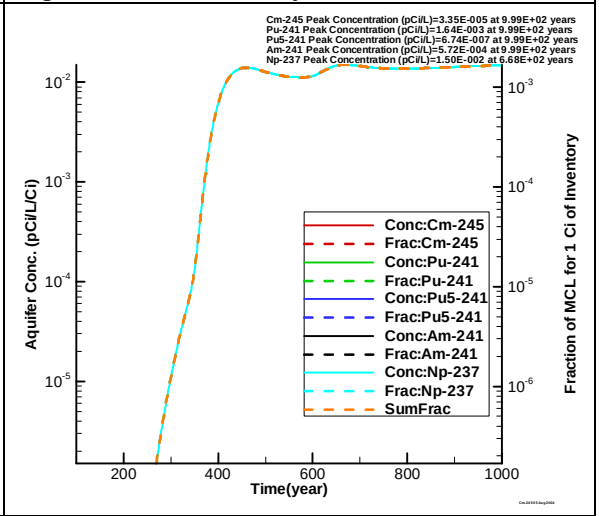

Figure A-47. Concs 100-1000 years for Cm-245

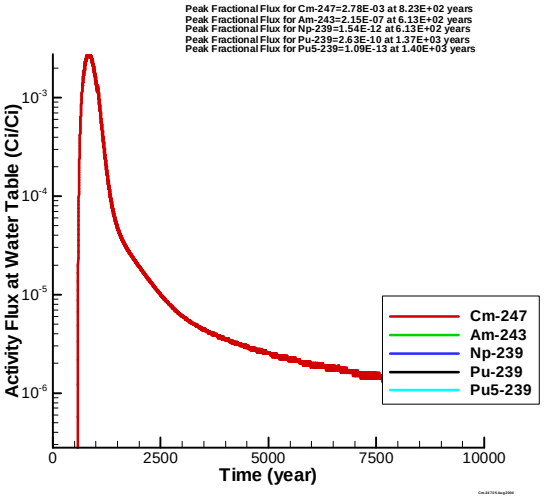

Figure A-48. Fluxes for Cm-247

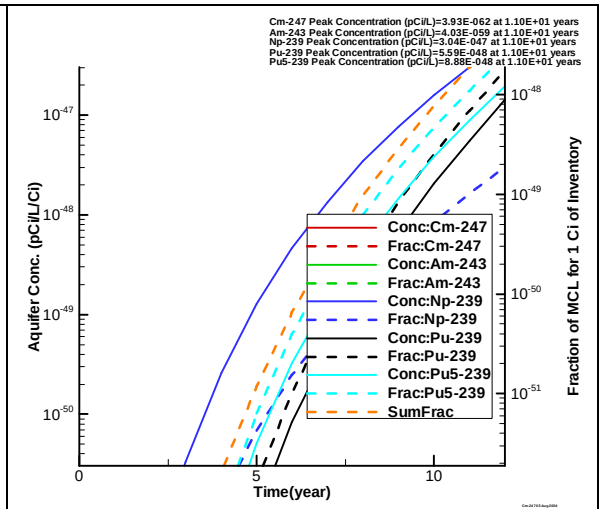

Figure A-49. Concs 0-12 years for Cm-247

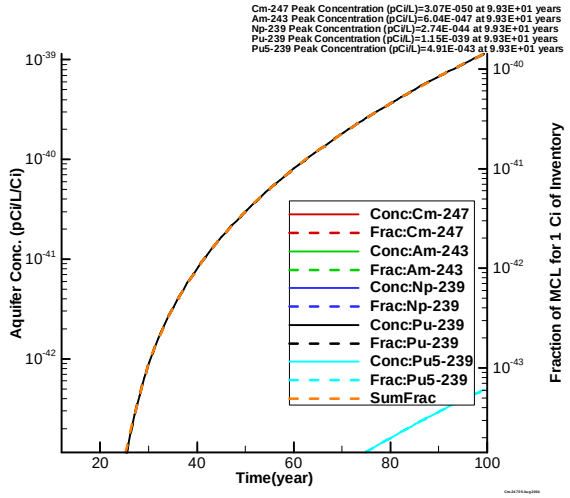

Figure A-50. Concs 12-100 years for Cm-247

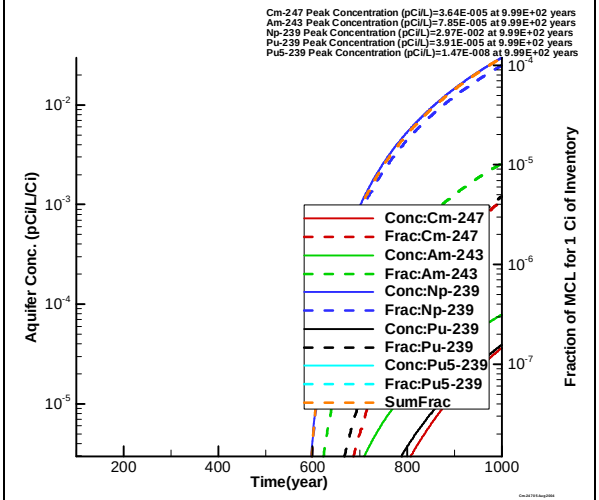

Figure A-51. Concs 100-1000 years for Cm-247

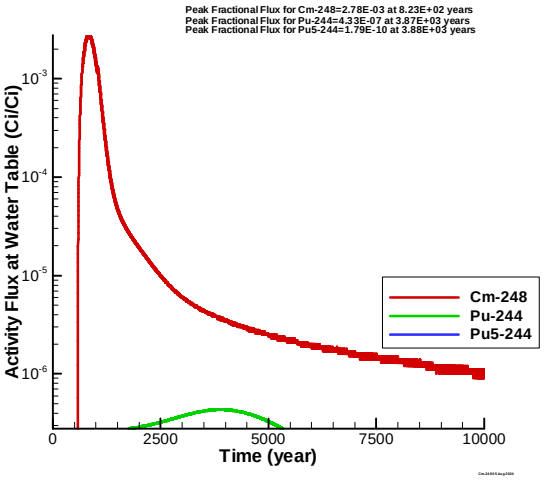

Figure A-52. Fluxes for Cm-248

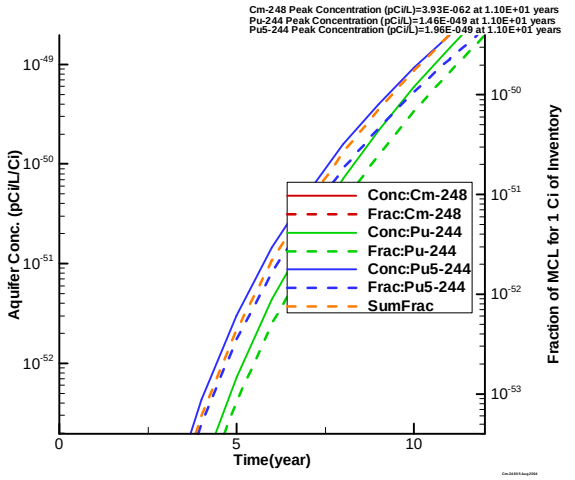

Figure A-53. Concs 0-12 years for Cm-248

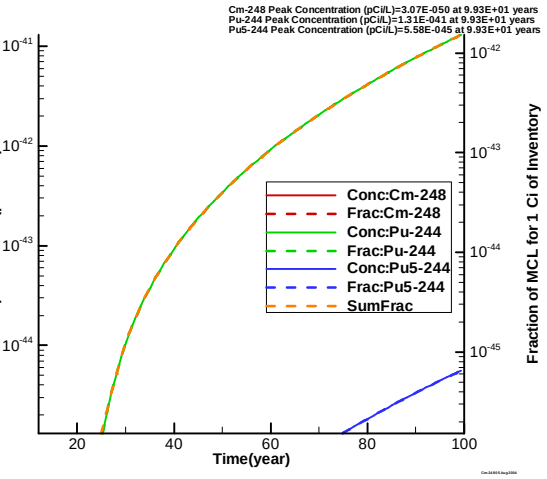

Figure A-54. Concs 12-100 years for Cm-248

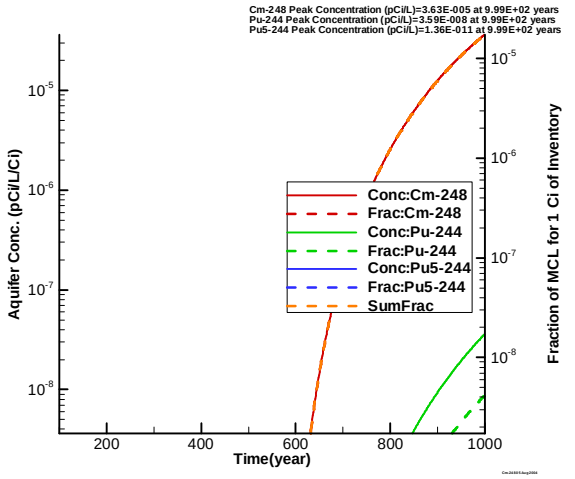

Figure A-55. Concs 100-1000 years for Cm-248

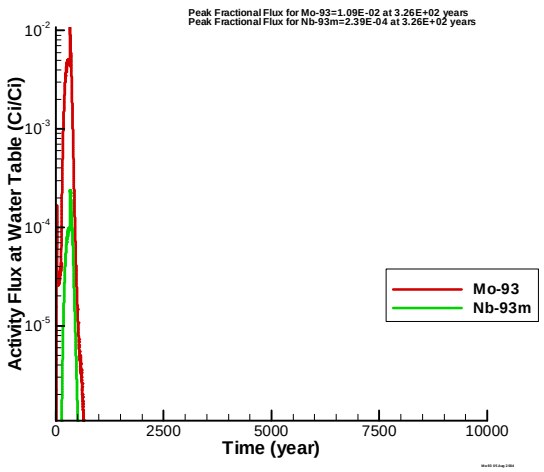

Figure A-56. Fluxes for Mo-93

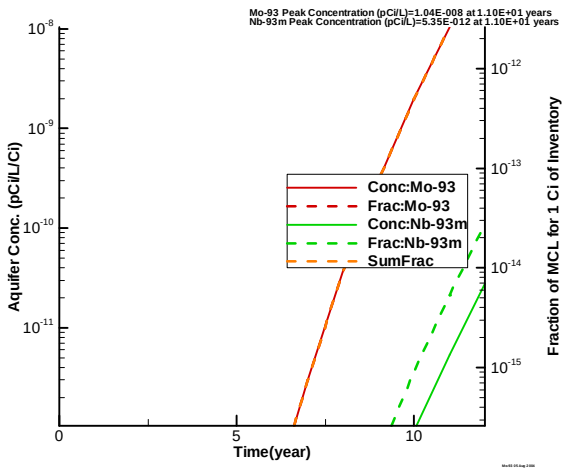

Figure A-57. Concs 0-12 years for Mo-93

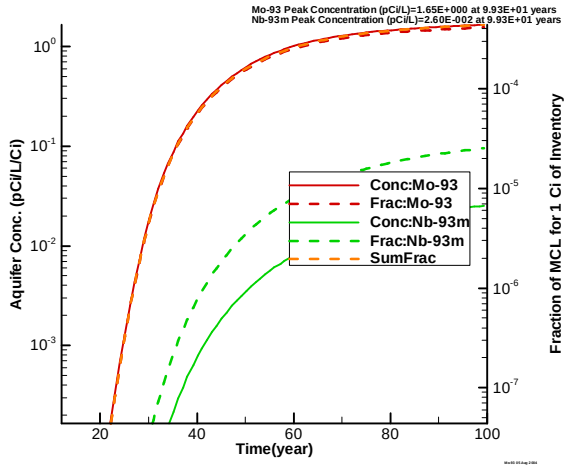

Figure A-58. Concs 12-100 years for Mo-93

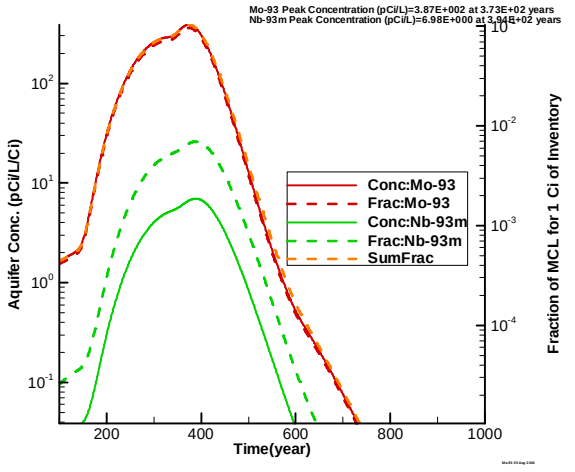

Figure A-59. Concs 100-1000 years for Mo-93

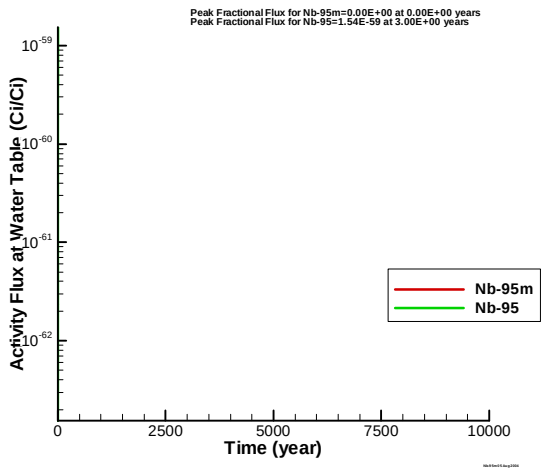

Figure A-60. Fluxes for Nb-95m

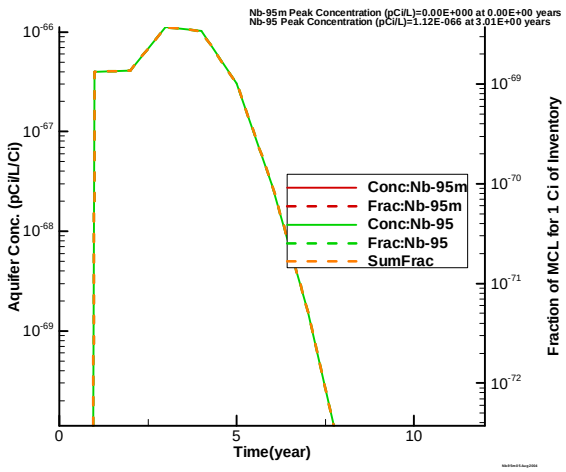

Figure A-61. Concs 0-12 years for Nb-95m

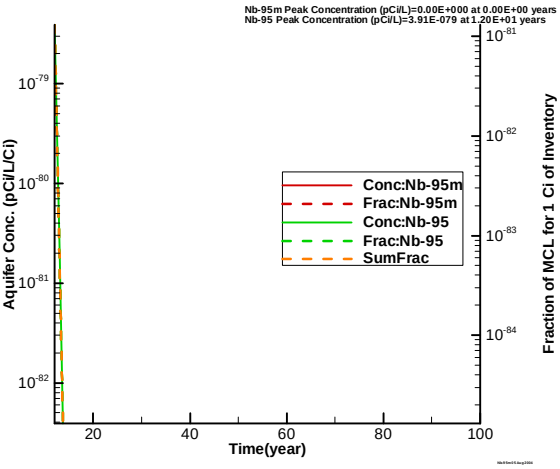

Figure A-62. Concs 12-100 years for Nb-95m

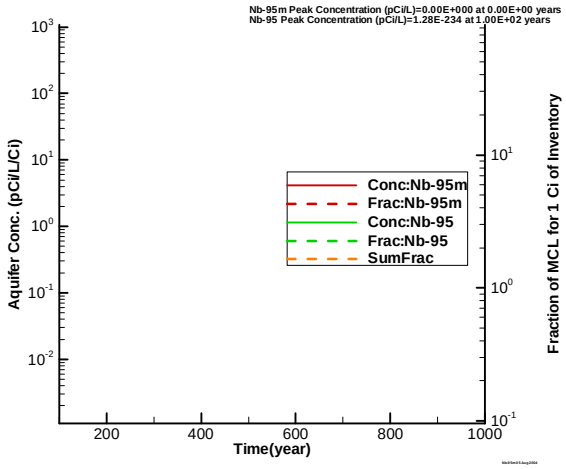

Figure A-63. Concs 100-1000 years for Nb-95m

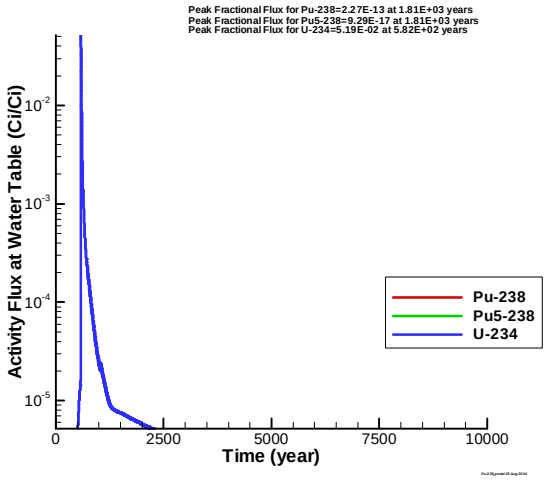

Figure A-64. Fluxes for Pu-238

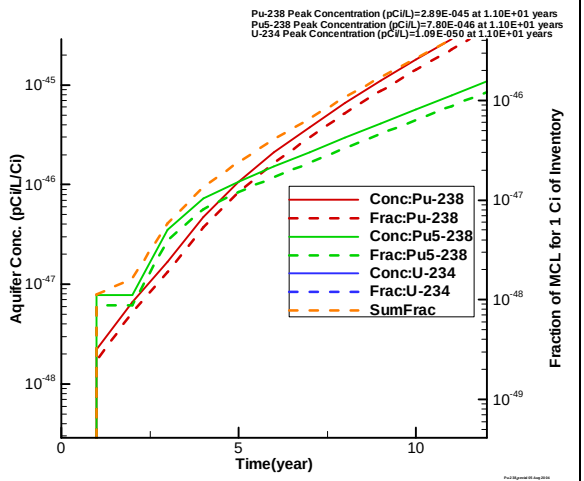

Figure A-65. Concs 0-12 years for Pu-238

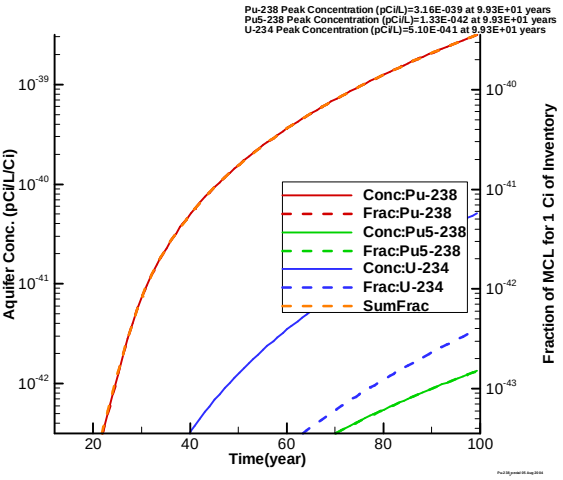

Figure A-66. Concs 12-100 years for Pu-238

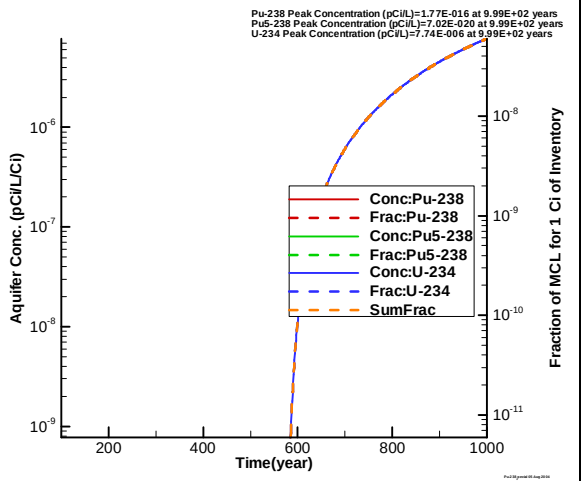

Figure A-67. Concs 100-1000 years for Pu-238

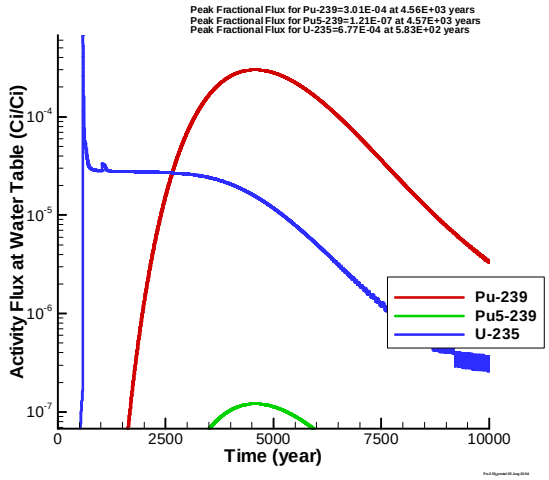

Figure A-68. Fluxes for Pu-239

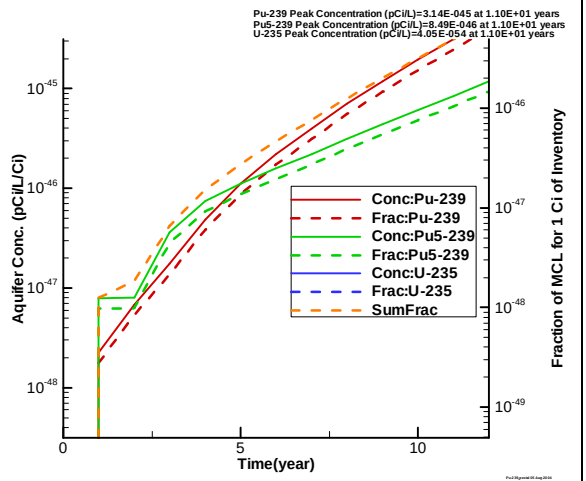

Figure A-69. Concs 0-12 years for Pu-239

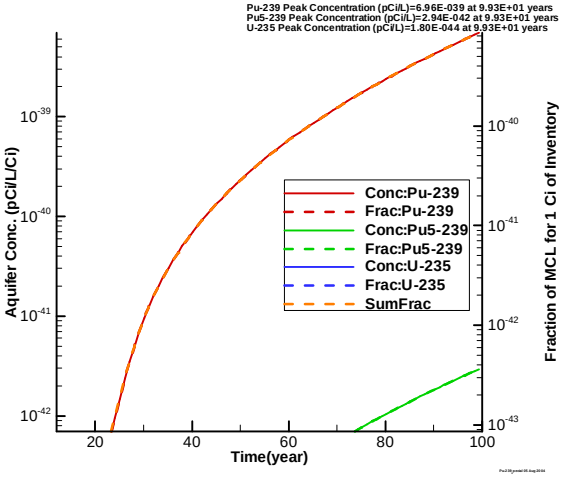

Figure A-70. Concs 12-100 years for Pu-239

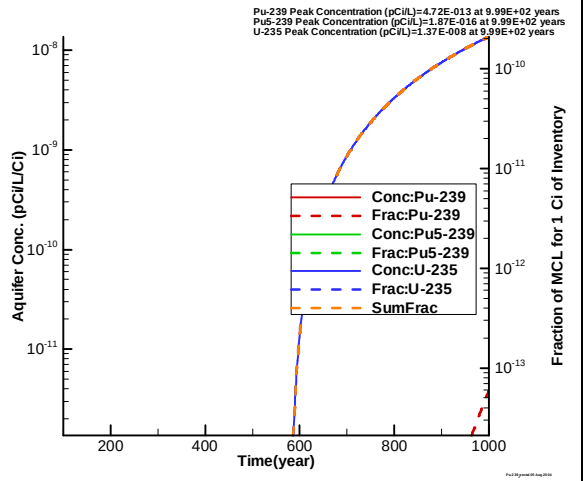

Figure A-71. Concs 100-1000 years for Pu-239

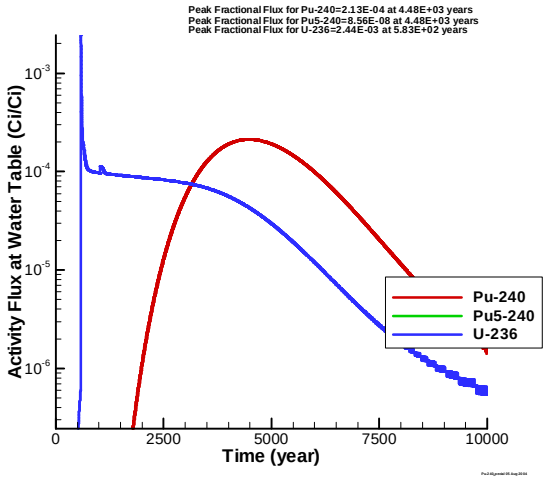

Figure A-72. Fluxes for Pu-240

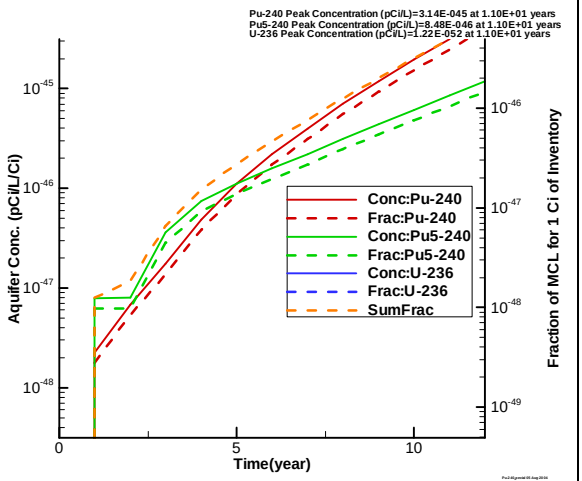

Figure A-73. Concs 0-12 years for Pu-240

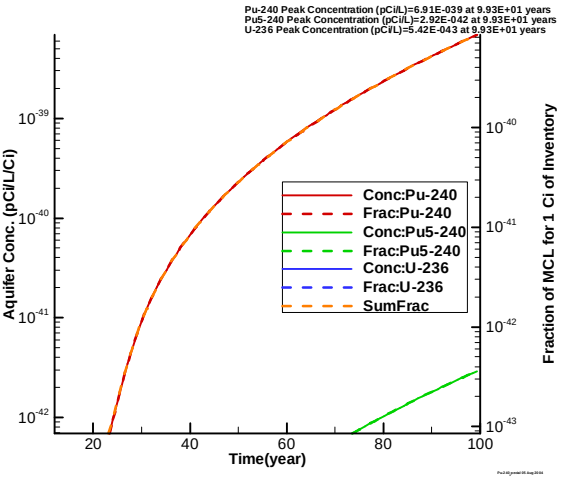

Figure A-74. Concs 12-100 years for Pu-240

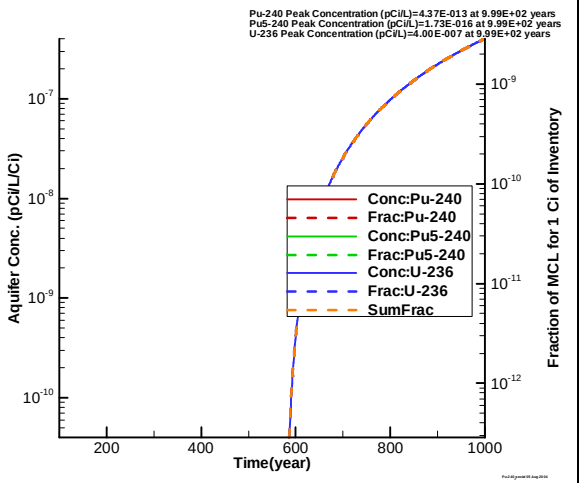

Figure A-75. Concs 100-1000 years for Pu-240

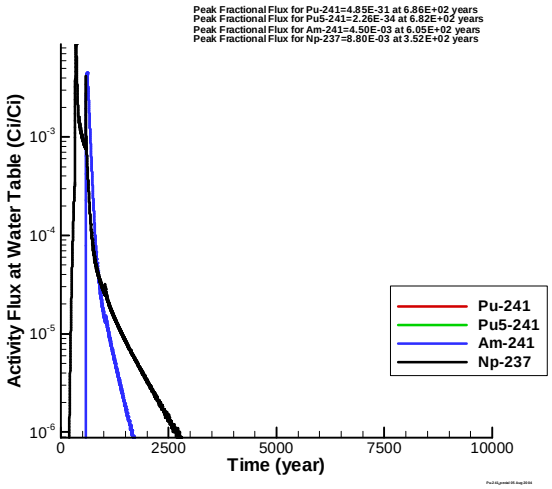

Figure A-76. Fluxes for Pu-241

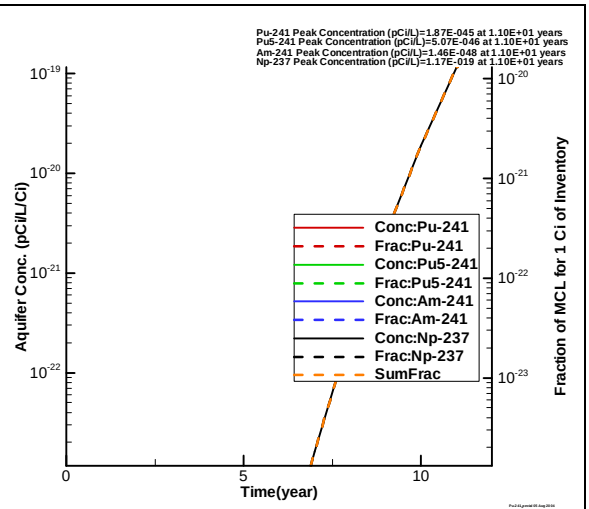

Figure A-77. Concs 0-12 years for Pu-241

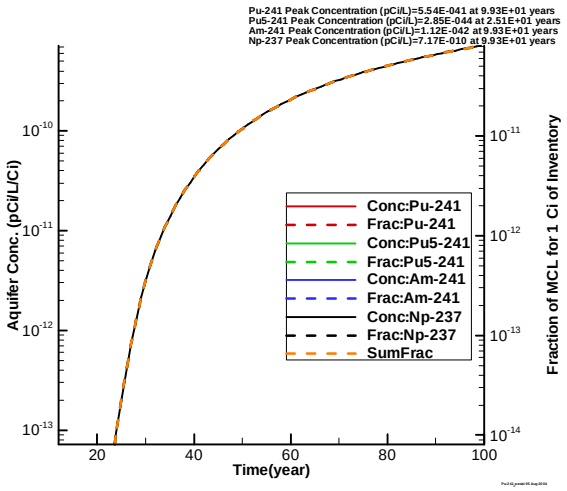

Figure A-78. Concs 12-100 years for Pu-241

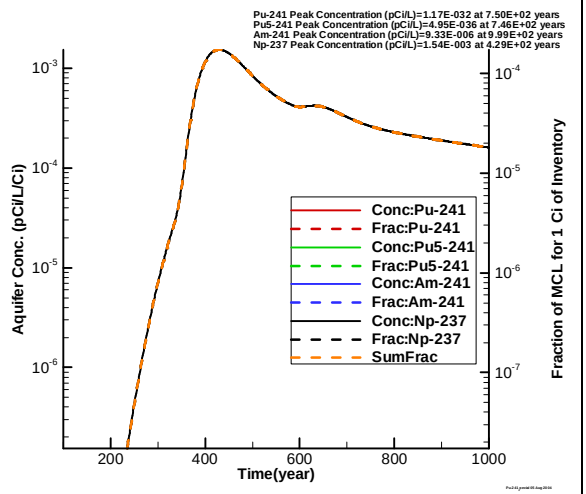

Figure A-79. Concs 100-1000 years for Pu-241

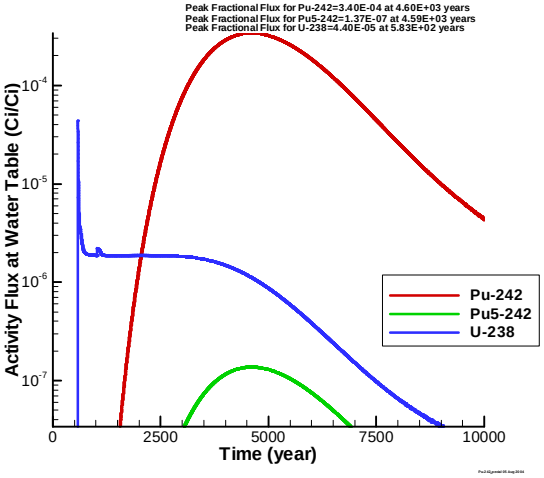

Figure A-80. Fluxes for Pu-242

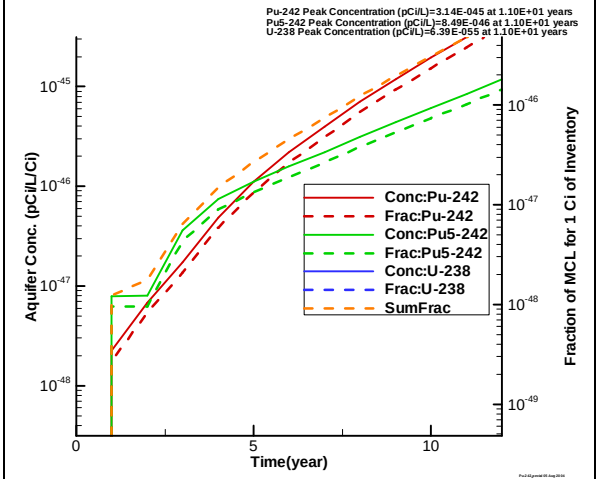

Figure A-81. Concs 0-12 years for Pu-242

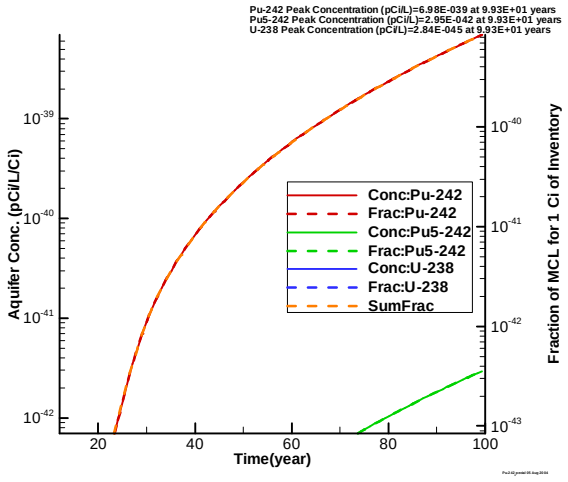

Figure A-82. Concs 12-100 years for Pu-242

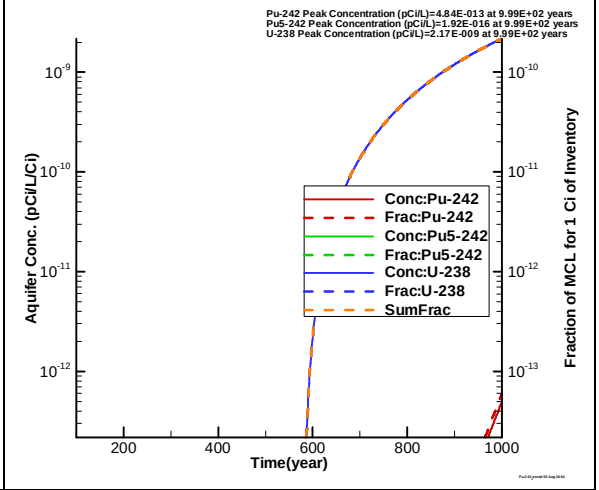

Figure A-83. Concs 100-1000 years for Pu-242

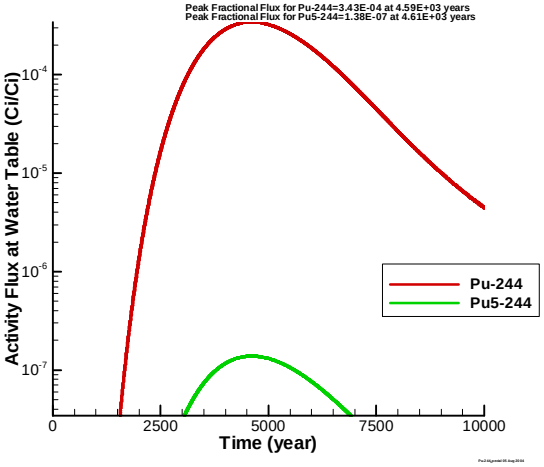

Figure A-84. Fluxes for Pu-244

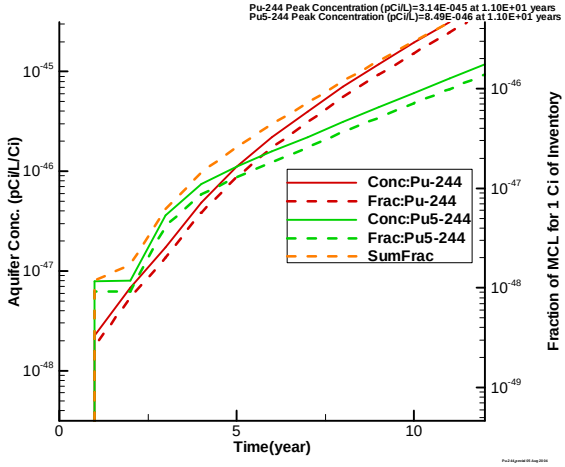

Figure A-85. Concs 0-12 years for Pu-244

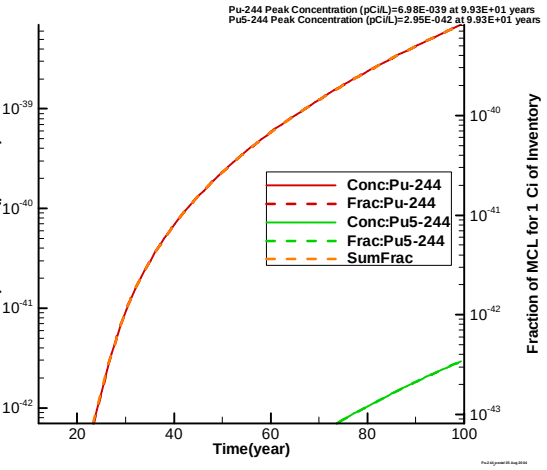

Figure A-86. Concs 12-100 years for Pu-244

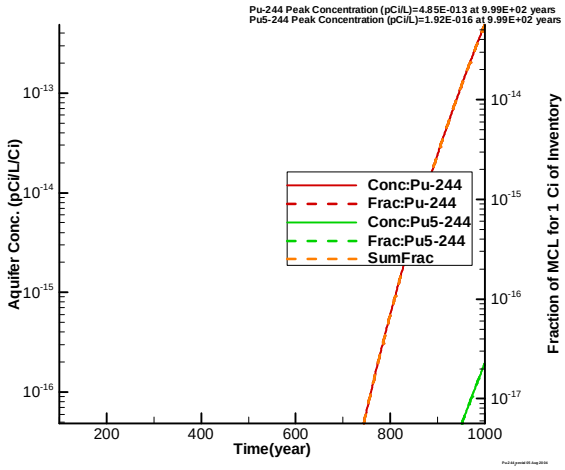

Figure A-87. Concs 100-1000 years for Pu-244

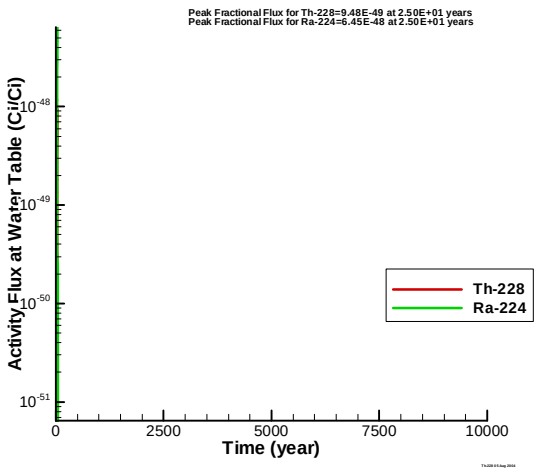

Figure A-88. Fluxes for Th-228

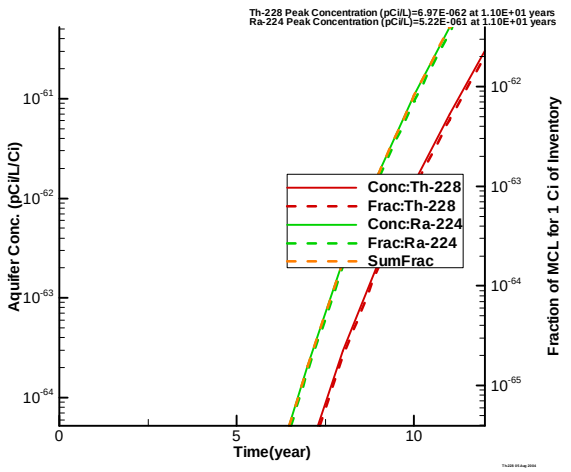

Figure A-89. Concs 0-12 years for Th-228

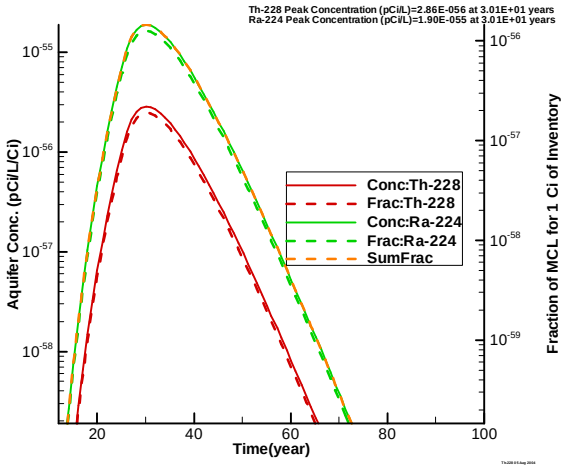

Figure A-90. Concs 12-100 years for Th-228

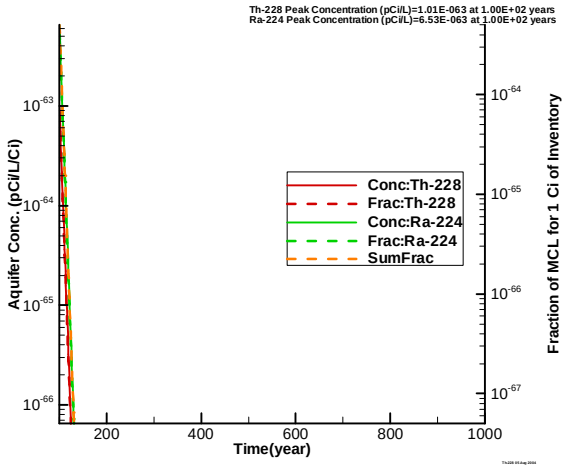

Figure A-91. Concs 100-1000 years for Th-228

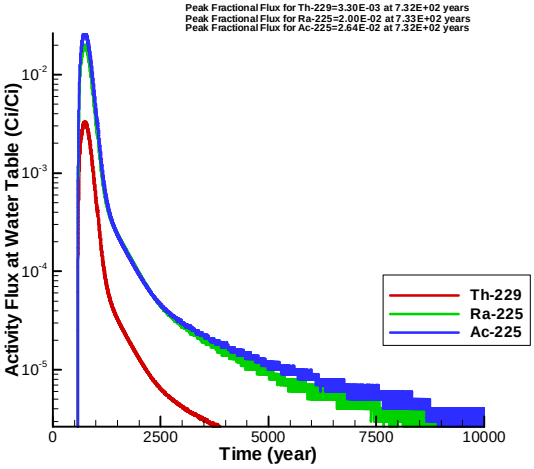

Figure A-92. Fluxes for Th-229

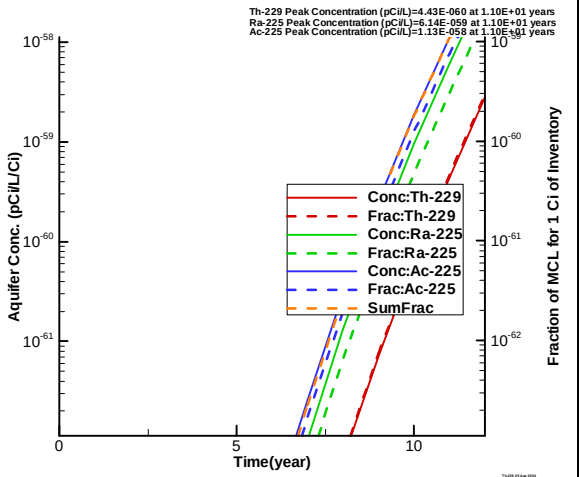

Figure A-93. Concs 0-12 years for Th-229

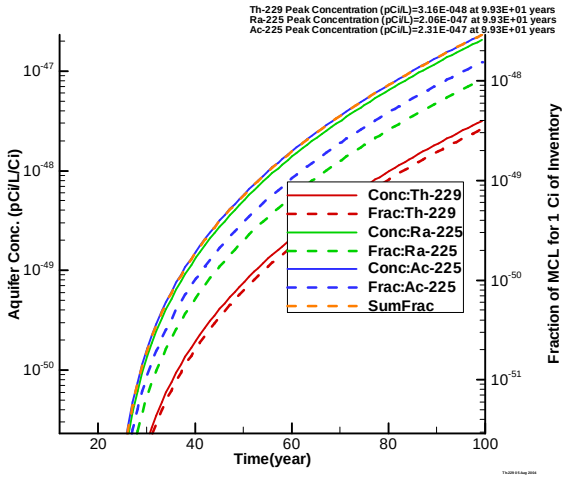

Figure A-94. Concs 12-100 years for Th-229

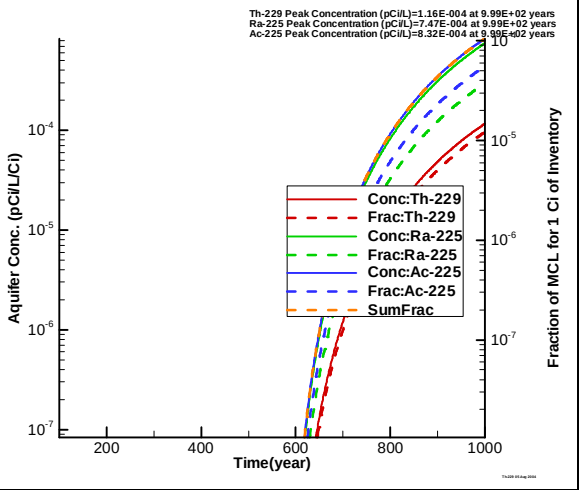

Figure A-95. Concs 100-1000 years for Th-229

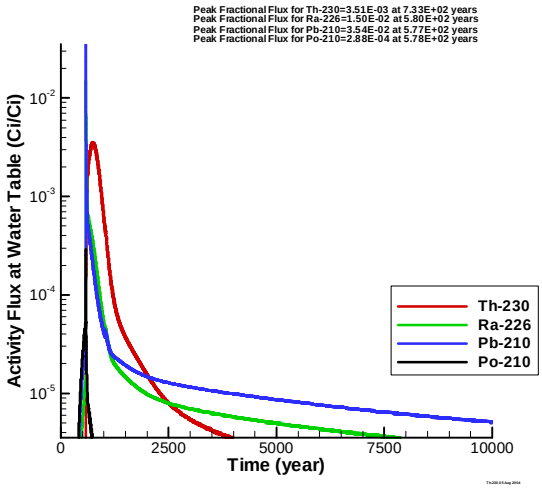

Figure A-96. Fluxes for Th-230

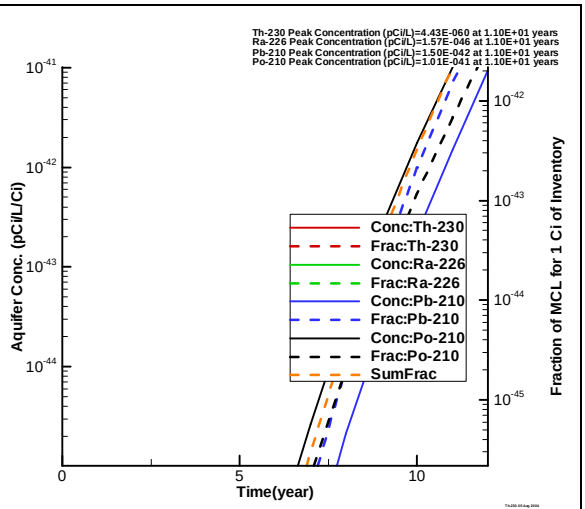

Figure A-97. Concs 0-12 years for Th-230

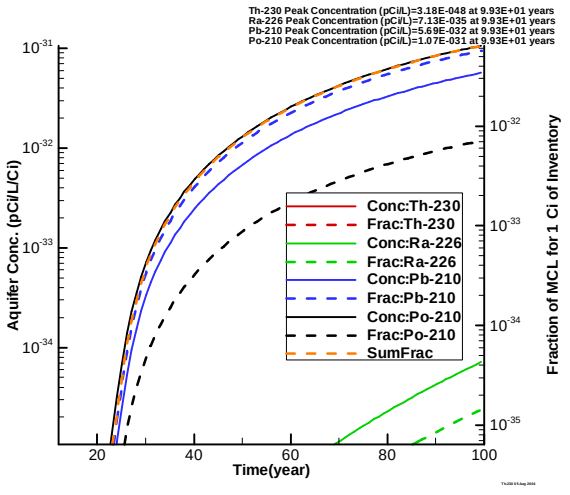

Figure A-98. Concs 12-100 years for Th-230

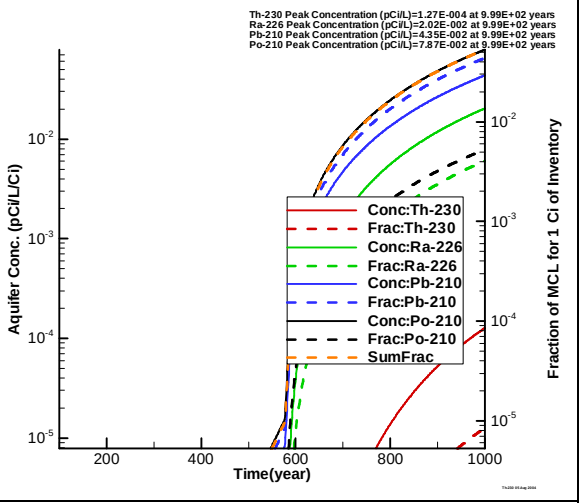

Figure A-99. Concs 100-1000 years for Th-230

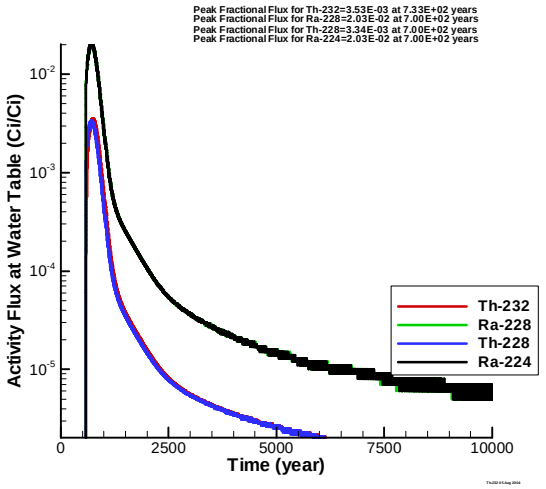

Figure A-100. Fluxes for Th-232

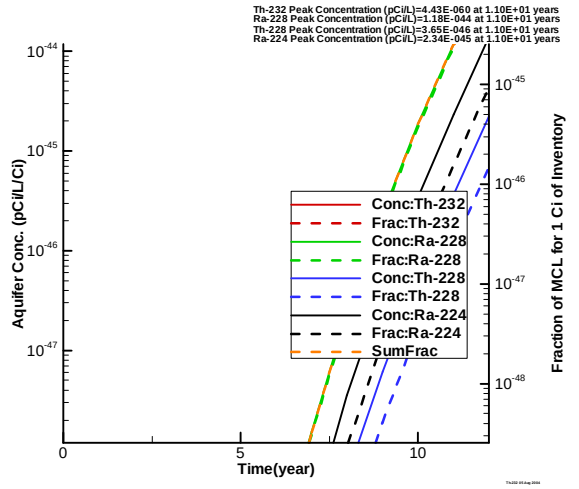

Figure A-101. Concs 0-12 years for Th-232

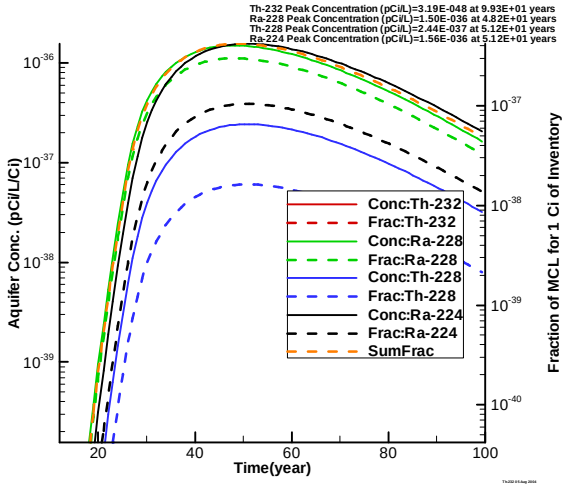

Figure A-102. Concs 12-100 years for Th-232

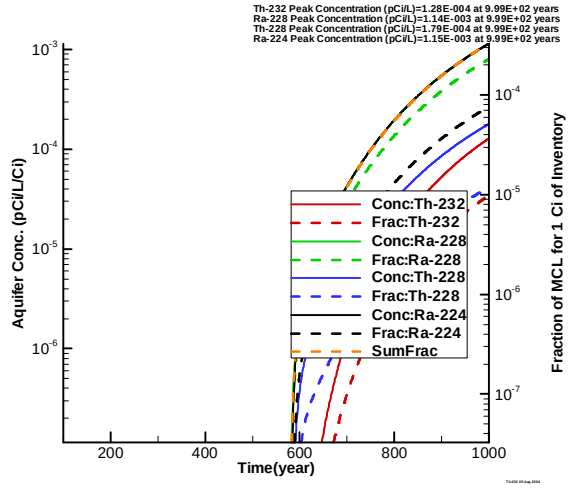

Figure A-103. Concs 100-1000 years for Th-232

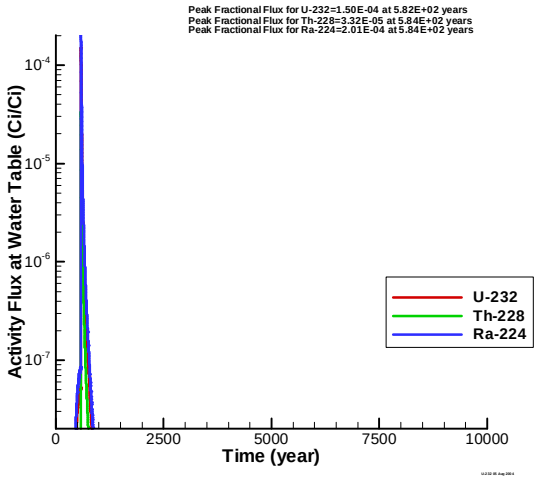

Figure A-104. Fluxes for U-232

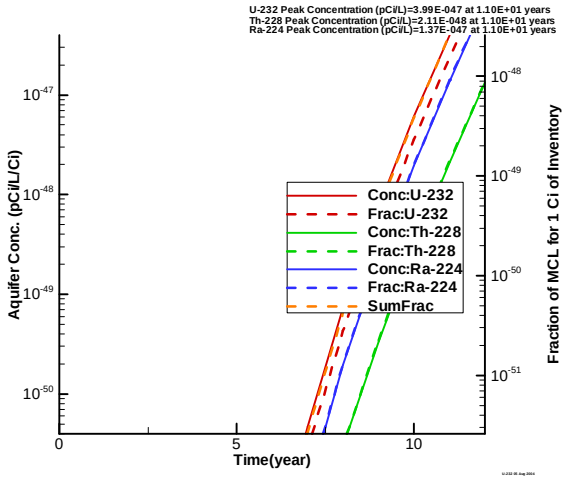

Figure A-105. Concs 0-12 years for U-232

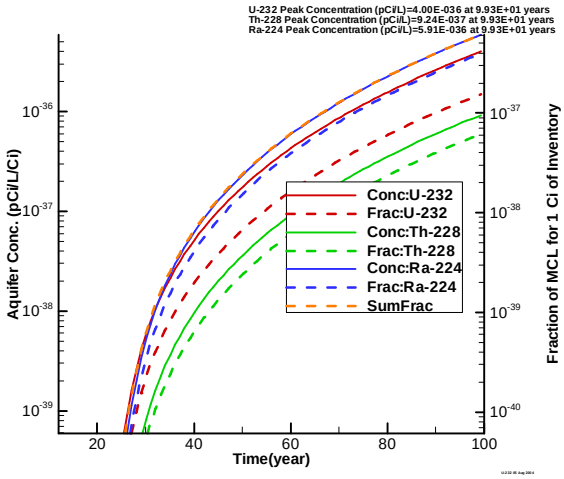

Figure A-106. Concs 12-100 years for U-232

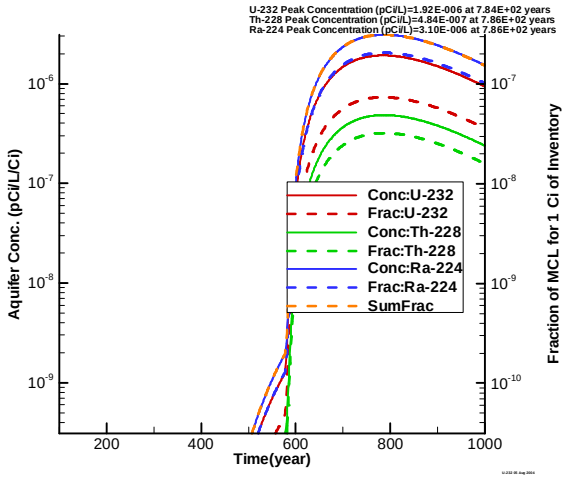

Figure A-107. Concs 100-1000 years for U-232

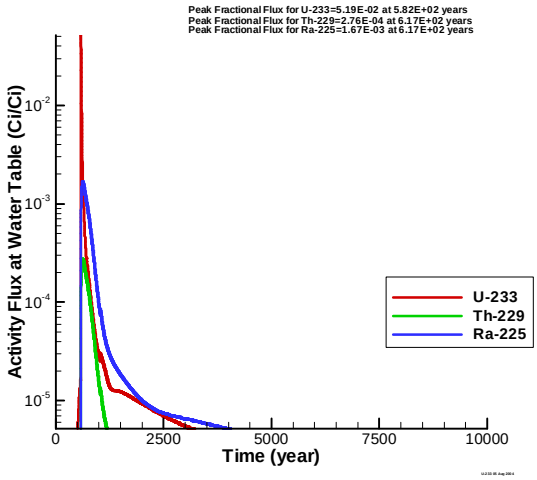

Figure A-108. Fluxes for U-233

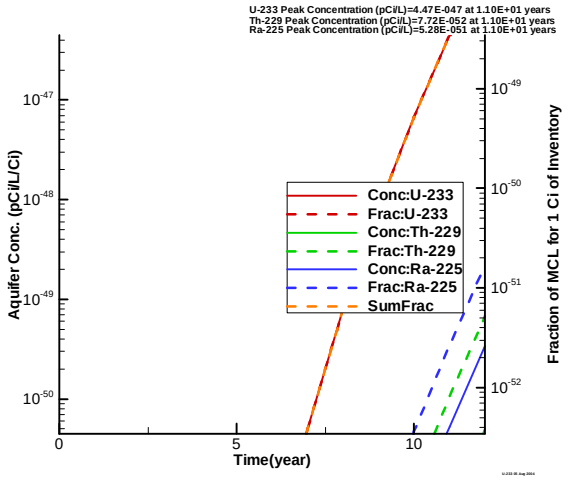

Figure A-109. Concs 0-12 years for U-233

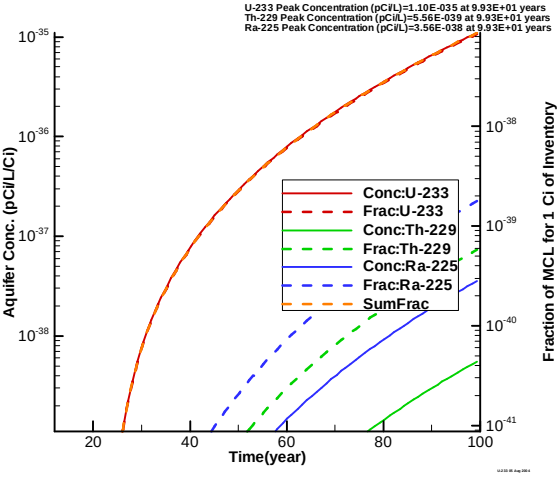

Figure A-110. Concs 12-100 years for U-233

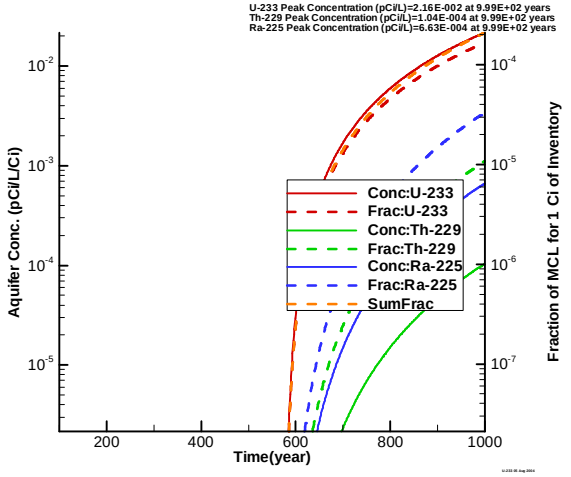

Figure A-111. Concs 100-1000 years for U-233

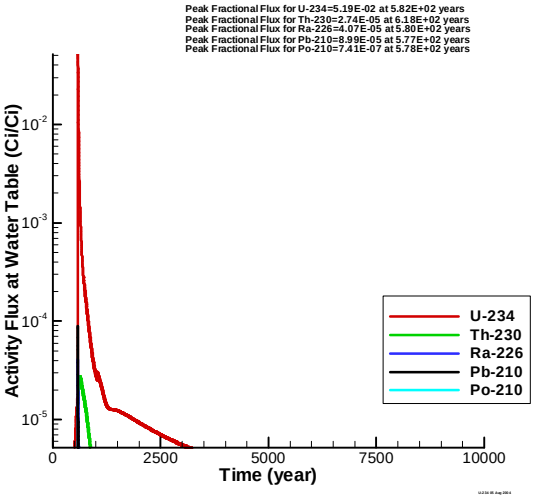

Figure A-112. Fluxes for U-234

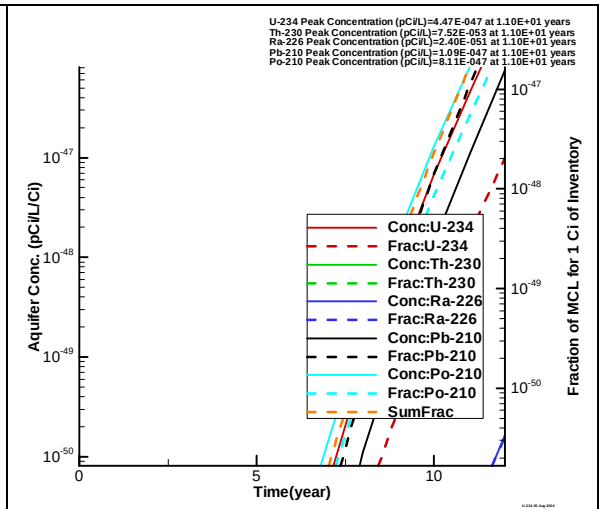

Figure A-113. Concs 0-12 years for U-234

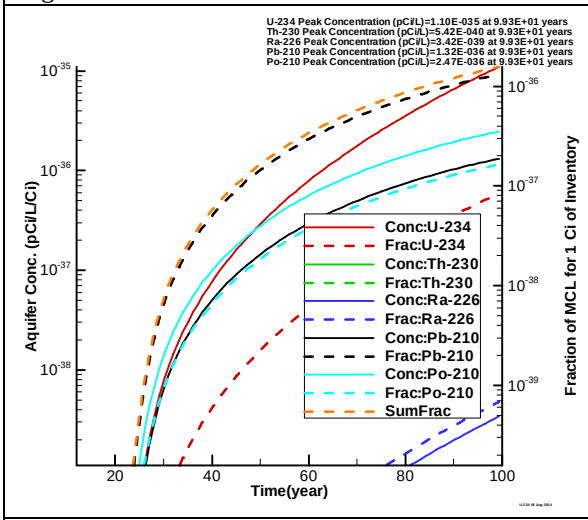

Figure A-114. Concs 12-100 years for U-234

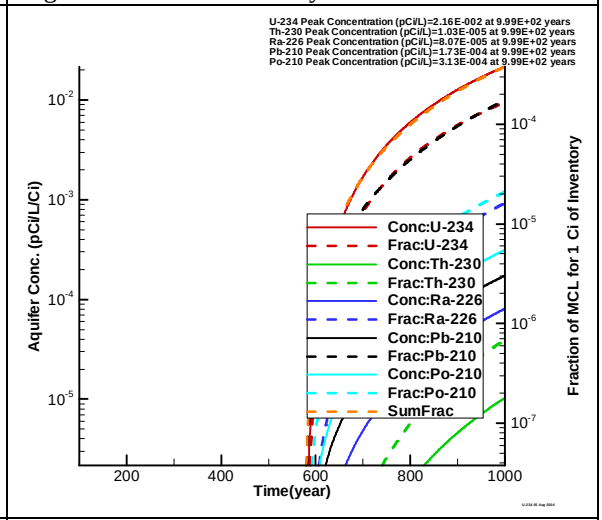

Figure A-115. Concs 100-1000 years for U-234

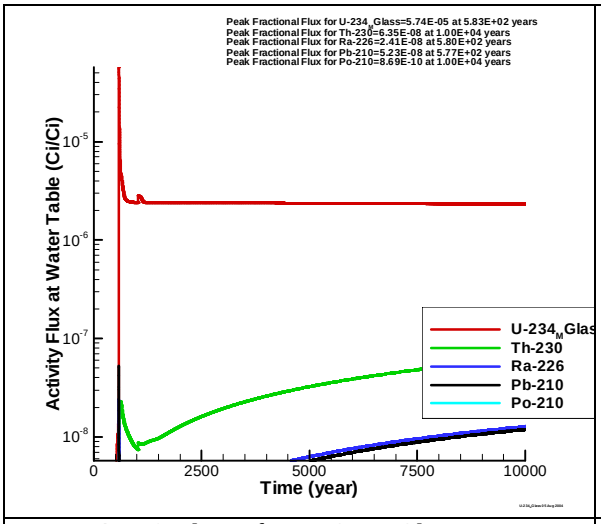

Figure A-116. Fluxes for U-234_MGlass

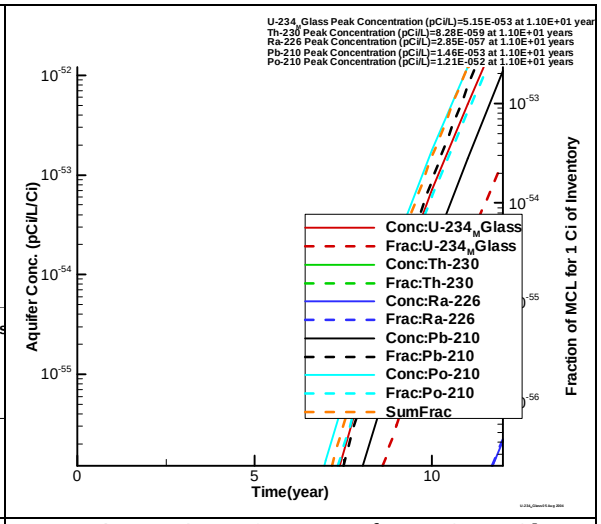

Figure A-117. Concs 0-12 years for U-234_MGlass

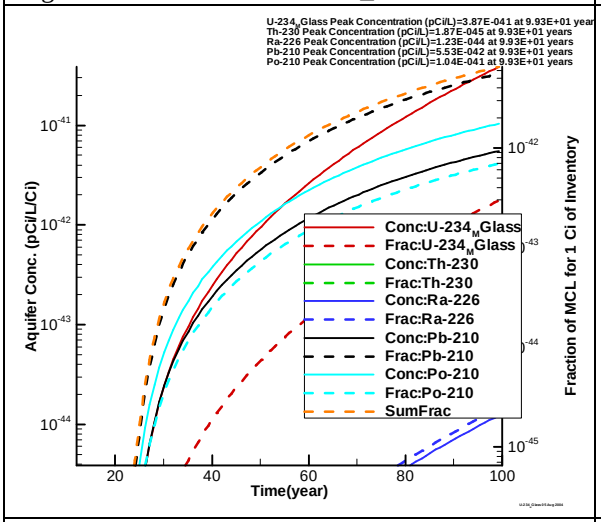

Figure A-118. Concs 12-100 years for U-234_MGlass

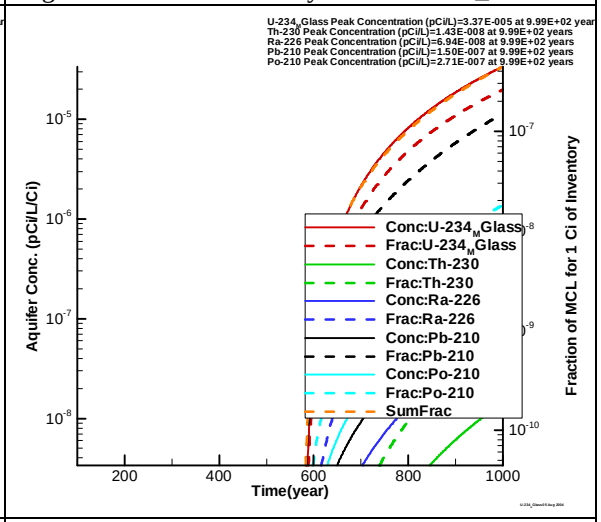

Figure A-119. Concs 100-1000 years for U-234_MGlass

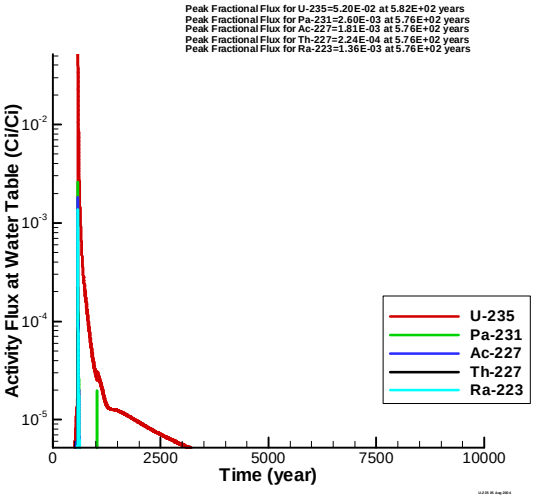

Figure A-120. Fluxes for U-235

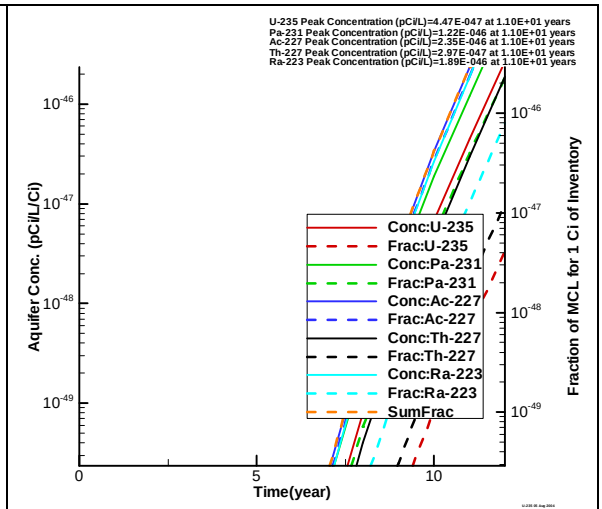

Figure A-121. Concs 0-12 years for U-235

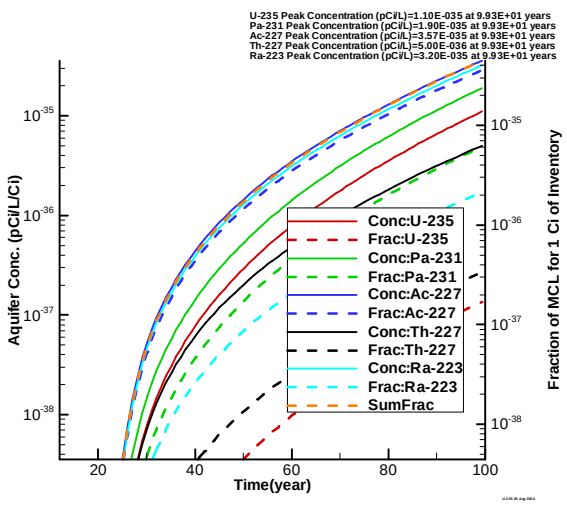

Figure A-122. Concs 12-100 years for U-235

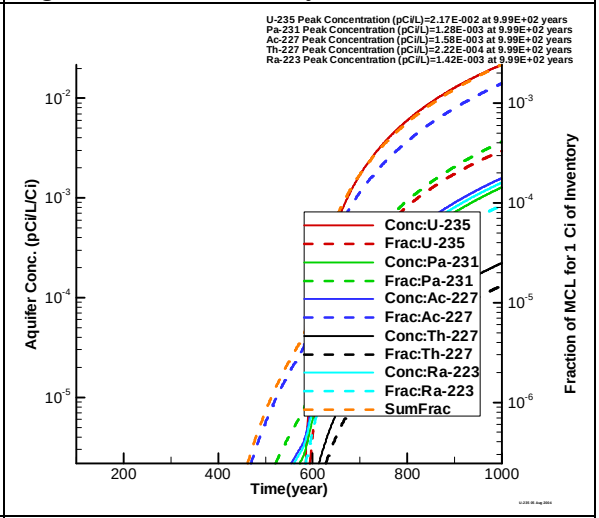

Figure A-123. Concs 100-1000 years for U-235

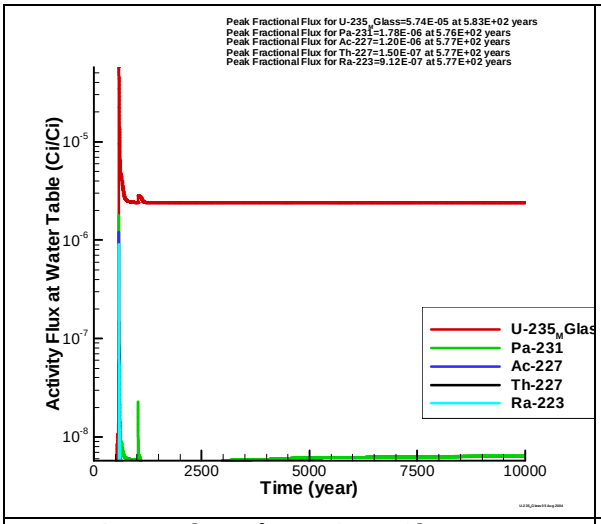

Figure A-124. Fluxes for U-235_MGlass

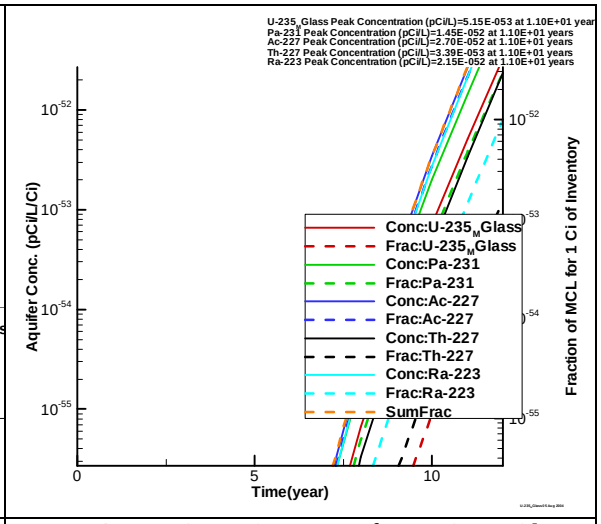

Figure A-125. Concs 0-12 years for U-235_MGlass

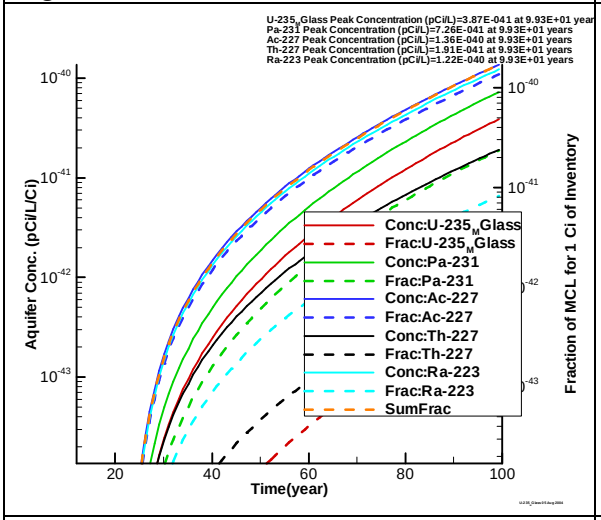

Figure A-126. Concs 12-100 years for U-235_MGlass

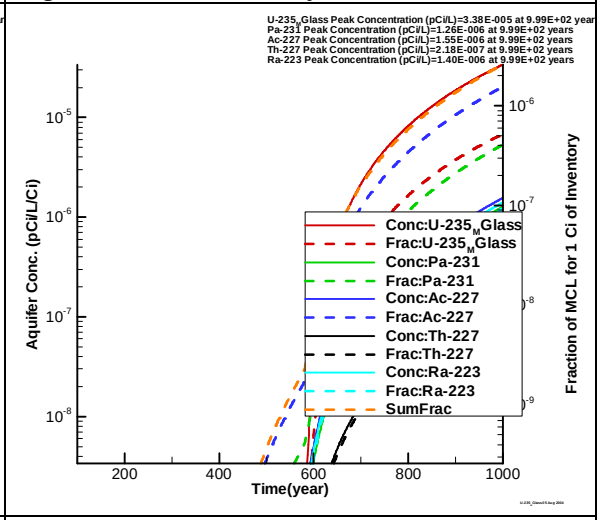

Figure A-127. Concs 100-1000 years for U-235_MGlass

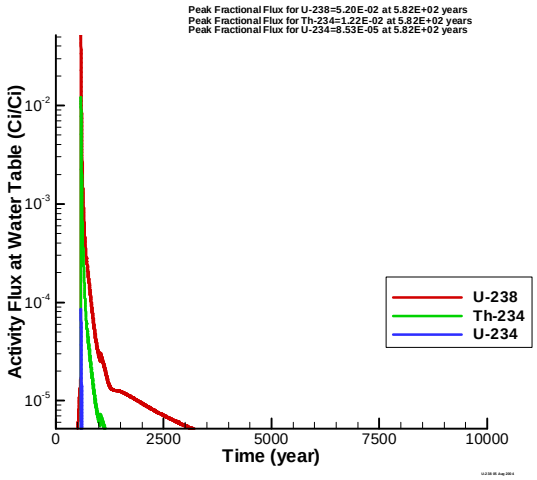

Figure A-128. Fluxes for U-238

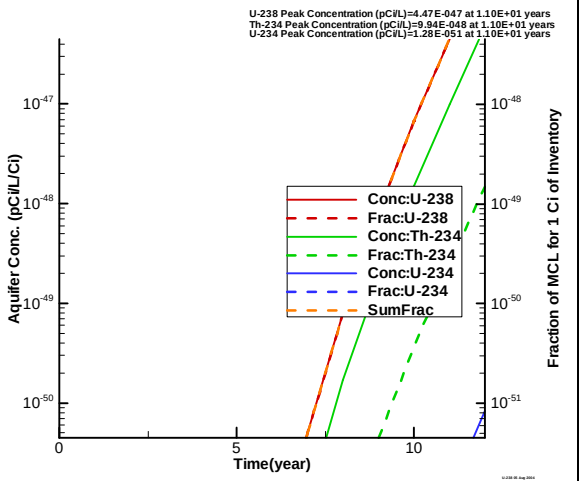

Figure A-129. Concs 0-12 years for U-238

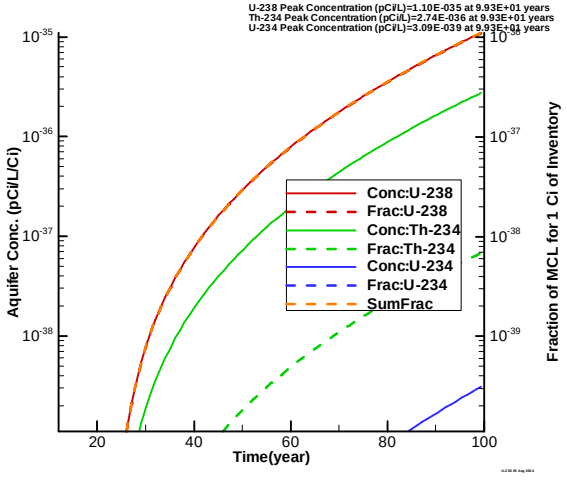

Figure A-130. Concs 12-100 years for U-238

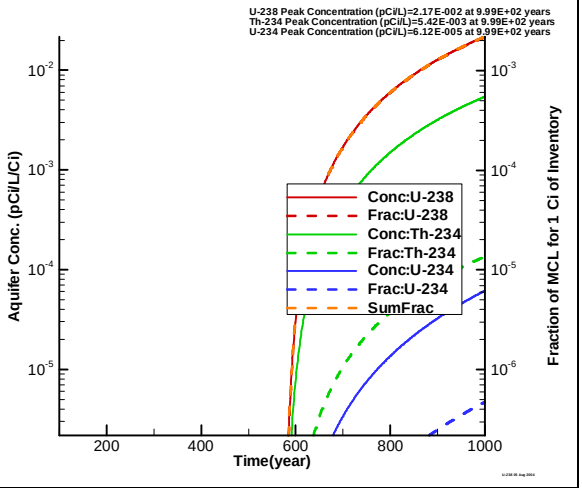

Figure A-131. Concs 100-1000 years for U-238

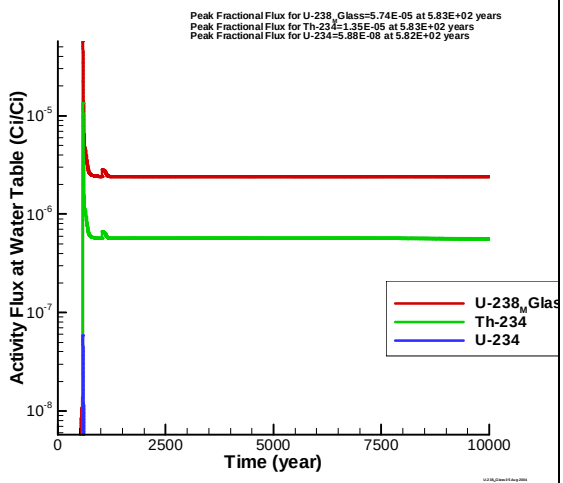

Figure A-132. Fluxes for U-238_MGlass

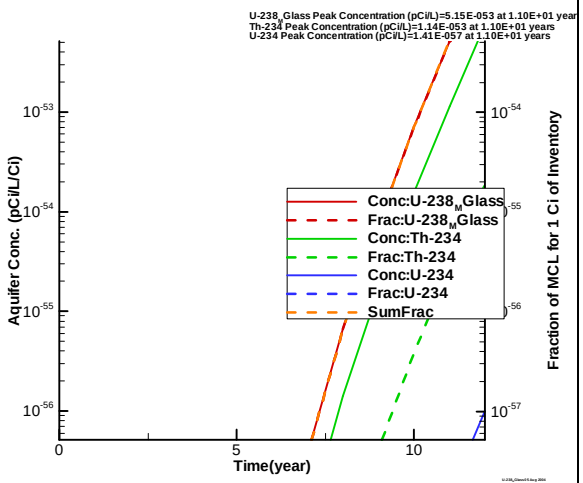

Figure A-133. Concs 0-12 years for U-238_MGlass

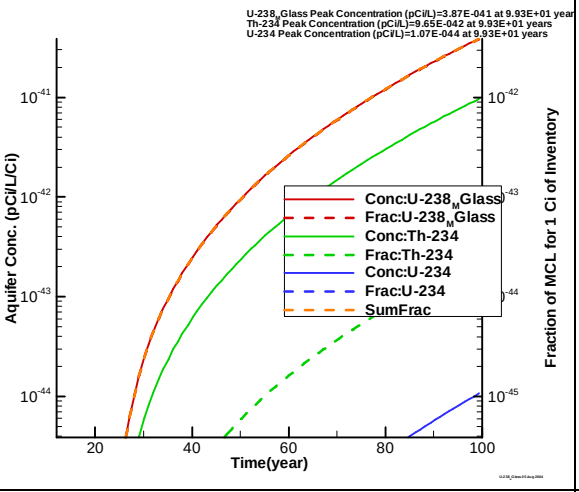

Figure A-134. Concs 12-100 years for U-238_MGlass

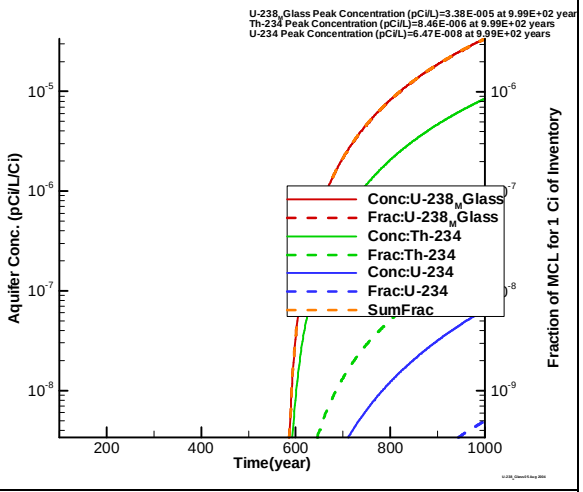

Figure A-135. Concs 100-1000 years for U-238_MGlass

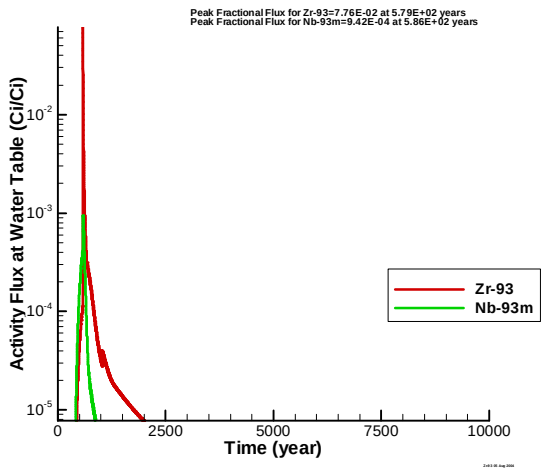

Figure A-136. Fluxes for Zr-93

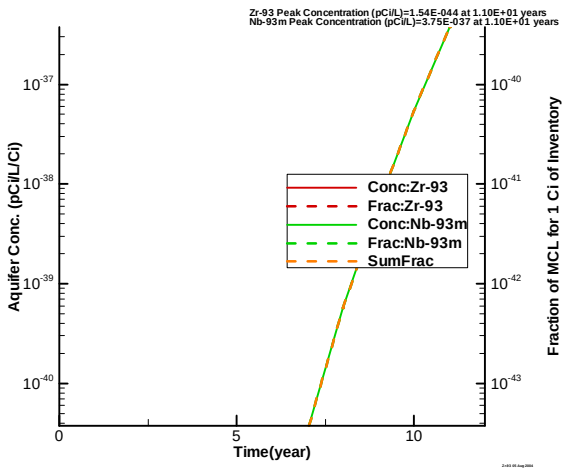

Figure A-137. Concs 0-12 years for Zr-93

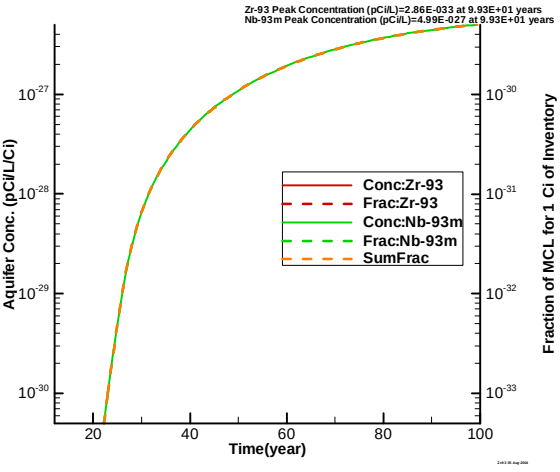

Figure A-138. Concs 12-100 years for Zr-93

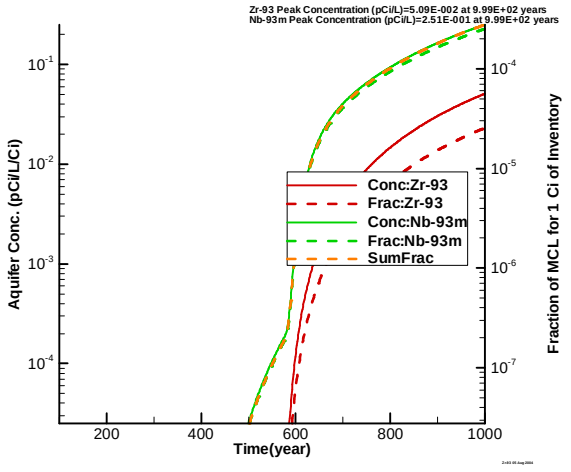

Figure A-139. Concs 100-1000 years for Zr-93

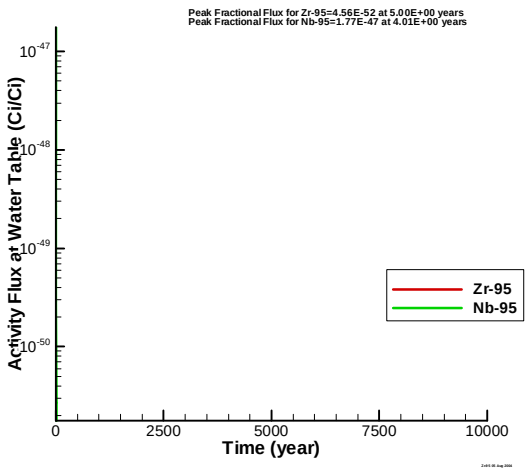

Figure A-140. Fluxes for Zr-95

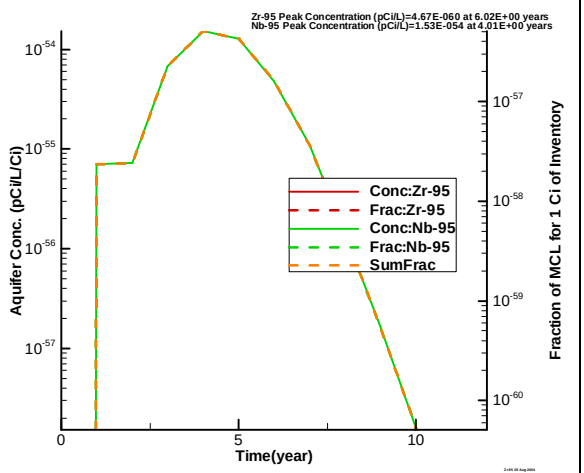

Figure A-141. Concs 0-12 years for Zr-95

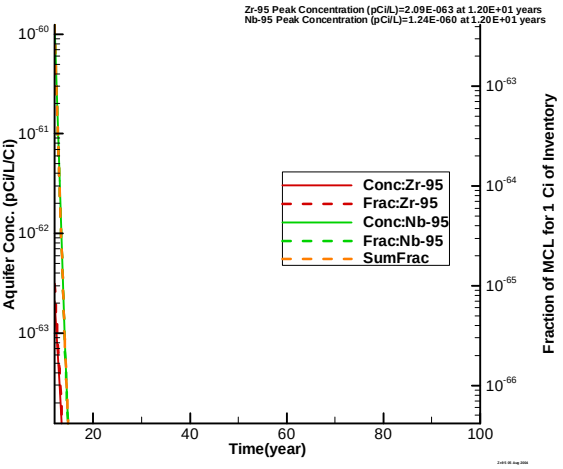

Figure A-142. Concs 12-100 years for Zr-95

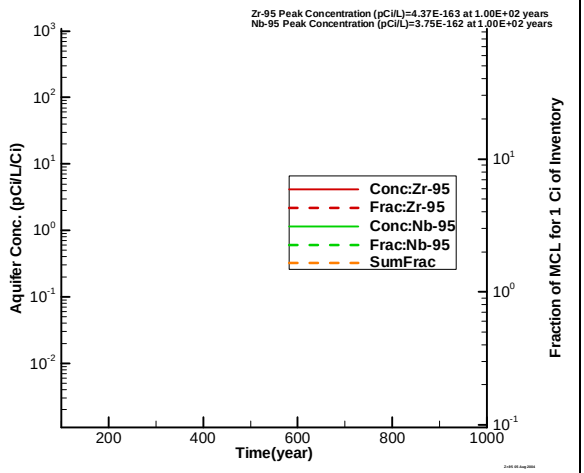

Figure A-143. Concs 100-1000 years for Zr-95

15 APPENDIX C. DESIGN CHECKS

Design Check Instructions for Intruder Analysis

Please check the volumes and geometry factors used for the intruder analysis (see Volumes.xls and individual folders). Separate folders were prepared for the following configurations:

656 ft long by 20 ft wide by 5 trenches
656 ft long by 40 ft wide by 3 trenches
656 ft long by 157 ft wide by 1 trench

The footprint for the boundary was set at 656 ft long by 157 ft wide. Check that the volumes and geometry factors were correctly entered in the appropriate spreadsheets and in Table 5.

Analysis files are located at

\\l-collard\H:\Slit2004\Intruder

Section 4 in the report (\\l-collard\H:\Slit2004\Report\Slit2004D.doc) describes the analysis. Review that portion of the report (about 2 pages) and check that the .doc files produces by executing the intruder software were copied correctly into the report. You should spot check 3 or 4 values on each report.

Thanks.

Review

I have checked the volumes and geometry factors for the three cases that you specified. Your calculations in the spreadsheet volumes.xls are correct and these values were correctly used in the disposal unit input files for the Intruder application.

I have reviewed Section 4 of the report Slit2004D.doc and did not have any comments about the written text. Table 5 correctly reports the areas and geometry factors. Tables 6-9 were correctly inserted from the Intruder application result in Word format.

I suggest that you add an explanation of the entry "---" before the tables, such as The entry "---" for limits indicates a value greater than or equal to the threshold value of 1E+20. The entry "---" for time means that there is no maximum because there is no limit.

I did notice that there are some parents missing in the tables compared to the full list of parents that Patricia and I included per requests in several emails. I wanted to bring this to your attention so that you can insure that all required parents are covered. The missing ones are:

Ac-227
Ar-39
Ca-41
Cs-134
Pa-231
S-35
Sc-46
W-181
W-185
W-188

Larry Koffman/WSRC/Srs@Srs

Response

The missing elements were removed because the final screening indicated that they need not be analyzed.

Design Check Instructions for 2004 Slit and Engineered Trench Special Analysis -Radon

Design Checking Instructions, Comments and Responses:

Design checking of the Radon-222 simulations and report was performed in two steps, checks of the original simulation and report and later for modifications incorporated in the analysis. The initial design check was performed by Thong Hang and the later design check by Sebastian Aleman. Design checking instructions, comments and the resolutions are presented below.

Initial Design Check Instructions issued to Thong Hang, containing comments and responses:

Design Check Instructions for evaluation of Radon release from the Slit and Engineered Trenches

The following files are transmitted with these instructions:

Trench Radon Analysis.doc	Text writeup for Trench analysis
Radon Flux.xls	Calculation spreadsheets for analysis
runBOUNDPu238.out	Simulation output for bounding case, Pu238
runBOUNDRa226.out	Simulation output for bounding case, Ra226
runBOUNDTh230.out	Simulation output for bounding case, Th230
runBOUNDU234.out	Simulation output for bounding case, U234
runBOUNDU238.out	Simulation output for bounding case, U238
runTrench.dat	Typical run file for trench simulations

1. Check the input parameters identified in Table 2 of "Trench Radon Analysis.doc" for being reasonable, noting the units used in the model: meters, grams, and years.

A single value of 0.2 was used for porosity in this work. The previous PA (WSRC-RP_94-218, Rev. 1) used different porosity values for different materials, e.g., 0.42 for soil and waste, 0.51 for backfill, 0.38 for drainage, 0.18 for barrier. Some explanation is needed to justify the use of a single porosity.

Text will be added.

2. Examine the "half-life" worksheet in Excel Spreadsheet "RadonFlux.xls" to verify that the appropriate half-lives were used for each isotope that was simulated.

The half-life of 7.538E+04 yrs was used for Th-230 in this report compared to 7.70E+4 yrs given in the PA.

The 7.538E+04 value comes from the Nuclear Wallet Cards, BNL and is regarded as more accurate than other estimates.

3. Spot check the output files for each isotope to verify that the input parameters are correctly represented.

Input parameters are correctly used in the output files for each isotope (i.e., runBOUNDPu238.out, runBOUNDRa226.out, runBOUNDTh230.out, runBOUNDU234.out, runBOUNDU238.out).

OK

4. Examine the typical run file to verify that the logic of the simulation makes sense.

A typical run file (runTrench.dat) was examined. Overall the logic of the simulation makes sense. The following comments result from further examination of all input files for 'non-compaction of waste' case and the input file shown in the Appendix for the 'dynamic compaction of waste' case:

a. Since three nodes are specified in X direction, only two X coordinate values need be specified at cell faces as follows:

   COORdinate X:
   0.0 1.0

The presence of the additional coordinate does not make a difference in the simulated results, however any future simulations will be changed in accordance with the comment.

b. Rather than from 0 to 7.8m, Y coordinates values should range from 0 to 7.88m as shown in Table 1 and Figure 2 (i.e., compacted waste zone plus soil cover zone excluding topsoil and upper backfill).

The use of a slightly shorter stack was used to round off the numbers when the grid coordinates were generated. The small difference (8 cm or 3.1 inches) is a conservative change. Fluxes will be larger by a very small amount because of the difference in dimensions. The incremental increase in accuracy to be obtained by changing the grid dimensions is not regarded as sufficient justification to spend the time needed implement that change now.

c. For the 'non-compaction of waste' case, the waste zone thickness is 4.9m. Hence the specifications for material zones should be revised as follows:

   MATErial type 1 from 1 1 to 3 24 $ WASTE
   MATErial type 2 from 1 25 to 3 38 $ SOIL

The use of Y =22 instead of Y=24 to define the Waste Zone thickness in the Bounding Case (no compaction of waste material) makes a small, less conservative, difference for the Bounding Case. Precise adherence to the thickness of the compacted soil thickness is not absolutely necessary since it only impacts how conservative the conservative Bounding Case is. However, since the changes are fairly easy to make, I've made them, recalculated the fluxes and the associated limits and incorporated them into the appropriate tables.

5. Check the Rn-222 instantaneous flux from the output file for each parent isotope and compare to value in the "Trench and ILV" worksheet in the file "Radon Flux.xls" to verify that the correct numbers were utilized in calculating the disposal limits for each of the 4 configuration scenarios. (1000-year case) – actually 1125 years simulated. Note, the flux numbers used in the Bounding case calculations are found in column L for the 1125-year simulations.

Output files (i.e., runBOUNDPu238.out, runBOUNDRa226.out, runBOUNDTh230.out, runBOUNDU234.out, runBOUNDU238.out) for the non-compacted case were examined and the following instantaneous flux values at 1125 yrs are obtained:

Parent Isotope	Instantaneous Rn-222 Flux at Land Surface @ 1125 yrs (Ci/m^2-yr)
Pu-238	4.811168E-6
U-238	1.83563E-5
U-234	1.65922E-2
Th-230	2.961
Ra-226	4.81993

These values are correctly used in cells L21 to L25 in the 'Trench and ILV Flux' worksheet of the file 'Radon Flux.xls' However, the purpose of this work is to determine the disposal limit for each isotope. Hence, rather than the flux at 1125 yrs, the peak flux values must be used. Since no flux files are provided for this design check, it is not clear if the instantaneous flux values at 1125 yrs are also peak values. Only instantaneous flux values for the non-compacted case (i.e., the bounding case) were checked, since no output files for the compacted case are available. It would be strongly recommended that the report include plots of instantaneous fluxes for each parent isotope for both compacted and non-compacted cases.

Agreed. The table shows only Ra-226 with a peak prior to 1125 years. The others peak at the 1125-year point but that is not apparent to the reader. The suggested changes have been incorporated.

Further examination of the 'Trench and ILV Flux' worksheet reveals that the conversion factor (i.e., 1E+12/ 31557600) used in columns G and M to convert 'Ci/m^2-yr' to 'pCi/m^2-s' is incorrect. The correct factor should be 1E+12/31536000. The value 31536000 that is the product of '365 x 24 x 3600' is to convert yr into s.

The value used represents the conversion from years to seconds assuming there are 365.25 days in a year, to account for leap years. I believe this to be more accurate for the purposes of this investigation.

6. Spot check calculations made in the Trench and ILV worksheet to determine the disposal unit limits for each of the 4 Scenarios.

The disposal areas per unit (m^2/disposal unit) are correctly calculated in cells O18, Q18, S18 and U18. The disposal limits for each of the four scenarios are also correctly determined from the instantaneous flux values in cells M21 to M25.
OK

7. Check the numbers in Tables 3 and 4 to be sure the numbers have been correctly transcribed from the "Trench and ILV" worksheet in the file "Radon Flux.xls".

The values shown in Tables 3 and 4 have been correctly transcribed from the 'Trench and ILV' worksheet. In Table 3, the values for Ra-226 have been revised to represent the peak flux that occurs at 64.3 days after source (see comments in item 5 above). The values for Ra-226 in Table 4 need be corrected accordingly.

It has been updated as were the other new values that resulted from re-definition of the Waste Zone from Y = 1 to 22 to Y = 1 to 24 (non-compacted BOUNDING case).

****

From
Thong Hang/WSRC/Srs 06/15/2004 01:11 PM

To
Robert Hiergesell/WSRC/Srs@Srs
cc
Tom Butcher/WSRC/Srs@srs, Cynthia Holding-Smith/WSRC/Srs@Srs

Subject
Re: Trench Radon Design Check -- Changes

****

Bob,

I have looked through your revised report. Just let you know that all comments in my design check have been addressed to my satisfaction.

Thong Hang, PhD
Engineering, Modeling, and Simulation Group
Savannah River National Laboratory
Bldg. 773-42A
Aiken, SC 29808
Phone: (803) 725-8204 Fax: (803) 725-8829
E-mail: thong.hang@srs.gov

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX XXXX

****

Robert Hiergesell/WSRC/Srs 07/19/2004 11:33 AM

To Sebastian Aleman/WSRC/Srs@srs
Cc Tom Butcher/WSRC/Srs@Srs

Subject
Fw: Trench Radon Design Check – Changes

****

Sebastian,

I'm forwarding the initial Slit Trench radon analysis Design Check that Thong Hang provided so that you can see the comments he generated and the dispositon of those comments.

Since a few changes were made to the model simulations and to the write up, I am attaching the revised document, which contains an example of the Porflow input file. The primary changes to the simulations involved the residual saturation, which changes the air-filled porosity, and the use of an Emanation Coefficient. There is a discussion of these items in the text of the report. Also, you can find the RESRAD discussion of the Emanation Coefficient at:
http://web.ead.anl.gov/resrad/datacoll/radon.htm

Please review the report documentation in Trench Radon Analysis3.doc. The spreadsheet with the calculations of parent isotope disposal limits is contained in Design Check Calcs.xls. Please check to make sure the newly calculated limits are correctly represented in Table 4 in the Radon Analysis write-up.

Thanks for your willingness to look at this. Call if you have questions or want to discuss anything.

_____

Robert A. Hiergesell
Savannah River National Laboratory
Waste Disposal and Environmental Development
Phone (803) 725-5219
Pager (803) 725-7243 Id# 10871
Fax# (803) 725-7673

****

From Robert Hiergesell/WSRC/Srs 07/21/2004 02:13 PM

To Sebastian Aleman/WSRC/Srs@srs
Cc Tom Butcher/WSRC/Srs@Srs

Subject
Design Check - Trench Model Report

****

Sebastian,

I have gone through your design check responses and incorporated them into the final document. Your comments were with regard to two numbers incorretly transcribed into Table 3 and a column in Table 4 in which the values had not been updated in accordance with the spreadsheet I sent you. You also provided a suggestion that the units on the Y-axis in Figure 3 be changed from Ci/year to pCi/m2-s. This also has been incorporated and an updated copy of the report is attached for your review.

If this action addresses your Design Check comments/suggestions to your satisfaction please send me an email to that effect for the purpose of documentation.

Thanks -- Bob

_____

Robert A. Hiergesell
Savannah River National Laboratory
Waste Disposal and Environmental Development
Phone (803) 725-5219
Pager (803) 725-7243 Id# 10871
Fax# (803) 725-7673

****

From Sebastian Aleman/WSRC/Srs 07/30/2004 09:56 AM

To Robert Hiergesell/WSRC/Srs@Srs

Subject
Re: Design Check - Trench Model Report
****

Bob,

Your have addressed by Design Check comments/suggestions to my satisfaction.

Thanks

Sebastian E. Aleman
Savannah River National Laboratory
Westinghouse Savannah River Company
773-42A, Room 147
Aiken, South Carolina 29802
voice: 803-725-8040
email: sebastian.aleman@srs.gov

Design Check Instructions for 2004 Slit and Engineered Trench Special Analysis -Groundwater

Background

Analyses were performed for a nominal 20-ft wide Slit Trench. Results for the Engineered Trench and other sized Slit Trenches will be derived from the 20-ft wide Slit Trench results.

Analyses were conducted for four pathways as follows:

1. groundwater

2. intruder (being performed by others)
3. radon (being performed by others)
4. air (previously design checked)

1. Groundwater

The groundwater pathway has five segments as follows:

a. Vadose zone steady-state flow fields
b. Vadose zone transient hydrogen ion transport. This step serves as a proxy for the effects of cellulose degradation products. This step sets the stage for contaminants with Kds that are assumed to be functions of the hydrogen ion concentration.
c. Vadose zone transient contaminant transport analysis
d. Aquifer steady-state flow field prepared by Greg Flach
e. Aquifer transient contaminant transport analysis. The effects of cellulose degradation products are assumed to be inconsequential in the aquifer because of the greater dilution.

1.a. Vadose zone steady-state flow fields

Mark Phifer prepared a report showing infiltration rates through a cap as a function of time. The rates and times in that report and the selections for the Special Analysis derived from that report are presented in Table 26 below. The infiltration rates are converted form in/yr to cm/yr within PORFLOW by scaling by 2.54.

Table 26. Infiltration rates for vadose zone steady-state flow fields

Phifer Report				Special Analysis Values		
Infiltration rate (in/yr)	Start (year)	End (year)		Infiltration rate (in/yr)	Start (year)	End (year)
15.748	-25	0		15.748	0	25
0.360	0	100		0.3600	25	125
0.410	100	300		0.4100	125	325
3.050	300	550		3.0500	325	575
7.900	550	1000		7.9000	575	1025
12.040	1000	1800				
13.760	1800	3400				
14.030	3400	5600				
14.080	5600	10,000				
14.090	10,000	96.667				
14.100	96,667	280,000		14.100	1025	10000
18.120	280,000	future				

The model geometry has a 20-ft wide waste zone for a trench that is 20 feet deep. 16 feet of waste are placed at the bottom of the trench and the waste is covered by 4 feet of clean backfill. The bottom of the trench is 25 feet above the water table. The left side of the trench is 5 feet from the edge of the model, because other trenches could be 10 feet away. The right-side of the model extends 25 feet beyond the right-side of the trench. All soils are deemed to be native soil.

Flow boundary conditions are no flux through the vertical sides. The top boundary condition is the infiltration rate through the cap. The bottom boundary condition is the water table with zero pressure.

Physical property information generally was copied from the PA. The clean backfill was assumed to be less compacted than in the PA and its Ksat was increased by an order of magnitude. Additionally, the moisture characteristics for backfill were substituted for the PA values that were based on Native Soil. The waste was assumed to be a sandier type material and its moisture characteristics were based on Topsoil. Its Ksat was increased another order of magnitude over that for the clean backfill, because the waste initially will be even less dense than the clean backfill.

A new feature simulates the effects of dynamic compaction that potentially could reduce the thickness of the waste from 16 feet to 2.5 feet. Changes to help simulate some aspects of the dynamic compaction included transferring all contaminants from the uppermost 13.5 feet of the waste zone to the lowermost 2.5 feet. Also, at the time of the dynamic compaction (125 years), the uppermost 13.5 feet of the waste zone was assumed to be replaced by clean backfill. The dynamic compaction reduced the Ksat in the clean backfill zone and the uppermost 13.5 feet of the original waste zone to 1E-4 cm/sec. For the lowermost 2.5 feet of the original waste zone, the Ksat was reduced to 2E-4 cm/sec by the dynamic compaction.

1.b. Vadose zone transient hydrogen ion analysis

The transient hydrogen ion analysis provided hydrogen ion concentrations to serve as independent variables to calculate the Kd values for contaminants. The transient analysis was performed for 10,000 years incorporating the steady-state flow fields as needed.

The geometry was read from the steady-state flow files.

For initial conditions, the background concentration of the hydrogen ions was set at a pH of 5.5. In the waste zone was set to a pH of 4.5 and fixed at that concentration, as a type of solubility-limited analysis. After dynamic compaction the pH in the lowermost 2.5 feet of the waste zone remained fixed at a pH of 4.5, but the pH in the uppermost 13.5 feet of the original waste zone was set at a pH of 5.5 and allowed to vary.

Boundary conditions consisted of zero flux out the sides and a pH of 5.5 at the top that enters with the flow. At the bottom, the boundary condition was commented out, that turns off diffusion, but allows advection to occur. This approach leads to slightly higher concentrations within the model domain. Because the Kds all are constant or decrease as the pH increases, this approach tends to reduce the Kds that in turn tend to increase the well concentrations.

The values for material properties were duplicated from the PA, e.g.,

Dispersivity set to zero
Diffusion
Porosity
Particle density

Differences from the PA were as follows:

The half life was not set, so no decay should occur.
A Freundlich nonlinear isotherm was simulated with a Kbar of 3.88679E-4 ml/g and an n of 0.38. PORFLOW states that it multiplies the Kbar value by the particle density. The K value provided by geochemists was 1.03E-3 ml/g. To counter PORFLOW multiplying by the particle density, the K value was divided by the particle density of 2.65 g/cc to produce the final Kbar value that was input.

2. Intruder
3. Radon
4. Air

Instructions
All files are located on my computer \\l-collard. The root shared directory is Slit2004. Flow input and output files are located in Slit2004\VadoseZ\Flow. Separate subdirectories exist for each steady-state flow period and are appropriately named.

1.a. Vadose zone steady-state flow fields

Fully check one steady-state flow run. The input file (run.dat) should be carefully inspected. Additionally the standard output file (run.out) should be inspected to see that include filenames were spelled correctly and that the analysis completed correctly.

Within the input file, check the following:

Geometry
Boundary conditions
Material properties

(A separate CD-ROM will be provided showing the PA analyses. On that CD, three steady-state flow analyses were completed, namely Slit\Por00, Slit\Por01 and Slit\Por02. Material properties in the current analysis should match those from the PA, except where described above.)

Within the output file, ensure that all include files were included and that the solution converged. Examine the velocity and pressure graphs (separate hard copies will be provided) to ensure that the results are consistent with the modeling.

After performing the full check on one steady-state flow run, check the differences with for all other input files. Ideally the only change in the input files should be the infiltration rate, except when dynamic

compaction occurs. Examine the velocity and pressure graphs (separate hard copies will be provided) for all steady-state flow fields to ensure that the results are consistent with each other.

Also, check that dynamic compaction was modeled as described in the Background Section.

1.b. Vadose zone transient hydrogen ion analysis

Within the input file (Slit2004\VadoseZ\Transport\pH.run.dat), check the following (for include files, the include file itself must be examined):

Geometry
Boundary conditions
Initial conditions
Material properties
Proper inclusion of steady-state flow files

The geometry should be refined near the top and bottom of the waste zone and somewhat near the water table at the bottom of the modeling domain.
Note that the analysis for the final stage from 1025 to 10,000 years was completed in the directory pH10000.

The hydrogen ion concentrations at each steady-state flow field stage were saved. The concentrations at the end of the stage should be the highest during that stage because the source is essentially infinite (fixed at a pH of 4.5). The highest pH will produce the lowest Kd that should produce the highest well concentration.

For the output file, ensure that the solution is appropriate and that excessive mass balance errors did not occur. Each stage was run independently to help see the mass balance results. One method is to examine the flux disparity information provided in a table after the SOLVE.

Examine the concentration plots (provided separately) for consistency with the models and between each other.

Document Review Comments					
Document No. WSRC-TR-2004-00300	Rev. 0	Title: Special Analysis: 2004 General Revision of Slit and Engineered Trench Limits (U)			Comments Due: 06/15/2004
#	Section/Page/ Paragraph/Line	Comment	Reviewer Initial	Response/Resolution	Reviewer Concur
1	Page iii	Add Sebastian E. Aleman as a design check.		accepted	
2	Page iii	Bob Hiergesell is listed as an author and design check. It should be one or the other.		Accepted, he is a coauthor only	
3	Page 7/P3	When you discuss general changes you should include a brief discussion of the change in the groundwater PORFLOW model footprint. For example, zoomed in aquifer model.		Accepted	
4	Page 7/P4	Include reference number for PA (5).		Accepted	
5	Page 7/P6/S1	Reword: Table 1 provides a summary of all isotopes with a current inventory fraction of …		Accepted. Wording included to indicate that Table 1 is a duplicate of the table in the body of the report.	
7	Page 8/S2/P2	The pathways/scenarios should be renumbered starting at 1.		Accepted	
8	Page 8/S2/P4	Add a discussion about changes to the groundwater model foot print.		Rejected. This section discusses changes relevant to multiple pathways. The change to the groundwater model footprint is discussed in the GW section on page 12 above Table 3.	
9	Page 9/S3	This is the section (or in an Appendix) where you need to discuss in detail the changes to the groundwater model from the PA. In particular, provide figures showing how the waste form changes in the vadose zone between pre and post dynamic compaction. Superimpose the 2-D vadose zone computational mesh. For the aquifer zone, present a 2-D cross-sectional view of the mesh showing the aquifer source nodes and particle tracks to the well observation nodes. Present information on how the handshaking between the fractional contaminant fluxes in the vadose zone and the aquifer source nodes is performed.		Accepted	
10	Page 9/S3.1/P2	Describe how you implemented the infiltration rate through the cover for a given steady-state flow period. Please capture the values for each flow period in a table. I would have used the average infiltration rate for each period since this integrates over time to the correct amount of water entering the vadose zone. Choosing the endpoints of the interval either under predicts or over predicts the groundwater infiltration into the vadose zone.		accepted	

Document Review Comments					
Document No. WSRC-TR-2004-00300	Rev. 0	Title: Special Analysis: 2004 General Revision of Slit and Engineered Trench Limits (U)			Comments Due: 06/15/2004
#	Section/Page/ Paragraph/Line	Comment	Reviewer Initial	Response/Resolution	Reviewer Concur
11	Page 9/S3.1	Split the discussion in S3.1 into two subsections; S3.1.1 for the vadose zone and S3.1.2 for the aquifer zone. The intro in S3.1 should address how the two subsections come together to provide the complete model.		Accepted	
12	Page 11/P2,3	Instead of discussing an individual material property (Ksat), please provide a table showing the material properties for each of the soils used in the vadose model. You can then comment on the various material properties as needed for emphasis or clarification. Show the impact on material properties following dynamic compaction. Also provide the soil-water retention curves used in the model.		Accepted	
13	Page 11/P6	I would delete the equation for the "average Kd". You already have described in the previous paragraph its ad-hoc implementation.		Accepted	
14	Page 11	Include a table showing the transport properties for each soil prior to and following dynamic compaction in the vadose zone. Provide a discussion of transport properties that are isotope dependent such as Kd.		Accepted. Changes made in this section and in Appendix A.	
15	Page 12/P3	Start discussion of aquifer source nodes in the new S3.1.2.		Accepted	
16	Page 12/P4	Can you describe or reference the methodology for converting the fractional contaminant flux to the water table into a series of aquifer source nodes? In particular, I am interested how you convert fluxes from a 2-D vadose model into volumetric sinks in the 3-D aquifer model. In future SA or PA, I would investigate the coupling of the vadose and aquifer model within a single PORFLOW run to avoid this handshaking. I know there are numerical and convergence issues, but I think they can be dealt with as they were with previous variably saturated models developed with FACT.		Added discussion earlier in Section 3.	

Document Review Comments					
Document No. WSRC-TR-2004-00300	Rev. 0	Title: Special Analysis: 2004 General Revision of Slit and Engineered Trench Limits (U)			Comments Due: 06/15/2004
#	Section/Page/ Paragraph/Line	Comment	Reviewer Initial	Response/Resolution	Reviewer Concur
17	Page 12/P5	For each radionuclide of interest (parent isotope), a single vadose zone and aquifer zone transport run is executed for the parent and daughter isotopes (if any). Some of these isotope chains share common daughters and granddaughters. Therefore, for these chains, the transport equations are coupled through their common daughters and technically should be solved together. The current methodology processes each isotope and or chain independent of another as single transport calculations. How does this methodology ensure that concentration levels are being accurately computed in the vadose and aquifer zones for each isotope of interest? How does the sum-of-fractions relate to this situation?		Actual inventories are never modeled, thus the reported concentrations are only relative to the initial inventory that was assumed. As long as the processes are linear, the parent can be run independent of the daughter and the "true" concentration for the daughter can be calculated by summing the concentrations from the separate runs. ???	
18	Page 12/P6	Do you need to add a discussion about the doubling of peak well concentrations from the PORFLOW results to account for 2 sources? You need to mention that isotopes are grouped by each chain with the parent being the first entry and daughter products trailing below (if any). Perhaps make the parent isotope bold.		Accepted.	
19	Page 13/T4	Table 4 needs to have Header Rows Repeat.		Accepted	

Document Review Comments					
Document No. WSRC-TR-2004-00300	Rev. 0	Title: Special Analysis: 2004 General Revision of Slit and Engineered Trench Limits (U)			Comments Due: 06/15/2004

#	Section/Page/ Paragraph/Line	Comment	Reviewer Initial	Response/Resolution	Reviewer Concur
20	Page 19/P1	Mesh refinement and coupling of the vadose and saturated zone are needed to quantify the impact of geometry changes in the trenches. By converting fractional contaminant fluxes into volumetric aquifer source nodes, you are changing the distribution of the contaminant into the aquifer zone. I don't know how sensitive the saturated model concentrations are to the distribution of aquifer source nodes. Mesh refinement, particularly in the vicinity of the observation wells will impact the well concentrations. Also the extent of the model boundary can impact the well concentrations, especially if the model boundary (boundary condition) is near the observation well. What are the boundary conditions at the model domain? Diffusive flux set to zero? These things are important.		Accepted in part. The model domain was extended for the highly mobile contaminants. Mesh refinement and coupling of the models are ideas that hopefully will be implemented soon. Mesh refinement for the ILV model did not increase concentrations on par with the dilution volume changes, indicating less sensitivity than expected. The boundary conditions are set to advection only. This statement was added to the text.	
21	Page 19/P1/L10	Change "my" to "may".		Accepted	
22	Page 19-29	Intruder Analysis, Radon Analysis and Air Analysis is outside the scope of this design check. Only GW pathways.		Accepted	
23	Page 30/T12	Table 12 needs to have Header Rows Repeat. Under Infiltration you have "No" for superceded. I thought the Phifer study superceded the infiltration scenario in the PA.		First part accepted. The supercede column states whether this document (WSRC-TR-2004-00300) supercedes the previous report. Phifer's report does replace a portion of the PA, but it is only referenced in this document.	
24	Page 32/S8	Was the UDQ-E verified for shallow and narrow trenches? Please provide a discussion of the findings. How do the results for I-129 apply to other isotopes?		Accepted	
25	Page 32/S9	I assume references to figures showing contaminant fluxes and well concentrations will be given here and discussed.		Accepted	
26	Page 33/T14	Table 14 needs to have Header Rows Repeat.		Accepted	
27	Page 36/T15	See comment 6 for Table 1.		Accepted. This table changed then was copied.	
28	Page 36/S10/P1	In reality, too many things changed between this report and the PA to adequately explain why the limits changed from the PA.		No effect. This paragraph states that there were many changes, then it briefly discusses some of the changes that were judged to be some of the most important changes.	

Document Review Comments					
Document No. WSRC-TR-2004-00300	Rev. 0	Title: Special Analysis: 2004 General Revision of Slit and Engineered Trench Limits (U)			Comments Due: 06/15/2004

#	Section/Page/ Paragraph/Line	Comment	Reviewer Initial	Response/Resolution	Reviewer Concur
30	Page 37/S11/P1	Three different versions of PORFLOW-3D were used in this study: Version 5.95.0 for the aquifer zone flow models, Version 5.96.0 for the vadose zone flow models and Version 5.97.0 for the aquifer and vadose zone transport models. From a software QA view, I would not feel completely comfortable with the results without prior testing of the software.		Accepted in principle. Cases were reanalyzed using Version 5.97.0, except for the aquifer study where results (used as inputs in this study) were provided by others. WPT is aware that the software QA could be improved. If money is available, WPT intends to apply additional testing and document the results. The current version of PORFLOW is more recent than that tested in the original QA document and new features are being used. Most of these features have been tested, but have not yet been formally documented.	
31	Page 37/P2/L3	Change “waste for” to “waste form”		Moot. Entire section on Future Work removed based on other’s comments	
32	Page 37/P3	See comment 20.		Moot. Entire section on Future Work removed based on other’s comments	
33	Page 37/P5/L4	Change “amout” to “amount”		Moot. Entire section on Future Work removed based on other’s comments	
34	Page 42/T16	Table 16 needs to have Header Rows Repeat.		Accepted	

Reviewer Name Print Name / Initials	Sebastian Aleman / SEA Signature _____	Phone / Location: 5-8040 / 773-42A	Date 15-June-04
Concurrence Signature QA Reviewer	_____/_____/_____	Phone / Location: _____	Date