SRNL-STI-2010-00760, REV. 0

DOSE ASSESSMENT OF THE FINAL INVENTORIES IN CENTER SLIT TRENCHES ONE THROUGH FIVE

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F. G. Smith, III

APRIL, 2011

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Prepared for the U.S. Department of Energy Under Contract Number DE-AC09-08SR22470

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ARRA	American Recovery and Reinvestment Act
2D	Two-dimensional
3D	Three-dimensional
CDP	Cellulose Degradation Products
CIG	Components-In-Grout
CST	Center Slit Trenches
DAS	Disposal Authorization Statement
DCF	Dose Conversion Factor
DOE	United States Department of Energy
E&CPT	Environmental & Chemical Process Technology
EPA	United States Environmental Protection Agency
ETF	Effluent Treatment Facility
ETP	Effluent Treatment Project
FGR	Federal Guidance Report
GSA	General Separations Area
HWMF	Hazardous Waste Management Facility
ICRP	International Commission on Radiological Protection
K_d	Distribution coefficient (volume/mass)
MCL	Maximum Contaminant Level
PA	Performance Assessment
SA	Special Analysis
SLIT	Slit Trench
SOF	Sum-of-Fractions
ST	Slit Trench
SWM	Solid Waste Management
UDQ	Unreviewed Disposal Question
WITS	Waste Information Tracking System

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1.0 EXECUTIVE SUMMARY

In response to a request from Solid Waste Management (SWM), this study evaluates the performance of waste disposed in Slit Trenches 1–5 by calculating exposure doses and concentrations. As of 8/19/2010, Slit Trenches 1–5 have been filled and are closed to future waste disposal in support of an ARRA-funded interim operational cover project. Slit Trenches 6 and 7 are currently in operation and are not addressed within this analysis. Their current inventory limits are based on the 2008 SA and are not being impacted by this study.

This analysis considers the location and the timing of waste disposal in Slit Trenches 1–5 throughout their operational life. In addition, the following improvements to the modeling approach have been incorporated into this analysis:

- Final waste inventories from WITS are used for the base case analysis where variance in the reported final disposal inventories is addressed through a sensitivity analysis.
- Updated K_d values are used.
- Area percentages of non-crushable containers are used in the analysis to determine expected infiltration flows for cases that consider collapse of these containers.
- An updated representation of ETF carbon column vessels disposed in SLIT3–Unit F is used. Preliminary analyses indicated a problem meeting the groundwater beta-gamma dose limit because of high H-3 and I-129 release from the ETF vessels. The updated model uses results from a recent structural analysis of the ETF vessels indicating that water does not penetrate the vessels for about 130 years and that the vessels remain structurally intact throughout the 1130-year period of assessment.
- Operational covers are included with revised installation dates and sets of Slit Trenches that have a common cover.

With the exception of the modeling enhancements noted above, the analysis follows the same methodology used in the 2008 PA (WSRC, 2008) and the 2008 SA (Collard and Hamm, 2008). Infiltration flows through the vadose zone are identical to the flows used in the 2008 PA, except for flows during the operational cover time period. The physical (i.e., non-geochemical) models of the vadose zone and aquifer are identical in most cases to the models used in the 2008 PA. However, the 2008 PA assumed a uniform distribution of waste within each Slit Trench (WITS Location) and assumed that the entire inventory of each trench was disposed of at the time the first Slit Trench was opened. The current analysis considers individual trench excavations (i.e., segments) and groups of segments (i.e., Inventory Groups also known as WITS Units) within Slit Trenches. Waste disposal is assumed to be spatially uniform in each Inventory Group and is distributed in time increments of six months or less between the time the Inventory Group was opened and closed.

The study was performed in the following manner:

- Transport through a nominal trench and vadose zone of a nominal one gram-mole of each parent radionuclide in each Inventory Group was calculated using the PORFLOW vadose zone model described in Chapter 4. Inventories were provided by Inventory Group and vadose zone modeling was performed at the same level. The vadose zone calculations considered both the case where all waste containers were non-crushable and the case where all waste containers were crushable. Vadose zone results for the two cases were blended using a probability defined as the ratio of the applicable WITS Inventory Group area of non-crushable containers versus the total waste area for that Inventory Group.

- Following the 2008 PA approach, non-crushable containers were assumed to collapse when the final cover is placed over the Slit Trenches in 2125. The collapse of the containers causes the cap to fail which causes a significant increase in infiltration flow through the trench. Vadose zone calculations were also performed for cases with and without the impact of Cellulose Degradation Products (CDP) applied to each radionuclide distribution coefficient (K_d).

- Vadose zone transport calculations produced contaminant fluxes to the water table for each radionuclide in a parent's chain and each case evaluated (Chapter 4). Those fluxes were scaled by the actual inventory of each parent to create sources for the PORFLOW aquifer transport model. In this step the fluxes from Slit Trenches 1, 2 and 5 were combined into a single set of sources and the fluxes from Slit Trenches 3 and 4 were combined into another set of sources. The Slit Trenches sources were combined in this way because at the start of the analysis only Slit Trenches 1, 2 and 5 were full and their final inventories were available.

- The aquifer transport model, described in Chapter 5, was run and the maximum radionuclide concentrations at or beyond the 100-m point of assessment was saved as a function of time for dose calculations.

- For each groundwater pathway, doses and concentrations were calculated as described in Chapter 6 using the radionuclide concentrations obtained from the aquifer transport calculations. The "worst case" radionuclide concentration (the maximum value from any of the cases analyzed at each time step) was used to make the dose calculations.

- As a separate analysis, non-groundwater pathway sums-of-fractions (SOF) were computed from the final radionuclide disposal inventory. These SOFs are based on the inventory values and 2008 SA limits currently within WITS.

Table 1-1 provides a summary of groundwater pathway dose and concentration results. Aquifer analyses are not performed on an individual disposal unit basis; instead, several disposal units are addressed simultaneously. In this study SLIT1, SLIT2, and SLIT5, were combined into one composite analysis referred to as SLIT125. SLIT3 and SLIT4 were similarly combined into a composite analysis referred to as SLIT34. Note that "SLIT" is sometimes abbreviated as "ST" (e.g., SLIT34 and ST34 are equivalent). The results for each individual disposal unit are then extracted from each composite analysis. The first part of the table lists maximum doses or concentrations found for groundwater exposure to gross alpha, beta-gamma, radium, uranium and groundwater all-pathways. The middle of the table shows a relative performance index for each groundwater exposure pathway obtained by dividing the maximum dose or concentration by its allowable value. The bottom part of Table 1-1 gives the year when the maximum occurred.

As shown in Table 1-1, the gross alpha concentration, beta-gamma dose and groundwater all-pathways dose fall between 7.5% and 92.0% of the allowable while the radium and uranium concentrations are relatively negligible. This result should not be surprising as it is the objective of SWM to make optimum use of both the volumetric capacity as well as the inventory capacity of all available disposal units. For both Slit Trench sets, the groundwater all-pathways dose is closest to the allowable. For both sets, the maximum groundwater all-pathways dose is largely caused by Np-237 and to a lesser extent by the U-235 chain with smaller contributions from other radionuclide chains.

Table 1-2 shows computed SOFs for the non-groundwater pathways. The largest SOF is 4.4% for post-drilling in Slit Trench 5.

Table 1-1 Summary of maximum doses and concentrations for groundwater exposure pathways.

	Gross Alpha (pCi/L)	Beta-Gamma (mrem/yr)	Radium (pCi/L)	Uranium (μg/L)	Groundwater All-pathways (mrem/yr)
Allowable	**15**	**4**	**5**	**30**	**25**
Maximum dose or concentration					
ST125	1.13E+00	6.49E-01	1.52E-03	1.68E-09	6.82E+00
ST34	3.95E+00	5.27E-01	9.49E-04	6.07E-09	2.30E+01
Relative Performance Index (ratio of maximum value to the allowable)					
ST125	7.53E-02	1.62E-01	3.04E-04	5.60E-11	2.73E-01
ST34	2.63E-01	1.32E-01	1.90E-04	2.02E-10	9.20E-01
Year when maximum dose or concentration occurred					
ST125	2920.2	2014.1	3126.0	3126.0	2926.2
ST34	2946.2	2542.9	3126.0	3126.0	2950.2

Table 1-2 Non-groundwater sums-of-fractions in Slit Trenches 1-5.

	Resident	Post-drilling	Air Pathway	Radon Pathway
Allowable	**100 mrem/yr**	**100 mrem/yr**	**10 mrem/yr**	**20 pCi/m^2-s**
ST1	1.29E-03	2.68E-03	9.11E-06	1.44E-07
ST2	1.34E-02	8.60E-03	2.64E-05	4.71E-09
ST3	2.40E-03	2.43E-02	2.77E-05	3.56E-09
ST4	2.49E-03	1.63E-02	2.79E-05	7.89E-09
ST5	7.21E-03	4.40E-02	1.19E-04	1.96E-08

During the scoping portion of this analysis, the impact of local subsidence on various nuclides was reviewed. A significant impact on the peak flux of Sr-90 to the water table was observed when comparing intact versus subsided cases. The effect of subsidence is pronounced for certain nuclides whose half-lives and chemical retardation (i.e., K_d values) parameters fall within certain ranges.

Three key factors in the Base case set of analyses are:

- The timing associated with placement of the operational cover was set to 9/30/2011.
- The use of mechanical dispersion in the aquifer model.
- The final disposal inventories were set to those values listed within WITS.

Each of these key factors was considered in a limited set of sensitivity analyses. The first set of sensitivity analyses indicated that a short-term shift in the timing of the operational cover plays a minor role in the resulting performance. Therefore, operational covers placed within the time frame of 12/1/2010 through 9/30/2011 are acceptable.

Following the 2008 PA, the aquifer model used for this analysis included mechanical dispersion. A limited sensitivity study on Np-237 indicated that if mechanical dispersion were not included calculated doses could increase by a factor of about 1.66. However, while dispersion does occur it is unknown how much is created via numerical dispersion, thus the true amount of mechanical dispersion that should be introduced is also unknown. Note that this analysis follows the same approach as the 2008 PA, thus no changes are required. Also, new DCFs likely will be implemented in the next PA revision which will more than compensate for any changes resulting from improving the approach to dispersion.

The base case disposal inventories were set to those values listed within WITS. At these concentration levels nuclide adsorption onto solids follows an approximately linear isotherm. This results in overall linear transport processes throughout the Vadose zone and Aquifer units. As such, a reported 5% variance within the final disposal inventories corresponds to a 5% variance within the computed doses for each pathway considered. This level of increase is within the available margin as can be seen for the doses listed in Table 1-1 versus allowable (23.0 mrem/yr times 1.05 = 24.2 mrem/yr, which is less than 25 mrem/yr).

Preliminary scoping analyses indicated a problem meeting the groundwater all-pathways dose limit primarily because of high concentrations of Np-237 in SLIT3 and SLIT4. Final modeling shows that no allowable performance objective is exceeded. Because doses are only slightly below one performance objective, options were considered that could reduce the doses. Options included the following:

1. using newer Dose Conversion Factors
2. benefits from a potential 100-acre expansion. (The benefits are approximations because only Np-237 in ST34 was reanalyzed.)
3. applying high-pH injection in selected trench segments at 90% efficiency
4. applying high-pH injection in selected trench segments at 60% efficiency

Maximum doses and concentrations for each of the options are provided in Table 1-3 along with a comparison to the Base case results. Relative to the Base case, maximum doses or concentrations either did not change or were reduced. The highest relative performance index for ST34's all-pathways was reduced by 88% for the option of new DCFs, while other options reduced it by 39% to 61%.

Table 1-3 Maximum doses and concentrations for groundwater exposure pathways for the Base case and options.

	Option	Gross Alpha (pCi/L)	Beta-Gamma (mrem/yr)	Radium (pCi/L)	Uranium (μg/L)	Groundwater All-pathways (mrem/yr)
Allowable		**15**	**4**	**5**	**30**	**25**
Maximum dose or concentration						
ST125	**Base case**	1.13	0.649	1.52E-03	1.68E-09	6.82
	New DCFs	1.13	0.649	1.52E-03	1.68E-09	0.88
ST34	**Base case**	3.95	0.527	9.49E-04	6.07E-09	23.0
	New DCFs	3.95	0.527	9.49E-04	6.07E-09	2.68
	100-acre expansion	2.20	0.527	9.49E-04	3.09E-09	14.0
	90% high-pH treatment	1.45	0.506	9.49E-04	2.72E-09	8.9
	60% high-pH treatment	2.23	0.512	9.49E-04	3.84E-09	13.2
Relative Performance (ratio of option to Base case)						
ST125	**Base case**	1.00	1.00	1.00	1.00	1.00
	New DCFs	1.00	1.00	1.00	1.00	0.13
ST34	**Base case**	1.00	1.00	1.00	1.00	1.00
	New DCFs	1.00	1.00	1.00	1.00	0.12
	100-acre expansion	0.56	1.00	1.00	0.51	0.61
	90% high-pH treatment	0.37	0.96	1.00	0.45	0.39
	60% high-pH treatment	0.56	0.97	1.00	0.63	0.57

Two important conclusions have been reached as a result of this study:

- The 2008 SA assumed a uniform distribution of waste within each Slit Trench and that the entire inventory of each trench was disposed of at the time the first Slit Trench was opened. These assumptions were the same as those used in the initial PA before any waste was disposed. If the overall doses and concentrations calculated in this study are divided by the applicable performance objective (e.g., 4 mrem/yr for the beta-gamma pathway) a performance indicator is produced that is equivalent to a sum-of-fractions (See Table 1-1). Each peak performance indicator is less than its respective WITS SOF calculated using limits for the 2008 SA. Therefore, this study, using the latest available information (e.g., most recent Kd's, DCF's, etc.) and data from the first 15 years of Slit Trench operations (i.e., actual disposal locations and timing) demonstrated that the 2008 SA limits in combination with these specific inventory distributions and timing were bounding.

- The actual installation of operational stormwater runoff covers over Slit Trenches 1-5 in December 2010 was assessed and determined to maintain acceptable performance for these Slit Trenches.

In summary, making use of the new DCFs significantly reduces the overall peak dose for all five slit trenches from 23.0 mrem/yr to 2.68 mrem/yr and forces the gross alpha pathway to become the most important with a peak concentration of 3.95 pCi/L. This degree of margin from the allowable values accommodates analysis uncertainties and indicates no further mitigative options are warranted. As such the results from the 100-acre expansion and high-pH treatment options remain within this report for documenting the insight gained while investigating these options and providing information for potential future use.

2.0 INTRODUCTION

2.1 Background

At the request of Solid Waste Management (SWM) (see the UDQ Screening provided in Appendix H, Reed, 2010) a study has been performed to assess the performance of Center Slit Trenches 1-5. Seven Slit Trenches comprise the “Center Slit Trench” grouping (CST) as shown in Figure 2-1 below. Slit Trenches 1–4 are west of the Components-in-Grout (CIG) trench disposal units and Slit Trenches 5-7 are east of the CIG trench disposal units. As of 8/19/2010, Slit Trenches 1–5 were filled and closed to future disposal. This study evaluates the performance of Slit Trenches 1–5 by calculating doses and concentrations resulting from the waste disposed in these trenches. Slit Trenches 6 and 7 are currently in operation and are not addressed within this analysis. Their current inventory limits are based on the 2008 SA and are not being impacted by this analysis.

Slit trench area designations in this analysis are as follows:

- Trench segment – the smallest area for which information is available. This information consists solely of X coordinates and Y coordinates for an excavation.
- Inventory Group or Segment Group – a group of trench segments for which inventories, first disposal date, and last disposal date are provided. Inventory groups are specified as WITS Units. For example, SLIT1 is an inventory group in WITS that consists of ten unique trench segments (see Table 4-1). For example, on SRNS Engineering Drawing C-CV-E-0070 (2009), trench segment 111 exists along the western edge of SLIT1. No specific inventory or operational times are available for that trench segment. The only specific information for that trench segment (referred to as a trench on the drawing) is that the coordinates for its perimeter are as follows:

TRENCH 111		
1	77435.3	58182.5
2	77468.4	58219.2
3	77535.2	58292.6
4	77589.2	58361.2
5	77607.6	58378.6
6	77648.4	58415.6
7	77688.5	58463.5
8	77703.6	58448.8
9	77655.8	58388.3
10	77617.7	58353.1
11	77532.6	58262.0
12	77449.7	58169.8

- Slit Trench or Slit Trench Disposal Unit – a WITS location consisting of a footprint area that is 656 feet long by 157 feet wide. A Slit Trench contains five ideal Trench Rows – each representing a nominal 20-foot wide trench cross-section that extends the entire 656 foot length in a straight line. The most recent Performance Assessment (PA) and SAs used the Slit Trench Disposal Unit designation to apply to the footprint.

- Ideal Trench Row – one of five such rows contained in a Slit Trench.
- Trench cross-section – a nominal cross-section for a single Ideal Trench Row where the trench excavation is 20 feet wide by 20 feet deep and the waste zone initially occupies the lower 16 feet of the cross-section.
- Ideal Trench Segment – part of an Ideal Trench Row assigned inventory based on disposals as of 4/2009.

The most recent PA was based on the assumption that all waste was disposed instantaneously, simultaneously, and uniformly throughout all Slit Trenches. The subsequent SA included an assumption that all of the Slit Trenches were capped simultaneously. The following improvements to the modeling approach used in the 2008 PA (WSRC, 2008) and 2008 SA (Collard and Hamm, 2008), have been incorporated into this analysis:

- Final waste inventories are used where the base case employs the WITS values and a 5% variance is addressed in a sensitivity analysis.
- Updated K_d values are used in the vadose zone and aquifer transport calculations.
- Area percentages of non-crushable containers are used in the analysis to determine expected infiltration flows for cases that consider collapse of these containers.
- The effect of high-pH injection in selected trench segments is modeled as an optional treatment at final disposal. Preliminary analyses indicated the potential for a problem satisfying the groundwater all-pathways dose limit primarily because of high concentrations of Np-237 in Slit Trenches 3 and 4. Increasing the pH in trench segments where significant amounts of Np-237 were buried reduces the Np^{+5} to the less mobile Np^{+4} form which is modeled via a high K_d value. Higher K_d values significantly impede Np-237 transport from a treated waste zone which reduces well concentrations. A description of a possible high-pH injection process is provided in Chapter 8.
- An updated representation of the ETF carbon column vessels disposed in SLIT3–Unit F is used (note that the ETF more recently has been referred to as the Effluent Treatment Project [ETP]). Preliminary analyses indicated a problem satisfying the groundwater beta-gamma dose limit because of high H-3 and I-129 release from the ETF vessels. The updated model uses results from a recent structural analysis of the ETF vessels showing that water does not penetrate the vessels for about 130 years and that the vessels remain structurally intact throughout the 1130-year period of assessment.
- Operational covers are included with revised installation dates and sets of Slit Trenches that share a common cover.
- Waste is assumed to be disposed in slit trench segments, rather than being uniformly distributed over the entire footprint of each Slit Trench. Disposal in segments improves the model accuracy by capturing where the waste was placed.

- Waste is assumed to be disposed in a trench segment during the time interval when that segment was operational, rather than at the time when the first waste was disposed in SLIT1.
- Relative to the PA, analysis durations for highly mobile radionuclides are extended beyond 130 years to account for the effects of dynamic compaction.

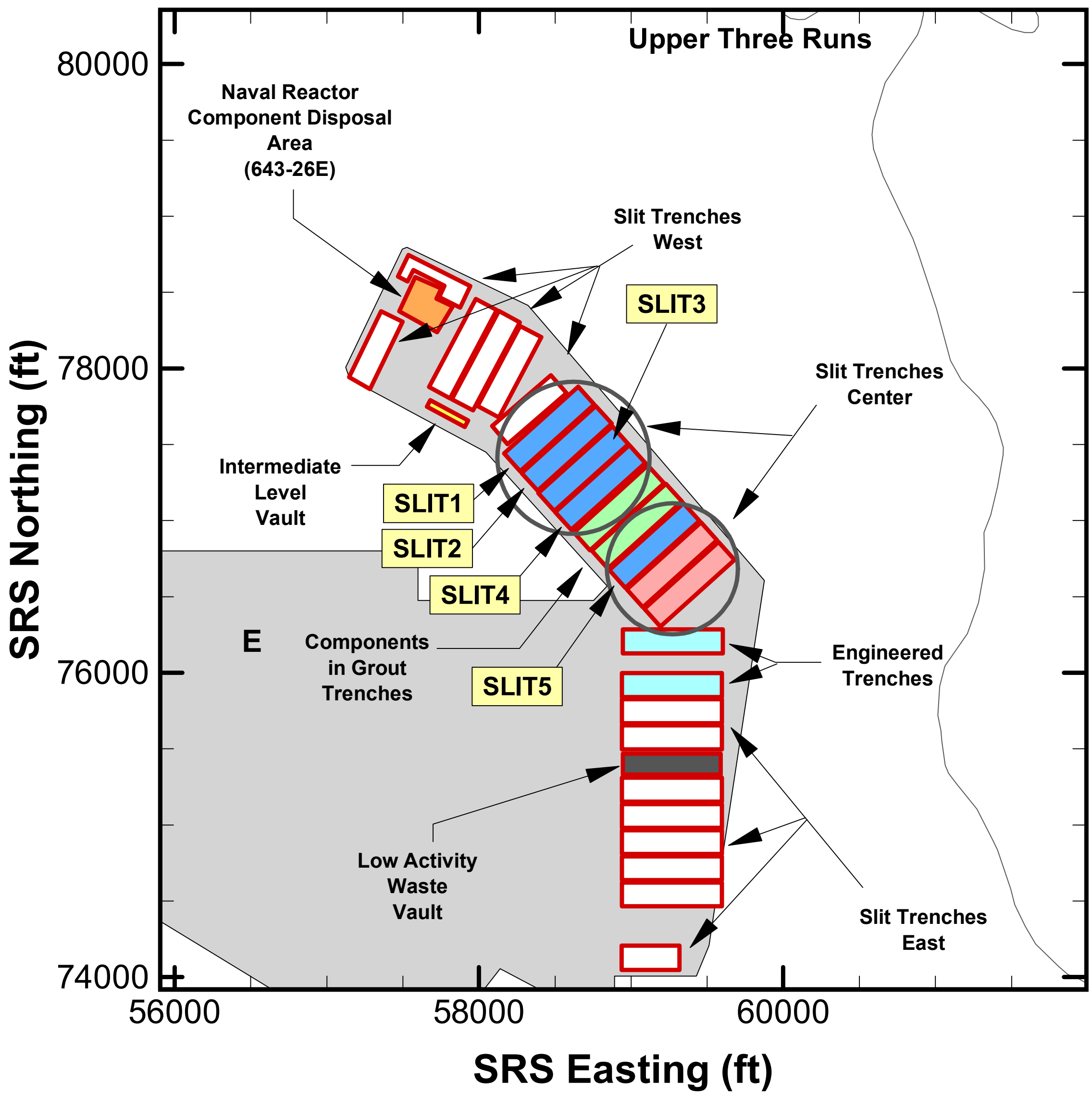

Figure 2-1 Aerial view showing E-Area Disposal Unit footprints in red where the seven center Slit Trenches are circled (the five of interest in this analysis are shaded in blue).

With the exception of the modeling improvements noted above, the analysis follows the same methodology used in the 2008 PA and 2008 SA. Infiltration flows through the vadose zone are identical to the flows used in the 2008 PA, except for flows during the operational cover time period. The physical (i.e., non-geochemical) models of the vadose zone and aquifer are identical to the models used in the 2008 PA. However, the 2008 PA assumed a uniform distribution of waste within each Slit Trench (WITS Location) and assumed that the entire inventory of each trench was disposed at the time the first waste was disposed in SLIT1. This analysis considers individual trench excavations (segments) and groups (WITS Units) of segments within Slit Trenches. Waste disposal is assumed to be spatially uniform in each segment group and is distributed in time increments of six months or less between the time the Segment Group was opened and closed.

The Slit Trenches and Inventory Groups considered in this analysis are listed in Table 2-1. Note that SLIT1 is treated as a single Inventory Group and SLIT2 is only subdivided into two Inventory Groups. For Slit Trenches 3–5 more detailed information on the operating history was provided based on current segmentation controls found in WITS. Coordinates for some trench segments that form Inventory Groups shaded in Table 2-1 were not available when this analysis was started in 4/2009. Therefore, for the purposes of this study, these Inventory Groups were combined as follows:

- SLIT3-Unit G through Unit M were combined into SLIT3-Unit ~North;
- SLIT4-Unit J through Unit N were combined into SLIT4-Unit ~South; and
- SLIT4-Unit O through Unit ZH were combined into SLIT4-Unit ~North.

Combined groups were assigned to ideal trench segments depicted as green rectangles within Figure 2-2. Individual trench segments that are not part of the above-listed combined groups are shown outlined in blue within Figure 2-2. The Slit Trenches are shown outlined with wider red lines.

Inventories for the combined Inventory Groups were set equal to the sums of the inventories of the individual Inventory Groups and the disposal times were set to the starting and ending times for the combined groups as shown in Table 2-1. Inventories for these combined groups were uniformly distributed over unoccupied ideal trench segments (i.e. segments not assigned waste from earlier disposals). For example, the first and last waste packages were disposed of in SLIT3-Unit~North on 7/8/2009 and 1/6/2010, respectively. The starting time for the simulations within this analysis is based on the first disposed package as of 12/21/1995.

Note that for the 2008 PA and 2008 SA analyses inventory limits were computed based on the following two key assumptions:

- A nominal inventory of 1 gmol for a specific parent was modeled. The nominal inventory was uniformly distributed over all seven center Slit Trenches, then results were multiplied by 7.06 to represent the approximate footprint area of the seven Slit Trenches.

- The time of burial for all waste was assumed to occur when the first burial occurred in SLIT1 on 12/21/1995.

The 2008 SA also had an assumption that covers were simultaneously placed over all of the center Slit Trenches. Analyses were performed for capping times at 5, 10 and 15 years from the time of first disposal (12/21/2000, 12/21/2005, and 12/21/2010).

Table 2-1. Slit Trench Inventory Groups and Times of Operation

Combined Inventory Group	WITS Unit (Inventory Group)	First Waste Package	Last Waste Package	Combined Inventory Group	WITS Unit (Inventory Group)	First Waste Package	Last Waste Package
	SLIT1	12/21/1995	9/19/2003		**SLIT4**		
					Unit A	3/3/2008	12/16/2008
	SLIT2				Unit B	1/10/2007	5/23/2007
	Unit 1	9/20/2001	10/22/2003		Unit C	12/10/2004	6/22/2005
	Unit A	9/24/2003	8/31/2006		Unit D	8/3/2004	1/25/2005
					Unit E	2/26/2004	6/28/2004
	SLIT3				Unit F	3/29/2005	9/8/2005
	Unit A	10/20/2003	1/6/2004		Unit G	5/19/2005	10/20/2005
	Unit B	12/10/2003	4/21/2004		Unit H	6/13/2005	1/4/2007
	Unit C	2/5/2004	4/15/2004		Unit I	5/2/2007	1/22/2008
	Unit D	3/23/2004	6/19/2007		Unit J	4/28/2009	6/8/2009
	Unit E	7/20/2004	5/9/2005		Unit K	5/6/2009	6/9/2009
	Unit F	2/10/2004	2/10/2004		Unit L	6/10/2009	6/12/2009
	Unit G	7/8/2009	9/9/2009		Unit M	6/17/2009	6/26/2009
	Unit H	9/9/2009	10/2/2009		Unit N	7/1/2009	7/10/2009
	Unit I	10/1/2009	11/6/2009	SLIT4-Unit ~South		4/28/2009	7/10/2009
	Unit J	11/12/2009	12/1/2009		Unit O	1/5/2010	1/12/2010
	Unit K	11/19/2009	12/11/2009		Unit P	1/6/2010	1/12/2010
	Unit L	12/3/2009	12/11/2009		Unit Q	1/7/2010	1/14/2010
	Unit M	12/3/2009	1/6/2010		Unit R	1/11/2010	1/20/2010
SLIT3-Unit ~North		7/8/2009	1/6/2010		Unit S	1/13/2010	1/20/2010
					Unit T	1/20/2010	5/26/2010
	SLIT5				Unit U	1/25/2010	1/29/2010
	Unit A	10/13/2004	4/7/2005		Unit V	5/27/2010	6/8/2010
	Unit B	5/9/2005	8/1/2005		Unit W	6/3/2010	6/9/2010
	Unit C	8/22/2005	1/5/2006		Unit X	6/14/2010	6/17/2010
	Unit D	12/13/2005	3/16/2006		Unit Y	6/14/2010	6/22/2010
	Unit E	2/13/2006	8/31/2006		Unit Z	6/15/2010	6/23/2010
	Unit F	5/27/2004	5/27/2004		Unit ZA	6/24/2010	7/1/2010
	Unit G	3/29/2005	7/21/2005		Unit ZB	6/30/2010	7/13/2010
	Unit H	5/2/2006	10/16/2006		Unit ZC	7/8/2010	7/15/2010
	Unit I	6/8/2005	8/4/2005		Unit ZD	7/13/2010	7/21/2010
	Unit J	7/18/2005	8/11/2005		Unit ZE	7/15/2010	7/21/2010
	Unit K	7/21/2005	8/17/2005		Unit ZF	7/27/2010	8/12/2010
	Unit L	8/3/2005	8/31/2005		Unit ZG	8/2/2010	8/12/2010
					Unit ZH	8/12/2010	8/19/2010
				SLIT4-Unit ~North		1/5/2010	8/19/2010

The 2008 PA and 2008 SA approach does not account for the spatial and temporal variations that are part of actual waste disposal operations which can have an impact on well concentrations and pathways doses, especially those segments with a shorter distance to the compliance boundary. As a new unit progresses through its operational life, the placement of actual inventories typically will have non-uniform distributions. The current study accounts for the spatial and temporal variations of inventories in Slit Trenches.

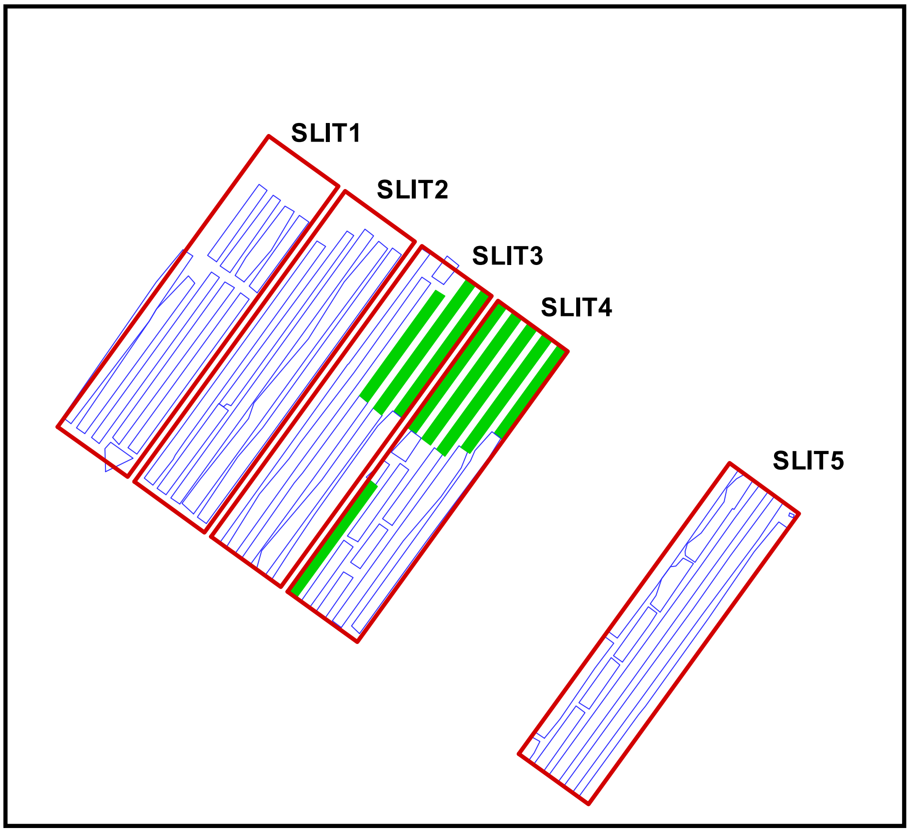

Figure 2-2 Slit Trench segments modeled with individual segments outlined in blue and ideal trench segments forming combined groups filled with green.

2.1.1 Analysis Categories

Analyses to satisfy DOE Order 435.1 (DOE 1999) include the following categories:

- Groundwater pathways
  - Gross alpha
  - Beta-gamma
  - Radium
  - Uranium
- Non-groundwater pathways
  - Air
  - Radon
  - Inadvertent intruder
- All-Pathways

Because it was assumed in the 2008 PA that air doses have no significant impact on the all-pathways analysis, the all-pathways reduces to a groundwater all-pathways. As was done in the 2008 PA and SA, the groundwater pathway is combined with the groundwater all-pathways analysis in this study. Thus, only two categories are addressed within this report; (1) groundwater pathways and (2) non-groundwater pathways.

2.2 Modeling Approach

This section presents approaches for modeling groundwater and non-groundwater pathways. The modeling approach for the groundwater pathways includes flow and transport in the vadose zone and aquifer, followed by performance calculations. The modeling approach for the non-groundwater pathways consists of comparing final inventories to limits from the 2008 SA to calculate sums-of-fractions.

The flow and transport modeling approaches used to compute concentration histories at the 100-meter boundary are described in Chapters 4 and 5. The PORFLOW code (version 5.97.0) is used for modeling flow and transport both in the vadose zone and the aquifer. Selected assumptions made in the modeling are discussed in Appendix F.

Four cases were considered in the vadose zone transport calculations:

1. Only crushable waste packages without Cellulose-degradation-products (CDP) present (Case01_off)
2. Only crushable waste packages with CDP present (Case01_on)
3. Only non-crushable waste packages without CDP present (Case11_off)
4. Only non-crushable waste packages with CDP present (Case11_on)

Four cases were considered in the aquifer transport calculations:

1. Only crushable waste packages without CDP present (Case01_off)
2. Only crushable waste packages with CDP present (Case01_on)
3. A blended fraction of fluxes to the water table for crushable and non-crushable waste packages without CDP present (Case01n11_off)
4. A blended fraction of fluxes to the water table for crushable and non-crushable waste packages with CDP present (Case01n11_on)

For each case, maximum concentration histories beyond the 100 meter boundary were stored for subsequent use in determining the “worst” case conditions. These concentration histories include all nuclides within the parent nuclide’s chain modeled with PORFLOW. These chains omit nuclides with half-lives less than 5 years. It is assumed that these nuclides are in secular equilibrium with their precursor. To compute doses, concentration histories for the worst case are expanded to include the short-lived nuclides that are not modeled but are assumed to be in secular equilibrium (i.e., full chains are employed). “Ideal files” that contain the concentration histories of all species within the full chain of each parent nuclide are produced in a separate post-modeling step that also converts PORFLOW gmol/ft^3 concentrations to pCi/L concentrations. The “Ideal files” are derived from PORFLOW output files and are formatted for input to the automated dose calculation software.

In general, to determine a worst case condition would require processing each case for each dose pathway of interest, then selecting the worst case from dose results. Instead of calculating each dose pathway for each case a more bounding process is employed where the worst case is established based on concentrations not doses. Worst case conditions are established by looping through all individual cases and creating worst case “ideal files” from the individual case “ideal files”. For each parent nuclide its worst case “ideal file” represents the maximum concentrations of each species within its full chain at each point in time. The resulting worst case will result in higher dose values for each dose pathway than the more involved approach of processing each case individually based on the dose pathway.

3.0 KEY INPUTS AND ASSUMPTIONS

The following key inputs and assumptions for this study of Slit Trenches 1 through 5 are important considerations in maintaining the validity of the analysis:

1. **Assumption: A continuous operational cover is placed over SLIT1, SLIT2, SLIT3, and SLIT4 within the time period from December 1, 2010 to September 30, 2011.**

   The base case performance calculations are based on operational covers becoming operative on September 30, 2011. This cover was assumed to extend over SLIT1, SLIT2, SLIT3, and SLIT4. A sensitivity study was performed to address the impact of this cover being placed at an earlier date. The earlier placement of the operational cover impacts only certain mobile species in a negative way – by delaying much of their release until subsidence occurs. The placement of the operational cover as early as January 1, 2011 was modeled. Negative impacts to the performance measures would fall within performance measures and objectives. Placement of the operational cover for a period of up to one month before the analysis time (i.e., up to December 1, 2010) will also produce acceptable results.

2. **Assumption: A continuous operational cover is placed over SLIT5 within the time period from December 1, 2010 to September 30, 2011.**

   The base case performance calculations are based on an operational cover becoming operative on September 30, 2011. This cover is assumed to extend over SLIT5 only. A sensitivity study was performed to address the impact of this cover being in-place or partially functioning at an earlier date. The earlier placement of the operational cover impacts only certain mobile species in a negative way. The placement of the operational cover as early as January 1, 2011 was modeled. Negative impacts to the performance measures would fall within performance guidelines. Placement of the operational cover for a period of up to one month before the analysis time (i.e., up to December 1, 2010) will also produce acceptable results.

3. **Assumption: The hydraulic performance of the operational and interim covers is maintained throughout their lifetimes.**

   This analysis assumes that the operational covers, interim covers and supporting drainage structures are maintained throughout their lifetimes such that the infiltration rate through these covers is a constant value (i.e., local failures are repaired in a timely manner). A constant infiltration rate of 40 cm/yr is assumed for uncovered surfaces. A constant infiltration rate of 0.9144 cm/yr (0.36 in/yr) is assumed for the operational and interim covers. A timely manner implies that the hydraulic character of the covers is brought back to the above specifications within two to three months and negative impacts are minimized during that period to the degree possible.

4. **Assumption: Dynamic compaction will not be performed over SLIT3-Unit F containing the ETF activated carbon vessels and the portion of SLIT2-Unit 1 containing M-Area Glass (as per Phifer, et al. 2009).**

Waste designated as Effluent Treatment Facility (ETF) special waste includes tritium (H-3) and I-129 adsorbed on activated carbon filters which are contained in sealed stainless steel containers. A structural analysis (Estochen, 2010) predicts that these containers will not become hydraulically active for 133 years and will not collapse until after 3125 (the end of the analysis period). The ETF waste forms were analyzed by assuming the containers remain impervious to water penetration for 133 years and structurally intact for the 1130 year duration of the calculation. For the portion of SLIT2-Unit1 containing M-Area Glass, dynamic compaction could potentially crack the glass waste form leading to a significant increase in surface area thus increasing mass transfer releases. This assumption is copied from the 2009 Closure Plan (Phifer et al., 2009).

5. **Assumption: Drainage systems designed to carry away runoff from operational, interim, and final covers remove essentially all runoff.**

   It is assumed that the excess rainfall that does not penetrate through the covers is completely removed from the hydraulic system. Here drainage systems are assumed to carry all runoff a sufficient distance from the disposal units being considered such that its contribution to local Vadose Zone recharge is negligible. The "drainage" systems for the operational and interim covers are also assumed to operate as designed and to be maintained such that the above assumption is valid throughout the life of these covers up to the end of institutional controls (i.e., calendar year 2125). For the final cover it is assumed that the hydraulic aspects of the as designed "drainage" systems are met.

4.0 VADOSE ZONE ANALYSIS

4.1 Trench Segment Properties

Trench segments are the smallest portions of disposal units (WITS Locations) for which property information is available and are thus the focal point for all analyses. In order to determine the required vadose zone and aquifer transport runs (analyses), the available information for each trench segment must be assessed. Key properties and their effects on determining required runs are as follows:

- **X coordinates and Y coordinates** – Geometry properties specified at the segment level are used to define areas and area fractions that are applied in the transition from vadose zone fluxes at the water table to aquifer sources at cells. These properties do not dictate the need for any transport runs, but do affect the distribution of the fluxes at the water table to aquifer source cells.

- **Edge/Center Trench Segment types** – During the period when operational covers are present, infiltration rates for uncovered regions near Edge trench segments affect results while Center trench segments only have covered regions included in their modeling domain. Therefore separate vadose zone models are required for Edge trench segments and Center trench segments.

- **Inventory groups** (WITS Units) - Inventories are provided for inventory groups where each group can include several trench segments. Because all the trench segments within an inventory group of the same Edge/Center type perform the same (when a unit inventory is imposed) only a single representative trench need be analyzed for each such inventory group. Each inventory group has its own disposal start and end date, thus each inventory group must be modeled separately in the vadose zone. Most inventory groups are modeled strictly as Center trench types (e.g., SLIT2-Unit1), some are modeled strictly as Edge trench types (e.g., SLIT4-UnitE), while others are dual-modeled as both Center and Edge types (e.g., SLIT1). For the dual-modeled inventory groups, the location of trench segments that belong to the Inventory Group will dictate which set of fluxes at the water table will be applied (e.g., as listed in Table 4-1 trench segment 111 as identified in Engineering Drawings is along the edge of SLIT1 and would be assigned Edge type results).

- **Percent Non-Crushables** – For the 2008 PA a 10% upper bound was applied to each Slit Trench disposal unit. For this analysis the WITS area of non-crushable containers for each inventory group was provided. That area was divided by the total area for that inventory group to determine the percentage of non-crushable containers present for that inventory group. The percent of non-crushable containers is only used in blending operations for each inventory group, thus this percent does not identify any additional required runs. However, a zero percent indicates that Case11 runs are not needed, thus reducing the number of required runs.

4.2 Inventory Groups

Figures 4-1 through 4-5 show the locations of the inventory groups. Inventory group identifiers, along with their corresponding trench segment nomenclature are provided in

Tables 4-1 through 4-5 for SLIT1, SLIT2, SLIT3, SLIT4, and SLIT5. The final nuclide inventory values in Ci per inventory group are provided in Appendix A.

Two types of trench segments are considered: (1) center trench segments and (2) edge trench segments. Depending on the location of a trench segment with respect to the operational cover, it is handled either as a center or edge trench. Surface infiltration rates differ for the edge trenches due to the presence of a region of uncovered ground surface at all times (i.e., independent of subsidence).

Figures 4-3 and 4-4 show areas where application of high-pH treatment was applied in option models. The option models were developed to show the potential effect of applying a treatment to increase pH in areas with high Np-237 (the dominant nuclide affecting dose in this analysis) inventories that would decrease its mobility, well concentrations and doses because doses approach the performance objectives.

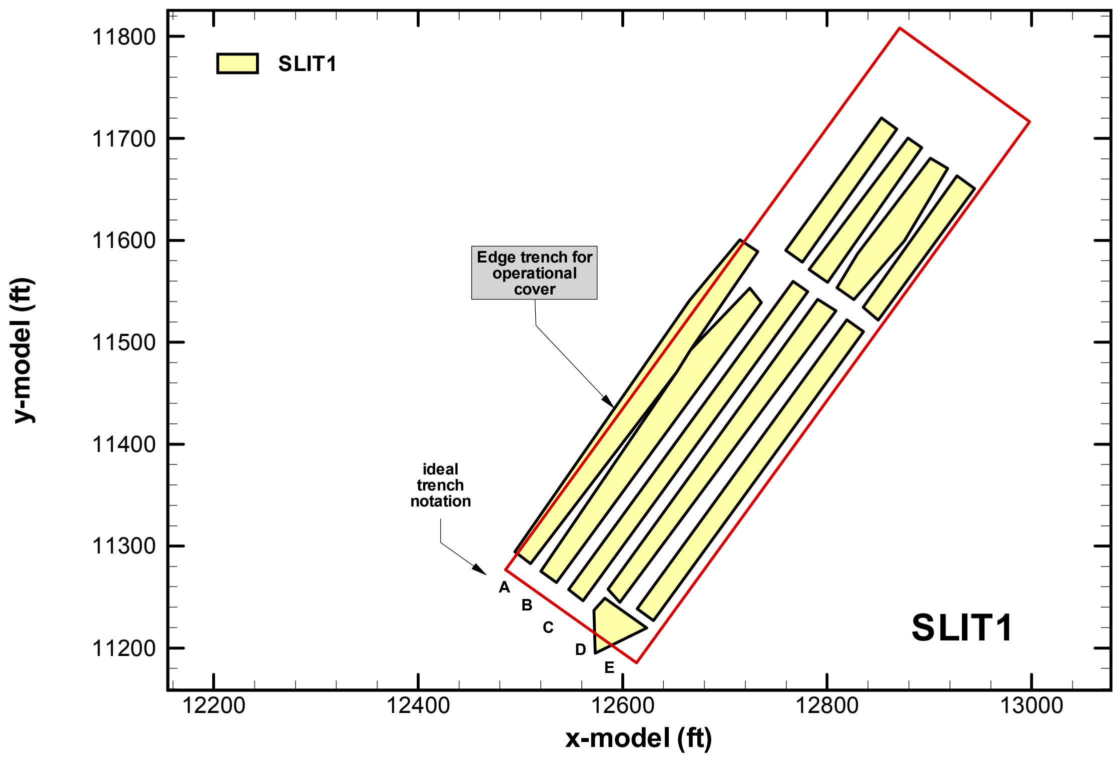

Figure 4-1 Slit Trench Disposal Unit 1 (SLIT1) inventory groups.

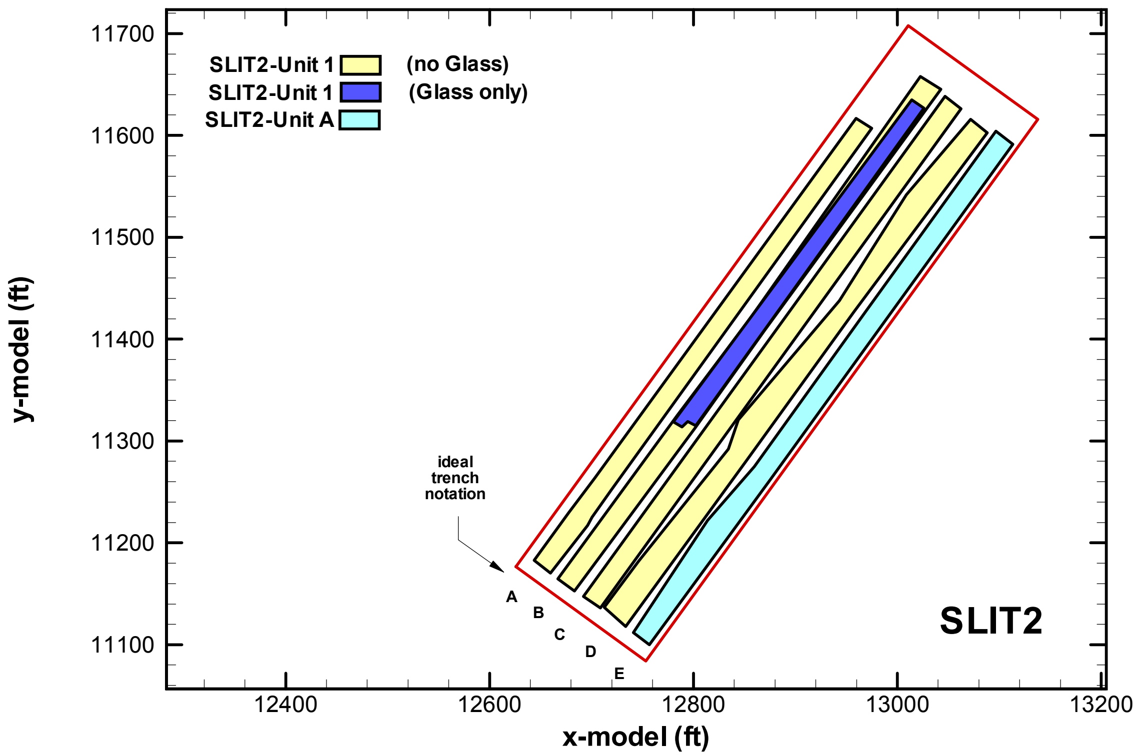

Figure 4-2 Slit Trench Disposal Unit 2 (SLIT2) inventory groups.

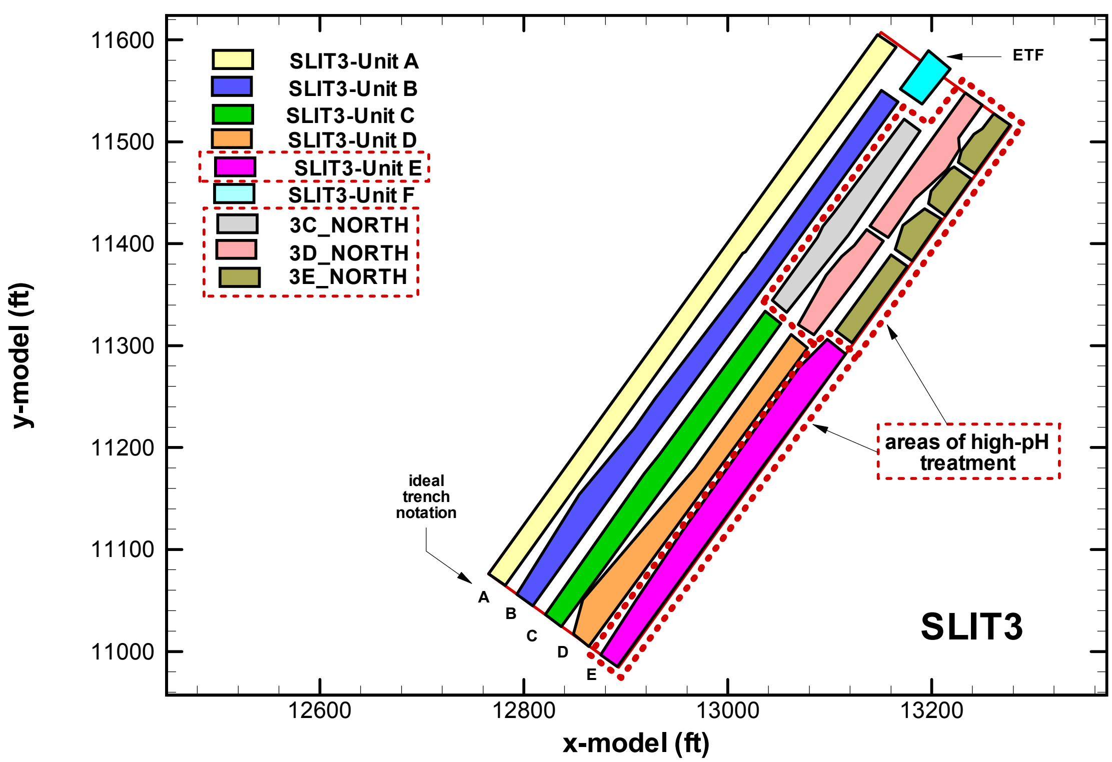

Figure 4-3 Slit Trench Disposal Unit 3 (SLIT3) inventory groups.

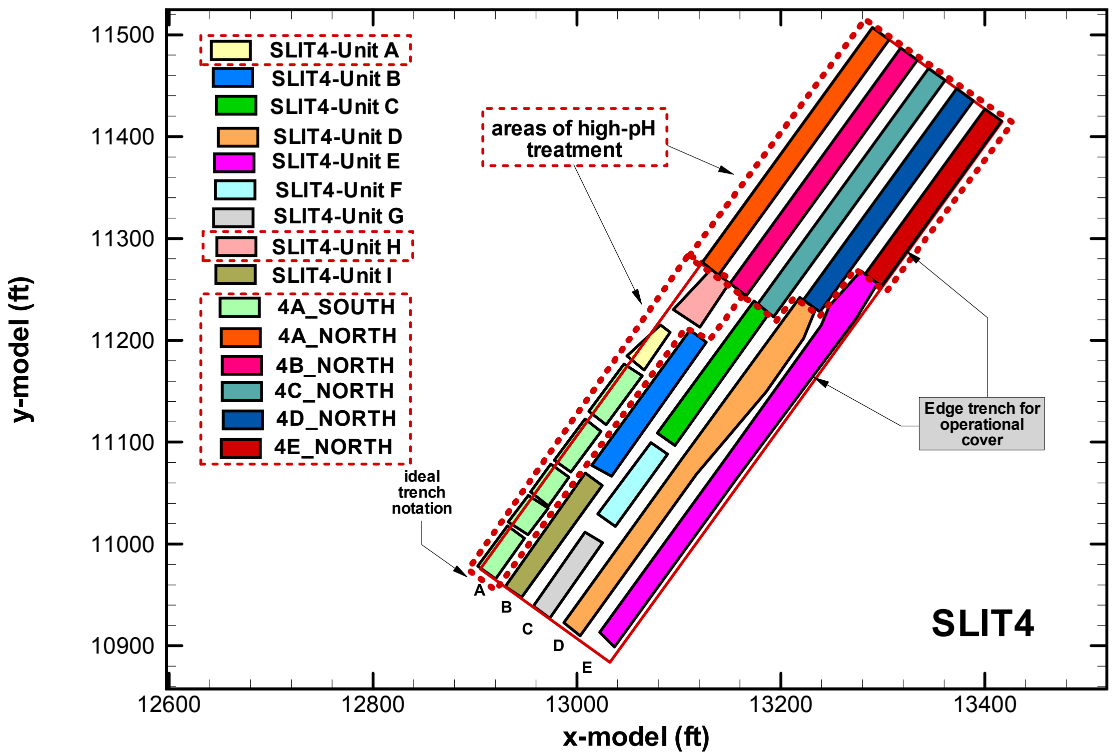

Figure 4-4 Slit Trench Disposal Unit 4 (SLIT4) inventory groups.

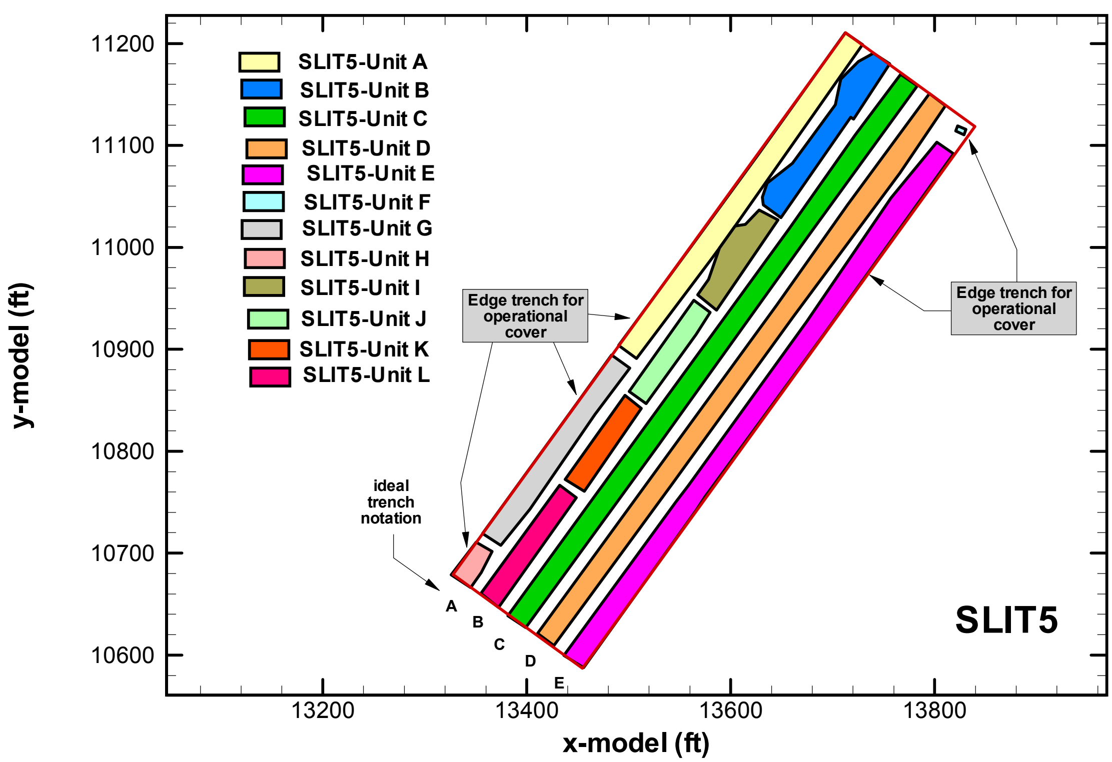

Figure 4-5 Slit Trench Disposal Unit 5 (SLIT5) inventory groups.

Table 4-1 SLIT1 inventory group identifiers.

Inventory Group	Survey Segment ID from Drawings	This Analysis Nomenclature	Model Cross-section	Trench Types considered
SLIT1	111	1Z	SLIT1	Center & Edge
	112	1B		
	113	1C		
	114	1D		
	115	1EX		
	111A	1A		
	112E	1BE		
	113E	1CE		
	114E	1DE		
	115E	1EE		

As Table 4-1 and Figure 4-1 indicate, SLIT1 contains only one inventory group. As shown in Figure 4-1 the ideal trench A is the only Edge trench type.

Table 4-2 SLIT2 inventory group identifiers.

Inventory Group	Survey Segment ID from Drawings	This Analysis Nomenclature	Model Cross-section	Trench Types considered
SLIT2-Unit1	211	2A	SLIT2-Unit1	Center only
	212 [a]	GLASS & 2B-GLASS		
	213	2C		
	214	2D		
SLIT2-UnitA	2A	2E	SLIT2-UnitA	Center only

a – all GLASS inventory was placed in a separate trench segment within the ideal trench B while no non-GLASS waste was placed in that separate trench segment.

As Table 4-2 and Figure 4-2 indicate, SLIT2 contains two inventory groups. As shown in Figure 4-2 the ideal trench B was broken into two separate trench segments, at the aquifer level, to handle the unique location of M-Area GLASS waste versus the other waste types present.

Table 4-3 SLIT3 inventory group identifiers.

Inventory Group	WITS designator	This Analysis Nomenclature	Model Cross-section	Trench Types considered
SLIT3-UnitA	SLIT3-UnitA	3A	SLIT3-UnitA	Center only
SLIT3-UnitB	SLIT3-UnitB	3B	SLIT3-UnitB	Center only
SLIT3-UnitC	SLIT3-UnitC	3C	SLIT3-UnitC	Center only
SLIT3-UnitD	SLIT3-UnitD	3D	SLIT3-UnitD	Center only
SLIT3-UnitE	SLIT3-UnitE [a]	3E	SLIT3-UnitE	Center only
SLIT3-UnitF	SLIT3-UnitF	3F	SLIT3-UnitF	Center only
SLIT3-UnitG	SLIT3-UnitG [a]	3C_North	3C_North + 3D_North + 3E_North	Center only
SLIT3-UnitH	SLIT3-UnitH [a]	3D_North		Center only
SLIT3-UnitI	SLIT3-UnitI [a]	3D_North		
SLIT3-UnitJ	SLIT3-UnitJ [a]	3E_North		Center only
SLIT3-UnitK	SLIT3-UnitK [a]	3E_North		
SLIT3-UnitL	SLIT3-UnitL [a]	3E_North		
SLIT3-UnitM	SLIT3-UnitM [a]	3E_North		

a – This trench segment has been identified as a segment for optional high-pH in-situ treatment.

As Table 4-3 indicates, SLIT3 contains 13 WITS inventory groups. However, as shown in Figure 4-3 SLIT3 contains only 9 model inventory groups where some of the original inventory groups were combined for analysis purposes. For each parent nuclide, the inventory within the groups SLIT3-Unit G through SLIT3-Unit M were summed into composite values and were then uniformly distributed (i.e., based on segment areas) to the three ideal trench segments C, D, and E (i.e., 3C_North, 3D_North, and 3E_North). At the vadose zone level these three ideal trench segments behave identically. Trench segment SLIT3-Unit F contains the ETF carbon vessels. In Figure 4-3 those trench segments identified for optional high-pH in-situ treatment have been outlined with red dashed boxes.

Note that within our analysis, each ideal trench segment such as 3E_North will have a different amount of inventory than 3C_North and 3D_North due to different area fractions. This labeling pattern of adding "_North" is similar to that used for SLIT1 on SRNS Drawing C-CV-E-0070 where 112E is the extension for 112.

Table 4-4 SLIT4 inventory group identifiers.

Inventory Group	WITS designator	This Analysis Nomenclature	Model Cross-section	Trench Types considered
SLIT4-UnitA	SLIT4-UnitA [a]	4A	SLIT4-UnitA	Center only
SLIT4-UnitB	SLIT4-UnitB	4B	SLIT4-UnitB	Center only
SLIT4-UnitC	SLIT4-UnitC	4C	SLIT4-UnitC	Center only
SLIT4-UnitD	SLIT4-UnitD	4D	SLIT4-UnitD	Center only
SLIT4-UnitE	SLIT4-UnitE	4E	SLIT4-UnitE	Edge only
SLIT4-UnitF	SLIT4-UnitF	4F	SLIT4-UnitF	Center only
SLIT4-UnitG	SLIT4-UnitG	4G	SLIT4-UnitG	Center only
SLIT4-UnitH	SLIT4-UnitH [a]	4H	SLIT4-UnitH	Center only
SLIT4-UnitI	SLIT4-UnitI	4I	SLIT4-UnitI	Center only
SLIT4-UnitJ	SLIT4-UnitJ [a]	4A_South	4A_South	Center only
SLIT4-UnitK	SLIT4-UnitK [a]			
SLIT4-UnitL	SLIT4-UnitL [a]			
SLIT4-UnitM	SLIT4-UnitM [a]			
SLIT4-UnitN	SLIT4-UnitN [a]			
SLIT4-UnitO	SLIT4-UnitO [a]	4A_North	4A_North +	Center only
SLIT4-UnitP	SLIT4-UnitP [a]			
SLIT4-UnitQ	SLIT4-UnitQ [a]			
SLIT4-UnitR	SLIT4-UnitR [a]			
SLIT4-UnitS	SLIT4-UnitS [a]			
SLIT4-UnitT	SLIT4-UnitT [a]	4B_North	4B_North +	Center only
SLIT4-UnitU	SLIT4-UnitU [a]			
SLIT4-UnitV	SLIT4-UnitV [a]			
SLIT4-UnitW	SLIT4-UnitW [a]			
SLIT4-UnitX	SLIT4-UnitX [a]	4C_North	4C_North +	Center only
SLIT4-UnitY	SLIT4-UnitY [a]			
SLIT4-UnitZ	SLIT4-UnitZ [a]			
SLIT4-UnitZA	SLIT4-UnitZA [a]			
SLIT4-UnitZB	SLIT4-UnitZB [a]	4D_North	4D_North +	Center only
SLIT4-UnitZC	SLIT4-UnitZC [a]			
SLIT4-UnitZD	SLIT4-UnitZD [a]			
SLIT4-UnitZE	SLIT4-UnitZE [a]			
SLIT4-UnitZF	SLIT4-UnitZF [a]	4E_North	4E_North	Edge only
SLIT4-UnitZG	SLIT4-UnitZG [a]			
SLIT4-UnitZH	SLIT4-UnitZH [a]			

a – This trench segment has been identified as a segment for optional high-pH in-situ treatment.

As Table 4-4 indicates, SLIT4 contains 34 WITS inventory groups. However, as shown in Figure 4-4 SLIT4 contains only 15 model inventory groups where some of the original inventory groups were combined for analysis purposes. Inventories within SLIT4-Unit J through Unit N were combined and given the label 4A_South. Inventories for segments SLIT4-Unit O through Unit ZH were obtained by reducing the overall SLIT4 inventories by the sum of the inventories in the other groups. This "North" sector was then separated into five ideal trench segments (4A_North, 4B_North, 4C_North, 4D_North, and 4E_North) whose inventories were computed based on uniform distributions. In Figure 4-4 those trench segments identified for optional high-pH in-situ treatment have been outlined with red dashed boxes. As shown in Figure 4-4, the ideal trench E is an Edge-trench type. 4E_North is an edge type trench while 4A thru 4D_North are center type trenches and must be handled differently in the aquifer analyses.

Table 4-5 SLIT5 inventory group identifiers.

Inventory Group	WITS designator	This Analysis Nomenclature	Model Cross-section	Trench Types considered
SLIT5-UnitA	SLIT5-UnitA	5A	SLIT5-UnitA	Edge only
SLIT5-UnitB	SLIT5-UnitB	5B	SLIT5-UnitB	Center only
SLIT5-UnitC	SLIT5-UnitC	5C	SLIT5-UnitC	Center only
SLIT5-UnitD	SLIT5-UnitD	5D	SLIT5-UnitD	Center only
SLIT5-UnitE	SLIT5-UnitE	5E	SLIT5-UnitE	Edge only
SLIT5-UnitF	SLIT5-UnitF	5F	SLIT5-UnitF	Edge only
SLIT5-UnitG	SLIT5-UnitG	5G	SLIT5-UnitG	Edge only
SLIT5-UnitH	SLIT5-UnitH	5H	SLIT5-UnitH	Edge only
SLIT5-UnitI	SLIT5-UnitI	5I	SLIT5-UnitI	Center only
SLIT5-UnitJ	SLIT5-UnitJ	5J	SLIT5-UnitJ	Center only
SLIT5-UnitK	SLIT5-UnitK	5K	SLIT5-UnitK	Center only
SLIT5-UnitL	SLIT5-UnitL	5L	SLIT5-UnitL	Center only

As Table 4-5 indicates, SLIT5 contains 12 inventory groups and each inventory was also handled separately at the vadose zone level. As shown in Figure 4-5, those segments within the ideal trenches A (i.e., Units A, G and H) and E (i.e., Units E and F) are both Edge trench types only. These diagrams are to scale and indicate the actual footprint area employed in determining allocation of inventory within the aquifer model. SLIT5-Unit F, as shown in Figure 4-5, has a very small aerial footprint.

4.3 Non-crushable Containers

The percentage of non-crushable containers within each inventory group is listed in Table 4-6. A WITS limit on the overall percentage of non-crushable containers of 10% for each disposal unit was imposed during disposal operations. From Table 4-6 the total non-crushable containers on a percentage basis (i.e., based on area) for each disposal unit is:

- SLIT1 – 0.00%
- SLIT2 – 3.12%
- SLIT3 – 7.65%
- SLIT4 – 5.66%
- SLIT5 – 0.85%

These percentages were computed by summing the non-crushable areas within each disposal unit and dividing by the total footprint area of the disposal unit (i.e., 157 ft by 656 ft). The largest percent of non-crushable containers for any inventory group is 32.51% in SLIT4-Unit B.

Table 4-6 Area percent of non-crushable waste containers by inventory group.

Group Inventory Name	Non-Crush Area (ft^2)	Inventory Group Area (ft^2)	Percent Non-Crushable
SLIT1	0	52626.30	0
SLIT2-Unit1	2028.0	47643.51	4.26
SLIT2-UnitA	18.0	13051.89	0.14
SLIT3-UnitA	447.1	12912.40	3.46
SLIT3-UnitB	9.3	12573.31	0.074
SLIT3-UnitC	2012.0	7841.03	25.66
SLIT3-UnitD	29.8	8334.00	0.36
SLIT3-UnitE	2206.8	9813.05	22.49
SLIT3-UnitF[a]	314.2	1228.30	25.58
SLIT3-UnitG	0	4750.57	0
SLIT3-UnitH	0	3690.56	0
SLIT3-UnitI	0	2607.94	0
SLIT3-UnitJ	0	1277.17	0
SLIT3-UnitK	0	1037.51	0
SLIT3-UnitL	0	1161.07	0
SLIT3-UnitM	0	1823.11	0
3C_North + 3D_North + 3E_North	0	16102.10	0
SLIT4-UnitA	0	753.38	0
SLIT4-UnitB	1112.9	3423.07	32.51
SLIT4-UnitC	295.7	3234.99	9.14
SLIT4-UnitD	960.0	8961.04	10.71
SLIT4-UnitE	1341.4	9447.20	14.20
SLIT4-UnitF	0	1801.51	0
SLIT4-UnitG	0	1801.49	0
SLIT4-UnitH	0	1417.81	0
SLIT4-UnitI	0	2714.09	0
SLIT4-UnitJ	0	1249.53	0
SLIT4-UnitK	0	1004.19	0
SLIT4-UnitL	0	751.64	0
SLIT4-UnitM	0	752.64	0
SLIT4-UnitN	0	1037.00	0
SLIT4-UnitO	0	785.68	0
SLIT4-UnitP	0	749.61	0
SLIT4-UnitQ	0	1218.43	0
SLIT4-UnitR	0	1654.63	0
SLIT4-UnitS	0	1519.55	0
4A_North + 4B_North + 4C_North + 4D_North + 4E_North	0	26298.44	0
4A_South	0	5050.75	0
SLIT5-UnitA	341.0	8341.94	4.09
SLIT5-UnitB	0	4466.69	0
SLIT5-UnitC	36.0	13586.94	0.27
SLIT5-UnitD	0	13578.35	0
SLIT5-UnitE	82.0	13356.25	0.61
SLIT5-UnitF	0	49.58	0
SLIT5-UnitG	0	4775.93	0
SLIT5-UnitH	24.0	866.95	2.77
SLIT5-UnitI	0	2813.92	0
SLIT5-UnitJ	74.0	2269.30	3.26
SLIT5-UnitK	0	2131.85	0
SLIT5-UnitL	0	2790.03	0

[a] SLIT3-UnitF is ETF vessels that were analyzed as non-crushables that never collapsed

4.4 Vadose Zone Conceptual Model

To provide better insight into the "Generic" waste form model, a brief description of this model is discussed within this section.

The original 2D vadose zone flow and transport model employed in the 2008 PA was based on a simple "Generic" waste form model. The inventory of a parent nuclide was uniformly distributed throughout a waste region 20 ft wide by 16 ft tall. The 2D vadose zone model is shown in Figure 4-6 below. This particular model was employed for all slit trench analyses in the 2008 PA analyses (i.e., used for East, Center, and West Slit Trenches). Each slit trench is assumed to be 20 ft by 20 ft in its vertical cross section where the initial top of the waste zone is 4 ft beneath ground surface. For the Center Slit Trench units the bottom of the waste zone is assumed to be 35 ft above the water table. The left and right vertical model domains were set 20 ft away from the trench to represent a reflective boundary (i.e., lines of symmetry).

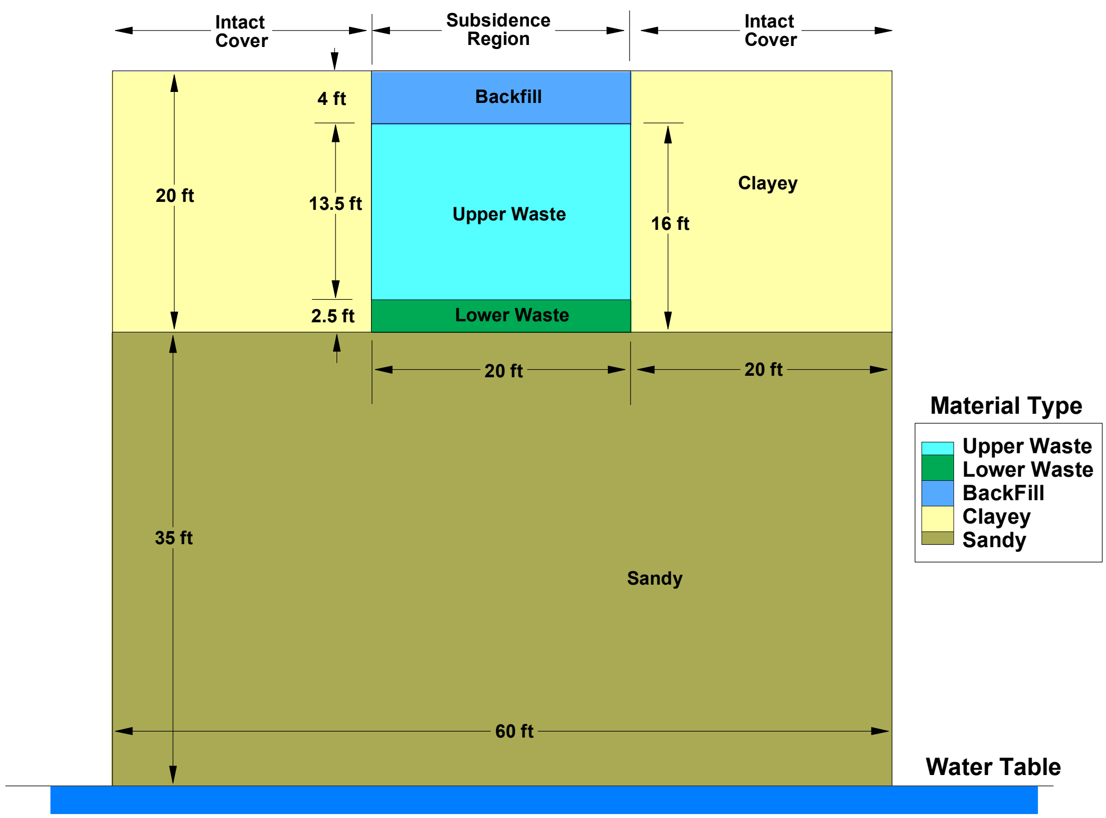

Figure 4-6 2D Vadose Zone flow and transport model used in 2008 PA and this study.

To address the potential of subsidence after the end of institutional control in calendar year 2125, infiltration rate conditions at the ground surface can differ directly over the waste zone as shown in Figure 4-6. For cases where subsidence is assumed to have occurred, the original waste zone (i.e., 20 ft by 16 ft) is collapsed into a final waste zone 20 ft wide by 2.5 ft tall. In the model this waste zone movement is handled by moving the inventories of the parent nuclide (and all of the tracked daughters in its chain) in the "Upper" region (i.e., Upper Waste Zone) to the "Lower" region (i.e., Lower Waste Zone).

The PORFLOW mesh employed for this "Generic" waste form model is shown in Figure 4-7 below (44x46 = 2024 elements). Because the material properties (specifically the hydraulic properties) are all based on soils, the mesh refinement near material interfaces is not generally severe. Thus, the relative coarse level of meshing shown in Figure 4-7 was adequate for the 2008 PA analyses, 2008 SA analyses, and also is adequate for these analyses.

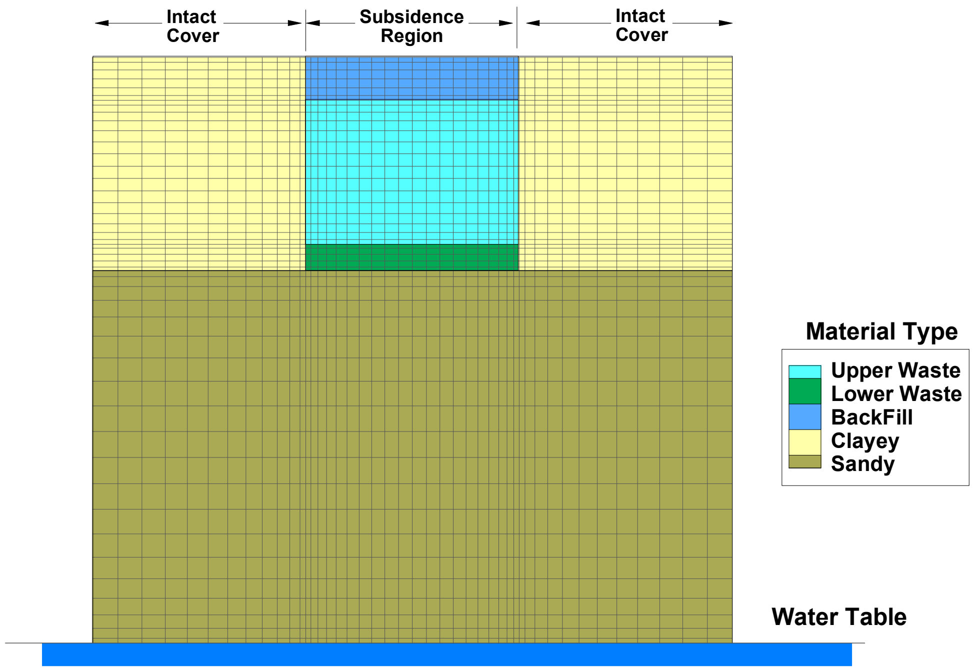

Figure 4-7 Mesh used in the 2008 PA 2D Vadose Zone flow and transport model.

4.5 Vadose Zone Flow Model

From the hydraulic perspective there are five major time periods of interest:

- The uncovered trench segment prior to placement of the operational cover;
- The operational cover period;
- The interim cover period;
- The final cover period; and
- The subsided trench segment period immediately after local subsidence, where applicable.

The time-dependent flow solutions were approximated by a series of steady-state time intervals. For each time interval infiltration rates were averaged over the specific time interval and the average value was applied over the entire time interval. For example, if the infiltration rate over a subsided surface varied linearly from 100 cm/yr to 80 cm/yr, then an average of 90 cm/yr was applied over the trench area that was subsided. Examples of the overall flow results for the five major time periods listed above are shown below in Figures 4-8 through 4-13 (with the operational cover period presented last).

For the time period prior to covering either a Center or Edge trench segment the flow 2D streamlines are shown in Figure 4-8. Note that the hydraulic resistance through the trench segment is less than neighboring native soils because it was backfilled with loose material with higher hydraulic conductivity. As such, streamlines tend to bend towards the trench segment as shown in Figure 4-8.

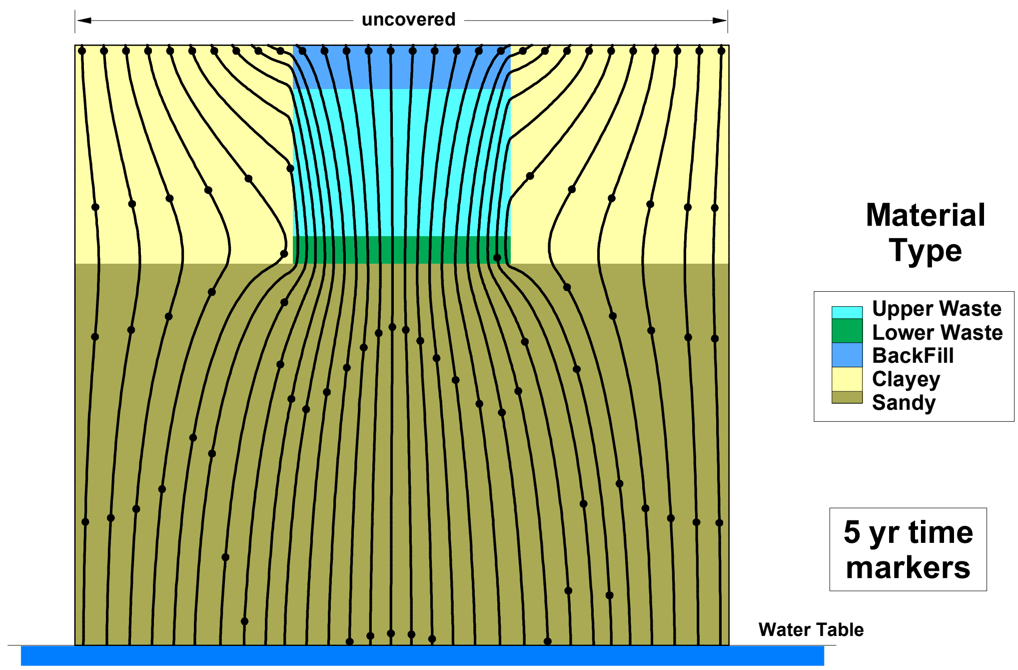

Figure 4-8 Flow results (streamlines) for the uncovered Center and Edge Trench Models prior to the application of the operational cover.

The background colors for all time slices shown are identically set to the initial material zone colors as shown in the prior geometry figures. Time markers associated with travel times based on the computed pore velocity fields are provided. Different marker timing is employed depending on the overall travel time for each time slice.

For the time period where the interim cover has been applied on either a Center or Edge trench segment the flow 2D streamlines are shown in Figure 4-9.

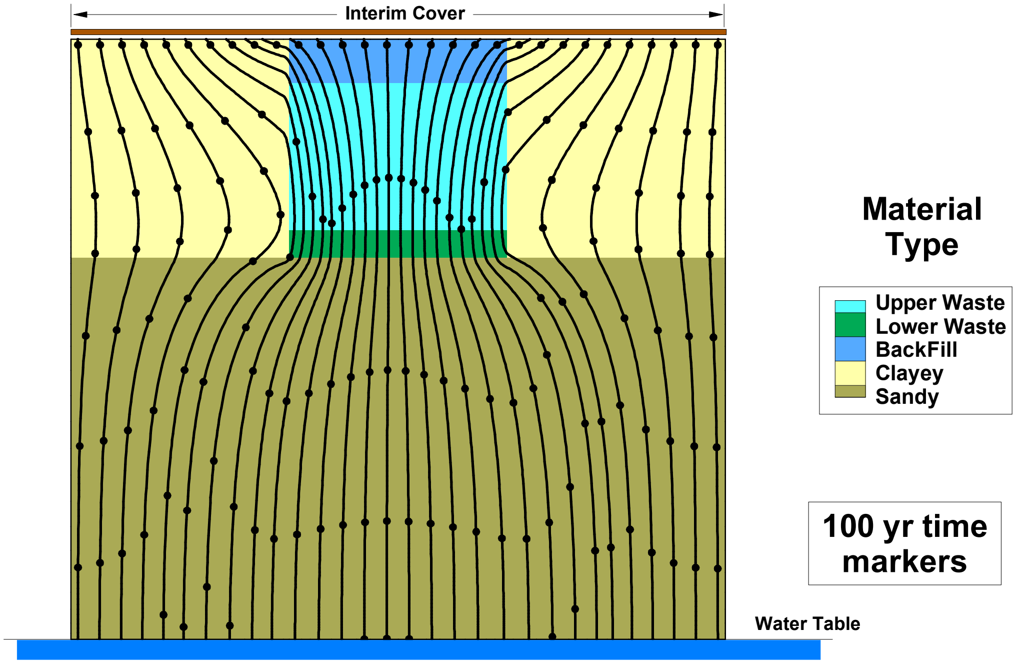

Figure 4-9 Flow results (streamlines) for the Center and Edge Trench Models during the interim cover time period.

For the time period where the final cover has been applied on either a Center or Edge trench segment a sample of the flow 2D streamlines is shown in Figure 4-10.

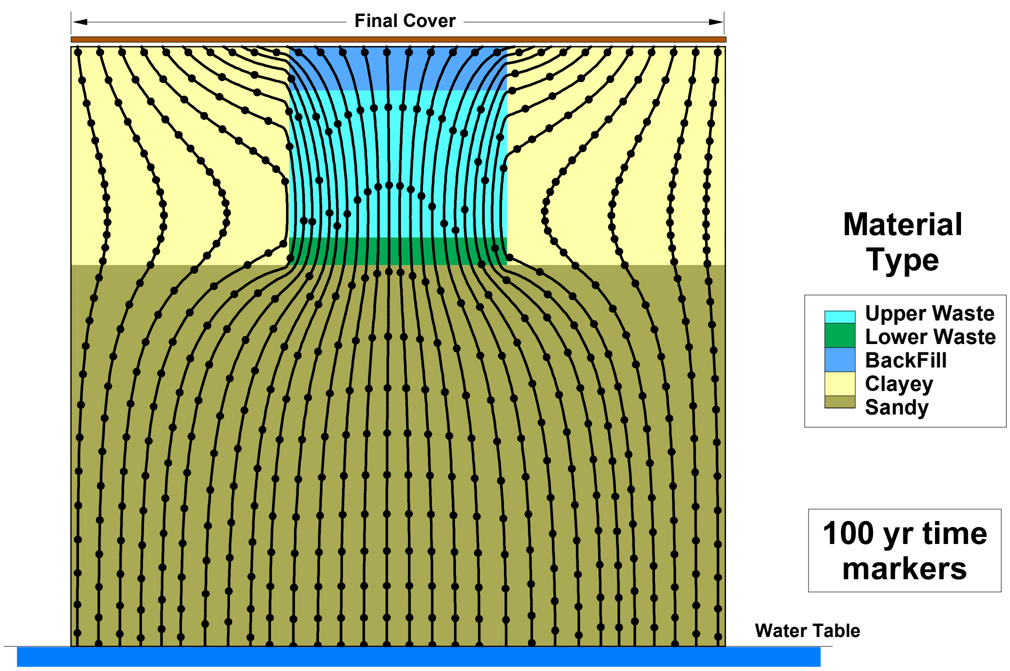

Figure 4-10 Sample flow results (streamlines) for the Center and Edge Trench Models during the final cover period.

For the time period right after local subsidence is assumed to have occurred on either a Center or Edge trench segment the flow 2D streamlines are shown in Figure 4-11.

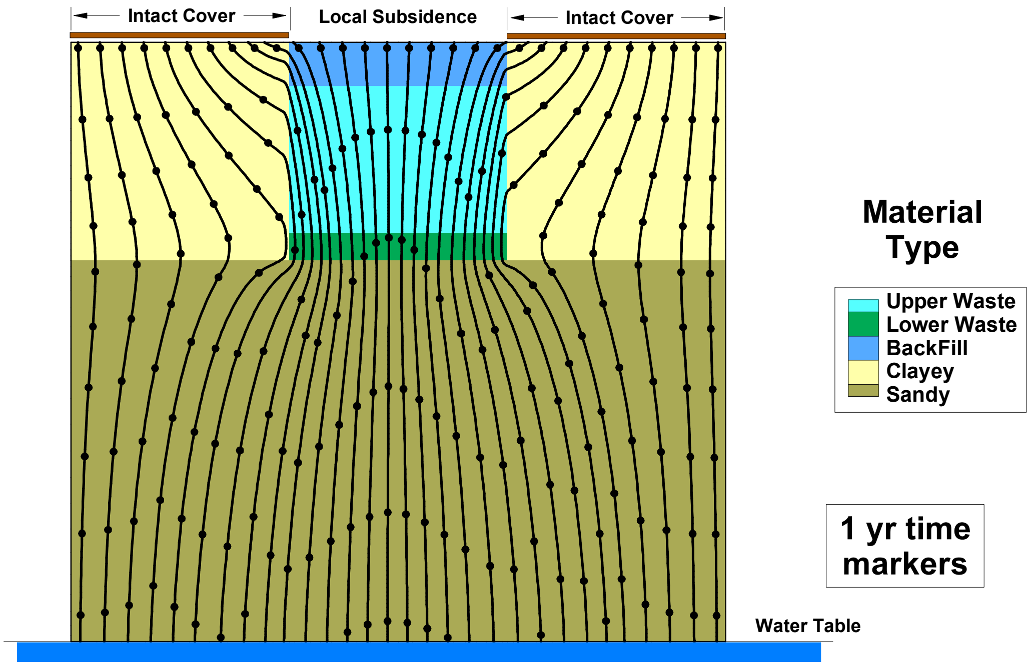

Figure 4-11 Flow results (streamlines) for the Center and Edge Trench Models right after local subsidence is assumed to have occurred.

For the time period where the operational cover is active, the flow solutions for the Center and Edge trench models are different due the difference between infiltration boundary conditions along the ground surface. Trench segments are either defined as Edge trenches or Center trenches as follows:

- For the single operational cover over SLIT1, SLIT2, SLIT3 and SLIT4 Edge trenches are located along the outer boundary of SLIT1 and SLIT4, while all others are Center trenches.
- For the single operational cover over SLIT5 Edge trenches are located along both outer boundaries of SLIT5, while all others are Center trenches.

During the time period where an operational cover is employed, the effects of the boundaries of the cover on those trench segments along its edges are addressed by using the Edge Trench Model rather than the Center Trench Model. A comparison of the flow fields (i.e., 2D streamlines with 20 year markers) is provided in Figures 4-12 and 4-13.

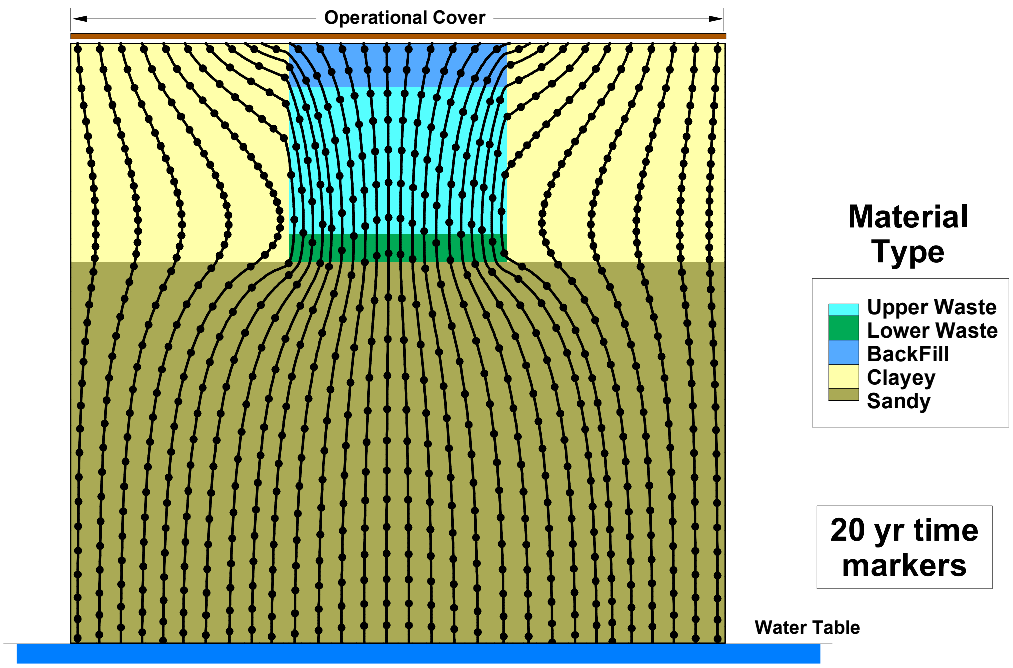

Figure 4-12 Streamlines from the Center Trench Model under an operational cover.

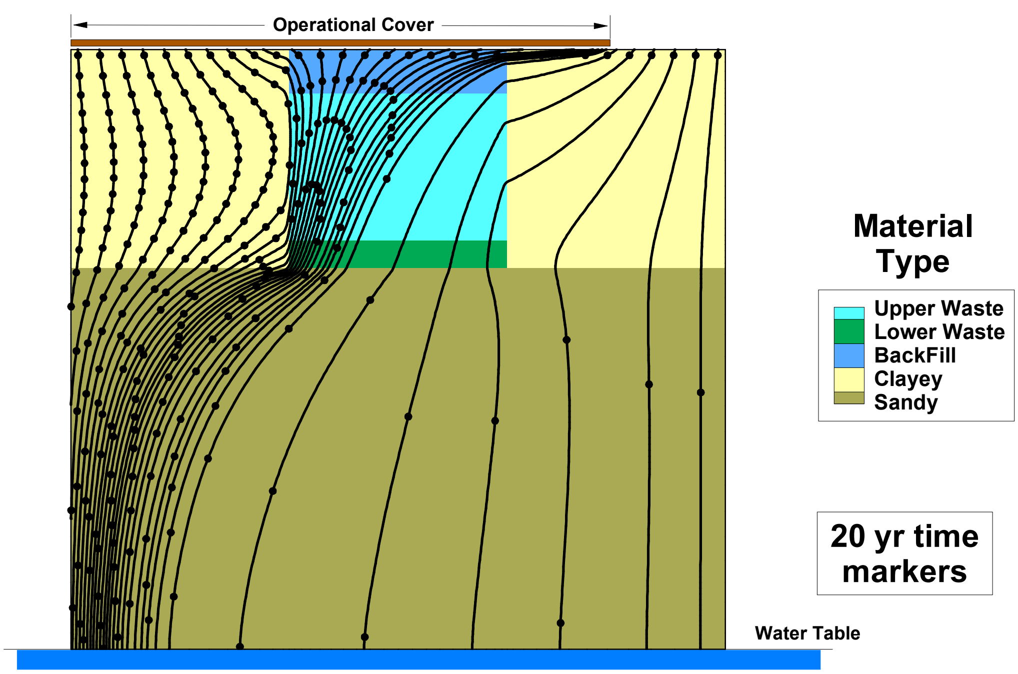

Figure 4-13 Streamlines from the Edge Trench Model under an operational cover.

Figures 4-12 and 4-13 indicate that the edge effects on the effectiveness of the operational cover can be significant. Note that a cover overhang of approximately 10 feet has been employed for the operational cover and that all runoff leaving the cover is assumed to have been carried away by supporting drainage systems.

4.5.1 Infiltration Approach for Non-crushable Containers

The "generic" trench model employed in the 2008 PA and the 2008 SA is used in this analysis. Each disposal unit consists of five rows of trenches. The closure plan (Phifer et al., 2009) provides information on the final cap with a cross-sectional geometry that is perpendicular to the long axis of the disposal unit (i.e., the crest of the closure cap extends lengthwise over the center trench row). Thus the five rows of trenches moving left to right across a Slit Trench cross-section can be described as follows:

- Left Side
- Left Middle – between the left side and the crest
- Crest – beneath the crest of the cap
- Right Middle – between the right side and the crest
- Right Side

In the 2008 PA only one generic trench type was employed to represent an average trench from among the five rows listed above. The only aspect that was different among the five rows (and required averaging) was the infiltration rate that would occur in situations where dynamic compaction was unsuccessful because of the presence of non-crushable containers. In those situations, the non-crushable containers were assumed to collapse immediately after final cap placement, causing the cap to fail.

Each trench row was assigned one of two states, either the cap failed or the cap did not fail. Thirty-two ($32 = 2^5$ total unique number of states) combined states were possible (e.g., infiltration through the Left Side with the Left Side collapsed and the other four trench rows not collapsed) for the five trench rows.

The 2008 PA and the current study analyzed two infiltration cases as follows:

1. Case01 - infiltration through a specific trench row is the average of the combined states where collapse never occurs for that specific trench row.
2. Case11 - infiltration through a specific trench row is the average of the combined states where collapse does occur for that specific trench row.

The probability of collapse was only applied after Case01 and Case11 had been analyzed. A probability of collapse was assigned to each trench row. In the 2008 PA, 10 percent was used as the probability because that was the maximum allowable fraction of the waste area that could be occupied by non-crushable containers. In the current analysis, the probability was calculated as the fraction of the waste area that was occupied by non-crushable containers (according to WITS). A blended Case01n11 was calculated by multiplying the results from Case11 by the area fraction of non-crushables then adding that to the product obtained from multiplying the results from Case01 by the area fraction of crushables. Because the current analysis was analyzed on a trench segment basis, the fraction was calculated and applied for the trench segment.

In the 2008 PA, operational covers were not considered, only interim and final covers. These last two covers will significantly extend beyond the disposal unit footprints such that, from an individual slit trench perspective, the surface infiltration rates should be approximately that of the cover's design value (with degradation as is applicable) and uncovered surface areas need not be considered.

For the 2008 SA and for this analysis, operational covers were considered. For trench rows where the boundary of the cover (i.e., cover overhang beyond the projected area of the trench row) approaches the edge of the trench row, surface infiltration rates of the uncovered region become important. This condition is seen for operational covers where their aerial extent is limited typically to overhangs on the order of 10 ft. To account for the increased infiltration rate within a trench row located nearest the boundary of an operational cover, an "Edge" trench model was created to supplement the primary "Center" trench type model. Note that the additional "Edge" trench type only applies during the time period where the operational cover is present (from time of installation until 2025).

Surface infiltration rates as a function of time were applied separately to the intact surfaces and the surface where subsidence could occur (see Figure 4-6 for locations). The subsidence infiltration rate is unique depending upon:

- the gap between the five trench rows within a given trench disposal unit;
- the particular trench of interest (i.e., a crest, middle, or side trench); and
- the state (i.e., intact or subsided) of the trenches uphill of the particular trench of interest (e.g., for a subsided side trench its infiltration rate is dependent upon the state of the crest and/or middle trenches).

For the 2008 PA effort and in this analysis it was assumed that the 157 foot wide trench disposal unit was laid out where each 20 ft wide trench was separated from its neighbors by a 10 ft "gap" spacing. The outer boundaries of side trenches were assumed to be 8.5 ft from the trench disposal unit boundaries.

To obtain infiltration rates for the various cases of interest (i.e., all intact trenches and various combinations of intact/subsided trenches) HELP code analyses were performed by Phifer (2004). The 32 actual combinations can be reduced to eight unique intact/subsided cases, because the left-side combinations will match the right-side combinations. (Note that subsidence on the right side of the crest does not affect the infiltration on the left side of the crest and vice versa.) The results of this set of analyses are presented in Figure 4-14 below. Figure 4-14 indicates that after the 100 year institutional control period (i.e., end of institutional control) the intact cap gradually degrades over time (Case 1). After subsidence (assumed to occur right after the end of institutional control) the subsided trench (Cases 2 through 8 in Figure 4-14) gradually plugs back up. At sufficiently long times, all trenches will revert to the original uncovered infiltration rate of 15.748 inch/yr (40 cm/yr).

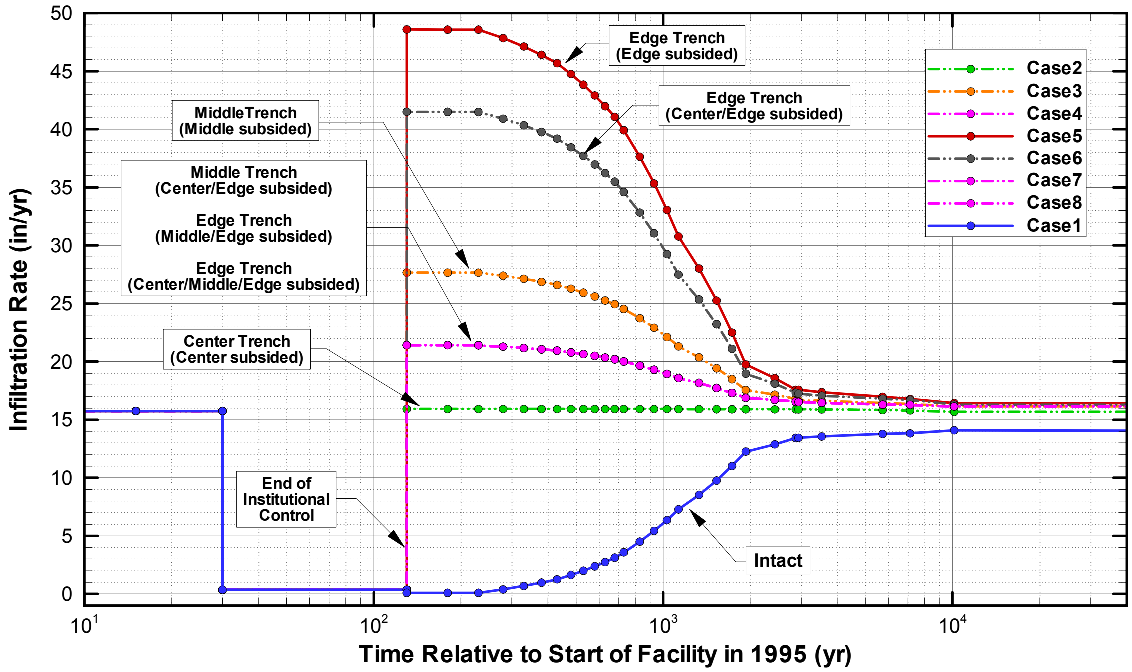

Figure 4-14 Infiltration rates employed in the 2008 PA.

In Figure 4-14 the Side trench row is referred to as the Edge trench and the Crest trench row is referred to as the Center trench. Because operational caps depend on the disposal unit they are not shown in Figure 4-14. The change at 30 years in this figure is due to construction of the interim cap. (For slit trenches other than SLIT1, the interim cap will be placed relatively earlier than 30 years.) Prior to the end of institutional control, all cases have the same infiltration rate, because it is assumed that all caps will be well maintained. If a trench is intact, its infiltration rate is not affected by the state of any other trenches. Note that three of the 8 cases (where a trench and its neighboring uphill trench subside) result in the same infiltration rate curve. To arrive at one average subsided case, Cases 2 through 8 are area averaged (i.e., note that there are two middle and side trenches for every crest trench). Also note that the worst case from an infiltration rate perspective is Case 5 which represents the situation where a Side trench subsides while both uphill trenches (i.e., Middle and Crest) remain intact.

During the 100-year maintenance phase for the interim cover the infiltration rate is assumed to be constant at 0.36 in/yr (0.9144 cm/yr). The same value is used for the operational cover (not shown). The estimated infiltration rates used in the 2008 PA and 2008 SA were based on a 10 ft gap between trench segments. For SLIT3 and later disposal units there is a 14 ft gap spacing. However, for this analysis the original infiltration rates are employed.

The infiltration rates employed for both Case01 (intact) and Case11 (average of Cases 2 through 8) are provided in Table 4-7. Each time interval that an "averaged" infiltration rate applies to is also listed. Only the first 18 time intervals are employed for the 1130 year simulation period. Note that hydraulic property changes (caused by subsidence or dynamic compaction) occur at 130 years and some time intervals are merely subdivisions to smooth infiltration changes.

Table 4-7 Time periods and infiltration rates employed for computing steady-state Vadose Zone flow solutions.

Flow Time period	Intact Case Infiltration rate (cm/yr)	Time Interval (yr-yr)	Case01 Avg.[b] Infiltration rate (cm/yr)	Case 11 Avg. Infiltration rate (cm/yr)[c]
TI01	40.00	0-covered[a]	40.00	40.00
TI02	0.91	covered-130	0.91	0.91
TI03	0.25	130-180	0.25	81.51
TI04	0.26	180-230	0.27	81.50
TI05	0.27	230-280	0.64	81.03
TI06	1.01	280-330	1.38	80.12
TI07	1.74	330-380	2.11	79.21
TI08	2.48	380-430	2.85	78.30
TI09	3.22	430-480	3.69	77.27
TI10	4.16	480-530	4.63	76.10
TI11	5.10	530-580	5.57	74.94
TI12	6.04	580-630	6.51	73.77
TI13	6.98	630-680	7.45	72.61
TI14	7.93	680-730	8.51	71.32
TI15	9.10	730-830	10.27	69.17
TI16	11.45	830-930	12.62	66.32
TI17	13.80	930-1030	14.97	63.46
TI18	16.15	1030-1130	17.32	60.61
TI19	18.50	1130-1330	20.08	57.48
TI20	21.66	1330-1530	23.24	54.07
TI21	24.82	1530-1730	26.39	50.66
TI22	27.97	1730-1930	29.55	47.25
TI23	31.13	1930-2430	31.93	44.83
TI24	32.72	2430-2870	33.41	43.47
TI25	34.11	2870-2935	34.13	42.78
TI26	34.15	2935-3530	34.29	42.60
TI27	34.44	3530-5730	34.71	42.18
TI28	34.97	5730-7130	35.05	41.75
TI29	35.13	7130-10130	35.46	41.33
TI30	35.79	10130-50130	35.73	41.04
TI31	35.66	50130-97130	35.74	41.04
TI32	35.81	97130-100130	35.83	41.04
TI33	35.84	100130-190130	38.93	41.53
TI34	42.01	190130-280130	44.02	44.02
TI35	46.03	280130-500130	46.02	46.02
TI36	46.03	500130-1000130	46.02	46.02

[a]Covered is time when operational cover is placed before 30 years
[b]Starting with TI03, the intact case year is start of a time interval, so the average infiltration rate is based on intact case infiltration rates for the current and next time periods
[c]Case11 infiltration rate only applied to subsidence region shown in Figure 4-7

4.6 Vadose Zone Transport Model

4.6.1 General Vadose Zone Transport Models

Following the 2008 PA approach, 2D vadose zone transport analyses were performed using a nominal inventory of one gmole for each parent nuclide of interest to obtain source terms (i.e., boundary conditions) used in subsequent aquifer transport simulations. These source terms were generated as mass fluxes (gmole/year) to the water table for each nuclide in the parent nuclide's abbreviated chain (i.e., five year half-life cutoff). While the 2008 PA aquifer model used mass fluxes based on one gmole of inventory for the parent, in this analysis aquifer model the mass fluxes were scaled to the actual inventory. The 2008 PA approach was used to develop limits, while the approach for this study is to analyze the performance of the actual inventory and to include the impact of spatial distributions versus the simplified assumption of uniform distributions used in the PA.

After establishing the infiltration rate curves shown in Figure 4-14, time intervals were selected for modeling purposes. Those time intervals included the initial uncapped period, the operational cap period, the interim cap period, and multiple time intervals for the final cap period. Some time intervals for the final cap period were selected to help smooth jumps in infiltration rates as calculated by the HELP model. Each Inventory Group was modeled separately, because its disposal time period was unique. Each Inventory Group was represented by the same nominal cross-section shown in Figure 4-7, but its infiltration boundary conditions were unique.

Each parent was assumed to be disposed at the halfway time of the disposal duration if all the segments within an Inventory Group were filled in less than six months. Thus, if the first disposal was made on January 1 and the last disposal was made on June 30, the model used a disposal time of April 1. If the disposal operations exceeded six months for the segments in an Inventory Group, then the disposal duration was separated into equal time intervals that were all equal to or shorter than six months and the parent was assumed to be injected in equal portions at the halfway time of each time interval. For example, if an Inventory Group operated from January 1 until August 31 the disposal duration was eight months. Two time intervals were assigned, each being four months long. Half of the inventory was injected on March 1 (halfway through the first time interval) and the other half of the inventory was injected on July 1 (halfway through the second time interval).

For the vadose zone transport model, a nominal inventory of one gmole was modeled. Because results vary in a linear fashion with inventory, the actual inventory was applied as a scaling factor when the aquifer model was invoked. As noted in the PA, some special waste forms were modeled in the vadose zone using finite release-rate source terms, which were based on special near-field release mechanisms or conditions. For example, the glass waste was assumed to leach from its waste form at a very slow rate and that release rate (as a fraction of 1 gmole) was invoked as a source term in the vadose zone model. For some special waste forms (e.g., the ETF Carbon vessels) no release was assumed to occur for the first 133 years, so the nominal 1 gmole inventory was decayed for 133 years and then applied to the model.

4.6.2 Special Vadose Zone Transport Models

All the 2008 PA special waste forms were modeled the same way in the current analysis, except for the I-129 in the ETF carbon vessels, and H-3 in the ETF carbon column vessels. An explanation of analyzing the H-3 in concrete performance is also presented in this section.

4.6.2.1 ETF Vadose Zone Transport Models

A revised structural analysis of the ETF vessels was conducted by Estochen (2010) (note that the ETF has been more recently referred to as the Effluent Treatment Project [ETP]). That analysis was interpreted by Phifer (2010) to state that the end of the analysis time period (1000 years after the end of institutional control) would occur hundreds of years before the ETF vessels would collapse from overburden crushing the stainless steel vessel that would be weakened by corrosion. Estochen (2010) also reported that the onset of hydraulic activity (flow through the vessel) would not commence for 133 years after burial. The closure plan states that dynamic compaction will not be performed over the ETF carbon vessels.

Given these unique conditions, the 1 gmole of H-3 and I-129 in the vessels were decayed for 133 years at which time the decayed inventory was injected into the waste zone. The vessels are 16-ft tall, with the 10-ft thick activated carbon layer beginning 3 ft above the base. Therefore the waste zone was defined to be 3 ft above the trench bottom to 13 ft above the waste bottom.

Because structural failure would never occur within the analysis time period, Case11, which is based on collapse of non-crushable containers would never occur and was not analyzed. Because the ETF vessels were actually used as organic removal columns and the K_d's were measured on waste zone samples, CDP was already present. It is assumed that when CDP has an effect, the CDP complexes with a contaminant to form a compound that remains intact throughout the remainder of its subsurface transport, thus K_d's that include CDP are used for the entire analysis. Therefore, only Case01 with CDP on was needed. However, the most recent K_d information (Kaplan 2010) indicates the I-129 K_d is not affected by CDP, so Case01 with CDP off would have produced the same results. The standard Case01 was also revised for the ETF vessels in that the contaminants were not moved to the lower 2.5 ft at the time of dynamic compaction, because dynamic compaction would not be applied and container crushing would not occur.

4.6.2.2 H-3 in Concrete Vadose Zone Transport Models

SLIT1 contains a significant amount of tritium in concrete rubble (3.87 Ci out of the H-3 total of 4.717 Ci). Because SLIT1 has been in operation since 12/21/1995, if this H-3 is treated as being disposed directly in soil it would have migrated to the aquifer prior to operational cap placement and caused a significant peak in the observed dose. However, H-3 in concrete actually is released by diffusion through the concrete material which results in a very slow release rate. Because modeling the release of H-3 by diffusion through a size distribution of concrete slabs would be difficult, a simplified approach was taken to account for this source term. Results from more mechanistic modeling of SLIT1 and SLIT2 (Flach et al., 2005) showed that the peak flux to the water table from one Ci of H-3 released from concrete was 0.429 of the peak flux from one Ci of H-3 released from generic waste material. The factor of 0.429 was derived from H-3 fractional fluxes at the water table calculated in the earlier analysis of SLIT1 and SLIT2. Figure 4-15, which is a simplified copy of Figure 2.5-6 in Flach et al. (2005) shows the fractional H-3 fluxes used in the derivation. In Figure 4-15, the concrete-uniform refers to concrete rubble from a building while the concrete-nonuniform refers to concrete rubble from a chimney stack.

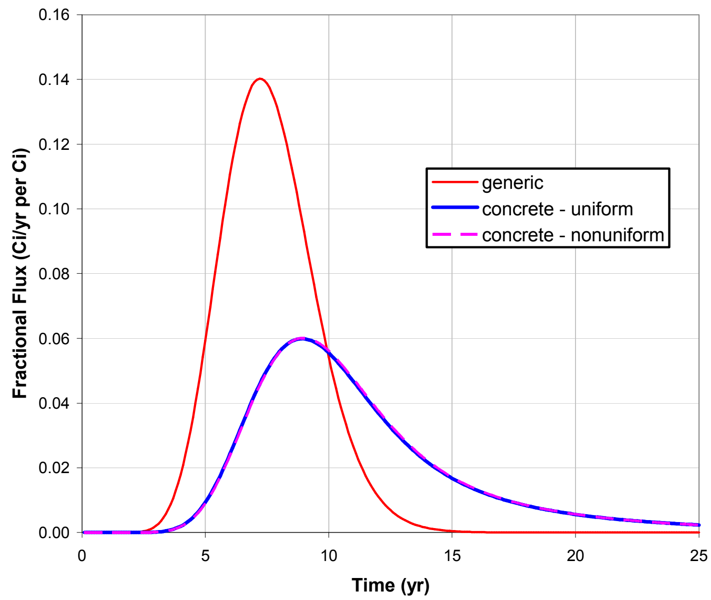

Figure 4-15 Tritium fluxes at the water table used to derive H-3_Concrete flux ratio.

Therefore, to model H-3 release from concrete in SLIT1, the flux to the water table of H-3 in concrete was approximated as:

$$\Phi_{H-3\ Concrete} = 0.429\ \Phi_{H-3\ Soil} \frac{I_{H-3\ Concrete}}{I_{H-3\ Generic}} \qquad (4.1)$$

In equation (4.1), Φ_{H-3} is the flux (gmol/yr) of tritium to the water table and I_{H-3} is the inventory (gmol) of tritium in either concrete or generic waste material. The calculated flux to the water table from generic H-3 sources is multiplied by 0.429 and the flux is adjusted for the relative inventories of each source of H-3. As shown in Figure 4-15, using the peak ratio 0.429 at each point in time overestimates the impact from H-3 in concrete during the early part of the release but underestimates the H-3 in concrete flux at later times. The H-3 in concrete flux calculated in this way was then processed through the aquifer analysis in the same way as the other sources.

4.6.3 Vadose Zone Transport Results

Vadose zone modeling results consisted of contaminant fluxes to the water table for each radionuclide in the parent's chain that was modeled. Each chain had results for all the applicable cases. Selected time histories for contaminant fluxes at the water table are provided in Appendix B. An example of a time-history plot of fractional fluxes for Np-237, the dominant radionuclide in the dominant chain, is provided in Figure 4-16 for the Inventory Group SLIT4-Unit~North.

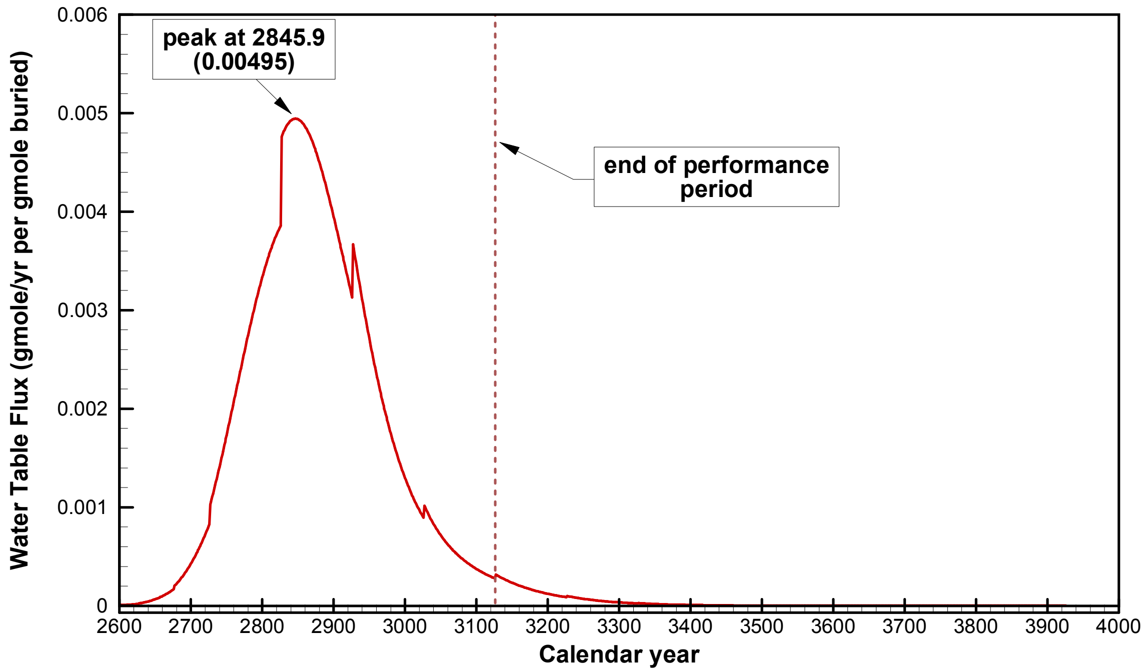

Figure 4-16 Np-237 fractional flux to water table for center trenches within SLIT4-Unit~North (e.g., 4A_North).

As mentioned in earlier sections, numerous vadose zone transport simulations are required to provide the various trench segment flux-to-water-table source terms to the Aquifer analysis. Here a limited number of the results for key nuclides and trench segments are highlighted. Composite plots showing all of the trench segments are first shown for several of the key nuclides in Figures 4-17 through 4-22 for the base case:

- H-3
- I-129
- Tc-99
- Sr-90
- Pa-231 (the dominant dose contributor in the U-235 chain)
- Np-237 (Np-237 is the dominant contributor to doses in its own chain)

The last two plots involve parents that have decay chains being computed but only fluxes for the dominant contributor are plotted for clarity. Figures 4-17 through 4-22 show the fractional flux (i.e., gmole/yr per gmole of parent buried) to the water table for each of the nuclides listed above for all "center" slit trench segments under the intact case (i.e., Case01) and no CDP present (i.e., off). In the early years the effect of operational cover timing can be seen especially for the more mobile species such as H-3, Tc-99, and I-129. A later cap placement means more inventory is released before the cap is placed producing higher early peaks and lower fluxes after cap placement. In later years the impact of the operational cover timing diminishes significantly for the less mobile species such as Sr-90, Pa-231, and Np-237. For these nuclides, the peaks typically occur well after placement of the operational cap and the peaks for all the inventory groups are about equal.

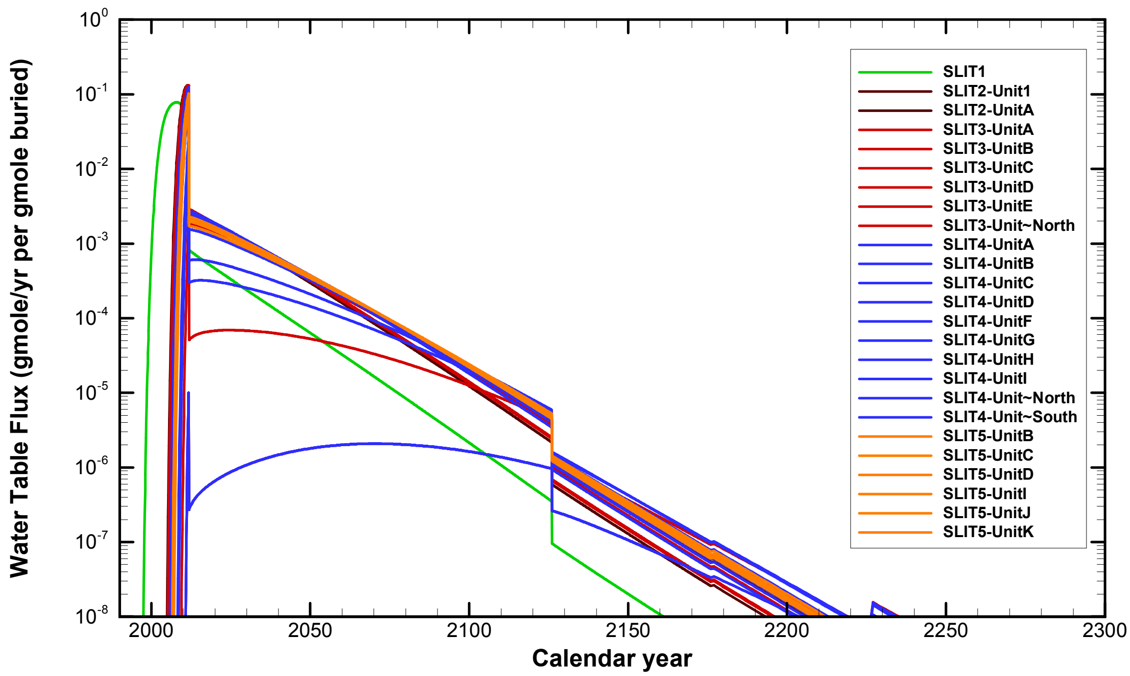

Figure 4-17 H-3 fractional flux to water table for all Center inventory groups.

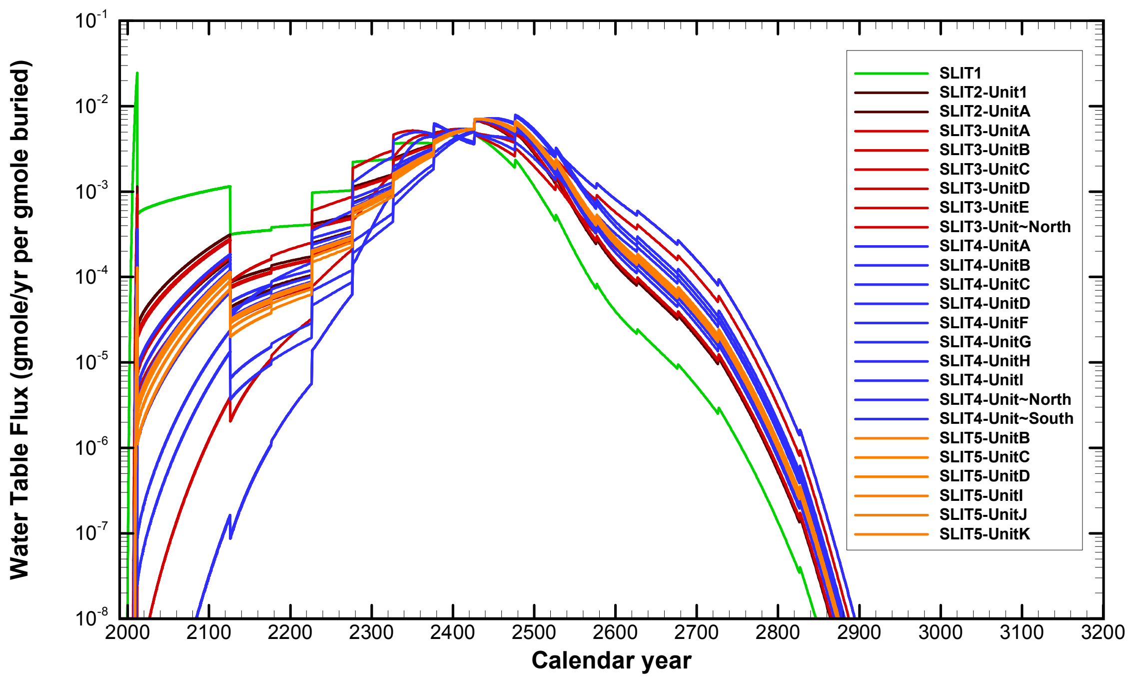

Figure 4-18 I-129 fractional flux to water table for all Center inventory groups.

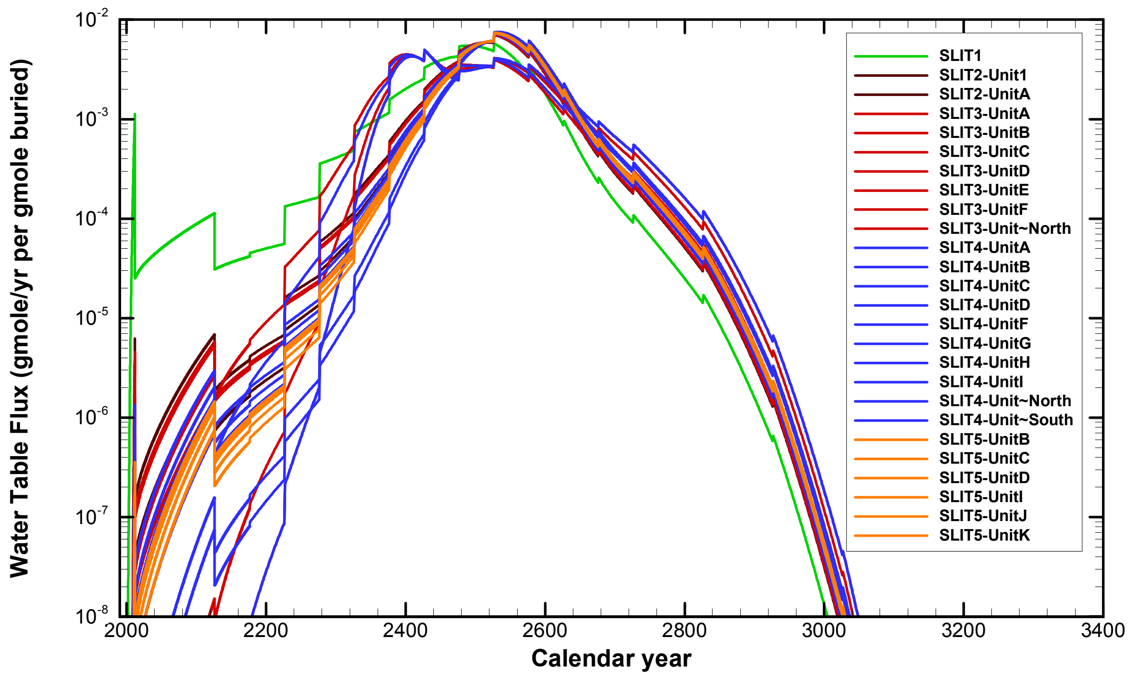

Figure 4-19 Tc-99 fractional flux to water table for all Center inventory groups.

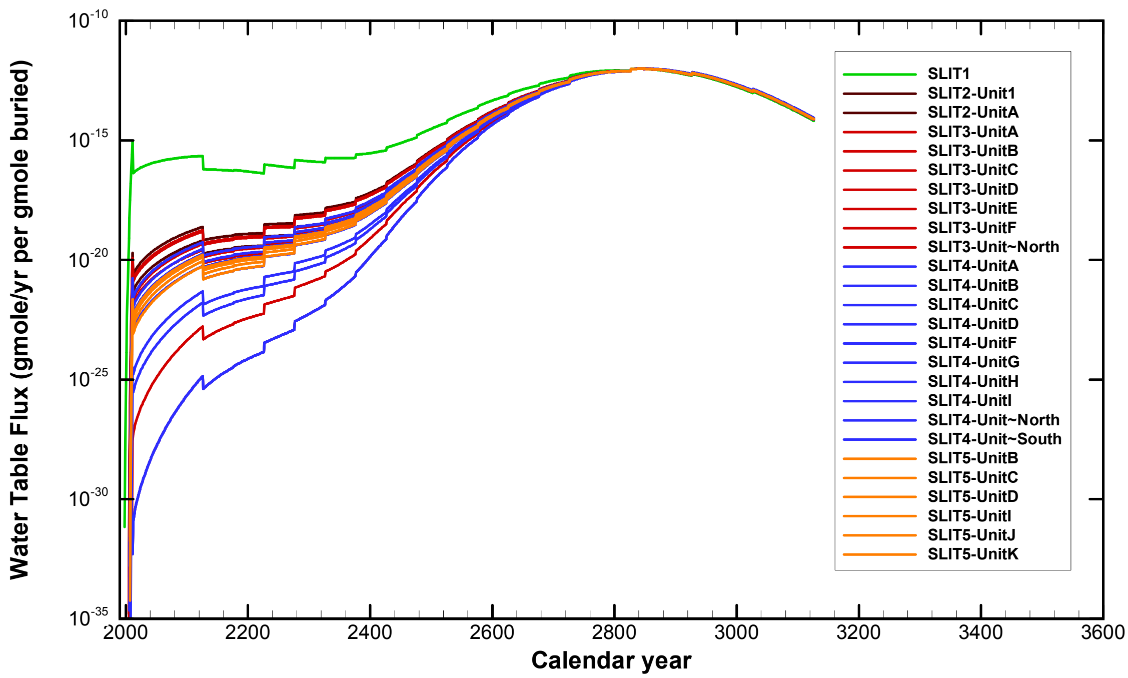

Figure 4-20 Sr-90 fractional flux to water table for all Center inventory groups.

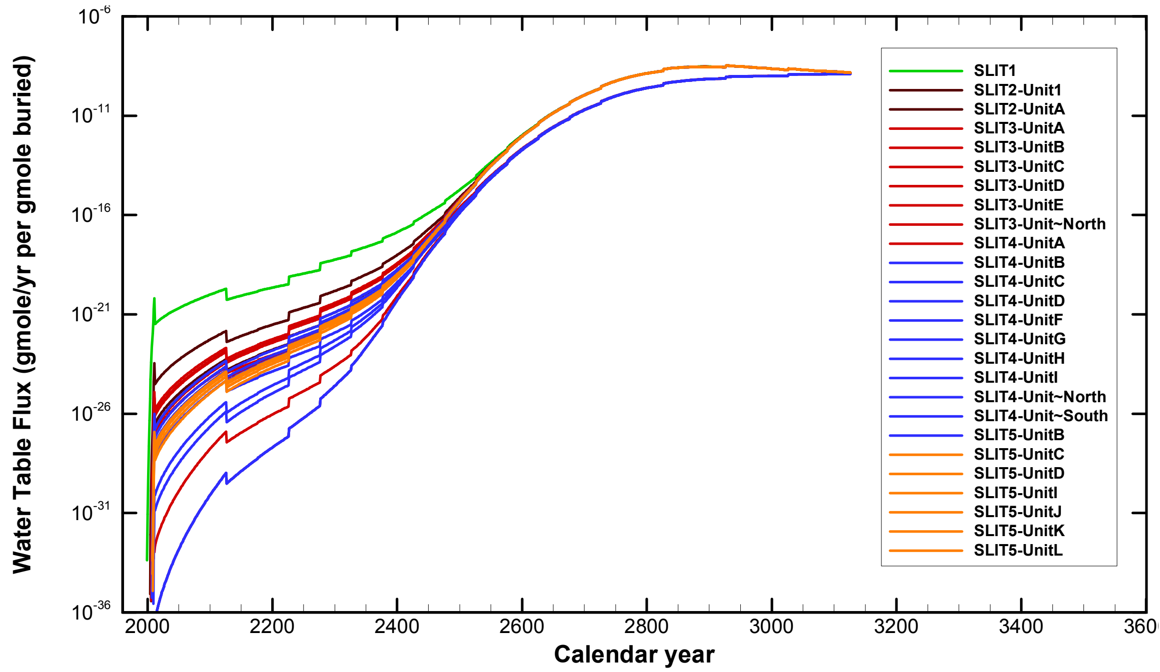

Figure 4-21 Pa-231 (from parent U-235) fractional flux to water table for all Center inventory groups.

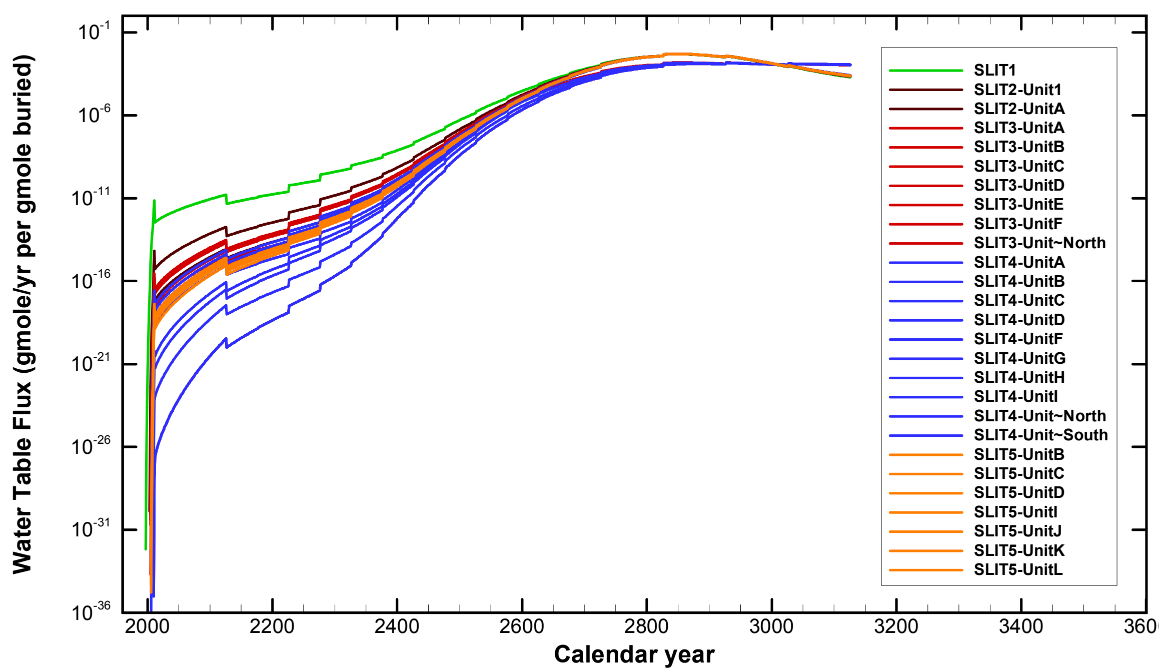

Figure 4-22 Np-237 fractional flux to water table for all Center inventory groups

The fractional flux to water table curves shown in Figures 4-17 through 4-22 are representative of the various flux profiles seen for the remaining nuclides. "Edge" trench segments (not plotted) typically show slightly higher fluxes during the operational cover phase due to increased water flow through the waste zone.

To see the impact of subsidence on the Np-237 flux to the water table four "center" trench segments were chosen for comparison of the intact case (Case01) to the blended results for the subsided case (Case01n11). Figure 4-23 illustrates the comparison where the condition of no CDP presence was chosen for viewing. Note that the blended results shown (i.e., Case01n11) are the result of an interpolation from the intact case (Case01) towards the 100% subsided case (Case11) based on the fraction of crushable containers present. Subsidence results in a significant early Np-237 release as shown by the dashed lines in Figure 4-23. Note that the overall peak values do not change significantly, only the time of the peak values.

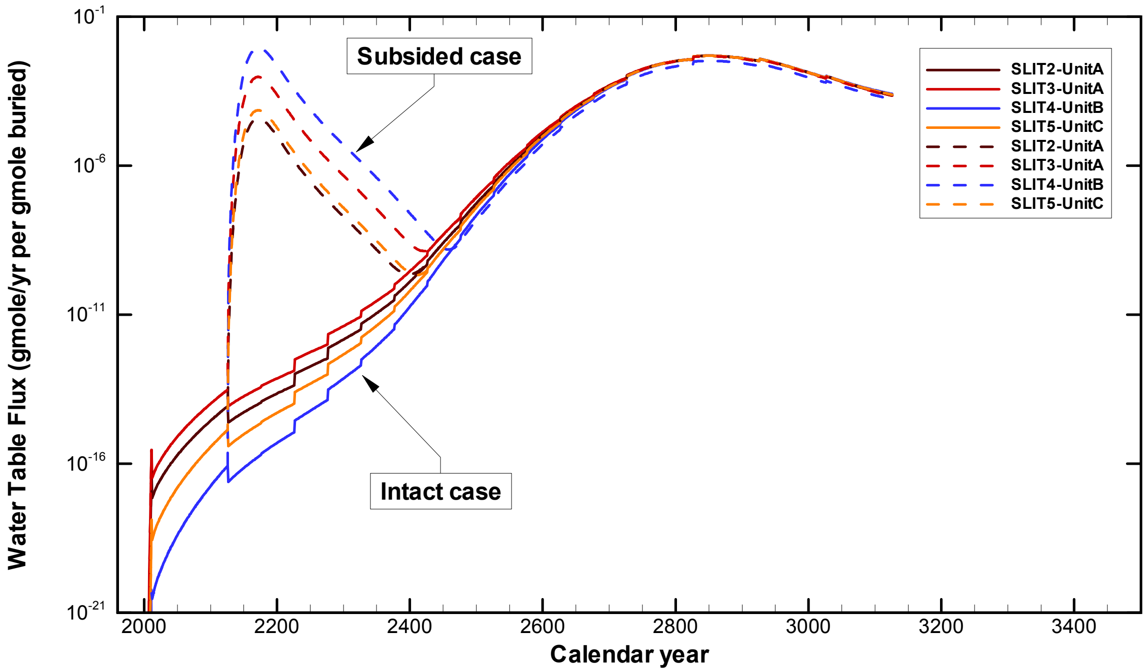

Figure 4-23 For select Center inventory groups the Np-237 fractional flux to water table comparison of intact (Case01) versus blended (Case01n11) cases without the presence of CDP.

During preliminary scoping analyses it was observed that subsidence impacts doses for Sr-90 significantly. Therefore, for waste packages containing Sr-90 we shall take a closer look below at how flux to the water table is impacted for non-crushable containers. To see this impact of subsidence on the Sr-90 flux to the water table the same four "center" trench segments were chosen for a comparison of the intact case (Case01) to the blended results for the subsided case (Case01n11). Figure 4-24 illustrates the comparison where the condition of no CDP presence was chosen for viewing. Again we see that subsidence results in a significant early Sr-90 release as shown by the dashed lines in Figure 4-24. Note that the overall peak values change significantly and are shifted to earlier times.

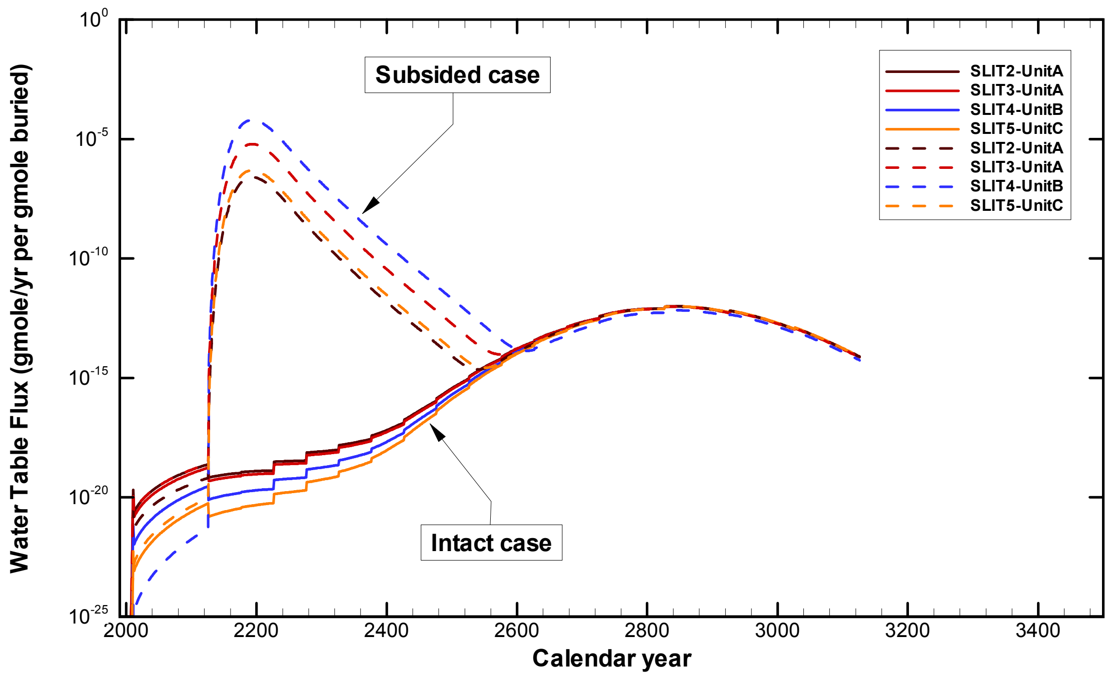

Figure 4-24 For select Center inventory groups the Sr-90 fractional flux to the water table comparison of intact (Case01) versus subsided (Case01n11) cases without the presence of CDP.

To illustrate the process used to compute a blended flux to the water table, one example for Sr-90 is reviewed. In Table 4-6 a listing of the percentage of non-crushable containers within each Inventory Group was provided. Table 4-6 shows a value of ~22.5% for SLIT3-UnitE. A comparison of the flux to water table for the PORFLOW transport runs Case01 (intact case) and Case11 (100% subsided case) is provided in Figure 4-25. The 22.5% blended case (Case01n11) is also shown as a blue dashed curve. As Figure 4-25 indicates, for Sr-90 subsidence results in a large (i.e., over a 10^5 increase) rise in the overall flux peak value.

The net impact of local subsidence on a specific trench segment is strongly dependent upon which nuclides are being considered. Two main factors that play competing roles in determining the impact of subsidence are:

- The nuclide's half-life because for the ~130 years prior to subsidence short lived nuclides will mostly decay leaving only residual amounts for later migration;
- The nuclide's retardation factor (i.e., its K_d value) because the amount of inventory released prior to subsidence decreases for increased K_d value which defines the residual that is available when subsidence occurs.

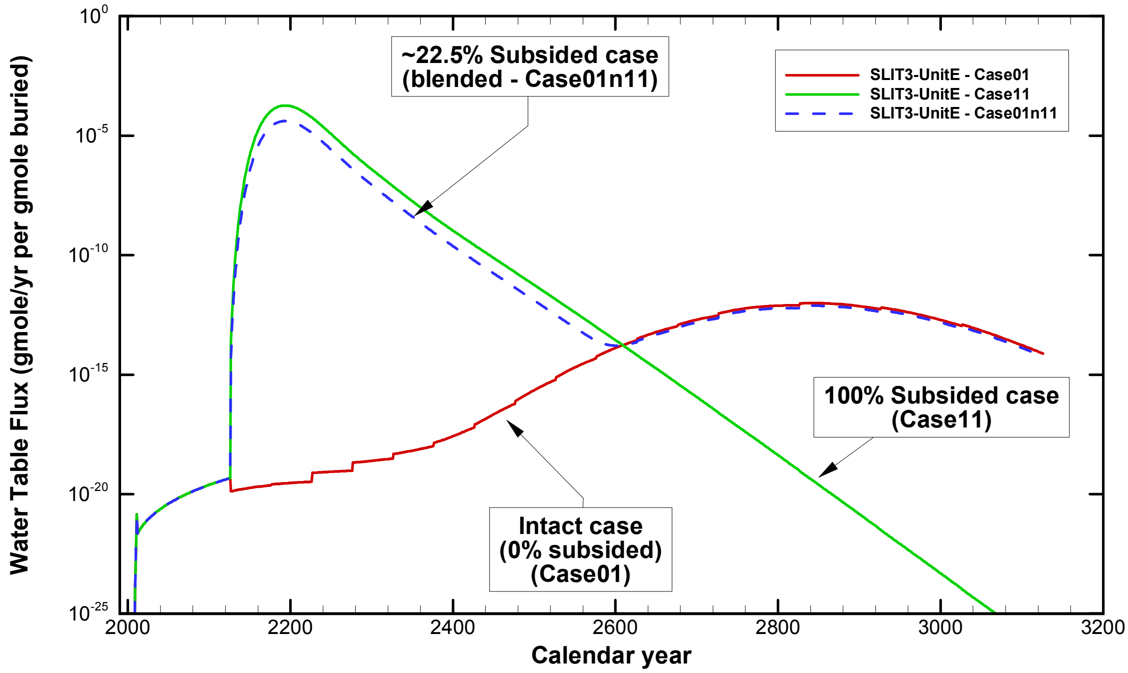

Figure 4-25 Example of flux blending process for Sr-90 in SLIT3-UnitE without the presence of CDP.

Figure 4-26 shows the effects of interactions between these factors on the flux to the water table for SLIT3-UnitE. Both intact and subsided cases are depicted in the figure. Table 4-8 presents the actual values for these factors for the five radionuclides that are plotted in Figure 4-26. The impact due to subsidence can be assessed by looking at the ratio of peak concentrations between the intact versus subsided cases. Note that Sr-90 has a half-life versus retardation factor that results in the highest impact when viewing results of intact versus local subsidence.

Table 4-8 The Low-pH K_d (ml/g) values and half-lives for selected nuclides.

Radionuclide	Half-life (yr)	Best Est. Sand K_d value at Low-pH	Best Est. Clay K_d value at Low-pH
H-3	12.32	0	0
I-129	1.57×10^{7}	0.3	0.9
Tc-99	2.111×10^{5}	0.6	1.8
Sr-90	28.9	5	17
Np-237	2.157×10^{6}	3	9

As Figure 4-26 illustrates:

- For H-3 negligible impacts result due to the significant decay prior to subsidence.
- For Sr-90 and Np-237 significant early impacts result due to their modest amounts of retardation present. Here Np-237 has a second peak in the out years due to its large half-life.
- For Tc-99 and I-129 similar behavior is observed where their impacts are small due to their low retardation and large half-lives.

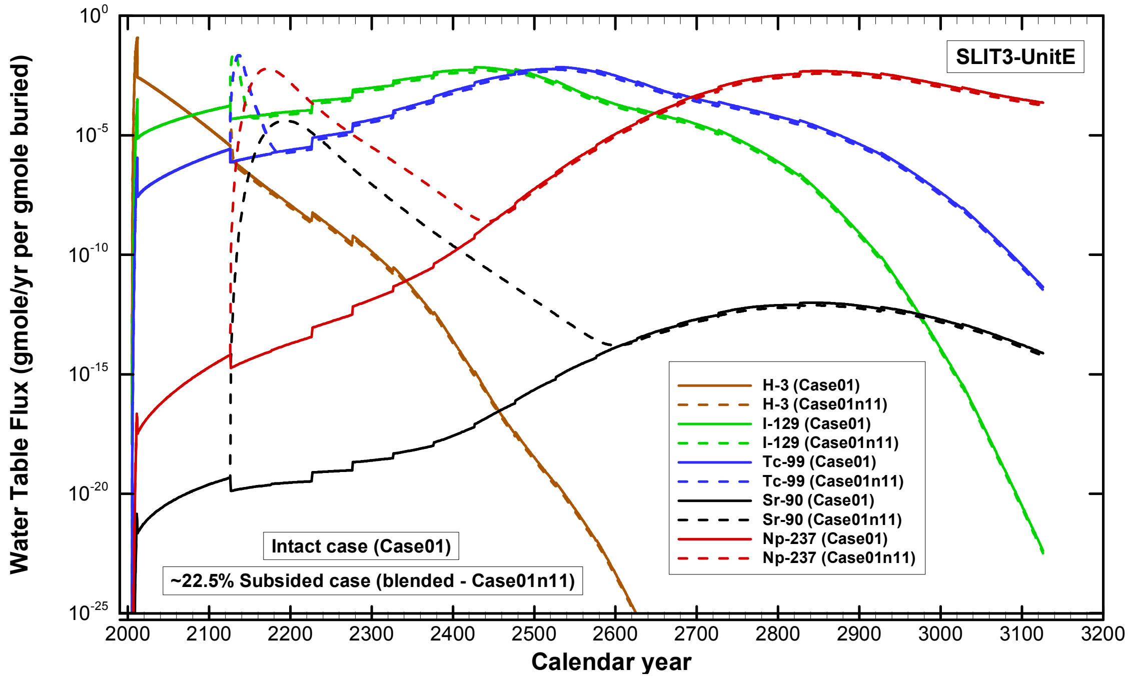

Figure 4-26 Impact on flux to water table due to local subsidence of SLIT3-UnitE for H-3, Tc-99, Sr-90 and Np-237.

Snapshots of fractional concentration profiles for the Np-237 analyses are provided in Figure 4-27 at various times (for the same trench segment as shown in Figure 4-4, 4A_North). The first time is calendar year 2126 immediately before dynamic compaction. The second time is year 2841 about when the Np-237 achieves its peak flux at the water table and most of the Np-237 has left the waste zone. The third time is 3026 when almost all the Np-237 has left the waste zone.

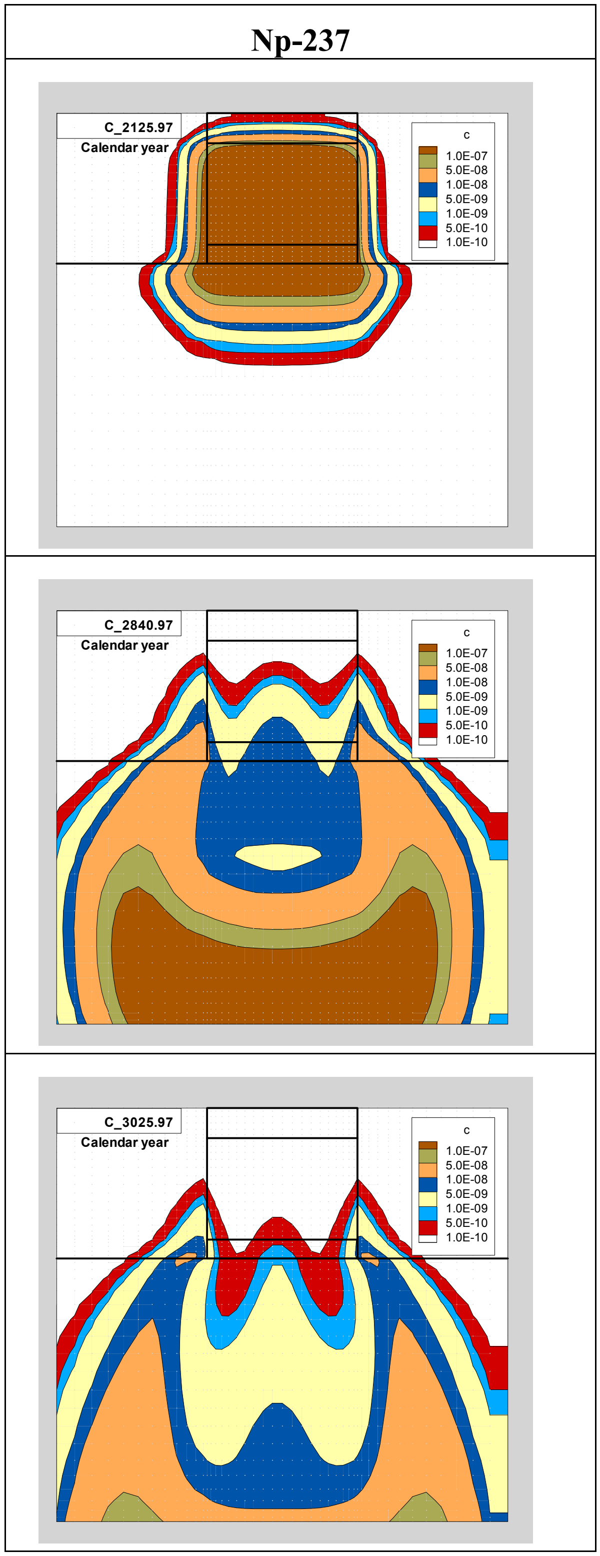

Figure 4-27 Np-237 fractional concentration profiles in the vadose zone for various times for center trenches within SLIT4-Unit~North (e.g., 4A_North).

5.0 AQUIFER ANALYSIS

The Aquifer flow model for the Center Slit Trenches from the 2008 Performance Assessment (PA, WSRC 2008) was used in this study. The 2008 PA methodology contained an assumption that the time-varying behavior of an aquifer system can be ignored and only one representative steady-state flow field needs to be considered. Long-term climatic effects were not considered nor were impacts such as surface alterations. A time-averaged flow field was developed for the General Separations Area (GSA) then a "cookie-cutting" procedure was applied to extract the aquifer model.

For providing maximum well concentration histories for subsequent performance evaluation analyses as discussed in Chapter 6, a set of Base cases was considered. A set of sensitivity analyses were also performed and the results of these sensitivity analyses are discussed in Chapter 7. Below only the results associated with the Base case set of analyses is discussed.

5.1 Aquifer Model Geometry

The Aquifer transport analyses relied on the PA Aquifer flow model geometry. An aerial view of this Center Slit Trench Aquifer model is shown in Figure 5-1**.**

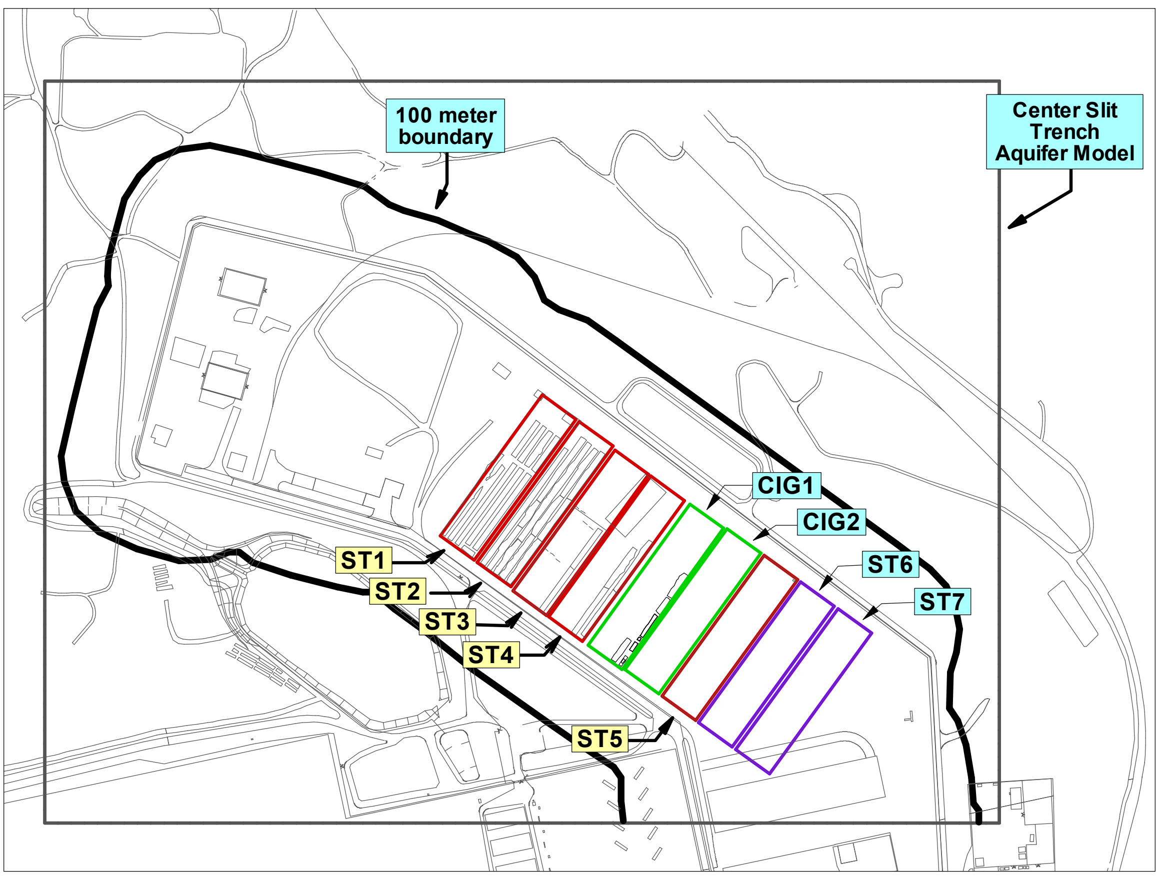

Figure 5-1 3D Aquifer flow model used in 2008 PA for analyzing Center Slit Trenches.

The model domain extends from about 40 to about 740 meters beyond the 100-meter boundary that surrounds the facility. The nearest point on the model boundary that is down-gradient from waste in Slit Trenches 1 through 5 is about 280 meters beyond the 100-meter boundary. Footprints of all Center Slit Trenches and CIG Trenches are contained within this model domain. The 100-meter boundary is provided as well.

In Figure 5-2 the same aerial view of the Aquifer model is shown with the aerial mesh. Elements uniform in size (i.e., 50 ft by 50 ft) were employed in the x and y directions where the discretizations were 72 elements in the x-direction and 56 elements in the y-direction. A total of 16 vertical elements (which were not uniform in size) were employed in the z-direction.

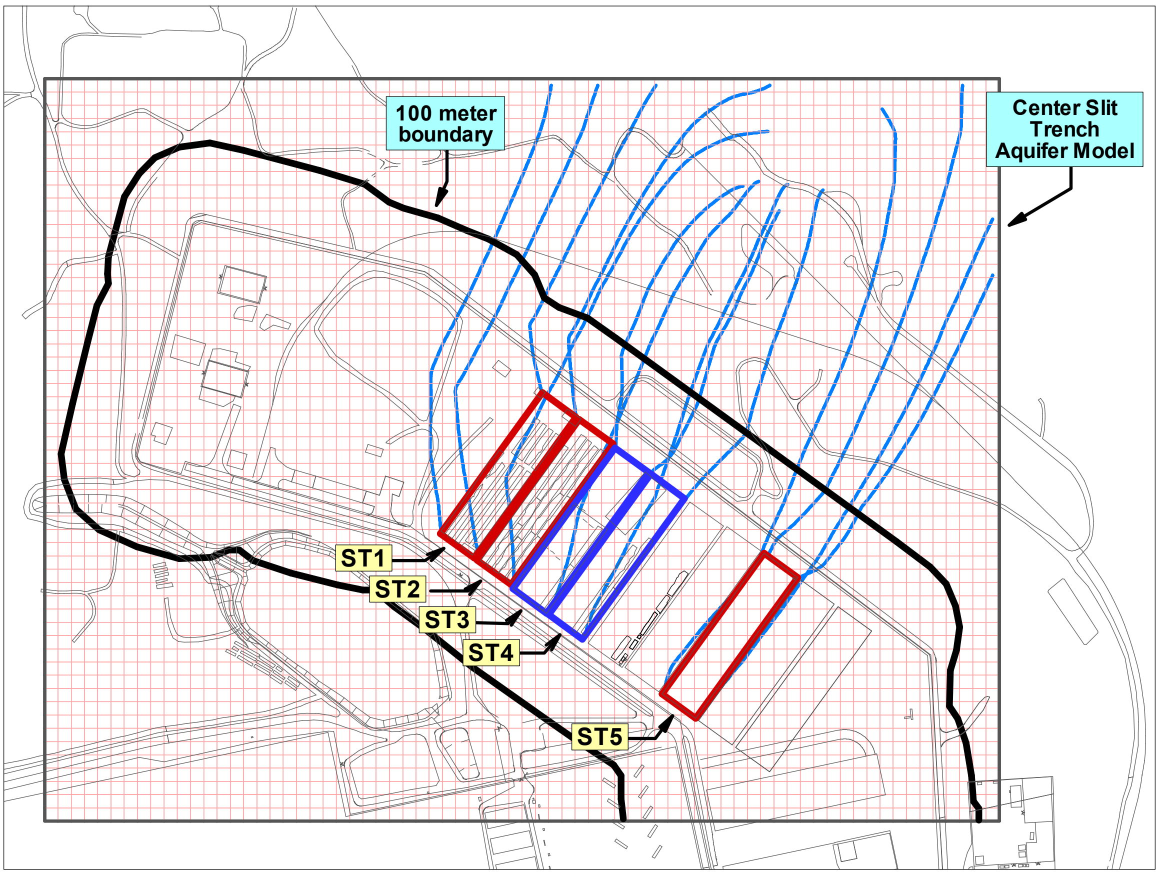

Figure 5-2 X-Y Cartesian mesh of the aquifer flow and transport model used for analyzing Center Slit Trenches.

3D streamlines are also shown in Figure 5-2 originating from several corners of the Center Slit Trenches. Some of the streamlines demonstrate a strong kink during their travel that represents the transition from the water table through the green clay into the Gordon Aquifer. All streamlines discharge into Upper Three Runs or its tributaries.

A close up of the Aquifer Model is shown in Figure 5-3 highlighting the five slit trench disposal units. The 3D streamlines show that SLIT5 is essentially isolated from the other modeled disposal units and likely would be most affected by its neighboring disposal units (e.g., the CIG trenches). Note that the Aquifer model does not include the effects that the covers may have on regional groundwater flows.

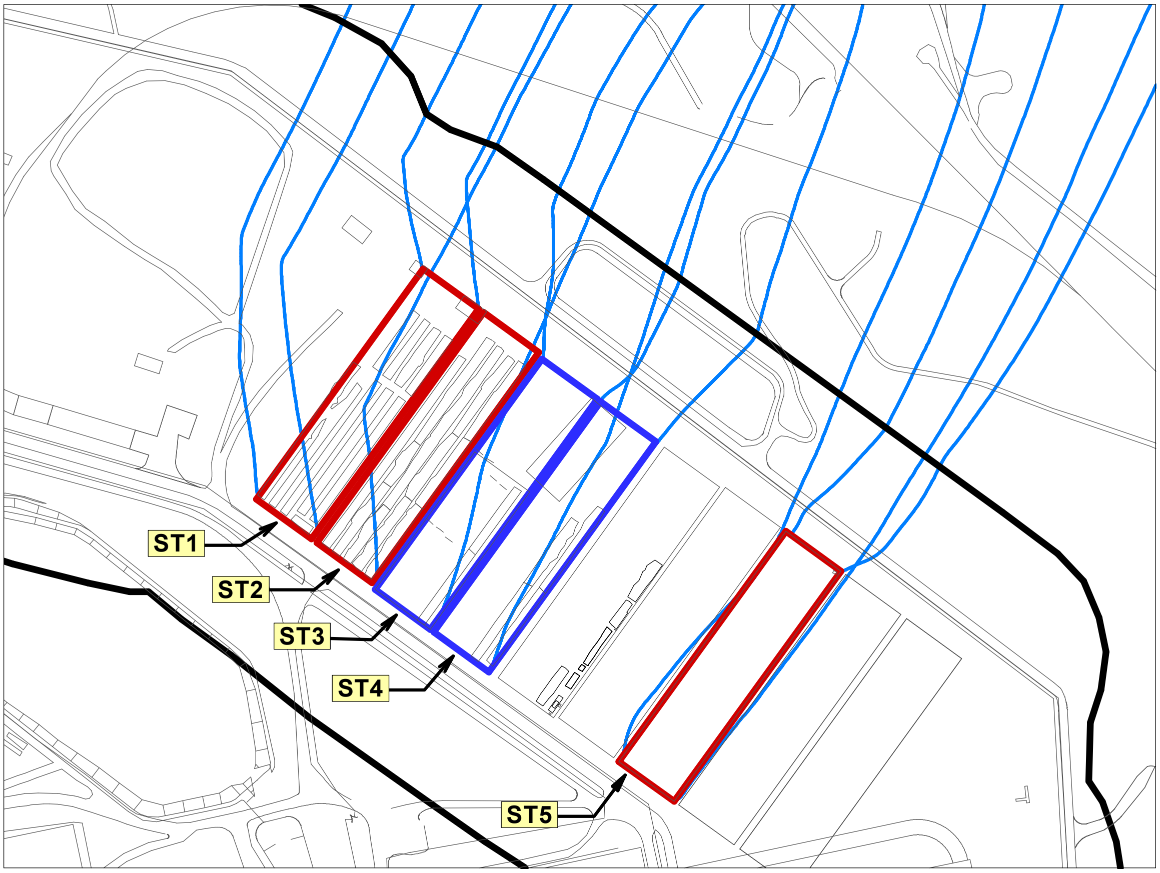

Figure 5-3 3D streamlines originating at the top of the water table then emanating out from the various corners of the Slit Trench Disposal units SLIT1, SLIT2, SLIT3, SLIT4, and SLIT5.

5.2 Conversion from Vadose Zone Fluxes at the Water Table to Aquifer Model Sources

Aquifer source terms are applied at the node level corresponding to the uppermost node location within the water table. These source terms are computed by a blending process where Vadose zone transport results are employed. For the Base case (i.e., under low-pH conditions) and for each parent nuclide two Vadose zone transport runs were made as shown in Table 5-1 (i.e., Case01 and Case11 shown shaded in orange). Source term blending, based on each Inventory Group's percent of non-crushable, was performed to create Case01n11 as shown shaded in blue in Table 5-1. For the low-pH conditions aquifer transport runs were performed for Case01 and Case01n11 as shown in Table 5-1.

Table 5-1 Aquifer source term blending matrix based on Vadose zone transport runs under low-pH conditions.

Transport Runs	0% non-crushable	Percent of non-crushable	100% non-crushable
Vadose zone	Case01 model results		Case11 model results
Aquifer	Case01 model results	Case01n11 (blended)	

5.2.1 Cellulose Degradation Product (CDP) Effects

For CDP effects (i.e., typically referred to as "on" or "off"), the aquifer analyses followed the pattern of the vadose zone analyses. Aquifer analyses were performed for each case with CDP present ("on") and a separate set of aquifer analyses was performed for each case with CDP absent ("off"), when needed. If the K_d's for all members in a chain were not changed by the CDP, only one set of aquifer analyses was performed with CDP being absent.

5.2.2 Non-crushable Areas

The vadose zone analyses included two cases, namely Case01 where dynamic compaction was completely effective because all waste containers were considered to be crushable and Case11 where dynamic compaction did not affect the waste zone because all the waste containers were considered to be non-crushable. The WITS area of non-crushable containers was applied to fluxes by Inventory Group to develop a blended source term case, Case01n11. The aquifer analyses included only Case01 and Case01n11.

Here Case01 refers to trenches where dynamic compaction was effective and the infiltration rates employed in the corresponding Vadose zone analyses assumed an intact trench throughout the entire performance period. Whereas, Case11 refers to trenches containing non-crushable containers and subsidence is assumed at the end of institutional controls right after placement of the cap. Case01n11 represents a blending of these two end state cases to reflect the fraction of non-crushable containers within each Inventory Group considered.

For each parent chain in a single Inventory Group, the blending operation consists of multiplying the Case11 fluxes by the ratio of the non-crushable area versus the total Inventory Group area and adding those results to the Case01 fluxes multiplied by the ratio of the crushable area versus the total Inventory Group area. For each radionuclide in the parent chain, a case-weighted average flux to the water table is calculated at each time step by Equation 5.1 as follows:

$$\boldsymbol{Flux}_{\boldsymbol{case}}^{\boldsymbol{blend}}(\boldsymbol{G},\boldsymbol{N},\boldsymbol{t}) = \phi_G \; \boldsymbol{Flux}_{\boldsymbol{Case}11}(\boldsymbol{G},\boldsymbol{N},\boldsymbol{t}) + (1-\phi_G)\; \boldsymbol{Flux}_{\boldsymbol{Case}01}(\boldsymbol{G},\boldsymbol{N},\boldsymbol{t}) \qquad (5.1)$$

where

$\boldsymbol{G}$ is the index representing an Inventory Group

$\boldsymbol{N}$ is the index representing a radionuclide (i.e., a parent or its progeny)

$\boldsymbol{t}$ represents the time step

ϕ_G is the fraction of the Inventory Group area occupied by non-crushable waste containers

Equation (5-1) results in aquifer source terms representing blended fluxes for Case01n11 as shown in Table 5-1.

5.2.3 Inventories and Segment Areas

The vadose zone transport models produced fractional fluxes at the water table based on nominal 1 gmol inventories. These fractional fluxes at the water table were scaled by the final inventories to produce aquifer sources. Final inventories were available at the WITS Unit (i.e., Inventory Group) level, while coordinates and areas were available at the trench segment level. Two steps were needed to combine the fluxes and inventories as follows:

1. Group inventories were distributed to each trench segment to produce Segment inventories.
2. Segment inventories were distributed to each aquifer source cell.

For each parent in a single trench segment, the first step was accomplished by multiplying the Group inventory by the ratio of the segment's area versus the group's area. For each parent in a single aquifer cell, the second step was accomplished by multiplying the segment's inventory by the ratio of the intersection area (of the aquifer cell and the segment) to the segment's area. The general formula is presented in Equation 5.2:

$$\boldsymbol{AqSource}(\boldsymbol{C},\boldsymbol{N},\boldsymbol{t}) = \sum_{\boldsymbol{S}}\left[\boldsymbol{Flux}\left(\boldsymbol{G}_{\boldsymbol{S}}^{\boldsymbol{L}},\boldsymbol{N},\boldsymbol{t}\right) * \boxed{\boldsymbol{Inventory}(\boldsymbol{G}_{\boldsymbol{S}},\boldsymbol{N}) * \frac{\boldsymbol{Area}(\boldsymbol{S})}{\boldsymbol{Area}(\boldsymbol{G}_{\boldsymbol{S}})} * \frac{\boldsymbol{Area}(\boldsymbol{S}) \cap \boldsymbol{Area}(\boldsymbol{C})}{\boldsymbol{Area}(\boldsymbol{S})}}\right] \quad (5.2)$$

where

$\boldsymbol{C}$ varies over each aquifer cell

$\boldsymbol{N}$ varies over each radionuclide

$\boldsymbol{t}$ varies over each time step

Fluxes are summed over each trench segment S where

$\boldsymbol{G}_{\boldsymbol{S}}$ is the Inventory Group of which the trench segment S is a member

$\boldsymbol{G}_{\boldsymbol{S}}^{\boldsymbol{L}}$ is used to select the flux data file based on the location of the segment, i.e., whether it is an edge segment or a center segment. The location does not affect the inventory.

Equation 5.2 was applied by retaining the fluxes in individual data files and introducing a multiplicative scaling factor that represents the boxed-in, right-hand portion of the equation.

5.3 Aquifer Model Changes

The aquifer flow model for the center set of slit trenches from the 2008 PA was applied without change. The aquifer transport model from the 2008 SA was applied with K_d and source term changes. New K_d's from Kaplan (2010) were substituted into the model. The new K_d's have many instances where CDP now has no impact, thus transport models for CDP being present were not run if the K_d's were the same as for the case with CDP being absent.

The source terms changed both in respect to the scaling factors and the fluxes at the water table. The scaling factors changed because of the following items:

- Segments were included to produce more accurate results and their footprint areas affected the scaling factors.
- Inventories were more accurately partitioned to segments to better account for actual inventory distributions and those inventories affected the scaling factors.

The fluxes at the water table changed because of the following items:

- New K_d's.
- Blending based on WITS non-crushable container areas.

To reduce the number of aquifer PORFLOW runs, SLIT1, SLIT2 and SLIT5 were combined into a single aquifer analysis (i.e., referred to as SLIT125). Meanwhile SLIT3 and SLIT4 were combined into a single aquifer analysis (i.e., referred to as SLIT34). SLIT1, SLIT2 and SLIT5 were combined because their final inventories were known when the analysis was started. SLIT3 and SLIT4 were combined because their final inventories were not known when the analysis was started, but a common cover would be placed over them. These combinations also reflected those groups of Slit Trenches for which plume interaction factors had previously been developed.

5.4 Aquifer Model Execution Sets

Eight sets of aquifer models were run as shown in Table 5-2 that constitutes the Base case. In Table 5-2 Case01 refers to the situation where only crushable containers exist and dynamic compaction is 100% effective, while Case01n11 refers to a blended situation. For Case01n11, weighting factors based on non-crushable areas are applied to Case01 and Case11 vadose zone results, where Case11 has only non-crushable containers.

Table 5-2 Aquifer model sets.

Infiltration Case	CDP state	Slit Trench Combination
Case01	off	SLIT1, SLIT2, SLIT5
Case01	on	SLIT1, SLIT2, SLIT5
Case01n11	off	SLIT1, SLIT2, SLIT5
Case01n11	on	SLIT1, SLIT2, SLIT5
Case01	off	SLIT3, SLIT4
Case01	on	SLIT3, SLIT4
Case01n11	off	SLIT3, SLIT4
Case01n11	on	SLIT3, SLIT4

These aquifer model sets did not have to be executed for all parents. If a parent did not appear in the inventory for a slit trench combination, it did not need to be executed (e.g., M-Area glass parents only appear in SLIT2, but never in the SLIT3 and SLIT4 combination, thus only the SLIT125 aquifer analysis was required). Also, if each member of the parent's chain had the same K_d for both CDP states, then only one execution was needed (e.g., only the off states were run). Parent radionuclides that needed to be executed for both CDP states are shown in Table 5-3.

Table 5-3 Parent runs needed for both CDP states.

Am-241	Cm-244	Cm-248	U-235_MGlass
Am-243	Cm-245	Pu-239	U-235_Paducah.Cask
Cf-249	Cm-246	Pu-241	
Cf-251	Cm-247	U-235	

5.5 Aquifer Model Results

Aquifer model results were well concentrations. At requested time intervals, PORFLOW (ACRI 2004) recorded the peak well concentration from the set of cells outside the 100-m boundary and the location of that cell. Thus, as a concentration front moves, so does the location selected by PORFLOW.

The PORFLOW results were recorded in a STAT.OUT file for those chain members that were explicitly modeled. Those results were fed to a computer program named IdealFileMaker that produced "ideal files" in the format expected by the LimitsAndDoses program. IdealFileMaker inserted concentrations for chain members that were not modeled (they were assumed to be in secular equilibrium with modeled precursors) and it converted all PORFLOW concentrations to pCi/L. Plume interactions factors were also applied during this step in the post-PORFLOW processing.

Besides being end produces, the well concentrations were intermediate products that were combined with other factors and summed across all the chains to produce doses. One example of a combined result is the total dose that relies on dose conversion factors. The combined results were then compared with performance measures and objectives to determine whether the performance was acceptable.

As mentioned earlier numerous Aquifer transport simulations were performed with the Base case parameter settings. A look at a set of off-nominal parameter settings is discussed in Chapter 7 as a sensitivity analysis about some of the Base cases. Additional off-nominal parameter settings were considered in Chapter 8 where four modeling options were investigated.

For each parent nuclide four different cases were considered (i.e., with and without CDP present plus intact or subsided caps). Here intact refers to Case01 where 0% non-crushables are considered and subsided refers to Case01n11 where non-crushables are incorporated. Here SLIT34 (i.e., composite of SLIT3 and SLIT4) and SLIT125 (i.e., composite of SLIT1, SLIT2, and SLIT5) results for a very limited number of key nuclides and case conditions are highlighted. Composite plots of the maximum well concentrations (these concentrations include plume interaction factors of 0.8 for SLIT34 and 0.7 for SLIT125) for the following parent nuclides are shown:

- H-3
- I-129
- Tc-99
- Sr-90

- U-235 (Pa-231 is the dominant contributor to dose)
- Np-237 (Np-237 is the dominant contributor to dose)

The results are provided in Figures 5-4 through 5-11 below. In all plots two cases are shown where no CDP is present. The two cases correspond to the intact case (Case01_off; solid lines) and the local subsidence blended case (Case01n11_off; dashed lines). Figures 5-4 through 5-7 provide results for H-3, I-129, Tc-99 and Sr-90. As can be seen in Figures 5-8 through 5-11, Pa-231 and Np-237 from the U-235 and Np-237 chains, respectively, have the highest concentrations and because they also have relatively high DCFs they are the dominant contributors to dose for these chains.

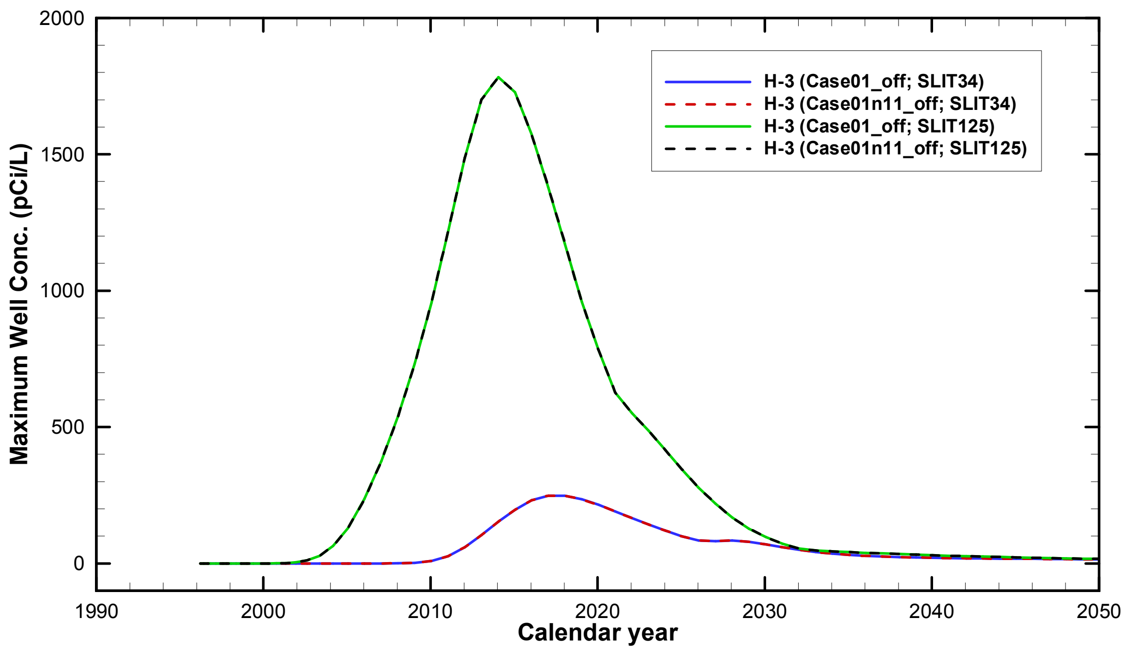

Figure 5-4 Well concentrations for H-3 in SLIT34 and SLIT125 aquifer analyses for the Base case scenario (intact versus subsided cases).

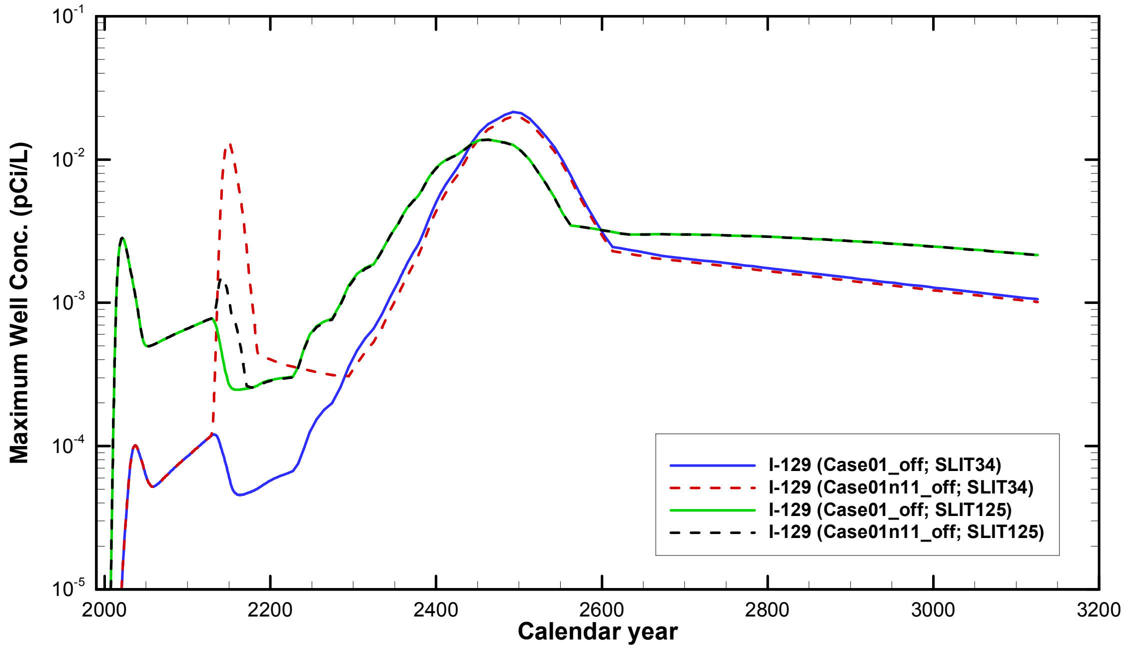

Figure 5-5 Well concentrations for I-129 in SLIT34 and SLIT125 aquifer analyses for the Base case scenario (intact versus subsided cases).

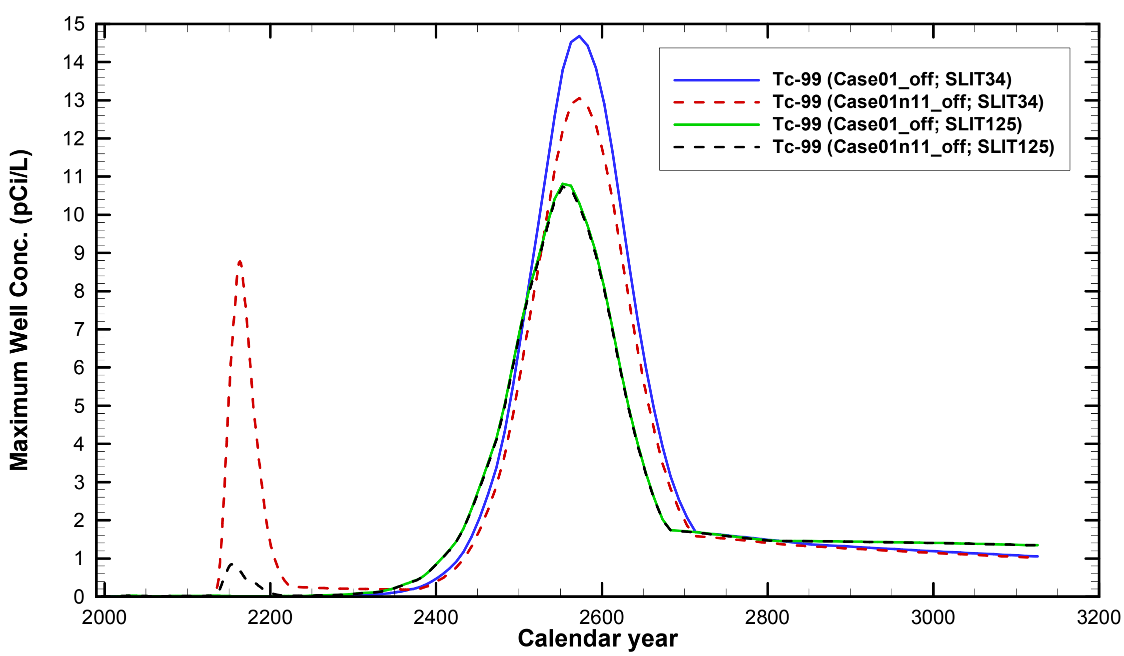

Figure 5-6 Well concentrations for Tc-99 in SLIT34 and SLIT125 aquifer analyses for the Base case scenario (intact versus subsided cases).

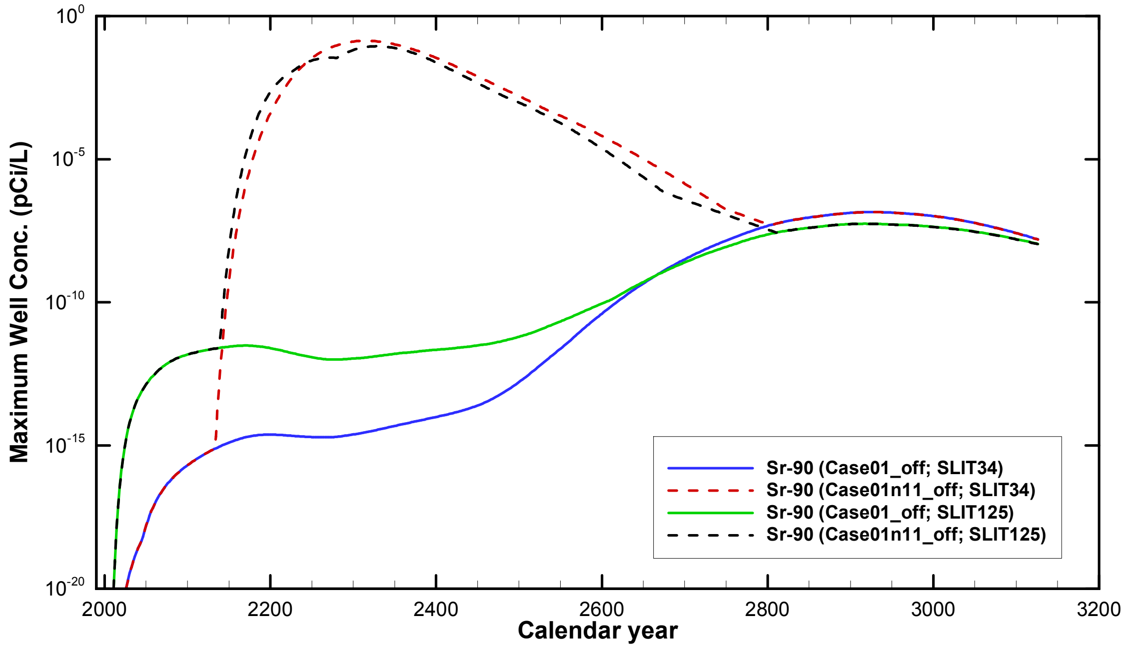

Figure 5-7 Well concentrations for Sr-90 in SLIT34 and SLIT125 aquifer analyses for the Base case scenario (intact versus subsided cases).

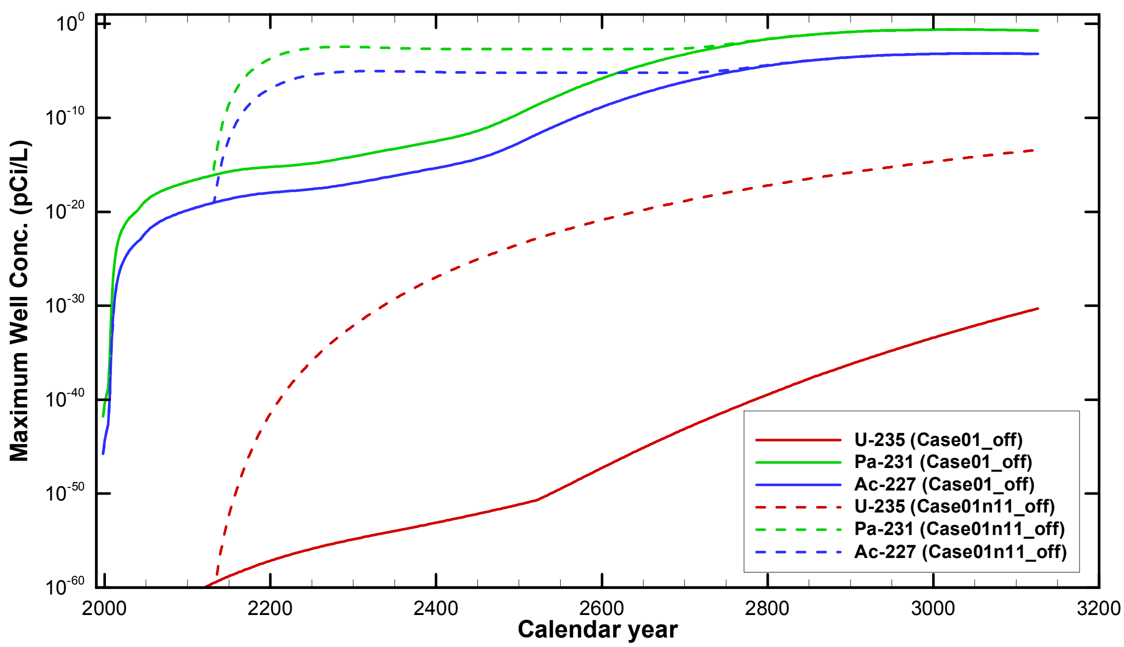

Figure 5-8 Well concentrations for U-235 chain in SLIT34 aquifer analysis for the Base case scenario (intact versus subsided cases).

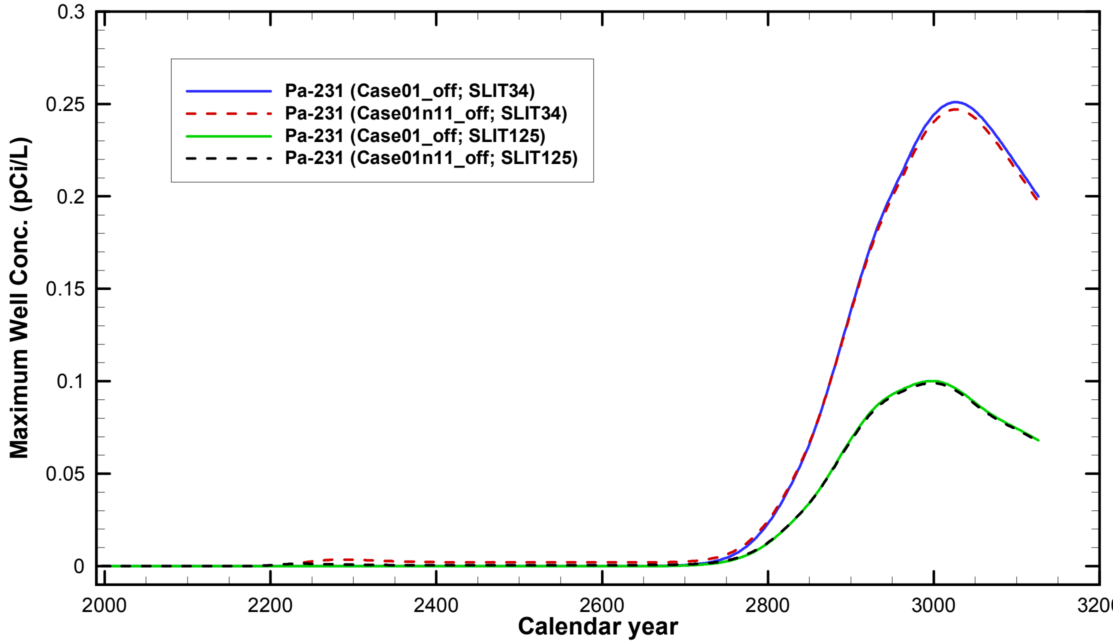

Figure 5-9 Well concentrations for Pa-231 in U-235 chain in SLIT34 and SLIT125 aquifer analyses for the Base case scenario (intact versus subsided cases).

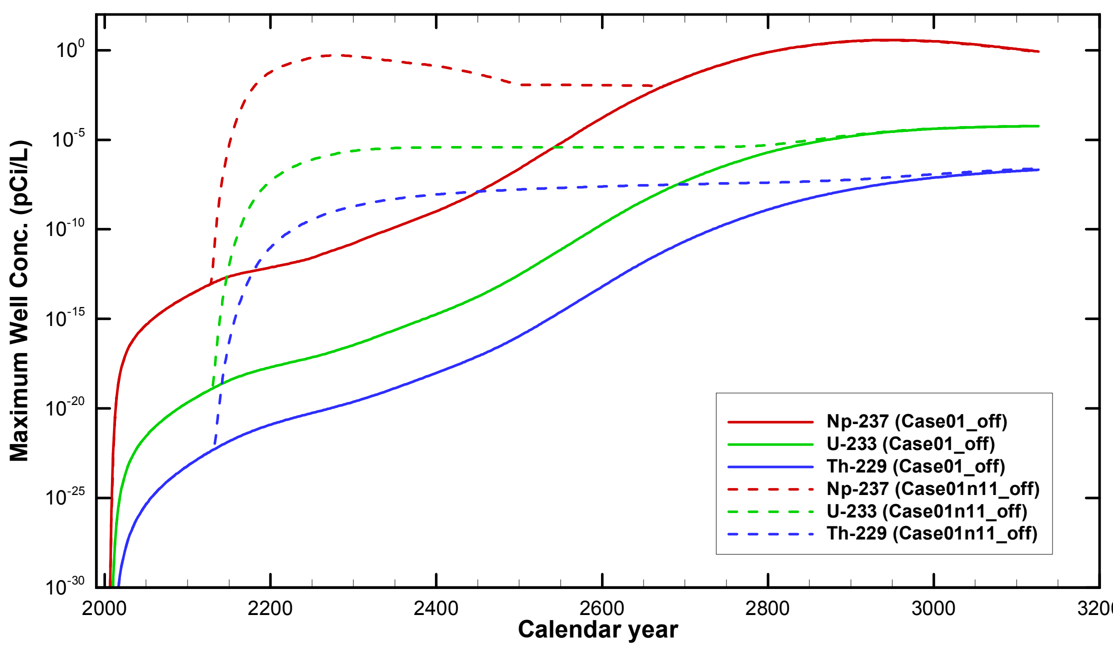

Figure 5-10 Well concentrations for Np-237 chain in SLIT34 aquifer analysis for the Base case scenario (intact versus subsided cases).

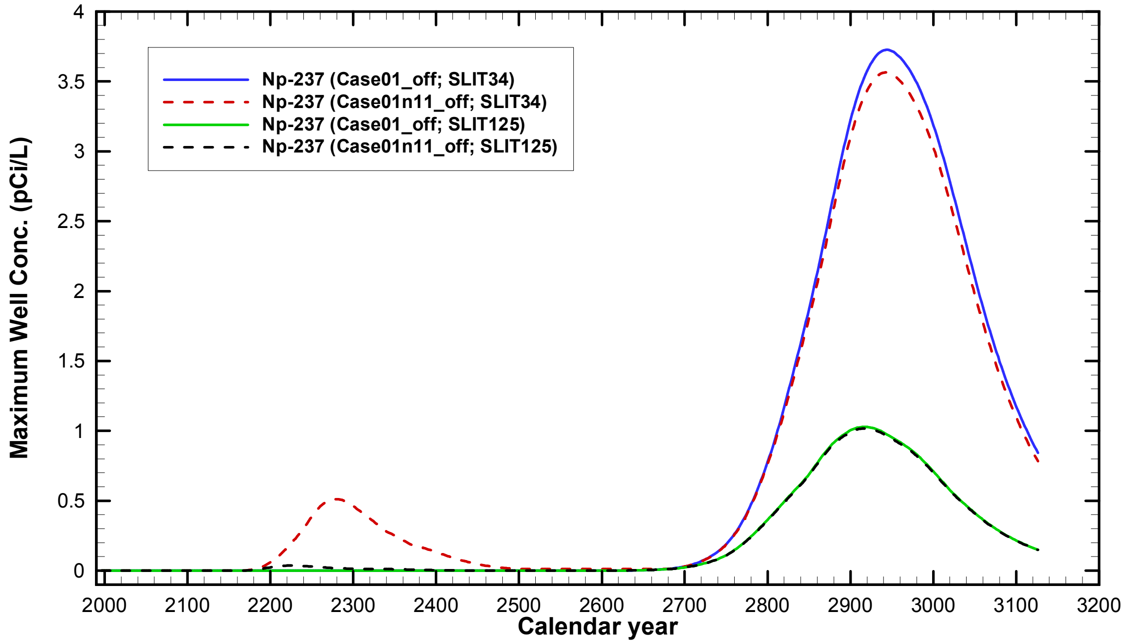

Figure 5-11 Well concentrations for Np-237 in SLIT34 and SLIT125 aquifer analyses for the Base case scenario (intact versus subsided cases).

5.5.1 Aquifer Results for Np-237

Because Np-237 dominates many of the dose pathways to be discussed in Chapter 6, we focus on the PORFLOW results for Np-237 within the SLIT34 Aquifer analyses. The PORFLOW computed concentrations are also adjusted by the SLIT34 plume interaction parameter (i.e., PORFLOW results are multiplied by a 1.25=1/0.8 factor). Thus, both the maximum well concentrations beyond the 100 meter boundary and the 2D concentration contours presented in Figures 5-13 through 5-17 represent concentration values (in pCi/L) that have been corrected to account for plume interactions associated with other disposal units.

In Figure 5-12 the maximum well concentration for Np-237 is shown for both the intact case (Case01) and the blended Subsidence case (Case01n11). Also highlighted are five calendar years (i.e., 2740, 2840, 2940, 3040, and 3120) where the Np-237 concentration is provided for the intact case (i.e., 0.137, 1.629, 3.722, 2.328, and 0.914 pCi/L), respectively.

Note that the peak value in the maximum well concentration for the intact case (Case01) is 3.726 pCi/L at year 2944. The peak value in the maximum well concentration for the subsided case (Case01n11) is 3.565 pCi/L at year 2942 (i.e., slightly less than 96% of the intact case).

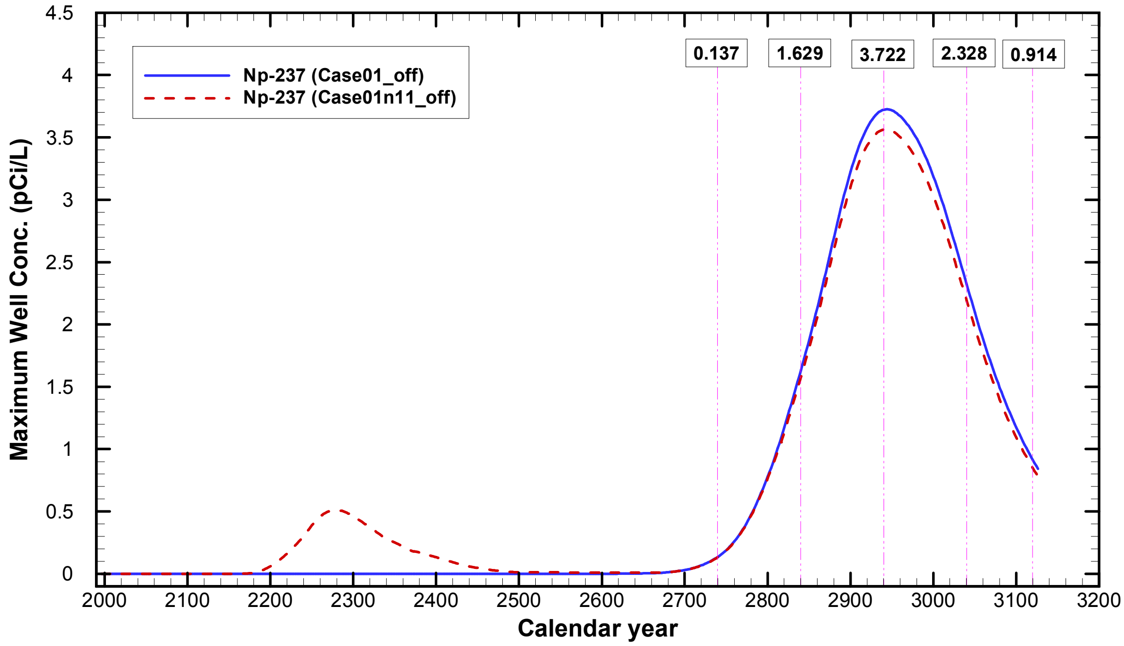

Figure 5-12 Well concentrations for Np-237 in SLIT34 aquifer analysis for the Base case scenario (intact versus subsided cases).

The Np-237 concentration profiles (in pCi/L and accounting for plume interactions) for the five selected times above are shown in Figures 5-13 through 5-17 for calendar years 2740, 2840, 2940, 3040, and 3120, respectively. These results are for the SLIT34 Aquifer Base case. In each of the figures the 3D concentration profile has been sliced at the same vertical K-plane (i.e., here K=11 within the PORFLOW Aquifer model) which corresponds to a depth below the ground surface of approximately 30 feet at the region highlighted with a blue circle. The slicing plane was selected to be consistent with the peak values presented in Figure 5-12. The plume concentrations in this region do not vary significantly over a modest vertical height corresponding to K=10 through 13 (i.e., 20 to 35 feet below ground level).

The location of the maximum well concentration is shown as a blue open circle in each figure. This location did not change much over the time period of interest here and the K-plane chosen corresponds with the approximate maximum values as well. In each of these figures the selected contours with the peak concentrations were selected to touch the 100 meter boundary.

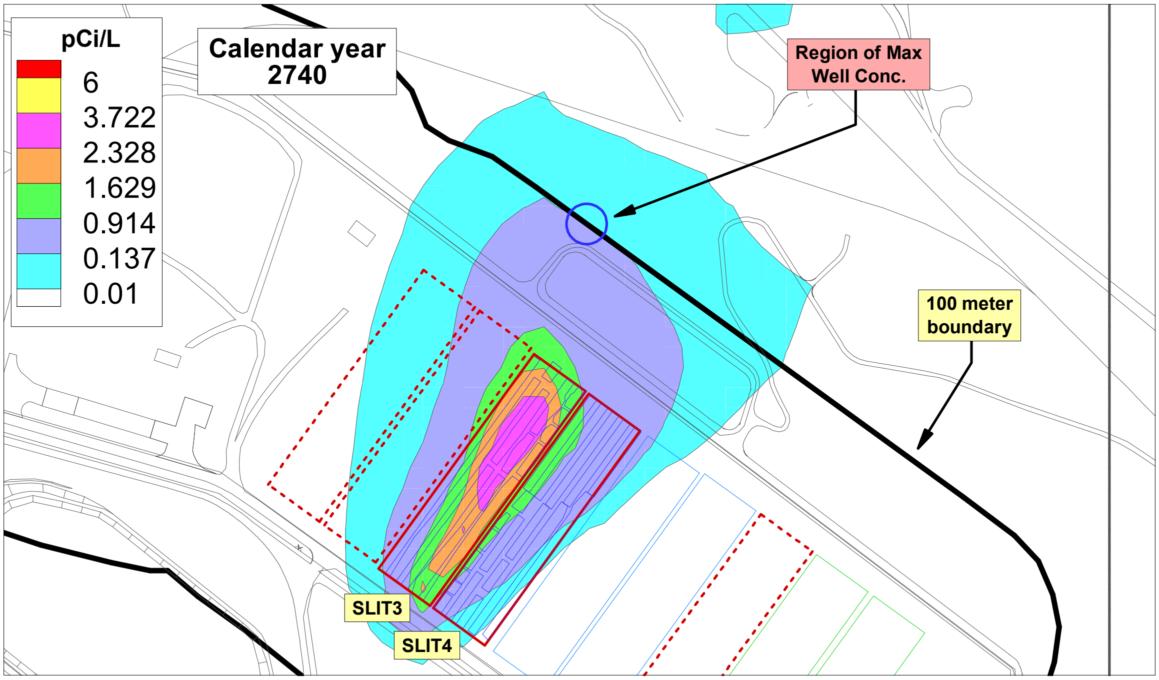

Figure 5-13 Concentration contours for Np-237 in the SLIT34 aquifer analysis for the intact case (without CDP) at the elevation where the maximum well concentration occurs for calendar year 2740.

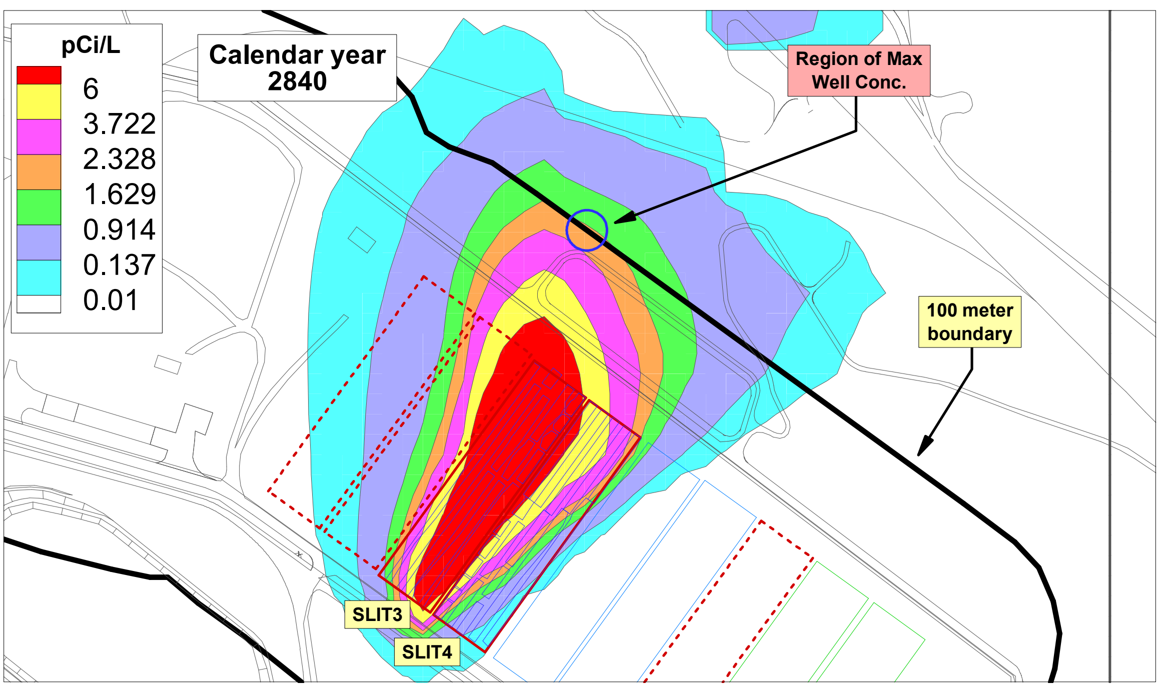

Figure 5-14 Concentration contours for Np-237 in the SLIT34 aquifer analysis for the intact case (without CDP) at the elevation where the maximum well concentration occurs for calendar year 2840.

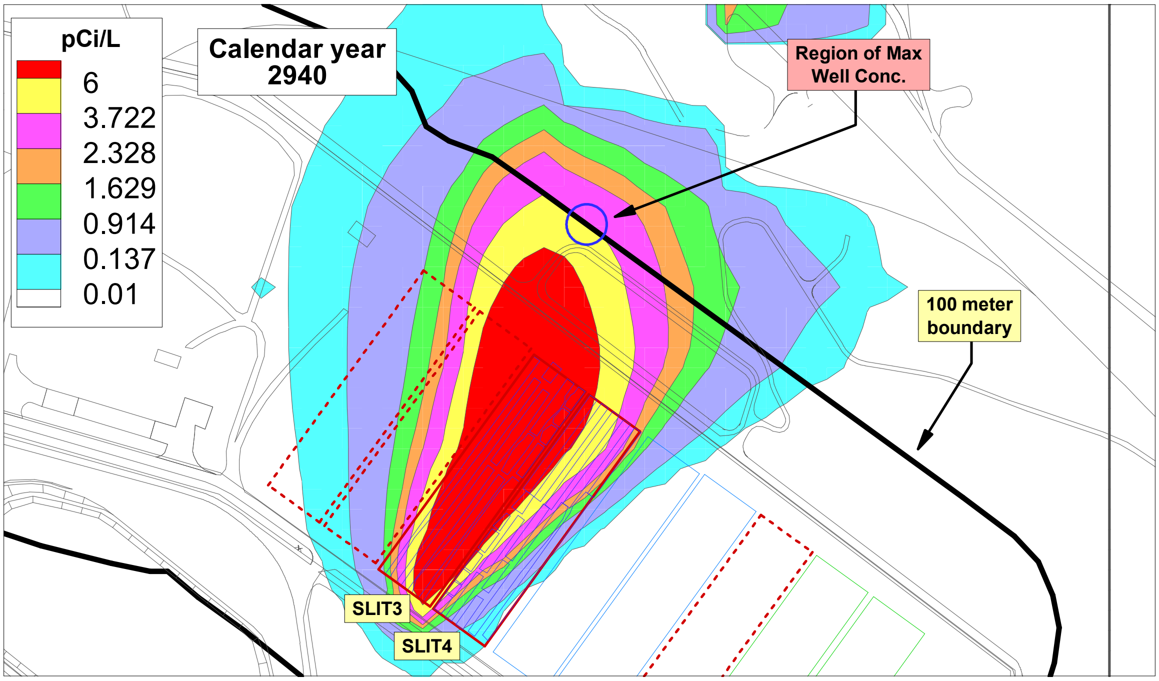

Figure 5-15 Concentration contours for Np-237 in the SLIT34 aquifer analysis for the intact case (without CDP) at the elevation where the maximum well concentration occurs for calendar year 2940.

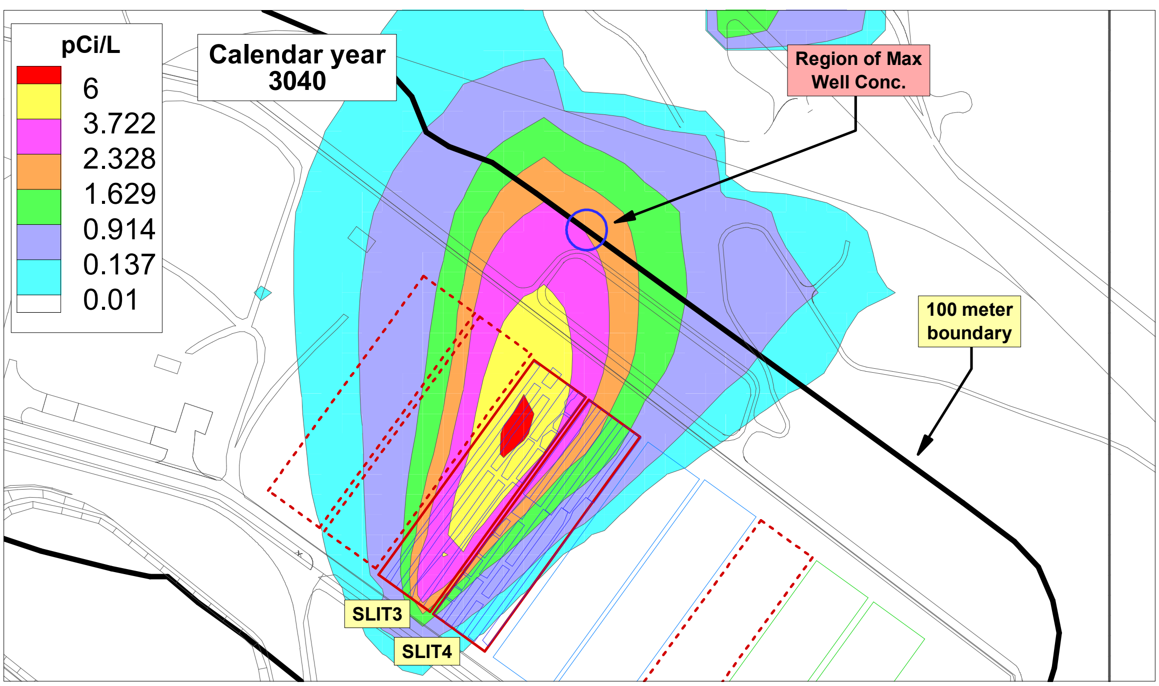

Figure 5-16 Concentration contours for Np-237 in the SLIT34 aquifer analysis for the intact case (without CDP) at the elevation where the maximum well concentration occurs for calendar year 3040.

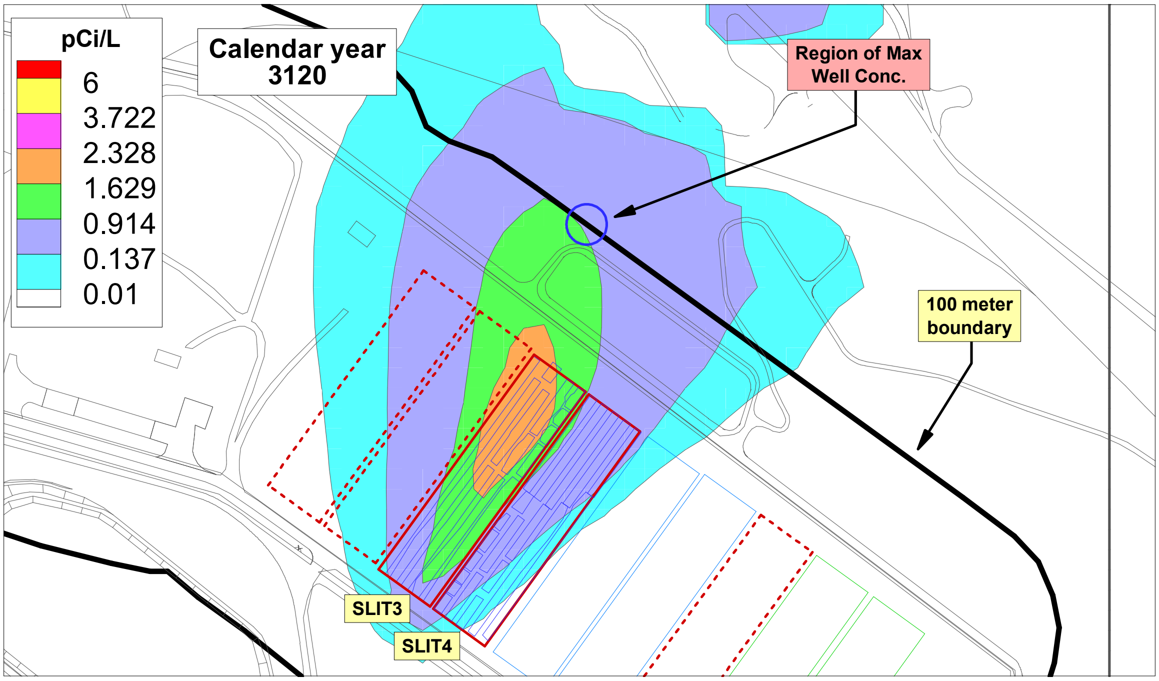

Figure 5-17 Concentration contours for Np-237 in the SLIT34 aquifer analysis for the intact case (without CDP) at the elevation where the maximum well concentration occurs for calendar year 3120.

To provide some insight into which trench segments may be contributing the most to the observed maximum well concentrations, 3D streamlines were employed to trace the path originating from various trench segments for year 2940 Case01_off (i.e., time near the peak year of 2944). Results from this effort are shown in Figure 5-18 where two of these streamlines are presented along with a concentration contour taken at a lower elevation than the previous figures (i.e., here a K-plane of 7, ~65-75 feet below the ground elevation). These results suggest that SLIT4-UnitB, SLIT4-UnitI, and SLIT4_South are contributing significantly to the total. However, to determine exactly which trench segments are the main contributors would require more analysis.

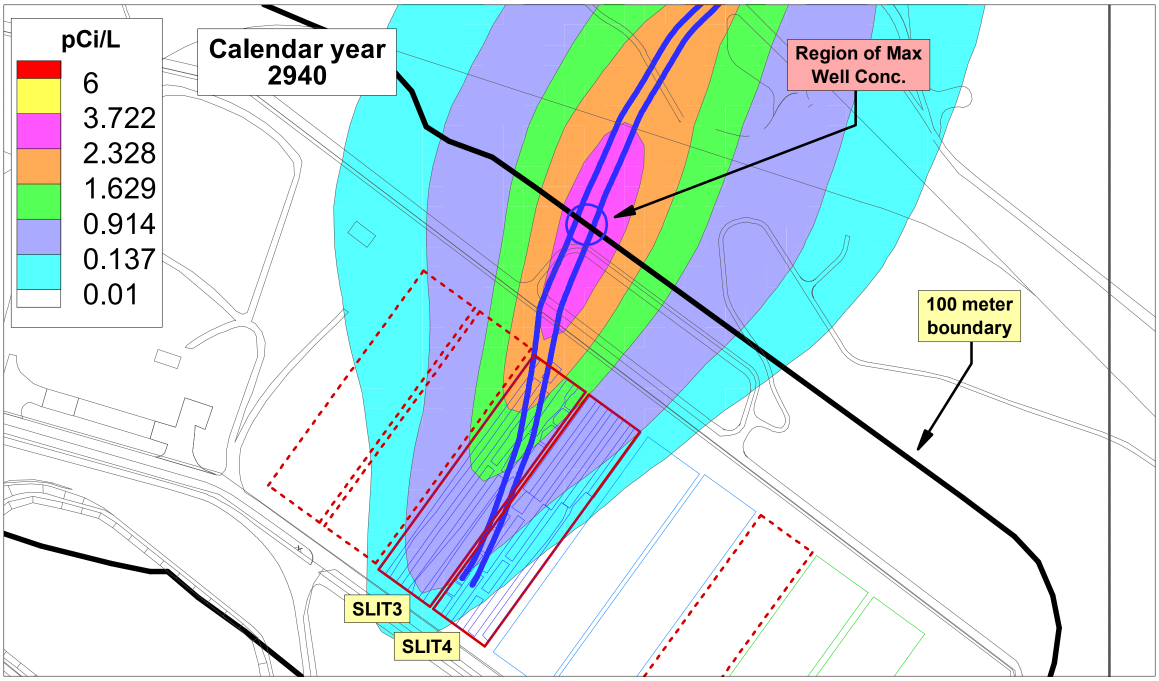

Figure 5-18 Concentration contours and 3D streamlines for Np-237 analysis for the intact case (without CDP) about 10 to 20 feet below the elevation where the maximum well concentration occurs for calendar year 2940.

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6.0 PERFORMANCE EVALUATION

6.1 Calculation Methodology

The pathways considered in this analysis with their respective allowable values (performance measures and objectives) are as follows:

Groundwater pathways

- Beta-Gamma with an allowable dose of 4 mrem/yr
- Gross Alpha with an allowable concentration of 15 pCi/L
- Radium (Ra-226 + Ra-228) with an allowable concentration of 5 pCi/L
- Uranium with an allowable concentration of 30 μg/L
- All-Pathways with an allowable dose of 25 mrem/yr

Non-groundwater pathways

- Inadvertent Intruder with an allowable dose of 100 mrem/yr
- Air with an allowable dose of 10 mrem/yr
- Radon with an allowable flux of 20 $pCi/m^2/s$

For the groundwater all-pathways calculations, the following exposure pathways were considered:

- Water Ingestion
- Vegetable Consumption
- Milk Consumption
- Meat Consumption

Surface water dose pathways from fish ingestion, shoreline exposure, swimming exposure, and boating exposure were not included in the groundwater all-pathways calculations. These parthways are not considered here because we are only looking at subsurface water (i.e., wells).

Because any case could occur, a composite "worst case" radionuclide concentration is used. Four cases were considered in the aquifer transport calculations:

1. All crushable waste packages without CDP present (Case01_off)
2. All crushable waste packages with CDP present (Case01_on)
3. A blended fraction of fluxes to the water table for crushable and non-crushable waste packages without CDP present (Case01n11_off)
4. A blended fraction of fluxes to the water table for crushable and non-crushable waste packages with CDP present (Case01n11_on)

To avoid processing doses for each pathway and each case to select the overall worst case, a simplified and conservative approach was adopted. At each time step, the greatest concentration for each radionuclide (the parent and all progeny in each chain) is selected from among all of the cases to produce a worst case concentration file. These concentrations are then used to calculate doses.

Final well concentrations at or beyond the 100-meter boundary are adjusted by dividing by plume interaction factors of 0.7 for the set of Slit Trenches 1, 2 and 5 (SLIT125) and 0.8 for the set of Slit Trenches 3 and 4 (SLIT34) (Jordan 2009) to account for contaminant source contributions from all disposal units (WITS Locations) that are external to the model. Maximum well concentrations for each set of Slit Trenches are adjusted by this plume interaction factor prior to the dose calculation step. The factor is applied while the "ideal" files are being created for each case of interest for each set of Slit Trenches according to the expression shown in Equation 6-1. The ideal files include concentrations for radionuclide chain members that were not explicitly modeled in PORFLOW. Such chain members are assumed to be in secular equilibrium with their precursors.

$$c^{ideal}_{max,ij}(t) = \left[\frac{c^{PORFLOW}_{max,ij}(t)}{\eta}\right] \qquad (6\text{-}1)$$

where:

$c^{ideal}_{max,ij}(t)$	-	Ideal file (plume interaction corrected) maximum concentration beyond the 100 m boundary at time t for the jth daughter of the ith parent.
$c^{PORFLOW}_{max,ij}(t)$	-	PORFLOW computed maximum concentration beyond the 100 m boundary at time t for the j^{th} daughter of the i^{th} parent.
t	-	Time in years.
η	-	Plume interaction factor

6.2 Waste Inventory

The list of parents with inventories in any of the five Slit Trenches is presented in Table 6-1, showing both the model names and WITS names. Final inventories by Slit Trench are provided in Appendix A.

6.3 Groundwater Pathways Results

Dose calculations were performed for the parent nuclides listed in Table 6-1 above. As described above, worst case "ideal" files were created based on "ideal" files generated from the four cases considered. The process to convert the abbreviated chain concentration history in the stat.out files generated by PORFLOW into full chain "ideal" files is performed by the FORTRAN code "**IdealFile_PlumeInteraction**". During this process the concentration values are adjusted by Eq. (6-1). The worst case "ideal files" are generated using the FORTRAN code "**PickWorstExistingIdeal**".

The worst case "ideal" files are used as input to the "**LimitsAndDoses**" FORTRAN code. The **LimitsAndDoses** code automates the overall process of computing inventory limits and doses and also provides a variety of information associated with the inventory limits and doses computed. The above process was further automated using an **AutoIt** (v3.3.4.0) script named "**MakeIdealLimits.au3**".

Table 6-1 List of parents with inventories in any of the five Slit Trenches 1–5.

Model Parent	WITS Parent	Model Parent	WITS Parent
Am-241	AM241	Np-237	NP237
Am-243	AM243	Pd-107	PD107
C-14	C14	Pu-238	PU238
C-14_NR.Pump	C14N	Pu-239	PU239
Cf-249	CF249	Pu-240	PU240
Cf-251	CF251	Pu-241	PU241
Cl-36	CL36	Pu-242	PU242
Cm-244	CM244	Pu-244	PU244
Cm-245	CM245	Ra-226	RA226
Cm-246	CM246	Se-79	SE79
Cm-247	CM247	Sn-126	SN126
Cm-248	CM248	Sr-90	SR90
H-3	H3	Sr-90_Mk50A	SR90R
H-3_Concrete	H3F	Tc-99	TC99
H-3_ETF.Carbon	H3C	Tc-99_Mk50A	TC99R
I-129	I129	Th-230	TH230
I-129_ETF.Carbon	I129C	Th-232	TH232
I-129_ETF.GT.73	I129I	U-233	U233
I-129_F.CG.8	I129G	U-234	U234
I-129_F.Dowex.21K	I129D	U-234_MGlass	U234G
I-129_F.Filtercake	I129J	U-235	U235
I-129_H.CG.8	I129H	U-235_MGlass	U235G
I-129_H.Filtercake	I129F	U-235_Paducah.Cask	U235P
I-129_Mk50A	I129R	U-236	U236
K-40	K40	U-236_MGlass	U236G
Mo-93	MO93	U-238	U238
Nb-94	NB94	U-238_MGlass	U238G
Ni-59	NI59	Zr-93	ZR93

6.3.1 Base Case Results

Results from the base case analysis which assumed no high-pH treatment, the existing 100 m boundary, and used 2008 PA DCF values are summarized in Tables 6-2 through 6-4. Table 6-2 shows the peak doses and concentrations for the five groundwater exposure pathways for the sets of Slit Trenches analyzed (ST125 and ST34) and approximate contributions from the individual Slit Trenches. The contributions from individual Slit Trenches are only approximate because the dose or concentration for the set of Slit Trenches is divided on the basis of the original parent inventories. That is, for each radionuclide *i* at each time step *t*, the dose for this radionuclide calculated for the set of Slit Trenches such as ST34 is split into a dose from Slit Trench 3 and Slit Trench 4 as shown in Equations 6-2a and 6-2b.

$$\boldsymbol{Dose}(\boldsymbol{i},\boldsymbol{t})_3 = \frac{\boldsymbol{Inventory}(\boldsymbol{i})_3}{\boldsymbol{Inventory}(\boldsymbol{i})_3 + \boldsymbol{Inventory}(\boldsymbol{i})_4}\boldsymbol{Dose}(\boldsymbol{i},\boldsymbol{t})_{34} \quad \text{(6-2a)}$$

$$\boldsymbol{Dose}(\boldsymbol{i},\boldsymbol{t})_4 = \frac{\boldsymbol{Inventory}(\boldsymbol{i})_4}{\boldsymbol{Inventory}(\boldsymbol{i})_3 + \boldsymbol{Inventory}(\boldsymbol{i})_4}\boldsymbol{Dose}(\boldsymbol{i},\boldsymbol{t})_{34} \quad \text{(6-2b)}$$

These calculations are only intended to give an estimate of the dose contribution from each individual Slit Trench because, in reality, the relative contributions will change over time in a complicated fashion depending on radionuclide transport from each individual Slit Trench and radionuclide decay. The only way to determine the actual contribution from each Slit Trench would be to run each Slit Trench individually through the analysis with appropriate plume interaction factors. Because plume interaction factors for individual Slit Trenches are not available, the method outlined above was used to provide an estimate of the relative impact of each Slit Trench.

Table 6-3 shows the maximum dose or concentration for each groundwater exposure pathway divided by the allowable to give a relative performance index. In all instances, the closest approach to an allowable value is reached for the groundwater all-pathways analysis. The radionuclide chains that contribute the most to the maximum groundwater all-pathways dose are Np-237 and U-235. For Slit Trenches 3 and 4, which had the highest groundwater all-pathways dose, the Np-237 chain accounted for 20.0 mrem/yr and the U-235 chain 2.9 mrem/yr of the total maximum dose of 23.0 mrem/yr.

Table 6-4 shows the years in which the maximum dose or concentration was reached. Note that the uranium and radium peaks are reached at the end of the analysis time and therefore have not reached maximum values. However, the relative performance indices for these two pathways are much less than the indices for the other three exposure pathways. Also note that when the peak doses from individual Slit Trenches occur at different times, summing the peak doses from individual trenches has no meaning.

Table 6-2 Peak doses and concentrations for groundwater exposure pathways.

	Gross Alpha (pCi/L)	Beta-Gamma (mrem/yr)	Radium (pCi/L)	Uranium (μg/L)	Groundwater All-pathways (mrem/yr)
Allowable	15 pCi/L	4 mrem/yr	5 pCi/L	30 μg/L	25 mrem/yr
ST1	1.45E-01	3.96E-01	1.24E-04	2.21E-10	8.41E-01
ST2	2.79E-01	1.82E-01	2.29E-04	3.94E-10	1.82E+00
ST5	7.03E-01	7.12E-02	1.16E-03	1.06E-09	4.16E+00
ST125	1.13E+00	6.49E-01	1.52E-03	1.68E-09	6.82E+00
ST3	2.21E+00	4.85E-01	2.14E-04	3.52E-09	1.24E+01
ST4	1.73E+00	6.54E-02	7.35E-04	2.55E-09	1.07E+01
ST34	3.95E+00	5.27E-01	9.49E-04	6.07E-09	2.30E+01

Table 6-3 Peak doses and concentrations for groundwater exposure pathways relative to allowables.

	Gross Alpha	Beta-Gamma	Radium	Uranium	Groundwater All-pathways
ST1	9.67E-03	9.90E-02	2.48E-05	7.37E-12	3.36E-02
ST2	1.86E-02	4.55E-02	4.58E-05	1.31E-11	7.28E-02
ST5	4.69E-02	1.78E-02	2.32E-04	3.53E-11	1.66E-01
ST125	7.53E-02	1.62E-01	3.04E-04	5.60E-11	2.73E-01
ST3	1.47E-01	1.21E-01	4.28E-05	1.17E-10	4.96E-01
ST4	1.15E-01	1.64E-02	1.47E-04	8.50E-11	4.28E-01
ST34	2.63E-01	1.32E-01	1.90E-04	2.02E-10	9.20E-01

Table 6-4 Years when peak doses and concentrations for groundwater exposure pathways are reached.

	Alpha	Beta-Gamma	Radium	Uranium	Groundwater All-pathways
ST1	2920.2	2014.1	3126.0	3126.0	2922.2
ST2	2924.2	2014.1	3126.0	3126.0	2930.2
ST5	2920.2	2014.1	3126.0	3126.0	2924.2
ST125	2920.2	2014.1	3126.0	3126.0	2926.2
ST3	2944.2	2946.2	3126.0	3126.0	2946.2
ST4	2948.2	2512.9	3126.0	3126.0	2954.2
ST34	2946.2	2542.9	3126.0	3126.0	2950.2

Doses, concentrations and allowable values from groundwater pathways for Slit Trenches 1, 2 and 5 and their sum are plotted in Figures 6-1 through 6-5 from the years 1995 to 3130. Doses, concentrations and allowable values from groundwater pathways for Slit Trenches 3 and 4 and their sum are plotted in Figures 6-6 through 6-10.

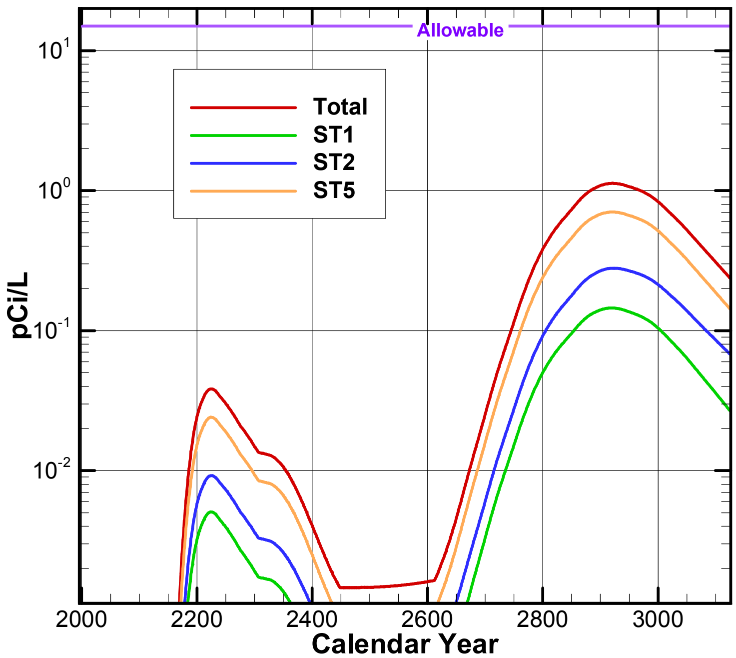

Figure 6-1 Gross alpha concentrations from Slit Trenches 1, 2 and 5.

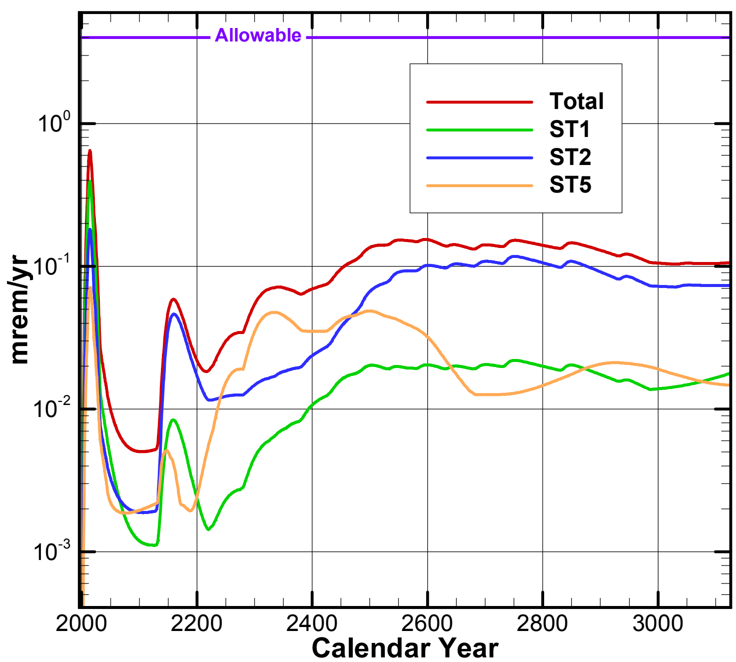

Figure 6-2 Beta-gamma doses from Slit Trenches 1, 2 and 5.

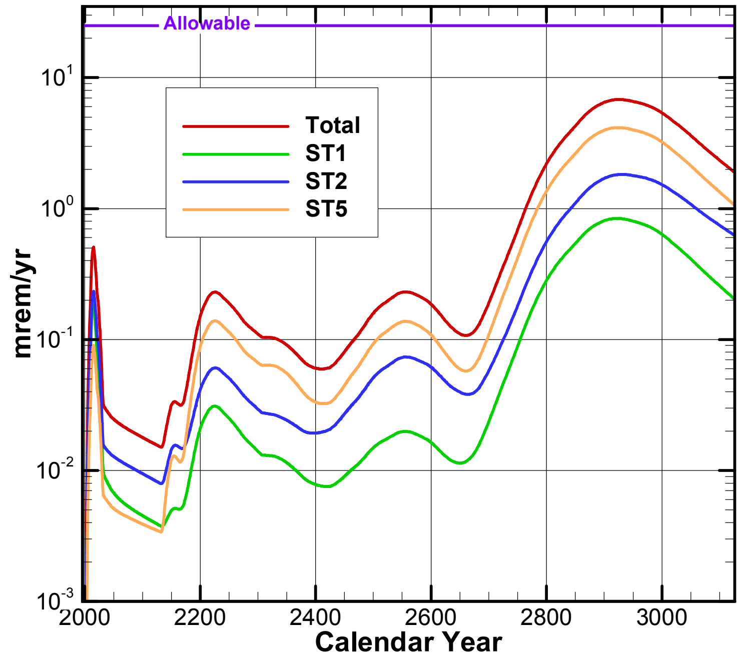

Figure 6-3 Groundwater all-pathways doses from Slit Trenches 1, 2 and 5.

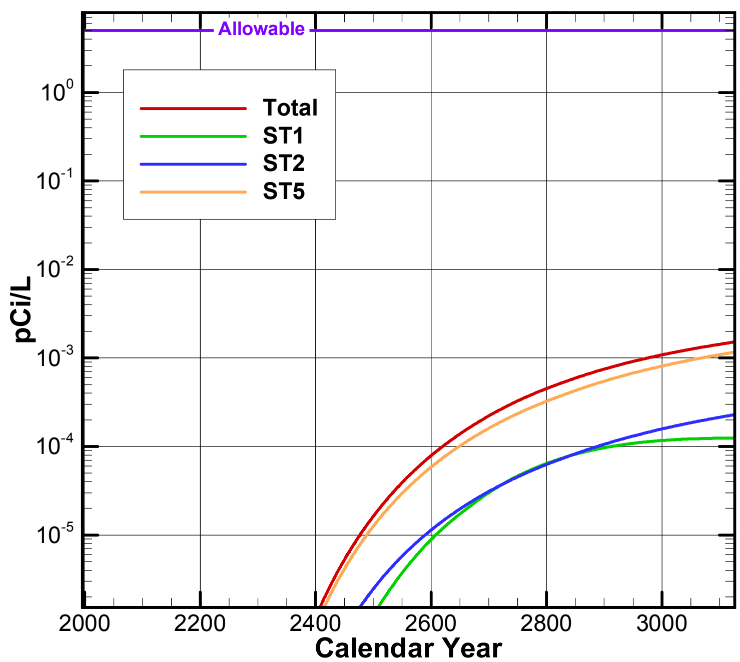

Figure 6-4 Radium concentrations from Slit Trenches 1, 2 and 5.

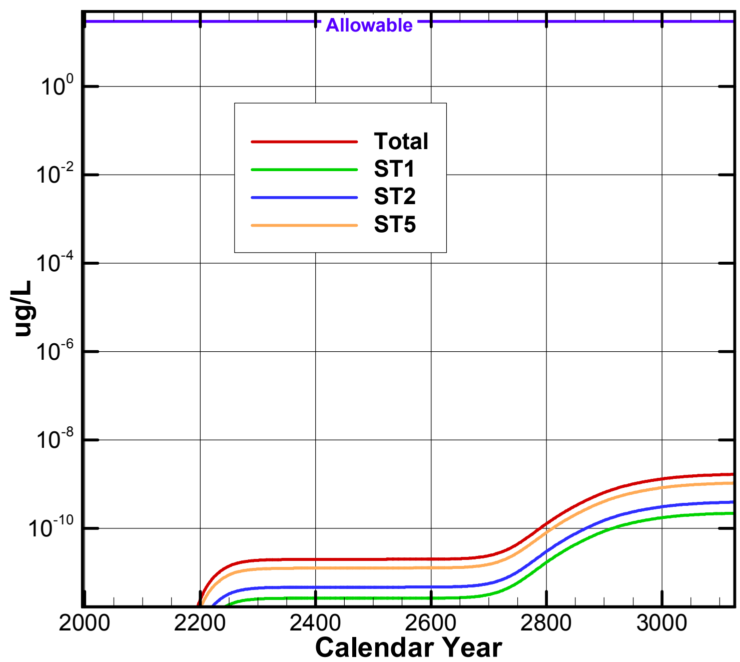

Figure 6-5 Uranium concentrations from Slit Trenches 1, 2 and 5.

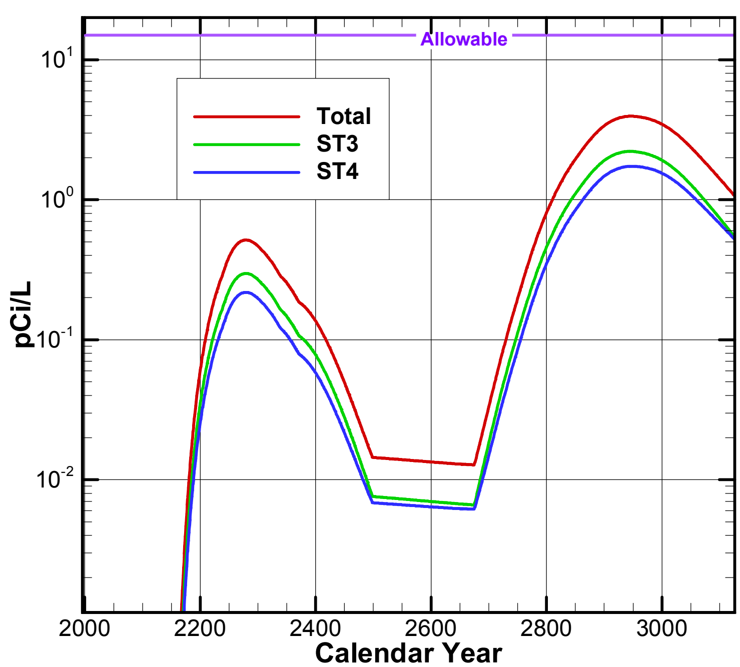

Figure 6-6 Gross alpha concentrations from Slit Trenches 3 and 4.

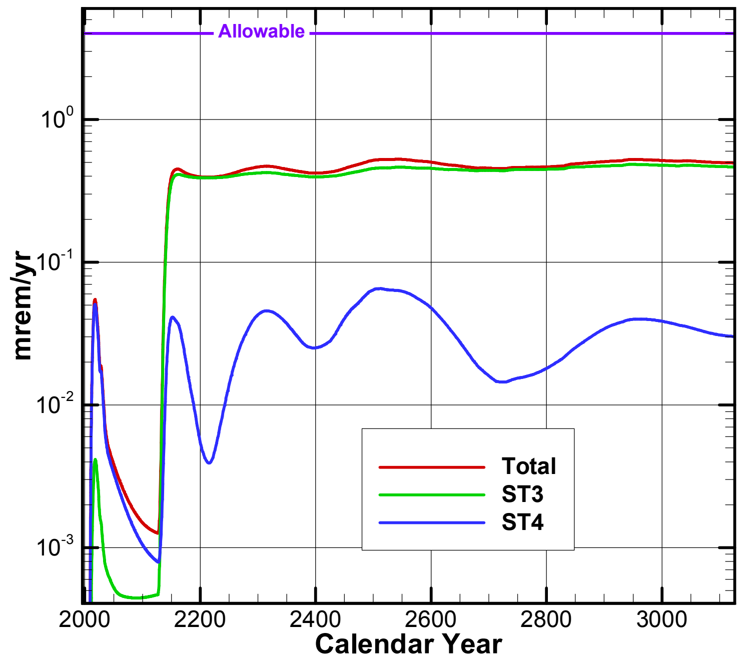

Figure 6-7 Beta-gamma doses from Slit Trenches 3 and 4.

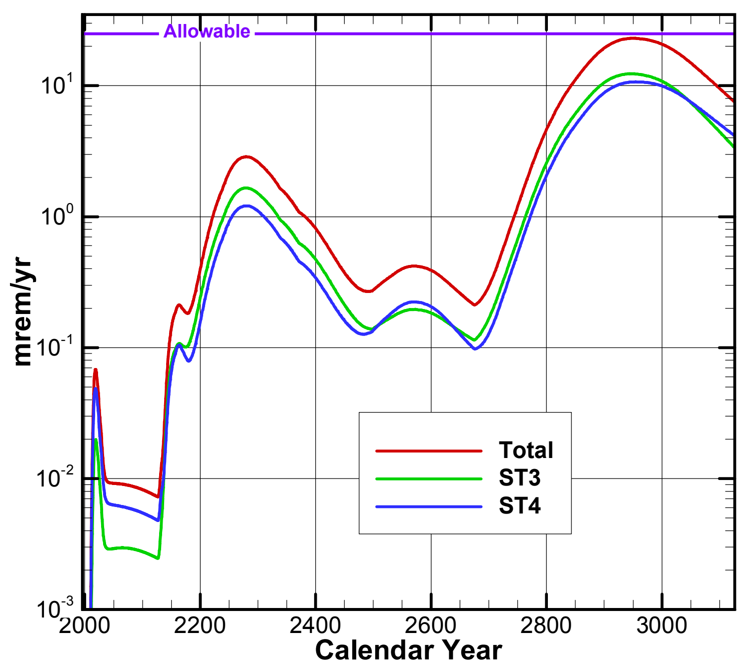

Figure 6-8 Groundwater all-pathways doses from Slit Trenches 3 and 4.

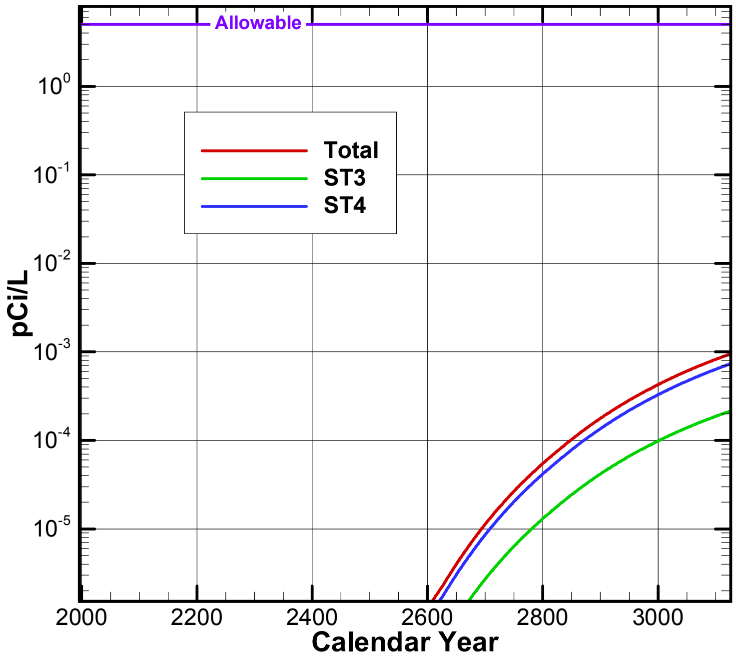

Figure 6-9 Radium concentrations from Slit Trenches 3 and 4.

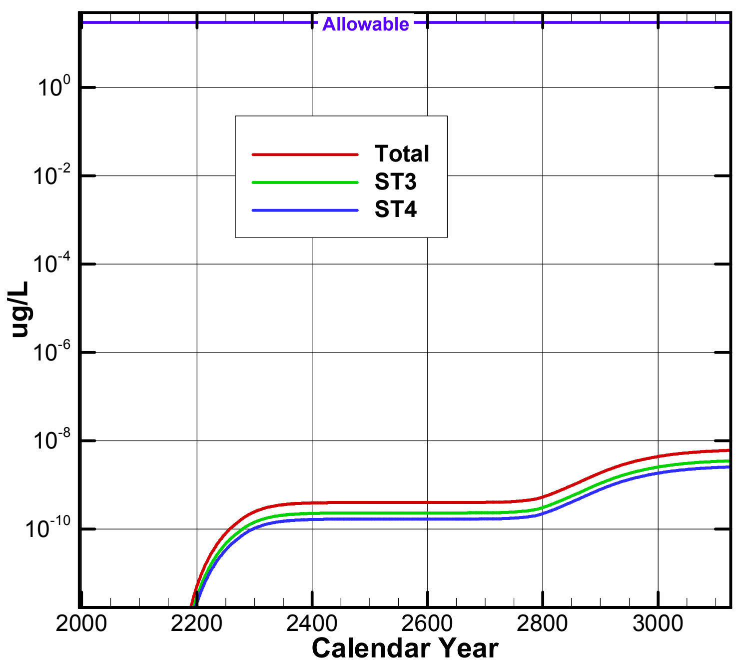

Figure 6-10 Uranium concentrations from Slit Trenches 3 and 4.

6.4 Non-Groundwater Pathway Results

To remain consistent with the 2008 PA and also the 2008 SA the following observations and assumptions are made for the non-groundwater pathways:

- The inadvertent intruder category starts after the placement of the final cap, thus an operational cap has no effect on this category.
- For the air and radon pathways the operational cap would serve to increase the travel distance from the waste to the surface, thus decreasing the flux and dose. This beneficial effect is ignored in this analysis and non-groundwater pathway limits are used without change.

Historically, the non-groundwater pathways have not had significant sum-of-fractions (SOF) contributions from waste packages such that the SOF for each of these pathways was significantly less than one. Therefore, having a SOF contribution of 10% or less for one of these pathways is judged to be not significant. SOF contributions for the non-groundwater pathways provided by SWM are listed in Table 6-5 (i.e., based on final inventories from WITS and the 2008 SA limit values). The largest value is 4.4% for the post-drilling scenario in Slit Trench 5. Therefore, the non-groundwater pathways are of low significance for Slit Trenches 1–5. A more complete listing of results from the non-groundwater pathways analyses is presented in Appendix E where the SOF contributions for individual parents are tabulated.

Table 6-5 Non-groundwater SOF contributions in Slit Trenches 1-5.

	Resident	Post-drilling	Air Pathway	Radon Pathway
Allowable	100 mrem/yr	100 mrem/yr	10 mrem/yr	20 pCi/m^2/s
ST1	1.29E-03	2.68E-03	9.11E-06	1.44E-07
ST2	1.34E-02	8.60E-03	2.64E-05	4.71E-09
ST3	2.40E-03	2.43E-02	2.77E-05	3.56E-09
ST4	2.49E-03	1.63E-02	2.79E-05	7.89E-09
ST5	7.21E-03	4.40E-02	1.19E-04	1.96E-08

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7.0 SENSITIVITIES

Sensitivities to three key parameters employed in the base case set of analyses are considered. They are as follows:

- Waste characterization accuracy of final inventories;
- Timing associated with placement of the operational cover; and
- Mechanical dispersion within the aquifer.

The results from these limited sensitivity analyses are presented below.

7.1 Inventory Variance

Historically, waste generators have revised waste characterizations which in turn affect the final inventories. If the final inventories vary by 5% or less, the performance measures and objectives will not be exceeded, because well concentrations and doses for these analyses are linear functions of the final inventory and the well concentrations and doses in this analysis are below the performance measures and objectives. The other two key parameters are considered in the following limited set of sensitivity analyses.

7.2 Operational Cover Timing

A key assumption in this analysis is that an operational cover will be placed over Slit Trenches 1-5 by 9/30/2011, which was explicitly modeled. In actual practice, operational covers will require months to construct and will be placed over the trenches at different times throughout the remainder of FY11 with the trenches all being covered by 9/30/2011. To assess the impact of cover timing, a single separate analysis was conducted assuming a cover time of 1/1/2011. Note that covering one month earlier (i.e., December of 2010) than the analysis cover time has an impact similar to the results provided below.

Cover timing will have little impact on the dose contribution from immobile radionuclides with long transport times. The dose contribution from mobile radionuclides with short half-lives (e.g. H-3) will be reduced if the covers are placed prior to 9/30/2011. However, for relatively mobile radionuclides with long half-lives such as I-129, earlier placement of an operational cap will lower the rate of transport up until the time when the interim cap is placed, which will lead to a higher peak concentration later. Additionally, because the overall doses are dominated by Np-237, examining its behavior is very informative.

The impact of operational cover timing was assessed by evaluating the peak flux to the water table from I-129 and Np-237 assuming capping times of 1/1/2011 and 9/30/2011 (i.e. a nine month difference). I-129 transport from Slit4-UnitB for Case01 with no CDP was used for this analysis with the results shown in Figure 7-1 below. The peak flux to the water table for I-129 increased by about 7% when an operational cover (cap) was placed over the Slit Trenches on 1/1/2011 instead of 9/30/2011.

Although limited in scope, this analysis indicates a relatively small impact to dose from operational cover placement between 1/1/2011 and 9/30/2011. Because the maximum relative performance index is about 0.92, applying a 7% increase to all nuclides would still produce a value (0.98) less than unity. The cover over SLIT5 was actually placed on 12/22/2010 which is ten days prior to the earliest cover time assumed for the sensitivity analysis. However, because the sensitivity analysis indicates that placing operational covers nine months earlier than assumed for the analysis base case will increase peak doses on the order of 7%, it is judged that this additional ten day interval will have the same impact on doses at the 100 m well. Also, as described in the next section, application of new DCFs would greatly decrease the final doses. I-129 results only apply to a small family of radionuclides, but the response of Np-237, which dominates the doses, would be most representative of the overall response to earlier operational cover placement.

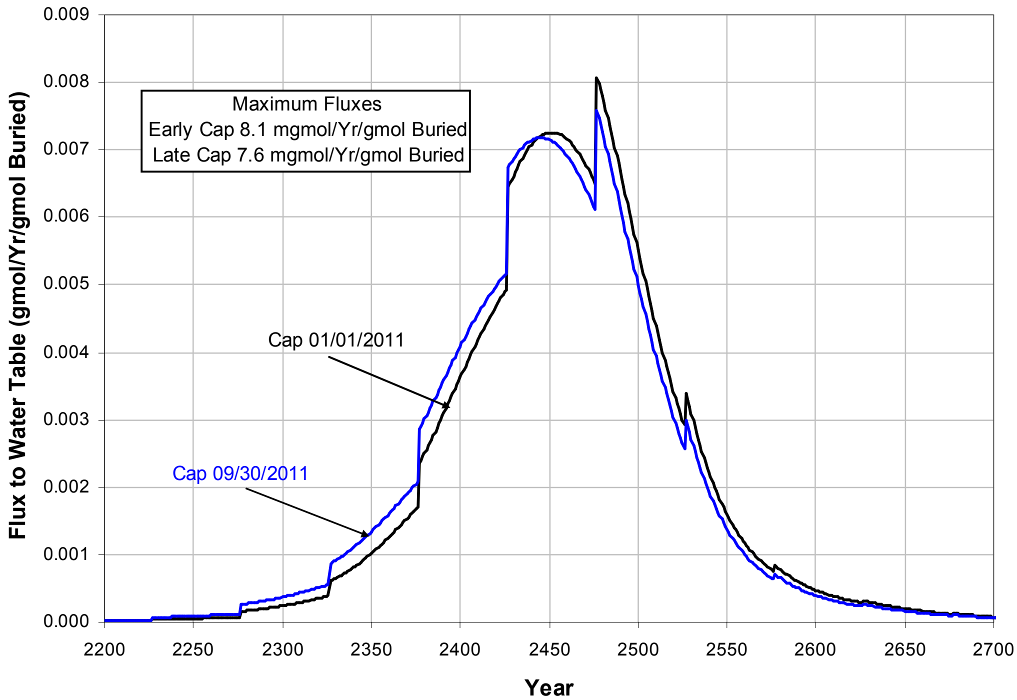

Figure 7-1 Impact on I-129 flux to the water table from SLIT4-UnitB with a nine month difference in operational cap placement.

Np-237 transport from Slit4-UnitB for Case01 without CDP was used for this analysis with the results shown in Figures 7-2 and 7-3 below. The peak flux to the water table for Np-237 decreased by about 0.02% (from 4.879E-3 to 4.878E-3 gmol/yr/gmol buried) when an operational cover (cap) was placed over the Slit Trenches on 1/1/2011 instead of 9/30/2011. Results for other inventory groups can respond differently depending on their operational cap timing, but it is likely that any differences in peak fluxes and concentrations will be less than one percent.

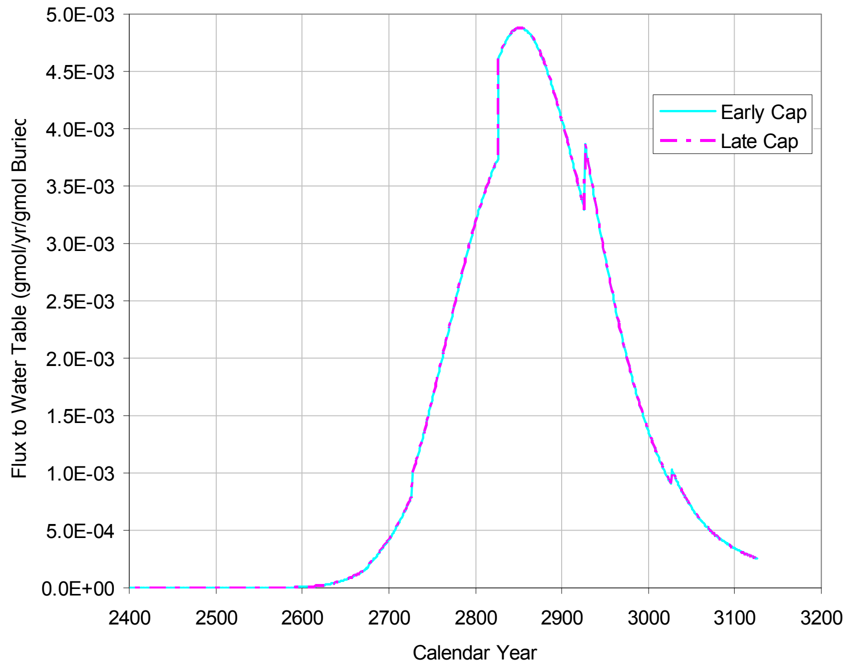

Figure 7-2 Impact on Np-237 flux to the water table from SLIT4-UnitB with a nine month difference in operational cap placement.

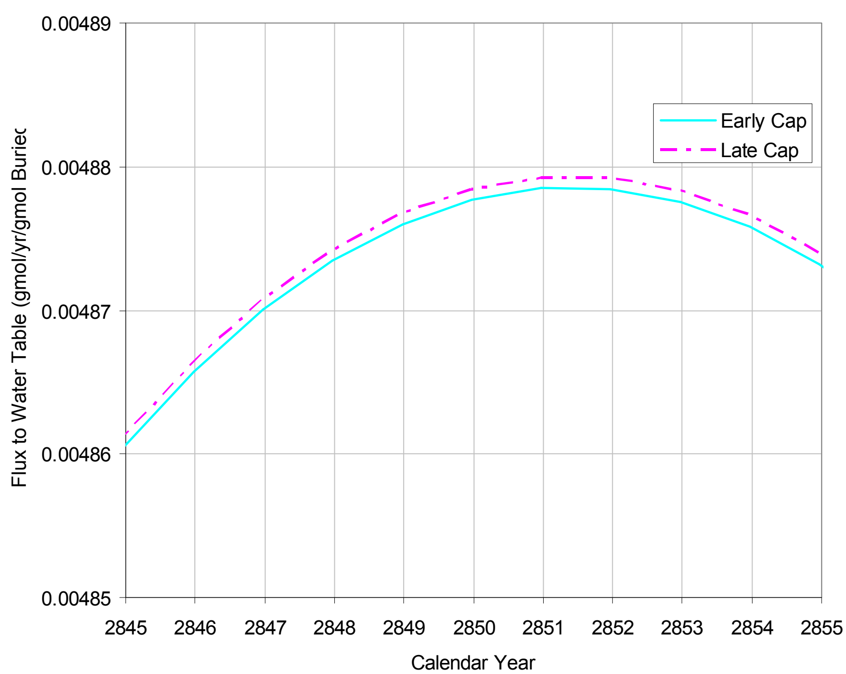

Figure 7-3 Impact near time of peak flux on Np-237 flux to the water table from SLIT4-UnitB with a nine month difference in operational cap placement

7.3 Mechanical Dispersion

The base case has mechanical dispersion activated which is an attempt to model the dispersive aspects within the aquifer. To assess the impact of mechanical dispersion on the maximum well concentrations an additional sensitivity case was considered. The Np-237 analysis for ST34 was chosen for this sensitivity case because it dominates the All-Pathways and Beta-Gamma dose results. The mechanical dispersion was turned off and the aquifer model was rerun with all other parameters left at their base case values.

A comparison of the Np-237 maximum well concentrations for the intact case (i.e., Case01_off) is provided in Figure 7-4 with and without mechanical dispersion. The intact case yields the highest peak well concentration. As Figure 7-4 highlights, the peak value increases by a factor of ~1.66 (6.19/3.73).

This ~1.66 increase would increase the peak dose for the all-pathways to ~38 mrem/yr (see Table 1-1). While that value would exceed the allowable of 25 mrem/yr, the true amount of dispersion that should be introduced is unknown. Solving the governing equations introduces numerical dispersion but that may be less that the true amount of dispersion, in which case some mechanical dispersion should be introduced, so the complete removal of mechanical dispersion likely is pessimistic. Regardless, if the new DCFs are incorporated (as discussed in Chapter 8) they would more than compensate for introducing all the mechanical dispersion that was included in this analysis.

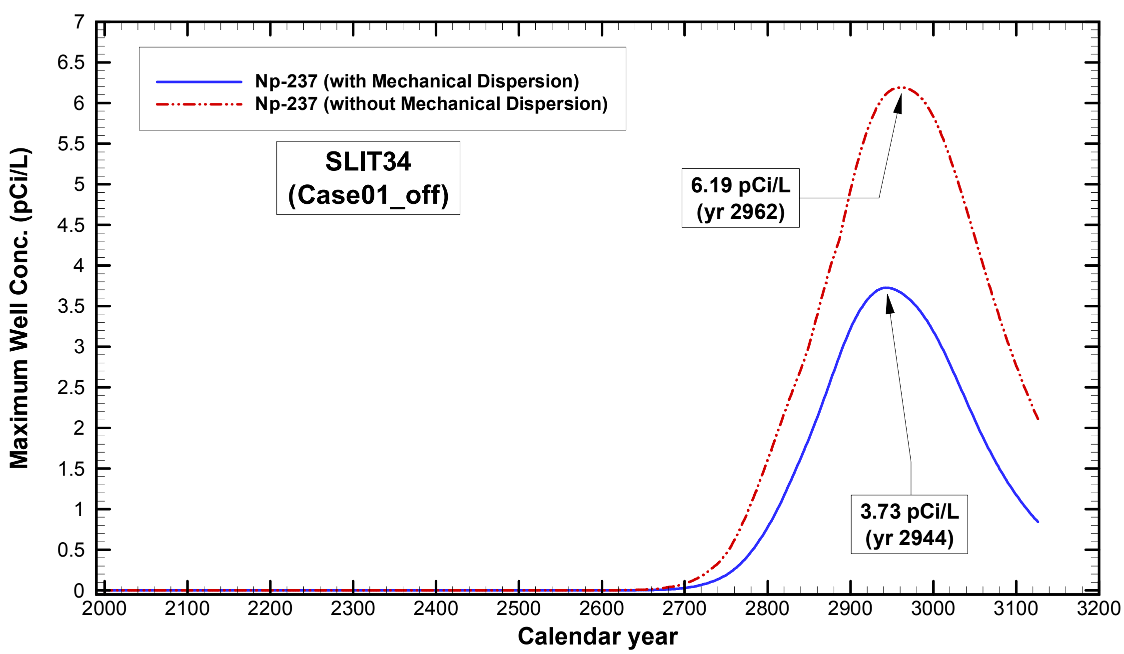

Figure 7-4 Impact of mechanical dispersion on Np-237 maximum well concentrations for ST34.

8.0 OPTIONS

As can been seen in Table 6-2 of Chapter 6 the peak dose for SLIT34 was computed to be 23.0 mrem/yr for the All-Pathways dose (and 6.82 mrem/yr for SLIT125). The maximum allowable value is 25 mrem/yr. This peak dose corresponds to the base case and a select number of sensitivities about this Base case were considered as discussed in Chapter 7. Given the small margin of 2.0 mrem/yr in the peak-to-allowable dose observed, other potential options were considered to address this margin.

As stated in Chapter 7 sensitivity associated with the following three key parameters were considered:

- Waste characterization accuracy of provided final inventories where a 5% variance was assumed. Here a net 5% impact results on computed doses due to the linearity of system of equations describing the transport processes.
- The timing associated with placement of the operational covers where early placement of 1/1/2010 was assumed. Here an ~9-month earlier placement of the operational covers results in an ~7% increase in dose for mobiles and an <1% increase in dose for intermediate-to-immobile radionuclides. Because the dominant radionuclide is the intermediate mobile Np-237 the overall impact to dose is <1% (i.e., in Chapter 7 the Np-237 impact is shown to be a very slight improvement in performance).
- The mechanical dispersion within the aquifer was set to zero leaving only the impact resulting from numerical dispersion. Here an increase in well concentrations of ~1.66 results where an ~1.66 increase in doses would be observed. The actual degree of mechanical dispersion is believed to be greater than the numerical value alone thus reducing this 1.66 factor.

To demonstrate adequate margin to accommodate the uncertainties associated with modeling parameters, such as those listed above, the base case was reanalyzed using more up to date DCFs. In this analysis the base case methodology employed the DCFs used in the prior 2008 PA and 2008 SA. The more recent DCFs available have values that range between factors of ~0.1 to ~10.0 of the older set of DCFs. For the dominant dose contributor (i.e., Np-237) its new DCF value is ~9% of its older value (i.e., new value of 1.1×10^{-7} Sv/Bq versus the old value of 1.20×10^{-6} Sv/Bq). Thus, a significant reduction in the computed All-Pathways peak dose is observed when the newer DCFs are employed. This option alone reduces the peak dose from the 23.0 mrem/yr value to 2.68 mrem/yr (i.e., an 88% reduction) for the groundwater All-Pathways route of exposure. Using the newer DCFs switches the result closest to its allowable to the peak concentration of 3.95 pCi/L corresponding to the groundwater Alpha pathway.

Thus, the use of the newer DCFs provides sufficient margin from the 25 mrem/yr allowance to accommodate the above mentioned sensitivities and other uncertainties not explicitly addressed in Chapter 7. For example, a composite adjustment factor can be computed for the above sensitivities where each factor is assumed to be a bias factor (i.e., no statistical combination is assumed):

- 1.05 (accounts for 5% variance in inventories)
- 1.01 (accounts for operational cover timing; based on the dominant species Np-237)
- 1.66 (accounts for numerical versus mechanical dispersion)

- 1.76 = 1.05*1.01*1.66 (composite factor)

The adjusted peak dose value for the groundwater All-Pathways now becomes:

- 2.68 mrem/yr (new Base case peak value)
- 4.72 = 2.68*1.76 mrem/yr (new Base case adjusted to accommodate sensitivities).

There is no impact of the newer DCFs on the groundwater Alpha pathway and its adjusted peak concentration value now becomes:

- 3.95 pCi/L (new Base case peak value)
- 6.95 = 3.95*1.76 pci/L (new Base case adjusted to accommodate sensitivities).

Thus, the unadjusted overall peak dose of 23.0 mrem/yr (based on groundwater All-Pathways when using the old DCFs) is replaced by the overall peak concentration of 3.95 pCi/L (based on groundwater Alpha pathway using the new DCFs) and 6.95 pCi/L when sensitivity bias is also included.

During the initial phases of this study it was assumed that the 2008 PA dose pathway methodology would be adhered to. The 2008 PA dose pathway methodology employs the FGR-11 DCFs and the availability of the newer ICRP-72 DCFs was not considered as an option. As such, the original 2.0 mrem/yr margin was considered to be inadequate to accommodate the sensitivities mentioned (and other uncertainties associated with this type of analysis). Therefore, options to mitigate the peak dose were considered. The following three operational options were investigated to determine their effectiveness in reducing peak doses and providing additional margin:

- A high-pH treatment injection system was employed at selected sets of trench segments to specifically reduce the migration of Np-237 (i.e., to take advantage of the increased retardation at higher pH levels). Two specific options were considered where the injection systems effectiveness was assumed to be either 60% or 90%. Here this proposed option resulted in an ~43% and ~61% reduction in peak dose for the 60% and 90% effectiveness systems, respectively. Note that the presence of high-pH adversely affects some radionuclides such as Tc-99 and I-129 but were shown to have negligible impact on the overall peak dose.
- The E-Area aerial footprint was increased to include a prior proposed 100-Acre extension. The new 100-meter performance boundary resulting from the 100-Acre extension results in a 160-to-220-meter extension from the existing center set of slit trenches (i.e., the 100 meters becomes 260-to-320 meters travel distance from the center slit trenches to the performance boundary). Here this proposed option resulted in an ~39% reduction in peak dose. The reduction is lower than originally anticipated due to the increased groundwater speeds experienced as the seepage faces are being approached. This analysis indicates that disposal units in the proposed extension areas will have less inventory capacity than anticipated due to the increased aquifer flow rates.

The following section provides a more detailed discussion comparing the results of these three options to the Base case analysis. The three options are then discussed in more detail in the last three sections. The results from using the newer DCFs produce peak doses with sufficient margin to negate the need to require the actual use of either of the last two operational options.

8.1 Dose Comparisons

For comparison purposes the base case is the set of analyses using:

- the 2008 PA DCFs (i.e., from FGR-11);
- the 100-meter boundary set by the original E-Area footprint; and
- Low pH K_d values only (i.e., no pH treatment systems employed).

Doses for both SLIT125 and SLIT34 were estimated for each groundwater pathway for the base case as well as for the various options considered. As mentioned above the following options were individually considered to reduce the computed peak dose (i.e., the peak dose in each case was obtained for the All-Pathways exposure in SLIT34 where Np-237 was the dominant contributor):

- Case 1 – using the newer DCFs (i.e., from ICRP-72);
- Case 2 – using a 100-meter boundary based on the proposed E-Area extension;
- Case 3 – using a high-pH injection system with a 60% effectiveness factor; and
- Case 4 – using a high-pH injection system with a 90% effectiveness factor.

The estimated doses and concentrations are provided in Tables 8-1 and 8-2 for SLIT125 and SLIT34, respectively. As Tables 8-1 and 8-2 indicate, the most significant doses or concentrations (i.e., the calculated value that consumes most of its allowable value) occur in SLIT34 under the groundwater Alpha and All-Pathways categories for each option considered (i.e., the highlighted regions in Table 8-2). Upon investigation we find that the dominant contributor to this peak dose is Np-237 for each option considered, as well.

Table 8-1 Comparison of groundwater doses in Slit Trenches 1, 2, and 5 based on various options.

ST125	DCF Source	100-meter Boundary	pH Treat	Alpha (pCi/L)	Beta-Gamma (mrem/yr)	Radium (pCi/L)	Uranium (μg/L)	Groundwater All-pathways (mrem/yr)
Allowable				15	4	5	30	25
Base case	FGR-11	original	0%	1.13	0.65	1.52E-03	1.68E-09	6.8
Case 1	ICRP-72	original	0%	1.13	0.65	1.52E-03	1.68E-09	0.9
Case 2	FGR-11	extension	0%	1.13	0.65	1.52E-03	1.68E-09	6.8
Case 3	FGR-11	original	60%	1.13	0.65	1.52E-03	1.68E-09	6.8
Case 4	FGR-11	original	90%	1.13	0.65	1.52E-03	1.68E-09	6.8

Table 8-2 Comparison of groundwater doses in Slit Trenches 3 and 4 based on various options.

ST34	DCF Source	100-meter Boundary	pH Treat	Alpha (pCi/L)	Beta-Gamma (mrem/yr)	Radium (pCi/L)	Uranium (μg/L)	Groundwater All-pathways (mrem/yr)
Allowable				15	4	5	30	25
Base case	FGR-11	original	0%	3.95	0.53	9.49E-04	6.07E-09	23.0
Case 1	ICRP-72	original	0%	3.95	0.53	9.49E-04	6.07E-09	2.68
Case 2	FGR-11	extension	0%	2.20	0.53	9.49E-04	3.09E-09	14.0
Case 3	FGR-11	original	60%	2.23	0.53	9.49E-04	3.84E-09	13.2
Case 4	FGR-11	original	90%	1.45	0.51	9.49E-04	2.72E-09	8.9

For the groundwater All-Pathways category the peak dose versus time for each option considered is shown in Figure 8-1. For each option the worst case was determined by processing and combining the four possible scenarios (i.e., intact versus subsided [Case01 and Case01n11] and CDP on or off).

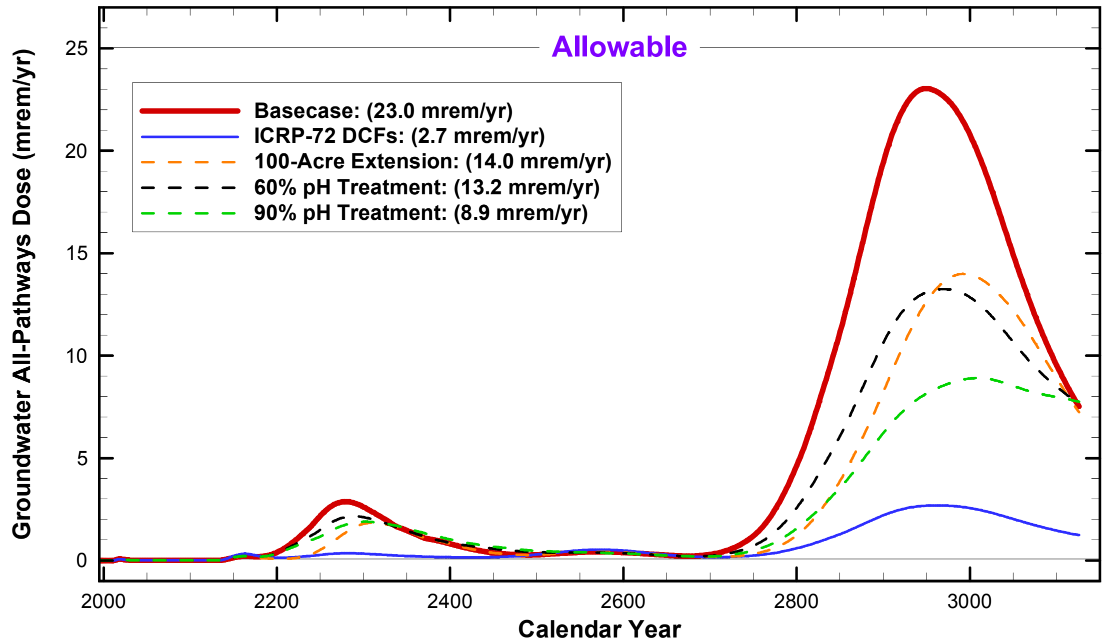

Figure 8-1 Slit Trench units 3 and 4 (SLIT34) maximum dose for various options compared to the Base case dose.

The thick red curve presents the worst case dose versus time for the base case with a peak dose of 23.0 mrem/yr. The solid blue curve presents Case 1 where the new DCFs were employed. Here a significant reduction in the peak dose is observed because the DCF for Np-237 was reduced by a 0.09 factor. The other options considered (i.e., movement of the 100-meter boundary and two pH treatment systems) are shown as dashed curves in Figure 8-1. The movement of the 100-meter performance boundary and the use of 60% effective high-pH injection systems have similar impacts on peak dose reduction. The use of 90% effective high-pH injection systems gains some additional reduction as seen in Figure 8-1.

Table 8-3 lists the estimated doses per pathway for SLIT125 and SLIT34 where the base case using the newer DCFs (i.e., Case 1 above) was assumed and where the composite sensitivity factor of 1.76 was applied. The most important adjusted peak dose or concentration is 6.95 pci/L based on the groundwater Alpha pathway.

Table 8-3 Groundwater doses in SLIT125 and SLIT34 based on the new DCFs with a composite sensitivity factor of 1.76 applied.

Case 1	DCF Source	100-meter Boundary	pH Treat	Alpha (pCi/L)	Beta-Gamma (mrem/yr)	Radium (pCi/L)	Uranium (μg/L)	Groundwater All-pathways (mrem/yr)
Allowable				**15 pCi/L**	**4 mrem/yr**	**5 pCi/L**	**30 μg/L**	**25 mrem/yr**
SLIT125	ICRP-72	original	0%	1.99	1.14	2.68E-03	2.96E-09	1.55
SLIT34	ICRP-72	original	0%	6.95	0.93	1.67E-03	1.07E-08	4.72

As the comparisons made above indicate, use of the newer DCFs (i.e., from ICRP-72) significantly reduce the peak doses and concentrations and provides sufficient margin (i.e., ~8.05 pCi/L = 15 – 6.95 pCi/L) to accommodate those sensitivity variables considered within Chapter 7. Given the size of the available remaining margin, uncertainties associated with other modeling parameters not explicitly addressed in this analysis should be covered. Examples of other uncertainties are the infiltration rates employed where (1) 14 ft versus 10 ft gaps are present between some disposal units and (2) the hydraulic performance of the covers during replacement periods.

Thus, the use of the newer DCFs alone provides insurance that the peak doses from Slit Trenches 1 through 5 will not exceed the 25 mrem/yr allowance throughout the 1000 year performance period. The next section discusses this option in more detail. Based on these results no other option is being recommended for application to Slit Trenches 1 through 5.

However, the other two options were analyzed during the course of this work (i.e., 100-Acre extension and high-pH treatment system) and the results from their analyses are provided in the last two sections of this chapter. These results are provided for information purposes only at this time and provide useful insight into their impacts on slit trench performance.

8.2 Application of ICRP 72 Dose Conversion Factors

Dose Conversion Factors (DCFs) utilized in this report are the same as those used in the E-Area PA which are from FGR 11. Newer DCFs were published by the ICRP (ICRP 1995), but were not approved for use by DOE when this analysis started. As an option, the newer DCFs were combined with the Base case well concentrations.

DCFs utilized in this report for the Base case are those from FGR 11, because DOE G 435.1-1 (DOE, 1999 on page IV-189) states

"(d) Performance assessments shall use DOE-approved dose coefficients (dose conversion factors) for internal and external exposure of reference adults."

However, FGR 11 is based on two ICRP reports (that have been superseded), namely:

- ICRP 26 (ICRP 1971) that provided guidance for assessing dose to workers; and
- ICRP 30 (ICRP 1978) that recommended biokinetic and dosimetric models.

ICRP 30 was superseded by ICRP 68 (ICRP 1994) that substantially changed biokinetic modes and gastrointestinal absorption fractions. ICRP 60 (ICRP 1991) changed the weighting factors for doses to various body organs. ICRP 72 (ICRP 1995) revised the DCFs.

A comparison of the old and new DCFs is provided in Table 8-4. Note that for the greatest contributor to dose, Np-237, its new DCF is 9.17E-02 of the old value. The only scenario affected by changes in the DCFs is the all-pathways (the water ingestion pathway utilizes MCLs from EPA). A comparison of the doses produced by applying the two sets of DCFs is provided in Table 8-5. Note that DOE Order 435.1 is currently being revised, so other requirements may change.

Table 8-4 Comparison of old and new DCFs

Nuclide	FGR 11 (Sv/Bq)	ICRP 72 (Sv/Bq)	ICRP 72 / FGR 11 (-)
Ac-225	3.00E-08	2.40E-08	8.00E-01
Ac-227	3.80E-06	1.10E-06	2.89E-01
Ac-228	5.85E-10	4.30E-10	7.35E-01
Ag-108	0.00E+00	0.00E+00	NA
Ag-108m	2.06E-09	2.30E-09	1.12E+00
Al-26	3.94E-09	3.50E-09	8.88E-01
Am-237	1.78E-11	1.80E-11	1.01E+00
Am-241	9.84E-07	2.00E-07	2.03E-01
Am-243	9.79E-07	2.00E-07	2.04E-01
Am-245	4.88E-11	6.20E-11	1.27E+00
Am-246m	2.54E-11	3.40E-11	1.34E+00
At-217	0.00E+00	0.00E+00	NA
At-218	0.00E+00	0.00E+00	NA
Au-194	5.08E-10	4.20E-10	8.27E-01
Be-10	1.26E-09	1.10E-09	8.73E-01
Bi-210	1.73E-09	1.30E-09	7.51E-01
Bi-210m	2.59E-08	1.50E-08	5.79E-01
Bi-211	0.00E+00	0.00E+00	NA
Bi-212	2.87E-10	2.60E-10	9.06E-01
Bi-213	1.95E-10	2.00E-10	1.03E+00
Bi-214	7.64E-11	1.10E-10	1.44E+00
Bk-247	1.27E-06	3.50E-07	2.76E-01
Bk-249	3.24E-09	9.70E-10	2.99E-01
Bk-250	1.57E-10	1.40E-10	8.92E-01
C-14	5.64E-10	5.80E-10	1.03E+00
Ca-41	3.44E-10	1.90E-10	5.52E-01
Cd-113	4.70E-08	2.50E-08	5.32E-01
Cf-249	1.28E-06	3.50E-07	2.73E-01
Cf-250	5.76E-07	1.60E-07	2.78E-01
Cf-251	1.31E-06	3.60E-07	2.75E-01
Cf-252	2.93E-07	9.00E-08	3.07E-01
Cl-36	8.18E-10	9.30E-10	1.14E+00
Cm-241	1.21E-09	9.10E-10	7.52E-01
Cm-242	3.10E-08	1.20E-08	3.87E-01
Cm-244	5.45E-07	1.20E-07	2.20E-01
Cm-245	1.01E-06	2.10E-07	2.08E-01
Cm-246	1.00E-06	2.10E-07	2.10E-01
Cm-247	9.24E-07	1.90E-07	2.06E-01
Cm-248	3.68E-06	7.70E-07	2.09E-01
Cm-250	2.10E-05	4.40E-06	2.10E-01
Co-60	2.77E-09	3.40E-09	1.23E+00
Co-60m	9.70E-13	1.70E-12	1.75E+00
Cs-135	1.91E-09	2.00E-09	1.05E+00
Es-253	9.10E-09	6.10E-09	6.70E-01
Fe-60	4.12E-08	1.10E-07	2.67E+00
Fr-221	0.00E+00	0.00E+00	NA

Nuclide	FGR 11 (Sv/Bq)	ICRP 72 (Sv/Bq)	ICRP 72 / FGR 11 (-)
Fr-223	2.33E-09	2.40E-09	1.03E+00
Ga-68	9.24E-11	1.00E-10	1.08E+00
Gd-152	4.34E-08	4.10E-08	9.45E-01
Ge-68	2.89E-10	1.30E-09	4.50E+00
H-3	1.73E-11	1.80E-11	1.04E+00
Hf-182	4.29E-09	3.00E-09	6.99E-01
Hg-194	1.66E-09	5.10E-08	3.07E+01
Ho-166m	2.18E-09	2.00E-09	9.17E-01
I-129	7.46E-08	1.10E-07	1.47E+00
In-115	4.26E-08	3.20E-08	7.51E-01
Ir-192	1.55E-09	3.10E-10	2.00E-01
Ir-192m	4.23E-10	2.70E-10	6.38E-01
K-40	5.02E-09	6.20E-09	1.24E+00
La-137	1.23E-10	8.10E-11	6.59E-01
La-138	1.59E-09	1.10E-09	6.92E-01
Lu-176	1.98E-09	1.80E-09	9.09E-01
Mn-53	2.92E-11	3.00E-11	1.03E+00
Mo-93	3.64E-10	3.10E-09	8.52E+00
Nb-93m	1.41E-10	1.20E-10	8.51E-01
Nb-94	1.93E-09	1.70E-09	8.81E-01
Ni-59	5.67E-11	6.30E-11	1.11E+00
Np-233	1.99E-12	2.20E-12	1.11E+00
Np-236a	2.34E-07	1.70E-08	7.26E-02
Np-237	1.20E-06	1.10E-07	9.17E-02
Np-239	8.82E-10	8.00E-10	9.07E-01
Np-240m	0.00E+00	0.00E+00	NA
P-32	2.37E-09	2.40E-09	1.01E+00
Pa-230	1.68E-09	9.20E-10	5.48E-01
Pa-231	2.86E-06	7.10E-07	2.48E-01
Pa-233	9.81E-10	8.70E-10	8.87E-01
Pa-234	5.84E-10	5.10E-10	8.73E-01
Pa-234m	0.00E+00	0.00E+00	NA
Pb-202	1.05E-08	8.80E-09	8.38E-01
Pb-205	4.41E-10	2.80E-10	6.35E-01
Pb-209	5.75E-11	5.70E-11	9.91E-01
Pb-210	1.45E-06	6.90E-07	4.76E-01
Pb-211	1.42E-10	1.80E-10	1.27E+00
Pb-212	1.23E-08	6.00E-09	4.88E-01
Pb-214	1.69E-10	1.40E-10	8.28E-01
Pd-107	4.04E-11	3.70E-11	9.16E-01
Po-210	5.14E-07	1.20E-06	2.33E+00
Po-211	0.00E+00	0.00E+00	NA
Po-212	0.00E+00	0.00E+00	NA
Po-213	0.00E+00	0.00E+00	NA
Po-214	0.00E+00	0.00E+00	NA
Po-215	0.00E+00	0.00E+00	NA
Po-216	0.00E+00	0.00E+00	NA
Po-218	0.00E+00	0.00E+00	NA
Pt-193	3.21E-11	3.10E-11	9.66E-01
Pu-236	3.15E-07	8.70E-08	2.76E-01

Nuclide	FGR 11 (Sv/Bq)	ICRP 72 (Sv/Bq)	ICRP 72 / FGR 11 (-)
Pu-237	1.20E-10	1.00E-10	8.33E-01
Pu-238	8.65E-07	2.30E-07	2.66E-01
Pu-239	9.56E-07	2.50E-07	2.62E-01
Pu-240	9.56E-07	2.50E-07	2.62E-01
Pu-241	1.85E-08	4.80E-09	2.59E-01
Pu-242	9.08E-07	2.40E-07	2.64E-01
Pu-243	9.02E-11	8.50E-11	9.42E-01
Pu-244	8.97E-07	2.40E-07	2.68E-01
Pu-246	3.66E-09	3.30E-09	9.02E-01
Ra-222	0.00E+00	0.00E+00	NA
Ra-223	1.78E-07	1.00E-07	5.62E-01
Ra-224	9.89E-08	6.50E-08	6.57E-01
Ra-225	1.04E-07	9.90E-08	9.52E-01
Ra-226	3.58E-07	2.80E-07	7.82E-01
Ra-228	3.88E-07	6.90E-07	1.78E+00
Rb-87	1.33E-09	1.50E-09	1.13E+00
Re-186	7.95E-10	1.50E-09	1.89E+00
Re-186m	1.08E-09	2.20E-09	2.04E+00
Re-187	2.57E-12	5.10E-12	1.98E+00
Rn-218	0.00E+00	0.00E+00	NA
Rn-219	0.00E+00	0.00E+00	NA
Rn-220	0.00E+00	0.00E+00	NA
Rn-222	0.00E+00	0.00E+00	NA
Ru-97	1.88E-10	1.50E-10	7.98E-01
Sb-126	2.89E-09	2.40E-09	8.30E-01
Sb-126m	2.54E-11	3.60E-11	1.42E+00
Sc-44	3.87E-10	3.50E-10	9.04E-01
Se-79	2.35E-09	2.90E-09	1.23E+00
Si-32	5.90E-10	5.60E-10	9.49E-01
Sm-146	5.51E-08	5.40E-08	9.80E-01
Sm-147	5.01E-08	4.90E-08	9.78E-01
Sn-126	5.27E-09	4.70E-09	8.92E-01
Sr-90	3.85E-08	2.80E-08	7.27E-01
Ta-180	9.82E-10	8.40E-10	8.55E-01
Ta-182	1.76E-09	1.50E-09	8.52E-01
Tc-97	4.63E-11	6.80E-11	1.47E+00
Tc-97m	3.36E-10	5.50E-10	1.64E+00
Tc-98	1.32E-09	2.00E-09	1.52E+00
Tc-99	3.95E-10	6.40E-10	1.62E+00
Te-123	1.13E-09	4.40E-09	3.89E+00
Th-226	2.50E-10	3.50E-10	1.40E+00
Th-227	1.03E-08	8.80E-09	8.54E-01
Th-228	1.07E-07	7.20E-08	6.73E-01
Th-229	9.54E-07	4.90E-07	5.14E-01
Th-230	1.48E-07	2.10E-07	1.42E+00
Th-231	3.65E-10	3.40E-10	9.32E-01
Th-232	7.38E-07	2.30E-07	3.12E-01
Th-234	3.69E-09	3.40E-09	9.21E-01
Ti-44	6.25E-09	5.80E-09	9.28E-01
Tl-202	3.98E-10	4.50E-10	1.13E+00

Nuclide	FGR 11 (Sv/Bq)	ICRP 72 (Sv/Bq)	ICRP 72 / FGR 11 (-)
Tl-206	0.00E+00	0.00E+00	NA
Tl-207	0.00E+00	0.00E+00	NA
Tl-208	0.00E+00	0.00E+00	NA
Tl-209	0.00E+00	0.00E+00	NA
U-230	2.44E-07	5.60E-08	2.30E-01
U-232	3.54E-07	3.30E-07	9.32E-01
U-233	7.81E-08	5.10E-08	6.53E-01
U-234	7.66E-08	4.90E-08	6.40E-01
U-235	7.19E-08	4.70E-08	6.54E-01
U-236	7.26E-08	4.70E-08	6.47E-01
U-237	8.48E-10	7.60E-10	8.96E-01
U-238	6.88E-08	4.50E-08	6.54E-01
U-240	1.16E-09	1.10E-09	9.48E-01
V-49	1.66E-11	1.80E-11	1.08E+00
Y-90	2.91E-09	2.70E-09	9.28E-01
Zr-93	4.48E-10	1.10E-09	2.46E+00

Table 8-5 All-pathways doses (mrem/yr) using FGR 11 and ICRP 72 DCFs

	ST125	ST34
FGR 11	6.82	23.0
ICRP 72	0.88	2.68
ICRP 72 / FGR 11	0.129	0.117

While the newer DCFs are not used for the base case in this analysis, they likely will become the standard for the next PA revision. Also, the newer DCFs were used in the F-Tank Farm PA (SRR 2008), the Saltstone PA (SRR 2009), and the Composite Analysis (SRNS 2010b) and are planned to be used in the ongoing H-Tank Farm PA – all these analyses were started after the 2008 PA.

8.3 100-Acre Extension

The Base case model employs the current 100-meter performance boundary that encompasses all of E-Area as shown as the solid black line in Figure 8-2 below. Extensions of E-Area, as shown by the various regions highlighted with solid brown lines, have been proposed over time (WSRC 2007). These extensions represent approximately a 100 acre increase in E-Area's footprint. The 100-meter boundary can be estimated by creating circles of 100-meter radius that are centered along the boundaries of the various regions of waste disposal units. Figure 8-2 shows the various disposal units that make up the set of center slit trenches 1 through 7.

Applying the same concept in computing a 100-meter performance boundary that encompasses all of E-Area, including this 100-acre extension, results in the boundary shown as a dashed black line in Figure 8-2. The new 100-meter boundary is tangent to the various 100-meter radius circles shown in Figure 8-2 in blue. The new 100-meter boundary is approximately 160 to 220 meters beyond the original boundary. As such, waste placed within the original center slit trenches will have a significant increase in its travel distance to the new 100-meter boundary (i.e., ~300% increase in travel distance).

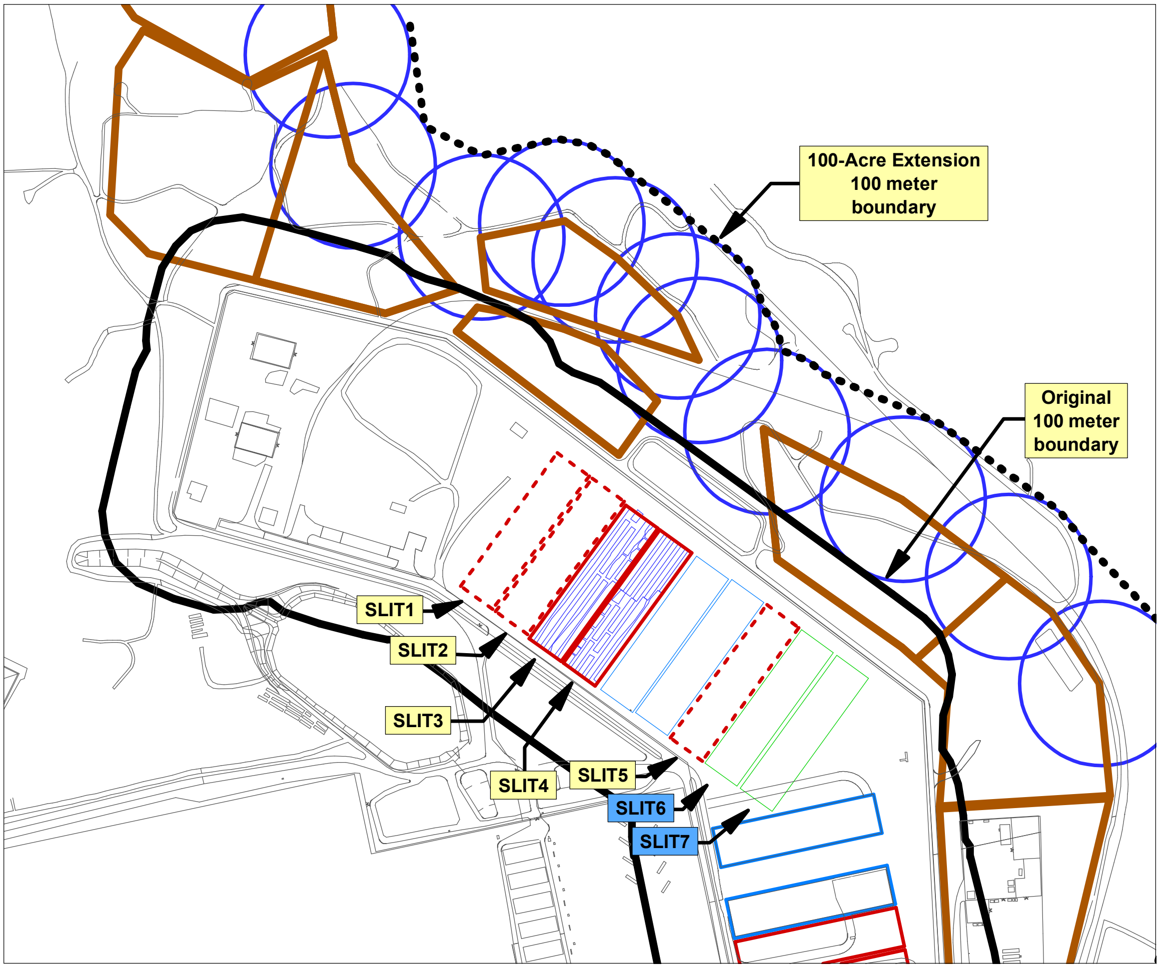

Figure 8-2 Aerial footprint of E-Area and proposed extension highlighting their corresponding 100-meter performance boundaries.

Figure 8-3 highlights the slit trenches of interest (i.e., SLIT34), as well as two 3D streamtraces (in blue) showing the typical transport paths taken for waste buried in the southern regions of SLIT4 and then crossing both 100-meter boundaries.

To see what impact this 100-acre extension would have on total dose associated with SLIT3 and SLIT4 units, aquifer transport runs for the dominant contributor to the groundwater All-Pathway was performed. Here, an upper bound estimate was computed based on the following:

- All dose contributors should see a decrease in value associated with the increased travel length resulting from the movement of the 100-meter performance boundary;
- Only the dominant contributor value (i.e., Np-237) will be reduced in the estimate while all other contributor values are assumed to be unaffected; and
- Plume interaction parameter considered the same.

The comparison is made using the base case (i.e., no high-pH treatment systems are being considered and DCFs are values used in 2008 PA). The results obtained for the groundwater All-Pathway are:

- 23.0 mrem/yr (100-meter boundary based on original footprint)
- 14.0 mrem/yr (100-meter boundary based on 100-acre extension)

As shown, an approximately 39% reduction in SLIT3 and SLIT4 dose impact is seen for the groundwater All-Pathways. This reduction would be larger if the actual contributions from all other radionuclides had been considered.

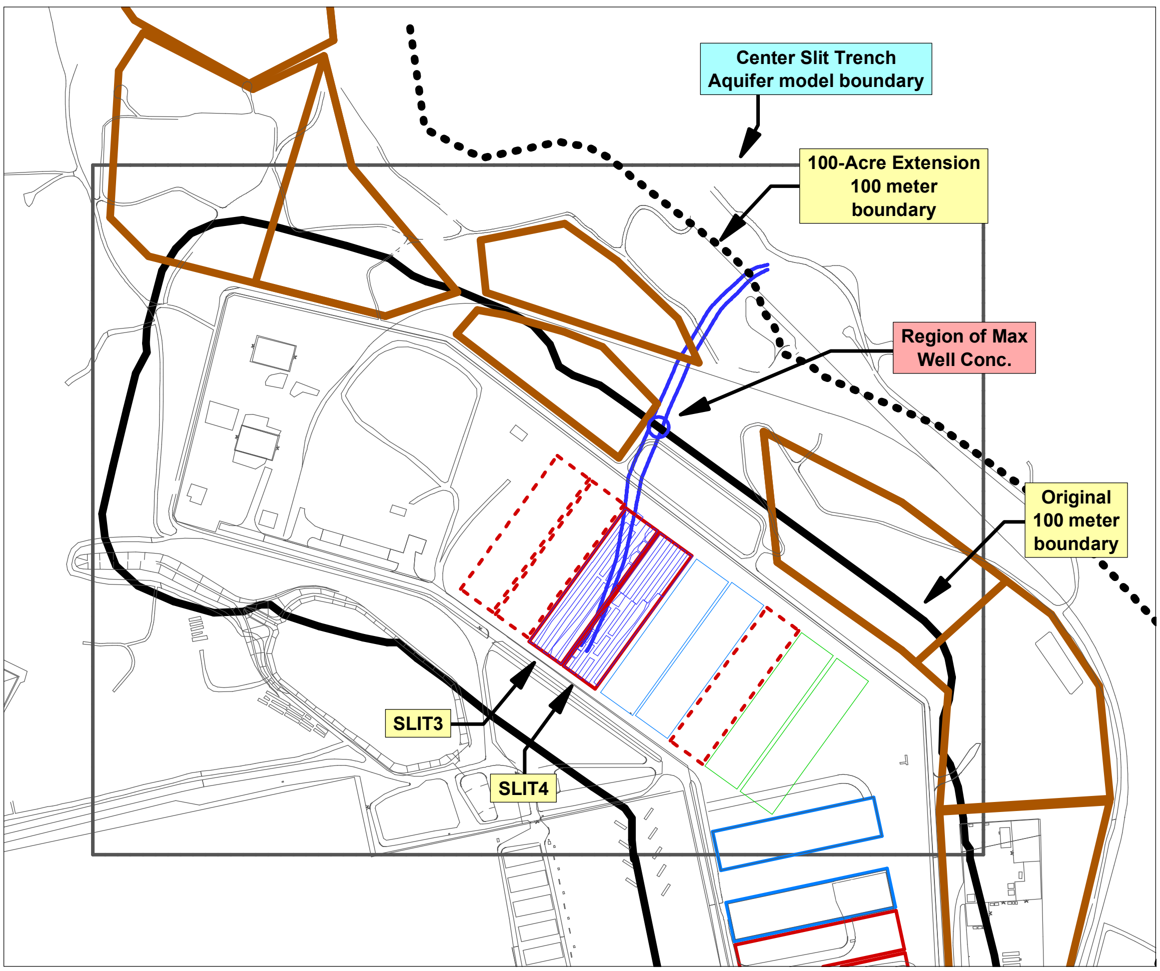

Figure 8-3 Aerial footprint of E-Area centering on the Center Slit Trenches showing the current (solid black line) and the proposed 100-acre extension (dashed black line) 100-meter performance boundaries.

A larger reduction in computed dose was anticipated given the significant increase in travel distance from the edge of the disposal units to the 100-meter boundaries. An approximately 300% increase in travel distance through the aquifer is provided. Based on a simple retarded velocity concept, and assuming a constant aquifer pore velocity, a 300% increase in travel time should be observed. However, as aquifer groundwater travels from the original disposal units towards their ultimate seepage face discharge points, the local groundwater increases in velocity. This can be seen in Figure 8-4 where 3D streamtraces placed at the edge of the disposal units (i.e., SLIT3 and SLIT4) are shown in blue with time markers provided. Within the region between the two 100-meter boundaries an estimated average velocity increase of 250% is observed. This corresponds to an overall average velocity from the disposal units to the 100-meter boundary at the 100-acre extension of ~170% of the average value to the original 100-meter boundary. Thus, the net effect of the 300% increased in travel distance is a 170% increase in travel time.

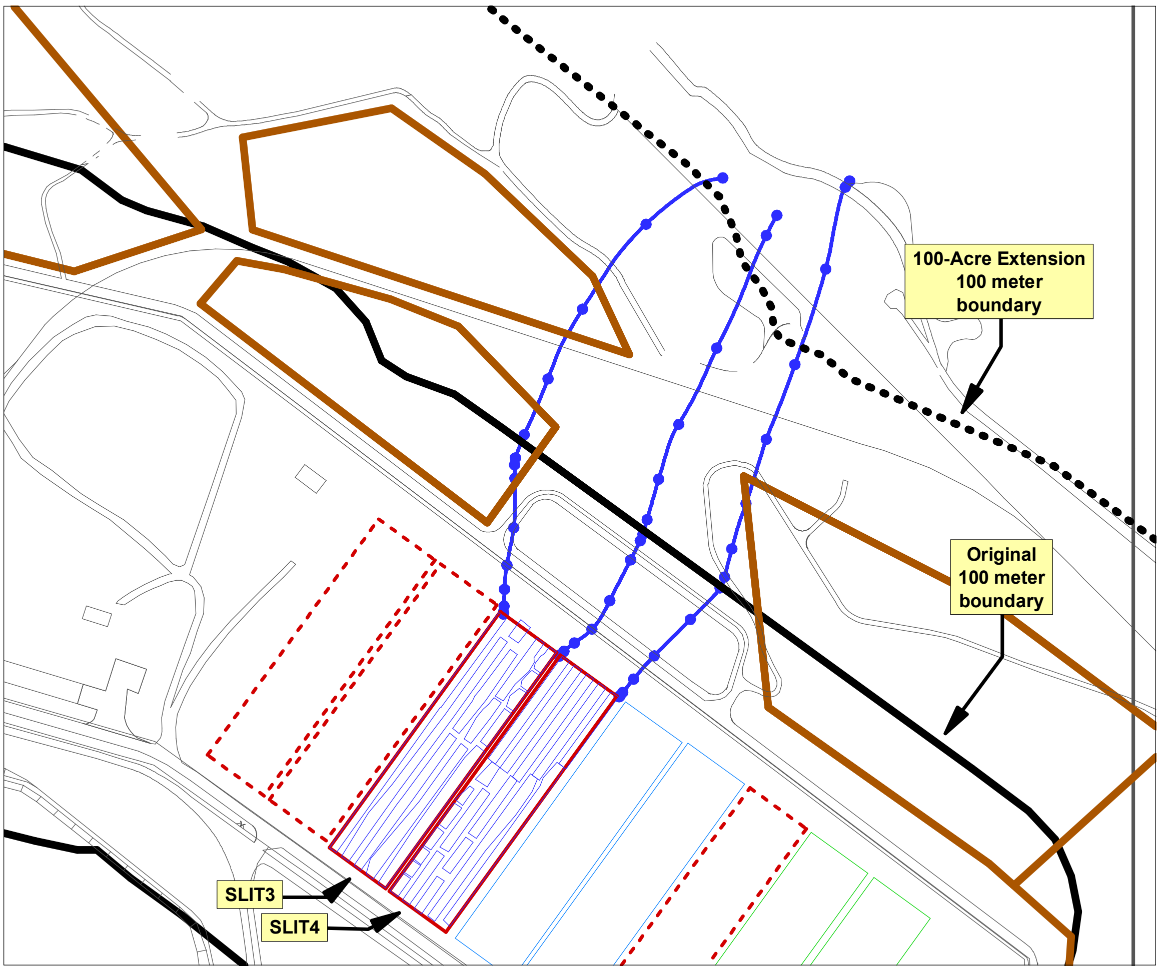

Figure 8-4 Aerial footprint of E-Area centering on the SLIT34 showing key 3D streamtraces with transport time markers.

The doses for the various groundwater pathways is provided in Table 8-6 where the base case (i.e., current 100-meter boundary, FGR-11 DCFs used in the 2008 PA and SA, and no pH treatment system employed) is compared to the same case except the 100-meter boundary is set to the one defined by the 100-acre extension..

Table 8-6 Groundwater dose comparison for SLIT34 based on base case using the original versus extended 100-meter performance boundaries.

SLIT34	DCF Source	100-meter Boundary	pH Treat	Alpha (pCi/L)	Beta-Gamma (mrem/yr)	Radium (pCi/L)	Uranium (μg/L)	Groundwater All-pathways (mrem/yr)
Allowable				15 pCi/L	4 mrem/yr	5 pCi/L	30 μg/L	25 mrem/yr
Base case	FGR-11	original	0%	3.95	0.53	9.49E-04	6.07E-09	23.0
Case 2	FGR-11	extension	0%	2.20	0.53	9.49E-04	3.09E-09	14.0

8.4 High-pH Treatment System

A preliminary scoping analysis performed in conjunction with the SEG boxes SA (Collard et al. 2010) indicated that Np-237 likely would be problematic in SLIT3 and SLIT4, unless some treatment was applied. However, changes implemented in the current analysis (e.g., using WITS non-crushable areas) produced dose results that are all less than performance objectives. Because some results are only slightly less than their performance objectives and uncertainties were not explicitly considered in the results, it is prudent to consider options that could reduce the well concentrations for important radionuclide chains. To that end, the option of applying high-pH treatment to trench segments containing high inventories of Np-237 in ST3 and ST4 was investigated. These segments are as follows:

- SLIT3-UnitE
- SLIT3-Unit~North
- SLIT4-UnitA
- SLIT4-UnitH
- SLIT4-Unit~South, and
- SLIT4-Unit~North.

In the preliminary scoping analysis the two main contributors to the groundwater pathway doses (i.e., for the beta-gamma and all-pathways pathways) were from the parents Np-237 and U-235. To reduce their contributions to exposures at or beyond the 100 meter boundary, supplemental treatment options were considered. Based on available geochemistry for the migration of Np in subsurface conditions a high-pH treatment option was considered. Here in situ injection of caustic within those trench segments listed above and displayed in Section 4.2 could be applied between the final dynamic compaction and the placement of the final cover.

8.4.1 High-pH Treatment Vadose Zone Transport Models

The adsorption (i.e., K_d value) of element Np onto both Sandy and Clayey soils in contact with varying pH pore water is shown in Figure 8-5 (after Kaplan, 2010). As illustrated in Figure 8-5 a significant increase in K_d for both Sandy and Clayey soils can be achieved when the local pore water pH is increased to the range of approximately 9 to 12. Under normal local conditions rainfall has a pH around 4.5 to 5.5 and the normal background pH within the vadose zone is expected to range from 4 to 6. As highlighted in Figure 8-5, two pH ranges were identified as follows:

- Low pH – local pore water in the range of 4 to 6 pH
- High pH – local pore water in the range of 9 to 12 pH

In each of these pH ranges the Np K_d values are relatively constant. The impact of increasing pore water pH also impacts several other key elements of interest either by increasing their K_d values or by decreasing them. A listing of the most important ones for this analysis is provided in Table 8-7. Note that an increase in K_d results in an increase in an element's retardation factor. Most elements in Table 8-7 experience an increased in K_d with pH; however, a small number of elements have the opposite trend, e.g., Tc and Iodine where one order drop in magnitude is observed. Therefore, any treatment option employing a pH shift must address both the negative as well as positive aspects of the treatment process. The shaded K_d values were employed during the high-pH treatment analyses (reduced K_d values were applied over a greater area than increased K_d values – see Figure 8-6). Analyses were conducted for generic and special waste forms containing Np, Pa, I or Tc.

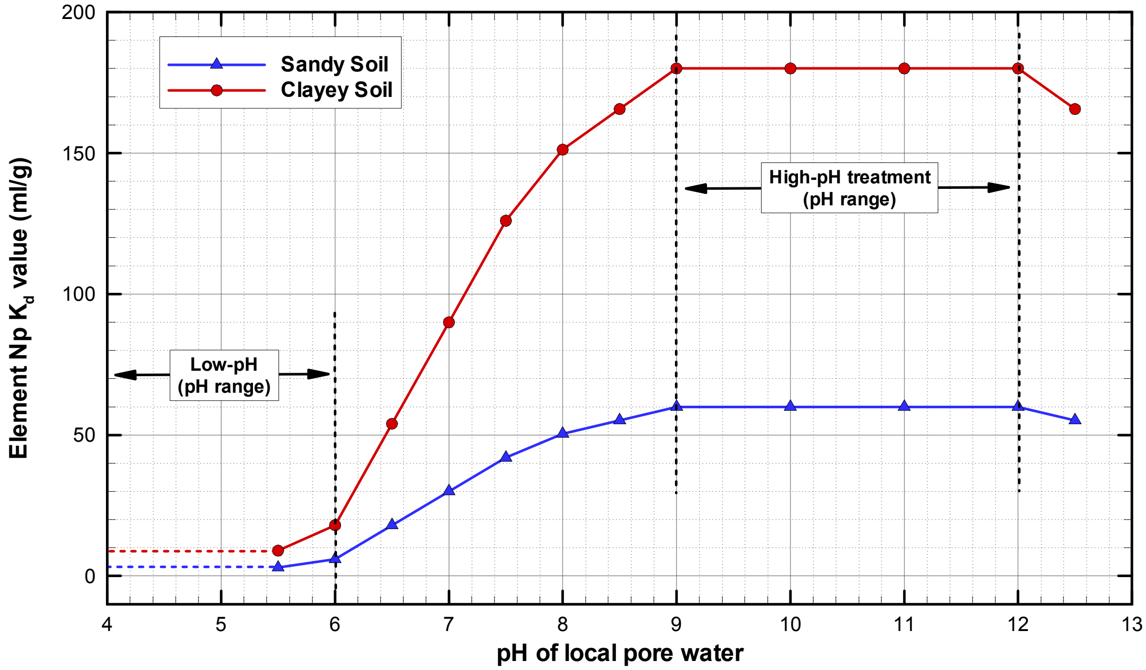

Figure 8-5 Expected adsorption of element Np onto Sandy and Clayey soils in contact with varying pH pore water (after Kaplan, 2010).

Table 8-7 Impact on K_d (ml/g) values for selected elements versus pH of pore water[a].

Element	Best Est. Sand K_d value at Low-pH	Best Est. Clay K_d value at Low-pH	Sand and Clay at High-pH Factor	Best Est. Sand K_d value at High-pH	Best Est. Clay K_d value at High-pH
Ac	1100	8500	1.5	1650	12750
I	0.3	0.9	0.1	0	0.1
Np	3	9	20	60	180
Pa	3	9	20	60	180
Tc	0.6	1.8	0.1	0.1	0.2
Th	900	2000	2	1800	4000
U	200	300	3	600	900

a – High-pH implies pore water whose pH is in the range of 9-to-12 and Low-pH implies pore water whose pH is in the range of 4-to-6. Note that the K_d values listed were taken from Appendix A of Kaplan (2010) under the category "Best Sand [or Clay] K_d CemLech (for cementitious leachate)" columns.

Thus, to reduce the impact of Np-237 a high pH treatment can be applied to the selected trench segments identified in Section 4.2. The treatment would reduce the Np from Np^{+5} to Np^{+4}, causing some of it to precipitate out of solution (believed to be nearly irreversible in nature). The effective K_d would increase by a factor of 20 and would be sustained for the entire analysis period (Kaplan 2010). The treatment would be applied immediately after performing dynamic compaction in 2125 to increase its effectiveness.

Examples of high pH treatment applied at SRS include the base injection system for the F-Area and H-Area Hazardous Waste Management Facility (HWMF) and remediation of seepage basins in F-Area and H-Area. The F-Area HWMF base injection system described in the 2010 Corrective Action Report (SRNS 2010) was started in 2005. The injected solution consists of sodium hydroxide and sodium bicarbonate mixed with domestic water to a pH of approximately 10. The solution is injected through wells directly into the acidic groundwater to reduce concentrations of metals and radionuclides.

Upon closure of the F-Area HWMF and H-Area HWMF, SRS placed a nine-inch layer of calcium carbonate rock and a three-inch layer of blast furnace slag atop a gravel layer in each basin (WSRC 1991). As water contacts the carbonaceous rock, the pH of the water is raised to between 8 and 9. At high-pH and low oxidation potential (provided by the slag) most heavy metals precipitate out into the soil. It is estimated that this passive chemical stabilization will be effective for 10,000 years. Similar technologies can be applied to the Slit Trenches to stabilize Np-237.

Two optional cases for high-pH treatment to reduce the mobility of Np-237 and its well concentrations were considered. Trench segments in Slit Trench 3 and Slit Trench 4 containing high Np-237 inventories were identified to receive high-pH treatment immediately after dynamic compaction. The first high-pH treatment option model assumes that the treatment has an effect on 90% of the contaminants in the waste zone. The assumption of 90% treatment efficiency provides a guideline that a treatment process would be designed to meet. It is unknown how efficient the treatment actually will be, because the waste zone is not homogeneous. Also some trench segments contain non-crushable containers which dynamic compaction is unlikely to rupture so the high pH treatment would not immediately interact with the contents of such containers. Because of these uncertainties, a second high-pH optional case was modeled where the efficiency was assumed to be 60%.

Analyses were performed for 100% effective treatment and 0% effective treatment and the results were blended as discussed in Section 8.4.2. Here the 90% effectiveness factor is the best estimate value where the 10% loss is to account for local regions where the high-pH solution does not reach or maintain its value long enough to convert the Np in its +5 valence state to the less mobile +4 valence state. The same 90% value for the effectiveness factor is applied for all elements considered. For the second optional case analysis, the only change is that a 60% effectiveness factor is adopted.

The list of parents with chain members that were modeled is as follows:

- Np-237 - K_ds increased
- U-235 - K_ds increased
- Tc-99 - K_ds decreased
- I-129 and its special waste forms - K_ds decreased.

The degree of $[OH]^-$ capacity of the sandy and clayey soils was not explicitly considered in these analyses. Instead for increased K_ds, the hydroxide plume was applied only within regions which provided the minimum impact on increasing overall retardation from the waste zone to the water table. Because, high-pH increases the retardation of Np-237 and Pa-231 (a progeny of U-235) only the waste zone was assigned high-pH conditions. Because high-pH decreases the retardation of Tc-99 and I-129 (and its special waste forms) both the region within the waste zone and the region beneath the waste zone were assigned high-pH conditions

Figure 8-6 shows where the Base case 2D vadose zone model was modified to accommodate these regions of high-pH treatment. For all nuclides affected (i.e., Np-237, Tc-99, Pa-231, and I-129 and its special waste forms) the K_d values associated with high-pH pore water were applied to the region highlighted in white (dashed) of Figure 8-6. For those negatively impacted parent nuclides (i.e., Tc-99, and I-129 and its special waste forms) the regions highlighted in white and red (dashed) are where their high-pH K_d values were applied.

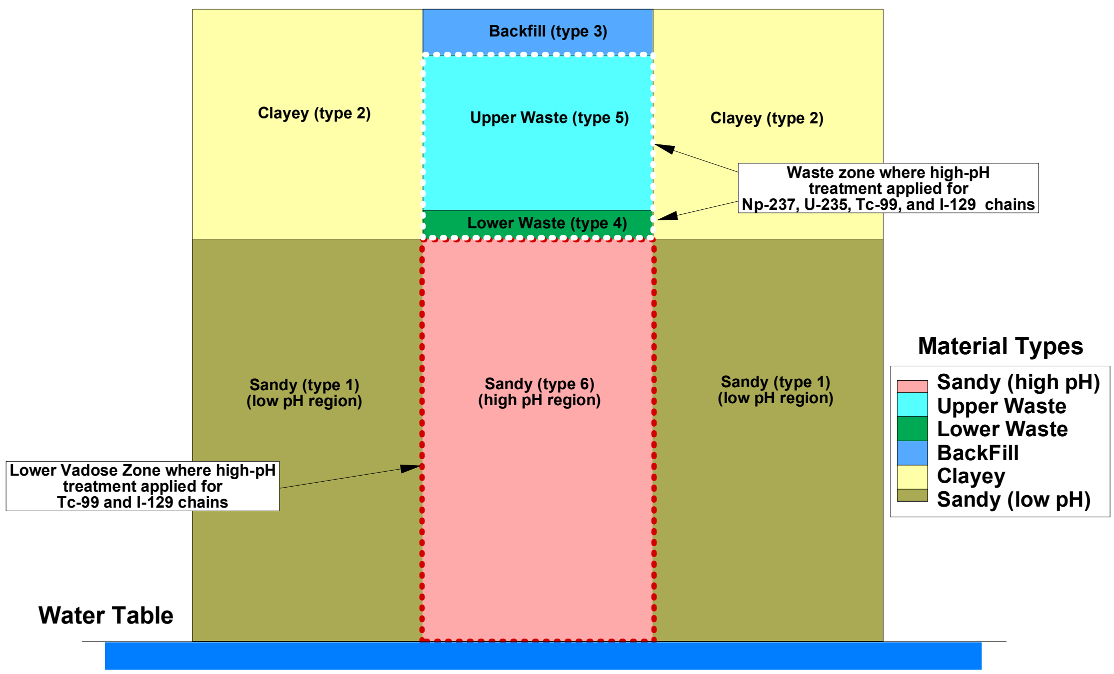

Figure 8-6 Locations where the base case 2D Vadose Zone transport model was modified to address the optional high-pH treatment process.

8.4.2 Conversion from Vadose Zone Fluxes at the Water Table to Aquifer Model Sources

Table 8-8 shows high-pH vadose zone transport runs shaded in orange and aquifer transport runs shaded in blue. For the vadose zone transport runs, Case01 has all crushable containers and Case11 has all non-crushable containers. Source term blending, based on each Inventory Group's percent of non-crushable and pH treatment efficiency, was performed to create Case01 and Case01n11.

Table 8-8 Aquifer source term blending matrix based on Vadose zone transport runs under high-pH treatment conditions.

pH Treatment Efficiency	0% non-crushable	Percent of non-crushable	100% non-crushable
100%	Case01 model results	Case01n11 (First level of blending)	Case11 model results
90% ($\alpha = 0.9$, option A) or 60% ($\alpha = 0.6$, option B)	Case01 (First level of blending)	Case01n11 (Second level of blending)	
0%	Case01 model results	Case01n11 (First level of blending)	Case11 model results

High-pH blending depends on the assumed efficiency (α) of the treatment (0.90 for option A and 0.60 for option B). Flux results (blended from Eq. (5-1) above as needed) were blended by multiplying the 100% effective fluxes (treated) by α and adding that product to the 0% effective fluxes (untreated) multiplied by (1-α). The general equation for this operation is Equation 8.1 below:

$$\boldsymbol{Flux}_{\boldsymbol{blend}}^{\boldsymbol{treat}}(\boldsymbol{G},\boldsymbol{N},\boldsymbol{t}) = \alpha \boldsymbol{Flux}_{\boldsymbol{treated}}(\boldsymbol{G},\boldsymbol{N},\boldsymbol{t}) + (1-\alpha)\boldsymbol{Flux}_{\boldsymbol{untreated}}(\boldsymbol{G},\boldsymbol{N},\boldsymbol{t}) \qquad (8.1)$$

where

$\boldsymbol{G}$ is the index representing an Inventory Group

$\boldsymbol{N}$ is the index representing a radionuclide (i.e., a parent or its progeny)

$\boldsymbol{t}$ represents the time step

Equation (8-1) results in aquifer source terms representing blended fluxes for Case01 and Case01n11 as shown in Table 8-8 shaded in blue.

8.4.3 Vadose Zone Transport Results

Of primary interest is the behavior of Np-237 for the optional high-pH treatment case relative to the untreated base case to help understand the benefits of the treatment. A time-history plot of fractional fluxes is provided in Figure 8-7 for the Inventory Group SLIT4-Unit~North looking at a center trench (e.g., 4A_North). Figure 8-7 indicates that the treatment effectively reduces the peak fractional flux during the time period of assessment by a factor of about 2.77 (i.e., 0.00495/0.00179). Np-237 has a half-life of 2.15E6 years, so it will decay little over the 1130 year period of assessment. Because little decay is occurring for Np-237, the areas under the two curves shown in Figure 8-7 are approximately equal.

Due to the finite time intervals employed for the vadose zone flows (i.e., 18 time periods were employed to account for infiltration rate changes over the 1130 year simulation period), discrete step changes occurred in the flux to the water table for all nuclides considered. For Np-237 shown in Figure 8-7 these step changes become more pronounced under the high-pH treatment case. Smoothing of this behavior could be achieved by increasing the number of flow time periods. However, peak fluxes would be reduced and increasing the number of flow time periods was not warranted.

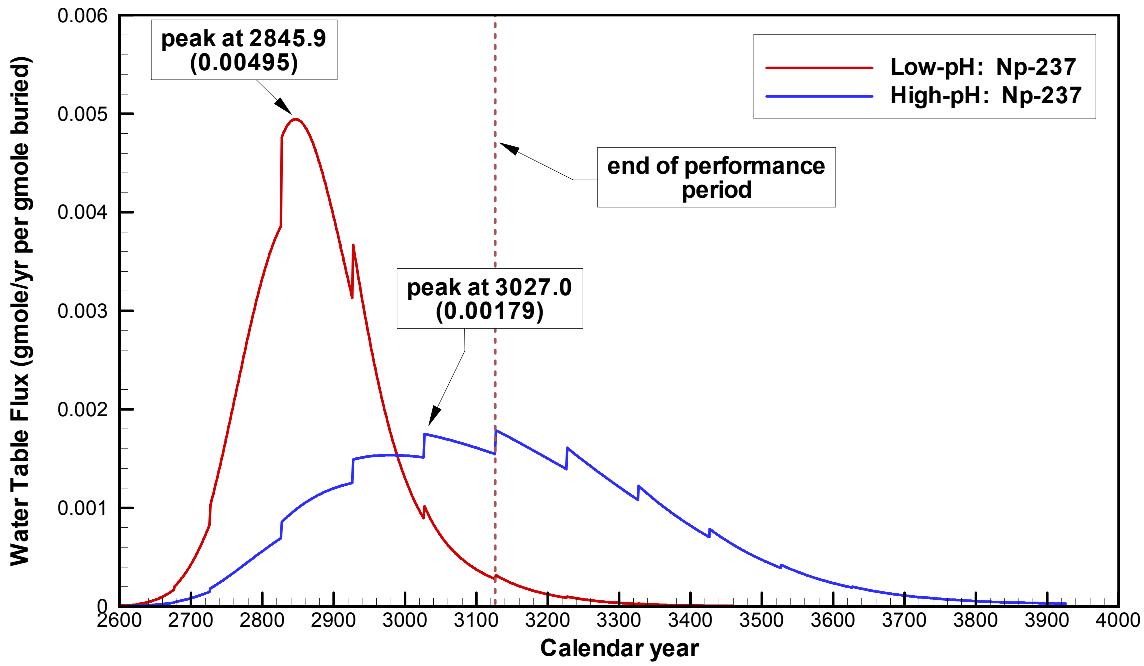

Figure 8-7 Np-237 fractional flux to water table for the untreated (low-pH) and treated (high-pH) cases for center trenches within SLIT4-Unit~North (e.g., 4A_North).

For the high-pH case Np-237 travels through two regions of significantly different K_d values. They are:

- The Waste Zone with a K_d value of 180 ml/g, (versus 9 for Low-pH);
- The Lower Vadose Zone with a K_d value of 3 ml/g, (the same as for Low-pH).

The overall retardation factor for the entire travel path from the waste zone to the water table is a weighted average of these two zones. This results in a net shift of the breakthrough curve to longer travel times, along with a spreading of the curve primarily due to the retardation locally within the Lower Vadose Zone remaining unchanged. To a lesser extent, diffusional aspects increase the spreading as observed.

Snapshots of fractional concentration profiles for the Np-237 analyses are provided in Figure 8-8 at various times (for the same trench segment as shown in Figure 4-27, 4A_North). The left column of figures shows the behavior for the untreated Np-237 (i.e., low-pH case), while the right column of figures shows the behavior for the treated Np-237 (i.e., high-pH case) if the treatment is 100% effective. The first time is calendar year 2126 immediately before dynamic compaction and high-pH treatment. The two columns show that no changes in behavior occur before treatment. The second time is year 2841 about when the untreated Np-237 achieves its peak flux at the water table. Most of the untreated Np-237 has left the waste zone, while much of the treated Np-237 remains in the waste zone. The third time is 3026 about when the treated Np-237 achieves its peak flux at the water table. Almost all the untreated Np-237 has left the waste zone, while much of the treated Np-237 remains in the waste zone, as can be seen by the concentration contours in and around the waste zone.

Np-237 Untreated (low pH) case	Np-237 Treated (high pH) case

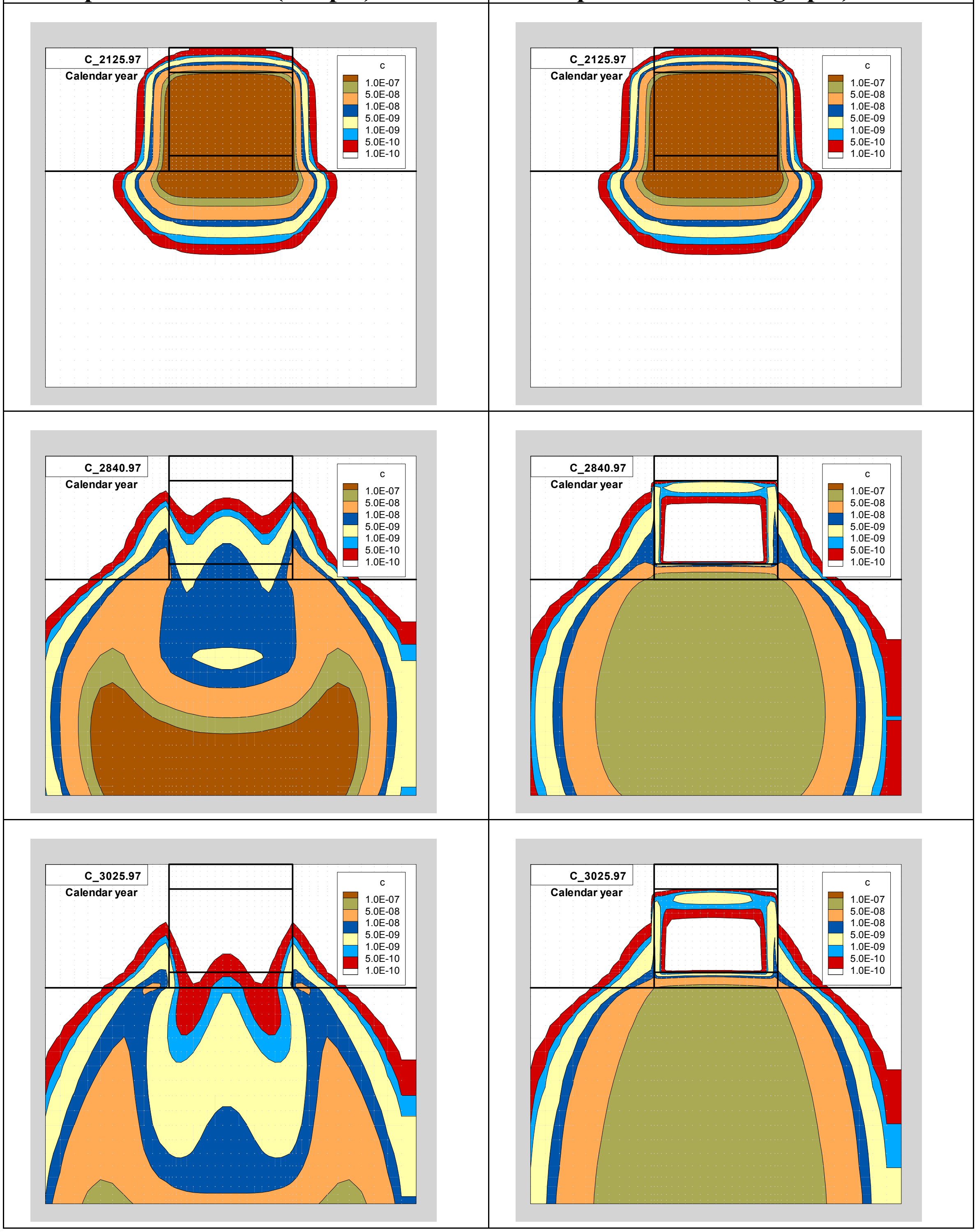

Figure 8-8 Np-237 fractional concentration profiles in the vadose zone for the untreated (low-pH) and treated (high-pH) cases at various times for center trenches within SLIT4-Unit~North (e.g., 4A_North).

8.4.4 Aquifer Model Results

Selected composite plots of the maximum well concentrations (these concentrations include plume interaction factors of 0.8 for SLIT34 and 0.7 for SLIT125) for affected generic parent nuclides are shown for the 90% effective high-pH treatment as follows:

- I-129
- Tc-99
- U-235 (Pa-231 is the dominant contributor to dose)
- Np-237 (Np-237 is the dominant contributor to dose)

The results are provided in Figures 8-9 through 8-14 below. In all plots two cases are shown where no CDP is present. The two cases correspond to the intact case (Case01_off; solid lines) and the local subsidence case (Case01n11_off; dashed lines). As can be seen in Figures 8-11 through 8-14, Pa-231 and Np-237 from the U-235 and Np-237 chains, respectively, have the highest concentrations for these chains (and when DCFs are applied they are the dominant contributors to dose for these chains).

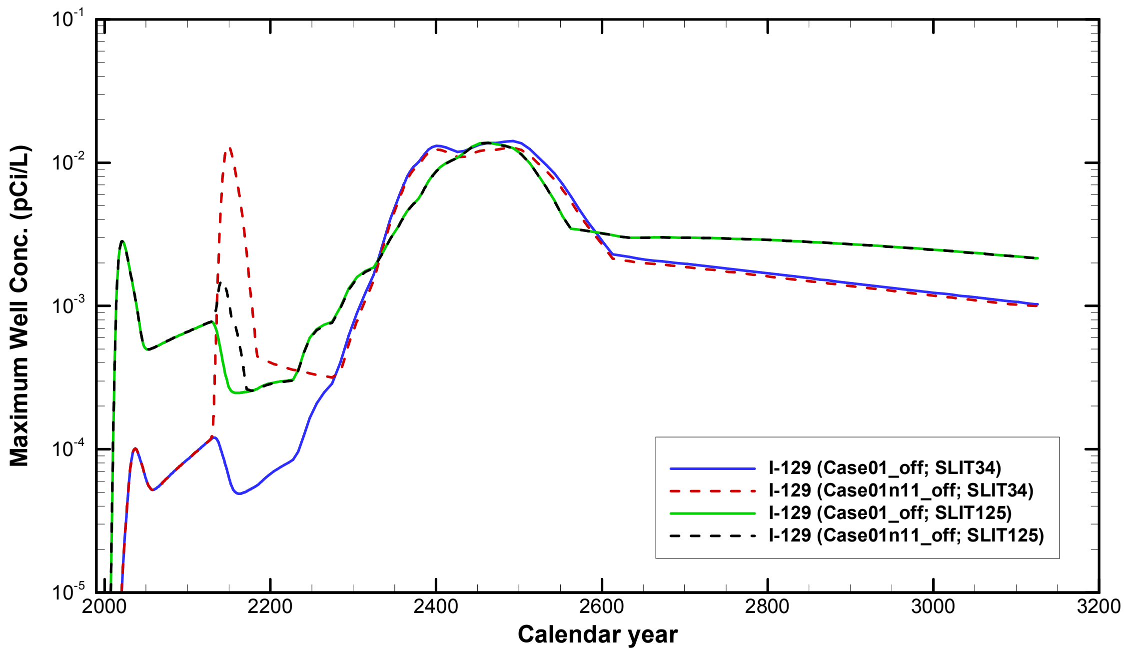

Figure 8-9 Well concentrations for I-129 in SLIT34 and SLIT125 aquifer analyses for 90% effective treatment scenario (intact versus subsided cases).

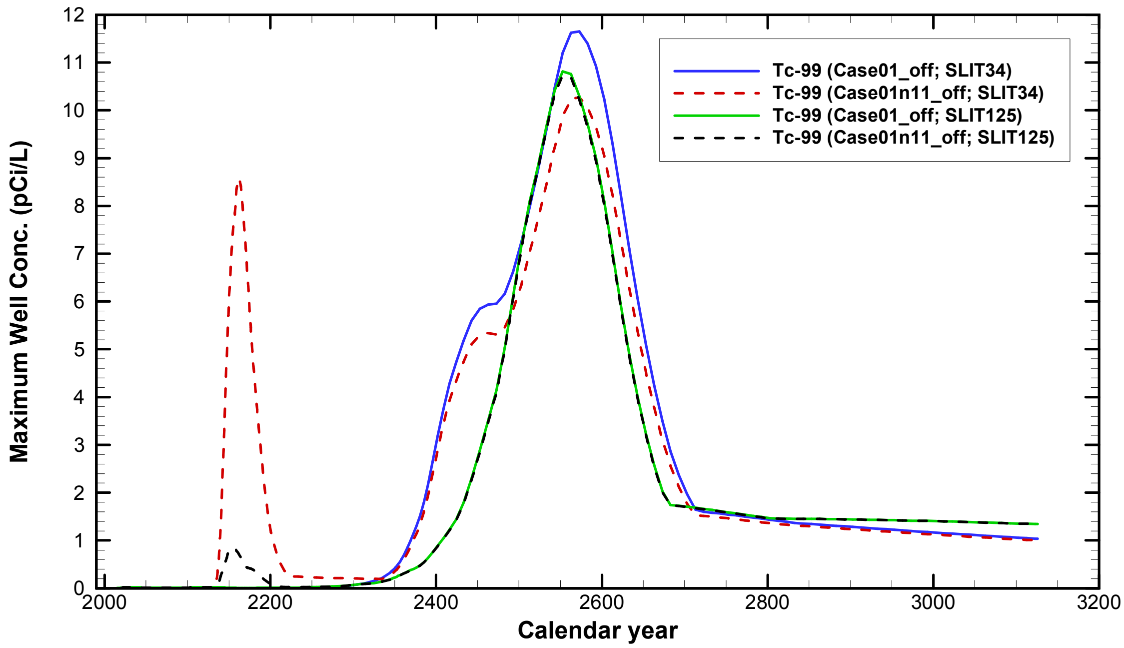

Figure 8-10 Well concentrations for Tc-99 in SLIT34 and SLIT125 aquifer analyses for 90% effective treatment scenario (intact versus subsided cases).

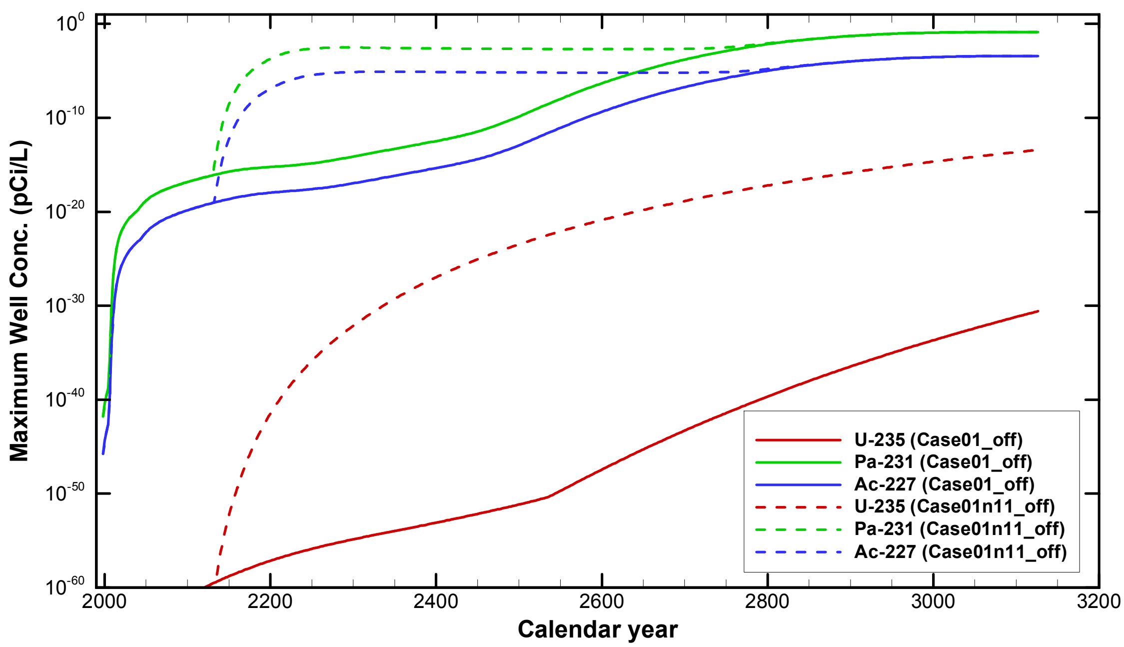

Figure 8-11 Well concentrations for U-235 chain in SLIT34 aquifer analysis for 90% effective treatment scenario (intact versus subsided cases).

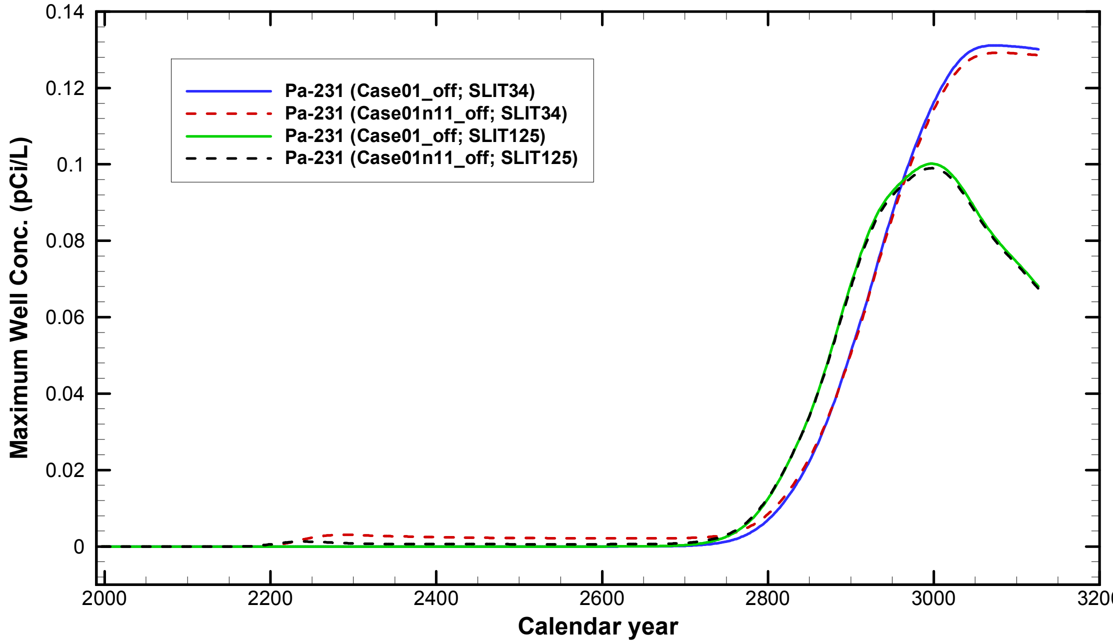

Figure 8-12 Well concentrations for Pa-231 in U-235 chain in SLIT34 and SLIT125 aquifer analyses for 90% effective treatment scenario (intact versus subsided cases).

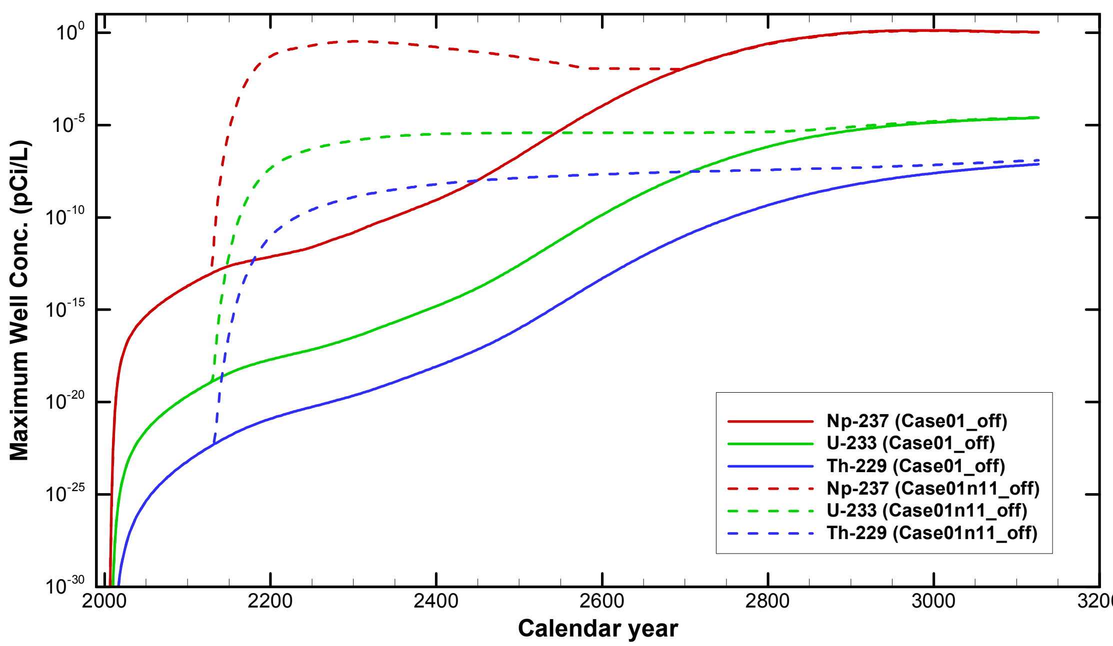

Figure 8-13 Well concentrations for Np-237 chain in SLIT34 aquifer analysis for 90% effective treatment scenario (intact versus subsided cases).

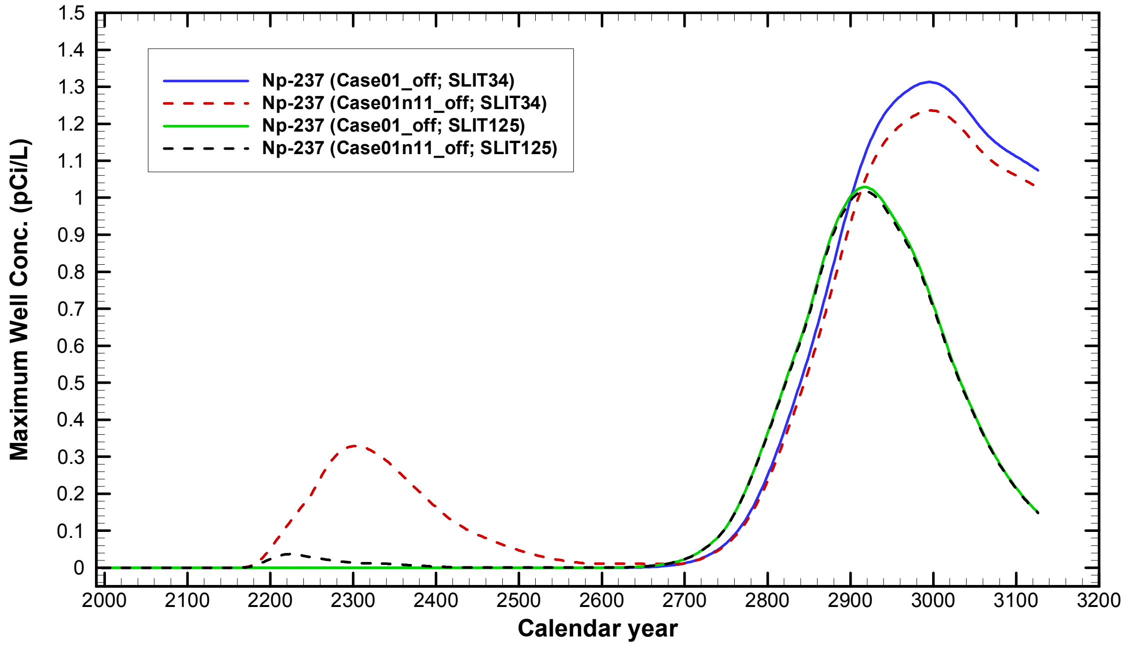

Figure 8-14 Well concentrations for Np-237 in SLIT34 and SLIT125 aquifer analyses for 90% effective treatment scenario (intact versus subsided cases).

8.4.4.1 Aquifer Results for Np-237

Because Np-237 dominates many of the dose pathways discussed in Chapter 6, we focus on the PORFLOW results for Np-237 within the SLIT34 Aquifer analyses. The PORFLOW computed concentrations are also adjusted by the SLIT34 plume interaction parameter (i.e., PORFLOW results are multiplied by a 1.25=1/0.8 factor). Thus, both the maximum well concentrations beyond the 100 meter boundary and the 2D concentration contours presented in Figures 8-15 through 8-20 represent concentration values (in pCi/L) that have been corrected for plume interactions with other disposal units.

In Figure 8-15 the maximum well concentration for Np-237 is shown for both the intact case (Case01) and the blended Subsidence case (Case01n11). Also highlighted are five calendar years (i.e., 2700, 2800, 2900, 3000, and 3100) where the Np-237 concentration is provided for the intact case (i.e., 0.012, 0.250, 0.995, 1.312, and 1.112 pCi/L), respectively. Note that for the subsided case its value is 1.235 pCi/L at year 3000 (i.e., slightly less than 95% of the intact case).

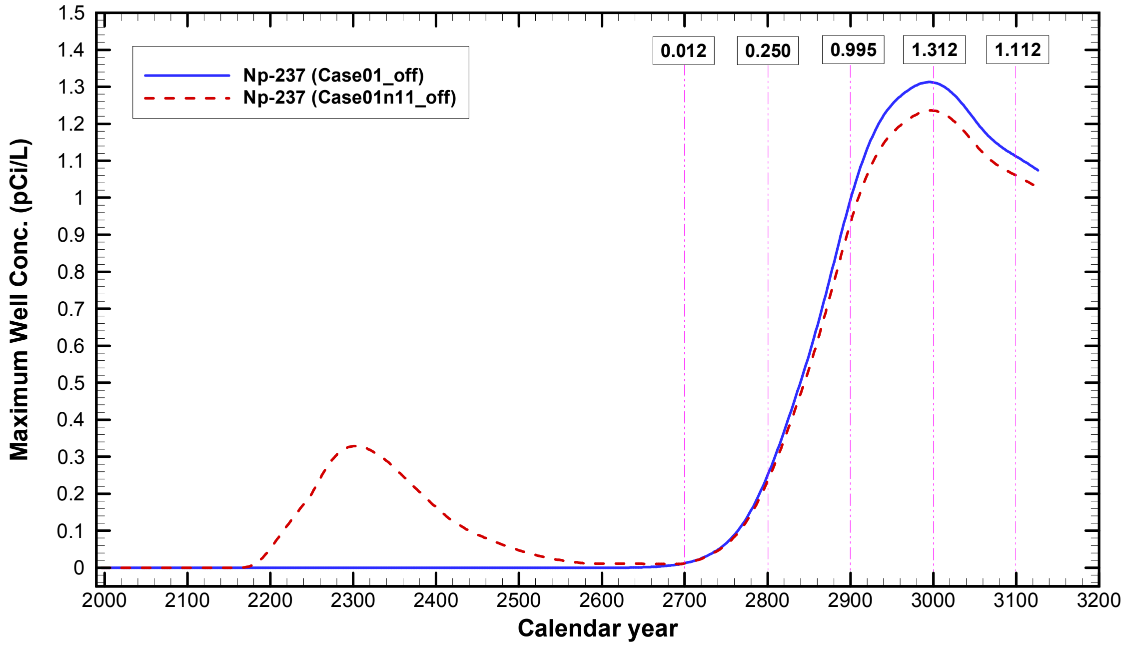

Figure 8-15 Well concentrations for Np-237 in SLIT34 aquifer analysis for two base cases.

The Np-237 concentration profiles (in pCi/L) for four of the selected times above are shown in Figures 8-16 through 8-19 for calendar years 2800, 2900, 3000, and 3100, respectively. These results are for the SLIT34 Aquifer optional case where the high-pH treatment process is assumed to be 90% effective. In each of the figures the 3D concentration profile has been sliced at the same vertical K-plane (i.e., here K=10 within the PORFLOW Aquifer model) which corresponds to a depth below the ground surface of approximately 40 feet. The slicing plane was selected to be consistent with the peak values presented in Figure 8-15.

The location of the maximum well concentration is shown as a blue open circle in each figure. This location did not change much over the time period of interest here and the K-plane chosen corresponds with the maximum values as well. In each of these figures the contours with the peak concentrations were selected to touch the 100 meter boundary.

To provide some insight into which trench segments may be contributing the most to the observed maximum well concentrations, 3D streamlines were employed to trace the path originating from various trench segments for year 3000 Case01_off (see Figure 8-20). In Figure 8-20 two of these streamlines are presented along with a concentration contour taken at a lower elevation than the previous figures (i.e., here a K-plane of 8, ~50-60 feet below the ground elevation). These results suggest that SLIT4-UnitB, SLIT4-UnitI, and SLIT4_South are contributing significantly to the total. However, to determine exactly which trench segments are the main contributors would require more analysis.

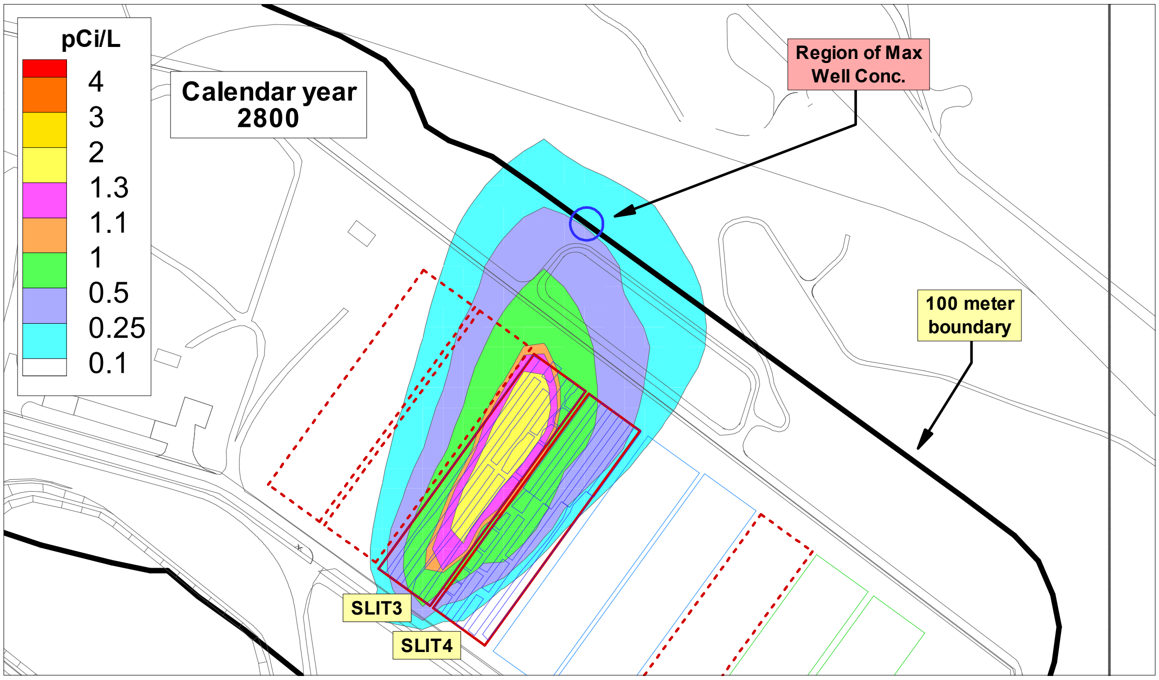

Figure 8-16 Concentration contours for Np-237 in the SLIT34 aquifer analysis for the intact case (without CDP) at the elevation where the maximum well concentration occurs for calendar year 2800.

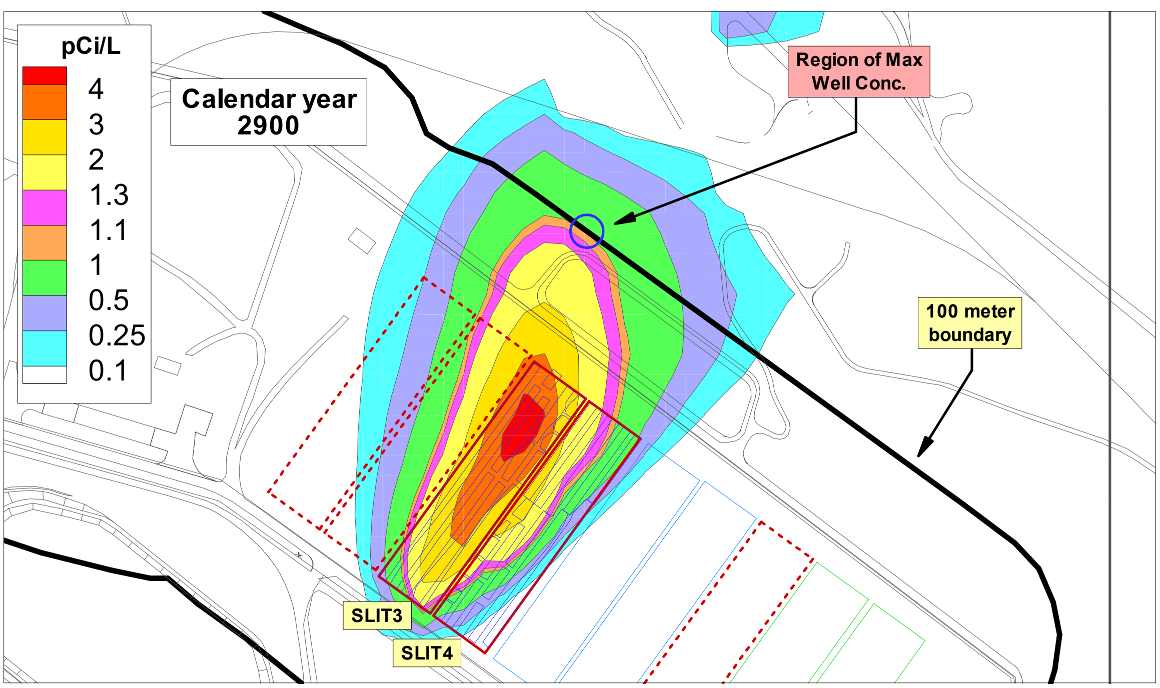

Figure 8-17 Concentration contours for Np-237 in the SLIT34 aquifer analysis for the intact case (without CDP) at the elevation where the maximum well concentration occurs for calendar year 2900.

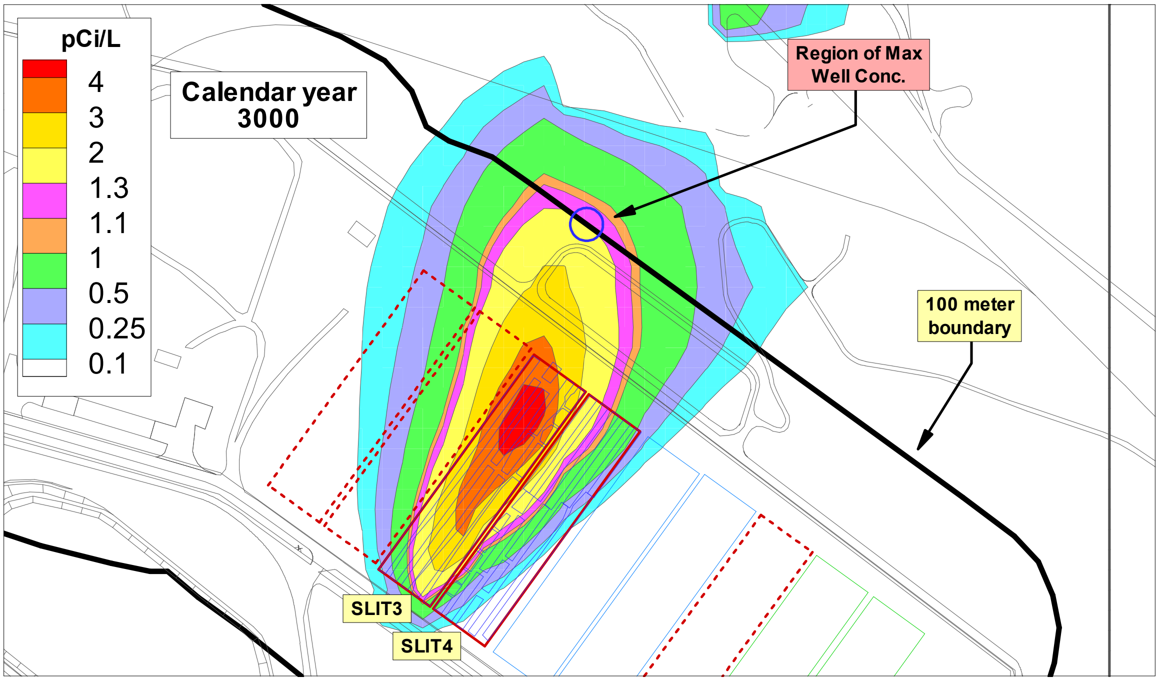

Figure 8-18 Concentration contours for Np-237 in the SLIT34 aquifer analysis for the intact case (without CDP) at the elevation where the maximum well concentration occurs for calendar year 3000.

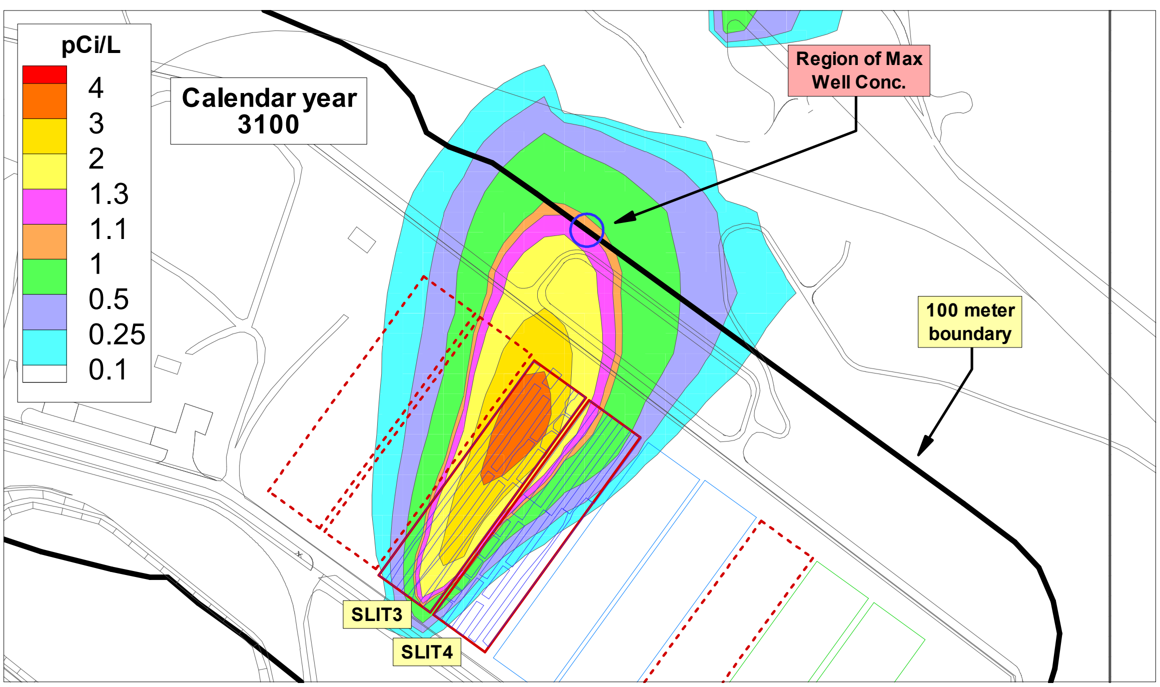

Figure 8-19 Concentration contours for Np-237 in the SLIT34 aquifer analysis for the intact case (without CDP) at the elevation where the maximum well concentration occurs for calendar year 3100.

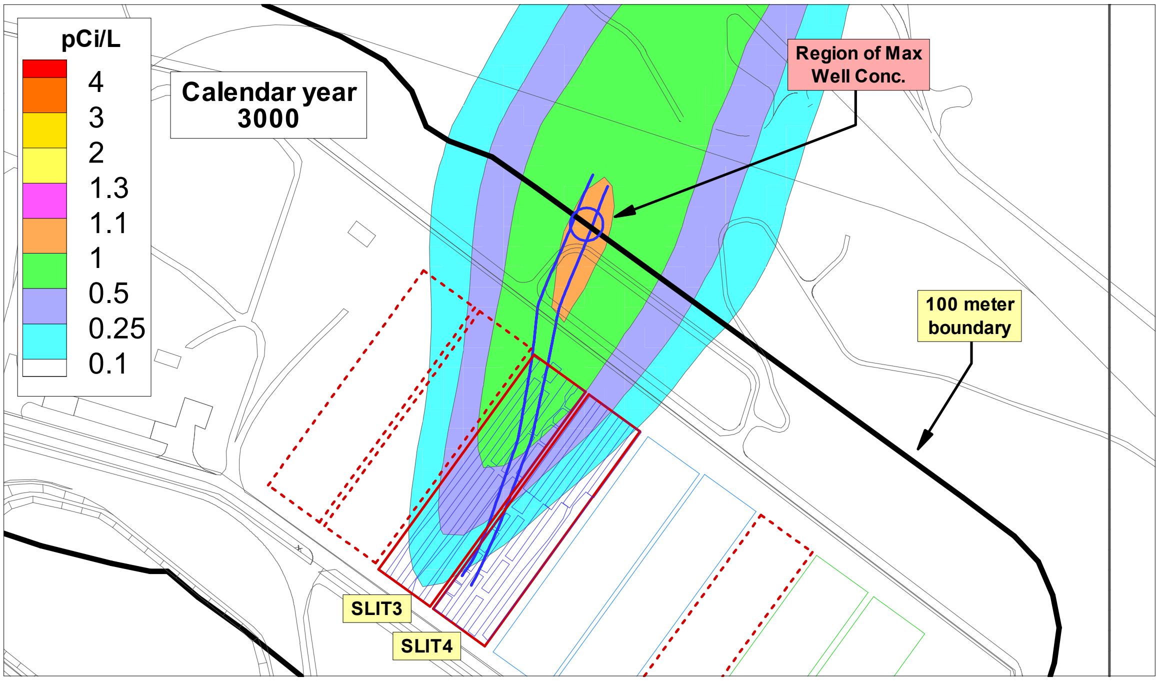

Figure 8-20 Concentration contours and 3D streamlines for Np-237 analysis for the intact case (without CDP) about 10 to 20 feet below the elevation where the maximum well concentration occurs for calendar year 3000.

8.4.5 Groundwater Pathways Performance Evaluation

Results from this case are summarized in Tables 8-9 through 8-11. Table 8-9 shows the peak doses and concentrations for the five groundwater exposure pathways for the sets of Slit Trenches analyzed (ST125 and ST34) and approximate contributions from the individual Slit Trenches.

Table 8-10 shows the maximum dose or concentration for each groundwater exposure pathway divided by the allowable to give a relative performance index. In all instances, the closest approach to an allowable value is reached for the groundwater all-pathways analysis. The radionuclide chains that contribute the most to the maximum groundwater all-pathways dose are Np-237 and U-235. For Slit Trenches 3 and 4, which had the highest groundwater all-pathways dose, Np-237 accounted for 7.0 mrem/yr and U-235 1.7 mrem/yr of the total maximum dose of 8.9 mrem/yr.

Table 8-11 shows the years in which the maximum dose or concentration was reached. Note that the uranium and radium peaks are reached at the end of the analysis time and therefore have not reached ultimate maximum values. However, the relative performance indices for these two pathways are much less than the indices for the other three exposure pathways. Also note that when the peak doses from individual Slit Trenches occur at different times, summing the peak doses from individual trenches has no meaning.

Table 8-9 Peak doses and concentrations for groundwater exposure pathways.

	Gross Alpha (pCi/L)	Beta-Gamma (mrem/yr)	Radium (pCi/L)	Uranium (μg/L)	Groundwater All-pathways (mrem/yr)
Allowable	15 pCi/L	4 mrem/yr	5 pCi/L	30 μg/L	25 mrem/yr
ST1	1.45E-01	3.96E-01	1.24E-04	2.21E-10	8.41E-01
ST2	2.79E-01	1.82E-01	2.29E-04	3.94E-10	1.82E+00
ST5	7.03E-01	7.12E-02	1.16E-03	1.06E-09	4.16E+00
ST125	1.13E+00	6.49E-01	1.52E-03	1.68E-09	6.82E+00
ST3	7.97E-01	4.69E-01	2.14E-04	1.58E-09	4.57E+00
ST4	6.55E-01	5.29E-02	7.35E-04	1.15E-09	4.35E+00
ST34	1.45E+00	5.06E-01	9.49E-04	2.72E-09	8.90E+00

Table 8-10 Peak doses and concentrations for groundwater exposure pathways relative to allowables.

	Gross Alpha	Beta-Gamma	Radium	Uranium	Groundwater All-pathways
ST1	9.67E-03	9.90E-02	2.48E-05	7.37E-12	3.36E-02
ST2	1.86E-02	4.55E-02	4.58E-05	1.31E-11	7.28E-02
ST5	4.69E-02	1.78E-02	2.32E-04	3.53E-11	1.66E-01
ST125	7.53E-02	1.62E-01	3.04E-04	5.60E-11	2.73E-01
ST3	5.31E-02	1.17E-01	4.28E-05	5.27E-11	1.83E-01
ST4	4.37E-02	1.32E-02	1.47E-04	3.83E-11	1.74E-01
ST34	9.67E-02	1.28E-01	1.90E-04	9.07E-11	3.56E-01

Table 8-11 Years when peak doses and concentrations for groundwater exposure pathways are reached.

	Alpha	Beta-Gamma	Radium	Uranium	Groundwater All-pathways
ST1	2920.2	2014.1	3126.0	3126.0	2922.2
ST2	2924.2	2014.1	3126.0	3126.0	2930.2
ST5	2920.2	2014.1	3126.0	3126.0	2924.2
ST125	2920.2	2014.1	3126.0	3126.0	2926.2
ST3	2998.2	3046.2	3126.0	3126.0	3000.2
ST4	3004.2	2502.9	3126.0	3126.0	3016.2
ST34	3000.2	2548.2	3126.0	3126.0	3008.2

Doses, concentrations and allowable values from groundwater pathways for Slit Trenches 1, 2 and 5 and their sum are plotted in Figures 8-21 through 8-25 from the years 1995 to 3130. Doses, concentrations and allowable values from groundwater pathways for Slit Trenches 3 and 4 and their sum are plotted in Figures 8-26 through 8-30.

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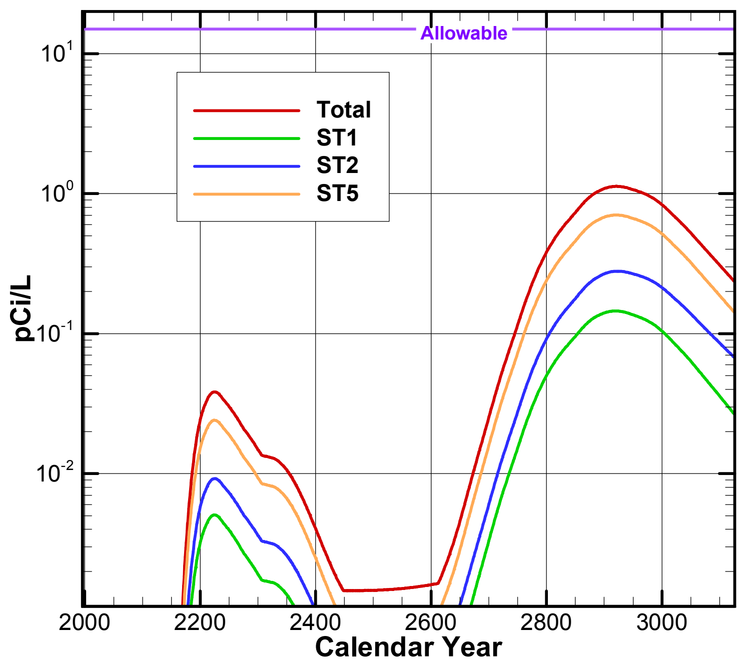

Figure 8-21 Gross alpha concentrations from Slit Trenches 1, 2 and 5.

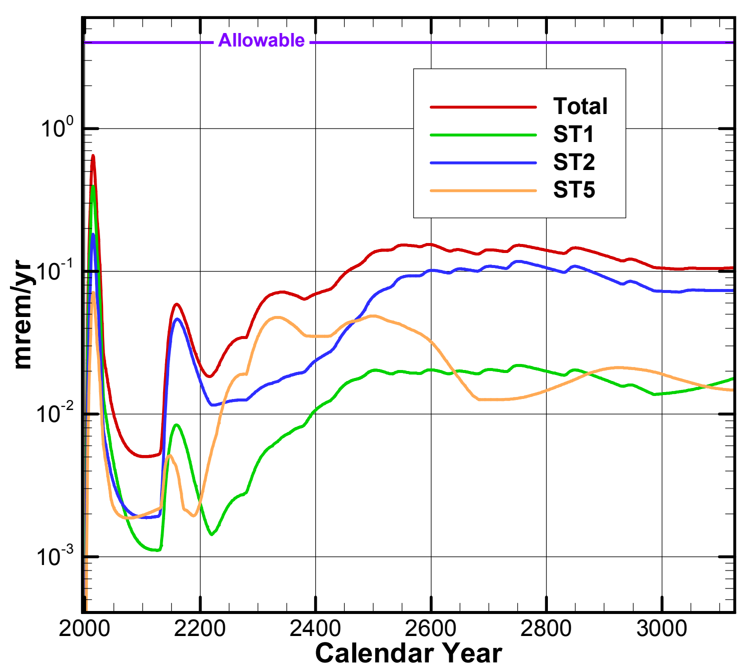

Figure 8-22 Beta-gamma doses from Slit Trenches 1, 2 and 5.

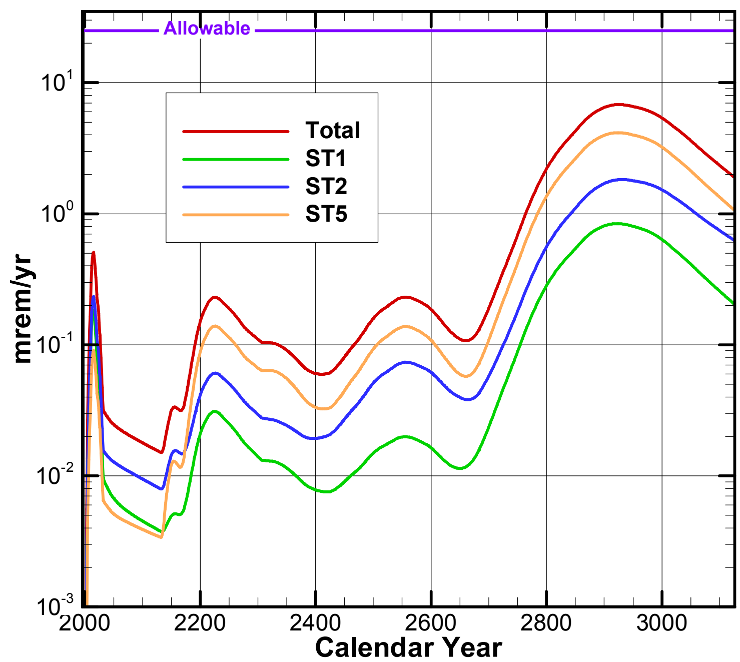

Figure 8-23 Groundwater all-pathways doses from Slit Trenches 1, 2 and 5.

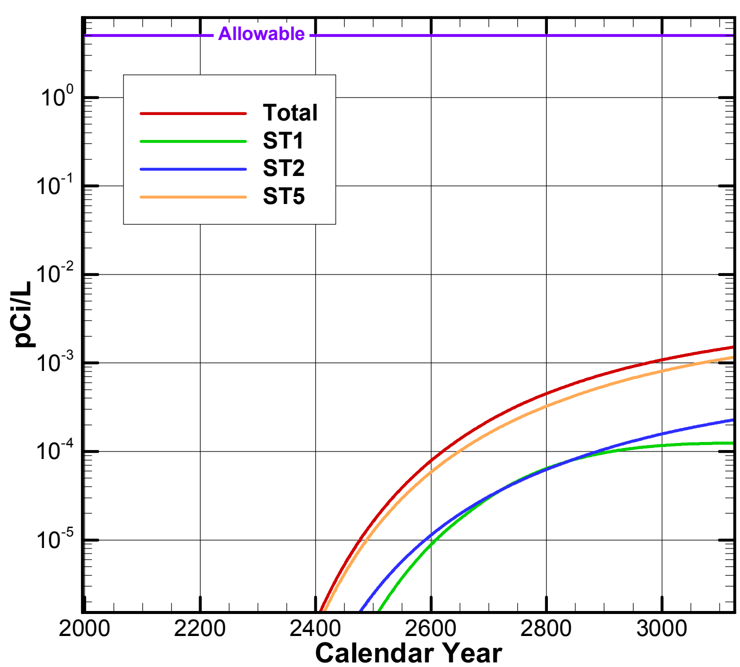

Figure 8-24 Radium concentrations from Slit Trenches 1, 2 and 5.

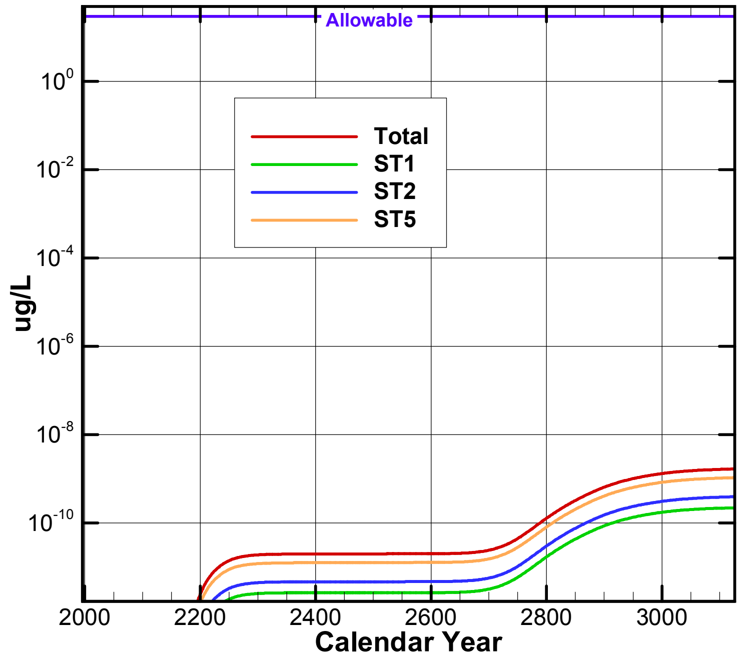

Figure 8-25 Uranium concentrations from Slit Trenches 1, 2 and 5.

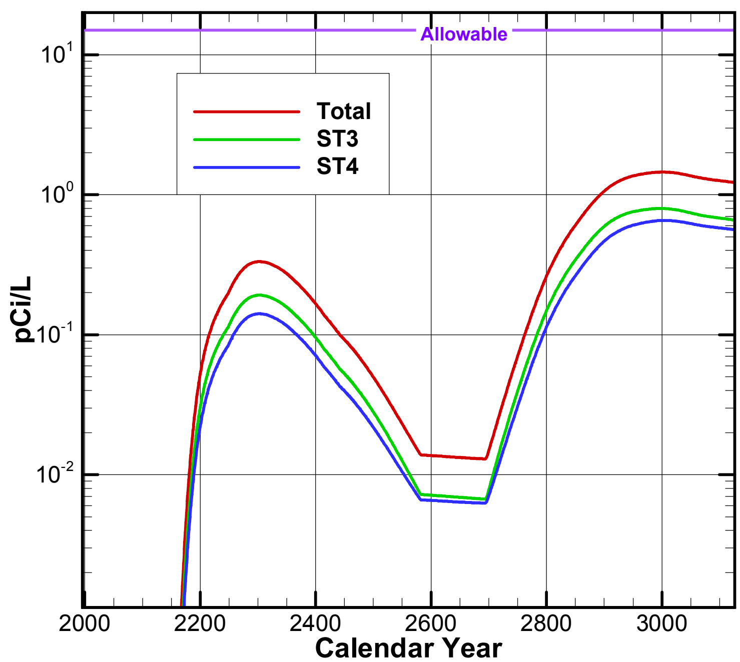

Figure 8-26 Gross alpha concentrations from Slit Trenches 3 and 4.

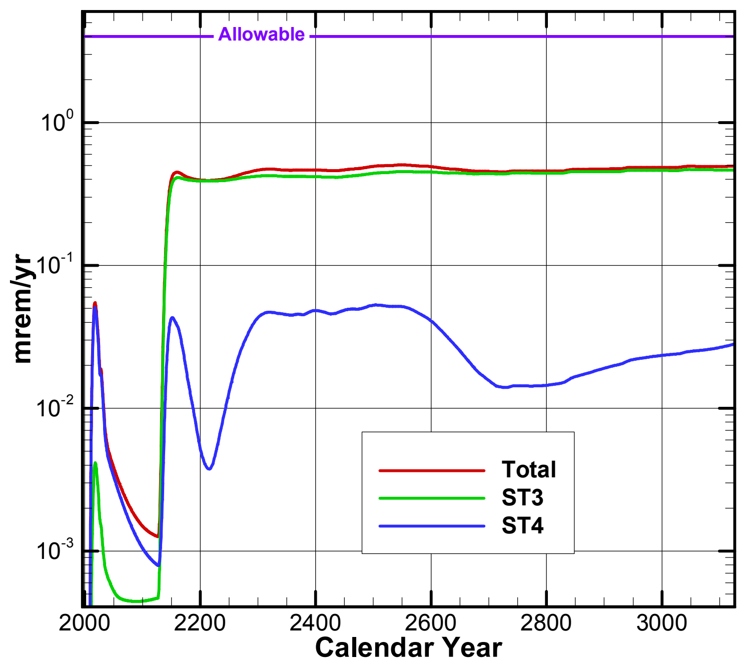

Figure 8-27 Beta-gamma doses from Slit Trenches 3 and 4.

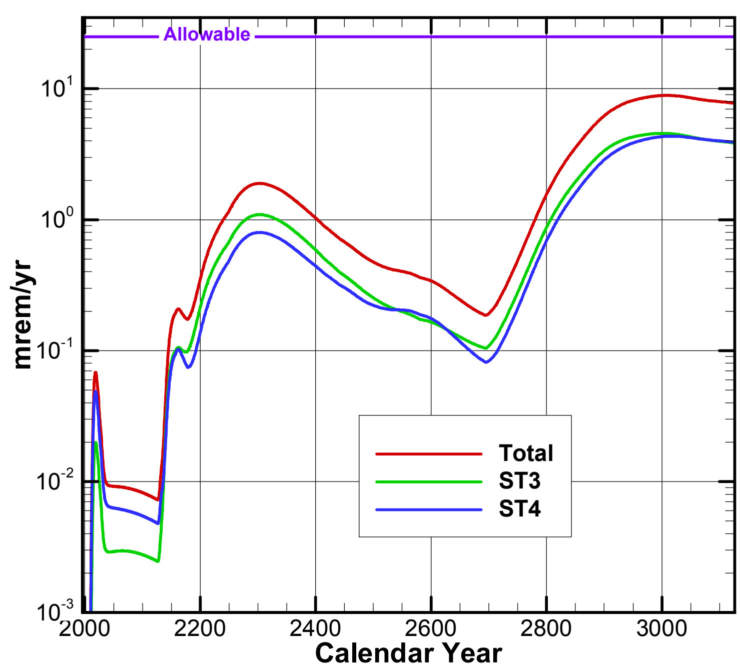

Figure 8-28 Groundwater all-pathways doses from Slit Trenches 3 and 4.

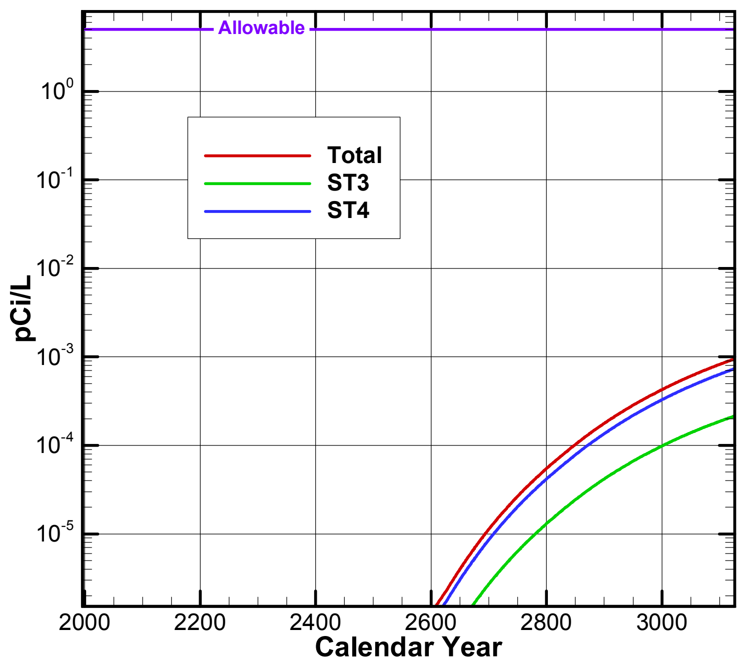

Figure 8-29 Radium concentrations from Slit Trenches 3 and 4.

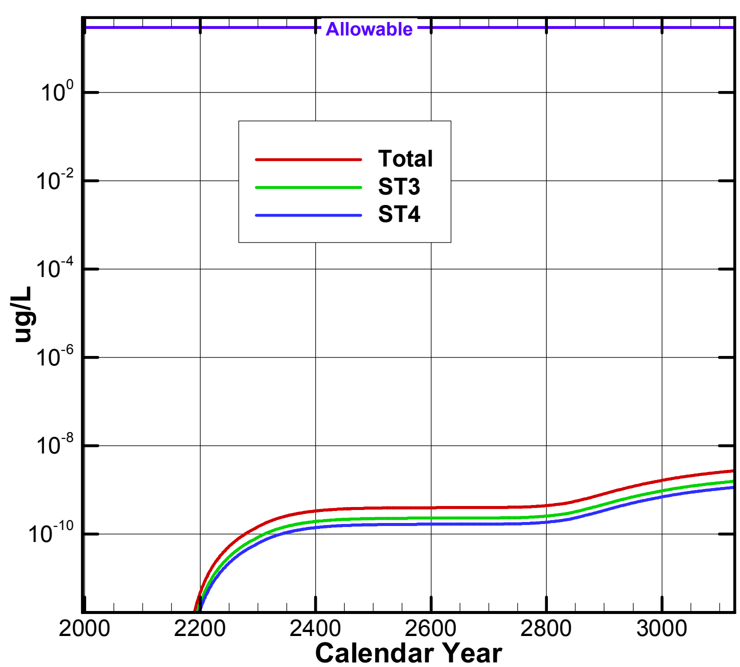

Figure 8-30 Uranium concentrations from Slit Trenches 3 and 4.

8.4.6 High-pH Treatment with 60% Effectiveness

Results from the case where high-pH treatment is 60% effective are summarized in Tables 8-12 through 8-14. Table 8-12 shows the peak doses and concentrations reached for the five groundwater exposure pathways for ST34 (treated trench segments were all within SLIT3 and SLIT4) and approximate contributions from the individual Slit Trenches.

Table 8-13 shows the peak dose or concentration for each groundwater exposure pathway divided by the allowable value to give a relative performance index. In all instances, the closest approach to an allowable value is reached for the groundwater all-pathways analysis. The radionuclide chains that contribute the most to the maximum groundwater all-pathways dose are Np-237 and U-235. For ST34, Np-237 accounted for 11.1 mrem/yr and U-235 2.0 mrem/yr of the total maximum dose of 13.2 mrem/yr.

Table 8-14 shows the years in which the peak dose or concentration were reached. Note that the uranium and radium peaks are reached at the end of the analysis time and therefore have not reached ultimate maximum values. However, the relative performance indices for these two pathways are much less than the indices for the other three exposure pathways.

For the Slit Trench set ST34, Table 8-15 shows a comparison of the dose and concentration results for the 60% treatment efficiency assumption versus the best estimate case assumption of 90% treatment efficiency. The largest doses are for the All-pathways, where the reduction in treatment efficiency increased the overall dose from 8.9 mrem/yr to 13.2 mrem/yr.

Table 8-12 Peak doses and concentrations for groundwater exposure pathways (60% effective high-pH treatment).

	Gross Alpha (pCi/L)	Beta-Gamma (mrem/yr)	Radium (pCi/L)	Uranium (μg/L)	Groundwater All-pathways (mrem/yr)
Allowable	15 pCi/L	4 mrem/yr	5 pCi/L	30 μg/L	25 mrem/yr
ST3	1.24E+00	4.72E-01	2.14E-04	2.22E-09	7.00E+00
ST4	9.88E-01	5.60E-02	7.35E-04	1.62E-09	6.29E+00
ST34	2.23E+00	5.12E-01	9.49E-04	3.84E-09	1.32E+01

Table 8-13 Peak doses and concentrations for groundwater exposure pathways relative to allowables (60% effective high-pH treatment).

	Gross Alpha	Beta-Gamma	Radium	Uranium	Groundwater All-pathways
ST3	8.27E-02	1.18E-01	4.28E-05	7.40E-11	2.80E-01
ST4	6.59E-02	1.42E-02	1.47E-04	5.40E-11	2.52E-01
ST34	1.49E-01	1.28E-01	1.90E-04	1.28E-10	5.28E-01

Table 8-14 Years when peak doses and concentrations for groundwater exposure pathways are reached (60% effective high-pH treatment).

	Alpha	Beta-Gamma	Radium	Uranium	Groundwater All-pathways
ST3	2956.2	3044.2	3126.0	3126.0	2960.2
ST4	2966.2	2512.9	3126.0	3126.0	2980.2
ST34	2960.2	2546.2	3126.0	3126.0	2970.2

Table 8-15 Peak doses and concentrations for groundwater exposure pathways for 90% and 60% high-pH treatment efficiencies

	Gross Alpha (pCi/L)	Beta-Gamma (mrem/yr)	Radium (pCi/L)	Uranium (μg/L)	Groundwater All-pathways (mrem/yr)
Allowable	15 pCi/L	4 mrem/yr	5 pCi/L	30 μg/L	25 mrem/yr
90% ST34	1.45E+00	5.06E-01	9.49E-04	2.72E-09	8.90E+00
60% ST34	2.23E+00	5.12E-01	9.49E-04	3.84E-09	1.32E+01

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APPENDIX A FINAL SLIT TRENCH INVENTORIES

This appendix contains a listing of the radionuclide inventories (in Curies) for each inventory group requiring groundwater pathway analyses for the center set of slit trenches SLIT1, SLIT2, SLIT3, SLIT4, and SLIT5. This set of radionuclides is the same set analyzed in the PA (WSRC, 2008) which was developed after a screening analysis described in PA Section 4.1.2.1 Groundwater Screening.

The tables provided show the inventory values to three significant figures. However, for SLIT4 more significant digits were employed to properly assign inventories to SLIT4-Unit~North, otherwise some negative inventories would have been assigned. These inventory values were employed in the Aquifer analyses discussed in Chapter 5 and the performance evaluations discussed in Chapter 6. These values correspond to those given in WITS and represent their final best estimate values. Inventory variance of up to 5% can occur and this possible variance has been addressed within Chapter 7 as a sensitivity variable.

Historically, waste generators have revised waste characterizations which in turn affect the final inventories. If the final inventories vary by five percent or less, the performance measures and objectives will not be challenged, because well concentrations and doses for these analyses are linear functions of the final inventory and because the well concentrations and doses in this analysis are slightly below the performance measures and objectives (see Table 1-1 and Table 1-2).

Table A-1 Inventory in Curies for special waste forms that appear only in SLIT1 and SLIT2-Unit 1.

Nuclide	SLIT1	SLIT2-Unit1
H-3_Concrete	3.87E+00	
I-129_F.CG.8		5.15E-05
I-129_F.Dowex.21K		4.41E-03
I-129_H.Filtercake	2.77E-07	
U-234_MGlass		2.80E+00
U-235_MGlass		1.87E-01
U-236_MGlass		1.42E-01
U-238_MGlass		1.05E+01

Table A-2 Inventory in Curies for SLIT1, SLIT2 and SLIT3.

Nuclide	SLIT1	SLIT2-Unit1	SLIT2-UnitA	SLIT3-Unit~North	SLIT3-UnitA	SLIT3-UnitB	SLIT3-UnitC	SLIT3-UnitD	SLIT3-UnitE	SLIT3-UnitF
Am-241	3.76E-02	1.58E-01	1.39E-03	2.85E-01	2.04E-02	1.72E-02	2.66E-02	1.16E-03	5.26E-02	7.77E-04
Am-243	6.13E-05	1.48E-03	2.09E-04	2.96E-04	3.48E-04	8.46E-04	5.29E-06	2.39E-04	6.57E-04	
C-14	8.92E-03	4.55E-02	2.69E-04	5.48E-03	3.02E-04	1.60E-04	2.69E-03	8.91E-04	6.69E-03	2.54E-03
C-14_NR.Pump	5.22E-02	7.68E-02					9.54E-04		4.86E-03	
Cf-249	6.66E-06	4.25E-05	5.81E-04	1.21E-05	2.67E-04	4.97E-05	6.08E-09		3.60E-06	
Cf-251	6.59E-05	1.88E-04	4.81E-04	5.15E-05	2.15E-04	6.66E-05	2.25E-05	4.22E-06	1.80E-05	
Cl-36		1.05E-05		2.10E-06						
Cm-244	3.84E-02	1.09E-01	1.55E-03	1.80E-01	1.13E-02	1.13E-01	2.03E-03	1.39E-03	1.86E-02	
Cm-245	2.74E-07	2.68E-06	2.34E-07	2.05E-05	4.14E-07	9.54E-06	2.00E-06	3.04E-07	1.60E-04	
Cm-246	1.53E-06	1.90E-05	2.87E-06	1.76E-05	4.71E-06	5.55E-05	3.44E-06	3.28E-06	6.78E-06	
Cm-247	1.43E-06	2.46E-09	1.41E-11	8.02E-09	2.31E-11	4.97E-05	2.00E-13	1.61E-11	3.17E-11	
Cm-248	1.43E-06	1.68E-06	2.41E-05	2.46E-16	1.11E-05	4.97E-05	9.07E-17		1.27E-07	
H-3	8.47E-01	1.06E+00	4.74E-03	3.72E-01	1.05E-01	2.67E-02	3.07E-02	3.33E-02	2.85E-01	
H-3_ETF.Carbon										2.77E-01
I-129	1.99E-05	1.90E-05	7.19E-07	3.32E-05	8.03E-07	1.43E-06	3.56E-06	3.70E-07	5.83E-06	
I-129_ETF.Carbon										1.64E-02
I-129_ETF.GT.73		8.64E-05							4.03E-05	
I-129_F.Filtercake	8.14E-05	3.45E-04			1.17E-05					
I-129_H.CG.8		1.18E-04								
I-129_Mk50A										
K-40	4.12E-03	3.21E-06		5.30E-06						
Mo-93	1.15E-05	3.40E-07								
Nb-94	1.08E-03	2.26E-03		5.39E-05	1.51E-06		1.91E-05		5.90E-04	
Ni-59	2.24E-02	3.64E-02	4.11E-05	7.78E-03	6.35E-05	1.46E-05	3.13E-04	2.20E-05	5.14E-03	1.12E-03
Np-237	1.18E-03	1.87E-03	1.99E-04	1.06E-02	1.27E-04	7.18E-05	6.01E-04	9.16E-05	6.94E-03	2.01E-04
Pd-107	1.10E-07	1.83E-10								
Pu-238	3.27E-01	6.21E-01	2.60E-02	1.41E+00	8.15E-01	8.17E-02	7.37E-01	1.82E-02	8.63E-01	1.13E-02
Pu-239	2.56E-02	1.97E-01	1.49E-03	5.23E-01	1.08E-01	5.58E-02	1.94E-01	6.12E-04	9.98E-02	4.54E-03
Pu-240	7.27E-03	7.56E-02	1.21E-03	1.39E-01	4.40E-02	1.78E-02	4.53E-02	7.80E-04	2.71E-02	
Pu-241	2.23E-01	2.22E+00	1.98E-02	3.60E+00	2.08E+00	2.30E-01	1.71E+00	1.01E-02	1.23E+00	1.17E-02
Pu-242	1.11E-04	1.02E-03	1.74E-05	6.20E-03	2.53E-05	4.73E-04	3.25E-04	1.64E-05	5.29E-04	7.70E-05
Pu-244	2.35E-15	5.10E-15		1.17E-16			4.29E-17		2.19E-16	
Ra-226	3.18E-03	6.49E-06							2.25E-05	
Se-79	2.70E-04	5.83E-04		6.18E-03	1.69E-06		5.33E-06	2.66E-10	1.22E-04	
Sn-126	1.82E-04	2.14E-06		8.96E-05	6.78E-06		9.64E-09	3.37E-11	1.06E-04	
Sr-90	3.24E+00	4.24E+00	4.65E-01	1.95E+01	8.17E-01	9.79E-01	2.51E-01	4.97E-01	9.46E+00	1.15E-03
Sr-90_Mk50A										
Tc-99	5.31E-03	1.89E-02	1.30E-03	1.02E-02	1.71E-03	1.84E-03	1.79E-03	4.00E-03	1.70E-02	2.15E-03
Tc-99_Mk50A										
Th-230	2.87E-04			1.85E-05					2.25E-05	
Th-232	2.34E-03	3.53E-06		2.02E-05	6.80E-07		9.07E-14		3.35E-05	
U-233	6.22E-03	2.71E-02	6.30E-05	8.96E-02	1.40E-02	7.76E-06	2.80E-04	8.40E-04	6.96E-03	7.70E-05
U-234	7.69E-02	2.31E-01	1.28E-01	6.57E-01	2.41E-01	8.64E-02	1.20E-02	3.49E-01	4.04E-01	1.32E-03
U-235	6.14E-03	2.16E-02	1.00E-02	2.18E-02	1.58E-02	5.24E-03	3.00E-04	6.92E-03	8.16E-03	
U-235_Paducah.Cask										
U-236	3.27E-03	5.01E-03	6.49E-03	1.44E-02	8.24E-03	2.20E-03	1.86E-03	9.79E-03	2.74E-03	
U-238	1.49E-01	6.22E-01	7.53E-01	1.27E-01	9.35E-01	3.53E-01	3.62E-03	1.54E-02	1.87E-02	3.09E-04
Zr-93	2.71E-05	2.26E-05		8.60E-07			1.91E-07		9.73E-07	

Table A-3 Inventory in Curies for SLIT4.

Nuclide	SLIT4-Unit~North	SLIT4-Unit~South	SLIT4-UnitA	SLIT4-UnitB	SLIT4-UnitC	SLIT4-UnitD	SLIT4-UnitE	SLIT4-UnitF	SLIT4-UnitG	SLIT4-UnitH	SLIT4-UnitI
Am-241	9.13E-02	1.02E-02	5.64E-02	2.96E-02	5.89E-03	1.87E-03	1.42E-03	6.51E-04	4.30E-02	1.37E-02	4.61E-02
Am-243	7.17E-04	4.45E-06	4.31E-07	1.07E-04	1.29E-04	1.04E-04	3.07E-04		2.26E-06	5.40E-05	1.55E-04
C-14	1.88E-02	3.44E-03	3.62E-03	1.11E-03	9.33E-04	1.49E-03	3.18E-03	3.08E-05	2.81E-03	4.36E-04	3.48E-03
C-14_NR.Pump					2.29E-02		1.30E-03				
Cf-249	1.44E-08	2.64E-09		1.11E-04	4.63E-06		6.47E-16		1.51E-07	3.07E-06	6.65E-06
Cf-251	3.30E-08	6.07E-09		1.07E-04	7.55E-06	5.95E-07	2.59E-17	1.26E-05	3.61E-07	3.23E-05	6.15E-06
Cl-36											
Cm-244	2.01E-02	4.39E-03	4.99E-05	1.26E-02	2.44E-02	1.49E-03	1.94E-03		1.47E-04	5.08E-03	4.72E-01
Cm-245	9.58E-06	6.75E-08		9.55E-05	2.36E-06	1.06E-07	3.22E-07		4.01E-06	2.75E-06	1.25E-04
Cm-246	1.75E-05	5.92E-08		1.15E-05	7.50E-07	1.40E-06	4.22E-06		4.02E-06	1.33E-07	1.84E-04
Cm-247	4.36E-11	3.00E-15		5.59E-04	6.88E-16	6.91E-12	2.08E-11		6.13E-14	2.75E-06	3.34E-05
Cm-248	1.23E-15	2.04E-16			1.92E-07		1.23E-16			3.23E-17	2.12E-09
H-3	8.10E+00	2.07E-02	1.02E-01	3.28E-02	7.10E-03	2.24E-01	6.66E-03	1.53E-03	9.02E-03	2.70E-03	5.70E-02
H-3_ETF.Carbon											
I-129	6.37E-06	1.04E-06	1.14E-07	1.92E-05	1.04E-06	5.34E-07	4.50E-06	2.71E-11	1.41E-06	5.73E-08	1.12E-06
I-129_ETF.Carbon											
I-129_ETF.GT.73										6.16E-05	
I-129_F.Filtercake		7.70E-06									
I-129_H.CG.8	3.38E-05										
I-129_Mk50A											
K-40	1.32E-08				6.54E-06						
Mo-93											
Nb-94	2.77E-04	4.30E-05			4.59E-04		2.59E-05		1.64E-04	6.91E-06	3.86E-07
Ni-59	8.04E-03	2.56E-03	2.39E-03	1.35E-06	6.88E-03	1.66E-05	4.12E-04		4.11E-04	1.16E-04	1.39E-06
Np-237	5.11E-03	8.24E-04	1.73E-05	4.56E-05	1.11E-03	4.92E-05	4.65E-05	3.05E-04	2.03E-05	3.41E-05	5.57E-05
Pd-107											
Pu-238	1.54E+00	1.16E-01	1.40E-02	2.82E-01	5.18E-02	8.93E-03	8.45E-01	2.13E-02	2.40E-02	9.54E-02	2.77E-01
Pu-239	1.76E-01	7.08E-02	2.12E-01	1.52E-01	1.13E-02	5.82E-03	9.65E-04	9.92E-04	1.73E-01	5.76E-02	1.55E-01
Pu-240	5.40E-02	1.68E-02	4.63E-02	4.92E-02	3.56E-03	2.33E-03	1.04E-03	1.12E-05	4.04E-02	1.31E-02	3.87E-02
Pu-241	2.07E+00	4.05E-01	7.46E-01	7.71E-01	6.41E-02	2.17E-02	2.47E-02	1.99E-02	7.29E-01	4.03E-01	1.04E+00
Pu-242	2.05E-03	9.54E-05	2.46E-03	1.13E-02	9.30E-06	4.21E-05	1.17E-05	1.42E-05	1.96E-03	4.67E-04	1.39E-03
Pu-244	5.83E-16	9.66E-17			1.03E-15		5.83E-17			1.53E-17	
Ra-226	2.50E-07	2.04E-12			7.74E-06			2.02E-05			
Se-79	9.16E-04	4.65E-05		6.04E-07	3.44E-09	3.33E-10	6.54E-06		4.75E-07	1.34E-05	
Sn-126	1.80E-05	8.44E-06		8.73E-10	3.07E-08	4.11E-11	1.00E-08		1.21E-08	1.86E-10	
Sr-90	1.35E+01	1.30E+00	3.87E-01	9.03E-02	4.31E-01	2.00E-01	5.83E-01	4.61E-04	8.28E-01	2.49E-01	8.68E-02
Sr-90_Mk50A											
Tc-99	8.35E-03	7.03E-04	1.63E-03	9.49E-03	1.54E-03	1.61E-02	7.11E-04	1.17E-03	3.82E-03	2.08E-04	7.60E-03
Tc-99_Mk50A											
Th-230	1.43E-04	1.24E-04			2.59E-08					1.63E-06	8.00E-06
Th-232	1.59E-04	1.24E-04	3.31E-11	4.85E-09	1.09E-06		1.23E-13			1.63E-06	8.01E-06
U-233	2.50E-01	1.93E-01	6.37E-06	5.65E-04	2.32E-04	8.68E-05	1.81E-04	6.15E-06	2.99E-05	2.82E-03	1.32E-04
U-234	8.61E-01	1.64E+00	5.78E-03	2.67E-03	5.39E-01	1.95E-01	1.82E-01	3.35E-01	4.93E-01	2.44E-03	2.32E-03
U-235	2.79E-02	5.39E-02	5.72E-10	1.50E-04	1.06E-02	4.01E-03	5.32E-03	6.76E-03	9.68E-03	1.02E-04	5.97E-06
U-235_Paducah.Cask											
U-236	4.35E-03	1.24E-02	1.01E-09	1.49E-07	8.29E-07	1.20E-04	8.53E-03	1.02E-04	9.35E-06	2.81E-04	1.75E-06
U-238	8.94E-02	1.21E-02	2.66E-02	8.26E-03	1.90E-04	1.53E-02	1.93E-01	1.77E-02	3.11E-03	5.61E-04	8.53E-03
Zr-93	2.63E-06	4.58E-07			4.59E-06		2.59E-07			6.80E-08	

Table A-4 Inventory in Curies for SLIT5.

Nuclide	SLIT5-UnitA	SLIT5-UnitB	SLIT5-UnitC	SLIT5-UnitD	SLIT5-UnitE	SLIT5-UnitF	SLIT5-UnitG	SLIT5-UnitH	SLIT5-UnitI	SLIT5-UnitJ	SLIT5-UnitK	SLIT5-UnitL
Am-241	2.71E-03	3.68E-03	6.54E-02	6.27E-03	6.48E-02	2.63E-03	1.66E-03	4.82E-01	2.74E-02	9.05E-06	1.03E-04	2.12E-05
Am-243	2.73E-06	9.55E-07	6.18E-05	1.35E-05	5.50E-03	4.64E-04	2.84E-05	5.57E-03	8.44E-08			
C-14	2.81E-04	3.14E-04	1.50E-03	1.88E-04	4.67E-03	2.90E-05	3.76E-04	6.49E-05	2.84E-02	1.61E-04	5.53E-05	2.44E-04
C-14_NR.Pump			4.54E-03				4.74E-04					
Cf-249		1.14E-07	2.27E-15		1.10E-02		2.37E-16	5.09E-04	1.40E-14			
Cf-251	5.61E-05	4.82E-05	3.75E-04	3.93E-06	1.00E-02		1.56E-05	4.45E-04	5.62E-16		2.22E-05	
Cl-36		2.26E-06										
Cm-244	1.45E-03	1.15E-03	5.08E-02	5.52E-03	4.79E-01		1.13E-04	8.83E-01	9.46E-06			
Cm-245	1.49E-07	3.60E-07	8.46E-06	1.24E-06	1.57E-04		2.33E-07	3.19E-04	7.03E-10			
Cm-246	4.84E-09	3.68E-07	2.42E-06	1.97E-06	5.02E-05		4.97E-07	6.78E-04	2.81E-10			
Cm-247	2.35E-14	5.33E-14	3.94E-12	4.34E-12	7.16E-05		1.84E-12	1.06E-04	8.44E-16			
Cm-248			4.32E-16	2.12E-11	1.31E-05		4.50E-17	3.40E-04	2.67E-15			
H-3	5.84E-03	6.25E-02	1.22E-01	3.22E-02	1.63E-01	2.68E-04	7.31E-03	6.69E-03	9.15E-04	2.81E-04	1.14E-03	1.84E-04
H-3_ETF.Carbon												
I-129	5.21E-08	1.21E-06	3.65E-05	3.09E-06	5.77E-06	1.03E-10	1.49E-06	8.92E-06	1.20E-07	3.17E-12	1.31E-09	4.93E-12
I-129_ETF.Carbon												
I-129_ETF.GT.73												
I-129_F.Filtercake				7.65E-07								
I-129_H.CG.8												
I-129_Mk50A			8.18E-06									
K-40					2.89E-04							
Mo-93												
Nb-94			9.08E-05	8.98E-18	2.07E-04		9.48E-06		5.63E-04			
Ni-59	3.16E-05	1.42E-04	1.39E-03	3.95E-05	1.06E-03		1.54E-04		8.44E-03			
Np-237	1.17E-03	1.39E-03	8.67E-04	4.23E-04	9.39E-04		5.21E-04	1.57E-04	4.39E-05	1.61E-05	4.82E-06	2.44E-05
Pd-107												
Pu-238	8.67E-02	1.01E-01	3.71E-01	3.34E-02	1.07E+00	1.26E-04	5.30E-02	2.36E+01	1.81E-02	1.51E-05	1.05E-02	9.69E-04
Pu-239	4.55E-03	1.36E-02	2.89E-01	2.44E-02	2.49E-01	3.02E-02	4.17E-03	9.65E-01	1.22E-01	1.61E-05	2.30E-04	1.94E-03
Pu-240	4.79E-04	3.35E-03	5.97E-02	5.18E-03	4.46E-02	8.97E-02	2.28E-03	2.42E-01	2.77E-02	1.61E-05	5.85E-06	4.69E-04
Pu-241	7.70E-02	1.29E-01	1.19E+00	1.31E-01	7.07E-01	1.71E+00	3.45E-02	4.00E+00	4.84E-01	1.24E-04	4.26E-03	1.01E-02
Pu-242	5.53E-05	1.06E-04	2.22E-03	9.80E-06	1.29E-03	1.41E-04	2.68E-05	7.92E-05	1.11E-03	1.53E-09	3.48E-06	3.56E-09
Pu-244			2.04E-16		7.47E-21		2.13E-17		1.27E-15			
Ra-226				5.94E-05	2.98E-04							
Se-79	8.27E-13	6.09E-06	1.23E-09	3.74E-04	2.49E-14		1.05E-05	6.12E-06	4.22E-09			
Sn-126	3.13E-05	1.53E-12	2.32E-09	1.51E-08	7.47E-14		2.39E-10	1.04E-06	1.27E-08			
Sr-90	3.71E-02	1.07E-02	8.69E+00	1.59E-01	8.66E-01		3.70E-02	3.15E+01	1.30E-01	3.95E-05	5.35E-03	7.16E-07
Sr-90_Mk50A			7.40E+00									
Tc-99	4.27E-03	2.86E-03	1.23E-02	7.82E-04	1.83E-02	5.13E-08	2.50E-03	3.65E-03	1.48E-04	6.67E-05	6.57E-04	3.69E-06
Tc-99_Mk50A			1.79E-03									
Th-230	3.14E-08		3.40E-05	6.18E-05	2.97E-04							
Th-232	3.14E-08		3.40E-05	2.45E-06	3.88E-07		4.50E-14	4.92E-11	2.67E-12			
U-233	5.16E-03	6.67E-04	2.02E+00	7.31E-04	6.05E-04		8.17E-04	2.59E-04	5.67E-05	6.32E-05	1.88E-05	9.60E-05
U-234	4.45E-01	2.91E-02	2.11E-01	1.40E-02	1.33E-02	4.42E-04	9.25E-02	2.56E-03	1.37E-01	3.52E-01	4.01E-01	1.27E-01
U-235	9.34E-03	7.33E-04	5.90E-03	5.46E-04	6.00E-04		1.89E-03	8.41E-06	2.62E-03	6.85E-03	7.92E-03	2.47E-03
U-235_Paducah.Cask						3.92E-01						
U-236	3.06E-04	1.55E-03	9.12E-03	1.30E-03	4.67E-05		3.69E-03	4.16E-06	2.34E-03	2.61E-03	7.54E-04	4.02E-03
U-238	5.91E-03	7.10E-03	1.90E-01	9.59E-03	4.32E-03	3.05E+00	9.06E-04	5.12E-04	1.35E-03	2.22E-05	5.49E-03	8.49E-03
Zr-93			9.08E-07	2.53E-09	3.32E-11		9.48E-08		5.62E-06			

APPENDIX B VADOSE ZONE RESULTS

In this appendix selected vadose zone results are provided in support of Chapter 4. One key result of a vadose zone analysis is the creation of the mass flux to the water table versus time. This flux to the water table becomes a source term for subsequent aquifer zone analyses as discussed in Chapter 5. In the following, fractional flux is defined as the flux to the water table per unit inventory of parent buried (e.g. g-mol/yr/g-mol parent buried) and is therefore independent of units used for the inventory.

This appendix is based on results from the optional high-pH treatment case with 90% effectiveness, which previously was more extensively documented (Chapter 8). The only results that would differ from the final base case with no treatment are for those trench segments identified to receive treatment and only for those chains that were modified, i.e., Np-237, U-235, Tc-99, and I-129 and its special waste forms. Some discussion about the effects of the treatment are included below.

Figures B-1 through B-6 show selected fractional flux results for SLIT2-Unit1. Fractional fluxes for C-14, I-129, U-234 and a special waste form of each radionuclide are shown.

Figures B-7 through B-16 show fractional flux results for I-129 and Tc-99 for one inventory group in each of the Slit Trenches. The primary purpose for these figures is to show the effects of differences between the burial time and the cap time. All results are for center trench types with Case01 infiltration rates and without CDP. The inventory groups selected and the burial times are as follows:

Inventory Group	First Burial	Last Burial
SLIT1	12/21/1995	9/19/2003
SLIT2-Unit1	9/20/2001	10/22/2003
SLIT3-UnitD	3/23/2004	6/19/2007
SLIT4-UnitF	3/29/2005	9/8/2005
SLIT5-UnitD	12/13/2005	3/16/2006

Figures B-17 through B-20 show fractional flux results for I-129 and Tc-99 in SLIT1 for both center and edge trench types. The primary purpose for these figures is to show the effects from being near the edge of an operational cap versus being near the center. All results are for Case01 infiltration rates where no CDP is present.

Figures B-21 through B-40 show fractional flux results for key radionuclide chains for both sets of infiltration cases (intact and subsided) in SLIT2-Unit1. Results are for cases where no CDP is present and only for center trench types. The primary purpose for these figures is to show the effects of non-crushable container collapse that causes cap failure and greatly increased infiltration. Only chains with at least one fractional flux greater than 1E-10 are shown. In some of the cases shown (e.g., Sr-90), the container collapse can increase the peak fractional flux by 10 orders of magnitude. If the increase in the fractional flux is accompanied by an appreciable inventory, then the peak well concentration can be problematic.

Figures B-41 and B-42 show fractional flux results with and without CDP effects. Results are for SLIT2-Unit1 Case01 that involves only center trench types. Only chains with at least one fractional flux greater than 1E-10 are shown. The CDP effects are most pronounced for nuclides in the chain that do not have the greatest fractional fluxes. For the Pu-241 chain, Am-241 is affected most, but it has a very high K_d for both cases, so its fractional fluxes are much less than the 1E-10 level. For the U-235 chain, Ac-227 is the only nuclide affected because its K_d is reduced by about one-half in sand (from 1000 ml/g to 605 ml/g). However, its fractional flux is much less than the 1E-10 level.

Figures B-43 through B-45 show the importance of cap timing relative to burial time, inventory and distribution area for the Np-237 chain. Results are for inventory groups SLIT3-UnitE and SLIT4-UnitC. The Np-237 Case01 without CDP for the center trench type is plotted for each member of the chain. Each chain member (Np-237, U-233 and Th-229) has its own figure. In these figures, Fractional Mass is the mass of contaminant divided by the mass of the Np-237 parent (in its Inventory Group) that was buried. Mass is the Fractional Mass multiplied by the Np-237 inventory of its Inventory Group. Flux is the Mass divided by the footprint area of its Inventory Group. One Fractional Mass difference between the two Inventory Groups is the duration between when the waste is buried until it is covered. A relatively later covering (i.e., for SLIT3-UnitE) typically allows a higher early peak (before the cover is installed) with a lower late peak (because its residual inventory is reduced by the higher early release). The other difference is that SLIT3-UnitE receives a high pH treatment in 2125. The treatment reduces and flattens the peak. With the treatment SLIT3-UnitE exhibits the lower peak, but its fractional mass at very late times exceeds that for SLIT4-UnitC.

The input differences between the two Inventory Groups are as follows:

Inventory Group	First Burial	Last Burial	Np-237 Inventory (Ci)	Footprint Area (ft^2)
SLIT3-UnitE	7/20/04	5/9/05	6.94E-3	9813
SLIT4-UnitC	12/10/04	6/22/05	1.11E-3	3235

Because SLIT3-UnitE has a Np-237 inventory that is nearly seven times that for SLIT4-UnitC, its Mass plot always is higher than the same plot for SLIT4-UnitC. When the footprint area (SLIT3-UnitE has an area that is about three times that for SLIT4-UnitC) is also considered, the Flux plots resemble the Fractional Mass plots, although the values near the peaks for the Flux plots are relatively closer to each other.

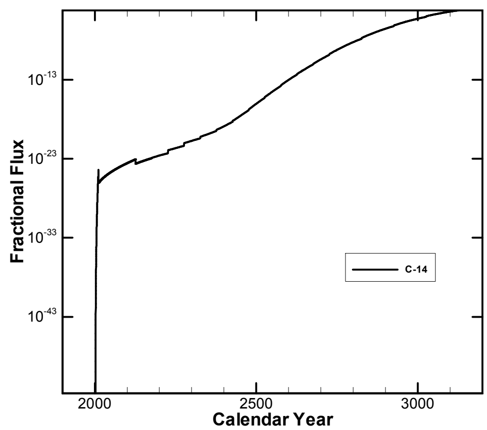

Figure B-1 C-14

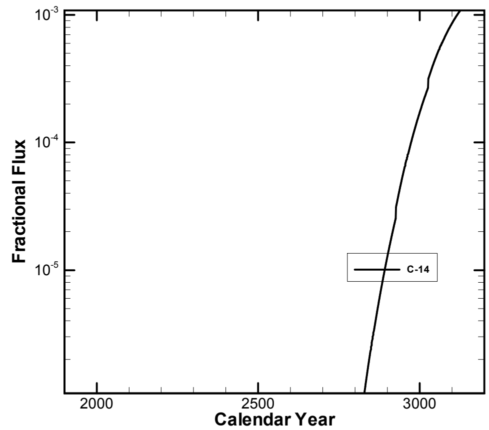

Figure B-2 C-14_NR.Pump

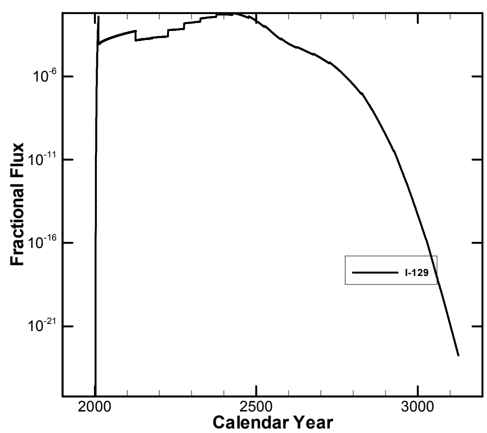

Figure B-3 I-129

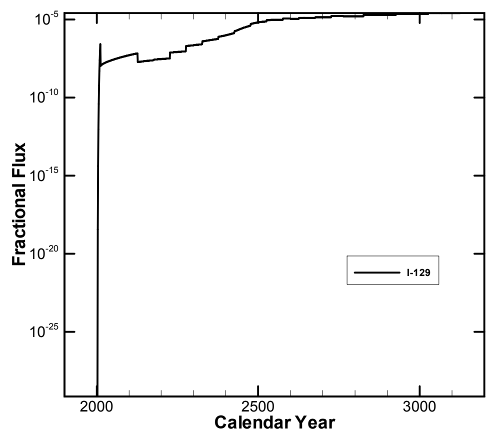

Figure B-4 I-129_ETF.GT.73

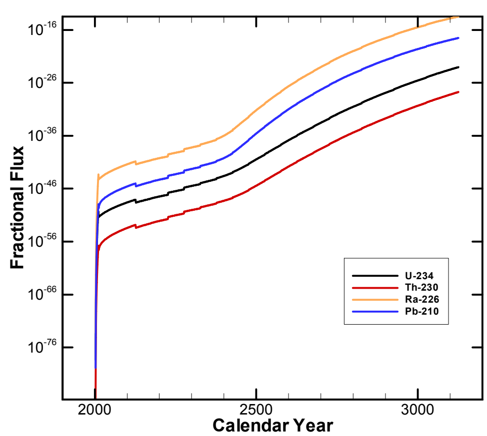

Figure B-5 U-234

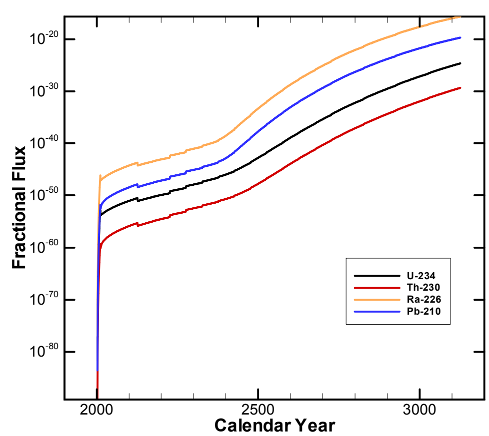

Figure B-6 U-234_Mglass

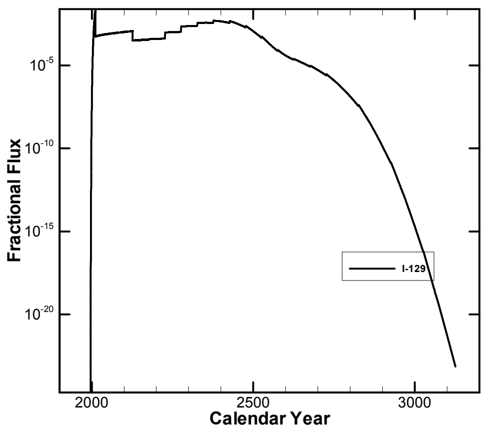

Figure B-7 ST1_I-129

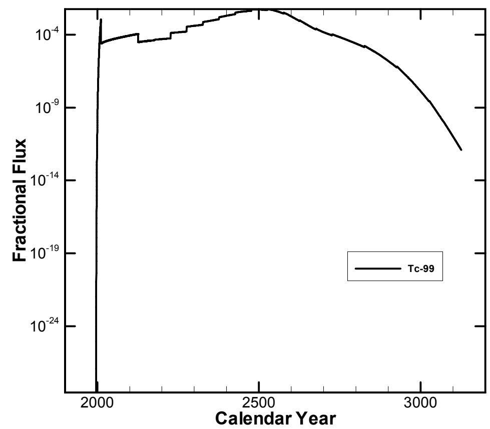

Figure B-8 ST1_Tc-99

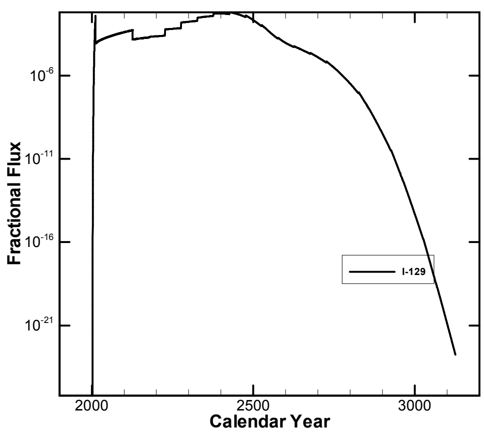

Figure B-9 ST2_I-129

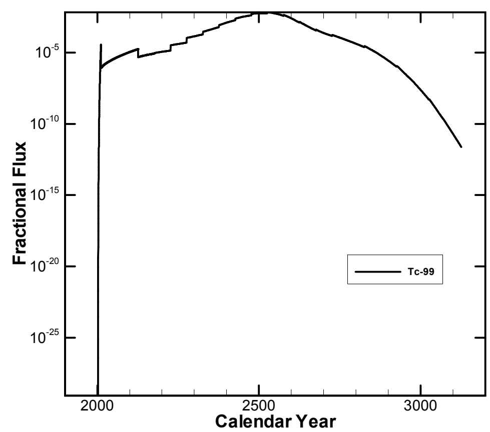

Figure B-10 ST2_Tc-99

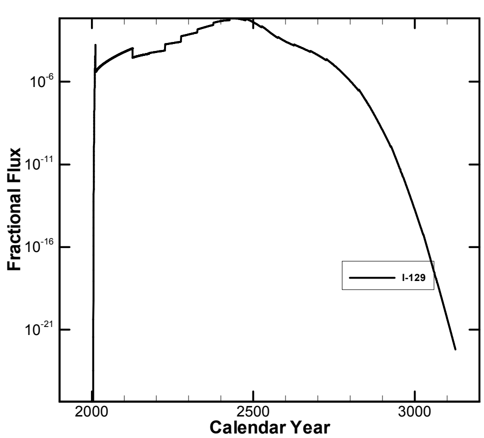

Figure B-11 ST3_I-129

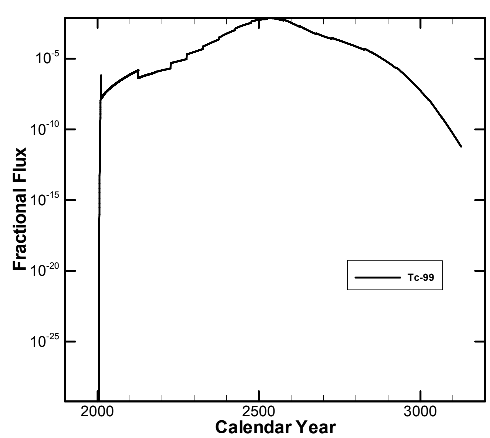

Figure B-12 ST3_Tc-99

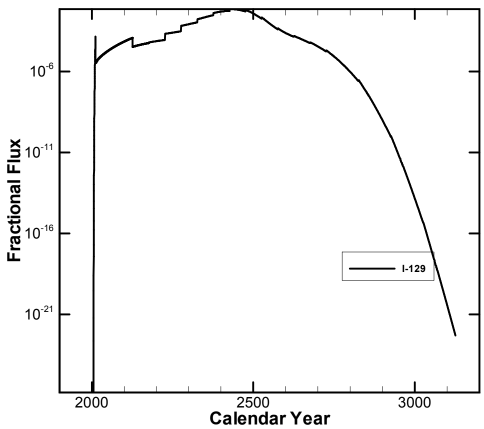

Figure B-13 ST4_I-129

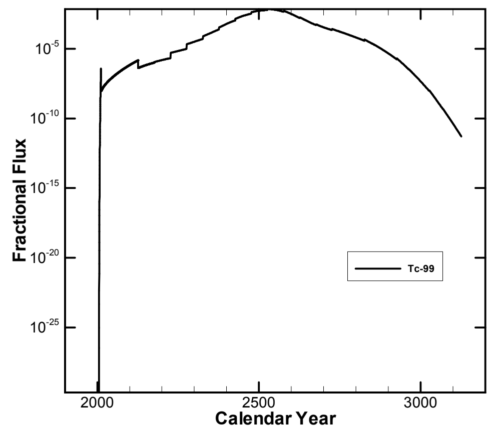

Figure B-14 ST4_Tc-99

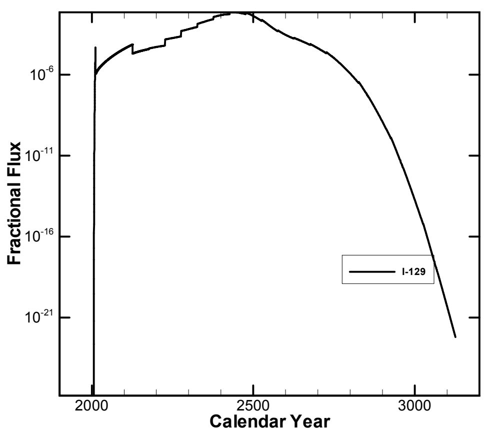

Figure B-15 ST5_I-129

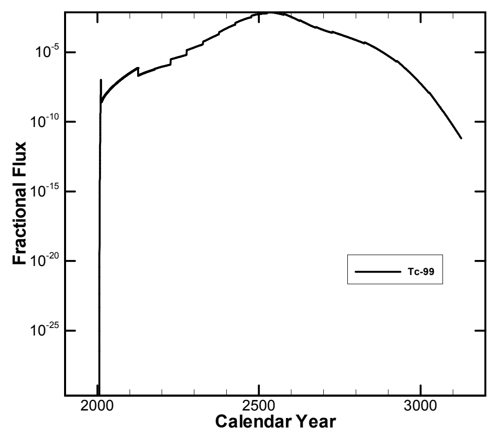

Figure B-16 ST5_Tc-99

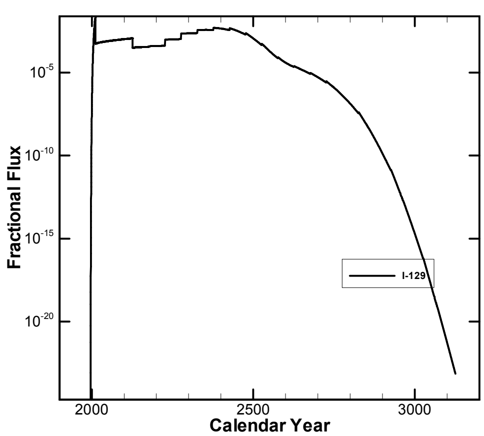

Figure B-17 Center_I-129

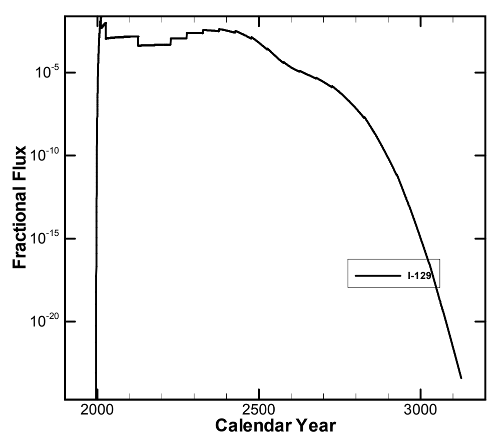

Figure B-18 Edge_I-129

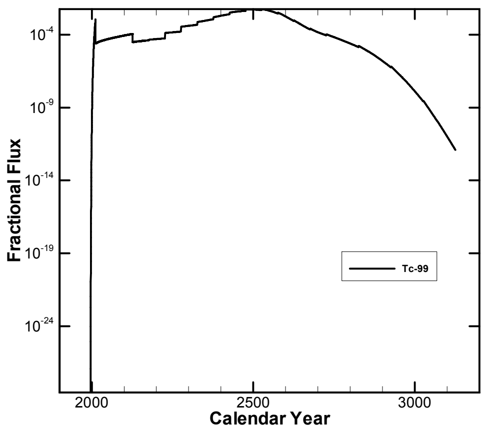

Figure B-19 Center_Tc-99

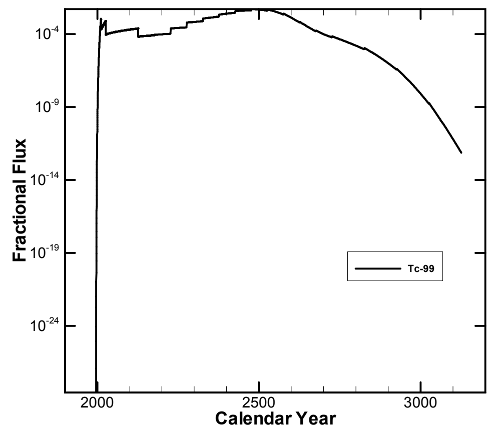

Figure B-20 Edge_Tc-99

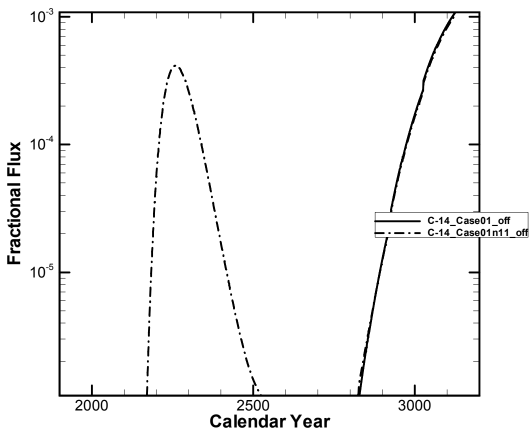

Figure B-21 C-14_NR.Pump

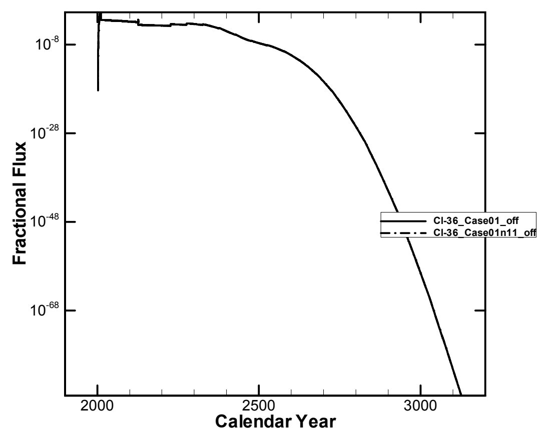

Figure B-22 Cl-36

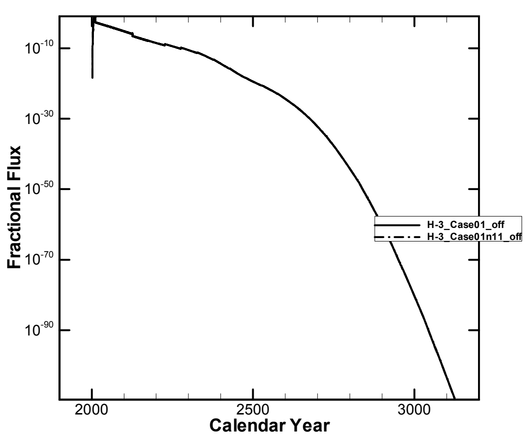

Figure B-23 H-3

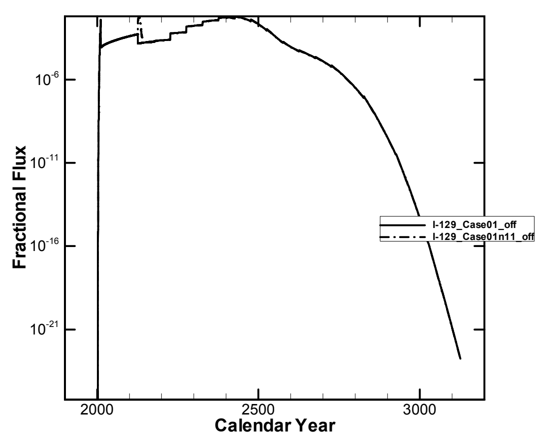

Figure B-24 I-129

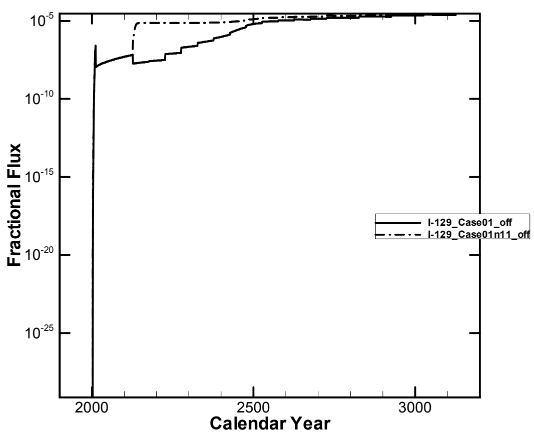

Figure B-25 I-129_ETF.GT.73

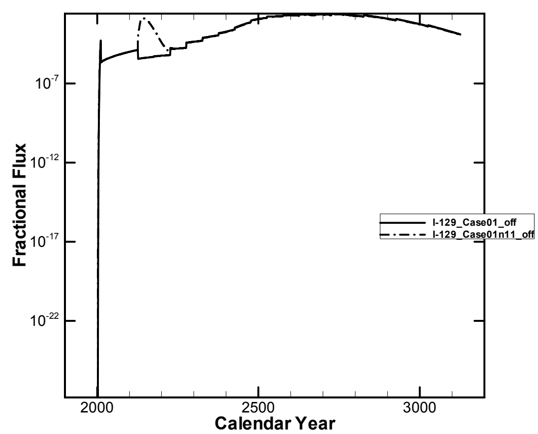

Figure B-26 I-129_F.CG.8

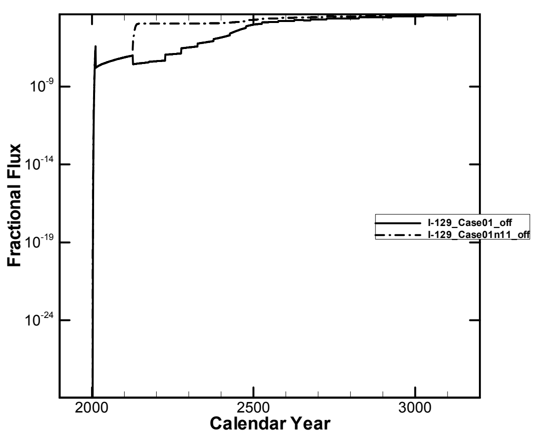

Figure B-27 I-129_F.Dowex.21K

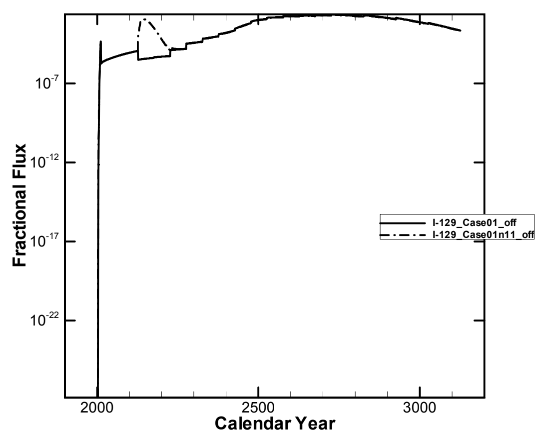

Figure B-28 I-129_F.Filtercake

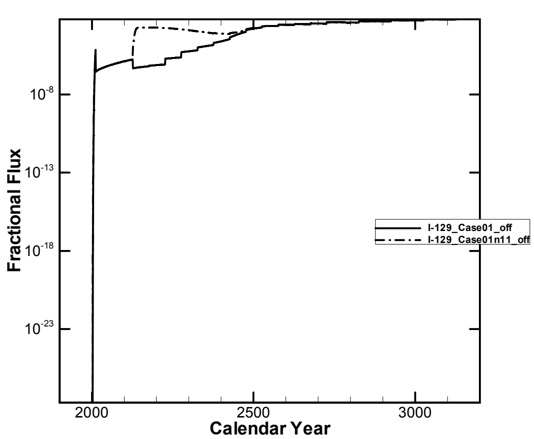

Figure B-29 I-129_H.CG.8

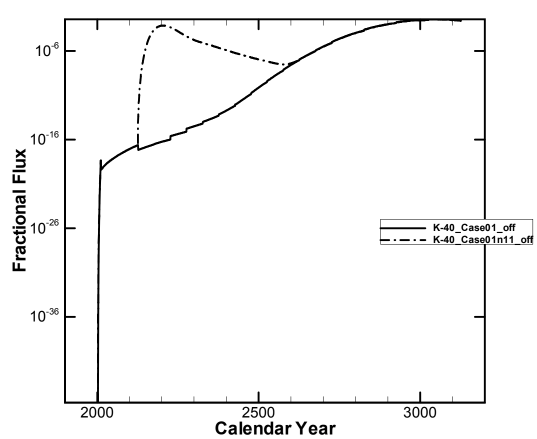

Figure B-30 K-40

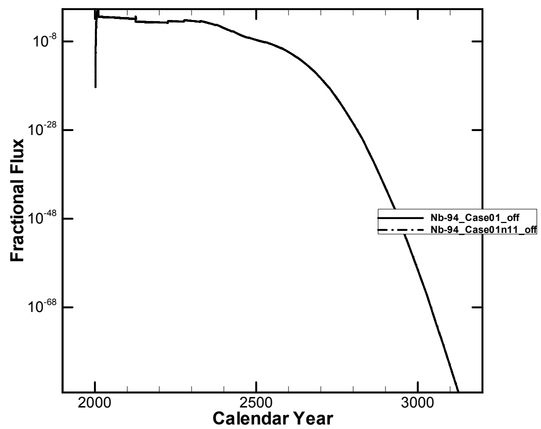

Figure B-31 Nb-94

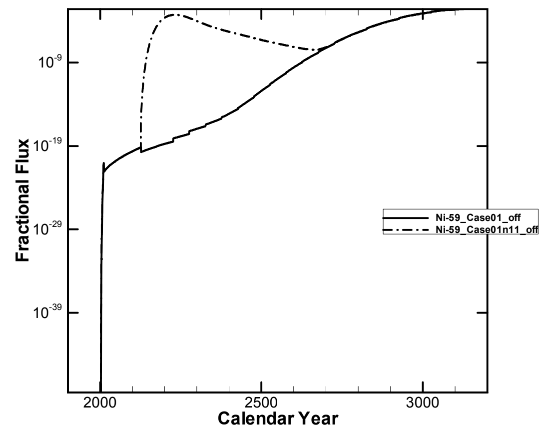

Figure B-32 Ni-59

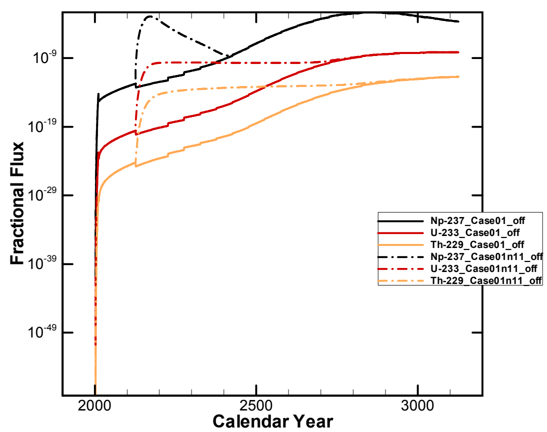

Figure B-33 Np-237

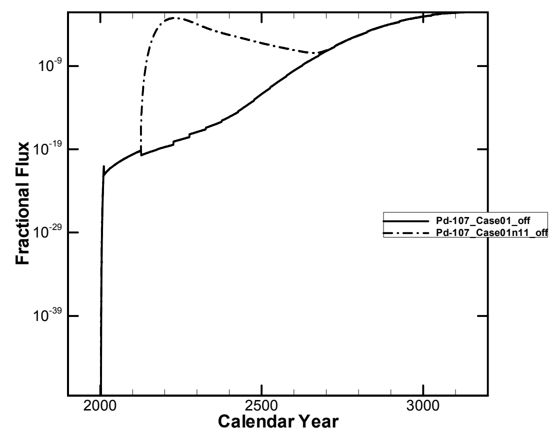

Figure B-34 Pd-107

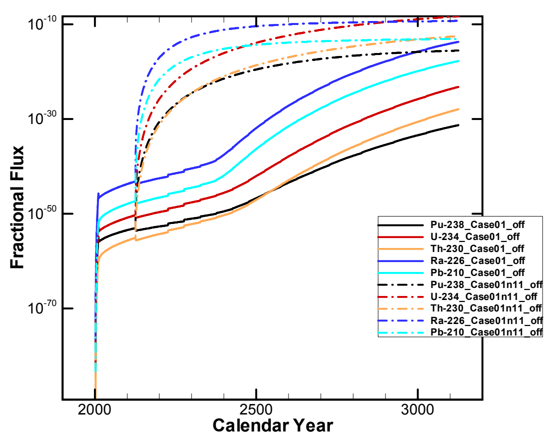

Figure B-35 Pu-238

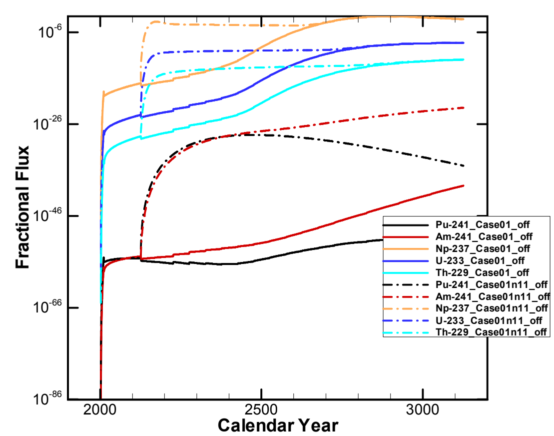

Figure B-36 Pu-241

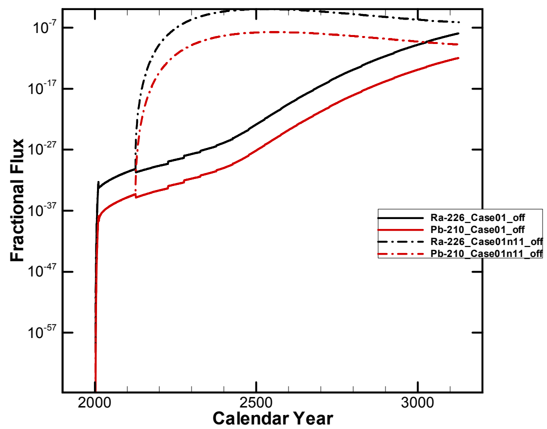

Figure B-37 Ra-226

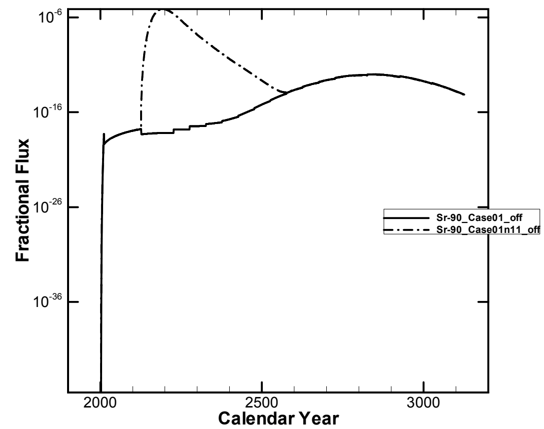

Figure B-38 Sr-90

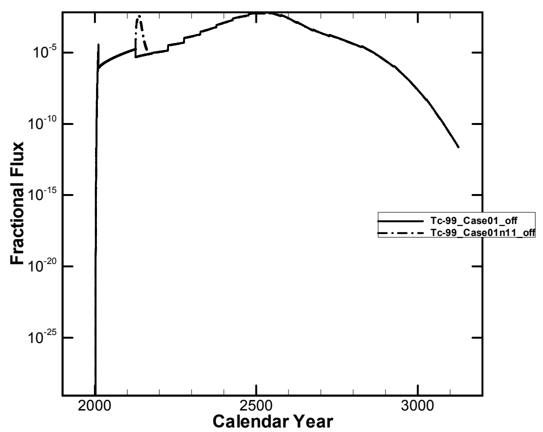

Figure B-39 Tc-99

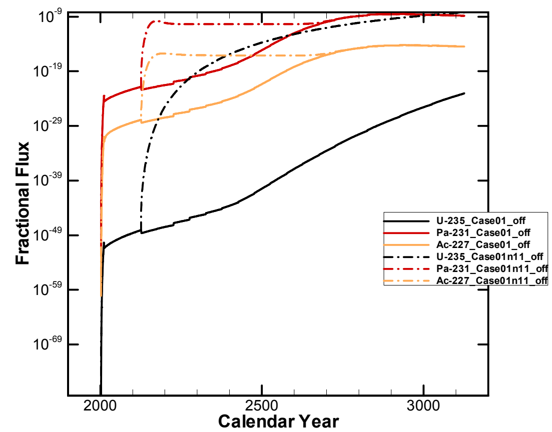

Figure B-40 U-235

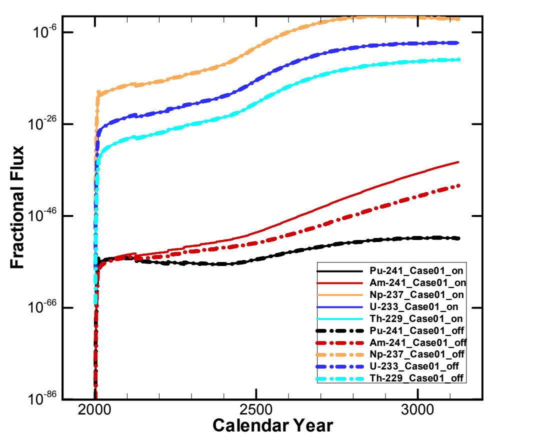

Figure B-41 Pu-241

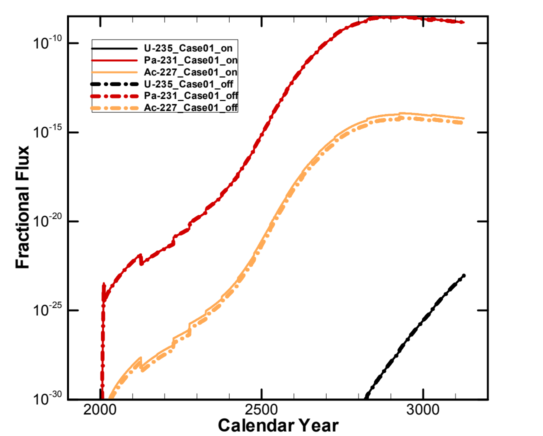

Figure B-42 U-235

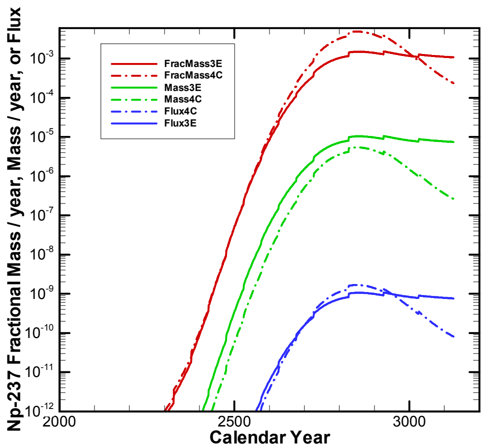

Figure B-43 Np-237

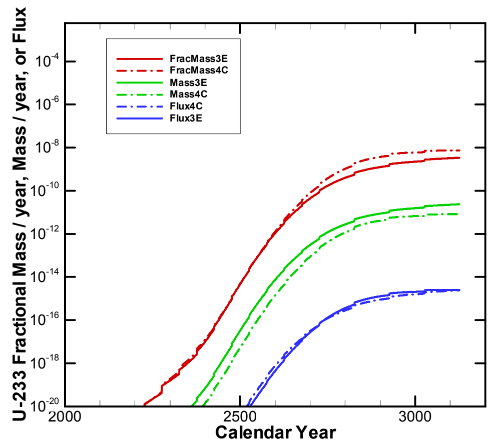

Figure B-44 U-233

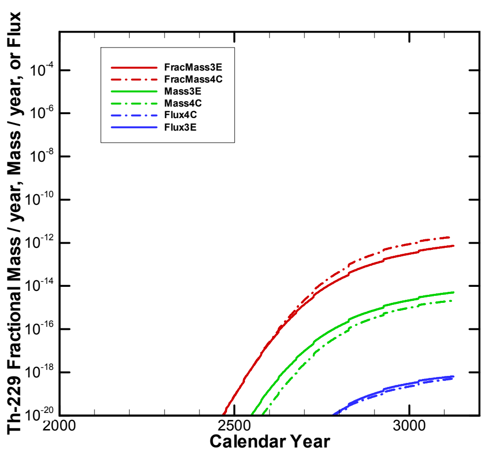

Figure B-45 Th-229

APPENDIX C AQUIFER RESULTS

In this appendix selected aquifer transport results are provided in support of Chapter 5. One key result of an aquifer zone analysis is the creation of the maximum well concentration beyond the 100 meter boundary versus time. This maximum well concentration versus time is employed in the subsequent performance evaluation analysis as discussed in Chapter 6. Where applicable, this appendix provides figures for the same set of nuclides as shown in Appendix B. The lists of figures for the two appendices are as follows:

Appendix B (vadose zone)	**Appendix C (aquifer)**
Generic vs. special waste forms	Generic vs. special waste forms
Cap timing effects	**Not applicable** – the aquifer model combines all trench segments, so no differentiation is possible
Operational cap: center trench type vs. edge trench type	**Not applicable** – the aquifer model combines all trench segments, so no differentiation is possible
Case01 (all crushable containers) vs. Case11 (all non-crushable containers)	Case01 (all crushable containers) vs. Case11n11 (a combination of crushable and non-crushable containers)
CDP present vs. CDP absent	CDP present vs. CDP absent
At the water table: Fractional mass, Mass (fractional mass * inventory), and Flux (mass / footprint area)	**Not applicable** – the flux is the only data that passes from the vadose zone results to the aquifer model

Figures C-1 through C-3 show maximum well concentrations for three nuclides disposed of as nominal and special waste forms in SLIT125 for Case01_off. In Figure C-1, the inventory of C-14_NR.Pump is somewhat higher at 0.134 Ci vs. 0.091 Ci for C-14. Release of the special waste form is delayed until 2125 which in turn delays its impact at the well. The delay minimally reduces its applied inventory to about 98% of its initial value, because the C-14 half-life is 5730 years. The special waste form for I-129 has a much higher K_d that delays and reduces its impact on the well concentrations. The U-234 special waste form is in glass that slowly leaches its contaminants, greatly reducing the well concentrations until long after the time period for the analysis.

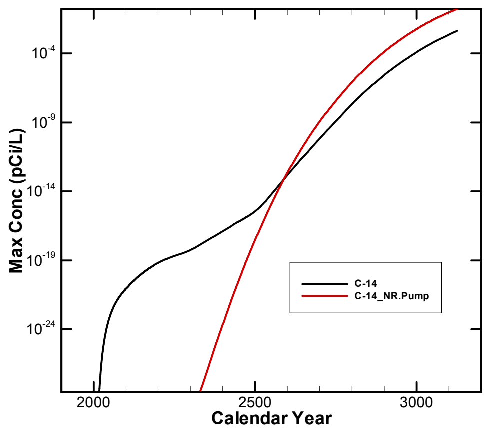

Figure C-1 C-14

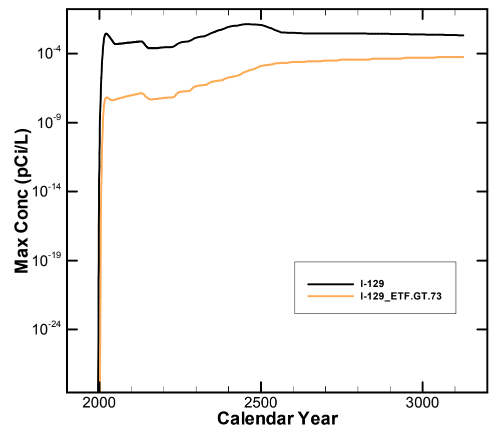

Figure C-2 I-129

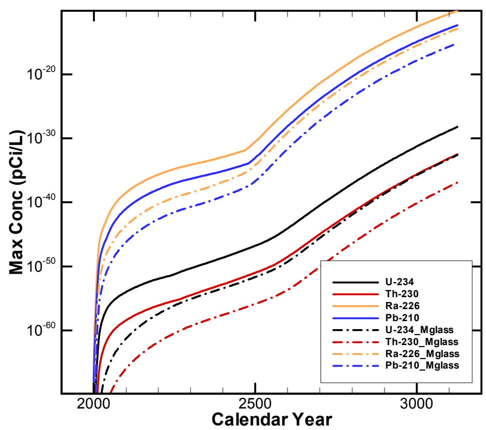

Figure C-3 U-234

Figures C-4 through C-23 show maximum well concentrations for the aquifer analyses that included the vadose zone results portrayed in Figures B-21 through B-40. Thus the aquifer analyses were for SLIT125 without CDP. The primary purpose for these figures is to show the effects of non-crushable container collapse that causes cap failure and greatly increased infiltration. In some instances of Case01n11 the maximum well concentration was greatly increased at a much earlier time than for Case01, but quickly decreased below the concentration for Case01 (e.g., Tc-99 in Figure C-22). In other instances, the early concentration increase was sustained for the entire analysis period (e.g., I-129_ETF.GT.73 in Figure C-8). Figure C-21 shows Sr-90 results where the peak well concentration for Case01n11 is about six orders of magnitude higher than the peak well concentration for Case01. Similar differences in the peak fractional fluxes are shown in Figure B-38.

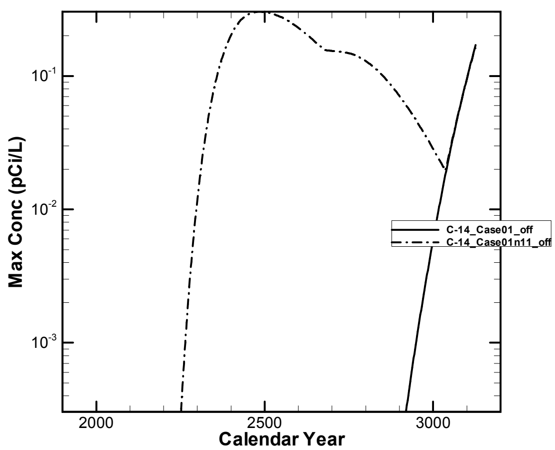

Figure C-4 C-14_NR.Pump

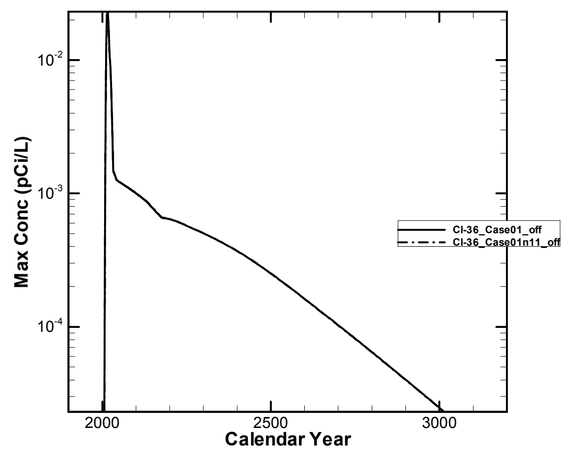

Figure C-5 Cl-36

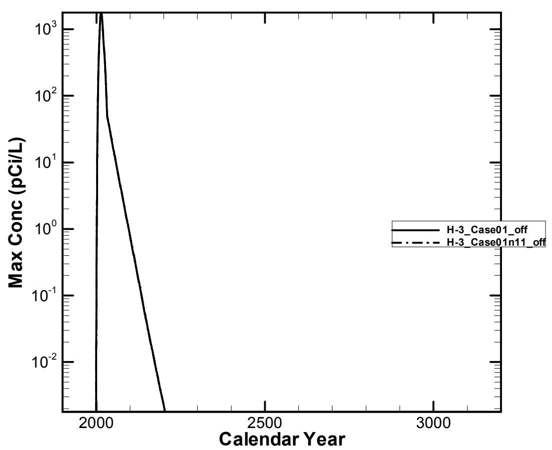

Figure C-6 H-3

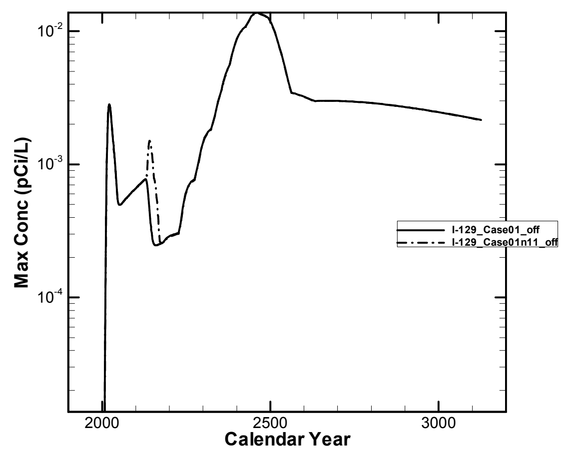

Figure C-7 I-129

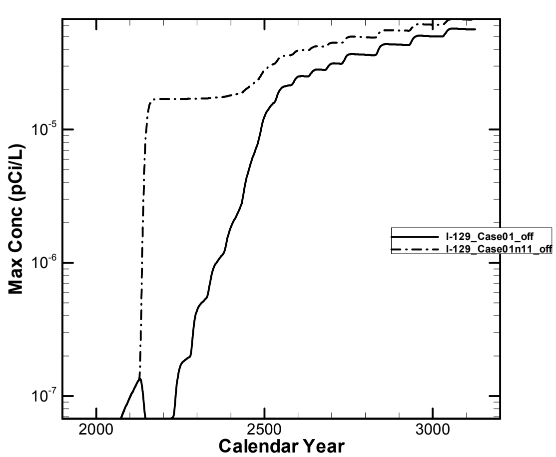

Figure C-8 I-129_ETF.GT.73

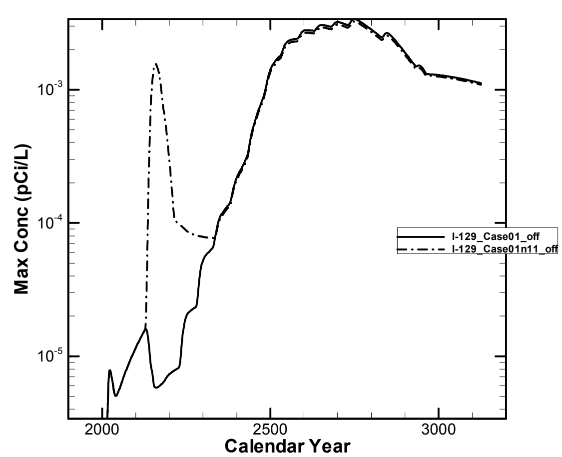

Figure C-9 I-129_F.CG.8

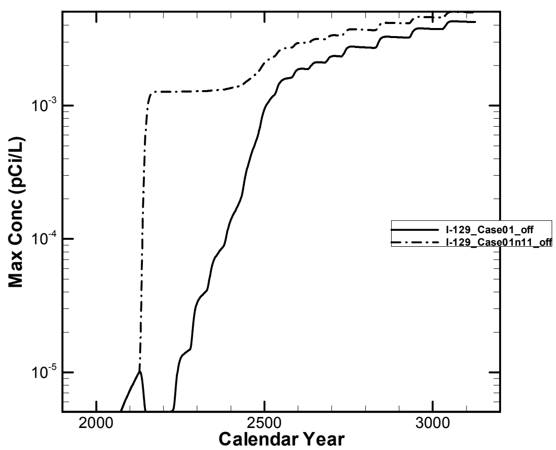

Figure C-10 I-129_F.Dowex.21K

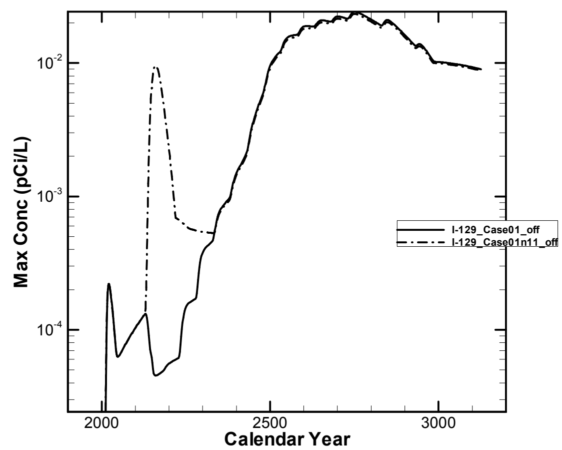

Figure C-11 I-129_F.Filtercake

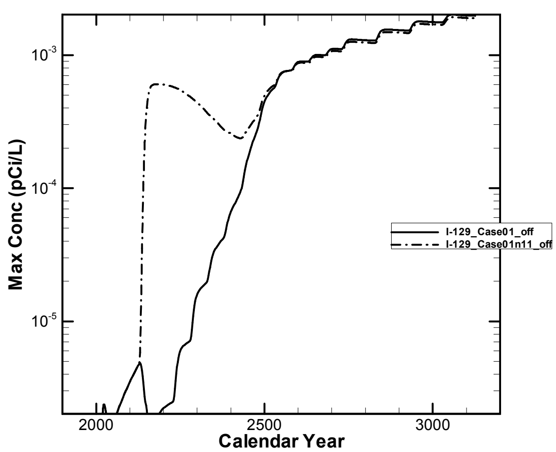

Figure C-12 I-129_H.CG.8

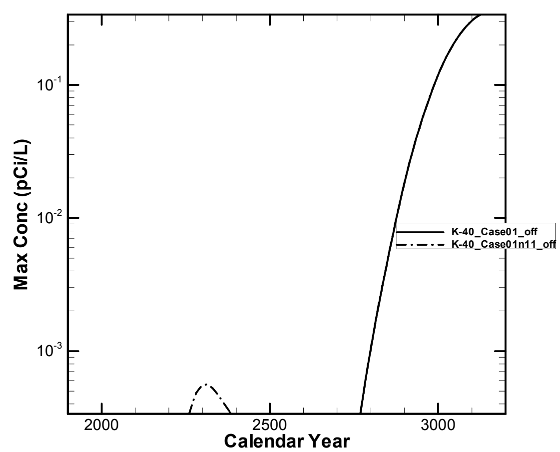

Figure C-13 K-40

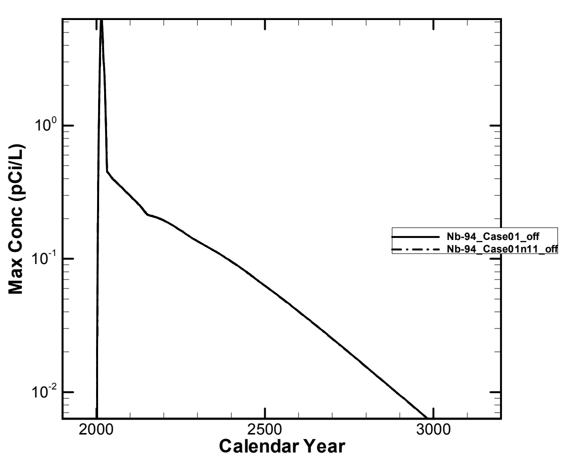

Figure C-14 Nb-94

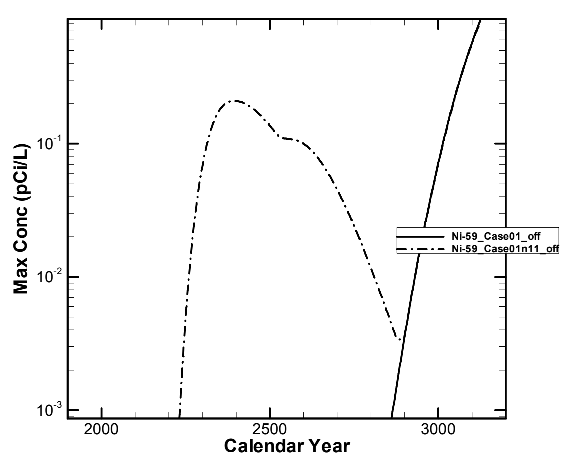

Figure C-15 Ni-59

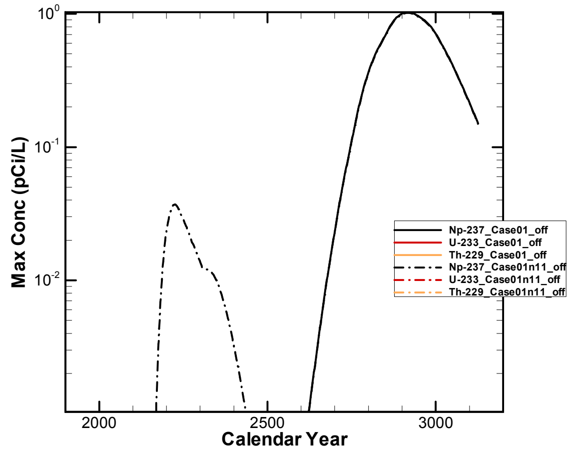

Figure C-16 Np-237

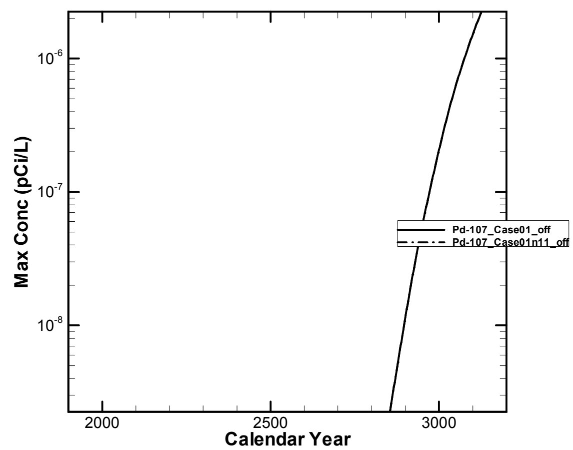

Figure C-17 Pd-107

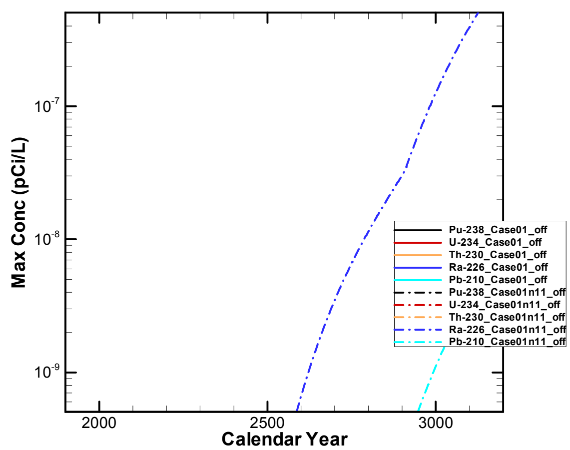

Figure C-18 Pu-238

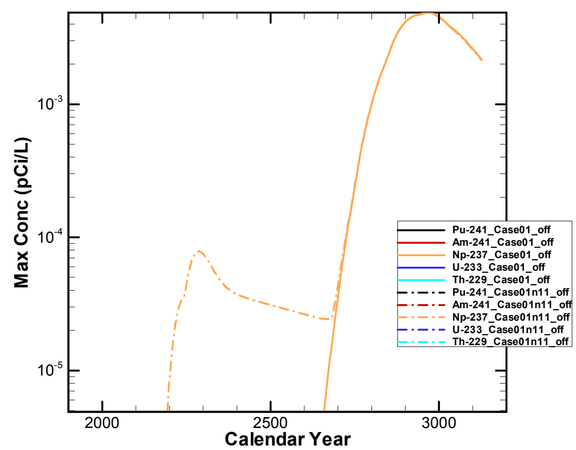

Figure C-19 Pu-241

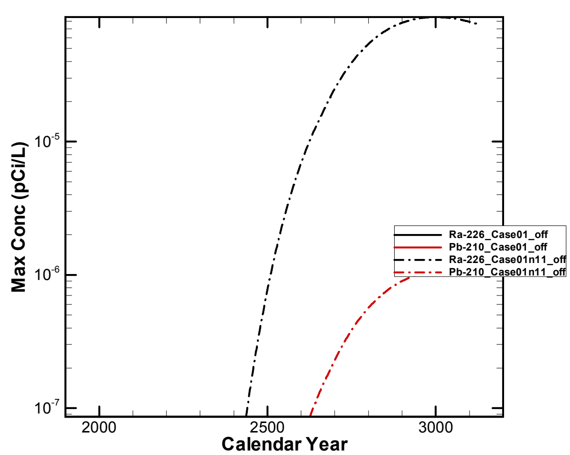

Figure C-20 Ra-226

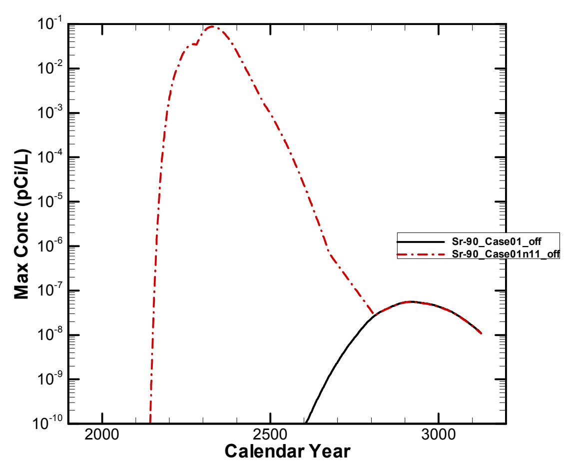

Figure C-21 Sr-90

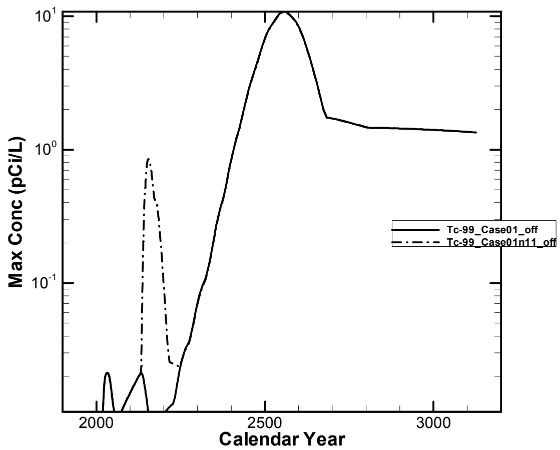

Figure C-22 Tc-99

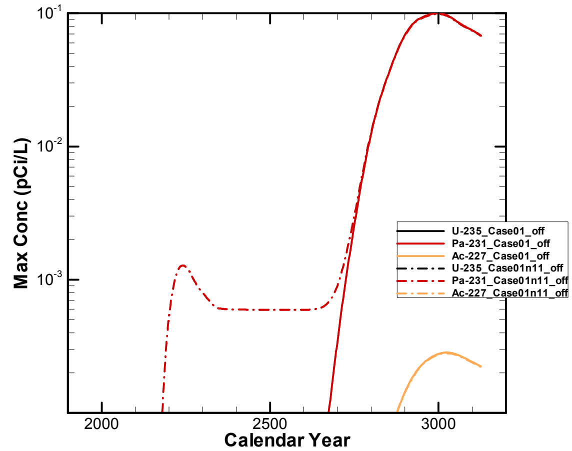

Figure C-23 U-235

Figures C-24 and C-25 show maximum well concentrations for SLIT125 for Case01_off and Case01_on. The CDP effects are most pronounced for nuclides in the chain that do not have the greatest well concentrations. For the Pu-241 chain, Am-241 is affected most, but it has a very high K_d for both cases, so its well concentrations are much less than the concentrations for Np-237. For the U-235 chain, the Ac-227 is the only nuclide affected because its K_d is reduced by about one-half in sand (from 1000 ml/g to 605 ml/g). However, its well concentrations are much less than the concentrations for Pa-231.

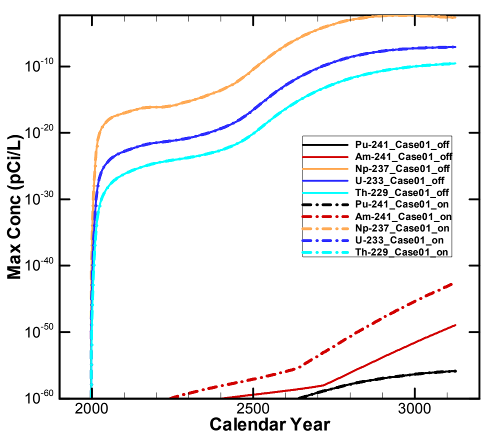

Figure C-24 Pu-241

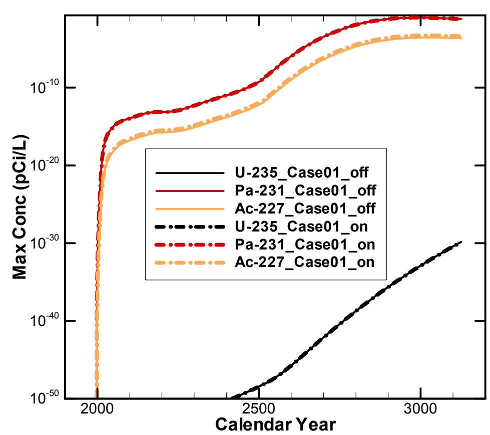

Figure C-25 U-235

APPENDIX D GROUNDWATER PATHWAY RESULTS

One of the cases analyzed in this study assumed that a 90% effective high-pH treatment was applied to Slit Trench segments SLIT3-UnitE, SLIT3-Unit~North (the ~ notation is used to refer to a composite trench inventory group), SLIT4-UnitA, SLIT4-UnitH, SLIT4-Unit~South, and SLIT4-Unit~North at the time of final closure. The figures in this appendix show some results from this particular analysis. Doses, concentrations and allowable values from groundwater pathways for Slit Trenches 1, 2 and 5 and their sum are plotted in Figures D-1 through D-5 from the years 1995 to 3130. Doses, concentrations and allowable values from groundwater pathways for Slit Trenches 3 and 4 and their sum are plotted in Figures D-6 through D-10. Each of the following 25 figures in this appendix show the ten radionuclides that have the largest contribution to the dose or concentration indicated in the figure title. Results are presented for each Slit Trench and each groundwater pathway. Figures D-11 through D-25 apply to SLIT1, SLIT2 and SLIT5. Figures D-26 through D-35 apply to SLIT3 and SLIT4.

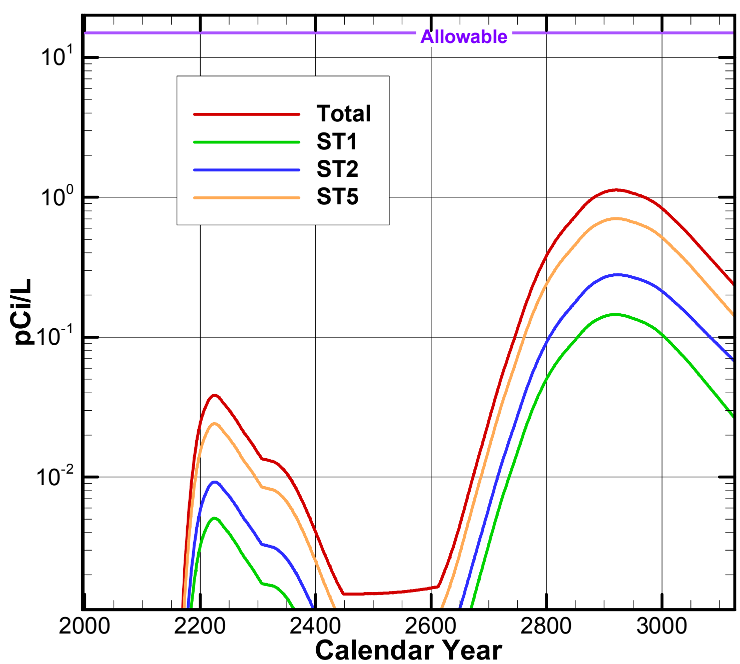

Figure D-1 Gross alpha concentrations from Slit Trenches 1, 2 and 5.

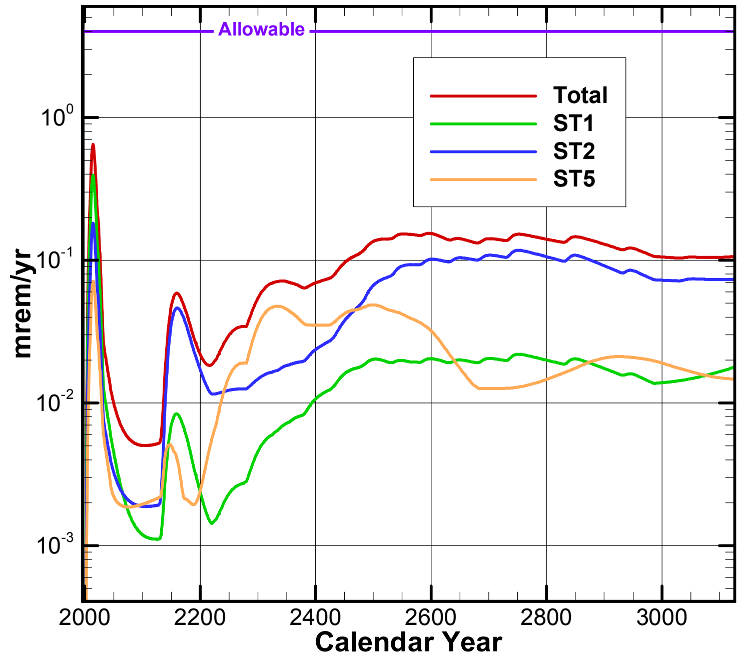

Figure D-2 Beta-gamma doses from Slit Trenches 1, 2 and 5.

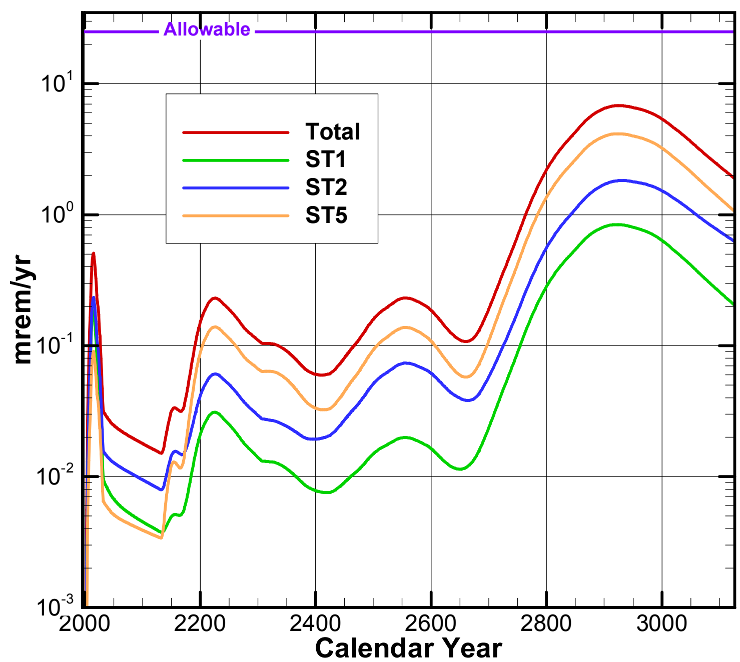

Figure D-3 Groundwater all-pathways doses from Slit Trenches 1, 2 and 5.

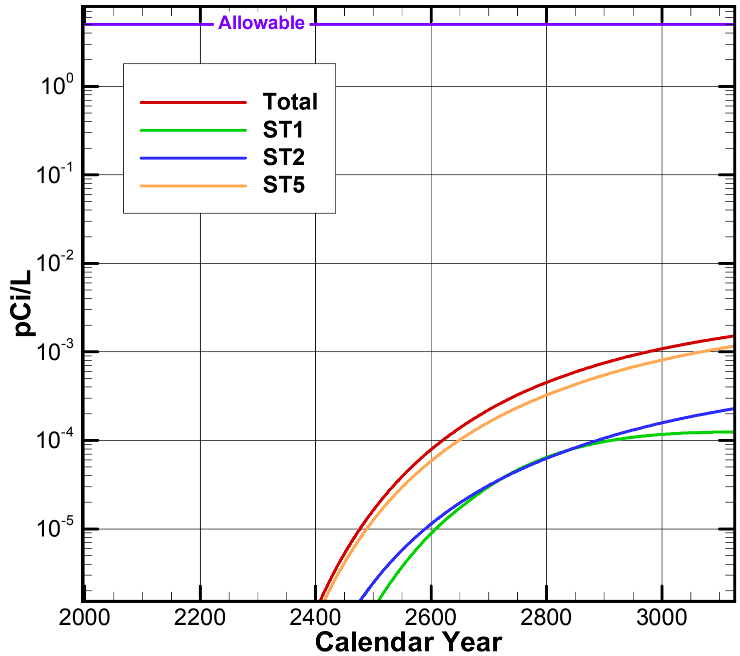

Figure D-4 Radium concentrations from Slit Trenches 1, 2 and 5.

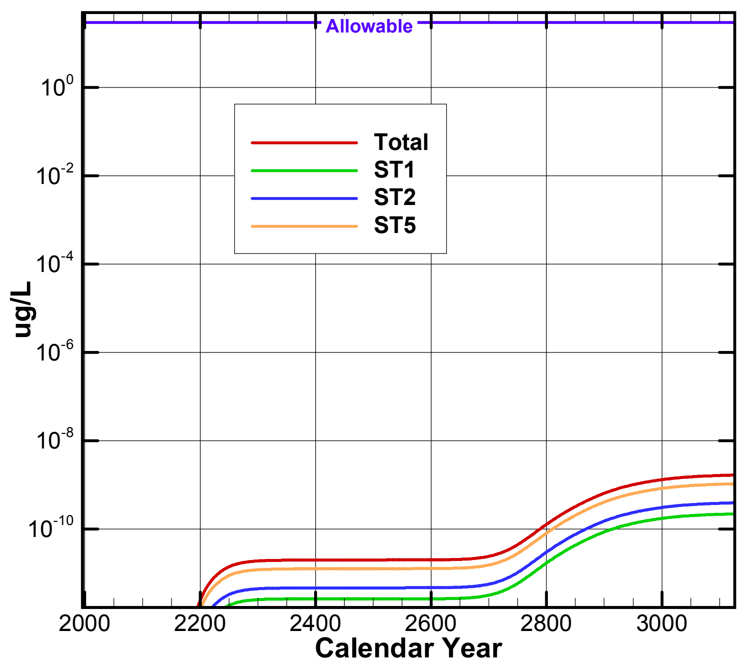

Figure D-5 Uranium concentrations from Slit Trenches 1, 2 and 5.

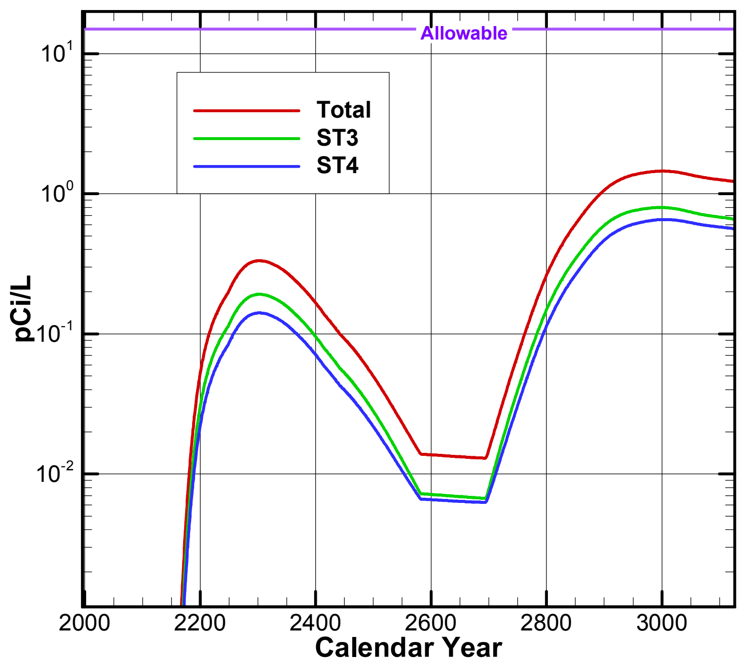

Figure D-6 Gross alpha concentrations from Slit Trenches 3 and 4.

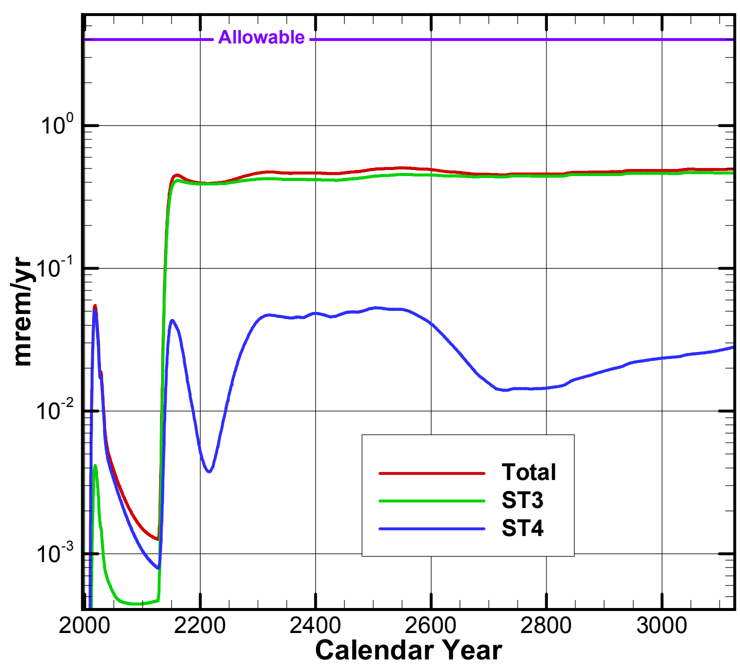

Figure D-7 Beta-gamma doses from Slit Trenches 3 and 4.

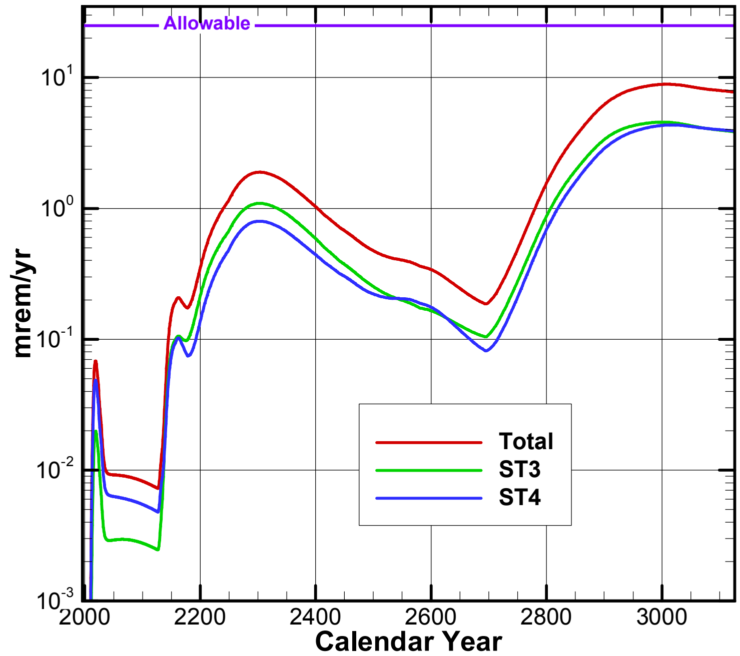

Figure D-8 Groundwater all-pathways doses from Slit Trenches 3 and 4.

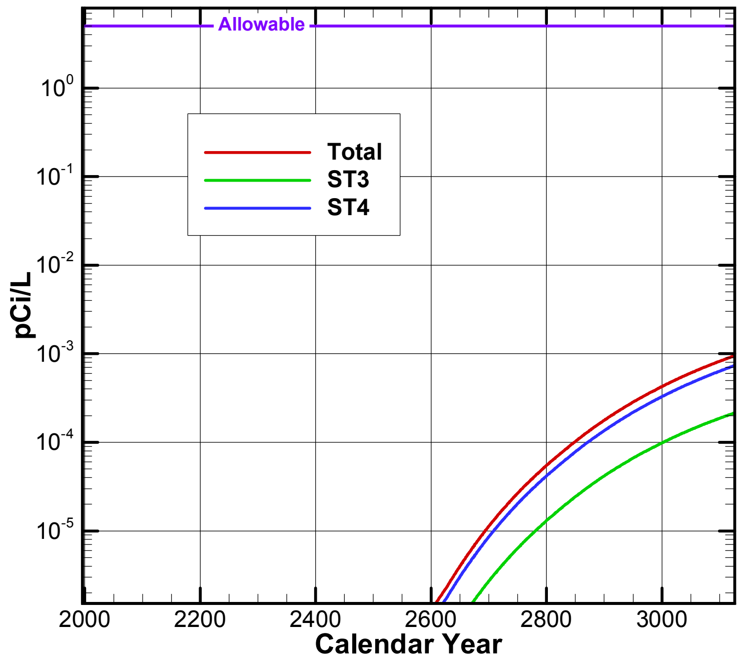

Figure D-9 Radium concentrations from Slit Trenches 3 and 4.

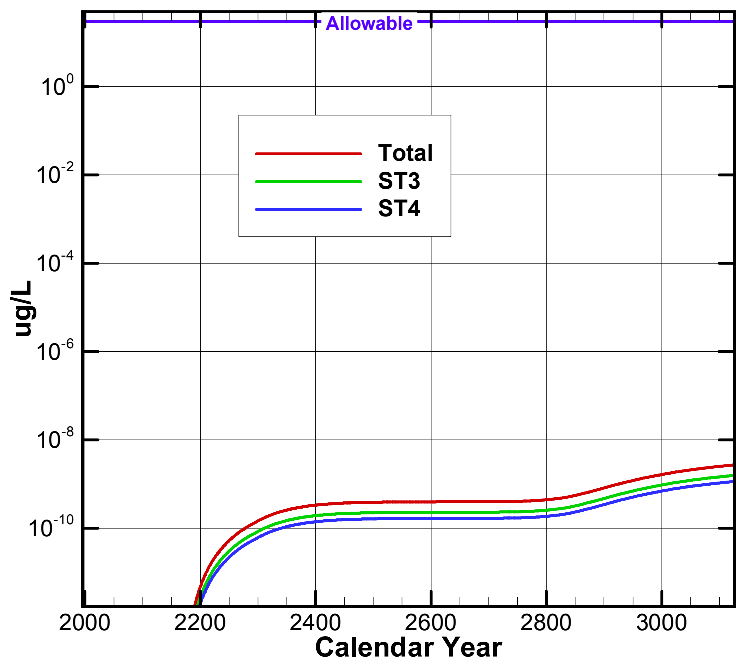

Figure D-10 Uranium concentrations from Slit Trenches 3 and 4.

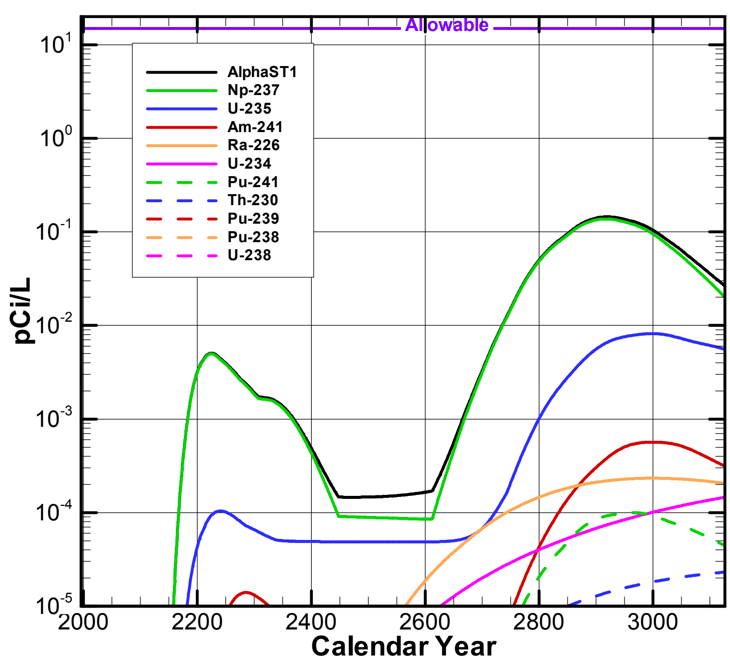

Figure D-11 Major contributors to gross alpha concentration from SLIT1.

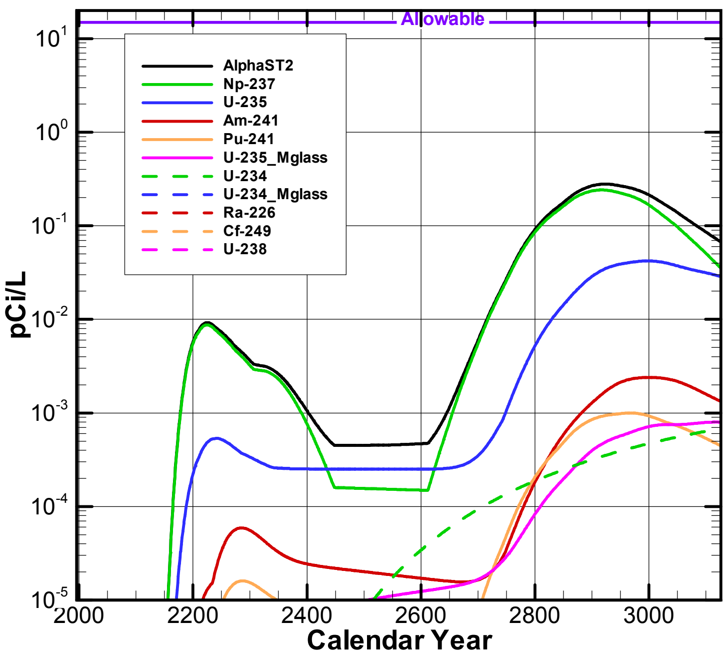

Figure D-12 Major contributors to gross alpha concentration from SLIT2.

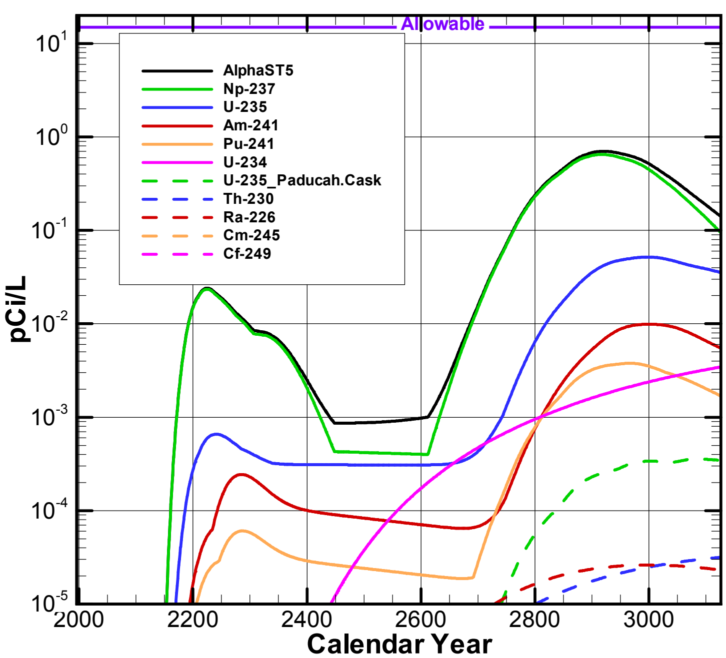

Figure D-13 Major contributors to gross alpha concentration from SLIT5.

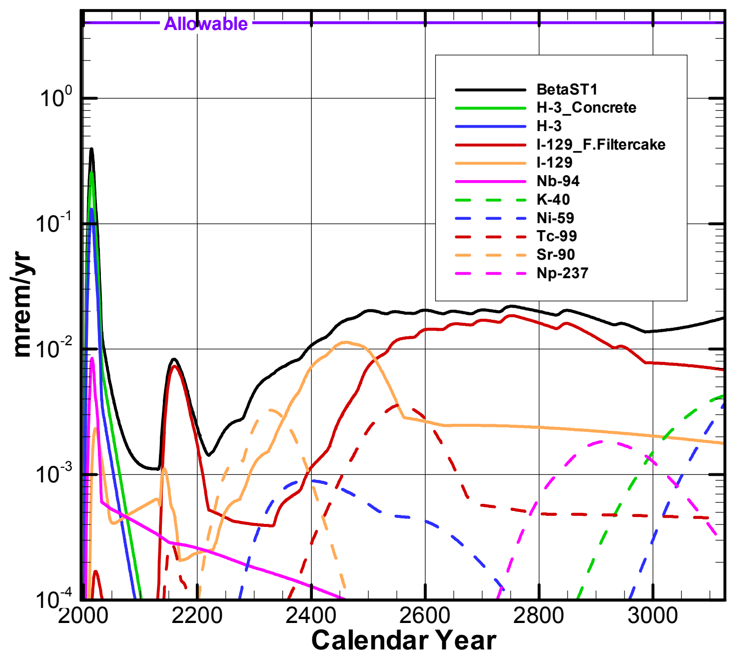

Figure D-14 Major contributors to beta-gamma dose from SLIT1.

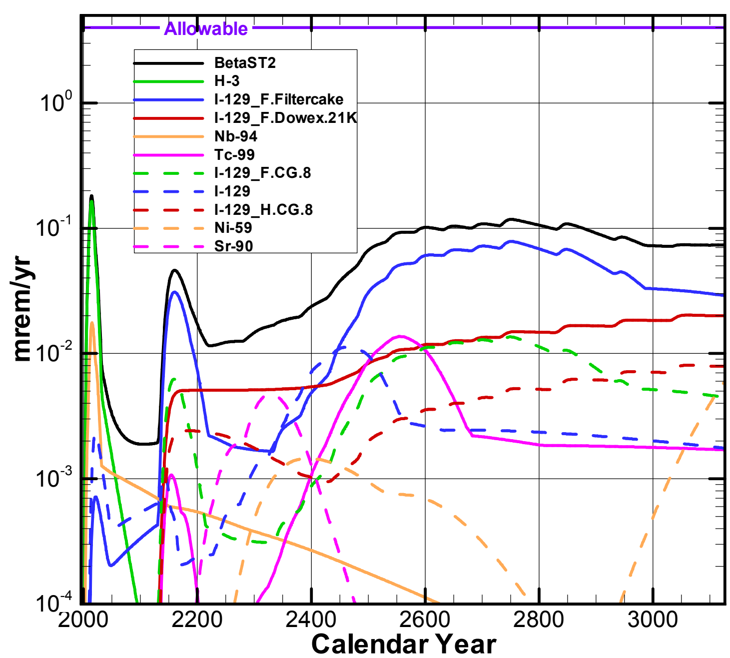

Figure D-15 Major contributors to beta-gamma dose from SLIT2.

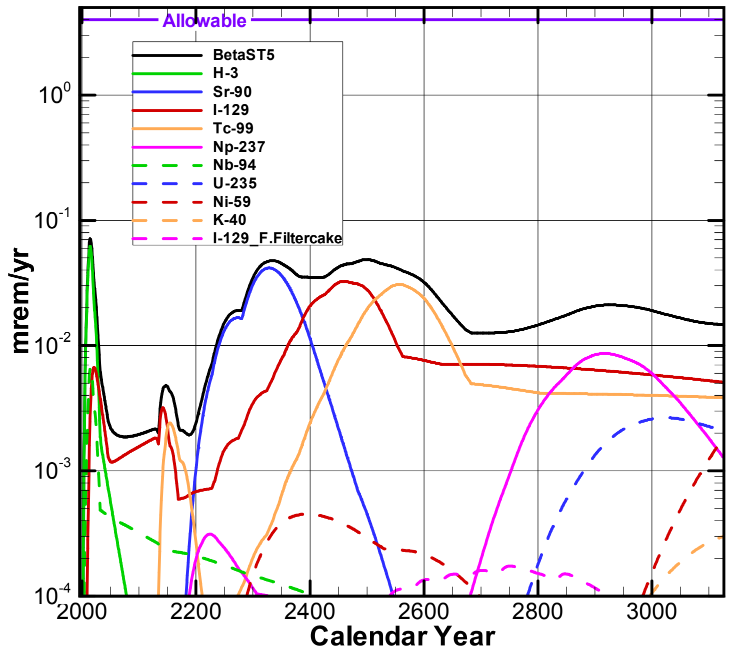

Figure D-16 Major contributors to beta-gamma dose from SLIT5.

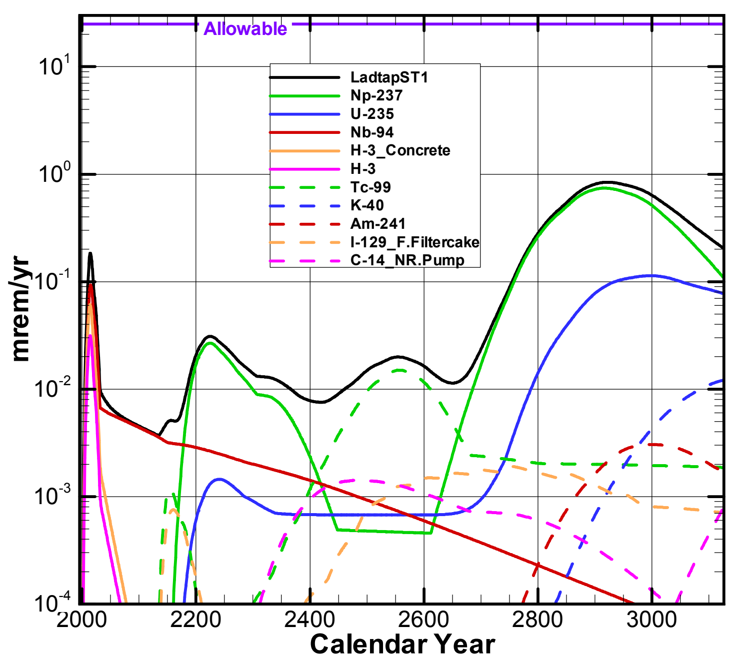

Figure D-17 Major contributors to groundwater all-pathways dose from SLIT1.

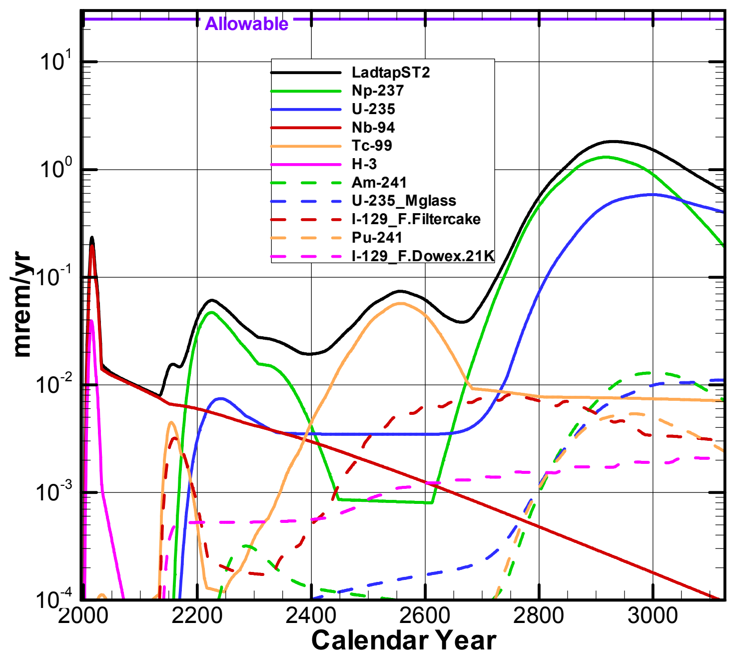

Figure D-18 Major contributors to groundwater all-pathways dose from SLIT2.

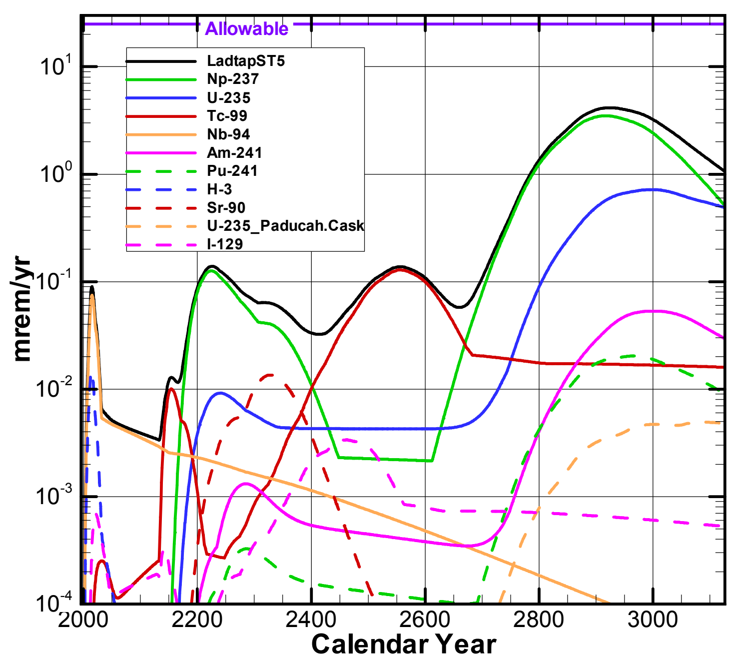

Figure D-19 Major contributors to groundwater all-pathways dose from SLIT5.

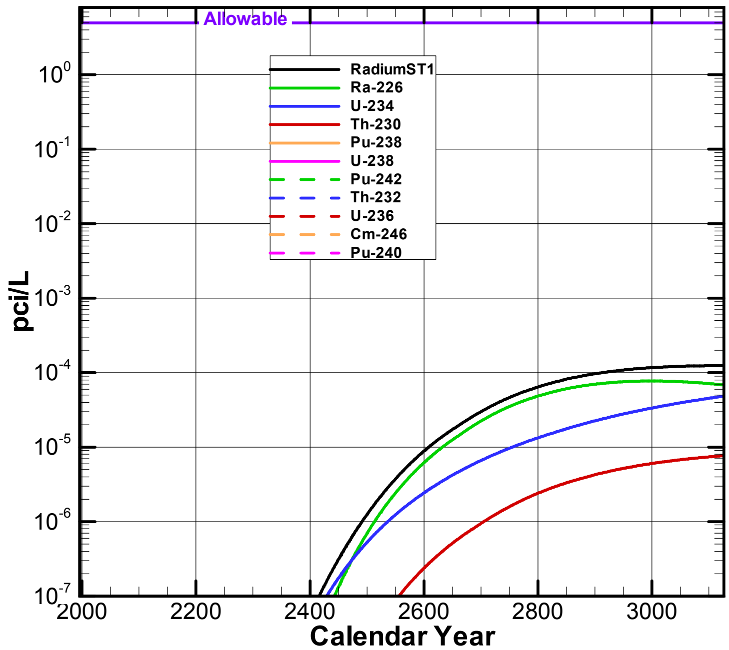

Figure D-20 Major contributors to radium concentration from SLIT1.

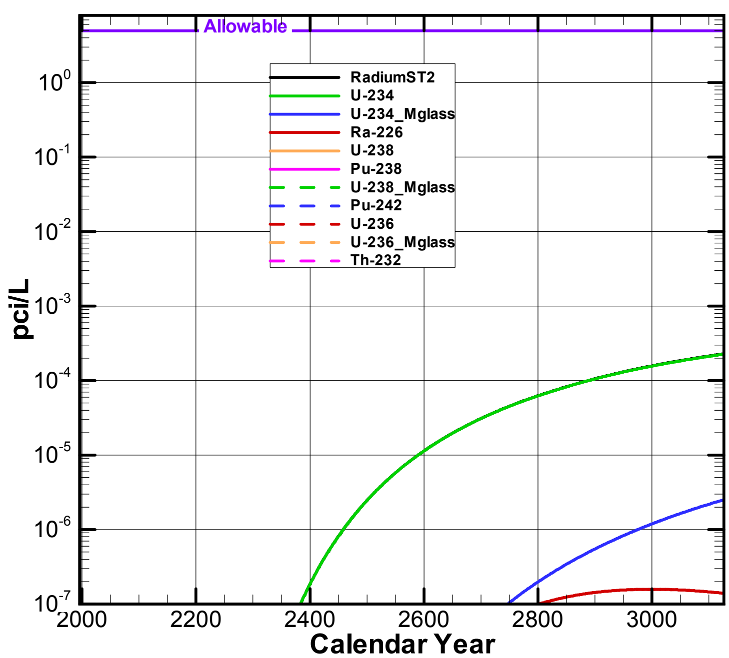

Figure D-21 Major contributors to radium concentration from SLIT2.

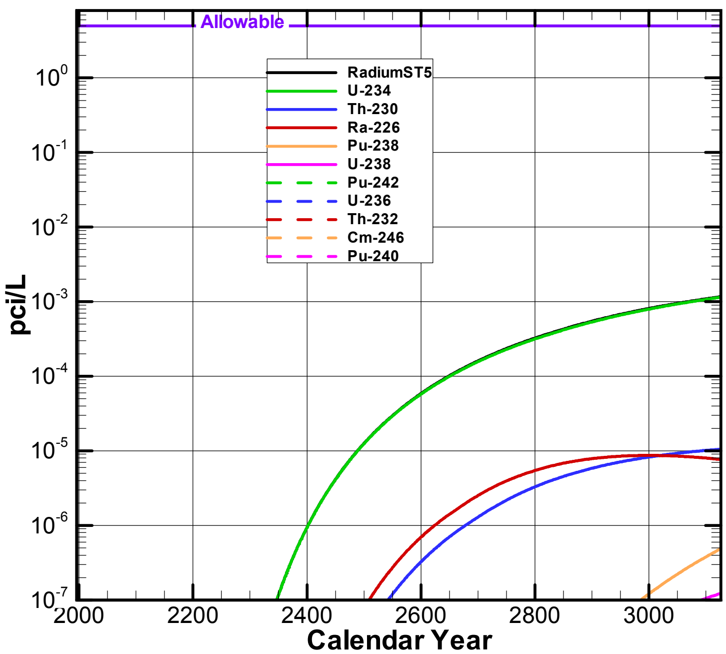

Figure D-22 Major contributors to radium concentration from SLIT5.

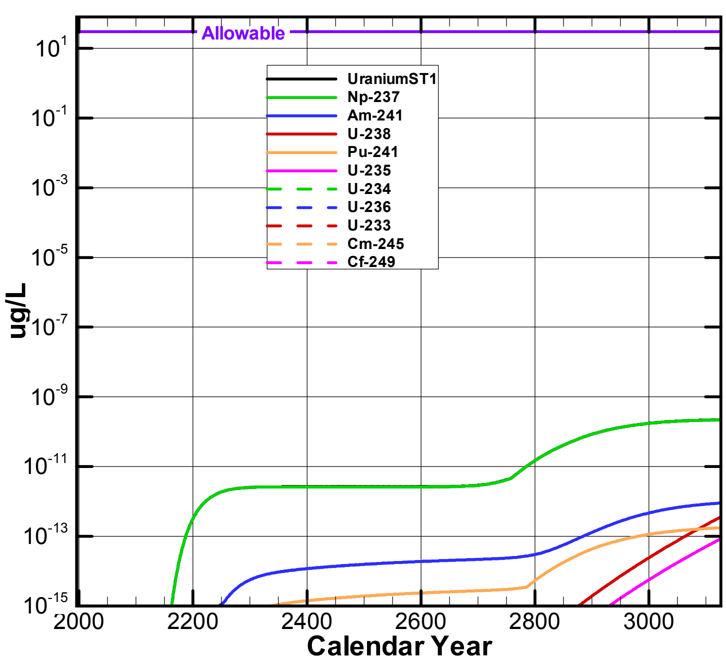

Figure D-23 Major contributors to uranium concentration from SLIT1.

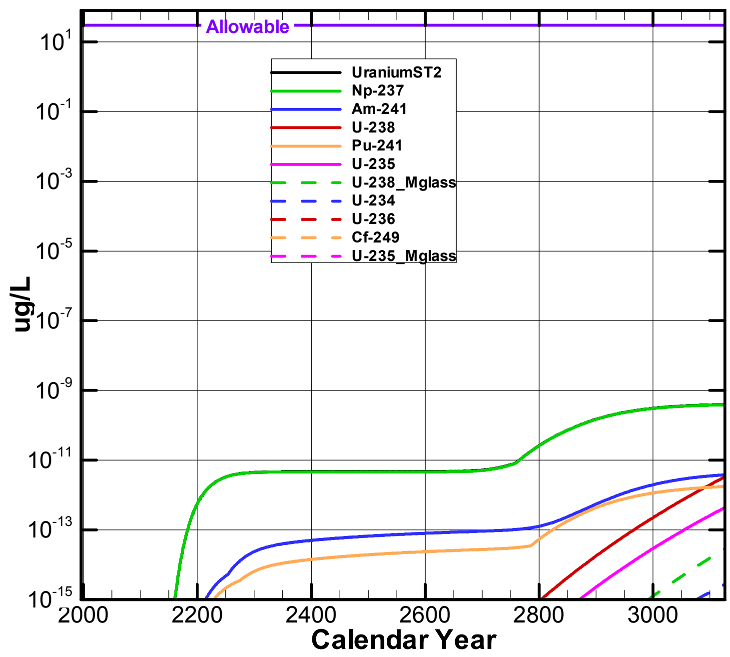

Figure D-24 Major contributors to uranium concentration from SLIT2.

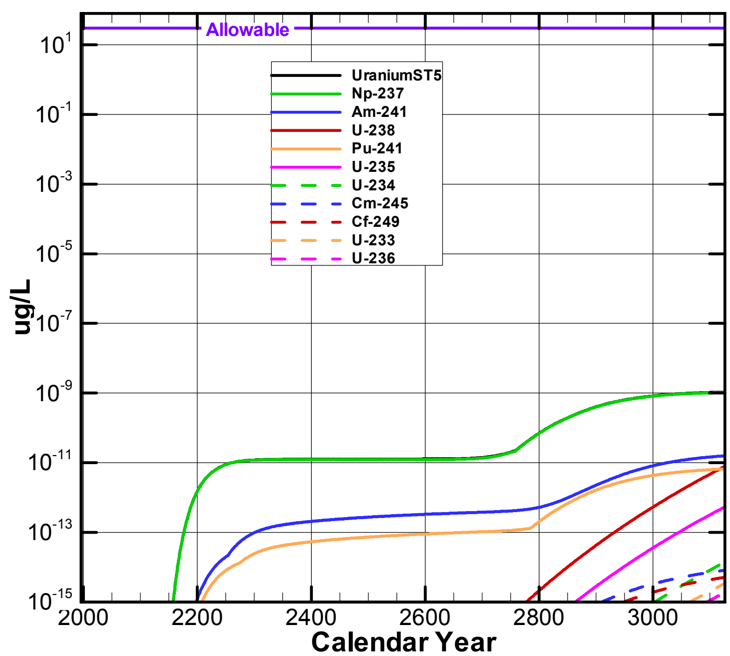

Figure D-25 Major contributors to uranium concentration from SLIT5.

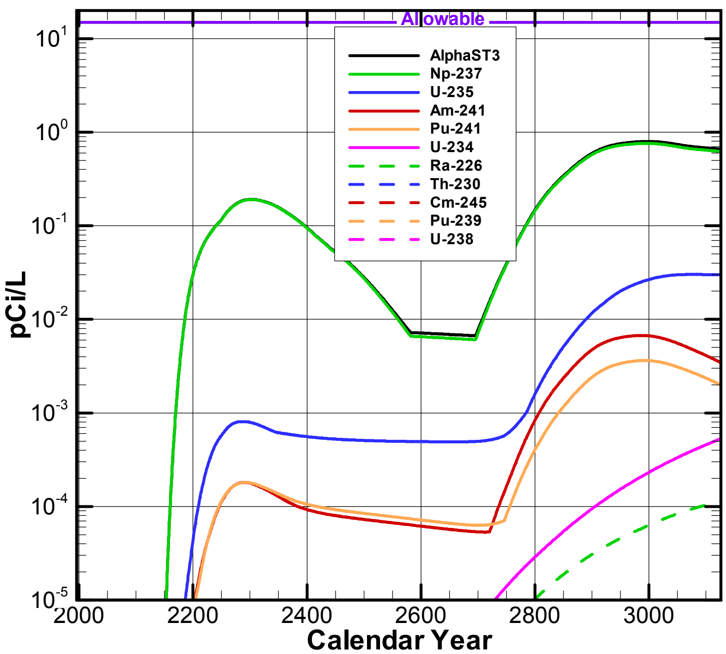

Figure D-26 Major contributors to gross alpha concentration from SLIT3.

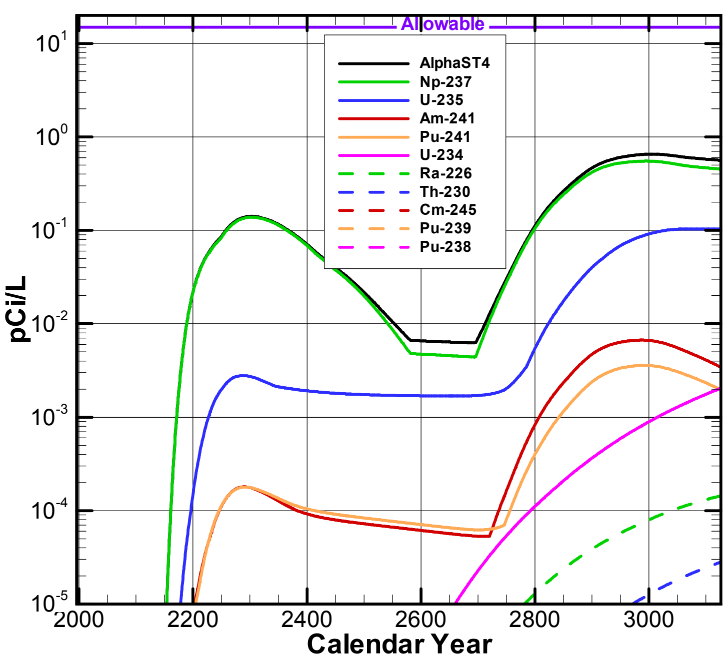

Figure D-27 Major contributors to gross alpha concentration from SLIT4.

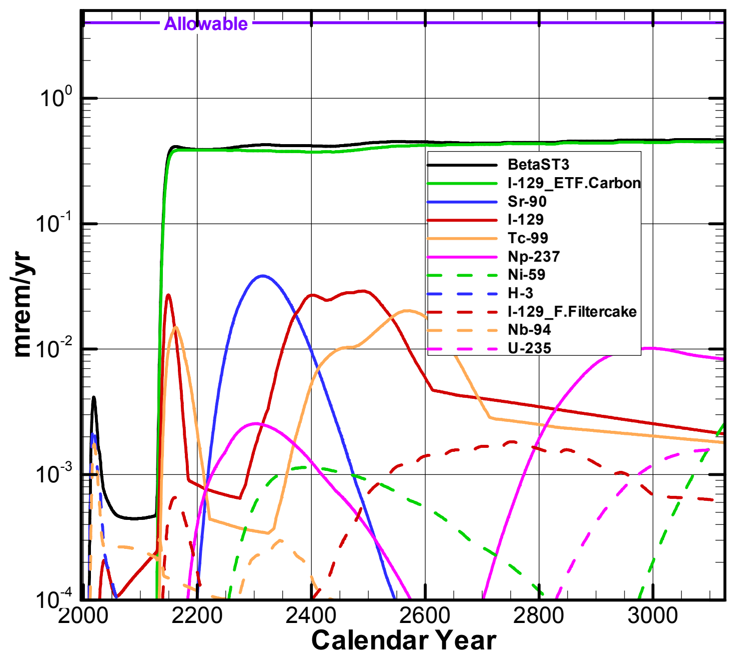

Figure D-28 Major contributors to beta-gamma dose from SLIT3.

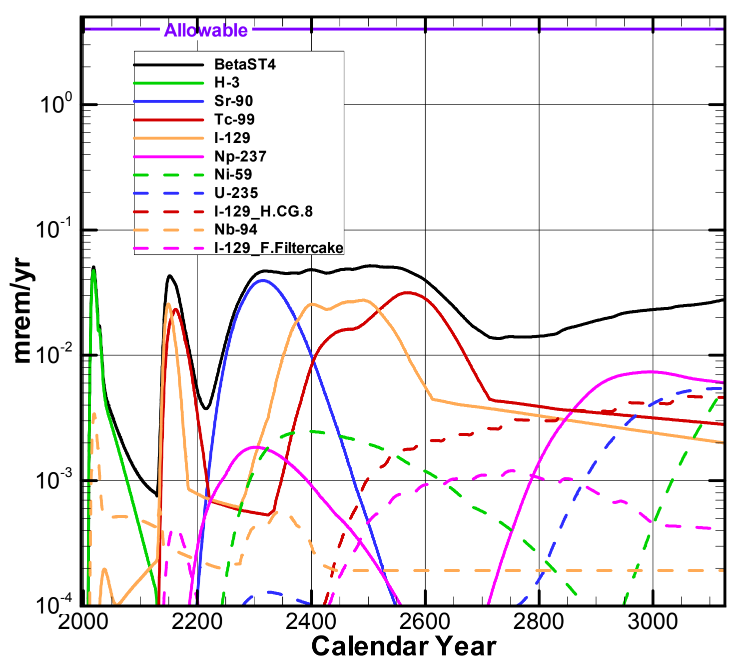

Figure D-29 Major contributors to beta-gamma dose from SLIT4.

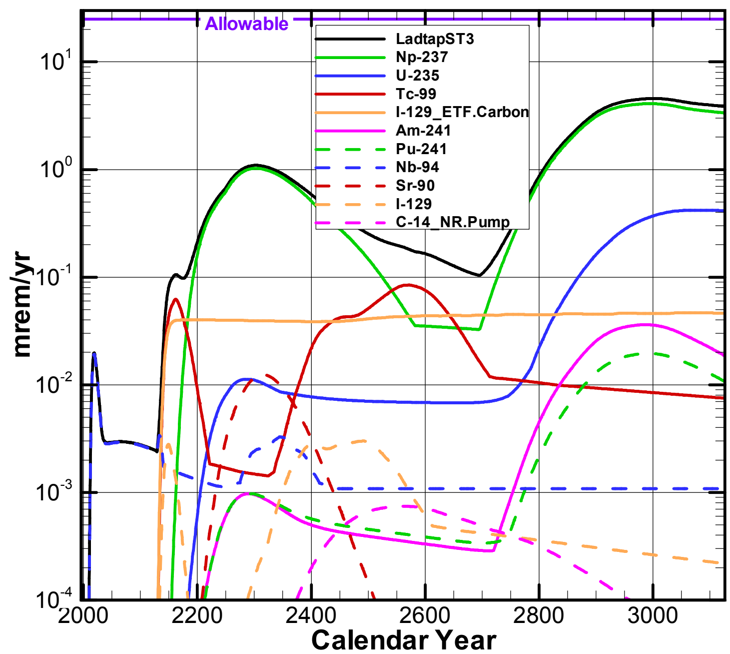

Figure D-30 Major contributors to groundwater all-pathways dose from SLIT3.

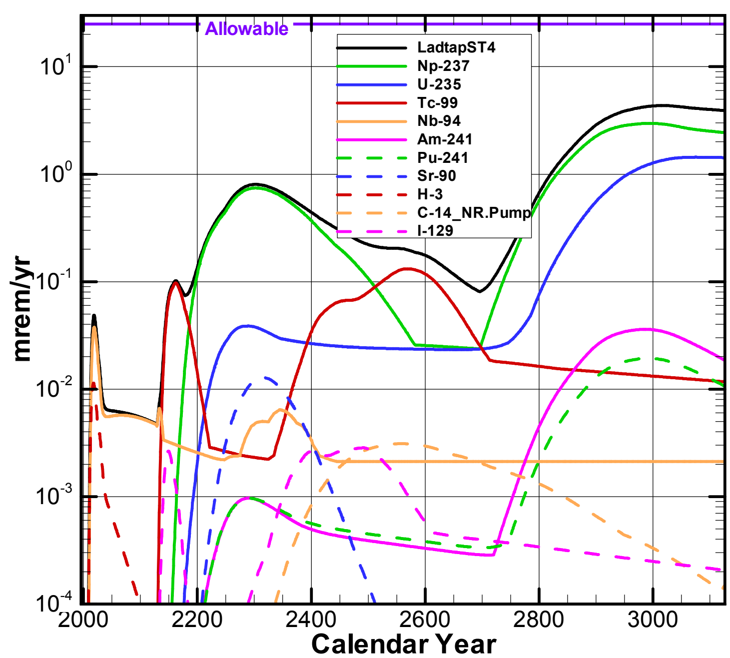

Figure D-31 Major contributors to groundwater all-pathways dose from SLIT4.

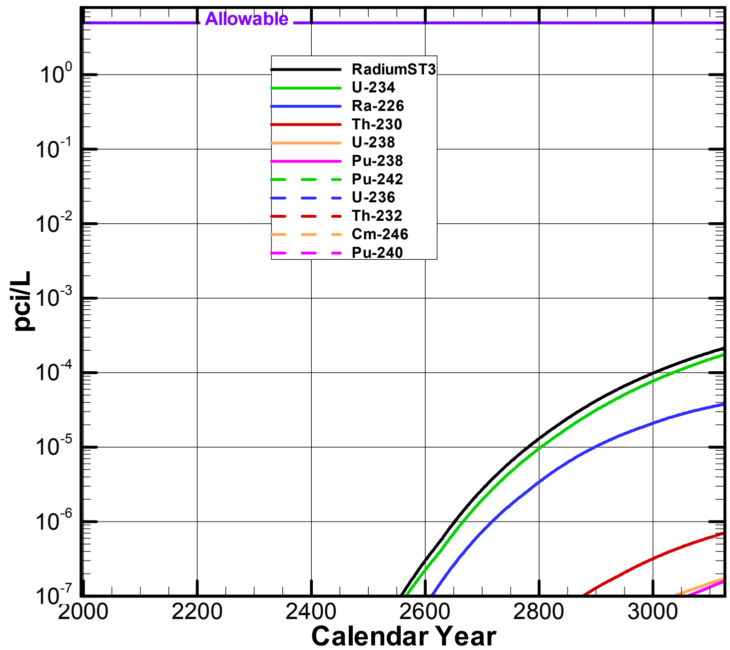

Figure D-32 Major contributors to radium concentration from SLIT3.

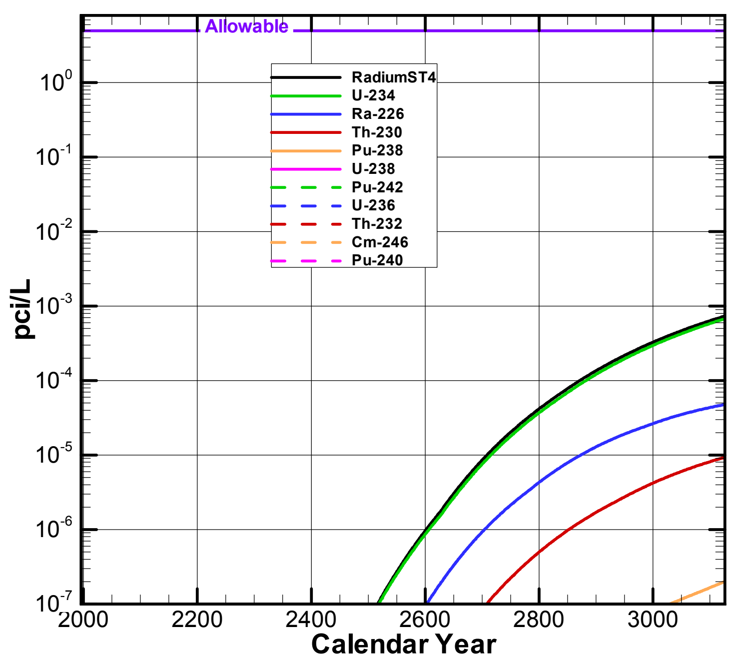

Figure D-33 Major contributors to radium concentration from SLIT4.

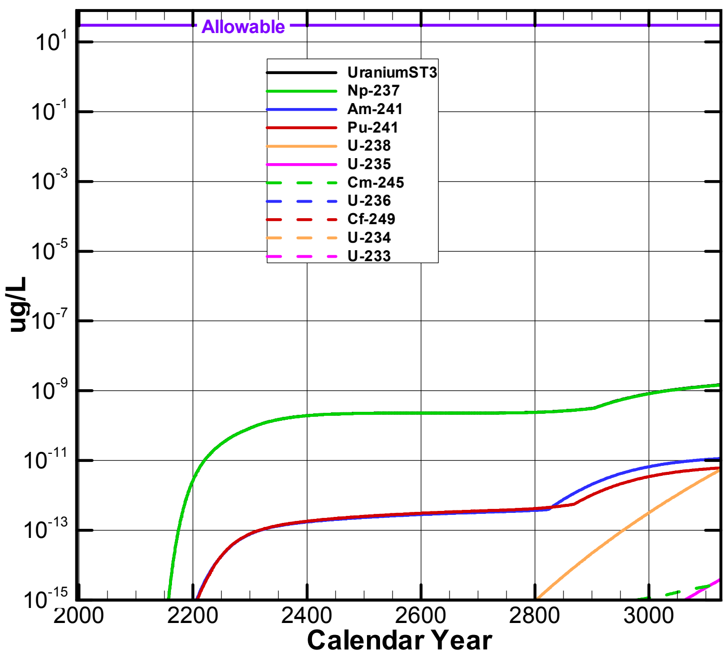

Figure D-34 Major contributors to uranium concentration from SLIT3.

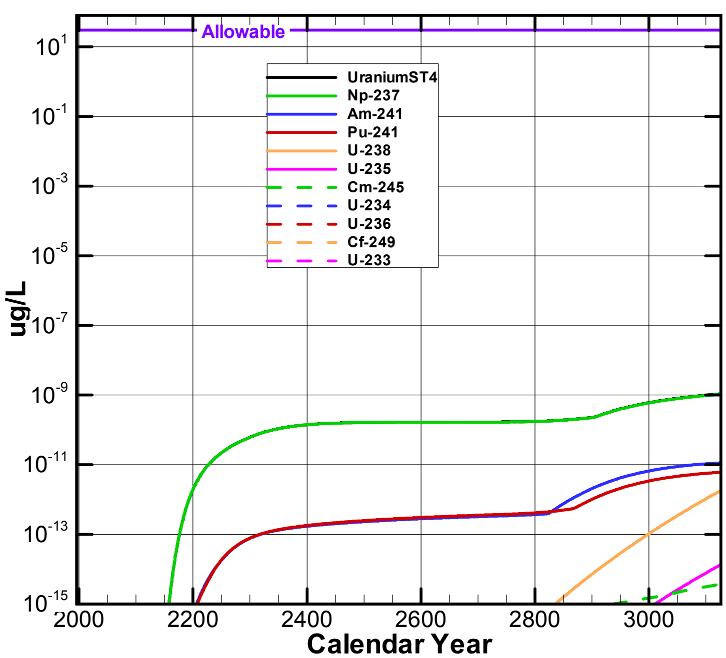

Figure D-35 Major contributors to uranium concentration from SLIT4.

APPENDIX E NON-GROUNDWATER PATHWAY RESULTS

Appendix E presents tables of non-groundwater pathways inventory consumption fractions (i.e., inventory divided by inventory limit, where the inventory limits were the most recent from the 2008 PA) for each Slit Trench and each radionuclide. The sums-of-fractions are also provided. The non-groundwater pathways considered are: resident intruder, post-drilling intruder, air and radon.

Table E-1. Non-groundwater inventory consumption fractions for SLIT1.

Parent	Residential	PostDrilling	Air	Radon
Am-241	6.06E-08	2.69E-05		
Am-242m	4.64E-08	5.23E-06		
Am-243	1.59E-07	5.58E-08		
C-14		4.47E-06	3.04E-08	
C-14_NR.Pump		2.61E-05	1.77E-07	
Cf-249	1.80E-08	5.13E-09		
Cf-251	4.68E-08	5.47E-08		
Cf-252	1.86E-18	2.72E-14		
Cm-242	2.30E-14	8.49E-11		
Cm-243	1.66E-13	3.11E-10		
Cm-244	8.84E-14	3.84E-07		
Cm-245	1.15E-10	3.56E-10		
Cm-246	1.53E-17	1.02E-09		
Cm-247	1.86E-08	1.10E-09		
Cm-248	2.58E-13	3.72E-09		
Co-60	2.35E-09	5.63E-09		
Cs-134	2.81E-23	8.80E-22		
Cs-135		2.98E-12		
Cs-137	3.40E-06	2.98E-04		
Eu-152	1.27E-10	4.45E-10		
Eu-154	2.40E-11	9.10E-11		
Eu-155	5.10E-24	8.57E-17		
H-3		4.07E-07	7.71E-08	
H-3_Concrete		1.86E-06	3.52E-07	
I-129	2.78E-15	5.16E-08	2.18E-08	
I-129_H.Filtercake	3.88E-17	7.21E-10	3.05E-10	
I-129_F.Filtercake	1.14E-14	2.12E-07	8.96E-08	
K-40	6.18E-05	8.24E-06		
Kr-85	7.76E-16	6.44E-14		
Mo-93		2.41E-11		
Na-22	2.93E-22	1.35E-21		
Nb-94	1.08E-04	3.98E-07		
Ni-59		5.40E-08		
Np-237	7.01E-06	1.08E-05		
Pu-238	2.55E-08	9.26E-05		4.30E-14
Pu-239	6.68E-09	1.72E-05		
Pu-240	6.06E-12	4.89E-06		
Pu-241	1.19E-08	5.37E-06		
Pu-242	1.55E-13	7.44E-08		
Pu-244	5.42E-17	1.81E-18		
Ra-226	3.50E-04	4.45E-05		1.43E-07
Ra-228	1.80E-11	9.37E-11		

Sb-125	9.26E-19	9.26E-19	6.95E-06	
Se-79			5.78E-09	
Sm-151		2.24E-11		
Sn-126	2.01E-05	8.77E-08	1.41E-06	
Sr-90		2.04E-03		
Tc-99	5.32E-12	2.23E-06		
Th-228	3.51E-22	6.79E-22		
Th-230	1.52E-05	1.52E-06		6.89E-10
Th-232	5.39E-04	1.57E-05		
U-232	3.65E-10	1.30E-09		
U-233	3.78E-07	1.55E-07		
U-233_Depleted	6.46E-06	2.64E-06		
U-234	2.00E-05	2.23E-05		1.08E-10
U-235	8.91E-07	2.00E-07		
U-235_Depleted	1.14E-05	2.56E-06		
U-236	1.18E-10	8.49E-07		
U-238	1.49E-04	3.73E-05		2.39E-14
Sum-of-fractions	1.29E-03	2.68E-03	9.11E-06	1.44E-07

Table E-2. Non-groundwater inventory consumption fractions for SLIT2.

Parent	Residential	PostDrilling	Air	Radon
Am-241	2.55E-07	1.13E-04		
Am-242m	1.96E-07	2.21E-05		
Am-243	4.39E-06	1.53E-06		
Ba-133	1.91E-15	9.95E-13		
C-14		2.29E-05	1.56E-07	
C-14_NR.Pump		3.84E-05	2.61E-07	
Cf-249	1.68E-06	4.80E-07		
Cf-250	9.10E-16	1.33E-07		
Cf-251	4.74E-07	5.55E-07		
Cf-252	6.37E-15	9.31E-11		
Cl-36		4.22E-07	7.07E-11	
Cm-242	6.29E-14	2.32E-10		
Cm-243	9.35E-14	1.75E-10		
Cm-244	2.55E-13	1.11E-06		
Cm-245	1.22E-09	3.79E-09		
Cm-246	2.19E-16	1.47E-08		
Cm-247	3.22E-11	1.91E-12		
Cm-248	4.64E-12	6.71E-08		
Co-60	9.82E-09	2.36E-08		
Cs-134	2.00E-23	6.27E-22		
Cs-135		4.94E-15		
Cs-137	1.07E-05	9.33E-04		
Eu-152	3.47E-09	1.21E-08		
Eu-154	9.56E-10	3.62E-09		
Eu-155	2.23E-19	3.74E-12		
H-3		5.12E-07	9.70E-08	
I-129	2.76E-15	5.12E-08	2.17E-08	
I-129_F.Dowex.21K	6.17E-13	1.15E-05	4.85E-06	
I-129_F.CG.8	7.22E-15	1.34E-07	5.67E-08	
I-129_H.CG.8	1.66E-14	3.08E-07	1.30E-07	

I-129_ETF.GT.73	1.21E-14	2.25E-07	9.50E-08	
I-129_F.Filtercake	4.83E-14	8.96E-07	3.79E-07	
K-40	4.82E-08	6.43E-09		
Kr-85	2.18E-14	1.81E-12		
Mo-93		7.14E-13		
Nb-94	2.26E-04	8.36E-07		
Ni-59		8.75E-08		
Np-237	1.22E-05	1.88E-05		
Pu-238	5.01E-08	1.82E-04		8.46E-14
Pu-239	5.16E-08	1.33E-04		
Pu-240	6.37E-11	5.15E-05		
Pu-241	1.19E-07	5.38E-05		
Pu-242	1.45E-12	6.92E-07		
Pu-244	1.17E-16	3.93E-18		
Ra-226	7.13E-07	9.08E-08		2.92E-10
S-35			6.51E-10	
Sb-125	2.71E-18	2.71E-18	2.03E-05	
Se-79			1.12E-08	
Sm-151		3.60E-14		
Sn-126	2.36E-07	1.03E-09	1.65E-08	
Sr-90		2.96E-03		
Tc-99	2.02E-11	8.50E-06		
Th-228	4.65E-25	8.99E-25		
Th-232	8.11E-07	2.36E-08		
U-232	5.19E-11	1.84E-10		
U-233	1.72E-06	7.04E-07		
U-233_Depleted	2.81E-05	1.15E-05		
U-234	9.33E-05	1.04E-04		5.02E-10
U-234_MGlass	7.27E-04	8.11E-04		3.92E-09
U-235	1.89E-06	4.24E-07		
U-235_Depleted	6.14E-05	1.38E-05		
U-235_MGlass	3.75E-04	8.43E-05		
U-236	4.14E-10	2.99E-06		
U-236_MGlass	5.12E-09	3.70E-05		
U-238	1.38E-03	3.44E-04		2.20E-13
U-238_MGlass	1.05E-02	2.63E-03		1.68E-12
Sum-of-fractions	1.34E-02	8.60E-03	2.64E-05	4.71E-09

Table E-3. Non-groundwater inventory consumption fractions for SLIT3.

Parent	Residential	PostDrilling	Air	Radon
Am-241	6.46E-07	2.87E-04		
Am-242m	2.13E-08	2.40E-06		
Am-243	6.22E-06	2.18E-06		
Ba-133	1.15E-16	5.98E-14		
C-14		9.26E-06	6.30E-08	
C-14_NR.Pump		2.91E-06	1.98E-08	
Cd-113m		7.39E-14		
Cf-249	8.96E-07	2.56E-07		
Cf-250	4.03E-16	5.89E-08		
Cf-251	2.68E-07	3.14E-07		
Cf-252	3.04E-15	4.44E-11		
Cl-36		8.40E-08	1.41E-11	
Cm-242	9.88E-15	3.64E-11		

Cm-243	1.97E-11	3.68E-08		
Cm-244	7.51E-13	3.27E-06		
Cm-245	8.11E-08	2.51E-07		
Cm-246	9.14E-16	6.12E-08		
Cm-247	6.46E-07	3.83E-08		
Cm-248	1.10E-11	1.58E-07		
Co-60	5.89E-10	1.41E-09		
Cs-134	1.32E-20	4.14E-19		
Cs-137	8.50E-06	7.44E-04		
Eu-152	4.77E-09	1.67E-08		
Eu-154	1.93E-09	7.33E-09		
Eu-155	9.69E-20	1.63E-12		
H-3		4.09E-07	7.75E-08	
H-3_ETF.Carbon		1.33E-07	2.52E-08	
I-129	6.33E-15	1.18E-07	4.97E-08	
I-129_ETF.Carbon	2.29E-12	4.26E-05	1.80E-05	
I-129_ETF.GT.73	5.64E-15	1.05E-07	4.43E-08	
I-129_F.Filtercake	4.79E-15	8.90E-08	3.77E-08	
K-40	7.96E-08	1.06E-08		
Kr-85	4.63E-14	3.85E-12		
Na-22	9.58E-23	4.40E-22		
Nb-94	6.64E-05	2.46E-07		
Ni-59		3.39E-08		
Np-237	1.10E-04	1.70E-04		
Pb-210	1.60E-16	1.01E-08		
Pu-238	3.03E-07	1.10E-03		5.12E-13
Pu-239	2.56E-07	6.59E-04		
Pu-240	2.27E-10	1.83E-04		
Pu-241	4.69E-07	2.12E-04		
Pu-242	1.07E-11	5.12E-06		
Pu-244	8.70E-18	2.91E-19		
Ra-226	2.47E-06	3.15E-07		1.01E-09
Ra-228	4.19E-13	2.18E-12		
Sb-125	1.02E-18	1.02E-18	7.67E-06	
Se-79			1.14E-07	
Sm-151		7.35E-10		
Sn-113			1.52E-12	
Sn-126	2.24E-05	9.75E-08	1.56E-06	
Sr-90		1.98E-02		
Tc-99	3.86E-11	1.62E-05		
Th-228	2.01E-22	3.89E-22		
Th-229	1.12E-06	2.04E-07		
Th-230	2.17E-06	2.17E-07		9.83E-11
Th-232	1.25E-05	3.65E-07		
U-232	1.21E-05	4.29E-05		
U-233	1.20E-04	4.90E-05		
U-233_Depleted	3.25E-06	1.33E-06		
U-234	4.55E-04	5.08E-04		2.45E-09
U-235	7.39E-05	1.66E-05		
U-235_Depleted	4.25E-05	9.56E-06		
U-236	1.41E-09	1.02E-05		
U-238	1.45E-03	3.63E-04		2.32E-13
Sum-of-fractions	2.40E-03	2.43E-02	2.77E-05	3.56E-09

Table E-4. Non-groundwater inventory consumption fractions for SLIT4.

Parent	Residential	PostDrilling	Air	Radon
Am-241	4.76E-07	2.11E-04		
Am-242m	9.79E-09	1.10E-06		
Am-243	4.11E-06	1.44E-06		
Ba-133	6.98E-15	3.64E-12		
C-14		1.86E-05	1.26E-07	
C-14_NR.Pump		1.21E-05	8.24E-08	
Cf-249	3.40E-07	9.70E-08		
Cf-250	7.01E-18	1.03E-09		
Cf-251	1.18E-07	1.38E-07		
Cf-252	8.82E-17	1.29E-12		
Cm-242	1.37E-14	5.06E-11		
Cm-243	3.13E-12	5.87E-09		
Cm-244	1.25E-12	5.42E-06		
Cm-245	1.01E-07	3.12E-07		
Cm-246	2.23E-15	1.50E-07		
Cm-247	7.73E-06	4.58E-07		
Cm-248	3.50E-14	5.05E-10		
Co-60	1.52E-09	3.64E-09		
Cs-134	1.29E-21	4.05E-20		
Cs-137	1.75E-05	1.53E-03		
Eu-152	4.87E-08	1.70E-07		
Eu-154	7.51E-09	2.85E-08		
Eu-155	1.70E-21	2.86E-14		
H-3		4.10E-06	7.78E-07	
I-129	4.95E-15	9.19E-08	3.89E-08	
I-129_H.CG.8	4.73E-15	8.78E-08	3.71E-08	
I-129_ETF.GT.73	8.62E-15	1.60E-07	6.78E-08	
I-129_F.Filtercake	1.08E-15	2.00E-08	8.46E-09	
K-40	9.83E-08	1.31E-08		
Kr-85	9.88E-14	8.20E-12		
Na-22	7.40E-22	3.40E-21		
Nb-94	9.76E-05	3.61E-07		
Ni-59		4.62E-08		
Np-237	4.47E-05	6.89E-05		
Pb-210	7.18E-17	4.55E-09		
Pu-238	2.50E-07	9.09E-04		4.22E-13
Pu-239	2.63E-07	6.78E-04		
Pu-240	2.20E-10	1.77E-04		
Pu-241	3.32E-07	1.50E-04		
Pu-242	2.77E-11	1.32E-05		
Pu-244	4.11E-17	1.37E-18		
Ra-226	3.10E-06	3.94E-07		1.27E-09
Ra-228	2.14E-12	1.11E-11		
Sb-125	3.53E-18	3.53E-18	2.65E-05	
Se-79			1.40E-08	
Sm-151		5.46E-13		
Sn-113			7.39E-14	
Sn-126	2.93E-06	1.28E-08	2.05E-07	

Sr-90		1.09E-02		
Tc-99	5.12E-11	2.15E-05		
Th-228	9.81E-22	1.90E-21		
Th-229	1.38E-05	2.51E-06		
Th-230	1.47E-05	1.47E-06		6.63E-10
Th-232	6.75E-05	1.97E-06		
U-232	2.42E-06	8.60E-06		
U-233	4.90E-04	2.01E-04		
U-233_Depleted	9.08E-07	3.72E-07		
U-234	1.11E-03	1.23E-03		5.96E-09
U-235	2.24E-04	5.05E-05		
U-235_Depleted	1.24E-05	2.80E-06		
U-236	9.28E-10	6.70E-06		
U-238	3.75E-04	9.38E-05		6.00E-14
Sum-of-fractions	2.49E-03	1.63E-02	2.79E-05	7.89E-09

Table E-5. Non-groundwater inventory consumption fractions for SLIT5.

Parent	Residential	PostDrilling	Air	Radon
Ag-108m	8.92E-11	1.37E-12		
Am-241	1.05E-06	4.66E-04		
Am-242m	3.03E-07	3.41E-05		
Am-243	3.03E-05	1.06E-05		
Ba-133	1.92E-16	1.00E-13		
C-14		1.81E-05	1.23E-07	
C-14_NR.Pump		2.51E-06	1.71E-08	
Cd-113m		2.50E-17		
Cf-249	3.12E-05	8.90E-06		
Cf-250	9.41E-16	1.38E-07		
Cf-251	7.80E-06	9.12E-06		
Cf-252	6.58E-15	9.62E-11		
Cl-36		9.06E-08	1.52E-11	
Cm-242	2.01E-14	7.40E-11		
Cm-243	5.69E-11	1.07E-07		
Cm-244	3.27E-12	1.42E-05		
Cm-245	2.05E-07	6.33E-07		
Cm-246	7.33E-15	4.91E-07		
Cm-247	2.31E-06	1.37E-07		
Cm-248	6.36E-11	9.19E-07		
Co-60	6.35E-05	1.52E-04		
Cs-134	5.22E-21	1.64E-19		
Cs-135		3.71E-18		
Cs-137	1.41E-05	1.23E-03		
Eu-152	3.91E-11	1.36E-10		
Eu-154	5.38E-07	2.04E-06		
Eu-155	2.32E-19	3.91E-12		
H-3		1.93E-07	3.66E-08	
I-129	8.01E-15	1.49E-07	6.29E-08	
I-129_F.Filtercake	1.07E-16	1.99E-09	8.41E-10	
I-129_Mk50A	1.14E-15	2.13E-08	9.00E-09	
K-40	4.33E-06	5.77E-07		
Kr-85	2.60E-13	2.16E-11		

Nb-94	8.70E-05	3.22E-07		
Ni-59		2.70E-08		
Np-237	3.28E-05	5.05E-05		
Pb-210	2.53E-15	1.60E-07		
Pu-238	1.95E-06	7.10E-03		3.30E-12
Pu-239	4.43E-07	1.14E-03		
Pu-240	3.95E-10	3.19E-04		
Pu-241	4.50E-07	2.04E-04		
Pu-242	7.06E-12	3.38E-06		
Pu-244	3.43E-17	1.15E-18		
Ra-226	3.93E-05	5.01E-06		1.61E-08
Ra-228	2.84E-13	1.48E-12		
Sb-125	1.57E-17	1.57E-17	1.18E-04	
Se-79			7.15E-09	
Sm-151		2.19E-07		
Sn-119m			2.92E-18	
Sn-121m		3.22E-21	8.69E-20	
Sn-126	3.56E-06	1.56E-08	2.50E-07	
Sr-90		2.61E-02		
Sr-90_Mk50A		4.66E-03		
Tc-99	4.54E-11	1.91E-05		
Tc-99_Mk50A	1.79E-12	7.52E-07		
Th-228	1.61E-22	3.11E-22		
Th-229	2.45E-06	4.45E-07		
Th-230	2.08E-05	2.08E-06		9.43E-10
Th-232	8.48E-06	2.47E-07		
U-232	3.20E-07	1.13E-06		
U-233	2.23E-03	9.14E-04		
U-233_Depleted	1.94E-07	7.92E-08		
U-234	4.74E-04	5.29E-04		2.55E-09
U-235	7.20E-05	1.62E-05		
U-235_Depleted	5.77E-06	1.30E-06		
U-235_Paducah.Cask	7.85E-04	1.77E-04		
U-236	9.27E-10	6.69E-06		
U-238	3.28E-03	8.20E-04		5.25E-13
Sum-of-fractions	7.21E-03	4.40E-02	1.19E-04	1.96E-08

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APPENDIX F SELECTED MODELING ASSUMPTIONS

In this appendix, selected assumptions in the modeling approach are listed. Some assumptions listed below tend to be conservative and some non-conservative. The tendencies of others are indeterminate due to many confounding influences that require detailed modeling and/or more detailed field information to sort out effects. However, these assumptions are necessary either because more complete information is unavailable or in order to reduce the complexity of the analysis.

1. **Assumption: The zero percentage of non-crushable containers in WITS for SLIT1 is acceptable.**

   Consideration of non-crushable containers was not included in WITS until several years after disposal operations began. Early disposals may not have recognized the need to identify non-crushable containers and thus some information may not have been recorded.

2. **Assumption: Final covers will perform the same over dynamically compacted areas and those that are not dynamically compacted (i.e., M-Area Glass and ETF Activated-Carbon Vessels).**

   Two unique areas are identified as not being dynamically compacted (i.e., M-Area Glass and ETF Activated-Carbon Vessels). Less dense sediments and bulk wastes, which may be present in areas that are not dynamically compacted, will undergo primary consolidation. Primary consolidation consists of consolidation due to static loads and piping of soil into larger voids that may be present due to bulk wastes. This type of consolidation is a relatively short-term process ranging from months to tens of years. It is anticipated that this type of consolidation would be complete within the time-frame between waste placement and final closure cap construction (>100 years). Secondary consolidation consists of the corrosion followed by the collapsing of containers with significant internal void space. This type of consolidation is typically a long-term process dependent upon the corrosion rate and characteristics of the containers. Analysis of the ETF Activated-Carbon Vessels, which does contain significant internal void space, indicates that they should remain structurally intact for much greater than 1,000 years (i.e. over the entire performance period). It is assumed that the M-Area Glass waste does not contain significant internal void space, and therefore it should be subject to little secondary consolidation.

3. **Assumption: Use of a clayey waste zone for the northern part of SLIT4 is adequate and appropriate.**

   Excavations in the northern part of SLIT4 have revealed more sandy sediments than are found elsewhere as noted by the need for many trench segments.

4. **Assumption: Collapse of non-crushable containers occurs in 2125, immediately after cover installation and loss of institutional control.**

   For most nuclides this is a conservative assumption, but for some nuclides (e.g., after the in-growth of mobile progeny) this is a non-conservative assumption. This assumption also contains the provision that no maintenance is performed after 2125 (i.e., if local subsidence occurs it is assumed that no remediation efforts are undertaken).

5. **Assumption: Uniform distribution of special waste form contaminants throughout the volume of trench inventory groups is acceptable.**

   While special waste forms typically occupy a small volume, their contents were assumed to be spread throughout the entire volume of their trench inventory groups. This is an improvement over the 2008 PA analysis which assumed distribution over the entire slit trench disposal unit volume.

6. **Assumption: Numerical dispersion does not have a significant impact.**

   Following the 2008 PA, the analysis in this report included mechanical dispersion although numerical dispersion is also present. Numerical dispersion is artificial, but it is indistinguishable from mechanical dispersion in the analysis. Both types of dispersion spread concentration fronts and decrease well concentrations. A limited scoping analysis for Np-237 indicates an approximate factor of 1.66 increase in maximum well concentrations when mechanical dispersion is not included. This increase would cause maximum doses from groundwater pathways for SLIT34 to significantly exceed allowed limits. However, this is a pessimistic case because some mechanical dispersion likely should be introduced and such effects would be offset by applying new DCFs.

7. **Assumption: Basing infiltration rates on 10-foot spacing between ideal trench segments is acceptable.**

   For SLIT3 and later slit trenches, the spacing between ideal trench segments is 14 feet which would increase infiltration under subsided conditions, (e.g., the instance of non-crushable container collapse). Infiltration rates at subsidence are increased approximately 10% for the 14 foot spacing and then over time return back to values similar to the 10 foot spacing rates. The nuclide Np-237 dominates the dose estimated for both SLIT125 and SLIT34 as discussed in Chapter 6. The peak well concentrations for Np-237 are occurring for the intact cases; therefore, this infiltration rate increase associated with subsidence has little impact on peak dose values.

8. **Assumption: For the all-pathways analysis an individual receiving the peak dose from the groundwater pathway receives zero dose from the air pathway.**

   "The all-pathways dose evaluated here includes only the groundwater transport pathway because the receptors for the groundwater and air pathways will likely be at different locations and the maximum doses from the two pathways will occur at different times." (2008 PA, Part C, page 101) Comparing the maximum air pathway dose (1.92E-04 mrem/yr in Table 1-2) to the minimum groundwater all-pathways dose (6.82 mrem/yr for SLIT125 in Table 1-1) shows that the air pathway would contribute a negligible amount to the total value.

9. Assumption: Drainage systems designed to carry away runoff from operational, interim, and final covers remove essentially all runoff throughout the entire performance period.

It is assumed that excess rainfall that does not penetrate through the covers (i.e., the operational, interim, and final) is completely removed from the hydraulic system. Here drainage systems are assumed to carry this runoff a sufficient distance from the disposal units being considered such that its contribution to vadose zone recharge is negligible. These "drainage" systems are assumed to operate as designed (or be maintained) such that the above assumption is valid throughout the life of these covers up to the end of institutional controls (i.e., calendar year 2125) and also function reasonably well for the remainder of time to the end of the performance period (i.e., calendar year 3125).

Drainage system performance is most critical during the operational closure and institutional control periods when relatively impermeable covers are shedding most precipitation as surface runoff. The drainage system is assumed to be maintained during these periods. During the period after institutional control when the final cover is in place and slowly degrading, significantly less runoff is occurring as conditions slowly return to background. During this final period runoff is typically expected to be less than two inches per year. For comparison, background runoff (i.e. no covers) determined from eight studies was seen to range from 0.1 to 4 inches/year with a median of 1.6 inches/year and a mode of 2 inches/year.

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APPENDIX G SUPPORTING DOCUMENTS

This appendix contains a copy of an Email from Jordan 2009, documenting plume interaction factors.

Jeffrey Jordan /SRNL/Srs
08/07/2009 01:15 PM

To Leonard Collard/SRNL/Srs@Srs, Luther Hamm/SRNL/Srs@Srs
cc Tom Butcher/SRNL/Srs@Srs, Patricia Lee/SRNL/Srs@srs, Steve Hensel/SRNL/Srs@Srs, Tsu-Te Wu/SRNL/Srs@Srs
bcc
Subject Center Slit Plume Interaction

I used the same approach for this plume interaction study as was done for the PA. Again, this is not a unique solution so if it comes down to needing more room in one or the other, we can revisit it. The attached word document has some more details and a few figures.

	Concentration Factor	Plume Interaction Factor
SLIT1c	0.70	1.43
SLIT2c	0.80	1.25
SLIT3c	0.60	1.67

Slit1c is for Slit Trench 1, 2, and 5
Slit2c is for Slit Trench 3 and 4
Slit3c is for Slit Trench 6 and 7

Plume - center slit.doc

The same approach was used as for the Performance Assessment. Instead of one zone covering all of the center slit trenches, three new zones were created. Slit1c covers the area for ST1, ST2, and ST5. Slit2c covers the area for ST3 and ST4. Slit3c covers the area for ST6 and ST7. The plume interaction factors for the other zones were kept at the same level as in the PA. The plume interaction factors for the three new zones were adjusted to meet the same limit as used in the PA. The final concentrations are in Figure 1. The new zones and the total concentration are shown in Figure 2. As a comparison, the total concentration for the new study was compared to the concentration for the PA, see Figure 3. The fact that the concentrations in this figure overlap each other serves as a check that the new study lies within the bounds of the PA study.

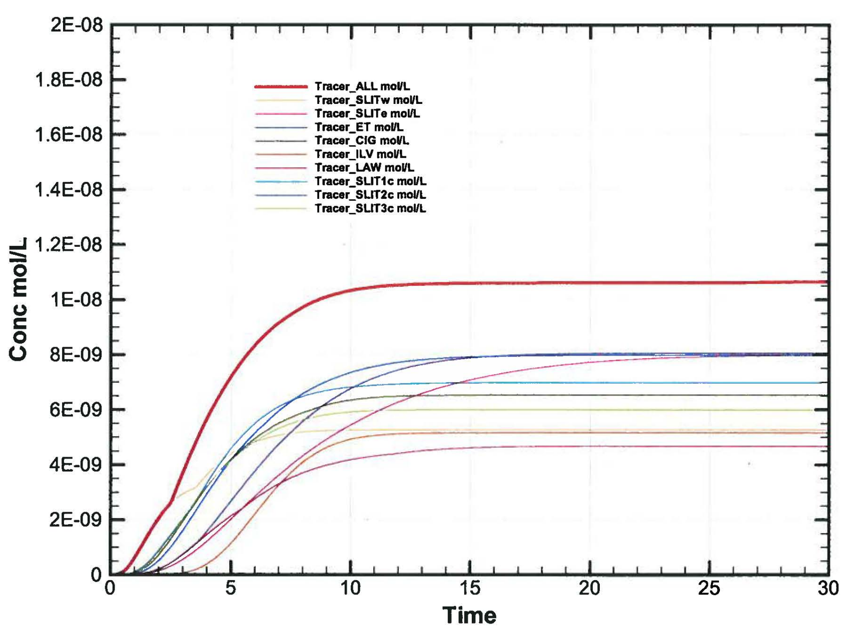

Figure 1 – Final Concentration at 100-m Boundary

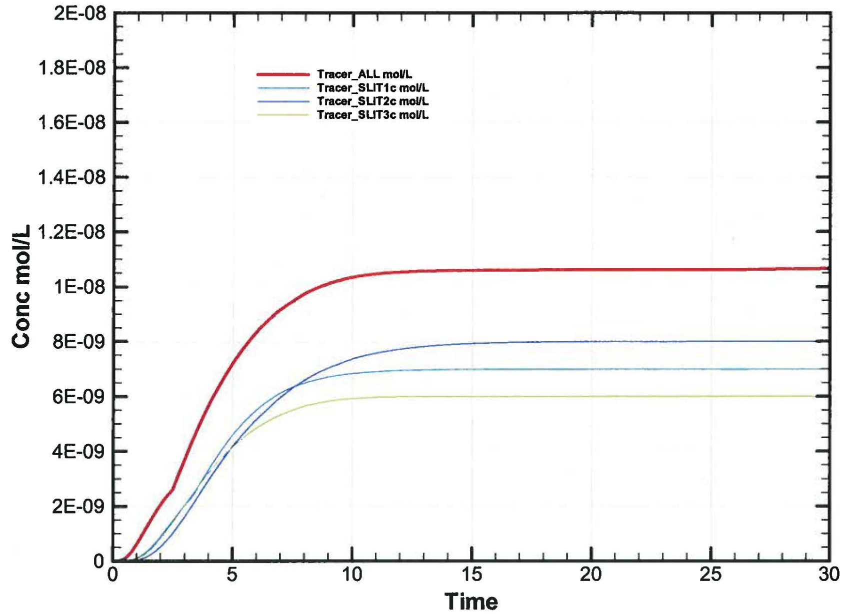

Figure 2 – Final Concentration at 100-m Boundary (Focus on Center Slit Trenches)

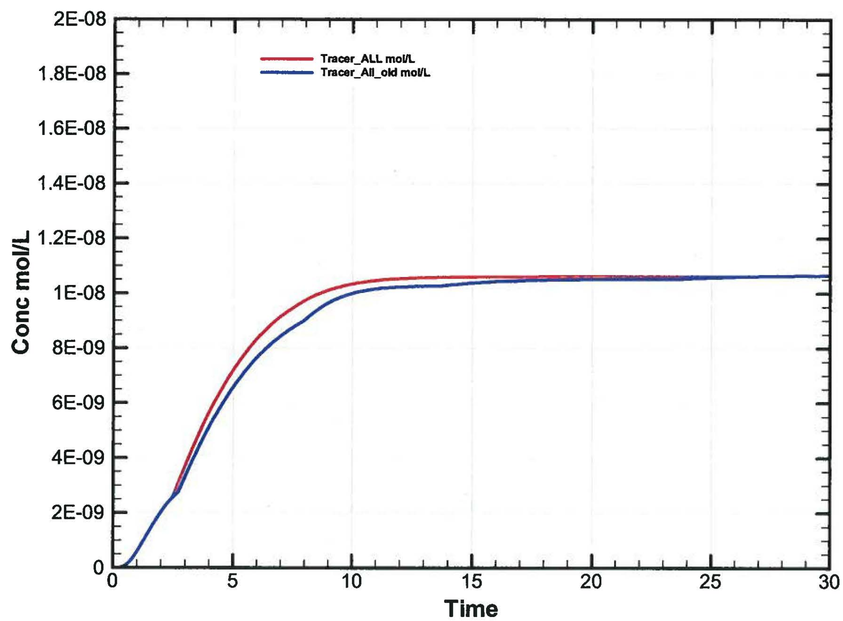

Figure 3 – Comparison of PA Concentration and New Concentration (All=Current Study, All_old=PA)

Distribution:

S. E. Aleman, 735-A
P. M. Almond, 773-43A
A. B. Barnes, 999-W
D. L Beeler, 704-60E
B. T. Butcher, 773-43A
L. B. Collard, 773-43A
D. A. Crowley, 773-43A
S. D. Fink, 773-A
G. P. Flach, 773-42A
B. J. Giddings, 786-5A
W. T. Goldston, 705-3C
J. C. Griffin, 773-A
L. L. Hamm, 773-42A
S. J. Hensel, 773-42A
C. C. Herman, 999-W
R. A. Hiergesell, 773-43A
J. M. Jordan, 703-41A
D. I. Kaplan, 773-43A
D. Li, 999-W
M. G. Looper, 704-36E
S. L. Marra, 773-A
A. M. Murray, 773-A
F. M. Pennebaker, 773-42A
M. A. Phifer, 773-42A
S. R. Reed, 704-56E
K. A. Roberts, 773-43A
R. R. Seitz, 773-43A
D. F. Sink, 704-56E
F. G. Smith, III 773-42A
R. F. Swingle, II 773-43A
G. A. Taylor, 773-43A
K. L. Tempel, 704-56E
T. Whiteside, 773-42A
W. R. Wilmarth, 773-A
C. Wilson (1 file copy & 1 electronic copy), 773-43A - Rm.213