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Radionuclide Inventory Screening Analysis Report for the PABC-2009

Revision 0

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1. INTRODUCTION

The Waste Isolation Pilot Plant (WIPP), located in southeastern New Mexico, has been developed by the U.S. Department of Energy (DOE) for the geologic (deep underground) disposal of transuranic (TRU) waste. Containment of TRU waste at the WIPP is regulated by the U.S. Environmental Protection Agency (EPA) according to the regulations set forth in Title 40 of the Code of Federal Regulations (CFR), Part 191. The DOE demonstrates compliance with the containment requirements according to the Certification Criteria in Title 40 CFR Part 194 by means of performance assessment (PA) calculations performed by Sandia National Laboratories (SNL). WIPP PA calculations estimate the probability and consequence of potential radionuclide releases from the repository to the accessible environment for a regulatory period of 10,000 years after facility closure. The models are maintained and updated with new information as part of a recertification process that occurs at five-year intervals after the first waste shipment is received at the site.

PA calculations were included in the 1996 Compliance Certification Application (CCA) (U.S. DOE 1996), and in a subsequent Performance Assessment Verification Test (PAVT) (MacKinnon and Freeze 1997a, 1997b and 1997c). Based in part on the CCA and PAVT PA calculations, the EPA certified that the WIPP met the containment criteria in the regulations and was approved for disposal of transuranic waste in May 1998 (U.S. EPA 1998). PA calculations were also an integral part of the 2004 Compliance Recertification Application (CRA-2004) (U.S. DOE 2004). During their review of the CRA-2004, the EPA requested an additional PA calculation, referred to as the CRA-2004 Performance Assessment Baseline Calculation (PABC) (Leigh et al. 2005), be conducted with modified assumptions and parameter values (Cotsworth 2005).

Since the CRA-2004 PABC, additional PA calculations were completed for the second WIPP recertification and documented in the 2009 Compliance Recertification Application (CRA-2009). The CRA-2009 PA resulted from continued review of the CRA-2004 PABC, including a number of technical changes and corrections, as well as updates to parameters and improvements to the PA computer codes (Clayton et al. 2008). To incorporate additional information which was received after the CRA-2009 PA was completed, but before the submittal of the CRA-2009, the EPA has requested an additional PA calculation, referred to as the 2009 Compliance Recertification Application Performance Assessment Baseline Calculation (PABC-2009), be undertaken which includes the updated information (Cotsworth 2009).

The Performance Assessment Inventory Report (PAIR) – 2008 (Crawford et al. 2009) was released on April 23, 2009, after the completion of the CRA-2009 PA. This inventory update is the basis for the PA inventory for PABC-2009. This radionuclide screening analysis report combines the activities previously documented by three separate analysis documents: "Calculation of the Waste Unit Factor for the Performance Assessment Baseline Calculation" (Leigh and Trone, 2005a), "Radionuclides Expected to Dominate Potential Releases in the Compliance Recertification Application" (Fox, 2003 / Leigh and Fox, 2005), and "Calculation of Radionuclide Inventories for Use in NUTS in the Performance Assessment Baseline Calculation" (Leigh and Trone, 2005b).

This analysis is governed by AP-145, *Analysis Plan for the CRA-2009 Performance Assessment Baseline Calculation* which discusses the methodology that will be used by Sandia National Laboratories to determine the WIPP repository radionuclide inventory information for use in the PA calculation for the PABC-2009.

This calculation was performed in accordance with the SNL Quality Assurance Program and was prepared as prescribed by the SNL NWMP Procedure, NP 9-1, Analyses, Appendix C, "Routine Calculations."

1.1 ACRONYMS

AP	Analysis Plan
CCA	Compliance Certification Application
CCDF	Complimentary Cumulative Distribution Function Code
CFR	Code of Federal Regulations
CH	Contact Handled
CRA	Compliance Recertification Application
DOE	Department of Energy
EPA	Environmental Protection Agency
EPAUNI	EPA Units Code
ERMS	Electronic Records Management System
LANL	Los Alamos National Laboratory
MTHM	Metric Tons of Heavy Metal
MWd	Megawatt-days
NP	NWMP Procedure
NWMP	Nuclear Waste Management Program
NWPA	Nuclear Waste Policy Act
ORIGEN	Oak Ridge Isotope Generation and Depletion Code
PA	Performance Assessment
PABC	Performance Assessment Baseline Calculation
PAIR	Performance Assessment Inventory Report
PAVT	Performance Assessment Verification Test
RH	Remote Handled
SNF	Spent Nuclear Fuel
SNL	Sandia National Laboratory
TRU	Transuranic
TWBID	Transuranic Waste Baseline Inventory Database
TWBIR	Transuranic Waste Baseline Inventory Report
WIPP	Waste Isolation Pilot Plant
WTS	Washington TRU Solutions LLC
WUF	Waste Unit Factor

2. CALCULATION OF WASTE UNIT FACTOR

2.1 PROBLEM DESCRIPTION

The waste unit factor (WUF), also referred to as the "Unit of Waste," is defined in the CCA as the number of millions of curies of alpha-emitting transuranic radionuclides with half-lives longer than 20 years destined for disposal in the WIPP repository (DOE 1996). Computation of a new waste unit factor based on the updated inventory information provided in Crawford et al. (2009), is required for the PABC-2009. This computation is performed using the following equation (Sanchez et al.1997):

$$f_w = \frac{\sum W_i}{10^6 Ci} \qquad (1)$$

Where:
f_w is the Waste Unit Factor, and
W_i is the WIPP-scale activity in curies (Ci), for alpha-emitting TRU repository wastes having half-lives greater than 20 years.

This calculation uses the WIPP-scale inventory provided in Crawford et al. (2009) at the following years: 2033, 2133, 2383, 3033, 7033, and 12,033.

2.2 ANALYSIS

In order to understand which radionuclides are considered important, with respect to WIPP PA, one must become familiar with Table B-1 in Appendix B, which identifies the release limits per 40 CFR 191. These release limits are normalized to a "Unit of Waste" (also called a "waste unit factor," f_w). For the TRU waste to be disposed of in the WIPP, the unit of waste is "An amount of TRU wastes containing one million curies of alpha-emitting transuranic radionuclides with half lives greater than 20 years." The unit of waste is determined in Tables A-1 through A-6 in Appendix A. From these tables it can be seen that of the 145 radionuclides in the current inventory report (Crawford et al. 2009), there are reported data for 17 transuranic waste radionuclides that contribute to the unit of waste. The overall quantity of transuranic waste radionuclides from Table B-2 that apply to the unit of waste at 2033 is 2.60E+06 curies, thus the value for the unit of waste is **2.60**. From this table it is easily identified that the plutonium and americium radionuclides dominate the unit of waste. For release to the accessible environment that involves a mix of radionuclides, the limits in Table B-2 are used to define normalized releases for comparison with the release limits. Now the unit of waste and the specific release limits are used to determine release limits and cumulative normalized release limits. To help describe the 40 CFR 191 containment requirements, the following two paragraphs were taken as is from *An Introduction to the Mechanics of Performance Assessment Using Examples of Calculations Done for the Waste Isolation Pilot Plant Between 1990 and 1992* (Rechard 1995). This reference gives a very thorough introduction to the mechanics of the WIPP PA process.

"Containment Requirements in 40 CFR 191.13 specify general limits on the release of transuranic waste, high-level waste, or spent nuclear fuel (SNF) from a geological repository. Environmental Protection Agency release limits are defined as the normalizing factors for various radionuclides listed in Table 1 of Appendix A of EPA regulation 40 CFR 191 (see Table B-1). According to the Containment Requirements, there must be a reasonable expectation, based on a performance assessment that includes all significant processes and events, that the cumulative release of any one radionuclide over 10,000 years to the accessible environment shall have (these two points alone determine the EPA limits drawn on all WIPP Complimentary Cumulative Distribution Function Codes (CCDFs):

- less than 1 chance in 10 of exceeding the promulgated EPA radionuclides limits (L_i), and
- less than 1 chance in 1000 of exceeding 10 times those quantities.

For a mix of radionuclides, the sum of all releases, where each radionuclide is normalized with respect to its L_i, shall have:

- Less than 1 chance in 10 of exceeding 1, and
- Less than 1 chance in 1000 of exceeding 10.

Where the sum of all releases is expressed by:

$$R_j = \frac{1}{f_w}\left\{\frac{Q_{1j}}{L_1} + \frac{Q_{2j}}{L_2} + \ldots + \frac{Q_{nRj}}{L_{nR}}\right\} = \sum_{i=1}^{nR} \frac{Q_{ij}}{f_w L_i} \le 1(or 10) \qquad (2)$$

Where:

f_w = waste unit factor = $\dfrac{\sum W_i}{10^6 Ci}$

W_i = activity in Curies (Ci) for α-emitting TRU repository wastes having half-lives ($\tau_{1/2}$) ≥ 20 years

L_i = the EPA release limit for radionuclide i (see Table 1 for examples of units)

nR = number of radionuclides contributing to the release

R_j = total normalized release (EPA unit) for the j^{th} scenario

Q_{ij} = cumulative release for radionuclide q_{ij} beyond a specified boundary, $\int_0^{10,000\,yr} q_{ij}dt$

q_{ij} = release rate into accessible environment at time t for radionuclide i and scenario j calculated from consequence model(s) (see Chapter 5.0 of Rechard 1995)"

3. RADIONUCLIDES EXPECTED TO DOMINATE POTENTIAL RELEASES

3.1 PROBLEM DESCRIPTION

Each potential radionuclide release mechanism modeled in performance assessment has as its source, an inventory of radionuclides that (1) the DOE expects will be disposed in WIPP and (2) analysts believe will be prevalent in a release via the individual release mechanism. For the PABC-2009, the DOE through its contractor, Los Alamos National Laboratory (LANL), gave a radionuclide inventory that it expected would be disposed in the WIPP (Crawford et al. 2009). The radionuclide inventory contains 145 radioisotopes. However, not all of the 145 radioisotopes were necessarily important to track in a PA for the WIPP repository. Many of the isotopes have low concentrations or are short lived (short ½ lives) and would not impact the PA simulations. In addition, tracking of all 145 radioisotopes is not practical since WIPP PA involves a suite of computationally intensive codes. Therefore, the number of isotopes tracked in the WIPP PA codes is reduced.

Three of the WIPP codes have radionuclide inventories as direct inputs: PANEL, NUTS, and CCDFGF. The three codes are used in calculations of releases via individual release mechanisms that are modeled in WIPP PA. PANEL provides the radionuclide source for direct brine release to the surface via a borehole (a potential short-term release mechanism), and it provides the radionuclide source for releases via a borehole to the Culebra member of the Rustler formation (a potential long-term release mechanism). NUTS calculates radionuclide releases via Salado formation to the accessible boundary (a potential long-term release mechanism). The inventory information is used in CCDFGF to calculate direct solid releases to the surface due to drilling activities (a potential short-term release mechanism). The criteria for selecting important radionuclides for each of these codes (and release mechanisms) varies slightly.

3.2 ANALYSIS

The first criteria applied is a determination of importance, based on the regulatory framework provided by the EPA in 40 CFR 191 (U.S. DOE 1996). Of the 145 radionuclides reported in the PAIR-2008 (Crawford et al. 2009), only some are regulated by 40 CFR 191, the regulations are identified in Table B-1 of Appendix B. The tables in Appendix A show the projected WIPP inventory of these isotopes as normalized releases (in EPA units). An EPA unit is defined as the inventory of that isotope in curies divided by the EPA release limit for that isotope in curies as specified in 40 CFR 191, Appendix A, Table 1 (reproduced in Table B-1). The repository is considered to comply with the EPA regulations if there is less than 0.1 probability that the cumulative release to the accessible environment is greater than 1 EPA unit. And less than a 0.001 probability that the cumulative release is greater than 10 EPA units.

Table 1 shows the radionuclide inventory in terms of EPA units at 0 years (2033), 100 years, 350 years, and 10,000 years. It is important to look at the contribution that is being made to the EPA units as a function of time because the contribution of radionuclides can change as they decay or build-up over time. Short-lived isotopes like ^{238}Pu decay quite rapidly, dropping to less than an

EPA unit by about 1000 years, while other isotopes like ^{230}Th that initially have less than one EPA unit grows to over one EPA unit in 10,000 years. Some isotopes at the bottom of the table have short half-lives and are not regulated by the EPA, but they also have significant curies and are the parents of regulated isotopes, so they were included in the calculations.

Table 1: Radionuclide Inventory Sorted by Maximum Release from the PAIR-2008

Radionu clide	Half-life (years)	EPA Units				
		0 Years	100 Years	350 Years	10,000 Years	Maximum
Pu-238	87.7 a	5.67E+03	2.57E+03	3.57E+02	2.79E-21	5.67E+03
Pu-239	2.41E+04 a	1.97E+03	1.97E+03	1.95E+03	1.48E+03	1.97E+03
Am-241	432.7 a	1.82E+03	1.60E+03	1.07E+03	8.50E-03	1.82E+03
Pu-240	6.56E+03 a	5.57E+02	5.51E+02	5.37E+02	1.93E+02	5.57E+02
Cs-137	30.17 a	3.44E+01	3.41E+00	1.06E-02	0.00E+00	3.44E+01
Sr-90	29.1 a	3.09E+01	2.86E+00	7.45E-03	0.00E+00	3.09E+01
U-234	2.46E+05 a	1.19E+00	2.30E+00	3.10E+00	3.14E+00	3.14E+00
Th-230	7.54e+04 a	2.29E-02	3.93E-02	1.03E-01	2.77E+00	2.77E+00
U-233	1.592E+05 a	7.96E-01	7.96E-01	7.95E-01	7.85E-01	7.96E-01
Np-237	2.14E+06 a	1.50E-01	2.06E-01	3.15E-01	5.29E-01	5.29E-01
Th-229	7.3E+03 a	5.00E-02	5.69E-02	7.41E-02	4.98E-01	4.98E-01
Cf-249	351 a	3.75E-01	3.08E-01	1.88E-01	9.66E-10	3.75E-01
Am-243	7.37E+03 a	3.06E-01	3.03E-01	2.96E-01	1.20E-01	3.06E-01
Pu-242	3.75E+05 a	2.92E-01	2.92E-01	2.92E-01	2.87E-01	2.92E-01
U-232	70 a	2.28E-01	8.70E-02	7.84E-03	2.43E-19	2.28E-01
Ra-226	1.60E+03 a	7.91E-02	7.58E-02	6.88E-02	2.18E-01	2.18E-01
Pb-210	22.3 a	6.18E-02	7.60E-02	6.87E-02	2.18E-01	2.18E-01
U-236	2.342E+07 a	6.16E-03	7.80E-03	1.18E-02	1.08E-01	1.08E-01
U-238	4.47E+09 a	1.05E-01	1.05E-01	1.05E-01	1.05E-01	1.05E-01
Am-242m	141.0 a	9.05E-02	5.73E-02	1.83E-02	1.42E-21	9.05E-02
Sm-151	90 a	5.29E-02	2.45E-02	3.57E-03	0.00E+00	5.29E-02
U-235	7.04E+08 a	1.73E-02	1.75E-02	1.79E-02	3.42E-02	3.42E-02
Cm-246	4.76E+03 a	2.52E-02	2.49E-02	2.40E-02	5.83E-03	2.52E-02
C-14	5730 a	2.17E-02	2.14E-02	2.08E-02	6.46E-03	2.17E-02
Ni-63	100 a	1.75E-02	8.24E-03	1.25E-03	0.00E+00	1.75E-02
Th-232	1.4E+10 a	1.32E-02	1.32E-02	1.32E-02	1.32E-02	1.32E-02
Cm-243	29.1 a	1.32E-02	1.16E-03	2.65E-06	0.00E+00	1.32E-02
Cm-245	8.5E+03 a	2.57E-03	5.32E-03	1.01E-02	8.30E-03	1.01E-02
Ac-227	21.77 a	9.31E-03	2.49E-03	2.29E-03	6.79E-03	9.31E-03
Pa-231	3.28E+04 a	2.17E-03	2.20E-03	2.29E-03	6.79E-03	6.79E-03
I-129	1.57E+07 a	6.52E-03	6.52E-03	6.52E-03	6.52E-03	6.52E-03
Tc-99	2.13E+05 a	2.03E-03	2.03E-03	2.03E-03	1.97E-03	2.03E-03
Sn-126	1.0E+05 a	1.41E-03	1.40E-03	1.40E-03	1.31E-03	1.41E-03
Cm-248	3.48E+05 a	5.05E-04	5.05E-04	5.04E-04	4.94E-04	5.05E-04
Pu-244	8.0E+07 a	1.35E-06	1.35E-06	1.35E-06	1.39E-06	1.39E-06
Sm-147	1.06E+11 a	4.04E-10	4.05E-10	4.05E-10	4.05E-10	4.05E-10
Cf-252	2.638 a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cm-244	18.1 a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pm-147	2.6234 a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Radionuclide	Half-life (years)	EPA Units				
		0 Years	100 Years	350 Years	10,000 Years	Maximum
Pu-241	14.4 a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ra-228	5.76 a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

(a) EPA Units Taken from Tables A-1 through A-6 in Appendix A

(b) Decay mode and half-life information taken from *Nuclides and Isotopes* (also called the "Chart of the Nuclides"), 16th Ed. (Lockheed Martin 2002).

Of the 145 isotopes given in Crawford et al. (2009), only 33 have more than 0.001 EPA units of inventory at any time within the 10,000-year regulatory period. These are ^{227}Ac, ^{241}Am, ^{242m}Am, ^{243}Am, ^{14}C, ^{249}Cf, ^{243}Cm, ^{245}Cm, ^{246}Cm, ^{137}Cs, ^{129}I, ^{63}Ni, ^{237}Np, ^{231}Pa, ^{210}Pb, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{242}Pu, ^{226}Ra, ^{151}Sm, ^{126}Sn, ^{90}Sr, ^{99}Tc, ^{229}Th, ^{230}Th, ^{232}Th, ^{232}U, ^{233}U, ^{234}U, ^{235}U, ^{236}U, ^{238}U. Consequently, only these have a direct potential to affect calculated releases. In addition to those, however, there are several unregulated short-lived isotopes that (1) have significant inventory, and (2) decay to regulated isotopes. These are: ^{252}Cf, ^{244}Cm, ^{248}Cm, ^{147}Pm, ^{241}Pu ^{244}Pu, ^{228}Ra and ^{147}Sm they are also included in Table 1.

Traditionally, 30 radioisotopes have been modeled in PANEL decay calculations. Those radioisotopes are: ^{241}Am, ^{243}Am, ^{252}Cf, ^{243}Cm, ^{244}Cm, ^{245}Cm, ^{248}Cm, ^{137}Cs, ^{237}Np, ^{231}Pa, ^{210}Pb, ^{147}Pm, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{244}Pu, ^{226}Ra, ^{228}Ra, ^{147}Sm, ^{90}Sr, ^{229}Th, ^{230}Th, ^{232}Th, ^{233}U, ^{234}U, ^{235}U, ^{236}U and ^{238}U. Of these 30 radioisotopes, 7 (^{252}Cf, ^{231}Pa, ^{210}Pb, ^{147}Pm, ^{226}Ra, ^{228}Ra and ^{147}Sm) are only included in the decay calculations, while the remaining 23 are used in both the decay calculations and the actinide mobilization calculations. The 23 radioisotopes modeled in PANEL encompasses 99.99% of the EPA units at the time of repository closure in the PABC-2009 inventory (See Table 2). Since PANEL is a fairly fast-running code, there was no need to reduce the number of radionuclides modeled in the PANEL calculations for the PABC-2009. Therefore, there are sufficient radionuclides modeled in the PANEL calculations to capture the dominant releases.

Table 2: Percent Contribution at 2033 to EPA Units for Isotopes Modeled in PANEL

ID	Total Inventory [Curies][a]			Source EPA Unit[b]			
	CH	RH	Total	CH	RH	Total	Cum %
Pu-238	1.47E+06	5.11E+03	1.47E+06	5.65E+03	1.96E+01	5.67E+03	56.21%
Pu-239	5.10E+05	2.92E+03	5.13E+05	1.96E+03	1.12E+01	1.97E+03	75.77%
Am-241	4.68E+05	4.48E+03	4.72E+05	1.80E+03	1.72E+01	1.82E+03	93.79%
Pu-240	1.44E+05	9.89E+02	1.45E+05	5.53E+02	3.80E+00	5.57E+02	99.31%
Cs-137	5.48E+02	8.89E+04	8.95E+04	2.11E-01	3.42E+01	3.44E+01	99.65%
Sr-90	5.03E+02	7.99E+04	8.04E+04	1.93E-01	3.07E+01	3.09E+01	99.96%
U-234	3.04E+02	5.18E+00	3.09E+02	1.17E+00	1.99E-02	1.19E+00	99.97%
U-233	1.56E+02	5.09E+01	2.07E+02	6.00E-01	1.96E-01	7.96E-01	99.98%
Am-243	7.17E+01	7.80E+00	7.95E+01	2.76E-01	3.00E-02	3.06E-01	99.98%
Pu-242	7.46E+01	1.25E+00	7.59E+01	2.87E-01	4.83E-03	2.92E-01	99.99%
U-238	2.71E+01	2.96E-01	2.73E+01	1.04E-01	1.14E-03	1.05E-01	99.99%
Th-229	8.81E+00	4.19E+00	1.30E+01	3.39E-02	1.61E-02	5.00E-02	99.99%
Th-230	5.87E-01	9.20E-03	5.97E-01	2.26E-02	3.54E-04	2.29E-02	99.99%

ID	Total Inventory [Curies][a]			Source EPA Unit[b]			
	CH	RH	Total	CH	RH	Total	Cum %
U-235	4.42E+00	7.04E-02	4.49E+00	1.70E-02	2.71E-04	1.73E-02	99.99%
Th-232	2.75E-01	6.86E-02	3.44E-01	1.06E-02	2.64E-03	1.32E-02	99.99%
Cm-243	1.34E+00	2.09E+00	3.43E+00	5.14E-03	8.04E-03	1.32E-02	99.99%
U-236	1.35E+00	2.48E-01	1.60E+00	5.20E-03	9.52E-04	6.16E-03	99.99%
Cm-245	5.86E-01	8.26E-02	6.69E-01	2.25E-03	3.18E-04	2.57E-03	99.99%
Cm-248	1.24E-01	7.63E-03	1.31E-01	4.75E-04	2.93E-05	5.05E-04	99.99%
Pu-244	3.48E-04	2.34E-06	3.51E-04	1.34E-06	8.99E-09	1.35E-06	99.99%
Cm-244	2.61E+03	4.36E+02	3.05E+03	N/A[c]	N/A[c]	N/A[c]	99.99%
Np-238	1.15E-01	1.34E-03	1.16E-01	N/A[c]	N/A[c]	N/A[c]	99.99%
Pu-241	5.06E+05	3.94E+03	5.10E+05	N/A[c]	N/A[c]	N/A[c]	99.99%

(a) Decayed radionuclide data taken from Crawford et al. 2009.
(b) Source EPA Units taken from Table A-1 in Appendix A.
(c) Cm-244, Np-238 and Pu-241 are not regulated isotopes and have no release limits (See Appendix B, Table B-1). Therefore, EPA Units cannot be calculated.

For NUTS, the selection of the dominant radionuclide was based on those that had an EPA unit release greater than 1.0 during the 10,000 year regulatory period, which resulted in the following: ^{241}Am, ^{137}Cs, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{90}Sr, ^{230}Th and ^{234}U. ^{137}Cs and ^{90}Sr are excluded from the NUTS calculation even though they had EPA units over unity at early times because they are short-lived radionuclides that will no longer be contributors to the release by the time radioactive material is transported via the Salado transport pathway to the accessible boundary. In addition, ^{241}Pu is added to the list of radionuclides to be modeled with NUTS since it is a parent isotope for ^{241}Am and has a significant inventory at the start of the calculation. In the NUTS calculations, ^{242}Pu, ^{229}Th and ^{233}U are included, as they have EPA unit releases close to 1.0 and were included previously. Including ^{241}Am, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{229}Th, ^{230}Th, ^{233}U and ^{234}U accounts for 99.34% of the EPA units at the time of repository closure in the PABC-2009 inventory (see Table 3). Therefore, there are sufficient radionuclides modeled in the NUTS calculations to capture the dominant releases.

Table 3: Percent Contribution at 2033 to EPA Units for Isotopes Modeled in NUTS

ID	Total Inventory [Curies][a]			Source EPA Unit[b]			
	CH	RH	Total	CH	RH	Total	Cum %
Pu-238	1.47E+06	5.11E+03	1.47E+06	5.65E+03	1.96E+01	5.67E+03	56.21%
Pu-239	5.10E+05	2.92E+03	5.13E+05	1.96E+03	1.12E+01	1.97E+03	75.77%
Am-241	4.68E+05	4.48E+03	4.72E+05	1.80E+03	1.72E+01	1.82E+03	93.79%
Pu-240	1.44E+05	9.89E+02	1.45E+05	5.53E+02	3.80E+00	5.57E+02	99.31%
U-234	3.04E+02	5.18E+00	3.09E+02	1.17E+00	1.99E-02	1.19E+00	99.32%
U-233	1.56E+02	5.09E+01	2.07E+02	6.00E-01	1.96E-01	7.96E-01	99.33%
Pu-242	7.46E+01	1.25E+00	7.59E+01	2.87E-01	4.83E-03	2.92E-01	99.34%
Th-229	8.81E+00	4.19E+00	1.30E+01	3.39E-02	1.61E-02	5.00E-02	99.34%
Th-230	5.87E-01	9.20E-03	5.97E-01	2.26E-02	3.54E-04	2.29E-02	99.34%
Pu-241	5.06E+05	3.94E+03	5.10E+05	N/A[c]	N/A[c]	N/A[c]	99.34%

(a) Decayed radionuclide data taken from Crawford et al. 2009.
(b) Source EPA Units taken from Table A-1 in Appendix A.

(c) Pu-241 is not a regulated isotope and has no release limit (See Appendix B, Table B-1). Therefore, EPA Units cannot be calculated.

The radionuclides that are important for modeling the direct solid release pathway (included in CCDFGF) are also based on those that had an EPA unit release greater than 1.0 during the 10,000 year regulatory period, which resulted in the following: ^{241}Am, ^{137}Cs, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{90}Sr, ^{230}Th and ^{234}U. ^{137}Cs and ^{90}Sr are maintained for this pathway even though they have relatively short half-lives because a human intrusion event can occur as early as 100 years after repository closure. ^{230}Th is excluded from the calculations as it is less than 0.1% of the total activity and was not included previously. ^{241}Pu is added to the list of radionuclides to be modeled with CCDFGF since it is a parent isotope for ^{241}Am and has a significant inventory at the start of the calculation. ^{244}Cm and ^{233}U are included in the CCDFGF calculations as they have EPA unit releases close to 1.0 and were included previously. The direct solid release pathway is modeled using 10 radionuclides: ^{241}Am, ^{244}Cm, ^{137}Cs, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{90}Sr, ^{233}U, and ^{234}U. These 10 radionuclides accounted for 99.98% of the EPA units at the time of repository closure in the PABC-2009 inventory (See Table 4). Therefore, there are sufficient radionuclides modeled in the CCDFGF calculations to capture the dominant releases.

Table 4: Percent Contribution at 2033 to EPA Units for Isotopes Modeled in CCDFGF

ID	Total Inventory [Curies][a]			Source EPA Unit[b]			
	CH	RH	Total	CH	RH	Total	Cum %
Pu-238	1.47E+06	5.11E+03	1.47E+06	5.65E+03	1.96E+01	5.67E+03	56.21%
Pu-239	5.10E+05	2.92E+03	5.13E+05	1.96E+03	1.12E+01	1.97E+03	75.77%
Am-241	4.68E+05	4.48E+03	4.72E+05	1.80E+03	1.72E+01	1.82E+03	93.79%
Pu-240	1.44E+05	9.89E+02	1.45E+05	5.53E+02	3.80E+00	5.57E+02	99.31%
Cs-137	5.48E+02	8.89E+04	8.95E+04	2.11E-01	3.42E+01	3.44E+01	99.65%
Sr-90	5.03E+02	7.99E+04	8.04E+04	1.93E-01	3.07E+01	3.09E+01	99.96%
U-234	3.04E+02	5.18E+00	3.09E+02	1.17E+00	1.99E-02	1.19E+00	99.97%
U-233	1.56E+02	5.09E+01	2.07E+02	6.00E-01	1.96E-01	7.96E-01	99.98%
Cm-244	2.61E+03	4.36E+02	3.05E+03	N/A[c]	N/A[c]	N/A[c]	99.98%
Pu-241	5.06E+05	3.94E+03	5.10E+05	N/A[c]	N/A[c]	N/A[c]	99.98%

(a) Decayed radionuclide data taken from Crawford et al. 2009.
(b) Source EPA Units taken from Table A-1 in Appendix A.
(c) Cm-244 and Pu-241 are not regulated isotopes and have no release limits (See Appendix B, Table B-1). Therefore, EPA Units cannot be calculated.

4. CALCULATION OF RADIONUCLIDE INVENTORIES FOR USE IN NUTS

4.1 PROBLEM DESCRIPTION

Crawford et al. (2009) reports that the DOE waste generator sites are expecting to dispose of TRU waste containing 145 different radionuclides in the WIPP. Not all of these radionuclides have significant inventories for disposal and not all of these radionuclides are expected to contribute to potential releases from the WIPP repository over the 10,000 year regulatory period. Section 3, identifies which radionuclides are expected to contribute to potential releases from the repository for the individual transport pathways modeled in performance assessment. For transport through the Salado to the accessible boundary and transport through the Salado to the Culebra which is modeled using the NUTS code in performance assessment, the important radionuclides are shown in Table 2 of Section 3.

The radionuclides in Table 2 are important contributors to the unit of waste at the time of repository closure and they have half-lives that are long enough to contribute to potential releases via the Salado. In addition, Section 3 identifies ^{241}Pu as being important because it is the parent isotope for ^{241}Am and it has a significant initial inventory. The inventory for ^{241}Pu at the time of repository closure (2033) is 5.06E+05 curies in contact handled (CH) TRU waste and 3.94E+03 curies in remote handled (RH) TRU waste (Table A-1 in Appendix A).

Because NUTS is a computationally intensive code, minimizing the number of radionuclides that NUTS must track in a calculation is beneficial. Therefore, inventories for the uranium, plutonium, americium and thorium isotopes need to be combined into "lumped" inventories to facilitate the NUTS calculations for performance assessment. Technical justification for lumping is provided below (see Table 5 for lumped values).

4.2 COMPUTATIONAL METHODOLOGY

4.2.1 Theory

The theory behind combining radionuclide inventories into "lumped" inventories for transport calculations is that radionuclides of the same elemental form will transport at the same rate (Leigh and Trone, 2005b). Therefore, the inventories for isotopes of uranium can be combined. Inventories for isotopes of plutonium can be combined, and inventories for isotopes of thorium can be combined. Using the isotopes identified in Table 2 as important: (1) the activity of ^{234}U and ^{233}U will be combined to produce values for the material U234L (the lumped uranium inventory) for the NUTS calculation, (2) the activity of ^{239}Pu, ^{240}Pu and ^{242}Pu will be combined to produce values for the material PU239L for the NUTS calculation, and (3) the activity of ^{230}Th and ^{229}Th will be combined to produce values for the material TH230L in the NUTS calculation.

In Table 2, ^{238}Pu is also listed as an important radionuclide for the NUTS calculation. The inventory of ^{238}Pu is not combined with the other plutonium isotopes because of its relatively short half-life.

Finally, the inventory of ^{241}Pu is combined with the inventory of ^{241}Am because ^{241}Pu is a parent isotope to ^{241}Am and ^{241}Pu has a relatively short half-life when compared to ^{241}Am. Combining the inventories for ^{241}Am and ^{241}Pu produces the inventory value for the material AM241L in the NUTS calculation.

The resulting decay chains for the NUTS calculations are:

$$^{238}\text{Pu} \rightarrow {}^{234}\text{U} \rightarrow {}^{230}\text{Th} \tag{3}$$

$$^{239}\text{Pu} \tag{4}$$

$$^{241}\text{Am} \tag{5}$$

4.2.2 Implementation

One can either add the curies of two isotopes to get a combined inventory or one can add the moles. Depending on the half-lives of the isotopes that are being combined, one method will result in a larger combined activity than the other. If for example, isotope A has a longer half-life than isotope B and the inventory of isotope B is to be combined with the inventory of isotope A, the method that results in the largest combined activity for isotope A is to add the curies of isotope B to the curies of isotope A. If on the other hand, the half-life of isotope A is shorter than the half-life of isotope B, the method that results in the largest combined activity for isotope A is to add the moles of isotope B to the moles of isotope A. Therefore, when combining the plutonium isotopes, ^{242}Pu, ^{240}Pu, and ^{239}Pu, the curies of ^{240}Pu are added to the curies of ^{239}Pu but the moles of ^{242}Pu are added to the moles of ^{239}Pu. When combining the thorium isotopes, the curies of ^{229}Th are added to the curies of ^{230}Th. When combining the uranium isotopes, the curies of ^{233}U are added to the curies of ^{234}U.

4.2.3 Equations

Equations 6 through 15 show the computational methodology for combining radionuclide activities into lumped activity values.

$$A_L(\text{Pu238})_{CH} = A(\text{Pu238})_{CH} \tag{6}$$

$$A_L(\text{Pu238})_{RH} = A(\text{Pu238})_{RH} \tag{7}$$

where:

$A_L(\text{Pu238})_{CH}$	activity value for the property INVCHD for the material PU238L
$A(\text{Pu238})_{CH}$	activity value for ^{238}Pu from Table 1 for CH-TRU
$A_L(\text{Pu238})_{RH}$	activity value for the property INVRHD for the material PU238L
$A(\text{Pu238})_{RH}$	activity value for ^{238}PU from Table 1 for RH-TRU

$$A_L(\text{Am241})_{CH} = A(\text{Am241})_{CH} + A(\text{Pu241})_{CH} * \tau_{1/2}(\text{Pu241}) / \tau_{1/2}(\text{Am241}) \tag{8}$$

$$A_L(\text{Am241})_{RH} = A(\text{Am241})_{RH} + A(\text{Pu241})_{RH} * \tau_{1/2}(\text{Pu241}) / \tau_{1/2}(\text{Am241}) \tag{9}$$

where:

$A_L(Am241)_{CH}$	activity value for the property INVCHD for the material AM241L
$A(Am241)_{CH}$	activity value for ^{241}Am from Table 1 for CH-TRU
$A(Pu241)_{CH}$	activity value for ^{241}Pu from Table 1 for CH-TRU
$A_L(Am241)_{RH}$	activity value for the property INVRHD for the material AM241L
$A(Am241)_{RH}$	activity value for ^{241}Am from Table 1 for RH-TRU
$A(Pu241)_{RH}$	activity value for ^{241}Pu from Table 1 for RH-TRU
$\tau_{1/2}$ (Am241)	half-life of ^{241}Am from Table 2
$\tau_{1/2}$ (Pu241)	half-life of ^{241}Pu from Table 2

$$A_L(Pu239)_{CH} = A(Pu239)_{CH} + A(Pu240)_{CH} + A(Pu242)_{CH} * \tau_{1/2}(Pu242)/\tau_{1/2}(Pu239) \quad (10)$$

$$A_L(Pu239)_{RH} = A(Pu239)_{RH} + A(Pu240)_{RH} + A(Pu242)_{RH} * \tau_{1/2}(Pu242)/\tau_{1/2}(Pu239) \quad (11)$$

where:

$A_L(Pu239)_{CH}$	activity value for the property INVCHD for the material PU239L
$A(Pu239)_{CH}$	activity value for ^{239}Pu from Table 1 for CH-TRU
$A(Pu240)_{CH}$	activity value for ^{240}Pu from Table 1 for CH-TRU
$A(Pu242)_{CH}$	activity value for ^{242}Pu from Table 1 for CH-TRU
$A_L(Pu239)_{RH}$	activity value for the property INVRHD for the material PU239L
$A(Pu239)_{RH}$	activity value for ^{239}Pu from Table 1 for RH-TRU
$A(Pu240)_{RH}$	activity value for ^{240}Pu from Table 1 for RH-TRU
$A(Pu242)_{RH}$	activity value for ^{242}Pu from Table 1 for RH-TRU
$\tau_{1/2}(Pu239)$	half-life of ^{239}Pu from Table 2
$\tau_{1/2}(Pu242)$	half-life of ^{242}Pu from Table 2

$$A_L(U234)_{CH} = A(U234)_{CH} + A(U233)_{CH} \quad (12)$$

$$A_L(U234)_{RH} = A(U234)_{RH} + A(U233)_{RH} \quad (13)$$

where:

$A_L(U234)_{CH}$	activity value for the property INVCHD for the material U234L
$A(U234)_{CH}$	activity value for ^{234}U from Table 1 for CH-TRU
$A(U233)_{CH}$	activity value for ^{233}U Table 1 for CH-TRU
$A_L(U234)_{RH}$	activity value for the property INVRHD for the material U234L
$A(U234)_{RH}$	activity value for ^{234}U from Table 1 for RH-TRU
$A(U233)_{RH}$	activity value for ^{233}U Table 1 for RH-TRU

$$A_L(Th230)_{CH} = A(Th230)_{CH} + A(Th229)_{CH} \quad (14)$$

$$A_L(Th230)_{RH} = A(Th230)_{RH} + A(Th229)_{RH} \quad (15)$$

where:

$A_L(Th230)_{CH}$	activity value for the property INVCHD for the material TH230L
$A(Th230)_{CH}$	activity value for ^{230}Th from Table 1 for CH-TRU
$A(Th229)_{CH}$	activity value for ^{229}Th Table 1 for CH-TRU
$A_L(Th230)_{RH}$	activity value for the property INVRHD for the material TH230L

$A(Th230)_{RH}$	activity value for ^{230}Th from Table 1 for RH-TRU
$A(Th229)_{RH}$	activity value for ^{229}Th Table 1 for RH-TRU

4.3 RESULTS

Using the radionuclide activity values from Table A-1 and the equations from Section 4.2 gives the values in Table 5 for the lumped radionuclide inventories at the end of 2033.

Table 5: Lumped Radionuclide Inventory Values As of 12/31/2033

Material	INVCHD (Total Curies)	INVRHD (Total Curies)
AM241L	4.85E+05	4.61E+03
PU238L	1.47E+06	5.11E+03
PU239L	6.55E+05	3.92E+03
TH230L	9.40E+00	4.20E+00
U234L	4.60E+02	5.61E+01

5. OXYANION MOLES

Memorandum to Records: *Calculation of Moles of Sulfate and Nitrate for PABC – 2009* (Fox, 2009) states: Los Alamos National Laboratory (LANL) provided masses of sulfate and nitrate in waste coming to the Waste Isolation Pilot Plant (WIPP) in the *Performance Assessment Inventory Report – 2008* (Crawford et. al. 2009). The values are 1.73E+06 kg of nitrate and 5.91E+05 kg of sulfate. A conversion to moles is needed for input to the 2009 Performance Assessment Baseline Calculation (PABC – 2009). The molecular weights for nitrate and sulfate are given in Tierney (1996). The molecular weight of nitrate used in Tierney (1996) is 6.20E-02 kg/mole. The molecular weight of sulfate used in Tierney (1996) is 9.606E-02 kg/mole. The conversion is as follows:

$$M_{waste}^{NO_3^-} = \left[\frac{1.73E+06\,kg}{6.20E-02\,kg\,/\,mole}\right] = 2.79E+07\ moles\ NO_3^- \tag{16}$$

$$M_{waste}^{SO_4^{-2}} = \left[\frac{5.91E+05\,kg}{9.606E-02\,kg\,/\,mole}\right] = 6.15E+06\ moles\ SO_4^{-2} \tag{17}$$

6. RELEVANT PROCEDURES AND REFERENCES

6.1 PROCEDURES

AP-145, *Analysis Plan for the CRA-2009 Performance Assessment Baseline Calculation.* Sandia National Laboratories, Carlsbad, NM. ERMS 551511.

NP 9-1, *Analyses.* Sandia National Laboratories Nuclear Waste Management Program Procedure, Revision 7. ERMS 549225.

NP 9-2, *Parameters.* Sandia National Laboratories Nuclear Waste Management Program Procedure, Revision 1. ERMS 544242.

6.2 REFERENCES

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APPENDIX A - Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste

Table A-1: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 2033)

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Ac-225	α, γ	10.0 d	8.79E+00	4.18E+00	---------	---------	---------
Ac-227	α, β^-, γ	21.77 a	2.26E+00	1.57E-01	100	260.00	9.31E-03
Ac-228	α, β^-, γ	6.15 h	2.61E-01	6.51E-02	---------	---------	---------
Ag-108	β-, □, ε, β+	2.39 m	5.47E-09	0.00E+00	---------	---------	---------
Ag-108m	ε, β+ , γ, *IT*	420 m	6.16E-08	0.00E+00	---------	---------	---------
Ag-109m	*ITe*$^-$	39.8 s	1.12E-07	6.41E-14	---------	---------	---------
Ag-110	β^-, γ, ε	24.6 s	6.90E-15	1.78E-24	---------	---------	---------
Ag-110m	β^-, γ, *ITe*$^-$	249.8 d	5.24E-13	1.35E-22	---------	---------	---------
Am-241	α, γ, *SF*	432.7 a	4.68E+05	4.48E+03	100	260.00	1.82E+03
Am-242	β^-, γ, ε *e*$^-$	16.02 h	2.29E+01	2.66E-01	---------	---------	---------
Am-242m	α, *ITe*$^-$, γ, *SF*	141.0 a	2.33E+01	2.71E-01	100	260.00	9.05E-02
Am-243	α, γ, *SF*	7.37E+03 a	7.17E+01	7.80E+00	100	260.00	3.06E-01
Am-245	β^-, γ	2.05 h	5.12E-14	1.51E-23	---------	---------	---------
At-217	α, β^-, γ	32 ms	8.80E+00	4.18E+00	---------	---------	---------
Ba-133	ε, □	10.53 a	1.98E-03	8.12E-08	---------	---------	---------
Ba-137m	*IT*	2.552 m	5.12E+02	8.32E+04	---------	---------	---------
Bi-210	α, β^-, γ	5.01 d	1.73E+00	1.42E+01	---------	---------	---------
Bi-211	α, β^-, γ	2.14 m	2.24E+00	1.56E-01	---------	---------	---------
Bi-212	α, β^-, γ	1.009 h	4.06E+01	2.02E+01	---------	---------	---------
Bi-213	α, β^-, γ	45.6 m	8.78E+00	4.17E+00	---------	---------	---------
Bi-214	α, β^-, γ	19.9 m	2.19E+00	1.81E+01	---------	---------	---------
Bk-249	α, β^-, γ, *SF*	3.2E+02 d	3.54E-09	1.04E-18	---------	---------	---------
Bk-250	β^-, γ	3.217 h	4.38E-12	1.63E-12	---------	---------	---------
C-14	β^-	5730 a	5.61E+00	1.86E-02	100	260.00	2.17E-02
Cd-109	γ, ε	462.0 d	1.13E-07	6.49E-14	---------	---------	---------
Cd-113m	β^-, *IT*	14.1 a	0.00E+00	2.45E+00	---------	---------	---------
Ce-144	β^-, γ	284.6 d	1.33E-10	6.36E-09	---------	---------	---------
Cf-249	α, γ, *SF*	351 a	9.74E+01	1.29E-01	100	260.00	3.75E-01
Cf-250	α, γ, *SF*	13.1 a	4.52E-02	1.20E-02	---------	---------	---------
Cf-251	α, γ	9.0E+02 a	2.96E-02	6.16E-04	100	260.00	1.16E-04
Cf-252	α, γ, *SF*	2.638 a	3.28E-02	1.83E-04	---------	---------	---------
Cl-36	β^-, ε, β^+	3.01E+01 a	2.00E-03	0.00E+00	---------	---------	---------
Cm-242	α, γ, *SF*	162.8 d	1.92E+01	2.23E-01	---------	---------	---------
Cm-243	α, γ, *SF*, ε	29.1 a	1.34E+00	2.09E+00	100	260.00	1.32E-02
Cm-244	α, γ, *SF*	18.1 a	2.61E+03	4.36E+02	---------	---------	---------

Table A-1: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 2033) – continued

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Cm-245	α, γ, *SF*	8.5E+03 a	5.86E-01	8.26E-02	100	260.00	2.57E-03
Cm-246	α, γ, *SF*	4.76E+03 a	3.79E+00	2.77E+00	100	260.00	2.52E-02
Cm-247	α, γ	1.56 E+07 a	2.65E-02	1.59E-07	100	260.00	1.02E-04
Cm-248	α, *SF*	3.48E+05 a	1.24E-01	7.63E-03	100	260.00	5.05E-04
Cm-250	α, β^-, *SF*	9700 a	7.97E-11	2.97E-11	---------	---------	---------
Co-60	β^-, γ	5.271 a	6.22E-02	1.22E+01	---------	---------	---------
Cs-134	β^-, γ, ε	2.065 a	5.01E-03	1.10E-01	---------	---------	---------
Cs-135	β^-	2.3E+06 a	0.00E+00	1.08E-02	1000	2600.00	4.17E-06
Cs-137	β^-, γ	30.17 a	5.48E+02	8.89E+04	1000	2600.00	3.44E+01
Es-254	α, □	276 d	7.99E-23	0.00E+00	---------	---------	---------
Eu-150	ε, □	36 a	1.28E-03	0.00E+00	---------	---------	---------
Eu-152	β^-, γ, $\varepsilon\beta^+$	13.48 a	1.37E+00	2.67E+00	---------	---------	---------
Eu-154	β^-, γ, εγ	8.59 a	3.55E+00	8.03E+01	---------	---------	---------
Eu-155	β^-, γ	4.71 a	4.79E-02	3.18E+01	---------	---------	---------
Fe-55	ε	2.73 a	3.82E-06	7.07E-04	---------	---------	---------
Fr-221	α, γ	4.8 m	8.78E+00	4.18E+00	---------	---------	---------
Fr-223	α, β^-, γ	21.8 m	3.09E-02	2.15E-03	---------	---------	---------
Gd-152	α	1.1E+14 a	1.79E-13	9.57E-13	100	260.00	4.37E-15
H-3	β^-	12.3 a	1.35E+03	6.74E+02	---------	---------	---------
Ho-166m	β-, □	1.2E+03 a	6.48E-05	2.01E-07	---------	---------	---------
I-129	β^-, γ	1.57E+07 a	1.69E+00	6.22E-03	100	260.00	6.52E-03
K-40	β^-, □, β^+	1.27E+09 a	5.50E-03	0.00E+00	---------	---------	---------
Kr-81	ε, □	2.35E+05 a	0.00E+00	1.80E-07	---------	---------	---------
Kr-85	β^-, γ	10.73 a	7.03E+00	4.02E+01	---------	---------	---------
Mn-54	ε, γ	312.2 d	8.33E-13	3.12E-14	---------	---------	---------
Mo-93	ε, □	3.5E+03 a	0.00E+00	1.82E-04	---------	---------	---------
Na-22	ε	2.6019 a	2.01E-04	1.83E-09	---------	---------	---------
Nb-93m	*IT*e^-	16.1 a	8.64E-04	7.29E-01	---------	---------	---------
Nb-94	β^-, □	2.0E+04 a	1.74E-04	1.89E-05	---------	---------	---------
Ni-59	ε	7.6E+04 a	1.13E-01	1.42E-02	1000	2600.00	4.88E-05
Ni-63	β^-	100 a	3.34E+00	4.22E+01	1000	2600.00	1.75E-02
Np-237	α, γ	2.14E+06 a	3.65E+01	2.49E+00	100	260.00	1.50E-01
Np-238	β^-, γ	2.117 d	1.15E-01	1.34E-03	---------	---------	---------
Np-239	β^-, γ	2.355 d	7.08E+01	7.70E+00	---------	---------	---------
Np-240m	β^-, γ, *IT*	7.22 m	3.52E-04	2.36E-06	---------	---------	---------

Table A-1: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 2033) – continued

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Pa-231	α, γ	3.28E+04 a	3.78E-01	1.87E-01	100	260.00	2.17E-03
Pa-233	β^-, γ	27.0 d	3.61E+01	2.47E+00	---------	---------	---------
Pa-234	β^-, γ	6.69 h	3.48E-02	3.80E-04	---------	---------	---------
Pa-234m	β^-, γ, *IT*	1.17 m	2.68E+01	2.93E-01	---------	---------	---------
Pb-209	β^-	3.25 h	8.79E+00	4.18E+00	---------	---------	---------
Pb-210	α, β^-, γ	22.3 a	1.75E+00	1.43E+01	100	260.00	6.18E-02
Pb-211	β^-, γ	36.1 m	2.24E+00	1.56E-01	---------	---------	---------
Pb-212	β^-, γ	10.64 h	4.05E+01	2.01E+01	---------	---------	---------
Pb-214	β^-, γ	27 m	2.19E+00	1.81E+01	---------	---------	---------
Pd-107	β^-	6.5E+06 a	0.00E+00	3.54E-04	1000	2600.00	1.36E-07
Pm-146	ε, □, β^-	5.53 a	0.00E+00	1.42E-08	---------	---------	---------
Pm-147	β^-, γ	2.6234 a	5.09E-02	1.18E+00	---------	---------	---------
Po-210	α, γ	138.38 d	1.75E+00	1.43E+01	---------	---------	---------
Po-211	α, γ	0.516 s	6.83E-03	4.75E-04	---------	---------	---------
Po-212	α	0.298 μs	2.59E+01	1.29E+01	---------	---------	---------
Po-213	α	4 μs	8.60E+00	4.09E+00	---------	---------	---------
Po-214	α, γ	163.7 μs	2.19E+00	1.81E+01	---------	---------	---------
Po-215	α, β^-, γ	1.780 ms	2.24E+00	1.56E-01	---------	---------	---------
Po-216	α, γ	0.145 s	4.05E+01	2.01E+01	---------	---------	---------
Po-218	α, β^-, γ	3.10 m	2.15E+00	1.78E+01	---------	---------	---------
Pr-144	β^-, γ	17.28 m	1.30E-10	6.23E-09	---------	---------	---------
Pu-236	α, γ, *SF*	2.87 a	2.51E-05	1.50E-10	---------	---------	---------
Pu-238	α, γ, *SF*	87.7 a	1.47E+06	5.11E+03	100	260.00	5.67E+03
Pu-239	α, γ, *SF*	2.41E+04 a	5.10E+05	2.92E+03	100	260.00	1.97E+03
Pu-240	α, γ, *SF*	6.56E+03 a	1.44E+05	9.89E+02	100	260.00	5.57E+02
Pu-241	α, β^-, γ	14.4 a	5.06E+05	3.94E+03	---------	---------	---------
Pu-242	α, γ, *SF*	3.75E+05 a	7.46E+01	1.25E+00	100	260.00	2.92E-01
Pu-243	β^-, γ	4.956 h	2.62E-02	1.57E-07	---------	---------	---------
Pu-244	α, *SF*	8.0E+07 a	3.48E-04	2.34E-06	100	260.00	1.35E-06
Ra-223	α, γ	11.435 d	2.27E+00	1.58E-01	---------	---------	---------
Ra-224	α, γ	3.66 d	4.04E+01	2.01E+01	---------	---------	---------
Ra-225	β^-, γ	14.9 d	8.80E+00	4.18E+00	---------	---------	---------
Ra-226	α, γ	1.60E+03 a	2.21E+00	1.83E+01	100	260.00	7.91E-02
Ra-228	β^-, γ	5.76 a	3.08E-01	7.69E-02	---------	---------	---------
Rb-87	β^-	4.88E+10 a	0.00E+00	9.68E-07	---------	---------	---------
Rh-106	β^-, γ	29.9 s	1.62E-07	2.65E-13	---------	---------	---------

Table A-1: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 2033) – continued

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Rn-219	α, γ	3.96 s	2.24E+00	1.56E-01	---------	---------	---------
Rn-220	α, γ	55.6 s	4.05E+01	2.01E+01	---------	---------	---------
Rn-222	α, γ	3.8235 d	2.19E+00	1.82E+01	---------	---------	---------
Ru-106	β⁻	1.02 a	1.64E-07	2.68E-13	---------	---------	---------
Sb-125	β⁻, γ	2.758 a	5.18E-03	3.82E-03	---------	---------	---------
Sb-126	β⁻, γ	12.4 d	2.80E-01	2.31E-01	---------	---------	---------
Sb-126m	γ, *ITe⁻*	11.0 s	2.00E+00	1.65E+00	---------	---------	---------
Se-79	β⁻	6.5E+04 a	7.35E-02	1.54E-01	1000	2600.00	8.76E-05
Sm-146	α	1.03E+08 a	0.00E+00	9.35E-15	---------	---------	---------
Sm-147	α	1.06E+11 a	1.96E-09	1.03E-07	100	260.00	4.04E-10
Sm-151	β⁻, γ	90 a	8.35E+00	1.29E+02	1000	2600.00	5.29E-02
Sn-121m	β⁻, γ, *ITe⁻*	55 a	0.00E+00	3.91E-02	1000	2600.00	1.50E-05
Sn-126	β⁻, γ	1.0E+05 a	2.00E+00	1.65E+00	1000	2600.00	1.41E-03
Sr-90	β⁻	29.1 a	5.03E+02	7.99E+04	1000	2600.00	3.09E+01
Tc-99	β⁻, γ	2.13E+05 a	4.33E+01	9.54E+00	10000	26000.00	2.03E-03
Te-123	ε	1.0E+13 a	1.80E-18	0.00E+00	---------	---------	---------
Te-125m	γ, *ITe⁻*	58 d	1.26E-03	9.24E-04	---------	---------	---------
Th-227	α, γ	18.72 d	2.21E+00	1.53E-01	---------	---------	---------
Th-228	α, γ	1.913 a	4.10E+01	2.03E+01	---------	---------	---------
Th-229	α, γ	7.3E+03 a	8.81E+00	4.19E+00	100	260.00	5.00E-02
Th-230	α, γ	7.54e+04 a	5.87E-01	9.20E-03	10	26.00	2.29E-02
Th-231	β⁻, γ	1.063 d	4.37E+00	6.95E-02	---------	---------	---------
Th-232	α, γ	1.4E+10 a	2.75E-01	6.86E-02	10	26.00	1.32E-02
Th-234	β⁻, γ	24.10 d	2.68E+01	2.93E-01	---------	---------	---------
Tl-204	β⁻, ε	3.78 a	2.34E-08	0.00E+00	---------	---------	---------
Tl-207	β⁻, γ	4.77 m	2.23E+00	1.55E-01	---------	---------	---------
Tl-208	β⁻, γ	3.053 m	1.46E+01	7.24E+00	---------	---------	---------
Tl-209	β⁻, γ	2.2 m	1.93E-01	9.19E-02	---------	---------	---------
U-232	α, γ, *SF*	70 a	3.95E+01	1.97E+01	100	260.00	2.28E-01
U-233	α, γ, *SF*	1.592E+05 a	1.56E+02	5.09E+01	100	260.00	7.96E-01
U-234	α, γ, *SF*	2.46E+05 a	3.04E+02	5.18E+00	100	260.00	1.19E+00
U-235	α, γ, *SF*	7.04E+08 a	4.42E+00	7.04E-02	100	260.00	1.73E-02
U-236	α, γ, *SF*	2.342E+07 a	1.35E+00	2.48E-01	100	260.00	6.16E-03
U-237	β⁻, γ	6.75 d	1.24E+01	9.68E-02	---------	---------	---------
U-238	α, γ, *SF*	4.47E+09 a	2.71E+01	2.96E-01	100	260.00	1.05E-01
U-240	β⁻, γ	14.1 h	3.45E-04	2.31E-06	---------	---------	---------

Table A-1: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 2033) – continued

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Y-90	β^-, γ	2.67 d	4.97E+02	7.89E+04	---------	---------	---------
Zn-65	$\beta^+, \gamma, \varepsilon$	243.8 d	3.35E-16	8.51E-17	---------	---------	---------
Zr-93	β^-, γ	1.5E+06 a	1.14E-03	8.01E-01	1000	2600.00	3.08E-04
Total:	---	---	3.10E+06	3.50E+05			1.01E+04

(a) Decayed radionuclide inventory information taken from Crawford Et Al. 2009.
(b) Release limits are determined in accordance with 40CFR191 (Appendix B, Table B-1). Left column corresponds to specific release limits (cumulative releases to the accessible environment for 10,000 years after disposal per "Unit of Waste" identified in Note 1(e) of Table 1, Appendix A, 40CFR191). *Right column corresponds* to release limit obtained for 2.32 Units of Waste. The 2.32 value for the Unit of Waste corresponds to the Units of Waste present at repository closure, 2033.
(c) Decay mode and half-life information taken from *Nuclides and Isotopes* (also called the "Chart of the Nuclides"), 16th Ed. (Lockheed Martin 2002).

Table A-2: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 2133)

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Ac-225	α, γ	10.0 d	1.02E+01	4.61E+00	---------	---------	---------
Ac-227	α, β^-, γ	21.77 a	4.62E-01	1.85E-01	100	260.00	2.49E-03
Ac-228	α, β^-, γ	6.15 h	2.72E-01	6.77E-02	---------	---------	---------
Ag-108	β-, □, ε, β+	2.39 m	3.17E-09	0.00E+00	---------	---------	---------
Ag-108m	ε, β+ , γ, *IT*	420 m	3.57E-08	0.00E+00	---------	---------	---------
Ag-109m	*ITe*$^-$	39.8 s	0.00E+00	0.00E+00	---------	---------	---------
Ag-110	$\beta^-, \gamma, \varepsilon$	24.6 s	0.00E+00	0.00E+00	---------	---------	---------
Ag-110m	β^-, γ, *ITe*$^-$	249.8 d	0.00E+00	0.00E+00	---------	---------	---------
Am-241	α, γ, *SF*	432.7 a	4.13E+05	3.93E+03	100	260.00	1.60E+03
Am-242	$\beta^-, \gamma, \varepsilon$ *e*$^-$	16.02 h	1.45E+01	1.69E-01	---------	---------	---------
Am-242m	α, *ITe*$^-$, γ, *SF*	141.0 a	1.47E+01	1.72E-01	100	260.00	5.73E-02
Am-243	α, γ, *SF*	7.37E+03 a	7.11E+01	7.72E+00	100	260.00	3.03E-01
Am-245	β^-, γ	2.05 h	0.00E+00	0.00E+00	---------	---------	---------
At-217	α, β^-, γ	32 ms	1.02E+01	4.62E+00	---------	---------	---------
Ba-133	ε, □	10.53 a	3.11E-06	1.28E-10	---------	---------	---------
Ba-137m	*IT*	2.552 m	5.08E+01	8.25E+03	---------	---------	---------
Bi-210	α, β^-, γ	5.01 d	2.12E+00	1.74E+01	---------	---------	---------
Bi-211	α, β^-, γ	2.14 m	4.56E-01	1.83E-01	---------	---------	---------
Bi-212	α, β^-, γ	1.009 h	1.57E+01	7.75E+00	---------	---------	---------
Bi-213	α, β^-, γ	45.6 m	1.01E+01	4.61E+00	---------	---------	---------
Bi-214	α, β^-, γ	19.9 m	2.12E+00	1.73E+01	---------	---------	---------
Bk-249	α, β^-, γ, *SF*	3.2E+02 d	0.00E+00	0.00E+00	---------	---------	---------
Bk-250	β^-, γ	3.217 h	4.36E-12	1.63E-12	---------	---------	---------
C-14	β^-	5730 a	5.55E+00	1.83E-02	100	260.00	2.14E-02
Cd-109	γ, ε	462.0 d	0.00E+00	0.00E+00	---------	---------	---------
Cd-113m	β^-, *IT*	14.1 a	0.00E+00	2.12E-02	---------	---------	---------
Ce-144	β^-, γ	284.6 d	0.00E+00	0.00E+00	---------	---------	---------
Cf-249	α, γ, *SF*	351 a	7.99E+01	1.06E-01	100	260.00	3.08E-01
Cf-250	α, γ, *SF*	13.1 a	2.25E-04	6.00E-05	---------	---------	---------
Cf-251	α, γ	9.0E+02 a	2.74E-02	5.70E-04	100	260.00	1.08E-04
Cf-252	α, γ, *SF*	2.638 a	1.27E-13	7.10E-16	---------	---------	---------
Cl-36	$\beta^-, \varepsilon, \beta^+$	3.01E+01 a	2.00E-03	0.00E+00	---------	---------	---------
Cm-242	α, γ, *SF*	162.8 d	1.21E+01	1.42E-01	---------	---------	---------
Cm-243	α, γ, *SF*, ε	29.1 a	1.18E-01	1.84E-01	100	260.00	1.16E-03
Cm-244	α, γ, *SF*	18.1 a	5.68E+01	9.49E+00	---------	---------	---------

Table A-2: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 2133) – continued

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Cm-245	α, γ, *SF*	8.5E+03 a	1.30E+00	8.29E-02	100	260.00	5.32E-03
Cm-246	α, γ, *SF*	4.76E+03 a	3.73E+00	2.73E+00	100	260.00	2.49E-02
Cm-247	α, γ	1.56 E+07 a	2.65E-02	1.61E-07	100	260.00	1.02E-04
Cm-248	α, *SF*	3.48E+05 a	1.24E-01	7.62E-03	100	260.00	5.05E-04
Cm-250	α, β^-, *SF*	9700 a	7.94E-11	2.96E-11	---------	---------	---------
Co-60	β^-, γ	5.271 a	1.21E-07	2.37E-05	---------	---------	---------
Cs-134	β^-, γ, ε	2.065 a	1.26E-17	2.77E-16	---------	---------	---------
Cs-135	β^-	2.3E+06 a	0.00E+00	1.08E-02	1000	2600.00	4.17E-06
Cs-137	β^-, γ	30.17 a	5.43E+01	8.82E+03	1000	2600.00	3.41E+00
Es-254	α, □	276 d	0.00E+00	0.00E+00	---------	---------	---------
Eu-150	ε, □	36 a	1.87E-04	0.00E+00	---------	---------	---------
Eu-152	β^-, γ, $\varepsilon\beta^+$	13.48 a	8.39E-03	1.63E-02	---------	---------	---------
Eu-154	β^-, γ, εγ	8.59 a	1.12E-03	2.54E-02	---------	---------	---------
Eu-155	β^-, γ	4.71 a	4.08E-08	2.71E-05	---------	---------	---------
Fe-55	ε	2.73 a	1.01E-17	1.87E-15	---------	---------	---------
Fr-221	α, γ	4.8 m	1.02E+01	4.61E+00	---------	---------	---------
Fr-223	α, β^-, γ	21.8 m	6.31E-03	2.53E-03	---------	---------	---------
Gd-152	α	1.1E+14 a	2.26E-13	1.05E-12	100	260.00	4.90E-15
H-3	β^-	12.3 a	4.92E+00	2.46E+00	---------	---------	---------
Ho-166m	β-, □	1.2E+03 a	6.12E-05	1.89E-07	---------	---------	---------
I-129	β^-, γ	1.57E+07 a	1.69E+00	6.22E-03	100	260.00	6.52E-03
K-40	β^-, □, β^+	1.27E+09 a	5.50E-03	0.00E+00	---------	---------	---------
Kr-81	ε, □	2.35E+05 a	0.00E+00	1.80E-07	---------	---------	---------
Kr-85	β^-, γ	10.73 a	1.09E-02	6.25E-02	---------	---------	---------
Mn-54	ε, γ	312.2 d	0.00E+00	0.00E+00	---------	---------	---------
Mo-93	ε, □	3.5E+03 a	0.00E+00	1.78E-04	---------	---------	---------
Na-22	ε	2.6019 a	5.41E-16	4.94E-21	---------	---------	---------
Nb-93m	*ITe*$^-$	16.1 a	1.09E-03	7.62E-01	---------	---------	---------
Nb-94	β^-, □	2.0E+04 a	1.73E-04	1.88E-05	---------	---------	---------
Ni-59	ε	7.6E+04 a	1.13E-01	1.42E-02	1000	2600.00	4.88E-05
Ni-63	β^-	100 a	1.57E+00	1.98E+01	1000	2600.00	8.24E-03
Np-237	α, γ	2.14E+06 a	5.10E+01	2.63E+00	100	260.00	2.06E-01
Np-238	β^-, γ	2.117 d	7.28E-02	8.49E-04	---------	---------	---------
Np-239	β^-, γ	2.355 d	7.01E+01	7.62E+00	---------	---------	---------
Np-240m	β^-, γ, *IT*	7.22 m	3.52E-04	2.37E-06	---------	---------	---------
Pa-231	α, γ	3.28E+04 a	3.87E-01	1.86E-01	100	260.00	2.20E-03

Table A-2: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 2133) – continued

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Pa-233	β^-, γ	27.0 d	5.05E+01	2.61E+00	---------	---------	---------
Pa-234	β^-, γ	6.69 h	3.48E-02	3.80E-04	---------	---------	---------
Pa-234m	β^-, γ, *IT*	1.17 m	2.68E+01	2.93E-01	---------	---------	---------
Pb-209	β^-	3.25 h	1.02E+01	4.61E+00	---------	---------	---------
Pb-210	α, β^-, γ	22.3 a	2.15E+00	1.76E+01	100	260.00	7.60E-02
Pb-211	β^-, γ	36.1 m	4.57E-01	1.83E-01	---------	---------	---------
Pb-212	β^-, γ	10.64 h	1.56E+01	7.73E+00	---------	---------	---------
Pb-214	β^-, γ	27 m	2.13E+00	1.74E+01	---------	---------	---------
Pd-107	β^-	6.5E+06 a	0.00E+00	3.54E-04	1000	2600.00	1.36E-07
Pm-146	ε, Γ, β^-	5.53 a	0.00E+00	4.78E-14	---------	---------	---------
Pm-147	β^-, γ	2.6234 a	1.71E-13	3.96E-12	---------	---------	---------
Po-210	α, γ	138.38 d	2.15E+00	1.76E+01	---------	---------	---------
Po-211	α, γ	0.516 s	1.39E-03	5.59E-04	---------	---------	---------
Po-212	α	0.298 μs	1.00E+01	4.94E+00	---------	---------	---------
Po-213	α	4 μs	9.94E+00	4.51E+00	---------	---------	---------
Po-214	α, γ	163.7 μs	2.13E+00	1.74E+01	---------	---------	---------
Po-215	α, β^-, γ	1.780 ms	4.57E-01	1.83E-01	---------	---------	---------
Po-216	α, γ	0.145 s	1.56E+01	7.72E+00	---------	---------	---------
Po-218	α, β^-, γ	3.10 m	2.09E+00	1.71E+01	---------	---------	---------
Pr-144	β^-, γ	17.28 m	0.00E+00	0.00E+00	---------	---------	---------
Pu-236	α, γ, *SF*	2.87 a	7.63E-16	4.13E-21	---------	---------	---------
Pu-238	α, γ, *SF*	87.7 a	6.66E+05	2.32E+03	100	260.00	2.57E+03
Pu-239	α, γ, *SF*	2.41E+04 a	5.08E+05	2.91E+03	100	260.00	1.97E+03
Pu-240	α, γ, *SF*	6.56E+03 a	1.42E+05	9.80E+02	100	260.00	5.51E+02
Pu-241	α, β^-, γ	14.4 a	4.11E+03	3.21E+01	---------	---------	---------
Pu-242	α, γ, *SF*	3.75E+05 a	7.46E+01	1.25E+00	100	260.00	2.92E-01
Pu-243	β^-, γ	4.956 h	2.62E-02	1.60E-07	---------	---------	---------
Pu-244	α, *SF*	8.0E+07 a	3.48E-04	2.34E-06	100	260.00	1.35E-06
Ra-223	α, γ	11.435 d	4.62E-01	1.85E-01	---------	---------	---------
Ra-224	α, γ	3.66 d	1.56E+01	7.71E+00	---------	---------	---------
Ra-225	β^-, γ	14.9 d	1.02E+01	4.62E+00	---------	---------	---------
Ra-226	α, γ	1.60E+03 a	2.15E+00	1.76E+01	100	260.00	7.58E-02
Ra-228	β^-, γ	5.76 a	3.21E-01	8.00E-02	---------	---------	---------
Rb-87	β^-	4.88E+10 a	0.00E+00	9.68E-07	---------	---------	---------
Rh-106	β^-, γ	29.9 s	0.00E+00	0.00E+00	---------	---------	---------
Rn-219	α, γ	3.96 s	4.57E-01	1.83E-01	---------	---------	---------

Table A-2: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 2133) – continued

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Rn-220	α, γ	55.6 s	1.56E+01	7.72E+00	---------	---------	---------
Rn-222	α, γ	3.8235 d	2.13E+00	1.74E+01	---------	---------	---------
Ru-106	β⁻	1.02 a	0.00E+00	0.00E+00	---------	---------	---------
Sb-125	β⁻, γ	2.758 a	7.03E-14	5.17E-14	---------	---------	---------
Sb-126	β⁻, γ	12.4 d	2.80E-01	2.31E-01	---------	---------	---------
Sb-126m	γ, *ITe⁻*	11.0 s	2.00E+00	1.65E+00	---------	---------	---------
Se-79	β⁻	6.5E+04 a	7.34E-02	1.54E-01	1000	2600.00	8.76E-05
Sm-146	α	1.03E+08 a	0.00E+00	9.63E-15	---------	---------	---------
Sm-147	α	1.06E+11 a	1.96E-09	1.03E-07	100	260.00	4.05E-10
Sm-151	β⁻, γ	90 a	3.87E+00	5.97E+01	1000	2600.00	2.45E-02
Sn-121m	β⁻, γ, *ITe⁻*	55 a	0.00E+00	9.76E-03	1000	2600.00	3.76E-06
Sn-126	β⁻, γ	1.0E+05 a	2.00E+00	1.65E+00	1000	2600.00	1.40E-03
Sr-90	β⁻	29.1 a	4.65E+01	7.39E+03	1000	2600.00	2.86E+00
Tc-99	β⁻, γ	2.13E+05 a	4.32E+01	9.53E+00	10000	26000.00	2.03E-03
Te-123	ε	1.0E+13 a	1.80E-18	0.00E+00	---------	---------	---------
Te-125m	γ, *ITe⁻*	58 d	1.70E-14	1.25E-14	---------	---------	---------
Th-227	α, γ	18.72 d	4.50E-01	1.81E-01	---------	---------	---------
Th-228	α, γ	1.913 a	1.58E+01	7.81E+00	---------	---------	---------
Th-229	α, γ	7.3E+03 a	1.02E+01	4.62E+00	100	260.00	5.69E-02
Th-230	α, γ	7.54e+04 a	1.01E+00	1.44E-02	10	26.00	3.93E-02
Th-231	β⁻, γ	1.063 d	4.42E+00	6.98E-02	---------	---------	---------
Th-232	α, γ	1.4E+10 a	2.75E-01	6.86E-02	10	26.00	1.32E-02
Th-234	β⁻, γ	24.10 d	2.68E+01	2.93E-01	---------	---------	---------
Tl-204	β⁻, ε	3.78 a	2.80E-16	0.00E+00	---------	---------	---------
Tl-207	β⁻, γ	4.77 m	4.55E-01	1.82E-01	---------	---------	---------
Tl-208	β⁻, γ	3.053 m	5.63E+00	2.78E+00	---------	---------	---------
Tl-209	β⁻, γ	2.2 m	2.23E-01	1.01E-01	---------	---------	---------
U-232	α, γ, *SF*	70 a	1.51E+01	7.52E+00	100	260.00	8.70E-02
U-233	α, γ, *SF*	1.592E+05 a	1.56E+02	5.09E+01	100	260.00	7.96E-01
U-234	α, γ, *SF*	2.46E+05 a	5.92E+02	6.18E+00	100	260.00	2.30E+00
U-235	α, γ, *SF*	7.04E+08 a	4.47E+00	7.07E-02	100	260.00	1.75E-02
U-236	α, γ, *SF*	2.342E+07 a	1.78E+00	2.51E-01	100	260.00	7.80E-03
U-237	β⁻, γ	6.75 d	1.01E-01	7.88E-04	---------	---------	---------
U-238	α, γ, *SF*	4.47E+09 a	2.71E+01	2.96E-01	100	260.00	1.05E-01
U-240	β⁻, γ	14.1 h	3.45E-04	2.32E-06	---------	---------	---------
Y-90	β⁻, γ	2.67 d	4.60E+01	7.30E+03	---------	---------	---------

Table A-2: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 2133) – continued

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Zn-65	$\beta^{+}, \gamma, \varepsilon$	243.8 d	0.00E+00	0.00E+00	---------	---------	---------
Zr-93	β^{-}, γ	1.5E+06 a	1.14E-03	8.00E-01	1000	2600.00	3.08E-04
Total:			**1.74E+06**	**4.24E+04**			**6.70E+03**

(a) Decayed radionuclide inventory information taken from Crawford Et Al. 2009.
(b) Release limits are determined in accordance with 40CFR191 (Appendix B, Table B-1). Left column corresponds to specific release limits (cumulative releases to the accessible environment for 10,000 years after disposal per "Unit of Waste" identified in Note 1(e) of Table 1, Appendix A, 40CFR191). Right column corresponds to release limit obtained for 2.32 Units of Waste. The 2.32 value for the Unit of Waste corresponds to the Units of Waste present at repository closure, 2033.
(c) Decay mode and half-life information taken from *Nuclides and Isotopes* (also called the "Chart of the Nuclides"), 16th Ed. (Lockheed Martin 2002).

Table A-3: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 2383)

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Ac-225	α, γ	10.0 d	1.35E+01	5.68E+00	---------	---------	---------
Ac-227	α, β^-, γ	21.77 a	4.09E-01	1.86E-01	100	260.00	2.29E-03
Ac-228	α, β^-, γ	6.15 h	2.72E-01	6.77E-02	---------	---------	---------
Ag-108	β-, □, ε, β+	2.39 m	8.10E-10	0.00E+00	---------	---------	---------
Ag-108m	ε, β+ , γ, *IT*	420 m	9.11E-09	0.00E+00	---------	---------	---------
Ag-109m	*ITe*$^-$	39.8 s	0.00E+00	0.00E+00	---------	---------	---------
Ag-110	β^-, γ, ε	24.6 s	0.00E+00	0.00E+00	---------	---------	---------
Ag-110m	β^-, γ, *ITe*$^-$	249.8 d	0.00E+00	0.00E+00	---------	---------	---------
Am-241	α, γ, *SF*	432.7 a	2.77E+05	2.63E+03	100	260.00	1.07E+03
Am-242	β^-, γ, ε *e*$^-$	16.02 h	4.63E+00	5.40E-02	---------	---------	---------
Am-242m	α, *ITe*$^-$, γ, *SF*	141.0 a	4.71E+00	5.49E-02	100	260.00	1.83E-02
Am-243	α, γ, *SF*	7.37E+03 a	6.94E+01	7.55E+00	100	260.00	2.96E-01
Am-245	β^-, γ	2.05 h	0.00E+00	0.00E+00	---------	---------	---------
At-217	α, β^-, γ	32 ms	1.35E+01	5.69E+00	---------	---------	---------
Ba-133	ε, □	10.53 a	3.05E-13	1.25E-17	---------	---------	---------
Ba-137m	*IT*	2.552 m	1.57E-01	2.56E+01	---------	---------	---------
Bi-210	α, β^-, γ	5.01 d	2.09E+00	1.56E+01	---------	---------	---------
Bi-211	α, β^-, γ	2.14 m	4.04E-01	1.84E-01	---------	---------	---------
Bi-212	α, β^-, γ	1.009 h	1.66E+00	7.60E-01	---------	---------	---------
Bi-213	α, β^-, γ	45.6 m	1.35E+01	5.67E+00	---------	---------	---------
Bi-214	α, β^-, γ	19.9 m	2.09E+00	1.56E+01	---------	---------	---------
Bk-249	α, β^-, γ, *SF*	3.2E+02 d	0.00E+00	0.00E+00	---------	---------	---------
Bk-250	β^-, γ	3.217 h	4.32E-12	1.61E-12	---------	---------	---------
C-14	β^-	5730 a	5.38E+00	1.78E-02	100	260.00	2.08E-02
Cd-109	γ, ε	462.0 d	0.00E+00	0.00E+00	---------	---------	---------
Cd-113m	β^-, *IT*	14.1 a	0.00E+00	1.47E-07	---------	---------	---------
Ce-144	β^-, γ	284.6 d	0.00E+00	0.00E+00	---------	---------	---------
Cf-249	α, γ, *SF*	351 a	4.87E+01	6.46E-02	100	260.00	1.88E-01
Cf-250	α, γ, *SF*	13.1 a	4.03E-10	1.08E-10	---------	---------	---------
Cf-251	α, γ	9.0E+02 a	2.26E-02	4.70E-04	100	260.00	8.87E-05
Cf-252	α, γ, *SF*	2.638 a	0.00E+00	0.00E+00	---------	---------	---------
Cl-36	β^-, ε, β^+	3.01E+01 a	2.00E-03	0.00E+00	---------	---------	---------
Cm-242	α, γ, *SF*	162.8 d	3.89E+00	4.53E-02	---------	---------	---------
Cm-243	α, γ, *SF*, ε	29.1 a	2.69E-04	4.20E-04	100	260.00	2.65E-06
Cm-244	α, γ, *SF*	18.1 a	3.97E-03	6.64E-04	---------	---------	---------

Table A-3: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 2383) – continued

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Cm-245	α, γ, *SF*	8.5E+03 a	2.55E+00	8.29E-02	100	260.00	1.01E-02
Cm-246	α, γ, *SF*	4.76E+03 a	3.60E+00	2.63E+00	100	260.00	2.40E-02
Cm-247	α, γ	1.56 E+07 a	2.65E-02	1.67E-07	100	260.00	1.02E-04
Cm-248	α, *SF*	3.48E+05 a	1.24E-01	7.62E-03	100	260.00	5.04E-04
Cm-250	α, β^-, *SF*	9700 a	7.86E-11	2.93E-11	---------	---------	---------
Co-60	β^-, γ	5.271 a	4.61E-22	1.14E-19	---------	---------	---------
Cs-134	β^-, γ, ε	2.065 a	0.00E+00	0.00E+00	---------	---------	---------
Cs-135	β^-	2.3E+06 a	0.00E+00	1.08E-02	1000	2600.00	4.17E-06
Cs-137	β^-, γ	30.17 a	1.68E-01	2.73E+01	1000	2600.00	1.06E-02
Es-254	α, □	276 d	0.00E+00	0.00E+00	---------	---------	---------
Eu-150	ε, □	36 a	1.52E-06	0.00E+00	---------	---------	---------
Eu-152	β^-, γ, $\varepsilon\beta^+$	13.48 a	2.46E-08	4.79E-08	---------	---------	---------
Eu-154	β^-, γ, εγ	8.59 a	1.99E-12	4.51E-11	---------	---------	---------
Eu-155	β^-, γ	4.71 a	0.00E+00	0.00E+00	---------	---------	---------
Fe-55	ε	2.73 a	0.00E+00	0.00E+00	---------	---------	---------
Fr-221	α, γ	4.8 m	1.35E+01	5.68E+00	---------	---------	---------
Fr-223	α, β^-, γ	21.8 m	5.58E-03	2.54E-03	---------	---------	---------
Gd-152	α	1.1E+14 a	2.26E-13	1.05E-12	100	260.00	4.90E-15
H-3	β^-	12.3 a	3.96E-06	1.98E-06	---------	---------	---------
Ho-166m	β-, □	1.2E+03 a	5.30E-05	1.64E-07	---------	---------	---------
I-129	β^-, γ	1.57E+07 a	1.69E+00	6.22E-03	100	260.00	6.52E-03
K-40	β^-, □, β^+	1.27E+09 a	5.50E-03	0.00E+00	---------	---------	---------
Kr-81	ε, □	2.35E+05 a	0.00E+00	1.80E-07	---------	---------	---------
Kr-85	β^-, γ	10.73 a	1.04E-09	5.97E-09	---------	---------	---------
Mn-54	ε, γ	312.2 d	0.00E+00	0.00E+00	---------	---------	---------
Mo-93	ε, □	3.5E+03 a	0.00E+00	1.69E-04	---------	---------	---------
Na-22	ε	2.6019 a	0.00E+00	0.00E+00	---------	---------	---------
Nb-93m	*ITe⁻*	16.1 a	1.09E-03	7.62E-01	---------	---------	---------
Nb-94	β^-, □	2.0E+04 a	1.72E-04	1.87E-05	---------	---------	---------
Ni-59	ε	7.6E+04 a	1.12E-01	1.42E-02	1000	2600.00	4.87E-05
Ni-63	β^-	100 a	2.39E-01	3.02E+00	1000	2600.00	1.25E-03
Np-237	α, γ	2.14E+06 a	7.90E+01	2.90E+00	100	260.00	3.15E-01
Np-238	β^-, γ	2.117 d	2.33E-02	2.71E-04	---------	---------	---------
Np-239	β^-, γ	2.355 d	6.85E+01	7.45E+00	---------	---------	---------
Np-240m	β^-, γ, *IT*	7.22 m	3.52E-04	2.38E-06	---------	---------	---------
Pa-231	α, γ	3.28E+04 a	4.08E-01	1.86E-01	100	260.00	2.29E-03

Table A-3: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 2383) – continued

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Pa-233	β^-, γ	27.0 d	7.83E+01	2.87E+00	---------	---------	---------
Pa-234	β^-, γ	6.69 h	3.48E-02	3.80E-04	---------	---------	---------
Pa-234m	β^-, γ, *IT*	1.17 m	2.68E+01	2.93E-01	---------	---------	---------
Pb-209	β^-	3.25 h	1.35E+01	5.68E+00	---------	---------	---------
Pb-210	α, β^-, γ	22.3 a	2.12E+00	1.58E+01	100	260.00	6.87E-02
Pb-211	β^-, γ	36.1 m	4.04E-01	1.84E-01	---------	---------	---------
Pb-212	β^-, γ	10.64 h	1.66E+00	7.58E-01	---------	---------	---------
Pb-214	β^-, γ	27 m	2.09E+00	1.56E+01	---------	---------	---------
Pd-107	β^-	6.5E+06 a	0.00E+00	3.54E-04	1000	2600.00	1.36E-07
Pm-146	ε, □, β^-	5.53 a	0.00E+00	9.91E-28	---------	---------	---------
Pm-147	β^-, γ	2.6234 a	0.00E+00	0.00E+00	---------	---------	---------
Po-210	α, γ	138.38 d	2.11E+00	1.58E+01	---------	---------	---------
Po-211	α, γ	0.516 s	1.23E-03	5.61E-04	---------	---------	---------
Po-212	α	0.298 µs	1.06E+00	4.84E-01	---------	---------	---------
Po-213	α	4 µs	1.32E+01	5.56E+00	---------	---------	---------
Po-214	α, γ	163.7 µs	2.09E+00	1.56E+01	---------	---------	---------
Po-215	α, β^-, γ	1.780 ms	4.04E-01	1.84E-01	---------	---------	---------
Po-216	α, γ	0.145 s	1.66E+00	7.57E-01	---------	---------	---------
Po-218	α, β^-, γ	3.10 m	2.06E+00	1.53E+01	---------	---------	---------
Pr-144	β^-, γ	17.28 m	0.00E+00	0.00E+00	---------	---------	---------
Pu-236	α, γ, *SF*	2.87 a	6.71E-17	0.00E+00	---------	---------	---------
Pu-238	α, γ, *SF*	87.7 a	9.25E+04	3.22E+02	100	260.00	3.57E+02
Pu-239	α, γ, *SF*	2.41E+04 a	5.05E+05	2.89E+03	100	260.00	1.95E+03
Pu-240	α, γ, *SF*	6.56E+03 a	1.39E+05	9.54E+02	100	260.00	5.37E+02
Pu-241	α, β^-, γ	14.4 a	2.56E+00	8.29E-02	---------	---------	---------
Pu-242	α, γ, *SF*	3.75E+05 a	7.46E+01	1.26E+00	100	260.00	2.92E-01
Pu-243	β^-, γ	4.956 h	2.62E-02	1.65E-07	---------	---------	---------
Pu-244	α, *SF*	8.0E+07 a	3.49E-04	2.36E-06	100	260.00	1.35E-06
Ra-223	α, γ	11.435 d	4.09E-01	1.86E-01	---------	---------	---------
Ra-224	α, γ	3.66 d	1.65E+00	7.56E-01	---------	---------	---------
Ra-225	β^-, γ	14.9 d	1.35E+01	5.69E+00	---------	---------	---------
Ra-226	α, γ	1.60E+03 a	2.12E+00	1.58E+01	100	260.00	6.88E-02
Ra-228	β^-, γ	5.76 a	3.21E-01	8.00E-02	---------	---------	---------
Rb-87	β^-	4.88E+10 a	0.00E+00	9.68E-07	---------	---------	---------
Rh-106	β^-, γ	*29.9 s*	*0.00E+00*	0.00E+00	---------	---------	---------
Rn-219	α, γ	3.96 s	4.04E-01	1.84E-01	---------	---------	---------

Table A-3: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 2383) – continued

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Rn-220	α, γ	55.6 s	1.66E+00	7.57E-01	---------	---------	---------
Rn-222	α, γ	3.8235 d	2.10E+00	1.56E+01	---------	---------	---------
Ru-106	β⁻	1.02 a	0.00E+00	0.00E+00	---------	---------	---------
Sb-125	β⁻, γ	2.758 a	0.00E+00	0.00E+00	---------	---------	---------
Sb-126	β⁻, γ	12.4 d	2.79E-01	2.31E-01	---------	---------	---------
Sb-126m	γ, ITe⁻	11.0 s	1.99E+00	1.65E+00	---------	---------	---------
Se-79	β⁻	6.5E+04 a	7.32E-02	1.54E-01	1000	2600.00	8.73E-05
Sm-146	α	1.03E+08 a	0.00E+00	9.63E-15	---------	---------	---------
Sm-147	α	1.06E+11 a	1.96E-09	1.03E-07	100	260.00	4.05E-10
Sm-151	β⁻, γ	90 a	5.64E-01	8.71E+00	1000	2600.00	3.57E-03
Sn-121m	β⁻, γ, ITe⁻	55 a	0.00E+00	3.04E-04	1000	2600.00	1.17E-07
Sn-126	β⁻, γ	1.0E+05 a	2.00E+00	1.65E+00	1000	2600.00	1.40E-03
Sr-90	β⁻	29.1 a	1.21E-01	1.92E+01	1000	2600.00	7.45E-03
Tc-99	β⁻, γ	2.13E+05 a	4.32E+01	9.53E+00	10000	26000.00	2.03E-03
Te-123	ε	1.0E+13 a	1.80E-18	0.00E+00	---------	---------	---------
Te-125m	γ, ITe⁻	58 d	0.00E+00	0.00E+00	---------	---------	---------
Th-227	α, γ	18.72 d	3.98E-01	1.81E-01	---------	---------	---------
Th-228	α, γ	1.913 a	1.68E+00	7.66E-01	---------	---------	---------
Th-229	α, γ	7.3E+03 a	1.36E+01	5.70E+00	100	260.00	7.41E-02
Th-230	α, γ	7.54e+04 a	2.64E+00	2.93E-02	10	26.00	1.03E-01
Th-231	β⁻, γ	1.063 d	4.54E+00	7.05E-02	---------	---------	---------
Th-232	α, γ	1.4E+10 a	2.75E-01	6.86E-02	10	26.00	1.32E-02
Th-234	β⁻, γ	24.10 d	2.68E+01	2.93E-01	---------	---------	---------
Tl-204	β⁻, ε	3.78 a	0.00E+00	0.00E+00	---------	---------	---------
Tl-207	β⁻, γ	4.77 m	4.02E-01	1.83E-01	---------	---------	---------
Tl-208	β⁻, γ	3.053 m	5.96E-01	2.73E-01	---------	---------	---------
Tl-209	β⁻, γ	2.2 m	2.97E-01	1.25E-01	---------	---------	---------
U-232	α, γ, SF	70 a	1.36E+00	6.78E-01	100	260.00	7.84E-03
U-233	α, γ, SF	1.592E+05 a	1.56E+02	5.08E+01	100	260.00	7.95E-01
U-234	α, γ, SF	2.46E+05 a	7.98E+02	6.89E+00	100	260.00	3.10E+00
U-235	α, γ, SF	7.04E+08 a	4.60E+00	7.14E-02	100	260.00	1.79E-02
U-236	α, γ, SF	2.342E+07 a	2.82E+00	2.58E-01	100	260.00	1.18E-02
U-237	β⁻, γ	6.75 d	6.29E-05	2.03E-06	---------	---------	---------
U-238	α, γ, SF	4.47E+09 a	2.71E+01	2.96E-01	100	260.00	1.05E-01
U-240	β⁻, γ	14.1 h	3.45E-04	2.33E-06	---------	---------	---------
Y-90	β⁻, γ	2.67 d	1.20E-01	1.90E+01	---------	---------	---------

Table A-3: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 2383) – continued

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Zn-65	$\beta^+, \gamma, \varepsilon$	243.8 d	0.00E+00	0.00E+00	---------	---------	---------
Zr-93	β^-, γ	1.5E+06 a	1.14E-03	8.00E-01	1000	2600.00	3.08E-04
Total:			**1.01E+06**	**7.19E+03**			**3.93E+03**

(a) Decayed radionuclide inventory information taken from Crawford Et Al. 2009.
(b) Release limits are determined in accordance with 40CFR191 (Appendix B, Table B-1). Left column corresponds to specific release limits (cumulative releases to the accessible environment for 10,000 years after disposal per "Unit of Waste" identified in Note 1(e) of Table 1, Appendix A, 40CFR191). Right column corresponds to release limit obtained for 2.32 Units of Waste. The 2.32 value for the Unit of Waste corresponds to the Units of Waste present at repository closure, 2033.
(c) Decay mode and half-life information taken from *Nuclides and Isotopes* (also called the "Chart of the Nuclides"), 16th Ed. (Lockheed Martin 2002).

Table A-4: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 3,033)

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Ac-225	α, γ	10.0 d	2.19E+01	8.34E+00	---------	---------	---------
Ac-227	α, β^-, γ	21.77 a	4.68E-01	1.85E-01	100	260.00	2.51E-03
Ac-228	α, β^-, γ	6.15 h	2.72E-01	6.77E-02	---------	---------	---------
Ag-108	β-, □, ε, β+	2.39 m	2.33E-11	0.00E+00	---------	---------	---------
Ag-108m	ε, β+ , γ, *IT*	420 m	2.62E-10	0.00E+00	---------	---------	---------
Ag-109m	*ITe*$^-$	39.8 s	0.00E+00	0.00E+00	---------	---------	---------
Ag-110	β^-, γ, ε	24.6 s	0.00E+00	0.00E+00	---------	---------	---------
Ag-110m	β^-, γ, *ITe*$^-$	249.8 d	0.00E+00	0.00E+00	---------	---------	---------
Am-241	α, γ, *SF*	432.7 a	9.76E+04	9.28E+02	100	260.00	3.79E+02
Am-242	β^-, γ, ε e^-	16.02 h	2.39E-01	2.79E-03	---------	---------	---------
Am-242m	α, *ITe*$^-$, γ, *SF*	141.0 a	2.43E-01	2.84E-03	100	260.00	9.46E-04
Am-243	α, γ, *SF*	7.37E+03 a	6.53E+01	7.10E+00	100	260.00	2.78E-01
Am-245	β^-, γ	2.05 h	0.00E+00	0.00E+00	---------	---------	---------
At-217	α, β^-, γ	32 ms	2.19E+01	8.35E+00	---------	---------	---------
Ba-133	ε, □	10.53 a	0.00E+00	0.00E+00	---------	---------	---------
Ba-137m	*IT*	2.552 m	4.73E-08	7.68E-06	---------	---------	---------
Bi-210	α, β^-, γ	5.01 d	3.10E+00	1.18E+01	---------	---------	---------
Bi-211	α, β^-, γ	2.14 m	4.62E-01	1.82E-01	---------	---------	---------
Bi-212	α, β^-, γ	1.009 h	2.76E-01	6.94E-02	---------	---------	---------
Bi-213	α, β^-, γ	45.6 m	2.19E+01	8.33E+00	---------	---------	---------
Bi-214	α, β^-, γ	19.9 m	3.10E+00	1.18E+01	---------	---------	---------
Bk-249	α, β^-, γ, *SF*	3.2E+02 d	0.00E+00	0.00E+00	---------	---------	---------
Bk-250	β^-, γ	3.217 h	4.21E-12	1.57E-12	---------	---------	---------
C-14	β^-	5730 a	4.97E+00	1.65E-02	100	260.00	1.92E-02
Cd-109	γ, ε	462.0 d	0.00E+00	0.00E+00	---------	---------	---------
Cd-113m	β^-, *IT*	14.1 a	0.00E+00	1.55E-24	---------	---------	---------
Ce-144	β^-, γ	284.6 d	0.00E+00	0.00E+00	---------	---------	---------
Cf-249	α, γ, *SF*	351 a	1.35E+01	1.79E-02	100	260.00	5.19E-02
Cf-250	α, γ, *SF*	13.1 a	4.26E-12	1.59E-12	---------	---------	---------
Cf-251	α, γ	9.0E+02 a	1.37E-02	2.84E-04	100	260.00	5.37E-05
Cf-252	α, γ, *SF*	2.638 a	0.00E+00	0.00E+00	---------	---------	---------
Cl-36	β^-, ε, β^+	3.01E+01 a	1.99E-03	0.00E+00	---------	---------	---------
Cm-242	α, γ, *SF*	162.8 d	2.01E-01	2.34E-03	---------	---------	---------
Cm-243	α, γ, *SF*, ε	29.1 a	3.66E-11	5.73E-11	100	260.00	3.61E-13
Cm-244	α, γ, *SF*	18.1 a	6.22E-14	1.04E-14	---------	---------	---------

Table A-4: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 3033) – continued

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Cm-245	α, γ, *SF*	8.5E+03 a	3.83E+00	8.05E-02	100	260.00	1.50E-02
Cm-246	α, γ, *SF*	4.76E+03 a	3.27E+00	2.39E+00	100	260.00	2.18E-02
Cm-247	α, γ	1.56 E+07 a	2.65E-02	1.78E-07	100	260.00	1.02E-04
Cm-248	α, *SF*	3.48E+05 a	1.23E-01	7.61E-03	100	260.00	5.04E-04
Cm-250	α, β^-, *SF*	9700 a	7.66E-11	2.86E-11	---------	---------	---------
Co-60	β^-, γ	5.271 a	0.00E+00	0.00E+00	---------	---------	---------
Cs-134	$\beta^-, \gamma, \varepsilon$	2.065 a	0.00E+00	0.00E+00	---------	---------	---------
Cs-135	β^-	2.3E+06 a	0.00E+00	1.08E-02	1000	2600.00	4.17E-06
Cs-137	β^-, γ	30.17 a	5.06E-08	8.21E-06	1000	2600.00	3.18E-09
Es-254	α, □	276 d	0.00E+00	0.00E+00	---------	---------	---------
Eu-150	ε, □	36 a	5.57E-12	0.00E+00	---------	---------	---------
Eu-152	$\beta^-, \gamma, \varepsilon\beta^+$	13.48 a	0.00E+00	0.00E+00	---------	---------	---------
Eu-154	$\beta^-, \gamma, \varepsilon\gamma$	8.59 a	0.00E+00	0.00E+00	---------	---------	---------
Eu-155	β^-, γ	4.71 a	0.00E+00	0.00E+00	---------	---------	---------
Fe-55	ε	2.73 a	0.00E+00	0.00E+00	---------	---------	---------
Fr-221	α, γ	4.8 m	2.19E+01	8.33E+00	---------	---------	---------
Fr-223	α, β^-, γ	21.8 m	6.39E-03	2.52E-03	---------	---------	---------
Gd-152	α	1.1E+14 a	2.26E-13	1.05E-12	100	260.00	4.90E-15
H-3	β^-	12.3 a	0.00E+00	0.00E+00	---------	---------	---------
Ho-166m	β-, □	1.2E+03 a	3.64E-05	1.13E-07	---------	---------	---------
I-129	β^-, γ	1.57E+07 a	1.69E+00	6.22E-03	100	260.00	6.52E-03
K-40	β^-, □, β^+	1.27E+09 a	5.50E-03	0.00E+00	---------	---------	---------
Kr-81	ε, □	2.35E+05 a	0.00E+00	1.80E-07	---------	---------	---------
Kr-85	β^-, γ	10.73 a	0.00E+00	0.00E+00	---------	---------	---------
Mn-54	ε, γ	312.2 d	0.00E+00	0.00E+00	---------	---------	---------
Mo-93	ε, □	3.5E+03 a	0.00E+00	1.49E-04	---------	---------	---------
Na-22	ε	2.6019 a	0.00E+00	0.00E+00	---------	---------	---------
Nb-93m	*ITe*$^-$	16.1 a	1.09E-03	7.62E-01	---------	---------	---------
Nb-94	β^-, □	2.0E+04 a	1.68E-04	1.83E-05	---------	---------	---------
Ni-59	ε	7.6E+04 a	1.12E-01	1.41E-02	1000	2600.00	4.84E-05
Ni-63	β^-	100 a	1.78E-03	2.25E-02	1000	2600.00	9.35E-06
Np-237	α, γ	2.14E+06 a	1.15E+02	3.24E+00	100	260.00	4.56E-01
Np-238	β^-, γ	2.117 d	1.20E-03	1.40E-05	---------	---------	---------
Np-239	β^-, γ	2.355 d	6.45E+01	7.01E+00	---------	---------	---------
Np-240m	β^-, γ, *IT*	7.22 m	3.53E-04	2.42E-06	---------	---------	---------
Pa-231	α, γ	3.28E+04 a	4.68E-01	1.84E-01	100	260.00	2.51E-03

Table A-4: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 3033) – continued

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Pa-233	β⁻, γ	27.0 d	1.14E+02	3.21E+00	---------	---------	---------
Pa-234	β⁻, γ	6.69 h	3.48E-02	3.80E-04	---------	---------	---------
Pa-234m	β⁻, γ, *IT*	1.17 m	2.68E+01	2.93E-01	---------	---------	---------
Pb-209	β⁻	3.25 h	2.19E+01	8.34E+00	---------	---------	---------
Pb-210	α, β⁻, γ	22.3 a	3.14E+00	1.19E+01	100	260.00	5.79E-02
Pb-211	β⁻, γ	36.1 m	4.63E-01	1.82E-01	---------	---------	---------
Pb-212	β⁻, γ	10.64 h	2.75E-01	6.91E-02	---------	---------	---------
Pb-214	β⁻, γ	27 m	3.11E+00	1.18E+01	---------	---------	---------
Pd-107	β⁻	6.5E+06 a	0.00E+00	3.54E-04	1000	2600.00	1.36E-07
Pm-146	ε, □, β⁻	5.53 a	0.00E+00	0.00E+00	---------	---------	---------
Pm-147	β⁻, γ	2.6234 a	0.00E+00	0.00E+00	---------	---------	---------
Po-210	α, γ	138.38 d	3.14E+00	1.19E+01	---------	---------	---------
Po-211	α, γ	0.516 s	1.41E-03	5.56E-04	---------	---------	---------
Po-212	α	0.298 μs	1.76E-01	4.42E-02	---------	---------	---------
Po-213	α	4 μs	2.14E+01	8.16E+00	---------	---------	---------
Po-214	α, γ	163.7 μs	3.11E+00	1.18E+01	---------	---------	---------
Po-215	α, β⁻, γ	1.780 ms	4.63E-01	1.82E-01	---------	---------	---------
Po-216	α, γ	0.145 s	2.74E-01	6.90E-02	---------	---------	---------
Po-218	α, β⁻, γ	3.10 m	3.05E+00	1.16E+01	---------	---------	---------
Pr-144	β⁻, γ	17.28 m	0.00E+00	0.00E+00	---------	---------	---------
Pu-236	α, γ, *SF*	2.87 a	6.69E-17	0.00E+00	---------	---------	---------
Pu-238	α, γ, *SF*	87.7 a	5.45E+02	1.90E+00	100	260.00	2.10E+00
Pu-239	α, γ, *SF*	2.41E+04 a	4.95E+05	2.83E+03	100	260.00	1.92E+03
Pu-240	α, γ, *SF*	6.56E+03 a	1.29E+05	8.90E+02	100	260.00	5.01E+02
Pu-241	α, β⁻, γ	14.4 a	3.82E+00	8.03E-02	---------	---------	---------
Pu-242	α, γ, *SF*	3.75E+05 a	7.45E+01	1.26E+00	100	260.00	2.91E-01
Pu-243	β⁻, γ	4.956 h	2.62E-02	1.76E-07	---------	---------	---------
Pu-244	α, *SF*	8.0E+07 a	3.49E-04	2.40E-06	100	260.00	1.35E-06
Ra-223	α, γ	11.435 d	4.68E-01	1.84E-01	---------	---------	---------
Ra-224	α, γ	3.66 d	2.74E-01	6.90E-02	---------	---------	---------
Ra-225	β⁻, γ	14.9 d	2.19E+01	8.35E+00	---------	---------	---------
Ra-226	α, γ	1.60E+03 a	3.14E+00	1.19E+01	100	260.00	5.79E-02
Ra-228	β⁻, γ	5.76 a	3.21E-01	8.00E-02	---------	---------	---------
Rb-87	β⁻	4.88E+10 a	0.00E+00	9.68E-07	---------	---------	---------
Rh-106	β⁻, γ	29.9 s	0.00E+00	0.00E+00	---------	---------	---------
Rn-219	α, γ	3.96 s	4.62E-01	1.82E-01	---------	---------	---------

Table A-4: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 3033) – continued

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Rn-220	α, γ	55.6 s	2.75E-01	6.91E-02	---------	---------	---------
Rn-222	α, γ	3.8235 d	3.11E+00	1.18E+01	---------	---------	---------
Ru-106	β⁻	1.02 a	0.00E+00	0.00E+00	---------	---------	---------
Sb-125	β⁻, γ	2.758 a	0.00E+00	0.00E+00	---------	---------	---------
Sb-126	β⁻, γ	12.4 d	2.78E-01	2.30E-01	---------	---------	---------
Sb-126m	γ, *ITe⁻*	11.0 s	1.98E+00	1.64E+00	---------	---------	---------
Se-79	β⁻	6.5E+04 a	7.28E-02	1.53E-01	1000	2600.00	8.67E-05
Sm-146	α	1.03E+08 a	0.00E+00	9.63E-15	---------	---------	---------
Sm-147	α	1.06E+11 a	1.96E-09	1.03E-07	100	260.00	4.05E-10
Sm-151	β⁻, γ	90 a	3.77E-03	5.83E-02	1000	2600.00	2.39E-05
Sn-121m	β⁻, γ, *ITe⁻*	55 a	0.00E+00	3.70E-08	1000	2600.00	1.42E-11
Sn-126	β⁻, γ	1.0E+05 a	1.99E+00	1.64E+00	1000	2600.00	1.40E-03
Sr-90	β⁻	29.1 a	2.31E-08	3.67E-06	1000	2600.00	1.42E-09
Tc-99	β⁻, γ	2.13E+05 a	4.31E+01	9.51E+00	10000	26000.00	2.02E-03
Te-123	ε	1.0E+13 a	1.80E-18	0.00E+00	---------	---------	---------
Te-125m	γ, *ITe⁻*	58 d	0.00E+00	0.00E+00	---------	---------	---------
Th-227	α, γ	18.72 d	4.56E-01	1.80E-01	---------	---------	---------
Th-228	α, γ	1.913 a	2.78E-01	6.99E-02	---------	---------	---------
Th-229	α, γ	7.3E+03 a	2.20E+01	8.36E+00	100	260.00	1.17E-01
Th-230	α, γ	7.54e+04 a	8.29E+00	7.28E-02	10	26.00	3.22E-01
Th-231	β⁻, γ	1.063 d	4.86E+00	7.23E-02	---------	---------	---------
Th-232	α, γ	1.4E+10 a	2.75E-01	6.86E-02	10	26.00	1.32E-02
Th-234	β⁻, γ	24.10 d	2.68E+01	2.93E-01	---------	---------	---------
Tl-204	β⁻, ε	3.78 a	0.00E+00	0.00E+00	---------	---------	---------
Tl-207	β⁻, γ	4.77 m	4.60E-01	1.81E-01	---------	---------	---------
Tl-208	β⁻, γ	3.053 m	9.89E-02	2.49E-02	---------	---------	---------
Tl-209	β⁻, γ	2.2 m	4.82E-01	1.83E-01	---------	---------	---------
U-232	α, γ, *SF*	70 a	2.60E-03	1.30E-03	100	260.00	1.50E-05
U-233	α, γ, *SF*	1.592E+05 a	1.56E+02	5.07E+01	100	260.00	7.94E-01
U-234	α, γ, *SF*	2.46E+05 a	8.29E+02	6.99E+00	100	260.00	3.22E+00
U-235	α, γ, *SF*	7.04E+08 a	4.92E+00	7.32E-02	100	260.00	1.92E-02
U-236	α, γ, *SF*	2.342E+07 a	5.40E+00	2.75E-01	100	260.00	2.18E-02
U-237	β⁻, γ	6.75 d	9.36E-05	1.97E-06	---------	---------	---------
U-238	α, γ, *SF*	4.47E+09 a	2.71E+01	2.96E-01	100	260.00	1.05E-01
U-240	β⁻, γ	14.1 h	3.46E-04	2.37E-06	---------	---------	---------
Y-90	β⁻, γ	2.67 d	2.29E-08	3.63E-06	---------	---------	---------

Table A-4: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 3033) – continued

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Zn-65	$\beta^+, \gamma, \varepsilon$	243.8 d	0.00E+00	0.00E+00	---------	---------	---------
Zr-93	β^-, γ	1.5E+06 a	1.14E-03	8.00E-01	1000	2600.00	3.08E-04
Total:			**7.25E+05**	**4.93E+03**			**2.80E+03**

(a) Decayed radionuclide inventory information taken from Crawford Et Al. 2009.
(b) Release limits are determined in accordance with 40CFR191 (Appendix B, Table B-1). Left column corresponds to specific release limits (cumulative releases to the accessible environment for 10,000 years after disposal per "Unit of Waste" identified in Note 1(e) of Table 1, Appendix A, 40CFR191). Right column corresponds to release limit obtained for 2.32 Units of Waste. The 2.32 value for the Unit of Waste corresponds to the Units of Waste present at repository closure, 2033.
(c) Decay mode and half-life information taken from *Nuclides and Isotopes* (also called the "Chart of the Nuclides"), 16th Ed. (Lockheed Martin 2002).

Table A-5: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 7033)

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Ac-225	α, γ	10.0 d	6.36E+01	2.14E+01	---------	---------	---------
Ac-227	α, β^-, γ	21.77 a	9.06E-01	1.76E-01	100	260.00	4.16E-03
Ac-228	α, β^-, γ	6.15 h	2.72E-01	6.77E-02	---------	---------	---------
Ag-108	β-, □, ε, β+	2.39 m	7.71E-21	0.00E+00	---------	---------	---------
Ag-108m	ε, β+ , γ, *IT*	420 m	8.67E-20	0.00E+00	---------	---------	---------
Ag-109m	ITe^-	39.8 s	0.00E+00	0.00E+00	---------	---------	---------
Ag-110	$\beta^-, \gamma, \varepsilon$	24.6 s	0.00E+00	0.00E+00	---------	---------	---------
Ag-110m	β^-, γ, ITe^-	249.8 d	0.00E+00	0.00E+00	---------	---------	---------
Am-241	α, γ, *SF*	432.7 a	1.63E+02	1.58E+00	100	260.00	6.33E-01
Am-242	$\beta^-, \gamma, \varepsilon\ e^-$	16.02 h	2.87E-09	3.34E-11	---------	---------	---------
Am-242m	α, ITe^-, γ, *SF*	141.0 a	2.91E-09	3.40E-11	100	260.00	1.13E-11
Am-243	α, γ, *SF*	7.37E+03 a	4.49E+01	4.87E+00	100	260.00	1.91E-01
Am-245	β^-, γ	2.05 h	0.00E+00	0.00E+00	---------	---------	---------
At-217	α, β^-, γ	32 ms	6.37E+01	2.14E+01	---------	---------	---------
Ba-133	ε, □	10.53 a	0.00E+00	0.00E+00	---------	---------	---------
Ba-137m	*IT*	2.552 m	0.00E+00	0.00E+00	---------	---------	---------
Bi-210	α, β^-, γ	5.01 d	2.24E+01	2.27E+00	---------	---------	---------
Bi-211	α, β^-, γ	2.14 m	8.94E-01	1.74E-01	---------	---------	---------
Bi-212	α, β^-, γ	1.009 h	2.73E-01	6.80E-02	---------	---------	---------
Bi-213	α, β^-, γ	45.6 m	6.35E+01	2.14E+01	---------	---------	---------
Bi-214	α, β^-, γ	19.9 m	2.23E+01	2.27E+00	---------	---------	---------
Bk-249	α, β^-, γ, *SF*	3.2E+02 d	0.00E+00	0.00E+00	---------	---------	---------
Bk-250	β^-, γ	3.217 h	3.59E-12	1.34E-12	---------	---------	---------
C-14	β^-	5730 a	3.06E+00	1.01E-02	100	260.00	1.18E-02
Cd-109	γ, ε	462.0 d	0.00E+00	0.00E+00	---------	---------	---------
Cd-113m	β^-, *IT*	14.1 a	0.00E+00	0.00E+00	---------	---------	---------
Ce-144	β^-, γ	284.6 d	0.00E+00	0.00E+00	---------	---------	---------
Cf-249	α, γ, *SF*	351 a	4.94E-03	6.55E-06	100	260.00	1.90E-05
Cf-250	α, γ, *SF*	13.1 a	3.64E-12	1.35E-12	---------	---------	---------
Cf-251	α, γ	9.0E+02 a	6.24E-04	1.30E-05	100	260.00	2.45E-06
Cf-252	α, γ, *SF*	2.638 a	0.00E+00	0.00E+00	---------	---------	---------
Cl-36	$\beta^-, \varepsilon, \beta^+$	3.01E+01 a	1.98E-03	0.00E+00	---------	---------	---------
Cm-242	α, γ, *SF*	162.8 d	2.41E-09	2.81E-11	---------	---------	---------
Cm-243	α, γ, *SF*, ε	29.1 a	0.00E+00	0.00E+00	100	260.00	0.00E+00
Cm-244	α, γ, *SF*	18.1 a	0.00E+00	0.00E+00	---------	---------	---------

Table A-5: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 7033) – continued

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Cm-245	α, γ, *SF*	8.5E+03 a	3.19E+00	5.86E-02	100	260.00	1.25E-02
Cm-246	α, γ, *SF*	4.76E+03 a	1.82E+00	1.33E+00	100	260.00	1.21E-02
Cm-247	α, γ	1.56 E+07 a	2.65E-02	1.93E-07	100	260.00	1.02E-04
Cm-248	α, *SF*	3.48E+05 a	1.22E-01	7.55E-03	100	260.00	5.00E-04
Cm-250	α, β^-, *SF*	9700 a	6.53E-11	2.43E-11	---------	---------	---------
Co-60	β^-, γ	5.271 a	0.00E+00	0.00E+00	---------	---------	---------
Cs-134	β^-, γ, ε	2.065 a	0.00E+00	0.00E+00	---------	---------	---------
Cs-135	β^-	2.3E+06 a	0.00E+00	1.08E-02	1000	2600.00	4.16E-06
Cs-137	β^-, γ	30.17 a	0.00E+00	0.00E+00	1000	2600.00	0.00E+00
Es-254	α, □	276 d	0.00E+00	0.00E+00	---------	---------	---------
Eu-150	ε, □	36 a	0.00E+00	0.00E+00	---------	---------	---------
Eu-152	β^-, γ, εβ^+	13.48 a	0.00E+00	0.00E+00	---------	---------	---------
Eu-154	β^-, γ, εγ	8.59 a	0.00E+00	0.00E+00	---------	---------	---------
Eu-155	β^-, γ	4.71 a	0.00E+00	0.00E+00	---------	---------	---------
Fe-55	ε	2.73 a	0.00E+00	0.00E+00	---------	---------	---------
Fr-221	α, γ	4.8 m	6.35E+01	2.14E+01	---------	---------	---------
Fr-223	α, β^-, γ	21.8 m	1.24E-02	2.40E-03	---------	---------	---------
Gd-152	α	1.1E+14 a	2.26E-13	1.05E-12	100	260.00	4.90E-15
H-3	β^-	12.3 a	0.00E+00	0.00E+00	---------	---------	---------
Ho-166m	β-, □	1.2E+03 a	3.61E-06	1.12E-08	---------	---------	---------
I-129	β^-, γ	1.57E+07 a	1.69E+00	6.21E-03	100	260.00	6.52E-03
K-40	β^-, □, β^+	1.27E+09 a	5.50E-03	0.00E+00	---------	---------	---------
Kr-81	ε, □	2.35E+05 a	0.00E+00	1.78E-07	---------	---------	---------
Kr-85	β^-, γ	10.73 a	0.00E+00	0.00E+00	---------	---------	---------
Mn-54	ε, γ	312.2 d	0.00E+00	0.00E+00	---------	---------	---------
Mo-93	ε, □	3.5E+03 a	0.00E+00	6.74E-05	---------	---------	---------
Na-22	ε	2.6019 a	0.00E+00	0.00E+00	---------	---------	---------
Nb-93m	*ITe*[-]	16.1 a	1.09E-03	7.61E-01	---------	---------	---------
Nb-94	β^-, □	2.0E+04 a	1.47E-04	1.59E-05	---------	---------	---------
Ni-59	ε	7.6E+04 a	1.08E-01	1.36E-02	1000	2600.00	4.67E-05
Ni-63	β^-	100 a	1.45E-16	1.84E-15	1000	2600.00	7.63E-19
Np-237	α, γ	2.14E+06 a	1.34E+02	3.42E+00	100	260.00	5.29E-01
Np-238	β^-, γ	2.117 d	1.44E-11	1.68E-13	---------	---------	---------
Np-239	β^-, γ	2.355 d	4.43E+01	4.81E+00	---------	---------	---------
Np-240m	β^-, γ, *IT*	7.22 m	3.56E-04	2.65E-06	---------	---------	---------
Pa-231	α, γ	3.28E+04 a	9.05E-01	1.76E-01	100	260.00	4.16E-03

Table A-5: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 7033) – continued

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Pa-233	β⁻, γ	27.0 d	1.33E+02	3.38E+00	---------	---------	---------
Pa-234	β⁻, γ	6.69 h	3.48E-02	3.80E-04	---------	---------	---------
Pa-234m	β⁻, γ, *IT*	1.17 m	2.68E+01	2.93E-01	---------	---------	---------
Pb-209	β⁻	3.25 h	6.36E+01	2.14E+01	---------	---------	---------
Pb-210	α, β⁻, γ	22.3 a	2.26E+01	2.29E+00	100	260.00	9.58E-02
Pb-211	β⁻, γ	36.1 m	8.96E-01	1.74E-01	---------	---------	---------
Pb-212	β⁻, γ	10.64 h	2.72E-01	6.78E-02	---------	---------	---------
Pb-214	β⁻, γ	27 m	2.24E+01	2.27E+00	---------	---------	---------
Pd-107	β⁻	6.5E+06 a	0.00E+00	3.54E-04	1000	2600.00	1.36E-07
Pm-146	ε, □, β⁻	5.53 a	0.00E+00	0.00E+00	---------	---------	---------
Pm-147	β⁻, γ	2.6234 a	0.00E+00	0.00E+00	---------	---------	---------
Po-210	α, γ	138.38 d	2.26E+01	2.29E+00	---------	---------	---------
Po-211	α, γ	0.516 s	2.73E-03	5.30E-04	---------	---------	---------
Po-212	α	0.298 µs	1.74E-01	4.33E-02	---------	---------	---------
Po-213	α	4 µs	6.22E+01	2.09E+01	---------	---------	---------
Po-214	α, γ	163.7 µs	2.24E+01	2.27E+00	---------	---------	---------
Po-215	α, β⁻, γ	1.780 ms	8.96E-01	1.74E-01	---------	---------	---------
Po-216	α, γ	0.145 s	2.72E-01	6.78E-02	---------	---------	---------
Po-218	α, β⁻, γ	3.10 m	2.20E+01	2.23E+00	---------	---------	---------
Pr-144	β⁻, γ	17.28 m	0.00E+00	0.00E+00	---------	---------	---------
Pu-236	α, γ, *SF*	2.87 a	6.53E-17	0.00E+00	---------	---------	---------
Pu-238	α, γ, *SF*	87.7 a	5.73E-09	6.67E-11	100	260.00	2.23E-11
Pu-239	α, γ, *SF*	2.41E+04 a	4.41E+05	2.53E+03	100	260.00	1.71E+03
Pu-240	α, γ, *SF*	6.56E+03 a	8.47E+04	5.83E+02	100	260.00	3.28E+02
Pu-241	α, β⁻, γ	14.4 a	3.18E+00	5.85E-02	---------	---------	---------
Pu-242	α, γ, *SF*	3.75E+05 a	7.40E+01	1.26E+00	100	260.00	2.89E-01
Pu-243	β⁻, γ	4.956 h	2.62E-02	1.91E-07	---------	---------	---------
Pu-244	α, *SF*	8.0E+07 a	3.53E-04	2.63E-06	100	260.00	1.37E-06
Ra-223	α, γ	11.435 d	9.05E-01	1.76E-01	---------	---------	---------
Ra-224	α, γ	3.66 d	2.72E-01	6.77E-02	---------	---------	---------
Ra-225	β⁻, γ	14.9 d	6.36E+01	2.14E+01	---------	---------	---------
Ra-226	α, γ	1.60E+03 a	2.26E+01	2.29E+00	100	260.00	9.59E-02
Ra-228	β⁻, γ	5.76 a	3.21E-01	8.00E-02	---------	---------	---------
Rb-87	β⁻	4.88E+10 a	0.00E+00	9.68E-07	---------	---------	---------
Rh-106	β⁻, γ	29.9 s	0.00E+00	0.00E+00	---------	---------	---------
Rn-219	α, γ	3.96 s	8.94E-01	1.74E-01	---------	---------	---------

Table A-5: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 7033) – continued

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Rn-220	α, γ	55.6 s	2.72E-01	6.78E-02	---------	---------	---------
Rn-222	α, γ	3.8235 d	2.24E+01	2.27E+00	---------	---------	---------
Ru-106	β⁻	1.02 a	0.00E+00	0.00E+00	---------	---------	---------
Sb-125	β⁻, γ	2.758 a	0.00E+00	0.00E+00	---------	---------	---------
Sb-126	β⁻, γ	12.4 d	2.70E-01	2.23E-01	---------	---------	---------
Sb-126m	γ, *ITe*⁻	11.0 s	1.93E+00	1.59E+00	---------	---------	---------
Se-79	β⁻	6.5E+04 a	6.97E-02	1.46E-01	1000	2600.00	8.31E-05
Sm-146	α	1.03E+08 a	0.00E+00	9.63E-15	---------	---------	---------
Sm-147	α	1.06E+11 a	1.96E-09	1.03E-07	100	260.00	4.05E-10
Sm-151	β⁻, γ	90 a	1.57E-16	2.43E-15	1000	2600.00	9.96E-19
Sn-121m	β⁻, γ, *ITe*⁻	55 a	0.00E+00	0.00E+00	1000	2600.00	0.00E+00
Sn-126	β⁻, γ	1.0E+05 a	1.93E+00	1.60E+00	1000	2600.00	1.36E-03
Sr-90	β⁻	29.1 a	0.00E+00	0.00E+00	1000	2600.00	0.00E+00
Tc-99	β⁻, γ	2.13E+05 a	4.25E+01	9.38E+00	10000	26000.00	2.00E-03
Te-123	ε	1.0E+13 a	1.80E-18	0.00E+00	---------	---------	---------
Te-125m	γ, *ITe*⁻	58 d	0.00E+00	0.00E+00	---------	---------	---------
Th-227	α, γ	18.72 d	8.82E-01	1.71E-01	---------	---------	---------
Th-228	α, γ	1.913 a	2.75E-01	6.86E-02	---------	---------	---------
Th-229	α, γ	7.3E+03 a	6.37E+01	2.14E+01	100	260.00	3.28E-01
Th-230	α, γ	7.54e+04 a	3.71E+01	3.16E-01	10	26.00	1.44E+00
Th-231	β⁻, γ	1.063 d	6.68E+00	8.27E-02	---------	---------	---------
Th-232	α, γ	1.4E+10 a	2.75E-01	6.86E-02	10	26.00	1.32E-02
Th-234	β⁻, γ	24.10 d	2.68E+01	2.93E-01	---------	---------	---------
Tl-204	β⁻, ε	3.78 a	0.00E+00	0.00E+00	---------	---------	---------
Tl-207	β⁻, γ	4.77 m	8.90E-01	1.73E-01	---------	---------	---------
Tl-208	β⁻, γ	3.053 m	9.79E-02	2.44E-02	---------	---------	---------
Tl-209	β⁻, γ	2.2 m	1.40E+00	4.70E-01	---------	---------	---------
U-232	α, γ, *SF*	70 a	6.52E-17	2.44E-20	100	260.00	2.51E-19
U-233	α, γ, *SF*	1.592E+05 a	1.56E+02	4.99E+01	100	260.00	7.90E-01
U-234	α, γ, *SF*	2.46E+05 a	8.20E+02	6.92E+00	100	260.00	3.18E+00
U-235	α, γ, *SF*	7.04E+08 a	6.76E+00	8.38E-02	100	260.00	2.63E-02
U-236	α, γ, *SF*	2.342E+07 a	1.79E+01	3.61E-01	100	260.00	7.02E-02
U-237	β⁻, γ	6.75 d	7.79E-05	1.44E-06	---------	---------	---------
U-238	α, γ, *SF*	4.47E+09 a	2.71E+01	2.96E-01	100	260.00	1.05E-01
U-240	β⁻, γ	14.1 h	3.49E-04	2.60E-06	---------	---------	---------
Y-90	β⁻, γ	2.67 d	0.00E+00	0.00E+00	---------	---------	---------

Table A-5: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 7033) – continued

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Zn-65	$\beta^+, \gamma, \varepsilon$	243.8 d	0.00E+00	0.00E+00	---------	---------	---------
Zr-93	β^-, γ	1.5E+06 a	1.14E-03	7.99E-01	1000	2600.00	3.08E-04
Total:			**5.28E+05**	**3.40E+03**			**2.04E+03**

(a) Decayed radionuclide inventory information taken from Crawford Et Al. 2009.
(b) Release limits are determined in accordance with 40CFR191 (Appendix B, Table B-1). Left column corresponds to specific release limits (cumulative releases to the accessible environment for 10,000 years after disposal per "Unit of Waste" identified in Note 1(e) of Table 1, Appendix A, 40CFR191). Right column corresponds to release limit obtained for 2.32 Units of Waste. The 2.32 value for the Unit of Waste corresponds to the Units of Waste present at repository closure, 2033.
(c) Decay mode and half-life information taken from *Nuclides and Isotopes* (also called the "Chart of the Nuclides"), 16th Ed. (Lockheed Martin 2002).

Table A-6: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 12,033)

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Ac-225	α, γ	10.0 d	9.76E+01	3.18E+01	---------	---------	---------
Ac-227	α, β^-, γ	21.77 a	1.60E+00	1.67E-01	100	260.00	6.79E-03
Ac-228	α, β^-, γ	6.15 h	2.72E-01	6.77E-02	---------	---------	---------
Ag-108	β-, □, ε, β+	2.39 m	0.00E+00	0.00E+00	---------	---------	---------
Ag-108m	ε, β+ , γ, *IT*	420 m	0.00E+00	0.00E+00	---------	---------	---------
Ag-109m	*ITe*⁻	39.8 s	0.00E+00	0.00E+00	---------	---------	---------
Ag-110	β^-, γ, ε	24.6 s	0.00E+00	0.00E+00	---------	---------	---------
Ag-110m	β^-, γ, *ITe*⁻	249.8 d	0.00E+00	0.00E+00	---------	---------	---------
Am-241	α, γ, *SF*	432.7 a	2.17E+00	3.95E-02	100	260.00	8.50E-03
Am-242	β^-, γ, ε *e*⁻	16.02 h	3.59E-19	4.19E-21	---------	---------	---------
Am-242m	α, *ITe*⁻, γ, *SF*	141.0 a	3.66E-19	4.26E-21	100	260.00	1.42E-21
Am-243	α, γ, *SF*	7.37E+03 a	2.81E+01	3.05E+00	100	260.00	1.20E-01
Am-245	β^-, γ	2.05 h	0.00E+00	0.00E+00	---------	---------	---------
At-217	α, β^-, γ	32 ms	9.77E+01	3.18E+01	---------	---------	---------
Ba-133	ε, □	10.53 a	0.00E+00	0.00E+00	---------	---------	---------
Ba-137m	*IT*	2.552 m	0.00E+00	0.00E+00	---------	---------	---------
Bi-210	α, β^-, γ	5.01 d	5.52E+01	7.06E-01	---------	---------	---------
Bi-211	α, β^-, γ	2.14 m	1.58E+00	1.65E-01	---------	---------	---------
Bi-212	α, β^-, γ	1.009 h	2.73E-01	6.80E-02	---------	---------	---------
Bi-213	α, β^-, γ	45.6 m	9.75E+01	3.17E+01	---------	---------	---------
Bi-214	α, β^-, γ	19.9 m	5.52E+01	7.06E-01	---------	---------	---------
Bk-249	α, β^-, γ, *SF*	3.2E+02 d	0.00E+00	0.00E+00	---------	---------	---------
Bk-250	β^-, γ	3.217 h	2.94E-12	1.10E-12	---------	---------	---------
C-14	β^-	5730 a	1.67E+00	5.54E-03	100	260.00	6.46E-03
Cd-109	γ, ε	462.0 d	0.00E+00	0.00E+00	---------	---------	---------
Cd-113m	β^-, *IT*	14.1 a	0.00E+00	0.00E+00	---------	---------	---------
Ce-144	β^-, γ	284.6 d	0.00E+00	0.00E+00	---------	---------	---------
Cf-249	α, γ, *SF*	351 a	2.51E-07	3.32E-10	100	260.00	9.66E-10
Cf-250	α, γ, *SF*	13.1 a	2.98E-12	1.11E-12	---------	---------	---------
Cf-251	α, γ	9.0E+02 a	1.32E-05	2.74E-07	100	260.00	5.16E-08
Cf-252	α, γ, *SF*	2.638 a	0.00E+00	0.00E+00	---------	---------	---------
Cl-36	β^-, ε, β^+	3.01E+01 a	1.95E-03	0.00E+00	---------	---------	---------
Cm-242	α, γ, *SF*	162.8 d	3.02E-19	3.52E-21	---------	---------	---------
Cm-243	α, γ, *SF*, ε	29.1 a	0.00E+00	0.00E+00	100	260.00	0.00E+00
Cm-244	α, γ, *SF*	18.1 a	0.00E+00	0.00E+00	---------	---------	---------

Table A-6: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 12033) – continued

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Cm-245	α, γ, *SF*	8.5E+03 a	2.12E+00	3.90E-02	100	260.00	8.30E-03
Cm-246	α, γ, *SF*	4.76E+03 a	8.75E-01	6.40E-01	100	260.00	5.83E-03
Cm-247	α, γ	1.56 E+07 a	2.65E-02	1.94E-07	100	260.00	1.02E-04
Cm-248	α, *SF*	3.48E+05 a	1.21E-01	7.47E-03	100	260.00	4.94E-04
Cm-250	α, β^-, *SF*	9700 a	5.35E-11	1.99E-11	---------	---------	---------
Co-60	β^-, γ	5.271 a	0.00E+00	0.00E+00	---------	---------	---------
Cs-134	β^-, γ, ε	2.065 a	0.00E+00	0.00E+00	---------	---------	---------
Cs-135	β^-	2.3E+06 a	0.00E+00	1.08E-02	1000	2600.00	4.16E-06
Cs-137	β^-, γ	30.17 a	0.00E+00	0.00E+00	1000	2600.00	0.00E+00
Es-254	α, □	276 d	0.00E+00	0.00E+00	---------	---------	---------
Eu-150	ε, □	36 a	0.00E+00	0.00E+00	---------	---------	---------
Eu-152	β^-, γ, $\varepsilon\beta^+$	13.48 a	0.00E+00	0.00E+00	---------	---------	---------
Eu-154	β^-, γ, εγ	8.59 a	0.00E+00	0.00E+00	---------	---------	---------
Eu-155	β^-, γ	4.71 a	0.00E+00	0.00E+00	---------	---------	---------
Fe-55	ε	2.73 a	0.00E+00	0.00E+00	---------	---------	---------
Fr-221	α, γ	4.8 m	9.75E+01	3.17E+01	---------	---------	---------
Fr-223	α, β^-, γ	21.8 m	2.18E-02	2.28E-03	---------	---------	---------
Gd-152	α	1.1E+14 a	2.26E-13	1.05E-12	100	260.00	4.90E-15
H-3	β^-	12.3 a	0.00E+00	0.00E+00	---------	---------	---------
Ho-166m	β-, □	1.2E+03 a	2.01E-07	6.22E-10	---------	---------	---------
I-129	β^-, γ	1.57E+07 a	1.69E+00	6.21E-03	100	260.00	6.52E-03
K-40	β^-, □, β^+	1.27E+09 a	5.50E-03	0.00E+00	---------	---------	---------
Kr-81	ε, □	2.35E+05 a	0.00E+00	1.75E-07	---------	---------	---------
Kr-85	β^-, γ	10.73 a	0.00E+00	0.00E+00	---------	---------	---------
Mn-54	ε, γ	312.2 d	0.00E+00	0.00E+00	---------	---------	---------
Mo-93	ε, □	3.5E+03 a	0.00E+00	2.50E-05	---------	---------	---------
Na-22	ε	2.6019 a	0.00E+00	0.00E+00	---------	---------	---------
Nb-93m	*ITe*$^-$	16.1 a	1.08E-03	7.59E-01	---------	---------	---------
Nb-94	β^-, □	2.0E+04 a	1.24E-04	1.34E-05	---------	---------	---------
Ni-59	ε	7.6E+04 a	1.03E-01	1.30E-02	1000	2600.00	4.47E-05
Ni-63	β^-	100 a	0.00E+00	0.00E+00	1000	2600.00	0.00E+00
Np-237	α, γ	2.14E+06 a	1.34E+02	3.41E+00	100	260.00	5.29E-01
Np-238	β^-, γ	2.117 d	1.81E-21	2.10E-23	---------	---------	---------
Np-239	β^-, γ	2.355 d	2.77E+01	3.01E+00	---------	---------	---------
Np-240m	β^-, γ, *IT*	7.22 m	3.61E-04	2.94E-06	---------	---------	---------
Pa-231	α, γ	3.28E+04 a	1.60E+00	1.67E-01	100	260.00	6.79E-03

Table A-6: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 12033) – continued

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Pa-233	β^-, γ	27.0 d	1.33E+02	3.38E+00	---------	---------	---------
Pa-234	β^-, γ	6.69 h	3.48E-02	3.80E-04	---------	---------	---------
Pa-234m	β^-, γ, *IT*	1.17 m	2.68E+01	2.93E-01	---------	---------	---------
Pb-209	β^-	3.25 h	9.76E+01	3.17E+01	---------	---------	---------
Pb-210	α, β^-, γ	22.3 a	5.59E+01	7.14E-01	100	260.00	2.18E-01
Pb-211	β^-, γ	36.1 m	1.58E+00	1.65E-01	---------	---------	---------
Pb-212	β^-, γ	10.64 h	2.72E-01	6.78E-02	---------	---------	---------
Pb-214	β^-, γ	27 m	5.53E+01	7.07E-01	---------	---------	---------
Pd-107	β^-	6.5E+06 a	0.00E+00	3.53E-04	1000	2600.00	1.36E-07
Pm-146	ε, □, β^-	5.53 a	0.00E+00	0.00E+00	---------	---------	---------
Pm-147	β^-, γ	2.6234 a	0.00E+00	0.00E+00	---------	---------	---------
Po-210	α, γ	138.38 d	5.58E+01	7.14E-01	---------	---------	---------
Po-211	α, γ	0.516 s	4.82E-03	5.04E-04	---------	---------	---------
Po-212	α	0.298 μs	1.74E-01	4.33E-02	---------	---------	---------
Po-213	α	4 μs	9.55E+01	3.11E+01	---------	---------	---------
Po-214	α, γ	163.7 μs	5.53E+01	7.07E-01	---------	---------	---------
Po-215	α, β^-, γ	1.780 ms	1.58E+00	1.65E-01	---------	---------	---------
Po-216	α, γ	0.145 s	2.72E-01	6.78E-02	---------	---------	---------
Po-218	α, β^-, γ	3.10 m	5.43E+01	6.95E-01	---------	---------	---------
Pr-144	β^-, γ	17.28 m	0.00E+00	0.00E+00	---------	---------	---------
Pu-236	α, γ, *SF*	2.87 a	6.33E-17	0.00E+00	---------	---------	---------
Pu-238	α, γ, *SF*	87.7 a	7.17E-19	8.36E-21	100	260.00	2.79E-21
Pu-239	α, γ, *SF*	2.41E+04 a	3.82E+05	2.19E+03	100	260.00	1.48E+03
Pu-240	α, γ, *SF*	6.56E+03 a	4.98E+04	3.43E+02	100	260.00	1.93E+02
Pu-241	α, β^-, γ	14.4 a	2.11E+00	3.89E-02	---------	---------	---------
Pu-242	α, γ, *SF*	3.75E+05 a	7.33E+01	1.26E+00	100	260.00	2.87E-01
Pu-243	β^-, γ	4.956 h	2.62E-02	1.92E-07	---------	---------	---------
Pu-244	α, *SF*	8.0E+07 a	3.58E-04	2.92E-06	100	260.00	1.39E-06
Ra-223	α, γ	11.435 d	1.60E+00	1.67E-01	---------	---------	---------
Ra-224	α, γ	3.66 d	2.72E-01	6.77E-02	---------	---------	---------
Ra-225	β^-, γ	14.9 d	9.76E+01	3.18E+01	---------	---------	---------
Ra-226	α, γ	1.60E+03 a	5.59E+01	7.15E-01	100	260.00	2.18E-01
Ra-228	β^-, γ	5.76 a	3.21E-01	8.00E-02	---------	---------	---------
Rb-87	β^-	4.88E+10 a	0.00E+00	9.68E-07	---------	---------	---------
Rh-106	β^-, γ	29.9 s	0.00E+00	0.00E+00	---------	---------	---------
Rn-219	α, γ	3.96 s	1.58E+00	1.65E-01	---------	---------	---------

Table A-6: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 12033) – continued

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Rn-220	α, γ	55.6 s	2.72E-01	6.78E-02	---------	---------	---------
Rn-222	α, γ	3.8235 d	5.53E+01	7.08E-01	---------	---------	---------
Ru-106	β⁻	1.02 a	0.00E+00	0.00E+00	---------	---------	---------
Sb-125	β⁻, γ	2.758 a	0.00E+00	0.00E+00	---------	---------	---------
Sb-126	β⁻, γ	12.4 d	2.61E-01	2.16E-01	---------	---------	---------
Sb-126m	γ, ITe⁻	11.0 s	1.86E+00	1.54E+00	---------	---------	---------
Se-79	β⁻	6.5E+04 a	6.61E-02	1.39E-01	1000	2600.00	7.88E-05
Sm-146	α	1.03E+08 a	0.00E+00	9.63E-15	---------	---------	---------
Sm-147	α	1.06E+11 a	1.96E-09	1.03E-07	100	260.00	4.05E-10
Sm-151	β⁻, γ	90 a	0.00E+00	0.00E+00	1000	2600.00	0.00E+00
Sn-121m	β⁻, γ, ITe⁻	55 a	0.00E+00	0.00E+00	1000	2600.00	0.00E+00
Sn-126	β⁻, γ	1.0E+05 a	1.87E+00	1.54E+00	1000	2600.00	1.31E-03
Sr-90	β⁻	29.1 a	0.00E+00	0.00E+00	1000	2600.00	0.00E+00
Tc-99	β⁻, γ	2.13E+05 a	4.19E+01	9.23E+00	10000	26000.00	1.97E-03
Te-123	ε	1.0E+13 a	1.80E-18	0.00E+00	---------	---------	---------
Te-125m	γ, ITe⁻	58 d	0.00E+00	0.00E+00	---------	---------	---------
Th-227	α, γ	18.72 d	1.56E+00	1.63E-01	---------	---------	---------
Th-228	α, γ	1.913 a	2.75E-01	6.86E-02	---------	---------	---------
Th-229	α, γ	7.3E+03 a	9.78E+01	3.18E+01	100	260.00	4.98E-01
Th-230	α, γ	7.54e+04 a	7.13E+01	6.04E-01	10	26.00	2.77E+00
Th-231	β⁻, γ	1.063 d	8.68E+00	9.42E-02	---------	---------	---------
Th-232	α, γ	1.4E+10 a	2.75E-01	6.86E-02	10	26.00	1.32E-02
Th-234	β⁻, γ	24.10 d	2.68E+01	2.93E-01	---------	---------	---------
Tl-204	β⁻, ε	3.78 a	0.00E+00	0.00E+00	---------	---------	---------
Tl-207	β⁻, γ	4.77 m	1.57E+00	1.64E-01	---------	---------	---------
Tl-208	β⁻, γ	3.053 m	9.79E-02	2.44E-02	---------	---------	---------
Tl-209	β⁻, γ	2.2 m	2.15E+00	6.98E-01	---------	---------	---------
U-232	α, γ, SF	70 a	6.32E-17	0.00E+00	100	260.00	2.43E-19
U-233	α, γ, SF	1.592E+05 a	1.55E+02	4.89E+01	100	260.00	7.85E-01
U-234	α, γ, SF	2.46E+05 a	8.09E+02	6.83E+00	100	260.00	3.14E+00
U-235	α, γ, SF	7.04E+08 a	8.79E+00	9.54E-02	100	260.00	3.42E-02
U-236	α, γ, SF	2.342E+07 a	2.76E+01	4.28E-01	100	260.00	1.08E-01
U-237	β⁻, γ	6.75 d	5.18E-05	9.55E-07	---------	---------	---------
U-238	α, γ, SF	4.47E+09 a	2.71E+01	2.96E-01	100	260.00	1.05E-01
U-240	β⁻, γ	14.1 h	3.54E-04	2.89E-06	---------	---------	---------
Y-90	β⁻, γ	2.67 d	0.00E+00	0.00E+00	---------	---------	---------

Table A-6: 40CFR191 Release Limits and Source Term EPA Units for WIPP-Scale TRU Waste (Calendar Year = 12033) – continued

Nuclide			WIPP TRU Waste				
ID	Decay Mode[c]	Half-life[c]	Total Inventory [Curies][a]		Release Limits Inventory [Ci][b]		Source EPA Unit
			CH	RH	(Ci/UW)	(Ci)	
Zn-65	$\beta^+, \gamma, \varepsilon$	243.8 d	0.00E+00	0.00E+00	---------	---------	---------
Zr-93	β^-, γ	1.5E+06 a	1.14E-03	7.97E-01	1000	2600.00	3.07E-04
Total:			**4.35E+05**	**2.88E+03**			**1.68E+03**

(a) Decayed radionuclide inventory information taken from Crawford Et Al. 2009.
(b) Release limits are determined in accordance with 40CFR191 (Appendix B, Table B-1). Left column corresponds to specific release limits (cumulative releases to the accessible environment for 10,000 years after disposal per "Unit of Waste" identified in Note 1(e) of Table 1, Appendix A, 40CFR191). Right column corresponds to release limit obtained for 2.32 Units of Waste. The 2.32 value for the Unit of Waste corresponds to the Units of Waste present at repository closure, 2033.
(c) Decay mode and half-life information taken from *Nuclides and Isotopes* (also called the "Chart of the Nuclides"), 16th Ed. (Lockheed Martin 2002).

APPENDIX B – 40CFR191 Release Limits and Unit of Waste for WIPP-Scale TRU Waste

Table B-1: 40CFR191 Release Limits for Containment Requirements[a]

[Cumulative releases to the accessible environment for 10,000 years after disposal]

Radionuclide	Release Limit per 1,000 MTHM or other unit of waste (b) (see notes) (c) (curies)
Americium-241 or –243	100
Carbon-14	100
Cesium-135 or –137	1,000
Iodine-129	100
Neptunium-237	100
Plutonium-238, -239, -240, or –242	100
Radium-226	100
Strontium-90	1,000
Technetium-99	10,000
Thorium-230 or –232	10
Tin-126	1,000
Uranium-233, -234, -235, -236, or –238	100
Any other alpha-emitting radionuclide with a half-life greater than 20 years	100
Any other radionuclide with a half-life greater than 20 years that does not emit alpha particles	1,000

Application of Table 1 {Appendix A to Part 191 for Subpart B} 40 CFR 191.

Note 1: Units of Waste. The Release Limits in Table 1 apply to the amount of wastes in any one of the following:

- An amount of spent nuclear fuel containing 1,000 metric tons of heavy metal (MTHM) exposed to a burnup between 25,000 megawatt-days per metric ton of heavy metal (MWd/MTHM) and 40,000 MWd/MTHM;
- The high-level radioactive wastes generated from reprocessing each 1,000 MTHM exposed to a burnup between 25,000 MWd/MTHM and 40,000 MWd/MTHM;
- Each 100,000,000 curies of gamma or beta-emitting radionuclides with half-lives greater than 20 years but less than 100 years (for use as discussed in Note 5 or with materials that are identified by the Commission as high-level radioactive waste in accordance with part B of the definition of high-level waste in the NWPA);
- Each 1,000,000 curies of other radionuclides (i.e., gamma or beta-emitters with half-lives greater than 100 years or any alpha-emitters with half-lives greater than 20 years)(for use as discussed in Note 5 or with materials that are identified by the Commission as high-level radioactive waste in accordance with part B of the definition of high-level waste in the NWPA); or
- An amount of transuranic wastes containing one million curies of alpha-emitting transuranic radionuclides with half-lives greater than 20 years.

(a) Based on Table 1 of Appendix A of 40 CFR 191.

(b) **Note!!! The categories of notes 1(a) through 1(e) are organized according to the waste type and not the radiation emission type. Only TRU wastes are allowed in the WIPP facility, thus only Note 1(e) should be used for identification of the "unit of waste" value. Also, alpha, beta and gamma emitting radionuclides with half-lives greater than 20 years all contribute to the "release limits".**

(c) Notes 2 through 6 of Table 1 from Appendix A of 40 CFR191 are not shown here.

Table B-2: 40CFR191 Unit of Waste for WIPP-Scale TRU Waste

Nuclide			WIPP TRU Waste												
ID	Decay Mode[a]	Half-life[a]	Total Inventory [Curies][b]						Transuranic Inventory [α-curies][c]						% of Unit of Waste
			2033	2133	2383	3033	7033	12,033	2033	2133	2383	3033	7033	12,033	2033
Ac-225	α, γ	10.0 d	1.30E+01	1.48E+01	1.92E+01	3.03E+01	8.50E+01	1.29E+02	---------	---------	---------	---------	---------	---------	---------
Ac-227	α, β⁻, γ	21.77 a	2.42E+00	6.48E-01	5.95E-01	6.52E-01	1.08E+00	1.77E+00	---------	---------	---------	---------	---------	---------	---------
Ac-228	α, β⁻, γ	6.15 h	3.26E-01	3.40E-01	3.40E-01	3.40E-01	3.40E-01	3.40E-01	---------	---------	---------	---------	---------	---------	---------
Ag-108	β-, □, ε, β+	2.39 m	5.47E-09	3.17E-09	8.10E-10	2.33E-11	7.71E-21	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Ag-108m	ε, β+ , γ, *IT*	420 m	6.16E-08	3.57E-08	9.11E-09	2.62E-10	8.67E-20	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Ag-109m	*ITe⁻*	39.8 s	1.12E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Ag-110	β⁻, γ, ε	24.6 s	6.90E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Ag-110m	β⁻, γ, *ITe⁻*	249.8 d	5.24E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Am-241	**α, γ, *SF***	**432.7 a**	**4.72E+05**	**4.17E+05**	**2.79E+05**	**9.85E+04**	**1.65E+02**	**2.21E+00**	**4.72E+05**	**4.17E+05**	**2.79E+05**	**9.85E+04**	**1.65E+02**	**2.21E+00**	**18.140%**
Am-242	β⁻, γ, ε *e⁻*	16.02 h	2.31E+01	1.47E+01	4.69E+00	2.42E-01	2.90E-09	3.64E-19	---------	---------	---------	---------	---------	---------	---------
Am-242m	**α, *ITe⁻*, γ, *SF***	**141.0 a**	**2.35E+01**	**1.49E+01**	**4.77E+00**	**2.46E-01**	**2.95E-09**	**3.70E-19**	**2.35E+01**	**1.49E+01**	**4.77E+00**	**2.46E-01**	**2.95E-09**	**3.70E-19**	**0.001%**
Am-243	**α, γ, *SF***	**7.37E+03 a**	**7.95E+01**	**7.88E+01**	**7.70E+01**	**7.24E+01**	**4.97E+01**	**3.11E+01**	**7.95E+01**	**7.88E+01**	**7.70E+01**	**7.24E+01**	**4.97E+01**	**3.11E+01**	**0.003%**
Am-245	β⁻, γ	2.05 h	5.12E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
At-217	α, β⁻, γ	32 ms	1.30E+01	1.48E+01	1.92E+01	3.03E+01	8.51E+01	1.29E+02	---------	---------	---------	---------	---------	---------	---------
Ba-133	ε, □	10.53 a	1.98E-03	3.11E-06	3.05E-13	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Ba-137m	*IT*	2.552 m	8.37E+04	8.30E+03	2.57E+01	7.73E-06	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Bi-210	α, β⁻, γ	5.01 d	1.59E+01	1.95E+01	1.77E+01	1.49E+01	2.46E+01	5.59E+01	---------	---------	---------	---------	---------	---------	---------
Bi-211	α, β⁻, γ	2.14 m	2.39E+00	6.40E-01	5.87E-01	6.44E-01	1.07E+00	1.74E+00	---------	---------	---------	---------	---------	---------	---------
Bi-212	α, β⁻, γ	1.009 h	6.08E+01	2.34E+01	2.42E+00	3.45E-01	3.41E-01	3.41E-01	---------	---------	---------	---------	---------	---------	---------
Bi-213	α, β⁻, γ	45.6 m	1.29E+01	1.48E+01	1.92E+01	3.02E+01	8.49E+01	1.29E+02	---------	---------	---------	---------	---------	---------	---------
Bi-214	α, β⁻, γ	19.9 m	2.03E+01	1.95E+01	1.77E+01	1.49E+01	2.46E+01	5.59E+01	---------	---------	---------	---------	---------	---------	---------
Bk-249	α, β⁻, γ, *SF*	3.2E+02 d	3.54E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Bk-250	β⁻, γ	3.217 h	6.01E-12	5.99E-12	5.93E-12	5.78E-12	4.93E-12	4.04E-12	---------	---------	---------	---------	---------	---------	---------
C-14	β⁻	5730 a	5.63E+00	5.56E+00	5.40E+00	4.99E+00	3.07E+00	1.68E+00	---------	---------	---------	---------	---------	---------	---------

Table B-2: 40CFR191 Unit of Waste for WIPP-Scale TRU Waste (continued)

Nuclide			WIPP TRU Waste												
ID	Decay Mode[a]	Half-life[a]	Total Inventory [Curies][b]						Transuranic Inventory [α-curies][c]						% of Unit of Waste
			2033	2133	2383	3033	7033	12,033	2033	2133	2383	3033	7033	12,033	2033
Cd-109	γ, ε	462.0 d	1.13E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Cd-113m	β⁻, IT	14.1 a	2.45E+00	2.12E-02	1.47E-07	1.55E-24	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Ce-144	β⁻, γ	284.6 d	6.49E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Cf-249	**α, γ, SF**	**351 a**	**9.75E+01**	**8.00E+01**	**4.88E+01**	**1.35E+01**	**4.95E-03**	**2.51E-07**	**9.75E+01**	**8.00E+01**	**4.88E+01**	**1.35E+01**	**4.95E-03**	**2.51E-07**	**0.004%**
Cf-250	α, γ, SF	13.1 a	5.72E-02	2.85E-04	5.10E-10	5.85E-12	4.99E-12	4.09E-12	---------	---------	---------	---------	---------	---------	---------
Cf-251	**α, γ**	**9.0E+02 a**	**3.02E-02**	**2.80E-02**	**2.31E-02**	**1.40E-02**	**6.37E-04**	**1.34E-05**	**3.02E-02**	**2.80E-02**	**2.31E-02**	**1.40E-02**	**6.37E-04**	**1.34E-05**	**0.000%**
Cf-252	α, γ, SF	2.638 a	3.30E-02	1.28E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Cl-36	β⁻, ε, β⁺	3.01E+01 a	2.00E-03	2.00E-03	2.00E-03	1.99E-03	1.98E-03	1.95E-03	---------	---------	---------	---------	---------	---------	---------
Cm-242	α, γ, SF	162.8 d	1.94E+01	1.23E+01	3.93E+00	2.03E-01	2.44E-09	3.06E-19	---------	---------	---------	---------	---------	---------	---------
Cm-243	**α, γ, SF, ε**	**29.1 a**	**3.43E+00**	**3.01E-01**	**6.89E-04**	**9.39E-11**	**0.00E+00**	**0.00E+00**	**3.43E+00**	**3.01E-01**	**6.89E-04**	**9.39E-11**	**0.00E+00**	**0.00E+00**	**0.000%**
Cm-244	α, γ, SF	18.1 a	3.05E+03	6.63E+01	4.63E-03	7.26E-14	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Cm-245	**α, γ, SF**	**8.5E+03 a**	**6.69E-01**	**1.38E+00**	**2.63E+00**	**3.91E+00**	**3.24E+00**	**2.16E+00**	**6.69E-01**	**1.38E+00**	**2.63E+00**	**3.91E+00**	**3.24E+00**	**2.16E+00**	**0.000%**
Cm-246	**α, γ, SF**	**4.76E+03 a**	**6.56E+00**	**6.46E+00**	**6.23E+00**	**5.66E+00**	**3.15E+00**	**1.52E+00**	**6.56E+00**	**6.46E+00**	**6.23E+00**	**5.66E+00**	**3.15E+00**	**1.52E+00**	**0.000%**
Cm-247	**α, γ**	**1.56 E+07 a**	**2.65E-02**	**2.65E-02**	**2.65E-02**	**2.65E-02**	**2.65E-02**	**2.65E-02**	**2.65E-02**	**2.65E-02**	**2.65E-02**	**2.65E-02**	**2.65E-02**	**2.65E-02**	**0.000%**
Cm-248	**α, SF**	**3.48E+05 a**	**1.31E-01**	**1.31E-01**	**1.31E-01**	**1.31E-01**	**1.30E-01**	**1.29E-01**	**1.31E-01**	**1.31E-01**	**1.31E-01**	**1.31E-01**	**1.30E-01**	**1.29E-01**	**0.000%**
Cm-250	**α, β⁻, SF**	**9700 a**	**1.09E-10**	**1.09E-10**	**1.08E-10**	**1.05E-10**	**8.97E-11**	**7.35E-11**	**1.09E-10**	**1.09E-10**	**1.08E-10**	**1.05E-10**	**8.97E-11**	**7.35E-11**	**0.000%**
Co-60	β⁻, γ	5.271 a	1.23E+01	2.38E-05	1.15E-19	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Cs-134	β⁻, γ, ε	2.065 a	1.15E-01	2.89E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Cs-135	β⁻	2.3E+06 a	1.08E-02	1.08E-02	1.08E-02	1.08E-02	1.08E-02	1.08E-02	---------	---------	---------	---------	---------	---------	---------
Cs-137	β⁻, γ	30.17 a	8.95E+04	8.88E+03	2.75E+01	8.26E-06	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Es-254	α, □	276 d	7.99E-23	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Eu-150	ε, □	36 a	1.28E-03	1.87E-04	1.52E-06	5.57E-12	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Eu-152	β⁻, γ, εβ⁺	13.48 a	4.04E+00	2.47E-02	7.24E-08	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Eu-154	β⁻, γ, εγ	8.59 a	8.39E+01	2.65E-02	4.71E-11	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------

Table B-2: 40CFR191 Unit of Waste for WIPP-Scale TRU Waste (continued)

Nuclide			WIPP TRU Waste												
ID	Decay Mode[a]	Half-life[a]	Total Inventory [Curies][b]						Transuranic Inventory [α-curies][c]						% of Unit of Waste
			2033	2133	2383	3033	7033	12,033	2033	2133	2383	3033	7033	12,033	2033
Eu-155	β⁻, γ	4.71 a	3.19E+01	2.71E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Fe-55	ε	2.73 a	7.11E-04	1.88E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Fr-221	α, γ	4.8 m	1.30E+01	1.48E+01	1.92E+01	3.02E+01	8.49E+01	1.29E+02	---------	---------	---------	---------	---------	---------	---------
Fr-223	α, β⁻, γ	21.8 m	3.30E-02	8.84E-03	8.12E-03	8.90E-03	1.48E-02	2.41E-02	---------	---------	---------	---------	---------	---------	---------
Gd-152	α	1.1E+14 a	1.14E-12	1.27E-12	1.27E-12	1.27E-12	1.27E-12	1.27E-12	---------	---------	---------	---------	---------	---------	---------
H-3	β⁻	12.3 a	2.02E+03	7.38E+00	5.94E-06	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Ho-166m	β-, □	1.2E+03 a	6.50E-05	6.14E-05	5.31E-05	3.65E-05	3.62E-06	2.02E-07	---------	---------	---------	---------	---------	---------	---------
I-129	β⁻, γ	1.57E+07 a	1.70E+00	1.70E+00	1.70E+00	1.70E+00	1.70E+00	1.69E+00	---------	---------	---------	---------	---------	---------	---------
K-40	β⁻, □, β⁺	1.27E+09 a	5.50E-03	5.50E-03	5.50E-03	5.50E-03	5.50E-03	5.50E-03	---------	---------	---------	---------	---------	---------	---------
Kr-81	ε, □	2.35E+05 a	1.80E-07	1.80E-07	1.80E-07	1.80E-07	1.78E-07	1.75E-07	---------	---------	---------	---------	---------	---------	---------
Kr-85	β⁻, γ	10.73 a	4.72E+01	7.35E-02	7.02E-09	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Mn-54	ε, γ	312.2 d	8.64E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Mo-93	ε, □	3.5E+03 a	1.82E-04	1.78E-04	1.69E-04	1.49E-04	6.74E-05	2.50E-05	---------	---------	---------	---------	---------	---------	---------
Na-22	ε	2.6019 a	2.01E-04	5.41E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Nb-93m	ITe⁻	16.1 a	7.30E-01	7.63E-01	7.63E-01	7.63E-01	7.62E-01	7.60E-01	---------	---------	---------	---------	---------	---------	---------
Nb-94	β⁻, □	2.0E+04 a	1.93E-04	1.92E-04	1.91E-04	1.86E-04	1.63E-04	1.37E-04	---------	---------	---------	---------	---------	---------	---------
Ni-59	ε	7.6E+04 a	1.27E-01	1.27E-01	1.27E-01	1.26E-01	1.22E-01	1.16E-01	---------	---------	---------	---------	---------	---------	---------
Ni-63	β⁻	100 a	4.55E+01	2.14E+01	3.26E+00	2.43E-02	1.98E-15	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Np-237	α, γ	**2.14E+06 a**	**3.90E+01**	**5.36E+01**	**8.19E+01**	**1.18E+02**	**1.38E+02**	**1.37E+02**	**3.90E+01**	**5.36E+01**	**8.19E+01**	**1.18E+02**	**1.38E+02**	**1.37E+02**	**0.001%**
Np-238	β⁻, γ	2.117 d	1.16E-01	7.36E-02	2.36E-02	1.22E-03	1.46E-11	1.83E-21	---------	---------	---------	---------	---------	---------	---------
Np-239	β⁻, γ	2.355 d	7.85E+01	7.78E+01	7.60E+01	7.15E+01	4.91E+01	3.07E+01	---------	---------	---------	---------	---------	---------	---------
Np-240m	β⁻, γ, IT	7.22 m	3.54E-04	3.54E-04	3.54E-04	3.55E-04	3.59E-04	3.64E-04	---------	---------	---------	---------	---------	---------	---------
Pa-231	α, γ	3.28E+04 a	5.65E-01	5.73E-01	5.94E-01	6.52E-01	1.08E+00	1.77E+00	---------	---------	---------	---------	---------	---------	---------
Pa-233	β⁻, γ	27.0 d	3.86E+01	5.31E+01	8.11E+01	1.17E+02	1.36E+02	1.36E+02	---------	---------	---------	---------	---------	---------	---------
Pa-234	β⁻, γ	6.69 h	3.52E-02	3.52E-02	3.52E-02	3.52E-02	3.52E-02	3.52E-02	---------	---------	---------	---------	---------	---------	---------

Table B-2: 40CFR191 Unit of Waste for WIPP-Scale TRU Waste (continued)

Nuclide			WIPP TRU Waste												
ID	Decay Mode[a]	Half-life[a]	Total Inventory [Curies][b]						Transuranic Inventory [α-curies][c]						% of Unit of Waste
			2033	2133	2383	3033	7033	12,033	2033	2133	2383	3033	7033	12,033	2033
Pa-234m	*β^-, γ, IT*	1.17 m	2.70E+01	2.70E+01	2.70E+01	2.70E+01	2.70E+01	2.70E+01	---------	---------	---------	---------	---------	---------	---------
Pb-209	β^-	3.25 h	1.30E+01	1.48E+01	1.92E+01	3.03E+01	8.50E+01	1.29E+02	---------	---------	---------	---------	---------	---------	---------
Pb-210	α, β^-, γ	22.3 a	1.61E+01	1.98E+01	1.79E+01	1.50E+01	2.49E+01	5.66E+01	---------	---------	---------	---------	---------	---------	---------
Pb-211	β^-, γ	36.1 m	2.40E+00	6.40E-01	5.88E-01	6.45E-01	1.07E+00	1.75E+00	---------	---------	---------	---------	---------	---------	---------
Pb-212	β^-, γ	10.64 h	6.06E+01	2.34E+01	2.41E+00	3.44E-01	3.40E-01	3.40E-01	---------	---------	---------	---------	---------	---------	---------
Pb-214	β^-, γ	27 m	2.03E+01	1.95E+01	1.77E+01	1.49E+01	2.47E+01	5.60E+01	---------	---------	---------	---------	---------	---------	---------
Pd-107	β^-	6.5E+06 a	3.54E-04	3.54E-04	3.54E-04	3.54E-04	3.54E-04	3.53E-04	---------	---------	---------	---------	---------	---------	---------
Pm-146	ε, ∃, β^-	5.53 a	1.42E-08	4.78E-14	9.91E-28	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Pm-147	β^-, γ	2.6234 a	1.23E+00	4.14E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Po-210	α, γ	138.38 d	1.61E+01	1.97E+01	1.79E+01	1.50E+01	2.49E+01	5.65E+01	---------	---------	---------	---------	---------	---------	---------
Po-211	α, γ	0.516 s	7.31E-03	1.95E-03	1.79E-03	1.97E-03	3.26E-03	5.32E-03	---------	---------	---------	---------	---------	---------	---------
Po-212	α	0.298 μs	3.87E+01	1.49E+01	1.54E+00	2.20E-01	2.17E-01	2.17E-01	---------	---------	---------	---------	---------	---------	---------
Po-213	α	4 μs	1.27E+01	1.45E+01	1.88E+01	2.96E+01	8.31E+01	1.27E+02	---------	---------	---------	---------	---------	---------	---------
Po-214	α, γ	163.7 μs	2.03E+01	1.95E+01	1.77E+01	1.49E+01	2.46E+01	5.60E+01	---------	---------	---------	---------	---------	---------	---------
Po-215	α, β^-, γ	1.780 ms	2.40E+00	6.40E-01	5.88E-01	6.45E-01	1.07E+00	1.75E+00	---------	---------	---------	---------	---------	---------	---------
Po-216	α, γ	0.145 s	6.06E+01	2.33E+01	2.41E+00	3.44E-01	3.40E-01	3.40E-01	---------	---------	---------	---------	---------	---------	---------
Po-218	α, β^-, γ	3.10 m	2.00E+01	1.92E+01	1.74E+01	1.46E+01	2.42E+01	5.50E+01	---------	---------	---------	---------	---------	---------	---------
Pr-144	β^-, γ	17.28 m	6.36E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Pu-236	α, γ, *SF*	2.87 a	2.51E-05	7.63E-16	6.71E-17	6.69E-17	6.53E-17	6.33E-17	---------	---------	---------	---------	---------	---------	---------
Pu-238	**α, γ, *SF***	**87.7 a**	**1.47E+06**	**6.69E+05**	**9.28E+04**	**5.47E+02**	**5.80E-09**	**7.26E-19**	**1.47E+06**	**6.69E+05**	**9.28E+04**	**5.47E+02**	**5.80E-09**	**7.26E-19**	**56.594%**
Pu-239	**α, γ, *SF***	**2.41E+04 a**	**5.13E+05**	**5.11E+05**	**5.07E+05**	**4.98E+05**	**4.44E+05**	**3.84E+05**	**5.13E+05**	**5.11E+05**	**5.07E+05**	**4.98E+05**	**4.44E+05**	**3.84E+05**	**19.690%**
Pu-240	**α, γ, *SF***	**6.56E+03 a**	**1.45E+05**	**1.43E+05**	**1.40E+05**	**1.30E+05**	**8.52E+04**	**5.02E+04**	**1.45E+05**	**1.43E+05**	**1.40E+05**	**1.30E+05**	**8.52E+04**	**5.02E+04**	**5.563%**
Pu-241	α, β^-, γ	14.4 a	5.10E+05	4.14E+03	2.65E+00	3.90E+00	3.24E+00	2.15E+00	---------	---------	---------	---------	---------	---------	---------
Pu-242	**α, γ, *SF***	**3.75E+05 a**	**7.59E+01**	**7.59E+01**	**7.58E+01**	**7.58E+01**	**7.52E+01**	**7.46E+01**	**7.59E+01**	**7.59E+01**	**7.58E+01**	**7.58E+01**	**7.52E+01**	**7.46E+01**	**0.003%**
Pu-243	β^-, γ	4.956 h	2.62E-02	2.62E-02	2.62E-02	2.62E-02	2.62E-02	2.62E-02	---------	---------	---------	---------	---------	---------	---------

Table B-2: 40CFR191 Unit of Waste for WIPP-Scale TRU Waste (continued)

Nuclide			WIPP TRU Waste												
ID	Decay Mode[a]	Half-life[a]	Total Inventory [Curies][b]						Transuranic Inventory [α-curies][c]						% of Unit of Waste
			2033	2133	2383	3033	7033	12,033	2033	2133	2383	3033	7033	12,033	2033
Pu-244	***α, SF***	**8.0E+07 a**	**3.51E-04**	**3.51E-04**	**3.51E-04**	**3.52E-04**	**3.56E-04**	**3.61E-04**	**3.51E-04**	**3.51E-04**	**3.51E-04**	**3.52E-04**	**3.56E-04**	**3.61E-04**	**0.000%**
Ra-223	α, γ	11.435 d	2.42E+00	6.47E-01	5.94E-01	6.52E-01	1.08E+00	1.76E+00	---------	---------	---------	---------	---------	---------	---------
Ra-224	α, γ	3.66 d	6.05E+01	2.33E+01	2.41E+00	3.43E-01	3.39E-01	3.39E-01	---------	---------	---------	---------	---------	---------	---------
Ra-225	β^-, γ	14.9 d	1.30E+01	1.48E+01	1.92E+01	3.03E+01	8.50E+01	1.29E+02	---------	---------	---------	---------	---------	---------	---------
Ra-226	α, γ	1.60E+03 a	2.06E+01	1.97E+01	1.79E+01	1.51E+01	2.49E+01	5.66E+01	---------	---------	---------	---------	---------	---------	---------
Ra-228	β^-, γ	5.76 a	3.85E-01	4.01E-01	4.01E-01	4.01E-01	4.01E-01	4.01E-01	---------	---------	---------	---------	---------	---------	---------
Rb-87	β^-	4.88E+10 a	9.68E-07	9.68E-07	9.68E-07	9.68E-07	9.68E-07	9.68E-07	---------	---------	---------	---------	---------	---------	---------
Rh-106	β^-, γ	29.9 s	1.62E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Rn-219	α, γ	3.96 s	2.39E+00	6.40E-01	5.87E-01	6.44E-01	1.07E+00	1.74E+00	---------	---------	---------	---------	---------	---------	---------
Rn-220	α, γ	55.6 s	6.06E+01	2.33E+01	2.41E+00	3.44E-01	3.40E-01	3.40E-01	---------	---------	---------	---------	---------	---------	---------
Rn-222	α, γ	3.8235 d	2.04E+01	1.95E+01	1.77E+01	1.49E+01	2.47E+01	5.60E+01	---------	---------	---------	---------	---------	---------	---------
Ru-106	β^-	1.02 a	1.64E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Sb-125	β^-, γ	2.758 a	9.00E-03	1.22E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Sb-126	β^-, γ	12.4 d	5.11E-01	5.11E-01	5.10E-01	5.08E-01	4.94E-01	4.77E-01	---------	---------	---------	---------	---------	---------	---------
Sb-126m	γ, ITe^-	11.0 s	3.65E+00	3.65E+00	3.64E+00	3.62E+00	3.53E+00	3.40E+00	---------	---------	---------	---------	---------	---------	---------
Se-79	β^-	6.5E+04 a	2.28E-01	2.28E-01	2.27E-01	2.26E-01	2.16E-01	2.05E-01	---------	---------	---------	---------	---------	---------	---------
Sm-146	α	1.03E+08 a	9.35E-15	9.63E-15	9.63E-15	9.63E-15	9.63E-15	9.63E-15	---------	---------	---------	---------	---------	---------	---------
Sm-147	α	1.06E+11 a	1.05E-07	1.05E-07	1.05E-07	1.05E-07	1.05E-07	1.05E-07	---------	---------	---------	---------	---------	---------	---------
Sm-151	β^-, γ	90 a	1.37E+02	6.36E+01	9.28E+00	6.21E-02	2.59E-15	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Sn-121m	β^-, γ, ITe^-	55 a	3.91E-02	9.76E-03	3.04E-04	3.70E-08	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Sn-126	β^-, γ	1.0E+05 a	3.65E+00	3.65E+00	3.65E+00	3.63E+00	3.53E+00	3.41E+00	---------	---------	---------	---------	---------	---------	---------
Sr-90	β^-	29.1 a	8.04E+04	7.44E+03	1.94E+01	3.70E-06	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Tc-99	β^-, γ	2.13E+05 a	5.28E+01	5.28E+01	5.27E+01	5.26E+01	5.19E+01	5.11E+01	---------	---------	---------	---------	---------	---------	---------
Te-123	ε	1.0E+13 a	1.80E-18	1.80E-18	1.80E-18	1.80E-18	1.80E-18	1.80E-18	---------	---------	---------	---------	---------	---------	---------
Te-125m	γ, ITe^-	58 d	2.18E-03	2.96E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------

Table B-2: 40CFR191 Unit of Waste for WIPP-Scale TRU Waste (continued)

Nuclide			WIPP TRU Waste												
ID	Decay Mode[a]	Half-life[a]	Total Inventory [Curies][b]						Transuranic Inventory [α-curies][c]						% of Unit of Waste
			2033	2133	2383	3033	7033	12,033	2033	2133	2383	3033	7033	12,033	2033
Th-227	α, γ	18.72 d	2.36E+00	6.31E-01	5.79E-01	6.35E-01	1.05E+00	1.72E+00	---------	---------	---------	---------	---------	---------	---------
Th-228	α, γ	1.913 a	6.13E+01	2.36E+01	2.44E+00	3.48E-01	3.44E-01	3.44E-01	---------	---------	---------	---------	---------	---------	---------
Th-229	α, γ	7.3E+03 a	1.30E+01	1.48E+01	1.93E+01	3.03E+01	8.52E+01	1.30E+02	---------	---------	---------	---------	---------	---------	---------
Th-230	α, γ	7.54e+04 a	5.97E-01	1.02E+00	2.67E+00	8.36E+00	3.75E+01	7.20E+01	---------	---------	---------	---------	---------	---------	---------
Th-231	β^-, γ	1.063 d	4.44E+00	4.49E+00	4.61E+00	4.93E+00	6.76E+00	8.77E+00	---------	---------	---------	---------	---------	---------	---------
Th-232	α, γ	1.4E+10 a	3.44E-01	3.44E-01	3.44E-01	3.44E-01	3.44E-01	3.44E-01	---------	---------	---------	---------	---------	---------	---------
Th-234	β^-, γ	24.10 d	2.71E+01	2.71E+01	2.71E+01	2.71E+01	2.71E+01	2.71E+01	---------	---------	---------	---------	---------	---------	---------
Tl-204	β^-, ε	3.78 a	2.34E-08	2.80E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Tl-207	β^-, γ	4.77 m	2.38E+00	6.37E-01	5.85E-01	6.41E-01	1.06E+00	1.74E+00	---------	---------	---------	---------	---------	---------	---------
Tl-208	β^-, γ	3.053 m	2.18E+01	8.41E+00	8.69E-01	1.24E-01	1.22E-01	1.22E-01	---------	---------	---------	---------	---------	---------	---------
Tl-209	β^-, γ	2.2 m	2.85E-01	3.25E-01	4.22E-01	6.65E-01	1.87E+00	2.84E+00	---------	---------	---------	---------	---------	---------	---------
U-232	α, γ, *SF*	70 a	5.92E+01	2.26E+01	2.04E+00	3.90E-03	6.52E-17	6.32E-17	---------	---------	---------	---------	---------	---------	---------
U-233	α, γ, *SF*	1.592E+05 a	2.07E+02	2.07E+02	2.07E+02	2.06E+02	2.05E+02	2.04E+02	---------	---------	---------	---------	---------	---------	---------
U-234	α, γ, *SF*	2.46E+05 a	3.09E+02	5.98E+02	8.05E+02	8.36E+02	8.27E+02	8.16E+02	---------	---------	---------	---------	---------	---------	---------
U-235	α, γ, *SF*	7.04E+08 a	4.49E+00	4.54E+00	4.67E+00	4.99E+00	6.84E+00	8.88E+00	---------	---------	---------	---------	---------	---------	---------
U-236	α, γ, *SF*	2.342E+07 a	1.60E+00	2.03E+00	3.08E+00	5.68E+00	1.83E+01	2.81E+01	---------	---------	---------	---------	---------	---------	---------
U-237	β^-, γ	6.75 d	1.25E+01	1.02E-01	6.50E-05	9.56E-05	7.94E-05	5.28E-05	---------	---------	---------	---------	---------	---------	---------
U-238	α, γ, *SF*	4.47E+09 a	2.73E+01	2.73E+01	2.73E+01	2.73E+01	2.73E+01	2.73E+01	---------	---------	---------	---------	---------	---------	---------
U-240	β^-, γ	14.1 h	3.47E-04	3.47E-04	3.47E-04	3.48E-04	3.52E-04	3.57E-04	---------	---------	---------	---------	---------	---------	---------
Y-90	β^-, γ	2.67 d	7.94E+04	7.35E+03	1.91E+01	3.66E-06	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Zn-65	$\beta^+, \gamma, \varepsilon$	243.8 d	4.20E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---------	---------	---------	---------	---------	---------	---------
Zr-93	β^-, γ	1.5E+06 a	8.02E-01	8.02E-01	8.02E-01	8.01E-01	8.00E-01	7.98E-01	---------	---------	---------	---------	---------	---------	---------
		Total:	3.45E+06	1.78E+06	1.02E+06	7.29E+05	5.32E+05	4.38E+05	2.60E+06	1.74E+06	1.02E+06	7.28E+05	5.30E+05	4.35E+05	100.000%
		WUF							**2.60**						

(a) Decay mode and half-life information taken from *Nuclides and Isotopes* (also called the "Chart of the Nuclides"), 16th Ed. (Lockheed Martin 2002).

(b) Decayed radionuclide inventory information taken from. (Crawford Et At. 2009). The inventory information given has been decayed through 2033.
(c) Transuranic inventory data corresponds to the activity (curie) data only for radionuclides that are categorized as "transuranic waste" per definitions in 40CFR191.

APPENDIX C – Parameter Data Entry Tables

The following Tables identify Parameter value changes associated with the 2009 Performance Assessment Baseline Calculation (PABC09). The data found in Tables C-1 through C-5 supports Parameter Data Entry form 9-2-1 for changing parameters affected by this document.

Table C-1: Waste Unit Factor (WUF) Parameter Change

Material	Property	Value / Median	Units	Distribution	Source
BOREHOLE	WUF	2.60	Curies	Constant	Appendix B, Table B-1

Table C-2: Radionuclide Parameter Changes

Material	Property	Value / Median	Units	Distribution	Source
AM241	INVCHD	4.68E+05	Curies	Constant	Crawford et. al. 2009, Table A1
AM241	INVRHD	4.48E+03	Curies	Constant	Crawford et. al. 2009, Table A1
AM243	INVCHD	7.17E+01	Curies	Constant	Crawford et. al. 2009, Table A1
AM243	INVRHD	7.80E+00	Curies	Constant	Crawford et. al. 2009, Table A1
CF252	INVCHD	3.28E-02	Curies	Constant	Crawford et. al. 2009, Table A1
CF252	INVRHD	1.83E-04	Curies	Constant	Crawford et. al. 2009, Table A1
CM243	INVCHD	1.34E+00	Curies	Constant	Crawford et. al. 2009, Table A1
CM243	INVRHD	2.09E+00	Curies	Constant	Crawford et. al. 2009, Table A1

Material	Property	Value / Median	Units	Distribution	Source
CM244	INVCHD	2.61E+03	Curies	Constant	Crawford et. al. 2009, Table A1
CM244	INVRHD	4.36E+02	Curies	Constant	Crawford et. al. 2009, Table A1
CM245	INVCHD	5.86E-01	Curies	Constant	Crawford et. al. 2009, Table A1
CM245	INVRHD	8.26E-02	Curies	Constant	Crawford et. al. 2009, Table A1
CM248	INVCHD	1.24E-01	Curies	Constant	Crawford et. al. 2009, Table A1
CM248	INVRHD	7.63E-03	Curies	Constant	Crawford et. al. 2009, Table A1
CS137	INVCHD	5.48E+02	Curies	Constant	Crawford et. al. 2009, Table A1
CS137	INVRHD	8.89E+04	Curies	Constant	Crawford et. al. 2009, Table A1
NP237	INVCHD	3.65E+01	Curies	Constant	Crawford et. al. 2009, Table A1
NP237	INVRHD	2.49E+00	Curies	Constant	Crawford et. al. 2009, Table A1
PA231	INVCHD	3.78E-01	Curies	Constant	Crawford et. al. 2009, Table A1
PA231	INVRHD	1.87E-01	Curies	Constant	Crawford et. al. 2009, Table A1
PB210	INVCHD	1.75E+00	Curies	Constant	Crawford et. al. 2009, Table A1
PB210	INVRHD	1.43E+01	Curies	Constant	Crawford et. al. 2009, Table A1
PM147	INVCHD	5.09E-02	Curies	Constant	Crawford et. al. 2009, Table A1
PM147	INVRHD	1.18E+00	Curies	Constant	Crawford et. al. 2009, Table A1

Material	Property	Value / Median	Units	Distribution	Source
PU238	INVCHD	1.47E+06	Curies	Constant	Crawford et. al. 2009, Table A1
PU238	INVRHD	5.11E+03	Curies	Constant	Crawford et. al. 2009, Table A1
PU239	INVCHD	5.10E+05	Curies	Constant	Crawford et. al. 2009, Table A1
PU239	INVRHD	2.92E+03	Curies	Constant	Crawford et. al. 2009, Table A1
PU240	INVCHD	1.44E+05	Curies	Constant	Crawford et. al. 2009, Table A1
PU240	INVRHD	9.89E+02	Curies	Constant	Crawford et. al. 2009, Table A1
PU241	INVCHD	5.06E+05	Curies	Constant	Crawford et. al. 2009, Table A1
PU241	INVRHD	3.94E+03	Curies	Constant	Crawford et. al. 2009, Table A1
PU242	INVCHD	7.46E+01	Curies	Constant	Crawford et. al. 2009, Table A1
PU242	INVRHD	1.25E+00	Curies	Constant	Crawford et. al. 2009, Table A1
PU244	INVCHD	3.48E-04	Curies	Constant	Crawford et. al. 2009, Table A1
PU244	INVRHD	2.34E-06	Curies	Constant	Crawford et. al. 2009, Table A1
RA226	INVCHD	2.21E+00	Curies	Constant	Crawford et. al. 2009, Table A1
RA226	INVRHD	1.83E+01	Curies	Constant	Crawford et. al. 2009, Table A1
RA228	INVCHD	3.08E-01	Curies	Constant	Crawford et. al. 2009, Table A1
RA228	INVRHD	7.69E-02	Curies	Constant	Crawford et. al. 2009, Table A1

Material	Property	Value / Median	Units	Distribution	Source
SR90	INVCHD	5.03E+02	Curies	Constant	Crawford et. al. 2009, Table A1
SR90	INVRHD	7.99E+04	Curies	Constant	Crawford et. al. 2009, Table A1
TH229	INVCHD	8.81E+00	Curies	Constant	Crawford et. al. 2009, Table A1
TH229	INVRHD	4.19E+00	Curies	Constant	Crawford et. al. 2009, Table A1
TH230	INVCHD	5.87E-01	Curies	Constant	Crawford et. al. 2009, Table A1
TH230	INVRHD	9.20E-03	Curies	Constant	Crawford et. al. 2009, Table A1
TH232	INVCHD	2.75E-01	Curies	Constant	Crawford et. al. 2009, Table A1
TH232	INVRHD	6.86E-02	Curies	Constant	Crawford et. al. 2009, Table A1
U233	INVCHD	1.56E+02	Curies	Constant	Crawford et. al. 2009, Table A1
U233	INVRHD	5.09E+01	Curies	Constant	Crawford et. al. 2009, Table A1
U234	INVCHD	3.04E+02	Curies	Constant	Crawford et. al. 2009, Table A1
U234	INVRHD	5.18E+00	Curies	Constant	Crawford et. al. 2009, Table A1
U235	INVCHD	4.42E+00	Curies	Constant	Crawford et. al. 2009, Table A1
U235	INVRHD	7.04E-02	Curies	Constant	Crawford et. al. 2009, Table A1
U236	INVCHD	1.35E+00	Curies	Constant	Crawford et. al. 2009, Table A1
U236	INVRHD	2.48E-01	Curies	Constant	Crawford et. al. 2009, Table A1

Material	Property	Value / Median	Units	Distribution	Source
U238	INVCHD	2.71E+01	Curies	Constant	Crawford et. al. 2009, Table A1
U238	INVRHD	2.96E-01	Curies	Constant	Crawford et. al. 2009, Table A1

Table C-3 - Lumped Radionuclide Parameter Changes

Material	Property	Value / Median	Units	Distribution	Source
AM241L	INVCHD	4.85E+05	Curies	Constant	Section 4.3, Table 5
AM241L	INVRHD	4.61E+03	Curies	Constant	Section 4.3, Table 5
TH230L	INVCHD	9.40E+00	Curies	Constant	Section 4.3, Table 5
TH230L	INVRHD	4.20E+00	Curies	Constant	Section 4.3, Table 5
PU238L	INVCHD	1.47E+06	Curies	Constant	Section 4.3, Table 5
PU238L	INVRHD	5.11E+03	Curies	Constant	Section 4.3, Table 5
U234L	INVCHD	4.60E+02	Curies	Constant	Section 4.3, Table 5
U234L	INVRHD	5.61E+01	Curies	Constant	Section 4.3, Table 5
PU239L	INVCHD	6.55E+05	Curies	Constant	Section 4.3, Table 5
PU239L	INVRHD	3.92E+03	Curies	Constant	Section 4.3, Table 5

Table C-4 - Waste Material Parameter Changes

Material	Property	Value / Median	Units	Distribution	Source
WAS_AREA	DIRONCHW	8.10E+01	kg/m^3	Constant	Crawford et. al. 2009, Table 5-4
WAS_AREA	DIRONRHW	1.70E+02	kg/m^3	Constant	Crawford et. al. 2009, Table 5-5
WAS_AREA	DIRNCCHW	1.90E+02	kg/m^3	Constant	Crawford et. al. 2009, Table 5-4
WAS_AREA	DIRNCRHW	6.30E+02	kg/m^3	Constant	Crawford et. al. 2009, Table 5-5
WAS_AREA	DCELLCHW	4.00E+01	kg/m^3	Constant	Crawford et. al. 2009, Table 5-4
WAS_AREA	DCELLRHW	2.20E+01	kg/m^3	Constant	Crawford et. al. 2009, Table 5-5
WAS_AREA	DCELCCHW	5.10E+00	kg/m^3	Constant	Crawford et. al. 2009, Table 5-4
WAS_AREA	DCELECHW	1.34E+00	kg/m^3	Constant	Crawford et. al. 2009, Table 4-4
WAS_AREA	DPLASCHW	3.8E+01	kg/m^3	Constant	Crawford et. al. 2009, Table 5-4
WAS_AREA	DPLASRHW	2.8E+01	kg/m^3	Constant	Crawford et. al. 2009, Table 5-5
WAS_AREA	DPLSCCHW	1.60E+01	kg/m^3	Constant	Crawford et. al. 2009, Table 5-4
WAS_AREA	DPLSCRHW	1.40E+01	kg/m^3	Constant	Crawford et. al. 2009, Table 5-5
WAS_AREA	DPLSECHW	6.59E+00	kg/m^3	Constant	Crawford et. al. 2009, Table 4-4
WAS_AREA	DRUBBCHW	5.6E+00	kg/m^3	Constant	Crawford et. al. 2009, Table 5-4
WAS_AREA	DRUBBRHW	6.6E+00	kg/m^3	Constant	Crawford et. al. 2009, Table 5-5

Table C-5 - Oxyanion Parameter Changes

Material	Property	Value / Median	Units	Distribution	Source
NITRATE	QINIT	2.79E+07	moles	Constant	Section 5
SULFATE	QINIT	6.15E+06	moles	Constant	Section 5

APPENDIX D – Generation of the EPAUNI input files using the InventoryDB database

A Microsoft Access database called InventoryDB (provided on the attached CD) was created to select the radionuclides of interest from the inventory data provided by LANL and to export the data into ASCII files formatted for use by EPAUNI. The inventory data were imported from the Excel spreadsheet "D 7 00_PAIR-2008_App B_Disposal_WSLevel_Volumes_Activites.xls" and placed into the table Inventory using the Access File/Get External Data/Import menu function and selecting the "2033 Normalized" sheet. Additionally, the same method was used to import the volume data for the CH waste streams from the sheet labeled "CH 2033" and the volume data for the RH waste streams from the sheet "RH 2033". The table RadsUsed was created to list the radionuclides to be included in each of the CH and RH input files for EPAUNI.

The volume data for the CH waste was joined to the inventory data using the query CH_Inventory. The data were combined using the site and waste stream fields of the two tables to join the data appropriately. The table RadsUsed was then joined through the Radionuclide and Handling fields to select out the set of data to be included in the EPAUNI input files. The SQL for the query is:

```
SELECT Inventory.[Site Code], Inventory.[Waste Stream ID], Volumes.Volume,
Inventory.Type, Inventory.Radionuclide, Inventory.[Scld Activity Ci],
RadsUsed.Handling, RadsUsed.SortOrder
FROM (Inventory INNER JOIN Volumes ON (Inventory.[Waste Stream ID] = Volumes.[Waste
Stream ID]) AND (Inventory.[Site Code] = Volumes.[Site ID])) INNER JOIN RadsUsed ON
(Inventory.Radionuclide = RadsUsed.Radionuclide) AND (Inventory.Handling =
RadsUsed.Handling)
WHERE (((RadsUsed.Handling)="CH"))
ORDER BY Inventory.[Waste Stream ID], RadsUsed.SortOrder;
```

The volume data, inventory data and the RadsUsed data for the RH waste streams were joined in a similar manner:

```
SELECT Inventory.[Site Code], Inventory.[Waste Stream ID], Volumes_RH.Volume,
Inventory.Type, Inventory.Radionuclide, Inventory.[Scld Activity Ci],
RadsUsed.Handling, RadsUsed.SortOrder
FROM (Inventory INNER JOIN RadsUsed ON (Inventory.Radionuclide =
RadsUsed.Radionuclide) AND (Inventory.Handling = RadsUsed.Handling)) INNER JOIN
Volumes_RH ON (Inventory.[Site Code] = Volumes_RH.[Site ID]) AND (Inventory.[Waste
Stream ID] = Volumes_RH.[Waste Stream ID])
WHERE (((RadsUsed.Handling)="RH"))
ORDER BY Inventory.[Site Code], Inventory.[Waste Stream ID], RadsUsed.SortOrder;
```

Crosstab (pivot) queries were then used with each of these two queries to organize the data into tables having waste streams as rows and volumes and radionuclides as columns. The SQL for the CH query is:

```
TRANSFORM First(CH_Inventory.[Scld Activity Ci]) AS [FirstOfScld Activity Ci]
SELECT CH_Inventory.[Site Code], CH_Inventory.[Waste Stream ID], CH_Inventory.Volume
FROM CH_Inventory
GROUP BY CH_Inventory.[Site Code], CH_Inventory.[Waste Stream ID], CH_Inventory.Volume
PIVOT [SortOrder] & ":" & [Radionuclide];
```

The SQL for the RH query is:

```
TRANSFORM First(RH_Inventory.[Scld Activity Ci]) AS [FirstOfScld Activity Ci]
SELECT RH_Inventory.[Site Code], RH_Inventory.[Waste Stream ID], RH_Inventory.Volume
FROM RH_Inventory
GROUP BY RH_Inventory.[Site Code], RH_Inventory.[Waste Stream ID], RH_Inventory.Volume
```

```
PIVOT [SortOrder] & ":" & [Radionuclide];
```

The data from the two crosstab queries were written to ASCII files using the code:

```
Sub WriteFile(fName As String, sql As String, ch As Boolean)
'write a formatted file
Dim db As Database
Dim rec As Recordset

Open fName For Output As #1
Set db = CurrentDb
Set rec = db.OpenRecordset(sql)
If Not rec.BOF And Not rec.EOF Then
    rec.MoveFirst
    If ch Then
        Print #1, "StreamRH (Really CH) Volume(m3) Am-241 Cm-244 Pu-238 Pu-239 Pu-240
Pu-241 U-234"
    Else
        Print #1, "StreamRH Volume(m3) Am-241 Cm-244 Pu-238 Pu-239 Pu-240 Pu-241 U-
234"
    End If
    Print #1, "        Cs-137 Sr-90 U-233"
    While Not rec.EOF
        Print #1, rec.Fields("Waste Stream ID"); " ";
        Debug.Print rec.Fields("Waste Stream ID"); " ";
        For i = 2 To 9
            Print #1, Format(Nz(rec.Fields(i), 0#), "0.00E+00"); " ";
            Debug.Print Format(Nz(rec.Fields(i), 0#), "0.00E+00"); " ";
        Next
        Print #1, ""
        Debug.Print ""
        Print #1, "       ";
        For i = 10 To 12
            Print #1, Format(Nz(rec.Fields(i), 0#), "0.00E+00"); " ";
        Next
        Print #1, ""
        rec.MoveNext
    Wend
    Close #1
End If
rec.Close
Set rec = Nothing
db.Close
Set db = Nothing
End Sub
```

The subroutine takes as arguments the name of the file to be written, the dataset to be used, and a Boolean parameter which is used to identify the data as CH or RH. The subroutine is called once for each of the CH and RH datasets using the form MainForm (Figure 1).

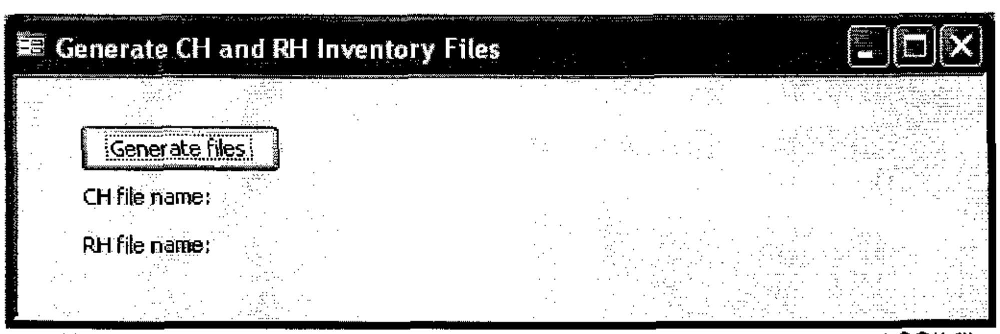

Figure 1. The main form of InventoryDB is used to export the inventory data to ASCII files for use by EPAUNI .

The user selects the "Generate files" button to export the data. The code for this button then prompts the user for files names for the CH and RH files, via the standard Windows Common Dialog control, and calls the WriteFile subroutine for each:

```
Private Sub Command0_Click()
'get CH file name
Dim s As String, i As Integer
   'CancelError is True.
    CommCtrl.CancelError = True
    On Error GoTo ErrHandler
   ' Set filters.
    CommCtrl.Filter = "All Files (*.*)|*.*|Text Files (*.txt)|*.txt|Input files
(*.INP)|*.INP"
   ' Specify default filter.
    CommCtrl.FilterIndex = 3
    CommCtrl.DefaultExt = ".INP"
    CommCtrl.DialogTitle = "Save CH data as"
    CommCtrl.FileName = ""
   ' Display the Open dialog box.
    CommCtrl.ShowSave
    WriteFile CommCtrl.FileName, "CH_Inventory_Crosstab", True
    Me.CH_file.Caption = CommCtrl.FileName
    s = CommCtrl.FileName
    i = InStr(s, "\")
    While i > 0
        s = Mid(s, i + 1)
        i = InStr(s, "\")
    Wend
    i = InStr(s, "CH")
    If i > 0 Then
        Mid(s, i, 2) = "RH"
    End If
    CommCtrl.FileName = s
    CommCtrl.DialogTitle = "Save RH data as"
   ' Display the Open dialog box.
    CommCtrl.ShowSave
    WriteFile CommCtrl.FileName, "RH_Inventory_Crosstab", False
    Me.RH_file.Caption = CommCtrl.FileName

   Exit Sub

ErrHandler:
' User pressed Cancel button.
   Exit Sub


End Sub
```

The operation of the database in producing the files was verified by comparing selected values in the data in the files to the data in the spreadsheet and verifying that the files had the same number of records as in the spreadsheet. The sheets "CH 2003" and "RH 2003" were used for these comparisons. For example, the spreadsheet for CH waste shows:

D 7 00_PAIR-2008_App B_Disposal_WSLevel_Volumes_Activites.xls

	A	B	C	D	E	F	G	H	I	J	K	L	M	
1	Site ID	Waste Stream ID	Volume	Am-241	Am-243	Cm-244	Cs-137	Np-237	Pu-238	Pu-239	Pu-240	Pu-241	Pu-242	P
2	AE	AECHDM-S	101.78	5.42E+01	1.88E+00	4.30E-02	9.74E-01	1.23E-01	5.21E+01	8.54E+01	6.44E+01	2.57E+01	2.62E-02	6.
3	AE	AECHHM-S	13.86	1.41E+01	5.13E-03	--	7.63E-04	1.83E-03	3.62E+00	4.13E+01	1.64E+01	2.95E-10	2.02E-03	
4	AE	AE-T001	511.88	1.89E+02	--	--	5.81E+00	2.19E+00	3.11E+01	4.66E+02	2.75E+02	1.20E+02	2.24E-01	
5	AE	AE-T003	23.32	4.47E+00	--	--	3.22E-03	1.45E-02	8.32E-01	2.89E+01	1.11E+01	1.32E+01	3.12E-04	
6	AE	MU-W002-S	4.50	6.72E+00	1.13E-03	--	9.16E-07	3.91E-03	--	2.27E-02	--	--	--	
7	AW	AW-N026.82	1.87	--	--	--	4.87E-01	--	--	7.65E-03	--	--	--	
8	AW	AW-N027.531	31.79	1.02E-01	--	--	--	1.19E-06	1.03E+02	1.04E+02	6.24E-01	9.80E-02	7.88E-06	
9	AW	AW-T033.1325	197.85	3.10E+02	1.72E+01	--	--	2.08E+00	6.49E+02	7.11E+02	1.62E+02	3.32E+02	4.64E-02	1.
10	AW	AW-W049	186.13	2.06E+02	--	--	--	1.72E-03	8.53E+00	5.80E+01	4.14E+01	1.89E+02	1.53E-02	
11	BT	BT-T002	16.90	1.22E-02	4.01E-05	7.85E-04	1.06E+01	5.74E-05	7.40E-01	7.36E-04	1.51E-03	3.62E-02	1.17E-05	6.
12	FR	FR-MOX-MT02	0.42	1.68E-06	--	--	--	2.24E-11	4.25E-07	2.99E-07	1.78E-07	2.63E-06	4.16E-09	
13	FR	FR-MOX-T01	5.62	2.24E-05	--	--	--	3.02E-10	5.73E-06	4.04E-06	2.40E-06	3.55E-05	5.62E-08	

CH 2033 / RH 2033 / 2033 Normalized / CH 2133 / RH 2133 / CH 2383 / RH 2383 / CH 30

D 7 00_PAIR-2008_App B_Disposal_WSLevel_Volumes_Activites.xls

	A	B	M	N	O	P	Q	R	S	T	U	V	W
1	Site ID	Waste Stream ID	Pu-242	Pu-244	Sr-90	Th-229	Th-230	Th-232	U-233	U-234	U-235	U-236	U-238
2	AE	AECHDM-S	2.62E-02	6.52E-16	9.95E-01	8.62E-03	2.18E-05	4.26E-14	4.20E-02	8.34E-02	1.50E-03	5.74E-05	4.41E-02
3	AE	AECHHM-S	2.02E-03	--	7.81E-04	3.21E-04	1.49E-06	1.08E-14	2.30E-07	5.67E-03	1.07E-04	1.46E-05	2.69E-03
4	AE	AE-T001	2.24E-01	--	4.01E+00	1.35E-03	1.28E-05	2.03E-04	3.08E-01	3.27E-02	9.23E-03	4.49E-04	1.63E-01
5	AE	AE-T003	3.12E-04	--	7.99E-03	4.02E-05	2.98E-08	1.68E-14	9.54E-03	1.34E-04	7.64E-05	1.49E-05	1.67E-03
6	AE	MU-W002-S	--	--	9.38E-07	1.09E-03	1.98E-13	--	5.06E-07	1.47E-09	6.71E-10	--	1.73E-05
7	AW	AW-N026.82	--	--	2.37E+00	--	--	--	--	--	3.02E-10	--	--
8	AW	AW-N027.531	7.88E-06	--	--	3.34E-08	2.42E-06	6.27E-16	9.63E-06	1.32E-02	6.99E-05	6.86E-07	2.46E-07
9	AW	AW-T033.1325	4.64E-02	1.15E-05	--	2.21E-02	1.83E-04	4.29E-06	6.74E+00	4.89E-01	1.50E-02	3.55E-03	8.38E-03
10	AW	AW-W049	1.53E-02	--	--	7.82E-11	8.45E-08	2.05E-14	9.66E-08	6.99E-04	1.42E-03	3.20E-05	1.56E-05
11	BT	BT-T002	1.17E-05	6.73E-13	1.04E+01	1.12E-11	5.74E-07	5.20E-13	7.72E-09	2.10E-03	2.65E-05	3.02E-04	1.22E-07
12	FR	FR-MOX-MT02	4.16E-09	--	--	2.99E-18	1.54E-14	2.89E-22	2.13E-15	6.86E-11	1.39E-14	2.49E-13	2.95E-17
13	FR	FR-MOX-T01	5.62E-08	--	--	4.04E-17	2.08E-13	3.90E-21	2.86E-14	9.26E-10	1.87E-13	3.36E-12	3.98E-16

CH 2033 / RH 2033 / 2033 Normalized / CH 2133 / RH 2133 / CH 2383 / RH 2383 / CH 30

The corresponding data in the CH input file are highlighted:

The CH input file:

```
StreamRH (Really CH) Volume(m3) Am-241 Cm-244 Pu-238 Pu-239 Pu-240 Pu-241 U-234
       Cs-137 Sr-90 U-233
AECHDM-S 1.02E+02 5.42E+01 4.30E-02 5.21E+01 8.54E+01 6.44E+01 2.57E+01 8.34E-02
      9.74E-01 9.95E-01 4.20E-02
AECHHM-S 1.39E+01 1.41E+01 0.00E+00 3.62E+00 4.13E+01 1.64E+01 2.95E-10 5.67E-03
      7.63E-04 7.81E-04 2.30E-07
AE-T001 5.12E+02 1.89E+02 0.00E+00 3.11E+01 4.66E+02 2.75E+02 1.20E+02 3.27E-02
      5.81E+00 4.01E+00 3.08E-01
AE-T003 2.33E+01 4.47E+00 0.00E+00 8.32E-01 2.89E+01 1.11E+01 1.32E+01 1.34E-04
      3.22E-03 7.99E-03 9.54E-03
MU-W002-S 4.50E+00 6.72E+00 0.00E+00 0.00E+00 2.27E-02 0.00E+00 0.00E+00 1.47E-09
      9.16E-07 9.38E-07 5.06E-07
AW-N026.82 1.87E+00 0.00E+00 0.00E+00 0.00E+00 7.65E-03 0.00E+00 0.00E+00 0.00E+00
      4.87E-01 2.37E+00 0.00E+00
AW-N027.531 3.18E+01 1.02E-01 0.00E+00 1.03E+02 1.04E+02 6.24E-01 9.80E-02 1.32E-02
      0.00E+00 0.00E+00 9.63E-06
AW-T033.1325 1.98E+02 3.10E+02 0.00E+00 6.49E+02 7.11E+02 1.62E+02 3.32E+02 4.89E-01
      0.00E+00 0.00E+00 6.74E+00
AW-W049 1.86E+02 2.06E+02 0.00E+00 8.53E+00 5.80E+01 4.14E+01 1.89E+02 6.99E-04
      0.00E+00 0.00E+00 9.66E-08
```

Note that the header specified the data as StreamRH (Really CH). The StreamRH title is used by EPAUNI to indicate that 10 radionuclides will be written into a logical record consisting of two physical records.

An example using the RH sheet shows:

D 7 00_PAIR-2008_App B_Disposal_WSLevel_Volumes_Activites.xls

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Site ID	Waste Stream ID	Volume	Am-241	Am-243	Cm-244	Cs-137	Np-237	Pu-238	Pu-239	Pu-240	Pu-241	Pu-242	Pu-[illegible]
2	AE	AE-T009	2,151.31	1.86E+02	5.69E-04	1.03E+00	4.00E+02	3.17E-02	1.29E+02	3.16E+02	6.89E+01	1.21E+02	--	--
3	AW	AW-T031.1322	114.51	2.52E+01	9.51E-04	3.13E-03	1.41E+04	3.33E-03	3.38E+01	3.63E+02	3.47E+01	1.82E+01	9.70E-04	--
4	AW	AW-W026	0.89	1.18E-01	--	--	6.42E-02	1.58E-06	--	2.21E-02	--	--	--	--
5	AW	AW-W028	79.83	--	--	--	8.91E+00	--	--	1.94E+00	1.02E-01	--	--	--
6	AW	AW-W046	40.80	6.82E+00	--	--	1.80E+04	9.59E-04	5.89E+00	4.67E+00	2.96E+00	5.61E+00	6.93E-04	--
7	AW	AW-W047	22.57	--	--	--	8.96E+02	--	--	9.30E-03	--	--	--	--
8	BT	BT-T001	2.67	3.64E+00	1.94E-02	1.52E-01	4.92E+03	2.70E-02	1.75E+02	3.76E-01	4.21E-01	7.63E+00	2.99E-03	--
9	BT	BT-T007	0.89	1.21E+00	6.48E-03	5.06E-02	1.64E+03	9.00E-03	5.82E+01	1.25E-01	1.40E-01	2.54E+00	9.97E-04	--
10	IN	ID-ANLE-S5000-S	88.11	2.01E+01	--	--	1.60E+02	1.54E-04	6.66E+00	2.92E+01	1.54E+01	6.82E+01	8.80E-01	--
11	IN	IN-AE-AGHC-01	95.23	4.77E+01	--	--	4.40E+02	3.63E-04	1.65E+01	7.38E+01	3.87E+01	1.66E+02	1.22E-02	--
12	IN	IN-AW-161	1.78	--	--	--	1.94E-01	--	--	2.31E+00	4.89E-02	--	--	--
13	IN	IN-ID-BTO-030	1.78	5.15E-03	6.88E-04	--	2.52E+01	7.26E-04	4.71E+00	6.18E-03	6.22E-03	--	6.02E-05	--

CH 2033 | RH 2033 | 2033 Normalized | CH 2133 | RH 2133 | CH 2383 | RH 2383 | CH 30

With the corresponding data from the file being:

The RH input file:

```
StreamRH Volume(m3) Am-241 Cm-244 Pu-238 Pu-239 Pu-240 Pu-241 U-234
        Cs-137 Sr-90 U-233
AE-T009 2.15E+03 1.86E+02 1.03E+00 1.29E+02 3.16E+02 6.89E+01 1.21E+02 2.70E-02
       4.00E+02 1.00E+02 3.32E-03
AW-T031.1322 1.15E+02 2.52E+01 3.13E-03 3.38E+01 3.63E+02 3.47E+01 1.82E+01 1.95E+00
       1.41E+04 1.84E+04 1.24E-06
AW-W026 8.90E-01 1.18E-01 0.00E+00 0.00E+00 2.21E-02 0.00E+00 0.00E+00 3.50E-11
       6.42E-02 2.23E-01 1.39E-10
AW-W028 7.98E+01 0.00E+00 0.00E+00 0.00E+00 1.94E+00 1.02E-01 0.00E+00 6.10E-09
       8.91E+00 2.43E+01 0.00E+00
AW-W046 4.08E+01 6.82E+00 0.00E+00 5.89E+00 4.67E+00 2.96E+00 5.61E+00 5.06E-04
       1.80E+04 1.92E+04 1.09E-07
AW-W047 2.26E+01 0.00E+00 0.00E+00 0.00E+00 9.30E-03 0.00E+00 0.00E+00 0.00E+00
       8.96E+02 9.54E+02 0.00E+00
BT-T001 2.67E+00 3.64E+00 1.52E-01 1.75E+02 3.76E-01 4.21E-01 7.63E+00 1.17E+00
       4.92E+03 4.77E+03 8.22E+00
```

The data files were subsequently transferred to the VMS Alpha system using FTP using mib.Sandia.gov as an intermediate transfer location.

Clayton, Daniel James

From: Fox, Brian L
Sent: Friday, July 17, 2009 2:56 PM
To: Clayton, Daniel James
Subject: Inventory Report and Parameter Changes

Attachments: Radionuclide Inventory Screening Analysis Report fot the PABC-2009.doc; Form NP 9.doc

Still no word from Moo and his review, here are the files, the tech and QA DRC are on my desk. I'll be back in town Monday 7/27, and will be reachable by cell. You have signature authority for me in the event that you need to push these documents through before then. Thanks.

Brian

Radionuclide Inventory Screeni...

Form NP 9.doc (131 KB)