DOC.20070326.0003

QA: QA

ANL-WIS-MD-000006 REV 02

March 2007

Radionuclide Screening

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1) ACN-001, DATED 05/18/2007

Prepared for:
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Under Contract Number
DE-AC04-94AL85000

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QA: QA

Radionuclide Screening

ANL-WIS-MD-000006 REV 02

March 2007

Sandia National Laboratories

Scientific Analysis/Calculation Signature Page/Change History

Complete only applicable items.

1. Total Pages: 138

2. Document Title			
Radionuclide Screening			
3. DI (including Rev. No.)			
ANL-WIS-MD-000006 REV 02			
	Printed Name	Signature	Date
4. Originator	Jim Cunnane	Joe Cunnane	3/21/07
5. Checker	Christine Stockman	Christine Stockman	3/21/07
6. QCS/Lead Lab QA Reviewer	Bruce Foster	Bruce Foster	3/21/07
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8. Responsible Manager	Geoff Freeze for/EL Hardin	ElHardin	3/21/07

9. Remarks

The Appendix C files are included on one CD.

Change History

10. Revision No.	11. Description of Change
00	Initial Issue
00 ICN 01	Changed accounting for naval fuel.
00 ICN 02	Replace citations of input transmittals with citations of calculations. Cite revised calculation CAL-WIS-MD-000004 REV 00 ICN 01. Make other changes.
00 ICN 03	Add Attachment II to consider neutron-activation products outside the commercial spent nuclear fuel matrix. Correct a typographical error in the activity of Np-237 in Table I-7. Make other minor changes.

01	Completely revise: (1) drop the inventory projections (the old Attachments I and II) to simplify the organization of the analysis and because of an updated CSNF waste stream is expected after the approval of this analysis; (2) revise the screening method to include (a) an intermediate solubility class, (b) external exposure, and (c) effects of the biosphere. Change bars are not used due to extensive revision. This revision (01) fulfills the commitments regarding radionuclide screening that were made in response to Technical Error Report TER-02-0064 (see AP-15.3Q, Control of Technical Product Errors.
02	This is a complete revision of the document. This revision addresses Condition Reports 5925 and 5600 by updating the radionuclide inventory and screening factor input data. Consistent with this purpose the current revision incorporates the content of previous revisions that has not been updated or superseded. Change tracking is not used because the changes in the document are too extensive.

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FIGURES

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TABLES

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ACRONYMS AND ABBREVIATIONS

ANL-W	Argonne National Laboratory–West
BSC	Bechtel SAIC Company, LLC
BWR	boiling water reactor
CR	Condition Report
CSNF	commercial spent nuclear fuel
DCS	Duke Cogema Stone & Webster
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
FGR-13	Federal Guidance Report No. 13
H	High solubility or sorption class
HLW	high-level radioactive waste
ICRP	International Commission on Radiological Protection
ICRP-72	ICRP Publication 72
INEEL	Idaho National Engineering and Environmental Laboratory
L	Low solubility or sorption class
M	Medium solubility or sorption class
MOX	mixed-oxide
NCRP	National Council on Radiation Protection and Measurements
NCRP-123	NCRP Report No. 123
NRC	U.S. Nuclear Regulatory Commission
NSNFP	National Spent Nuclear Fuel Program
QA	Quality Assurance
OCRWM	Office of Civilian Radioactive Waste Management
PWR	pressurized water reactor
SNF	spent nuclear fuel
TSPA	total system performance assessment
TSPA-LA	total system performance assessment for the license application
TWP	technical work plan
YMP	Yucca Mountain Project

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1. PURPOSE

The waste forms under consideration for disposal in the repository at Yucca Mountain contain scores of radionuclides. It would be impractical and highly inefficient to model all of these radionuclides in a total system performance assessment (TSPA). Thus, the purpose of this radionuclide screening analysis is to remove from further consideration (screen out) radionuclides that are unlikely to significantly contribute to radiation dose to the public from a nuclear waste repository at Yucca Mountain. The remaining nuclides (those screened in) are recommended for consideration in TSPA modeling for license application. This analysis also covers radionuclides that may not be screened in based on dose, but need to be included in TSPA modeling for other reasons. For example, U.S. Environmental Protection Agency (EPA) and U.S. Nuclear Regulatory Commission (NRC) regulations require consideration of the combined activity of ^{226}Ra and ^{228}Ra in groundwater (40 CFR 197.30 [DIRS 173176], 10 CFR 63.331 [DIRS 173176]). In addition, parent radionuclides (e.g., ^{245}Cm and ^{241}Pu) that contribute to the inventory of the screened-in progeny should be included in TSPA modeling.

The radionuclide screening analysis considers two different postclosure time periods: the period up to 10,000 years and the period after 10,000 years up to 1 million years after emplacement. For the purposes of the screening analysis, four modeling cases are considered within the nominal and disruptive scenario classes: (1) nominal, which entails long-term degradation of disposal containers and waste forms, (2) human-intrusion, (3) intrusive igneous, and (4) eruptive igneous. Because the first three cases require groundwater transport, they are called groundwater scenarios below. The screening analysis considers the following waste form types: commercial spent nuclear fuel (CSNF) from light water reactors; U.S. Department of Energy (DOE) spent nuclear fuel (SNF), excluding navy spent fuel, which is not considered in this analysis; and high-level waste (HLW) in the form of borosilicate glass. Within these waste form types, average and outlying (high-burnup, high-initial enrichment, low-age, or otherwise exceptional) waste forms are considered.

The purpose of this revision (Revision 02) is to update the radionuclide inventory and screening factor input data (Condition Reports (CRs) 5925 and 5600). Consistent with this purpose, the current revision incorporates the content of previous revisions that has not been updated or superseded.

In a review of Revision 00 of this radionuclide screening analysis, the NRC found that "processes that affect transport in the biosphere, such as uptake by plants and bioaccumulation are not accounted for," and that "the direct exposure pathway is not accounted for" (Beckman 2001 [DIRS 156122], Section 5.3.2.1). The NRC also found that the solubility and sorption classes were too broadly defined, noting, for example, that Se is in the same solubility and sorptivity groups as neptunium and uranium, yet is "more soluble than neptunium and uranium by several orders of magnitude" (Beckman 2001 [DIRS 156122], Section 5.3.2.1). This revision includes the responses to the specific concerns raised by the NRC and other reviewers that were documented in Revision 01 (BSC 2002 [DIRS 160059]). As does Revision 01 (BSC 2002 [DIRS 160059]), this revision uses screening factors that take into account various environmental transport and exposure pathways in the biosphere. It also retains the three solubility and sorption classes used in Revision 01 (BSC 2002 [DIRS 160059]) to better segregate the radionuclides into appropriate groups for radionuclide screening.

This document was prepared in accordance with *Technical Work Plan for Postclosure Waste Form Testing and Modeling* (BSC 2006 [DIRS 177389]), with the following exceptions:

- The procedure used for this scientific analysis was SCI-PRO-005, *Scientific Analyses and Calculations*.
- Inputs were managed in accordance with SCI-PRO-004, *Managing Technical Product Inputs.*
- Although it was not identified in Section 9 of the technical work plan (TWP) (BSC 2006 [DIRS 177389]), GoldSim V 8.02.500 (see Section 3.1) was used for radionuclide inventory decay calculations.

These deviations from the TWP are justified because SCI-PRO-005 superseded LP-SIII.9Q-BSC and SCI-PRO-004 superseded LP-3.15Q-BSC, which were the corresponding procedures identified in the TWP (BSC 2006 [DIRS 177389], Section 4.2). Current revisions of applicable procedures were used. Also, the use of GoldSim V 8.02.500 is justified because an application was needed to calculate the radionuclide inventories at selected decay times up to one million years after emplacement, and the radionuclide transport module in GoldSim V 8.02.500 is qualified and suitable for performing the needed calculations.

2. QUALITY ASSURANCE

The Quality Assurance (QA) Program applies to the development of this document because this analysis is associated with the characterization of the waste form in support of total system performance assessment for the license application (TSPA-LA) (BSC 2006 [DIRS 177389], Section 8). The TWP contains the process control evaluation used to evaluate the control of electronic management of data (BSC 2006 [DIRS 177389], Appendix A) during analysis and documentation activities. This evaluation determined that the methods identified in the implementing procedures are adequate. Planning and preparation of this report was initiated under the Bechtel SAIC Company (BSC) QA Program. Therefore, forms and associated documentation prepared prior to October 2, 2006, the date this work transitioned to the Lead Laboratory, were completed in accordance with BSC procedures. Forms and associated documentation complete on or after October 2, 2006, were prepared in accordance with Lead Laboratory procedures. Current revisions of applicable procedures were used.

This document does not investigate structures, systems, or components on the Q-list (BSC 2005 [DIRS 175539]).

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3. USE OF SOFTWARE

3.1 SOFTWARE APPROVED FOR QUALITY ASSURANCE WORK

This section identifies and describes the controlled and baselined software (as defined in IM-PRO-003, *Software Management*) used in this analysis and how the requirements of SCI-PRO-005 (Attachment 2, Section 3) were satisfied for the use of this software.

This analysis used GoldSim Version 8.02.500 (GoldSim V. 8.02.500 [DIRS 174650], STN: 10344-8.02-05), run under Windows 2000 on the computer identified as Master06, to do radionuclide inventory decay calculations for selected times up to a million years. These calculations were performed using the radionuclide transport module within the range of use of GoldSim V. 8.02.500. This software was selected because it is qualified baseline software and the radionuclide transport module in GoldSim V. 8.02.500 simulates radioactive decay and is suitable for calculating the radionuclide inventories at the selected decay times. It was obtained from Software Configuration Management and installed on a workstation with Windows NT Server (CPU QWS-151635) in accordance with Section 6.1 of IM-PRO-003. The GoldSim run files are included in Appendix C and are discussed in Section 6.2.3. The use of GoldSim V. 8.02.500, as described above, was consistent with the intended use and within the documented validation range of the software. There are no limitations on the output due to the use of the GoldSim V. 8.02.500 software.

This analysis also used RadNuScreen Version 1.0 (RadNuScreen V1.0 [DIRS 157983], STN: 10732-1.0-00). RadNuScreen V1.0 is qualified baseline software. It was obtained from Software Configuration Management and installed on a Dell Optiplex GX 260 personal computer (Serial No. HZ5N921) in accordance with Section 4.1 of IT-PRO-0011, *Software Management.* RadNuScreen 1.0 is appropriate for this application because it was designed specifically for use in radionuclide screening analyses. The software was used with Excel 2000 9.0.6923 SP-3 and the Windows 2000 (Version 5.0, Build 2195, Service Pack 4) operating system. This software was used within the documented validation range (BSC 2002 [DIRS 158525], Section 2.5). Input and output workbook files are provided in Appendix C. Except for the Screening Summary file, which is an output summary, the first two worksheets in each workbook file provide the inputs, while the remaining worksheets provide the outputs. There are no limitations on the output due to the use of RadNuScreen V1.0.

3.2 COMMERCIAL OFF-THE-SHELF SOFTWARE USED

This section identifies and describes the exempt software (as defined in IM-PRO-003, Section 2) used in this analysis and how the requirements of SCI-PRO-005 (Attachment 2, Section 3) were satisfied for the use of this software.

Microsoft Excel 2003 (11.8033.8036) SP2, a commercially available spreadsheet software package, was used to process radionuclide inventory data and GoldSim and RadNuScreen inputs and results. Excel is appropriate for these uses because the calculations require simple mathematical expressions and operations that are available as standard functions in Excel. The specific standard functions of Excel that were used for calculations are described at the point of use (Appendices A and C). These standard functions of Excel are exempt from the software qualification and documentation requirements of IM-PRO-003 (Section 2.0, third paragraph, 5th dash).

The workbooks and spreadsheets used in this analysis are named using `Courier font` and are listed in Appendix C. The spreadsheets are described at the point of use in Section 6.2 and Appendices A and C.

4. INPUTS

4.1 DIRECT INPUTS

The direct inputs to this analysis fall into three categories: (1) inputs to the calculation of the radionuclide screening factors, (2) initial radionuclide inventories, and (3) inputs used to the calculate the radionuclide inventories in the HLW, DOE SNF, and mixed-oxide (MOX) CSNF at selected times up to one-million years. These inputs are summarized in Table 4-1 and discussed in more detail in the following subsections.

4.1.1 Screening Factors

The approach used to calculate screening factors is described in Appendix A. The direct inputs to these calculations are provided in Tables 4-1 and 4-2.

As described in Appendix A, the generic screening factors were obtained from the National Council on Radiation Protection and Measurements (NCRP) report, *Screening Models for Releases of Radionuclides to Atmosphere, Surface Water and Ground* (NCRP 1996 [DIRS 101882]). This document, also referred to herein as NCRP Report No. 123 (NCRP-123), describes simple models that can be used for assessing doses from radionuclides released to the environment, and includes the screening factors that convert radionuclide concentrations in water and air to related doses. Because the screening models are designed to be conservative (if compliance can be demonstrated using these models, it is generally understood that no further complex calculations are necessary), the selected input parameter values fall within the upper end of their respective ranges.

The NCRP is a nongovernmental, not-for-profit, public service organization and has status as an educational and scientific body. The NCRP was chartered by the U.S. Congress to collect, analyze, develop, and disseminate in the public interest information and recommendations about radiation protection and radiation measurements, quantities, and units—particularly those concerned with radiation protection—and to develop basic concepts about radiation quantities, units and measurements; about the application of these concepts; and about radiation protection. The recommendations promulgated by the NCRP provide the scientific basis for radiation protection efforts throughout the country.

The NCRP publishes, in the form of reports, the consensus of scientific opinion on various radiation protection and measurement problems. The reports carry the full weight of the NCRP. They are reviewed by critical reviewers, usually four to eight Council members selected because of their expertise, and also by the full NCRP membership and collaborating organizations. The information provided by the NCRP is judged as technically adequate for the purposes for which it is used in this analysis. The NCRP reports are determined to be sources of established fact data. The data are considered qualified for the intended use in this analysis. The data are presented, discussed, and used in Appendices A and C.

Table 4-1. Summary of Direct Inputs

Input	Value	Units	Source
YMP-Generated Usage Factors	Table 4-2	Various (see Table 4-2)	See Table 4-2
Surface Water Screening Factors	Appendix III, `Site-Specific Screening Factors.xls` (GW Screening Factors)	Sv per Bq/m^3	NCRP 1996 [DIRS 101882], Table C.1
Air Screening Factors	Appendix III, `Site-Specific Screening Factors.xls` (IG Screening Factors)	Sv per Bq/m^3	NCRP 1996 [DIRS 101882], Table B.1
Ingestion, Inhalation, and External Dose Coefficients	Table A-2	Sv/Bq	EPA 2000 [DIRS 153733]
Ingestion Dose Factors	Table A-2	Sv/Bq	NCRP 1996 [DIRS 101882], Table A.1
Dose Coefficients for ^{244}Pu, ^{252}Cf, ^{248}Cm and ^{250}Cm	Table A-2	Sv/Bq	ICRP 1996 [DIRS 152446]
Mass of Ingested Soil Used in Soil Ingestion Screening Factor	0.365	kg/yr	NCRP 1996 [DIRS 101882], Table 7.1
Contaminated Soil Layer Thickness	1	cm	NCRP 1996 [DIRS 101882], p. 68
Average Tillage Depth	0.175	m	DTN: MO0403SPAAEIBM.002 [DIRS 169392]
Average Surface Soil Density	1,500	kg/m^3	DTN: MO0609SPASRPBM.004 [DIRS 177742]
Radionuclide Half-Lives	Table 4-3	Various (see Table 4-3)	Baum et al. 2002 [DIRS 175238]
Radionuclide Branching Ratios	Table 4-4	Unitless fractions	Firestone et al. 1998 [DIRS 178201]
Initial Radionuclide Inventory in SRS HLW	Table 4-5	Curies	Allison 2004 [DIRS 168734], Tables 5 to 8
Initial Radionuclide Inventory in LaBS Glass Canisters	Table 4-6	Curies	Marra et al. 2005 [DIRS 173215], Table 4
Initial Radionuclide Inventory for Hanford HLW	Table 4-7	Curies	Hamel 2003 [DIRS 164947], Table 2
Initial Radionuclide Inventory for West Valley HLW	Table 4-8	Curies	CRWMS M&O 2000 [DIRS 151947], Table 5-6
Initial Radionuclide Inventory for INEEL HLW	Table 4-9	Curies	CRWMS M&O 2000 [DIRS 151947], Table 5-8
Initial Radionuclide Inventory for ANL-W Ceramic Waste	Table 4-10	Curies	CRWMS M&O 2000 [DIRS 151947], Table 5-9

Table 4-1. Summary of Direct Inputs (Continued)

Input	Value	Units	Source
Initial Radionuclide Inventory for ANL-W Metal Waste	Table 4-11	Curies	CRWMS M&O 2000 [DIRS 151947], Table 5-0
Initial Radionuclide Inventories for MOX spent nuclear fuel	Table 4-12	Curies/Assembly	CRWMS M&O 1998 [DIRS 105977], Attachment file, *50-0g-cr.out*
Year of final MOX discharge	2035	Calendar Year	DCS 2005 [DIRS 173189], Table 3-2
Initial Radionuclide Inventories for DOE SNF	Table 4-13	Curies	DOE 2004 [DIRS 169354], Appendix D

Average and Bounding PWR Assembly Radionuclide Inventories	Appendix C; Excel file: *PWR_000-00C-MGR0-00100-000-00BATTACH_IX.xls* Average: `PWR.ave.2.Curies`
	`PWR.ave.3.Curies`
	Bounding:
	`PWR.bou.2.Curies`
	`PWR.bou.3.Curies`
		Curies/Assembly	BSC 2004 [DIRS 169061], Attachment IX

Average and Bounding BWR Assembly Radionuclide Inventories	Appendix C; Excel file: *BWR_000-00C-MGR0-00200-000-00aATTACH_XIII.xls*
	Average:
	`BWR.ave.2.Curies`
	`BWR.ave.3.Curies`
	Bounding:
	`BWR.max.2.Curies`
	`BWR.max.3.Curies`
		Curies/Assembly	BSC 2003 [DIRS 164364], Attachment XIII

NOTES: ANL-W = Argonne National Laboratory–West; BWR = boiling water reactor; INEEL = Idaho National Engineering and Environmental Laboratory; PWR = pressurized water reactor; SRS = Savannah River Site; YMP = Yucca Mountain Project.

4.1.2 Usage Factors

YMP-generated usage factors are listed in Table 4-2. They were either taken from, or developed based on, the data that constitute input to the biosphere model (BSC 2004 [DIRS 169460]) (see references provided in Table 4-2 for detailed description of how these parameters were developed). The inputs are appropriate for use in the screening analysis because they pertain to the local biosphere (or are generic values that have been found appropriate to represent the local biosphere) and are the most recent available at the time of this analysis.

Table 4-2. YMP-Generated Usage Factors

Description	Value	Reference
Soil exposure time for the groundwater scenarios	3,285 h/yr	Calculated in Appendix A, Section A.1.2, based on: BSC 2005 [DIRS 172827], Tables 7-1 and 7-2 DTN: MO0407SPACRBSM.002 [DIRS 170677]
Soil exposure time for the eruptive igneous scenario	3,545 h/yr	Calculated in Appendix A, Section A.1.2, based on: BSC 2005 [DIRS 172827], Tables 7-1 and 7-2 DTN: MO0407SPACRBSM.002 [DIRS 170677]
Drinking water consumption	730.5 L/yr	BSC 2005 [DIRS 172827], Section 7.1.2 DTN: MO0407SPACRBSM.002 [DIRS 170677]
Consumption of locally raised fish	0.23 kg/yr	BSC 2005 [DIRS 172827], Section 7.1.2 DTN: MO0407SPACRBSM.002 [DIRS 170677]
Combined consumption of locally grown leafy and root vegetables, fruit, and grain	21.42 kg/yr	BSC 2005 [DIRS 172827], Section 7.1.2 DTN: MO0407SPACRBSM.002 [DIRS 170677]
Consumption of locally produced milk	4.66 kg/yr	BSC 2005 [DIRS 172827], Section 7.1.2 DTN: MO0407SPACRBSM.002 [DIRS 170677]
Combined consumption of locally produced beef, poultry, and eggs	8.57 kg/yr	BSC 2005 [DIRS 172827], Section 7.1.2 DTN: MO0407SPACRBSM.002 [DIRS 170677]
Inadvertent ingestion of soil	100 mg/day (0.0365 kg/yr)	BSC 2005 [DIRS 172827], Section 7.1.2 DTN: MO0407SPACRBSM.002 [DIRS 170677]
Mass of inhaled resuspended soil for the groundwater scenarios	1.22×10^{-3} kg/yr	Calculated in Appendix A, Section A.1.2, based on: BSC 2006 [DIRS 177101], Table 7-1 DTN: MO0605SPAINEXI.003 [DIRS 177172] BSC 2005 [DIRS 172827], Tables 7-1, 7-2, and 7-3 DTN: MO0407SPACRBSM.002 [DIRS 170677]
Mass of inhaled resuspended soil for the eruptive igneous scenarios	2.13×10^{-3} kg/yr	Calculated in Appendix A, Section A.1.2, based on: BSC 2006 [DIRS 177101], Table 7-1 DTN: MO0605SPAINEXI.003 [DIRS 177172] BSC 2005 [DIRS 172827], Tables 7-1, 7-2, and 7-3 DTN: MO0407SPACRBSM.002 [DIRS 170677]

4.1.3 Dose Coefficients

The dose coefficients for ingestion were obtained from two primary sources. The dose coefficients used to develop generic screening factors were obtained from NCRP-123 (NCRP 1996 [DIRS 101882], Table A.1) and are based on Federal Guidance Report No. 11 (Eckerman et al. 1988 [DIRS 101069]). The second source of dose coefficients for ingestion was Federal Guidance Report No. 13 (FGR-13) (EPA 2000 [DIRS 153733]), which was also a source of dose coefficients for inhalation and external exposure. Federal Guidance Reports are documents issued by the U.S. Environmental Protection Agency to provide the Federal and State agencies technical information to assist their implementation of radiation protection programs and regulations. These Federal Guidance reports are considered sources of established fact data. The data are presented, discussed, and used in Appendices A and C.

In addition, International Commission on Radiological Protection (ICRP) Publication 72 (ICRP 1996 [DIRS 152446]) was used in this analysis as a source of dose coefficients for intakes of ^{244}Pu, ^{252}Cf, and ^{248}Cm because these radionuclides were not included in the FGR-13 database. The ICRP Publication 72 (ICRP-72) database is one of the most current and comprehensive compilations of dose coefficients for members of the public and workers, and is a source that scientists would use in their standard work practices. This database is consistent with the database of dose coefficients included in FGR-13. Based on the reliability of the input source, charter and purpose of the ICRP, and use of the information by the scientific community, the dose coefficients summarized in ICRP-72 can be considered established fact, consistent with the definition provided in SCI-PRO-004.

4.1.4 Input to Radionuclide Inventory Calculations

Radionuclide half-life data, and branching ratio data for daughter products, are used as input to GoldSim decay calculations. Radionuclide half-life data are also used as input to the RadNuScreen 1.0 calculations to distinguish radionuclides with half-lives greater than or equal to a user-specified cutoff value (BSC 2002 [DIRS 158525]) from those with half-lives less than the specified cutoff value (see Section 6.2.4). The input radionuclide half-life data are given in Table 4-3. This table provides the input half-life data for all of the nuclides for which activities were calculated in the GoldSim decay calculations that feed the screening analysis and is a complete list of the radionuclides that were considered in the screening analysis. These half-lives are taken from *Nuclides and Isotopes* (Baum et al. 2002 [DIRS 175238]), which is appropriate for use in this analysis because it is recognized as a compilation of established fact data.

Radionuclide decay branching ratio data are provided in Table 4-4. These data are used as input to the GoldSim decay calculations. These branching ratio data are taken from *Table of the Isotopes* (Firestone et al. 1998 [DIRS 178201]), which is appropriate for this analysis because it is recognized as a source of established fact data.

Tables 4-5 through 4-13 contain "initial" (indexed to a specified calendar year) radionuclide inventories for the various waste forms. These initial inventories are used as input to the GoldSim decay calculations.

The sources for the input data in Tables 4-5 through 4-13 were selected because they are the best sources available for use in this screening analysis. The following paragraphs describe why the data in Tables 4-5, 4-6, and 4-7, which were obtained from outside sources, are qualified for use in this analysis in accordance with Section 6.2.1(M) of SCI-PRO-005. Qualification of the other external source data in Table 4-1 (i.e., DCS 2005 [DIRS 173189], Table 3-2; DOE 2004 [DIRS 169354], Appendix D) for use in this analysis in accordance with Section 6.2.1(M) of SCI-PRO-005 is also addressed below.

The source of the data in Table 4-5 is a report entitled *Projected Glass Composition and Curie Content of Canisters from the Savannah River Site* (Allison 2004 [DIRS 168734], Tables 5 to 8), which was provided as an attachment to a letter from Jeffrey M. Allison, Manager, Savannah River Operations Office, to John Arthur, III, Deputy Director, Office of Civilian Radioactive Waste Management (OCRWM), in response to a request for "Referenceable Information on High-Level Waste (HLW) Radionuclide Inventories in Support of the Yucca Mountain License Application." This report was prepared for the Westinghouse Savannah River Company. As documented in the source (Allison 2004 [DIRS 168734]), the content was checked and approved by the cognizant Defense Waste Processing Facility engineering managers. This source is cognizant and authoritative. The data are therefore qualified for use in this analysis in accordance with Section 6.2.1(M) of SCI-PRO-005, based on the "reliability of the data source" criterion.

The source of the data in Table 4-7 (Hamel 2003 [DIRS 164947], Table 2) is a paper entitled *Estimates of Immobilized High-Level Waste (HLW) to be Produced in the Hanford Waste Treatment and Immobilization Plant(WTP)*, which was provided as an attachment to a letter from William F. Hamel, Director WTP Engineering & Commissioning Division, to William J. Taylor, Assistant Manager for Waste Treatment and Immobilization Plant. As documented in the attachment, "the radiochemical estimates were derived for the Best Basis Inventory as of December 2002." Because this source is cognizant and authoritative, the data are qualified for use in this analysis in accordance with Section 6.2.1(M) of SCI-PRO-005, based on the "reliability of the data source" criterion.

Data presented in *Vitrified Plutonium Waste Form Data for Yucca Mountain License Application* (Marra et al. 2005 [DIRS 173215]) provide radionuclide inventories for use in postclosure analysis and are considered qualified for use in this document per Section 6.2.1(M) of SCI-PRO-005, qualifications of personnel or organizations generating the data. Prepared by Westinghouse Savannah River Company, which has been studying the disposal of plutonium during the plutonium immobilization program, the report provides the latest vitrified plutonium waste form data for use in TSPA-LA. The lead author, Marra, has a PhD in ceramic and materials engineering. He has written extensively on borosilicate and LaBS glasses for use as immobilizers of high-level waste in his long association with Savannah River Laboratory. He has a national and international reputation and his work appears in peer-reviewed journals. This source (Marra et al. 2005 [DIRS 173215]) reports the best available information on the radionuclide inventory for the LaBS glass and vitrified plutonium waste form.

The data presented in *Mixed Oxide Fuel Interface Document for Office of Civilian Radioactive Waste Management* (DCS 2005 [DIRS 173189]) demonstrate the properties of interest and are considered qualified for use in this document per Section 6.2.1(M) of SCI-PRO-005 because of the reliability of the data source. *Mixed Oxide Fuel Interface Document for Office of Civilian Radioactive Waste Management* (DCS 2005 [DIRS 173189]) was generated to provide the latest MOX spent nuclear fuel data for OCRWM and was prepared by Duke Cogema Stone & Webster (DCS) for use in TSPA-LA. DCS, the limited liability company selected by the DOE to implement the MOX Fuel Fabrication and Reactor Irradiation Services program, comprises three partner companies—Duke Project Services Group; COGEMA, Inc.; and Stone & Webster, Inc.—and various respected subcontractor firms, all world and industry leaders in their respective fields of expertise. In March 1999, the DOE contracted DCS to:

- Design and operate a Mixed Oxide (MOX) Fuel Fabrication Facility
- Design the commercial MOX fuel
- Use MOX fuel in commercial nuclear plants.

Although the inventory, burnup, and discharge schedule information is still in planning stages, it is the best currently available.

The data presented in *Source Term Estimates for DOE Spent Nuclear Fuels* (DOE 2004 [DIRS 169354], Appendix D) demonstrate the properties of interest and are considered qualified for use in this document per Section 6.2.1(M) of SCI-PRO-005 because of the reliability of the data source. As documented in Section 3 of the source (DOE 2004 [DIRS 169354]), the radionuclide inventory estimates were developed by the National Spent Nuclear Fuel Program (NSNFP) to support preclosure and postclosure licensing and design for the Yucca Mountain repository. The work was performed under the NSNFP QA program in accordance with Revision 13 of *Quality Assurance Requirements and Description* (DOE 2003 [DIRS 162903]). The NSNFP QA program has been accepted by representatives of the Office of Quality Assurance within OCRWM. More specifically, NSNFP procedure PSO 3.03, *Engineering Analyses*, requires the validation of models used in NSNFP engineering analyses to ensure that processes, systems, and phenomena are represented to an appropriate level of detail based on the intended use of the results. The last paragraph in Section 3 of the source (DOE 2004 [DIRS 169354]) states that, based on the QA controls implemented, "the estimates presented here are considered to be adequate to support dose calculations for postclosure analyses."

As referenced in the last two rows of Table 4-1, average and bounding radionuclide inventories (indexed to the year 2033 and at 100, 200, 300, 400, 500, 1,000, 2,000, 5,000, 10,000, 20,000, 30,000, 100,000, 300,000, and 1,000,000 years thereafter) for PWR (BSC 2004 [DIRS 169061], Attachment IX) and BWR (BSC 2003 [DIRS 164364], Attachment XIII) spent fuel assemblies are used as direct inputs to the RadNuScreen V1.0 calculations. These sources for the PWR and BWR radionuclide inventory data were selected because they are the best sources available for use in this screening analysis.

Table 4-3. Radionuclide Half-Lives

Nuclide	Half-Life	Nuclide	Half-Life	Nuclide	Half-Life	Nuclide	Half-Life
^{225}Ac	10.0 d	^{58}Co	70.88 d	^{231}Pa	3.28E4 yrs	^{32}Si	1.6E2 yrs
^{227}Ac	21.772 yrs	^{60}Co	5.271 yrs	^{232}Pa	1.31 d	^{145}Sm	340 d
^{228}Ac	6.15 h	^{134}Cs	2.065 yrs	^{233}Pa	26.967 d	^{146}Sm	1.03E8 yrs
^{108}Ag	2.39 m	^{135}Cs	2.3E6 yrs	^{234}Pa	6.69 h	^{147}Sm	1.06E11 yrs
^{108m}Ag	420 yrs	^{137}Cs	30.07 yrs	^{234m}Pa	1.17 m	^{148}Sm	7E15 yrs
^{109m}Ag	39.8 s	^{150}Eu	36 yrs	^{205}Pb	1.5E7 yrs	^{151}Sm	90 yrs
^{110}Ag	24.6 s	^{152}Eu	13.54 yrs	^{209}Pb	3.25 h	^{113}Sn	115.1 d
^{110m}Ag	249.8 d	^{154}Eu	8.593 yrs	^{210}Pb	22.3 yrs	^{119m}Sn	293 d
^{239}Am	11.9h	^{155}Eu	4.75 yrs	^{211}Pb	36.1 m	^{121}Sn	1.128 d
^{241}Am	432.7 yrs	^{55}Fe	2.73 yrs	^{212}Pb	10.64 h	^{121m}Sn	44 yrs
^{242}Am	16.02 h	^{221}Fr	4.8 m	^{214}Pb	27 m	^{123}Sn	129.2 d
^{242m}Am	141 yrs	^{223}Fr	21.8 m	^{107}Pd	6.5E6 yrs	^{126}Sn	2.3E5 yrs
^{243}Am	7.37E3 yrs	^{150}Gd	1.8E6 yrs	^{145}Pm	17.7 yrs	^{90}Sr	28.78 yrs
^{245}Am	2.05h	^{152}Gd	1.1E14 yrs	^{146}Pm	5.53 yrs	^{182}Ta	114.43 d
^{246}Am	39 m	^{153}Gd	241.6 d	^{147}Pm	2.6234 yrs	^{160}Tb	72.3 d
^{39}Ar	269 yrs	^{3}H	12.32 yrs	^{210}Po	138.38 d	^{98}Tc	4.2E6 yrs
^{42}Ar	33 yrs	^{174}Hf	2.0E15 yrs	^{211}Po	0.516 s	^{99}Tc	2.13E5 yrs
^{217}At	32 ms	^{182}Hf	9E6 yrs	^{212}Po	0.298 µs	^{123}Te	6E14 yrs
^{218}At	1.5 s	^{166m}Ho	1.20E3 yrs	^{213}Po	3.8 µs	^{123m}Te	119.7 d
^{219}At	56 s	^{129}I	1.57E7 yrs	^{214}Po	163.7 µs	^{125m}Te	58 d
^{132}Ba	> 1.0E21 yrs	^{113m}In	1.658 h	^{215}Po	1.781 ms	^{127}Te	9.4 h
^{133}Ba	10.53 yrs	^{115}In	4.4E14 yrs	^{216}Po	0.145 s	^{127m}Te	109 d
^{137m}Ba	2.552 m	^{192}Ir	73.83 d	^{218}Po	3.10 m	^{128}Te	7.7E24 yrs
^{10}Be	1.5E6 yrs	^{192m}Ir	241 yrs	^{144}Pr	17.28 m	^{130}Te	2. 5E21 yrs
^{210}Bi	5.01 d	^{194}Ir	19.3 h	^{144m}Pr	7.2 m	^{227}Th	18.68 d
^{211}Bi	2.14 m	^{40}K	1.27E9 yrs	^{193}Pt	50 yrs	^{228}Th	1.912 yrs
^{212}Bi	1.009 h	^{42}K	12.360 h	^{236}Pu	2.87 yrs	^{229}Th	7.3E3 yrs
^{213}Bi	45.6 m	^{81}Kr	2.3E5 yrs	^{238}Pu	87.7 yrs	^{230}Th	7.54E4 yrs
^{214}Bi	19.9 m	^{85}Kr	10.76 yrs	^{239}Pu	2.410E4 yrs	^{231}Th	1.063 d
^{215}Bi	7.6 m	^{138}La	1.05E11 yrs	^{240}Pu	6.56E3 yrs	^{232}Th	1.40E10 yrs
^{243}Bk	4.5h	^{176}Lu	3.75E10 yrs	^{241}Pu	14.4 yrs	^{234}Th	24.10 d
^{249}Bk	330 d	^{54}Mn	312.1 d	^{242}Pu	3.75E5 yrs	^{204}Tl	3.78 yrs
^{250}Bk	3.213 h	^{93}Mo	3.5E3 yrs	^{243}Pu	4.956 h	^{206}Tl	4.20 m
^{14}C	5715 yrs	^{100}Mo	8E18 yrs	^{244}Pu	8.0E7 yrs	^{207}Tl	4.77 m
^{41}Ca	1.03E5 yrs	^{22}Na	2.604 yrs	^{246}Pu	10.85 d	^{208}Tl	3.053 m
^{45}Ca	162.7 d	^{91}Nb	7E2 yrs	^{223}Ra	11.435 d	^{209}Tl	2.16 m
^{109}Cd	461 d	^{92}Nb	3.5E7 yrs	^{224}Ra	3.66 d	^{210}Tl	1.30 m
^{113}Cd	7.7E15 yrs	^{93m}Nb	16.1 yrs	^{225}Ra	14.9 d	^{171}Tm	1.92 yrs
^{113m}Cd	14.1 yrs	^{94}Nb	2.0E4 yrs	^{226}Ra	1599 yrs	^{232}U	69.8 yrs
^{139}Ce	137.6 d	^{95}Nb	34.99 d	^{228}Ra	5.76 yrs	^{233}U	1.593E5 yrs

Table 4-3. Radionuclide Half-Lives (Continued)

Nuclide	Half-Life	Nuclide	Half-Life	Nuclide	Half-Life	Nuclide	Half-Life
^{144}Ce	284.6 d	^{95m}Nb	3.61 d	^{87}Rb	4.88E10 yrs	^{234}U	2.46E5 yrs
^{249}Cf	351 yrs	^{144}Nd	2.38E15 yrs	^{187}Re	4.12E10 yrs	^{235}U	7.04E8 yrs
^{250}Cf	13.1 yrs	^{59}Ni	7.6E4 yrs	^{102}Rh	207 d	^{236}U	2.342E7 yrs
^{251}Cf	9.0E2 yrs	^{63}Ni	101 yrs	^{106}Rh	29.9 s	^{237}U	6.75 d
^{252}Cf	2.646 yrs	^{235}Np	1.085 yrs	^{217}Rn	0.6ms	^{238}U	4.47E9 yrs
^{36}Cl	3.01E5 yrs	^{236m}Np	1.55E5 yrs	^{218}Rn	35 ms	^{240}U	14.1 h
^{242}Cm	162.8 d	^{237}Np	2.14E6 yrs	^{219}Rn	3.96 s	^{50}V	1.4E17 yrs
^{243}Cm	29.1 yrs	^{238}Np	2.117 d	^{220}Rn	55.6 s	^{90}Y	2.67 d
^{244}Cm	18.1 yrs	^{239}Np	2.355 d	^{222}Rn	3.8235 d	^{91}Y	58.5 d
^{245}Cm	8.5E3 yrs	^{240}Np	1.032 h	^{106}Ru	1.020 yrs	^{64}Zn	1.1E19 yrs
^{246}Cm	4.76E3 yrs	^{240m}Np	7.22 m	^{125}Sb	2.758 yrs	^{65}Zn	243.8 d
^{247}Cm	1.56E7 yrs	^{186}Os	2.0E15 yrs	^{126}Sb	12.4 d	^{93}Zr	1.5E6 yrs
^{248}Cm	3.48E5 yrs	^{194}Os	6.0 yrs	^{126m}Sb	11 s	^{95}Zr	64.02 d
^{250}Cm	8.3E3 yrs	^{32}P	14.28 d	^{79}Se	2.9E5 yrs	^{96}Zr	2E19 yrs

NOTE: Source of half-life data is Baum et al. 2002 [DIRS 175238].

The half lives are given in: years (yrs), hours (h), minutes (m), seconds (s), milliseconds (ms), and microseconds (μs).

Table 4-4. Radionuclide Branching Ratio Data

Radionuclide	Daughter 1	Daughter 1 Branching Ratio	Daughter 2	Daughter 2 Branching Ratio	Daughter 3	Daughter 3 Branching Ratio
^{225}Ac	^{221}Fr	1				
^{227}Ac	^{227}Th	0.9862	^{223}Fr	0.0138		
^{228}Ac	^{228}Th	1				
^{108}Ag	^{108}Cd	0.9715	^{108}Pd	0.0285		
^{108m}Ag	^{108}Ag	0.087	^{108}Pd	0.913		
^{109m}Ag	^{109}Ag	1				
^{110}Ag	^{110}Cd	0.997	^{110}Pd	0.003		
^{110m}Ag	^{110}Ag	0.0136	^{110}Cd	0.9864		
^{239}Am	^{239}Pu	0.9999	^{235}Np	0.0001		
^{241}Am	^{237}Np	1				
^{242}Am	^{242}Cm	0.827	^{242}Pu	0.173		
^{242m}Am	^{242}Am	0.99541	^{238}Np	0.00459		
^{243}Am	^{239}Np	1				
^{245}Am	^{245}Cm	1				
^{246}Am	^{246}Cm	1				
^{39}Ar	^{39}K	1				
^{42}Ar	^{42}K	1				
^{217}At	^{213}Bi	0.99988	^{217}Rn	0.00012		

Table 4-4. Radionuclide Branching Ratio Data (Continued)

Radionuclide	Daughter 1	Daughter 1 Branching Ratio	Daughter 2	Daughter 2 Branching Ratio	Daughter 3	Daughter 3 Branching Ratio
^{218}At	^{214}Bi	0.999	^{218}Rn	0.001		
^{219}At	^{215}Bi	0.97	^{219}Rn	0.03		
^{132}Ba						
^{133}Ba	^{133}Cs	1				
^{137m}Ba	^{137}Ba	1				
^{10}Be	^{10}B	1				
^{210}Bi	^{210}Po	1				
^{211}Bi	^{207}Tl	0.99724	^{211}Po	0.00276		
^{212}Bi	^{208}Tl	0.3594	^{212}Po	0.6406		
^{213}Bi	^{209}Tl	0.0209	^{213}Po	0.9791		
^{214}Bi	^{210}Tl	0.00021	^{214}Po	0.99979		
^{215}Bi	^{215}Po	1				
^{243}Bk	^{243}Cm	0.9985	^{239}Am	0.0015		
^{249}Bk	^{249}Cf	0.9999855	^{245}Am	0.0000145		
^{250}Bk	^{250}Cf	1				
^{14}C	^{14}N	1				
^{41}Ca	^{41}K	1				
^{45}Ca	^{45}Sc	1				
^{109}Cd	^{109}Ag	1				
^{113}Cd	^{113}In	1				
^{113m}Cd	^{113}Cd	0.0014	^{113}In	0.9986		
^{139}Ce	^{139}La	1				
^{144}Ce	^{144}Pr	1				
^{249}Cf	^{245}Cm	1				
^{250}Cf	^{246}Cm	0.99923				
^{251}Cf	^{247}Cm	1				
^{252}Cf	^{248}Cm	0.96908	SF	0.03092		
^{36}Cl	^{36}Ar	0.981	^{36}S	0.019		
^{242}Cm	^{238}Pu	1				
^{243}Cm	^{239}Pu	0.9971	^{243}Am	0.0029		
^{244}Cm	^{240}Pu	1				
^{245}Cm	^{241}Pu	1				
^{246}Cm	^{242}Pu	0.999737				
^{247}Cm	^{243}Pu	1				
^{248}Cm	^{244}Pu	0.9174	SF	0.0839		
^{250}Cm	SF	0.86	^{246}Pu	0.08	^{250}Bk	0.06
^{58}Co	^{58}Fe	1				

Table 4-4. Radionuclide Branching Ratio Data (Continued)

Radionuclide	Daughter 1	Daughter 1 Branching Ratio	Daughter 2	Daughter 2 Branching Ratio	Daughter 3	Daughter 3 Branching Ratio
^{60}Co	^{60}Ni	1				
^{134}Cs	^{134}Ba	0.999997	^{134}Xe	0.000003		
^{135}Cs	^{135}Ba	1				
^{137}Cs	^{137m}Ba	1				
^{150}Eu	^{150}Sm	1				
^{152}Eu	^{152}Gd	0.2792	^{152}Sm	0.7208		
^{154}Eu	^{154}Gd	0.9998	^{154}Sm	0.0002		
^{155}Eu	^{155}Gd	1				
^{55}Fe	^{55}Mn	1				
^{221}Fr	^{217}At	1				
^{223}Fr	^{223}Ra	0.99994	^{219}At	0.00006		
^{150}Gd	^{146}Sm	1				
^{152}Gd	^{148}Sm	1				
^{153}Gd	^{153}Eu	1				
^{3}H	^{3}He	1				
^{174}Hf	^{170}Yb	1				
^{182}Hf	^{182}Ta	1				
^{166m}Ho	^{166}Er	1				
^{129}I	^{129}Xe	1				
^{113m}In	^{113}In	1				
^{115}In	^{115}Sn	1				
^{192}Ir	^{192}Pt	0.9524	^{192}Os	0.0476		
^{192m}Ir	^{192}Ir	1				
^{194}Ir	^{194}Pt	1				
^{40}K	^{40}Ca	0.8928	^{40}Ar	0.1072		
^{42}K	^{42}Ca	1				
^{81}Kr	^{81}Br	1				
^{85}Kr	^{85}Rb	1				
^{138}La	^{138}Ce	0.336	^{138}Ba	0.664		
^{176}Lu	^{176}Hf	1				
^{54}Mn	^{54}Cr	1				
^{93}Mo	^{93}Nb	1				
^{100}Mo	^{100}Ru	1				
^{22}Na	^{22}Ne	1				
^{91}Nb	^{91}Zr	1				
^{92}Nb	^{92}Zr	1				
^{93m}Nb	^{93}Nb	1				

Table 4-4. Radionuclide Branching Ratio Data (Continued)

Radionuclide	Daughter 1	Daughter 1 Branching Ratio	Daughter 2	Daughter 2 Branching Ratio	Daughter 3	Daughter 3 Branching Ratio
^{94}Nb	^{94}Mo	1				
^{95}Nb	^{95}Mo	1				
^{95m}Nb	^{95}Nb	0.944	^{95}Mo	0.056		
^{144}Nd	^{140}Ce	1				
^{59}Ni	^{59}Co	1				
^{63}Ni	^{63}Cu	1				
^{235}Np	^{235}U	0.999974	^{231}Pa	0.000026		
^{236m}Np	^{236}U	0.873	^{236}Pu	0.125	^{232}Pa	0.0016
^{237}Np	^{233}Pa	1				
^{238}Np	^{238}Pu	1				
^{239}Np	^{239}Pu	1				
^{240}Np	^{240}Pu	1				
^{240m}Np	^{240}Pu	0.9989	^{240}Np	0.0011		
^{186}Os	^{182}W	1				
^{194}Os	^{194}Ir	1				
^{32}P	^{32}S	1				
^{231}Pa	^{227}Ac	1				
^{232}Pa	^{232}U	0.99997	^{232}Th	0.00003		
^{233}Pa	^{233}U	1				
^{234}Pa	^{234}U	1				
^{234m}Pa	^{234}U	0.9984	^{234}Pa	0.0016		
^{205}Pb	^{205}Tl	1				
^{209}Pb	^{209}Bi	1				
^{210}Pb	^{210}Bi	1				
^{211}Pb	^{211}Bi	1				
^{212}Pb	^{212}Bi	1				
^{214}Pb	^{214}Bi	1				
^{107}Pd	^{107}Ag	1				
^{145}Pm	^{145}Nd	1				
^{146}Pm	^{146}Sm	0.34	^{146}Nd	0.66		
^{147}Pm	^{147}Sm	1				
^{210}Po	^{206}Pb	1				
^{211}Po	^{207}Pb	1				
^{212}Po	^{208}Pb	1				
^{213}Po	^{209}Pb	1				
^{214}Po	^{210}Pb	1				
^{215}Po	^{211}Pb	0.9999977				

Table 4-4. Radionuclide Branching Ratio Data (Continued)

Radionuclide	Daughter 1	Daughter 1 Branching Ratio	Daughter 2	Daughter 2 Branching Ratio	Daughter 3	Daughter 3 Branching Ratio
^{216}Po	^{212}Pb	1				
^{218}Po	^{214}Pb	0.9998	^{218}At	0.0002		
^{144}Pr	^{144}Nd	1				
^{144m}Pr	^{144}Pr	0.9993	^{144}Nd	0.0007		
^{193}Pt	^{193}Ir	1				
^{236}Pu	^{232}U	1				
^{238}Pu	^{234}U	1				
^{239}Pu	^{235}U	1				
^{240}Pu	^{236}U	1				
^{241}Pu	^{241}Am	0.99998	^{237}U	0.0000245		
^{242}Pu	^{238}U	1				
^{243}Pu	^{243}Am	1				
^{244}Pu	^{240}U	0.99879	SF	0.00121		
^{246}Pu	^{246}Am	1				
^{223}Ra	^{219}Rn	1				
^{224}Ra	^{220}Rn	1				
^{225}Ra	^{225}Ac	1				
^{226}Ra	^{222}Rn	1				
^{228}Ra	^{228}Ac	1				
^{87}Rb	^{87}Sr	1				
^{187}Re	^{187}Os	1				
^{102}Rh	^{102}Pd	0.2	^{102}Ru	0.8		
^{106}Rh	^{106}Pd	1				
^{217}Rn	^{213}Po	1				
^{218}Rn	^{214}Po	1				
^{219}Rn	^{215}Po	1				
^{220}Rn	^{216}Po	1				
^{222}Rn	^{218}Po	1				
^{106}Ru	^{106}Rh	1				
^{125}Sb	^{125}Te	1				
^{126}Sb	^{126}Te	1				
^{126m}Sb	^{126}Sb	0.14	^{126}Te	0.86		
^{79}Se	^{79}Br	1				
^{32}Si	^{32}P	1				
^{145}Sm	^{145}Pm	1				
^{146}Sm	^{142}Nd	1				
^{147}Sm	^{143}Nd	1				

Table 4-4. Radionuclide Branching Ratio Data (Continued)

Radionuclide	Daughter 1	Daughter 1 Branching Ratio	Daughter 2	Daughter 2 Branching Ratio	Daughter 3	Daughter 3 Branching Ratio
^{148}Sm	^{144}Nd	1				
^{151}Sm	^{151}Eu	1				
^{113}Sn	^{113}In	1				
^{119m}Sn	^{119}Sn	1				
^{121}Sn	^{121}Sb	1				
^{121m}Sn	^{121}Sn	0.776	^{121}Sb	0.224		
^{123}Sn	^{123}Sb	1				
^{126}Sn	^{126m}Sb	1				
^{90}Sr	^{90}Y	1				
^{182}Ta	^{182}W	1				
^{160}Tb	^{160}Dy	1				
^{98}Tc	^{98}Ru	1				
^{99}Tc	^{99}Ru	1				
^{123}Te	^{123}Sb	1				
^{123m}Te	^{123}Te	1				
^{125m}Te	^{125}Te	1				
^{127}Te	^{127}I	1				
^{127m}Te	^{127}Te	0.976	^{127}I	0.024		
^{128}Te	^{128}Xe	1				
^{130}Te	^{130}Xe	1				
^{227}Th	^{223}Ra	1				
^{228}Th	^{224}Ra	1				
^{229}Th	^{225}Ra	1				
^{230}Th	^{226}Ra	1				
^{231}Th	^{231}Pa	1				
^{232}Th	^{228}Ra	1				
^{234}Th	^{234}Pa	1				
^{204}Tl	^{204}Pb	0.971	^{204}Hg	0.029		
^{206}Tl	^{206}Pb	1				
^{207}Tl	^{207}Pb	1				
^{208}Tl	^{208}Pb	1				
^{209}Tl	^{209}Pb	1				
^{210}Tl	^{210}Pb	1				
^{171}Tm	^{171}Yb	1				
^{232}U	^{228}Th	1				
^{233}U	^{229}Th	1				
^{234}U	^{230}Th	1				

Table 4-4. Radionuclide Branching Ratio Data (Continued)

Radionuclide	Daughter 1	Daughter 1 Branching Ratio	Daughter 2	Daughter 2 Branching Ratio	Daughter 3	Daughter 3 Branching Ratio
^{235}U	^{231}Th	1				
^{236}U	^{232}Th	1				
^{237}U	^{237}Np	1				
^{238}U	^{234}Th	1				
^{240}U	^{240}Np	1				
^{50}V	^{50}Cr	0.17	^{50}Ti	0.83		
^{90}Y	^{90}Zr	1				
^{91}Y	^{91}Zr	1				
^{64}Zn	No branching ratio data – analyzed as a stable isotope					
^{65}Zn	^{65}Cu	1				
^{93}Zr	^{93m}Nb	0.95	^{93}Nb	0.05		
^{95}Zr	^{95}Nb	1				
^{96}Zr	^{96}Mo	1				

Source: Firestone et al. 1998 [DIRS 178201].

NOTE: SF denotes decay by spontaneous fission.

Table 4-5. Initial Radionuclide Inventories (Indexed to Year 2030) for the Savannah River Site HLW

Nuclide	Batch 1A, 2030 Curies/Canister (495 Canisters)	Batch 1B, 2030 Curies/Canister (726 Canisters)	Batches 2&3, 2030 Curies/Canister (705 Canisters)	Batches 4 to 10, 2030 Curies/Canister (3,134 Canisters)
^{225}Ac	1.3282×10^{-4}	1.7080×10^{-4}	1.8717×10^{-5}	8.2840×10^{-5}
^{227}Ac	6.4196×10^{-8}	4.6920×10^{-8}	8.5283×10^{-8}	6.8448×10^{-8}
^{228}Ac	6.9192×10^{-13}	1.1175×10^{-4}	2.4903×10^{-5}	9.0666×10^{-4}
^{241}Am	4.1273	4.5983	2.2002×10^{1}	7.1435×10^{1}
^{242}Am			6.6693×10^{-2}	5.1878×10^{-2}
^{242m}Am			6.7011×10^{-2}	5.2125×10^{-2}
^{243}Am	2.3323×10^{-2}	3.5501×10^{-2}	3.6707×10^{-1}	4.2980×10^{-9}
^{217}At	1.3282×10^{-4}	1.7080×10^{-4}	1.8717×10^{-5}	8.2840×10^{-5}
^{137m}Ba	1.6339×10^{1}	4.2629×10^{1}	9.6603×10^{1}	1.6101×10^{4}
^{210}Bi	1.1521×10^{-8}	4.4662×10^{-8}	8.1711×10^{-9}	7.7611×10^{-9}
^{211}Bi	6.3833×10^{-8}	4.6596×10^{-8}	8.4631×10^{-8}	6.7920×10^{-8}
^{212}Bi	6.2238×10^{-13}	1.1011×10^{-4}	2.4404×10^{-5}	1.0197×10^{-3}
^{213}Bi	1.3282×10^{-4}	1.7080×10^{-4}	1.8717×10^{-5}	8.2839×10^{-5}
^{214}Bi	4.1170×10^{-8}	1.4127×10^{-7}	3.5758×10^{-8}	3.8892×10^{-8}
^{113}Cd		2.5600×10^{-11}	1.1300×10^{1}	
^{144}Ce				1.8341×10^{-11}
^{249}Cf			3.3937×10^{-3}	
^{251}Cf			8.0311×10^{-3}	
^{242}Cm			5.5318×10^{-2}	4.3029×10^{-2}
^{243}Cm			2.1456×10^{-1}	
^{244}Cm	1.9216	1.4347	1.0841×10^{1}	2.7755×10^{1}
^{245}Cm	3.4999×10^{-4}		2.6618×10^{-3}	6.1466×10^{-3}
^{246}Cm	3.3726×10^{-3}	2.8278×10^{-2}	1.7033×10^{-2}	4.3231×10^{-2}
^{247}Cm			6.8174×10^{-7}	1.7100×10^{-6}
^{60}Co		7.4081×10^{-3}	1.0787×10^{-1}	3.4211
^{134}Cs				2.7687×10^{-4}

Table 4-5. Initial Radionuclide Inventories (Indexed to Year 2030) for the Savannah River Site HLW (Continued)

Nuclide	Batch 1A, 2030 Curies/Canister (495 Canisters)	Batch 1B, 2030 Curies/Canister (726 Canisters)	Batches 2&3, 2030 Curies/Canister (705 Canisters)	Batches 4 to 10, 2030 Curies/Canister (3,134 Canisters)
^{135}Cs	3.2400×10^{-4}	5.1600×10^{-4}	7.4399×10^{-4}	1.2400×10^{-1}
^{137}Cs	1.7272×10^{1}	4.5063×10^{1}	1.0212×10^{2}	1.7020×10^{4}
^{154}Eu		5.1497×10^{-1}	6.5684×10^{-1}	3.5987×10^{1}
^{155}Eu		1.0664×10^{-2}		
^{221}Fr	1.3282×10^{-4}	1.7080×10^{-4}	1.8717×10^{-5}	8.2840×10^{-5}
^{223}Fr	8.8591×10^{-10}	6.4750×10^{-10}	1.1769×10^{-9}	9.4458×10^{-10}
^{129}I		7.2900×10^{-5}	5.2200×10^{-6}	
^{93m}Nb	3.1423×10^{-2}	1.7693×10^{-1}	6.7727×10^{-2}	
^{59}Ni	1.1696×10^{-2}	4.4488×10^{-2}	2.1595×10^{-1}	
^{63}Ni	1.7865	2.0289	1.1694×10^{1}	
^{237}Np	8.6761×10^{-3}	1.0542×10^{-2}	9.3651×10^{-3}	2.1704×10^{-2}
^{238}Np			3.1898×10^{-4}	2.4813×10^{-4}
^{239}Np	2.3323×10^{-2}	3.5501×10^{-2}	3.6707×10^{-1}	4.2965×10^{-9}
^{231}Pa	1.6097×10^{-7}	1.3325×10^{-7}	2.5896×10^{-7}	2.0920×10^{-7}
^{233}Pa	8.6759×10^{-3}	1.0542×10^{-2}	9.3643×10^{-3}	2.1702×10^{-2}
^{234}Pa	1.0848×10^{-5}	8.5280×10^{-6}	2.7840×10^{-5}	2.6400×10^{-5}
^{234m}Pa	6.7800×10^{-3}	5.3300×10^{-3}	1.7400×10^{-2}	1.6500×10^{-2}
^{209}Pb	1.3282×10^{-4}	1.7080×10^{-4}	1.8717×10^{-5}	8.2837×10^{-5}
^{210}Pb	1.1539×10^{-8}	4.4721×10^{-8}	8.1881×10^{-9}	7.7802×10^{-9}
^{211}Pb	6.3833×10^{-8}	4.6596×10^{-8}	8.4631×10^{-8}	6.7920×10^{-8}
^{212}Pb	6.2238×10^{-13}	1.1011×10^{-4}	2.4404×10^{-5}	1.0197×10^{-3}
^{214}Pb	4.1170×10^{-8}	1.4127×10^{-7}	3.5758×10^{-8}	3.8892×10^{-8}
^{107}Pd		1.2800×10^{-3}	2.8700×10^{-4}	
^{147}Pm	6.7127×10^{-4}		7.0991×10^{-2}	1.0272
^{210}Po	1.1031×10^{-8}	4.3050×10^{-8}	7.7192×10^{-9}	7.2573×10^{-9}
^{211}Po	1.7426×10^{-10}	1.2721×10^{-10}	2.3104×10^{-10}	1.8542×10^{-10}
^{212}Po	3.9876×10^{-13}	7.0551×10^{-5}	1.5636×10^{-5}	6.5334×10^{-4}

Table 4-5. Initial Radionuclide Inventories (Indexed to Year 2030) for the Savannah River Site HLW (Continued)

Nuclide	Batch 1A, 2030 Curies/Canister (495 Canisters)	Batch 1B, 2030 Curies/Canister (726 Canisters)	Batches 2&3, 2030 Curies/Canister (705 Canisters)	Batches 4 to 10, 2030 Curies/Canister (3,134 Canisters)
^{213}Po	1.2996×10^{-4}	1.6711×10^{-4}	1.8314×10^{-5}	8.1050×10^{-5}
^{214}Po	4.1161×10^{-8}	1.4124×10^{-7}	3.5751×10^{-8}	3.8884×10^{-8}
^{215}Po	6.3833×10^{-8}	4.6596×10^{-8}	8.4632×10^{-8}	6.7920×10^{-8}
^{216}Po	6.2243×10^{-13}	1.1012×10^{-4}	2.4405×10^{-5}	1.0197×10^{-3}
^{218}Po	4.1178×10^{-8}	1.4130×10^{-7}	3.5766×10^{-8}	3.8900×10^{-8}
^{144}Pr				1.8341×10^{-11}
^{144m}Pr				2.6227×10^{-13}
^{238}Pu	2.7255×10^{1}	4.6471×10^{1}	2.1417×10^{1}	5.4948×10^{2}
^{239}Pu	4.1858	3.3772	5.2864	1.1291×10^{1}
^{240}Pu	1.1210	1.1747	1.6894	5.3319
^{241}Pu	3.6146	6.8403	5.2572	9.6093×10^{1}
^{242}Pu	9.8616×10^{-4}	1.9614×10^{-3}	3.1613×10^{-3}	1.1502×10^{-2}
^{243}Pu			6.8174×10^{-7}	1.7100×10^{-6}
^{223}Ra	6.3833×10^{-8}	4.6596×10^{-8}	8.4632×10^{-8}	6.7920×10^{-8}
^{224}Ra	6.2243×10^{-13}	1.1012×10^{-4}	2.4405×10^{-5}	1.0197×10^{-3}
^{225}Ra	1.3288×10^{-4}	1.7091×10^{-4}	1.8745×10^{-5}	8.2962×10^{-5}
^{226}Ra	4.1214×10^{-8}	1.4139×10^{-7}	3.5806×10^{-8}	3.8956×10^{-8}
^{228}Ra	6.9194×10^{-13}	1.1175×10^{-4}	2.4904×10^{-5}	9.0666×10^{-4}
^{106}Rh				1.1359×10^{-8}
^{219}Rn	6.3833×10^{-8}	4.6596×10^{-8}	8.4632×10^{-8}	6.7920×10^{-8}
^{220}Rn	6.2243×10^{-13}	1.1012×10^{-4}	2.4405×10^{-5}	1.0197×10^{-3}
^{222}Rn	4.1178×10^{-8}	1.4130×10^{-7}	3.5766×10^{-8}	3.8900×10^{-8}
^{106}Ru				1.1359×10^{-8}
^{126}Sb	5.6126×10^{-4}	3.2333×10^{-3}	4.3252×10^{-3}	
^{126m}Sb	4.0090×10^{-3}	2.3095×10^{-2}	3.0894×10^{-2}	
^{79}Se	6.7775×10^{-3}	5.8681×10^{-2}	4.3088×10^{-2}	
^{147}Sm	1.8313×10^{-10}		2.2158×10^{-9}	3.0168×10^{-8}

Table 4-5. Initial Radionuclide Inventories (Indexed to Year 2030) for the Savannah River Site HLW (Continued)

Nuclide	Batch 1A, 2030 Curies/Canister (495 Canisters)	Batch 1B, 2030 Curies/Canister (726 Canisters)	Batches 2&3, 2030 Curies/Canister (705 Canisters)	Batches 4 to 10, 2030 Curies/Canister (3,134 Canisters)
^{151}Sm		2.9702×10^{1}	9.9075×10^{1}	
^{126}Sn	4.0090×10^{-3}	2.3095×10^{-2}	3.0894×10^{-2}	
^{90}Sr	1.6010×10^{2}	1.2159×10^{3}	1.6155×10^{3}	1.4104×10^{4}
^{99}Tc	1.3598×10^{-1}	1.2399×10^{-1}	8.6792×10^{-2}	7.8193
^{227}Th	6.3086×10^{-8}	4.6073×10^{-8}	8.3704×10^{-8}	6.7178×10^{-8}
^{228}Th	6.2278×10^{-13}	1.1012×10^{-4}	2.4407×10^{-5}	1.0198×10^{-3}
^{229}Th	1.3297×10^{-4}	1.7108×10^{-4}	1.8785×10^{-5}	8.3143×10^{-5}
^{230}Th	5.5935×10^{-6}	1.4574×10^{-5}	6.2142×10^{-6}	8.6012×10^{-6}
^{231}Th	2.1615×10^{-4}	2.1310×10^{-4}	4.5314×10^{-4}	3.6930×10^{-4}
^{232}Th	9.0127×10^{-13}	1.1500×10^{-4}	2.5900×10^{-5}	9.4400×10^{-4}
^{234}Th	6.7800×10^{-3}	5.3300×10^{-3}	1.7400×10^{-2}	1.6500×10^{-2}
^{207}Tl	6.3658×10^{-8}	4.6469×10^{-8}	8.4400×10^{-8}	6.7734×10^{-8}
^{208}Tl	2.2362×10^{-13}	3.9564×10^{-5}	8.7685×10^{-6}	3.6639×10^{-4}
^{209}Tl	2.8690×10^{-6}	3.6893×10^{-6}	4.0429×10^{-7}	1.7893×10^{-6}
^{232}U				1.2826×10^{-4}
^{233}U	1.5999×10^{-2}	3.0197×10^{-2}	7.3702×10^{-3}	3.2899×10^{-2}
^{234}U	1.9137×10^{-2}	2.7487×10^{-2}	2.6428×10^{-2}	5.8085×10^{-2}
^{235}U	2.1615×10^{-4}	2.1310×10^{-4}	4.5314×10^{-4}	3.6930×10^{-4}
^{236}U	5.1916×10^{-4}	7.3003×10^{-4}	6.5233×10^{-4}	1.5442×10^{-3}
^{237}U	8.8673×10^{-5}	1.6780×10^{-4}	1.2897×10^{-4}	2.3573×10^{-3}
^{238}U	6.7800×10^{-3}	5.3300×10^{-3}	1.7400×10^{-2}	1.6500×10^{-2}
^{90}Y	1.60×10^{2}	1.22×10^{3}	1.62×10^{3}	1.41×10^{4}
^{93}Zr	3.27×10^{-2}	1.87×10^{-1}	9.37×10^{-2}	

Source: Allison 2004 [DIRS 168734], Tables 5 to 8.

NOTE: In using the data in this table, it was noticed that the ^{113}Cd inventory data is probably not correct. This observation is discussed in Section 6.2.3.

Table 4-6. Initial LaBS Glass Radionuclide Inventory (Indexed to the Year 2003) per Canister (815 Canisters)

Isotope	2003 LaBS Glass (Curies/canister)	2003 DWPF Canister (Curies/canister)	2003 VPWF Canister (Curies/canister)
^{60}Co		1.16×10^{2}	1.02×10^{2}
^{90}Sr		2.70×10^{4}	2.38×10^{4}
^{90}Y		2.70×10^{4}	2.38×10^{4}
^{99}Tc		7.82	6.88
^{106}Ru		1.14	1.00
^{134}Cs		2.26	1.99
^{135}Cs		1.24×10^{-1}	1.09×10^{-1}
^{137}Cs		3.15×10^{4}	2.77×10^{4}
^{137m}Ba		2.94×10^{4}	2.59×10^{4}
^{144}Ce		4.23×10^{-1}	3.72×10^{-1}
^{144m}Pr		4.23×10^{-1}	3.72×10^{-1}
^{147}Pm		1.22×10^{3}	1.07×10^{3}
^{154}Eu		2.97×10^{2}	2.61×10^{2}
^{232}Th	7.19×10^{-6}	9.44×10^{-4}	8.38×10^{-4}
^{232}U		1.66×10^{-4}	1.46×10^{-4}
^{233}U		3.29×10^{-2}	2.90×10^{-2}
^{234}U	1.11×10^{-1}	1.16×10^{-2}	1.21×10^{-1}
^{235}U	2.38×10^{-3}	3.69×10^{-4}	2.70×10^{-3}
^{236}U		1.54×10^{-3}	1.36×10^{-3}
^{238}U	1.21×10^{-3}	1.65×10^{-2}	1.57×10^{-2}
^{237}Np	1.40×10^{-3}	2.11×10^{-2}	2.00×10^{-2}
^{238}Pu	2.46×10^{2}	6.79×10^{2}	8.44×10^{2}
^{239}Pu	9.08×10^{2}	1.13×10^{1}	9.18×10^{2}
^{240}Pu	2.96×10^{2}	5.21	3.01×10^{2}
^{241}Pu	5.42×10^{3}	3.49×10^{2}	5.73×10^{3}
^{242}Pu	9.74×10^{-2}	1.15×10^{-2}	1.07×10^{-1}
^{241}Am	3.98×10^{2}	6.60×10^{1}	4.56×10^{2}
^{242m}Am		5.89×10^{-2}	5.18×10^{-2}
^{244}Cm		7.74×10^{1}	6.81×10^{1}
^{245}Cm		6.16×10^{-3}	5.42×10^{-3}
^{246}Cm		4.34×10^{-2}	3.82×10^{-2}
^{247}Cm		1.71×10^{-6}	1.50×10^{-6}

Source: Marra et al. 2005 [DIRS 173215], Table 4.

NOTE: DWPF = Defense Waste Processing Facility; VPWF = vitrified plutonium waste form.

Table 4-7. Initial Radionuclide Inventories (Indexed to the Year 2030) for the Hanford Site HLW

Isotope	Inventory (Curies)	Isotope	Inventory (Curies)	Isotope	Inventory (Curies)	Isotope	Inventory (Curies)
^{227}Ac	52	^{154}Eu	28,084	^{242}Pu	1	^{232}U	33
^{241}Am	138,408	^{155}Eu	1	^{226}Ra	0.09	^{233}U	510
^{243}Am	15	^{129}I	48	^{228}Ra	2	^{234}U	220
^{137m}Ba	2,3464,803	^{93m}Nb	1,138	^{106}Ru	0	^{235}U	9
^{113m}Cd	3,867	^{59}Ni	1,370	^{125}Sb	15	^{236}U	6
^{242}Cm	0	^{63}Ni	104,703	^{79}Se	122	^{238}U	199
^{243}Cm	7	^{237}Np	141	^{151}Sm	2,797,968	^{90}Y	25,114,788
^{244}Cm	98	^{231}Pa	272	^{126}Sn	579	^{93}Zr	4,810
^{60}Co	179	^{238}Pu	3,880	^{90}Sr	25,114,788		
^{134}Cs	1	^{239}Pu	69,042	^{99}Tc	29,697		
^{137}Cs	23,464,803	^{240}Pu	12,262	^{229}Th	2		
^{152}Eu	369	^{241}Pu	30,931	^{232}Th	8		

Source: Hamel 2003 [DIRS 164947], Table 2.

Table 4-8. Initial Radionuclide Inventories (Indexed to the Year 1996) for the West Valley HLW

Nuclide	Inventory (Curies)	Nuclide	Inventory (Curies)	Nuclide	Inventory (Curies)	Nuclide	Inventory (Curies)
^{3}H	5.87×10^{1}	^{125m}Te	3.97×10^{2}	^{215}Po	9.43	^{238}U	8.54×10^{-1}
^{14}C	1.37×10^{2}	^{129}I	2.10×10^{-1}	^{216}Po	8.62	^{236}Np	9.47
^{55}Fe	1.42×10^{2}	^{134}Cs	6.87×10^{2}	^{219}Rn	9.43	^{237}Np	2.35×10^{1}
^{60}Co	3.49×10^{2}	^{135}Cs	1.61×10^{2}	^{220}Rn	8.62	^{239}Np	3.47×10^{2}
^{59}Ni	1.06×10^{2}	^{137}Cs	6.29×10^{6}	^{223}Fr	1.30×10^{-1}	^{236}Pu	8.43×10^{-1}
^{63}Ni	8.17×10^{3}	^{137m}Ba	5.95×10^{6}	^{223}Ra	9.43	^{238}Pu	8.04×10^{3}
^{79}Se	6.02×10^{1}	^{144}Ce	3.11×10^{-3}	^{224}Ra	8.62	^{239}Pu	1.65×10^{3}
^{90}Sr	5.81×10^{6}	^{144}Pr	3.11×10^{-3}	^{228}Ra	1.58	^{240}Pu	1.22×10^{3}
^{90}Y	5.81×10^{6}	^{146}Pm	5.11	^{227}Ac	9.43	^{241}Pu	6.13×10^{4}
^{93}Zr	2.72×10^{2}	^{147}Pm	1.80×10^{4}	^{228}Ac	1.58	^{242}Pu	1.65
^{93m}Nb	2.07×10^{2}	^{151}Sm	8.05×10^{4}	^{227}Th	9.30	^{241}Am	5.35×10^{4}
^{99}Tc	1.70×10^{3}	^{152}Eu	2.69×10^{2}	^{228}Th	8.62	^{242}Am	2.87×10^{2}
^{106}Ru	2.31×10^{-1}	^{154}Eu	5.91×10^{4}	^{229}Th	2.15×10^{-1}	^{242m}Am	2.89×10^{2}
^{106}Rh	2.31×10^{-1}	^{155}Eu	1.03×10^{4}	^{230}Th	5.87×10^{-2}	^{243}Am	3.47×10^{2}
^{107}Pd	1.10×10^{1}	^{207}Tl	9.40	^{232}Th	1.64	^{242}Cm	2.38×10^{2}
^{113m}Cd	1.60×10^{3}	^{208}Tl	3.09	^{231}Pa	1.52×10^{1}	^{243}Cm	1.16×10^{2}
^{121m}Sn	1.61×10^{1}	^{211}Pb	9.43	^{232}U	6.87	^{244}Cm	6.07×10^{3}
^{126}Sn	1.04×10^{2}	^{212}Pb	8.62	^{233}U	9.53	^{245}Cm	8.81×10^{-1}
^{125}Sb	1.62×10^{3}	^{211}Bi	9.43	^{234}U	4.61	^{246}Cm	1.01×10^{-1}
^{126}Sb	1.46×10^{1}	^{212}Bi	8.62	^{235}U	1.01×10^{-1}		
^{126m}Sb	1.04×10^{2}	^{212}Po	5.52	^{236}U	2.96×10^{-1}		

Source: CRWMS M&O 2000 [DIRS 151947], Table 5-6.

Table 4-9. Initial Radionuclide Inventories (Indexed to the Year 2035) of the HLW from INEEL

Nuclide	Inventory (Curies)	Nuclide	Inventory (Curies)	Nuclide	Inventory (Curies)	Nuclide	Inventory (Curies)
^{3}H	3.56×10^{3}	^{125}Sb	1.03	^{230}Th	3.95×10^{-1}	^{239}Pu	1.81×10^{3}
^{14}C	2.78×10^{-2}	^{129}I	5.64	^{232}Th	9.89×10^{-8}	^{240}Pu	1.57×10^{3}
^{60}Co	3.21×10^{1}	^{134}Cs	3.28×10^{-2}	^{232}U	4.63×10^{-3}	^{241}Pu	1.93×10^{4}
^{90}Sr	7.04×10^{6}	^{135}Cs	1.63×10^{2}	^{233}U	1.33×10^{-3}	^{242}Pu	3.42
^{90}Y	7.04×10^{6}	^{137}Cs	5.95×10^{6}	^{234}U	9.95×10^{1}	^{241}Am	1.27×10^{4}
^{93m}Nb	4.74×10^{2}	^{137m}Ba	5.60×10^{6}	^{235}U	5.90×10^{-1}	^{243}Am	1.39×10^{-2}
^{94}Nb	5.36×10^{-3}	^{147}Pm	2.67×10^{1}	^{236}U	1.54	^{243}Cm	4.70×10^{-4}
^{99}Tc	3.41×10^{3}	^{154}Eu	5.98×10^{3}	^{238}U	2.94×10^{-2}	^{244}Cm	1.03×10^{-2}
^{102}Rh	1.99×10^{-5}	^{155}Eu	7.55	^{237}Np	6.26		
^{126}Sn	8.91×10^{1}	^{226}Ra	9.69×10^{-3}	^{238}Pu	8.98×10^{4}		

Source: CRWMS M&O 2000 [DIRS 151947], Table 5-8.

Table 4-10. Initial Radionuclide Inventories (Indexed to the Year 2000) of the ANL-W Ceramic Waste

Nuclide	Inventory (Curies)	Nuclide	Inventory (Curies)	Nuclide	Inventory (Curies)	Nuclide	Inventory (Curies)
^{90}Sr	7.13×10^{5}	^{154}Eu	2.07×10^{3}	^{234}U	2.76	^{240}Pu	1.50×10^{3}
^{129}I	3.38×10^{-1}	^{155}Eu	1.93×10^{4}	^{235}U	8.77×10^{-2}	^{241}Pu	1.08×10^{4}
^{134}Cs	7.90×10^{3}	^{226}Ra	2.99×10^{-5}	^{236}U	6.34×10^{-2}	^{242}Pu	1.23×10^{-1}
^{135}Cs	1.59×10^{1}	^{230}Th	4.65×10^{-3}	^{238}U	2.76×10^{-1}	^{241}Am	1.62×10^{3}
^{137}Cs	8.49×10^{5}	^{232}Th	2.31×10^{-9}	^{237}Np	1.33	^{243}Am	2.77×10^{-1}
^{144}Ce	4.94×10^{4}	^{232}U	2.63×10^{-3}	^{238}Pu	3.58×10^{2}	^{243}Cm	1.60×10^{-1}
^{147}Pm	4.48×10^{5}	^{233}U	1.98×10^{-4}	^{239}Pu	1.68×10^{4}	^{244}Cm	1.90

Source: CRWMS M&O 2000 [DIRS 151947], Table 5-9.

Table 4-11. Initial Radionuclide Inventories (Indexed to the Year 2000) of the ANL-W Metal Waste

Nuclide	Inventory (Curies)	Nuclide	Inventory (Curies)	Nuclide	Inventory (Curies)	Nuclide	Inventory (Curies)
^{14}C	4.29	^{106}Ru	2.13×10^{4}	^{236}U	1.82×10^{-2}	^{242}Pu	2.02×10^{-6}
^{60}Co	3.16×10^{3}	^{126}Sn	2.81	^{238}U	9.71×10^{-2}	^{241}Am	3.05×10^{-2}
^{59}Ni	1.07×10^{1}	^{125}Sb	1.38×10^{4}	^{237}Np	2.40×10^{-5}	^{243}Am	4.79×10^{-6}
^{63}Ni	4.12×10^{2}	^{232}U	1.21×10^{-4}	^{238}Pu	6.64×10^{-3}	^{243}Cm	3.04×10^{-6}
^{93m}Nb	2.93×10^{1}	^{233}U	5.83×10^{-5}	^{239}Pu	3.32×10^{-1}	^{244}Cm	3.13×10^{-5}
^{94}Nb	2.73	^{234}U	7.68×10^{-1}	^{240}Pu	2.92×10^{-2}		
^{99}Tc	1.27×10^{2}	^{235}U	2.53×10^{-2}	^{241}Pu	1.93×10^{-1}		

Source: CRWMS M&O 2000 [DIRS 151947], Table 5-10.

Table 4-12. Initial Radionuclide Inventories (Indexed to the Year 2045) for MOX Spent Fuel Assemblies

Nuclide	Inventory (Curies)	Nuclide	Inventory (Curies)	Nuclide	Inventory (Curies)	Nuclide	Inventory (Curies)
^{225}Ac	4.79E-09	^{58}Co	1.97E-12	^{232}Pa	0.00E+00	^{145}Sm	5.28E-04
^{227}Ac	2.97E-07	^{60}Co	1.23E+03	^{233}Pa	5.61E-02	^{146}Sm	2.01E-07
^{228}Ac	1.89E-12	^{134}Cs	4.02E+03	^{234}Pa	1.70E-04	^{147}Sm	2.84E-06
^{108}Ag	1.69E-03	^{135}Cs	3.94E-01	^{234m}Pa	1.31E-01	^{148}Sm	2.36E-11
^{108m}Ag	1.95E-02	^{137}Cs	5.50E+04	^{205}Pb	1.56E-36	^{151}Sm	3.49E+02
^{109m}Ag	2.07E-05	^{150}Eu	5.45E-05	^{209}Pb	4.79E-09	^{113}Sn	3.50E-07
^{110}Ag	3.92E-03	^{152}Eu	4.15E+00	^{210}Pb	1.45E-09	^{119m}Sn	9.80E-01
^{110m}Ag	2.88E-01	^{154}Eu	3.34E+03	^{211}Pb	2.98E-07	^{121}Sn	2.23E+00
^{239}Am	0.00E+00	^{155}Eu	6.32E+02	^{212}Pb	4.06E-03	^{121m}Sn	2.98E+00
^{241}Am	2.97E+03	^{55}Fe	1.56E+02	^{214}Pb	1.07E-08	^{123}Sn	1.67E-06
^{242}Am	2.24E+01	^{221}Fr	4.79E-09	^{107}Pd	1.62E-01	^{126}Sn	6.26E-01
^{242m}Am	2.25E+01	^{223}Fr	4.10E-09	^{145}Pm	5.83E-02	^{90}Sr	1.88E+04
^{243}Am	4.70E+01	^{152}Gd	1.58E-12	^{146}Pm	8.46E-01	^{182}Ta	2.17E-07
^{245}Am	9.97E-11	^{153}Gd	3.39E-04	^{147}Pm	6.16E+03	^{160}Tb	9.92E-13
^{246}Am	1.20E-13	^{3}H	1.95E+02	^{210}Po	1.45E-09	^{98}Tc	5.61E-06
^{39}Ar	3.51E-13	^{174}Hf	4.22E-15	^{211}Po	8.18E-10	^{99}Tc	8.10E+00
^{42}Ar	9.39E-16	^{182}Hf	1.99E-07	^{212}Po	2.60E-03	^{123}Te	1.17E-12
^{217}At	4.79E-09	^{166m}Ho	1.21E-03	^{213}Po	4.69E-09	^{123m}Te	1.17E-08
^{218}At	0.00E+00	^{129}I	2.62E-02	^{214}Po	1.07E-08	^{125m}Te	1.58E+02
^{219}At	0.00E+00	^{113m}In	3.51E-07	^{215}Po	2.98E-07	^{127}Te	8.57E-07
^{132}Ba	4.69E-42	^{115}In	6.82E-12	^{216}Po	4.06E-03	^{127m}Te	8.75E-07
^{133}Ba	1.94E-05	^{192}Ir	3.37E-08	^{218}Po	1.07E-08	^{128}Te	8.81E-29
^{137m}Ba	5.20E+04	^{192m}Ir	3.37E-08	^{144}Pr	7.67E+01	^{130}Te	6.03E-33
^{10}Be	5.62E-05	^{194}Ir	1.87E-10	^{144m}Pr	1.07E+00	^{227}Th	2.93E-07
^{210}Bi	1.45E-09	^{40}K	9.29E-26	^{193}Pt	4.63E-06	^{228}Th	4.05E-03
^{211}Bi	2.98E-07	^{42}K	9.42E-16	^{236}Pu	9.15E-03	^{229}Th	4.79E-09
^{212}Bi	4.06E-03	^{81}Kr	1.43E-07	^{238}Pu	1.64E+03	^{230}Th	5.06E-06
^{213}Bi	4.79E-09	^{85}Kr	1.71E+03	^{239}Pu	3.07E+02	^{231}Th	5.81E-04
^{214}Bi	1.07E-08	^{138}La	1.47E-10	^{240}Pu	7.92E+02	^{232}Th	4.06E-12
^{215}Bi	0.00E+00	^{176}Lu	6.72E-12	^{241}Pu	1.30E+05	^{234}Th	1.31E-01
^{243}Bk	0.00E+00	^{54}Mn	2.25E-01	^{242}Pu	3.45E+00	^{204}Tl	2.32E-25
^{249}Bk	6.87E-06	^{93}Mo	2.75E-02	^{243}Pu	9.30E-07	^{206}Tl	1.91E-15
^{250}Bk	8.59E-12	^{100}Mo	8.09E-15	^{244}Pu	6.38E-07	^{207}Tl	2.97E-07
^{14}C	5.50E-01	^{22}Na	1.50E-16	^{246}Pu	1.20E-13	^{208}Tl	1.46E-03
^{41}Ca	2.75E-35	^{91}Nb	2.17E-05	^{223}Ra	2.98E-07	^{209}Tl	1.01E-10
^{45}Ca	4.71E-09	^{92}Nb	1.10E-06	^{224}Ra	4.06E-03	^{171}Tm	1.18E-04

Table 4-12. Initial Radionuclide Inventories (Indexed to the Year 2045) for MOX Spent Fuel Assemblies (Continued)

Nuclide	Inventory (Curies)	Nuclide	Inventory (Curies)	Nuclide	Inventory (Curies)	Nuclide	Inventory (Curies)
^{109}Cd	2.07E-05	^{93m}Nb	2.67E+01	^{225}Ra	4.79E-09	^{232}U	4.49E-03
^{113}Cd	3.69E-14	^{94}Nb	8.44E-01	^{226}Ra	1.07E-08	^{233}U	3.43E-06
^{113m}Cd	2.28E+01	^{95}Nb	1.12E-11	^{228}Ra	1.89E-12	^{234}U	7.40E-02
^{139}Ce	1.49E-09	^{95m}Nb	6.00E-14	^{87}Rb	6.94E-06	^{235}U	5.81E-04
^{144}Ce	7.67E+01	^{144}Nd	7.56E-10	^{187}Re	1.10E-08	^{236}U	7.10E-03
^{249}Cf	5.37E-05	^{59}Ni	1.73E+00	^{102}Rh	1.90E-01	^{237}U	3.11E+00
^{250}Cf	2.30E-04	^{63}Ni	2.25E+02	^{106}Rh	6.42E+02	^{238}U	1.31E-01
^{251}Cf	2.59E-06	^{235}Np	8.69E-06	^{217}Rn	0.00E+00	^{240}U	6.37E-07
^{252}Cf	3.48E-05	^{236m}Np	2.84E-06	^{218}Rn	0.00E+00	^{50}V	1.96E-15
^{36}Cl	3.89E-08	^{237}Np	5.61E-02	^{219}Rn	2.98E-07	^{90}Y	1.88E+04
^{242}Cm	1.86E+01	^{238}Np	1.01E-01	^{220}Rn	4.06E-03	^{91}Y	6.40E-14
^{243}Cm	4.79E+01	^{239}Np	4.70E+01	^{222}Rn	1.07E-08	^{64}Zn	1.89E-17
^{244}Cm	5.62E+03	^{240}Np	7.64E-10	^{106}Ru	6.42E+02	^{65}Zn	7.35E-06
^{245}Cm	1.14E+00	^{240m}Np	6.37E-07	^{125}Sb	6.44E+02	^{93}Zr	6.17E-01
^{246}Cm	2.02E-01	^{186}Os	8.47E-15	^{126}Sb	8.77E-02	^{95}Zr	5.10E-12
^{247}Cm	9.30E-07	^{194}Os	1.89E-10	^{126m}Sb	6.26E-01	^{96}Zr	6.05E-13
^{248}Cm	3.21E-06	^{32}P	2.66E-07	^{79}Se	3.96E-02		
^{250}Cm	4.81E-13	^{231}Pa	1.04E-06	^{32}Si	2.86E-07		

Source: CRWMS M&O 1998 [DIRS 105977], Attachment III, *50-0G-CR.OUT*.

NOTE: See `McClure et al_50-OG-CR.out.xls`.

Table 4-13. Initial Radionuclide Inventories (Indexed to the Year 2030) for DOE Spent Nuclear Fuels

Nuclide	Nominal Fuel Inventories (Curies)	Bounding Fuel Inventories (Curies)	Bounding U/Th Carbide Inventories (Curies)	Nuclide	Nominal Fuel Inventories (Curies)	Bounding Fuel Inventories (Curies)	Bounding U/Th Carbide Inventories (Curies)
^{227}Ac	5.79×10^{1}	1.18×10^{2}	7.82	^{239}Pu	4.75×10^{5}	7.70×10^{5}	2.65×10^{2}
^{241}Am	2.24×10^{6}	4.13×10^{6}	6.19×10^{3}	^{240}Pu	3.64×10^{5}	6.20×10^{5}	5.33×10^{2}
^{242m}Am	4.75×10^{3}	8.82×10^{3}	4.56	^{241}Pu	9.38×10^{6}	2.25×10^{7}	3.04×10^{4}
^{243}Am	4.05×10^{3}	7.58×10^{3}	8.99×10^{1}	^{242}Pu	5.06×10^{2}	8.38×10^{2}	7.59
^{14}C	1.82×10^{4}	2.79×10^{4}	4.51×10^{1}	^{226}Ra	7.98×10^{-2}	1.08×10^{-1}	6.44×10^{-3}
^{36}Cl	2.98×10^{2}	4.67×10^{2}	2.08	^{228}Ra	3.43	7.03	1.79
^{243}Cm	1.13×10^{3}	2.17×10^{3}	4.38×10^{1}	^{106}Ru	2.60×10^{5}	4.67×10^{5}	4.79×10^{-5}
^{244}Cm	1.35×10^{5}	2.58×10^{5}	1.05×10^{4}	^{79}Se	2.91×10^{2}	5.39×10^{2}	4.12×10^{1}
^{60}Co	7.98×10^{5}	1.17×10^{6}	5.92×10^{2}	^{126}Sn	2.81×10^{2}	5.15×10^{2}	4.33×10^{1}
^{134}Cs	6.70×10^{5}	1.21×10^{6}	4.65×10^{1}	^{90}Sr	2.27×10^{7}	4.19×10^{7}	2.19×10^{6}

Table 4-13. Initial Radionuclide Inventories (Indexed to the Year 2030) for DOE Spent Nuclear Fuels (Continued)

Nuclide	Nominal Fuel Inventories (Curies)	Bounding Fuel Inventories (Curies)	Bounding U/Th Carbide Inventories (Curies)	Nuclide	Nominal Fuel Inventories (Curies)	Bounding Fuel Inventories (Curies)	Bounding U/Th Carbide Inventories (Curies)
^{135}Cs	3.13×10^{2}	5.78×10^{2}	4.82×10^{1}	^{99}Tc	8.85×10^{3}	1.63×10^{4}	6.51×10^{2}
^{137}Cs	2.77×10^{7}	5.14×10^{7}	2.30×10^{6}	^{229}Th	4.76×10^{1}	9.76×10^{1}	2.29×10^{1}
^{154}Eu	3.35×10^{5}	6.10×10^{6}	2.25×10^{4}	^{230}Th	4.89	6.78	3.98×10^{-1}
^{155}Eu	9.11×10^{4}	1.65×10^{5}	1.36×10^{3}	^{232}Th	8.01	8.17	2.70
^{55}Fe	5.33×10^{4}	1.01×10^{5}	5.49×10^{-2}	^{208}Tl	8.03×10^{3}	1.63×10^{4}	1.10×10^{3}
^{3}H	1.06×10^{5}	1.92×10^{5}	5.98×10^{3}	^{232}U	2.17×10^{4}	4.42×10^{4}	2.99×10^{3}
^{129}I	1.95×10^{1}	3.63×10^{1}	1.97	^{233}U	1.82×10^{4}	2.21×10^{4}	4.02×10^{3}
^{85}Kr	9.54×10^{5}	1.76×10^{6}	5.90×10^{4}	^{234}U	7.29×10^{3}	1.03×10^{4}	5.69×10^{2}
^{237}Np	2.11×10^{2}	3.93×10^{2}	2.45×10^{1}	^{235}U	1.43×10^{2}	2.16×10^{2}	5.40
^{231}Pa	7.05×10^{1}	1.43×10^{2}	9.25	^{236}U	2.83×10^{2}	4.98×10^{2}	1.68×10^{1}
^{210}Pb	4.04×10^{-2}	5.57×10^{-2}	3.34×10^{-3}	^{238}U	7.77×10^{2}	7.89×10^{2}	5.37×10^{-2}
^{147}Pm	3.57×10^{6}	6.43×10^{6}	1.86×10^{2}	^{90}Y	2.27×10^{7}	4.19×10^{7}	2.19×10^{6}
^{238}Pu	8.49×10^{5}	1.60×10^{6}	3.04×10^{5}				

Source: DOE 2004 [DIRS 169354], Appendix D, pp. D569 and D580.

4.2 CRITERIA

The following acceptance criteria from *Yucca Mountain Review Plan, Final Report* (NRC 2003 [DIRS 163274]) were identified in the TWP (BSC 2006 [DIRS 177389], Table 3-1) as applicable to this analysis:

- **Radionuclide Release Rates Acceptance Criteria** (NRC 2003 [DIRS 163274], Section 2.2.1.3.4.3)

Acceptance Criterion 1 – *System Description and Model Integration are Adequate*

(1) Total system performance assessment adequately incorporates important design features, physical phenomena, and couplings, and uses consistent and appropriate assumptions throughout the radionuclide release rates and solubility limits abstraction process.

This analysis incorporates the best available information on the radionuclide inventory in the various waste forms that are to be disposed.

(2) to (8) are not applicable to this analysis.

Acceptance Criterion 2 – *Data Are Sufficient for Model Justification*

(2) Sufficient data have been collected on the characteristics of the natural system and engineered materials to establish initial and boundary conditions for conceptual

models and simulations of thermal-hydrologic-chemical processes. For example, sufficient data should be provided on design features, such as the type, quantity, and reactivity of materials, that may affect radionuclide release for this abstraction.

This analysis provides sufficient data on radionuclide content of the waste forms and the variability in this radionuclide content to provide an acceptable basis for identifying radionuclides that may contribute to release.

(1), (3), and (4) are not applicable to this analysis.

The TWP (BSC 2006 [DIRS 177389], Section 3.3) requires that technical products address and document the accuracy, precision, and representativeness of the work performed as part of the uncertainty analyses. In addition, technical products will meet the level of detail and accuracy needed to support the TSPA-LA model.

In this analysis, the best available input data and qualified computer codes are used to ensure accuracy of the output analysis results. Representativeness of the work is addressed by considering a broad range of waste forms and associated estimates of their radionuclide inventories so that possible variability in the radionuclide inventory that may contribute to dose at any point in time up to a million years is addressed. Uncertainties are discussed in Section 6.4.

4.3 CODES, STANDARDS, AND REGULATIONS

The TWP (BSC 2006 [DIRS 177389], Section 3.1) states that this work will conform, as appropriate, to guidance provided in ASTM C 1174-97 1998 [DIRS 105725], *Standard Practice for Prediction of the Long-Term Behavior of Materials, Including Waste Forms, Used in Engineered Barrier Systems (EBS) for Geological Disposal of High-Level Radioactive Waste*. This analysis conforms to this guidance in that it conforms "to methods used to aid in the prediction of the long-term behavior of materials, such as 'engineered barrier' system (EBS) materials and waste forms, used in the geologic disposal of high-level nuclear waste in the U.S. Government disposal site."

The TWP (BSC 2006 [DIRS 177389], Section 3.2) also states that parts of 10 CFR Part 63 [DIRS 173273] are applicable to this work. Certain 10 CFR Part 63 [DIRS 173273] and 40 CFR Part 197 [DIRS 173176] sections are relevant to the use of the results from analyses performed as a part of TSPA-LA. The output from this analysis will be used in the TSPA-LA postclosure analysis.

5. ASSUMPTIONS

5.1 ASSUMPTION 1

The as-built characteristics of PWR and BWR assemblies and the calculated "average" and "outlying" radionuclide activities as functions of time developed by *BWR Source Term Generation and Evaluation* (CRWMS M&O 1999 [DIRS 136428], Assumption 3.1), *PWR Source Term Generation and Evaluation* (CRWMS M&O 1999 [DIRS 136429], Assumption 3.1), *BWR Source Term Generation and Evaluation* (BCS 2003 [DIRS 164364], Assumption 3.1, Section 5.3, Attachment XIII), and *PWR Source Term Generation and Evaluation* (BSC 2004 [DIRS 169061], Assumption 3.1, Section 5.4, Attachment IX) are adequate for the screening analysis. The characteristics of the average CSNF waste forms were determined by weighted averages from the projected CSNF waste stream of the enrichments, burnups, and ages, where the weights are the numbers of assemblies with a given value of each characteristic in the waste stream. The characteristics of the outlying CSNF waste forms are the maximum burnup, the maximum initial enrichment, and the minimum age in the waste stream for each fuel type. The rationale for this assumption, which is strong enough to justify a claim that further confirmation is not required, is that this information is the most recent available at the time of this analysis and was developed in accordance with the OCRWM quality assurance program. The possible consequences of uncertainties in this assumption are addressed in Section 6.5. This assumption is used in Sections 6.2 and 6.3.

5.2 ASSUMPTION 2

The use of calculated "average," "bounding," and "outlying" radionuclide activities for DOE SNF is adequate to represent the variability in the various types of DOE SNF for this screening analysis. The "average" and "bounding" inventories were developed by *Source Term Estimates for DOE Spent Nuclear Fuels* (DOE 2004 [DIRS 169354], Appendix D). In addition to the "average" and "bounding" radionuclide activities, the activities in uranium/thorium carbide fuel were chosen as an "outlying" DOE SNF waste form to assess the full range of DOE SNF inventory variability for the screening calculations. This fuel type was chosen because it contains substantial activities of ^{233}U and ^{230}Th, whose potential importance to dose should be evaluated. The initial activities for these three DOE SNF types are listed in Table 4-13. The rationale for this assumption, which is strong enough to justify a claim that further confirmation is not required, is that this information is the most recent available at the time of this analysis. The possible consequences of uncertainties in this assumption are addressed in Section 6.5. This assumption is used in Sections 4.1.4, 6.2, and 6.3.

5.3 ASSUMPTION 3

The variability in radionuclide activities for HLW is adequately represented by the range of initial inventory data in Tables 4-5 through 4-11. The rationale for this assumption, which is strong enough to justify a claim that further confirmation is not required, is that this information includes all of the HLW types and is the most recent available at the time of this analysis. The possible consequences of uncertainties in this assumption are addressed in Section 6.5. This assumption is used in Sections 6.2 and 6.3.

5.4 ASSUMPTION 4

The inventory listed in Table 4-5 for ^{113}Cd is assumed to be associated with ^{113m}Cd. As discussed in Section 6.2.3, the specific activity of ^{113}Cd is sufficiently low (the half life of ^{113}Cd is 7.7×10^{15} years; see Table 4-3) that it is unlikely to be correctly assigned. For this analysis, it is assumed that the Curie inventory assigned to ^{113}Cd in Table 4-5 should be assigned to ^{113m}Cd.

This assumption remains to be verified (TBV-7772).

6. SCIENTIFIC ANALYSIS DISCUSSION

6.1 PREVIOUS RADIONUCLIDE SCREENING ACTIVITIES

Oversby (1987 [DIRS 106998]) conducted early work on radionuclide screening related to the Yucca Mountain repository. Radionuclide screening was required for a series of total system performance analyses including *Total-System Performance Assessment for Yucca Mountain – SNL Second Iteration (TSPA-1993)* (Wilson et al. 1994 [DIRS 100191]), *System Performance Assessment - 1995: An Evaluation of the Potential Yucca Mountain Repository* (CRWMS M&O 1995 [DIRS 100198]), *Total System Performance Assessment* (DOE 1998 [DIRS 100550]), and *Total System Performance Assessment for the Site Recommendation* (CRWMS M&O 2000 [DIRS 153246]). Other organizations, including the NRC and the Electric Power Research Institute (EPRI), have conducted performance assessments requiring radionuclide screening (for example, Wescott et al. 1995 [DIRS 100476] and EPRI 2002 [DIRS 158069]). The results of the cited radionuclide screening activities are provided in Table 6-1.

The formal screening method that was introduced in Revision 00 of the radionuclide screening analysis (CRWMS M&O 2000 [DIRS 150561], Section 4) drew favorable comments from the NRC (Beckman 2001 [DIRS 156122], Section 5.3.2.1):

> This clear description of the screening process used to identify important radionuclides is an improvement in the transparency of the TSPA. Also, consideration of important radionuclides for the human intrusion and igneous event scenarios in the inventory abstraction [report] is an improvement in the comprehensiveness of the analysis. . . . The approach appears to account for all waste types that will be emplaced in the repository and seems complete in this regard.

However, the NRC also provided constructive criticism (Beckman 2001 [DIRS 156122], Section 5.3.2.1). This revision seeks to build upon the strengths of the earlier revisions, including responding to comments by the NRC, and updating input data sources to address CR-5925 and CR-5600. Specific comments and how they are addressed in the present analysis are treated fully in Section 6.7.1.

6.2 CONCEPTUAL BASIS

6.2.1 Summary of the Screening Process

As described in Section 1, the purpose of this screening analysis is to compile a comprehensive list of the radionuclides in the various waste forms slated for disposal and to screen out from the list those radionuclides that are unlikely to significantly contribute to radiation dose from the repository.

The starting list of radionuclides, for which the inventory is greater than zero after 100 years of decay, was developed by compiling a list of the light element, fission product, and actinide radionuclides in MOX fuel (CRWMS M&O 1998 [DIRS 105977], Attachment III, *50-0G-CR.OUT*). As documented in the workbook `McClure et al_50-0G-Cr.out.xls` (see

Appendix C), the lists of light element, fission product, and actinide radionuclides with non-zero inventories were compiled and merged to obtain a complete list of the radionuclides present in the MOX fuel. Comparison of this list with the lists of radionuclides present in the other waste forms showed that the list was a comprehensive list of radionuclides present in the various waste forms slated for disposal.

The screening analysis considers four release scenarios (nominal, human intrusion, intrusive igneous, and eruptive igneous) and two time periods (the period up to 10,000 years and the period after 10,000 years up to 1 million years). The nominal scenario envisions the gradual deterioration of the disposal containers, the subsequent exposure of the waste to the potentially corrosive effects of the environment, and the natural transport of radioactive contaminants through unsaturated and saturated zone groundwater to the accessible environment, where the groundwater is withdrawn by the human population. The human-intrusion scenario considers the possibility that future inhabitants of the Yucca Mountain area might drill down into the repository, through a waste package, and down to the water table. Under the human-intrusion scenario (as compared to the nominal scenario), the waste would be exposed to the environment sooner and radioactive contaminants would have a quicker path to the saturated zone groundwater through the postulated borehole. The intrusive igneous scenario envisions the intrusion of magma into the repository where it damages waste packages, making radioactive contaminants available for transport in the unsaturated zone. As noted above, the nominal, human-intrusion, and intrusive igneous scenarios may be called the groundwater scenarios. Under the eruptive scenario, a volcanic eruption releases waste directly into the atmosphere.

Table 6-1. Radionuclides Included in Other TSPAs

Nuclide	TSPA 1993[a]	TSPA 1995[b]	TSPA for Viability Assessment[c]	TSPA for Site Recommendation[d]	NRC[e]	EPRI[f]
^{227}Ac	^{227}Ac	^{227}Ac		^{227}Ac		
^{108m}Ag	^{108m}Ag					
^{241}Am	^{241}Am	^{241}Am		^{241}Am	^{241}Am	^{241}Am
^{242m}Am	^{242m}Am	^{242m}Am				
^{243}Am	^{243}Am	^{243}Am		^{243}Am	^{243}Am	
^{14}C	^{14}C	^{14}C	^{14}C	^{14}C	^{14}C	
^{36}Cl	^{36}Cl	^{36}Cl				^{36}Cl
^{243}Cm	^{243}Cm					
^{244}Cm	^{244}Cm	^{244}Cm				
^{245}Cm	^{245}Cm	^{245}Cm			^{245}Cm	
^{246}Cm	^{246}Cm	^{246}Cm			^{246}Cm	
^{135}Cs	^{135}Cs	^{135}Cs			^{135}Cs	^{135}Cs
^{137}Cs	^{137}Cs			^{137}Cs	^{137}Cs	
^{129}I	^{129}I	^{129}I	^{129}I	^{129}I	^{129}I	^{129}I
^{93}Mo	^{93}Mo					
^{93m}Nb		^{93m}Nb				

Table 6-1. Radionuclides Included in Other TSPAs (Continued)

Nuclide	TSPA 1993[a]	TSPA 1995[b]	TSPA for Viability Assessment[c]	TSPA for Site Recommendation[d]	NRC[e]	EPRI[f]
^{94}Nb	^{94}Nb	^{94}Nb			^{94}Nb	^{94}Nb
^{59}Ni	^{59}Ni	^{59}Ni			^{59}Ni	
^{63}Ni	^{63}Ni	^{63}Ni				
^{237}Np	^{237}Np	^{237}Np	^{237}Np	^{237}Np	^{237}Np	^{237}Np
^{231}Pa	^{231}Pa	^{231}Pa	^{231}Pa	^{231}Pa		^{231}Pa
^{210}Pb	^{210}Pb	^{210}Pb		^{210}Pb	^{210}Pb	
^{107}Pd	^{107}Pd	^{107}Pd				
^{238}Pu	^{238}Pu	^{238}Pu		^{238}Pu		
^{239}Pu	^{239}Pu	^{239}Pu	^{239}Pu	^{239}Pu	^{239}Pu	^{239}Pu
^{240}Pu	^{240}Pu	^{240}Pu		^{240}Pu	^{240}Pu	^{240}Pu
^{241}Pu	^{241}Pu	^{241}Pu				
^{242}Pu	^{242}Pu	^{242}Pu	^{242}Pu	^{242}Pu		^{242}Pu
^{226}Ra	^{226}Ra	^{226}Ra		^{226}Ra	^{226}Ra	^{226}Ra
^{228}Ra		^{228}Ra		^{228}Ra		
^{79}Se	^{79}Se	^{79}Se	^{79}Se		^{79}Se	^{79}Se
^{151}Sm	^{151}Sm	^{151}Sm				
^{121m}Sn	^{121m}Sn					
^{126}Sn	^{126}Sn	^{126}Sn				^{126}Sn
^{90}Sr	^{90}Sr			^{90}Sr		
^{99}Tc	^{99}Tc	^{99}Tc	^{99}Tc	^{99}Tc	^{99}Tc	^{99}Tc
^{229}Th	^{229}Th	^{229}Th		^{229}Th		^{229}Th
^{230}Th	^{230}Th	^{230}Th		^{230}Th	^{230}Th	^{230}Th
^{232}Th		^{232}Th		^{232}Th		^{232}Th
^{232}U	^{232}U			^{232}U		
^{233}U	^{233}U	^{233}U		^{233}U		^{233}U
^{234}U	^{234}U	^{234}U	^{234}U	^{234}U	^{234}U	^{234}U
^{235}U	^{235}U	^{235}U		^{235}U		^{235}U
^{236}U	^{236}U	^{236}U		^{236}U		^{236}U
^{238}U	^{238}U	^{238}U		^{238}U	^{238}U	^{238}U
^{93}Zr	^{93}Zr	^{93}Zr				^{93}Zr

[a] Wilson et al. 1994 [DIRS 100191], Table 5-11.
[b] CRWMS M&O 1995 [DIRS 100198], Tables 3.7-1 and 3.7-2.
[c] DOE 1998 [DIRS 100550], Table 3.14.
[d] CRWMS M&O 2000 [DIRS 150561], Table 34.
[e] Wescott et al. 1995 [DIRS 100476], Table 5.1.
[f] EPRI 2002 [DIRS 158069], Section 6.5.

For the groundwater scenarios, the screening process first requires a subdivision of the complete set of radionuclides for a given waste form into screening sets according to transport characteristics of each radionuclide (Sections 6.2.4 through 6.2.5). As discussed in Sections 6.2.4 and 6.2.5, the solubility and sorption characteristics of each radioelement are used in combining the radionuclides into nine screening sets. The screening process then ranks radionuclides within a screening set according to the product of the activity in the waste form and a screening factor corresponding to each radionuclide without regard to solubility or sorption. Because radionuclide mobilization and transport under the eruptive scenario do not require groundwater transport, which may sort elements according to sorption and solubility, no subdivision according to groundwater transport characteristics is needed for the eruptive scenario, i.e., for the eruptive case, all of the radionuclides are grouped together into one screening set.

The radionuclide screening is based on the premise that the products of the activity inventories and the screening factors indicate the relative importance of each radionuclide with respect to the radiological dose that the reasonably maximally exposed individual might receive. As discussed in Section 4.1.2, usage factors that pertain to the reasonably maximally exposed individual's biosphere are used in developing the screening factors. The units of the product of activity and screening factor need not correspond to a dose to an individual as long as the units are consistent across radionuclides within a waste form and the product provides a measure of relative importance. For example, a valid pair of units is activity in Curies (Ci) and screening factor in (Sv/yr)/(Bq/m^3), which corresponds to the groundwater scenarios. The resulting units Ci × (Sv/yr)/(Bq/m^3) do not correspond to the dose to an individual, but the product still provides a measure of relative importance because it is proportional to dose under the assumptions of the screening for a particular screening time and waste form and other parameters quantifying the intake and uptake of radionuclides.

A radionuclide is screened out for a particular screening set and waste form at a particular time if the sum of its screening product and those of the radionuclides below it in rank fails to contribute 5% of the total of the screening products within the screening set. The complement of this fraction (95%) may be called the screening-product cutoff fraction. As described in Section 6.2.3, the screening is performed at a number of screening times for each waste form. A radionuclide that is screened out for all screening times and for all screening sets in which it is included is considered screened out for the waste form. A radionuclide that is screened out for all waste forms is screened out generally.

As described in Appendix A, air screening factors from NCRP-123 (NCRP 1996 [DIRS 101882], Table B.1)—adjusted to reflect the local biosphere and updated effective dose coefficients (EPA 2000 [DIRS 153733])—are assumed sufficiently representative of human dose effects for the eruptive igneous scenario to be used in the screening analysis. The usage factors built in to the NCRP screening factors, that is, the assumed times spent in various activities such as gardening and bathing or the quantities of water or food products consumed, are not necessarily appropriate for local Yucca Mountain repository conditions. The NCRP screening factors are adjusted for use in the present analysis by replacing the NCRP generic usage factors (NCRP 1996 [DIRS 101882], Table 7.1) with YMP-generated usage factors (Section 4.1.2). The rationale for using the adjusted air screening factors is as follows.

The eruptive volcanic event bypasses the groundwater and releases radioactive effluents directly into the atmosphere. Fallout from the volcanic ashes containing radioactive particles then deposits onto the Earth's surface. Radiological exposure pathways considered by the NCRP air screening factors include inhalation of airborne particulates; direct exposure to contaminated soil; consumption of contaminated crops and soil; and consumption of milk and meat from animals that consume contaminated forage (NCRP 1996 [DIRS 101882], Section 8.2.1). Neglect of these exposure pathways in Revision 01 of this document (BSC 2002 [DIRS 160059]) drew comments from the NRC, which noted that "processes that affect transport in the biosphere, such as uptake by plants and bioaccumulation are not accounted for" and that "the direct exposure pathway is not accounted for" (Beckman 2001 [DIRS 156122], Section 5.3.2.1).

As described in Appendix A, freshwater screening factors provided by NCRP-123 (NCRP 1996 [DIRS 101882], Table C.1)—adjusted to reflect the local biosphere and updated effective dose coefficients (EPA 2000 [DIRS 153733])—are used as the basis for the nominal, human-intrusion, and intrusive igneous scenarios (the groundwater scenarios) screening factors developed in this screening analysis. In the present analysis, the screening factors are adjusted by replacing the generic usage factors (NCRP 1996 [DIRS101882], Table 7.1) with YMP-generated usage factors (Section 4.1.2).

The nominal, human-intrusion, and intrusive igneous scenarios entail the transport of radionuclides to the accessible environment through groundwater. In contrast, the eruptive volcanic event bypasses the groundwater and injects radionuclides directly into the atmosphere. The freshwater screening factors include dose from: exposure to irrigated soil; consumption of drinking water, irrigated crops, and soil; consumption of milk and meat from animals that consume irrigated forage; and consumption of freshwater fish (NCRP 1996 [DIRS 101882], Section 8.2.2). Neglect of these factors in Revision 01 of this document (BSC 2002 [DIRS 160059]) drew comments from the NRC, which noted that "processes that affect transport in the biosphere, such as uptake by plants and bioaccumulation are not accounted for," and that "the direct exposure pathway is not accounted for" (Beckman 2001 [DIRS 156122], Section 5.3.2.1). The generic usage factors built in to the NCRP screening factors apply to a generic biosphere. The NCRP development of the freshwater screening factors acknowledges the use of agricultural irrigation, so the resulting screening factors were intended to apply to climates where irrigation is practiced. The sorption adjustment factors do not play any role in the pathways for ingestion of water, soil, or locally produced terrestrial food. Appendix A describes the development of screening factors based on the replacement of the NCRP usage factors by YMP-generated values.

The following sections describe how the screening analysis accounts for exposure time and variation in waste package contents, how the screening sets are determined for the groundwater scenarios, and how RadNuScreen 1.0 performs the screening.

6.2.2 Accounting for Variations in Waste Packages

Some waste packages will contain spent CSNF (BWR, PWR, and MOX) fuel only, while others will contain canisters of vitrified HLW only and others will contain a mixture of canisters, each of which contains either DOE SNF or HLW. As indicated by the data in Tables 4-5 through 4-13, there is considerable variability in the radionuclide inventory of these waste form types. In addition, the design of the transportation, aging, and disposal canister and the fuel baskets varies according to intended contents. Under such conditions, the random failure of only a few waste packages or systematic differences in breach time or radionuclide transport characteristics that depend on waste form or waste package type could mean that any of the several waste forms could independently determine the most important radionuclides that contribute to dose at any point in time. Therefore, the screening calculation is performed for a broad range of CSNF, HLW, and DOE SNF waste types in order to capture the variability in the inventories of the waste form types that may contribute to dose at any point in time.

6.2.3 Accounting for Time of Exposure

Due to radioactive decay and in-growth, the radionuclide inventory in each waste form changes over time. Therefore, the screening analysis is performed independently at a number of times spanning the period up to a million years after emplacement and is approximately evenly spaced on a logarithmic scale (at multiples of roughly two to three). Screening analyses are conducted for screening times of 100, 200, 300, 500, 1,000, 2,000, 5,000, and 10,000 years after emplacement. In addition, an independent screening for times at 20,000, 30,000, 100,000, 300,000, and 1 million years after emplacement is also performed. These sets of screening times capture the main features of the changing relative activities of dominant radionuclides (Benedict et al. 1981 [DIRS 103523], Figure 11.29). To be screened out for the 10,000-year regulatory period, a radionuclide must be screened out at all times less than or equal to 10,000 years. Likewise, for the screening analysis for times after 10,000 yrs, to be screened out generally, a radionuclide must be screened out at all screening times between 10,000 and 1 million years.

The projected radionuclide inventories of each of the waste forms for each of the screening times listed above are input data to this analysis for PWR and BWR fuels (Table 4-1). The radionuclide inventories, at each of the screening times, for HLW (including LaBS glass), DOE SNF, MOX fuel, and the metal and ceramic waste forms from EBRII fuel processing, are calculated as part of this analysis using GoldSim V 8.02.500 (see Section 3.1). The inputs to these inventory calculations are provided in the workbook `InitialRadInvData_JCC010207.xls`. The input data compiled in this workbook include the radionuclide half-life data (Table 4-3), the radionuclide branching ratio data (Table 4-4) and the initial radionuclide inventory data (Tables 4-5 through 4-13). These inputs are used to develop the GoldSim inputs that are echoed in the GoldSim output compiled in the Excel workbook `GoldSim_Cunnane_Input_and_Results_Q_Rev03.xls` included in Appendix C. GoldSim initially calculated the radionuclide inventory at the year 2060 (see the output file *Decay_Calcs_Pre_2060_Q_Rev03.gsm* in Appendix C); the file *Decay_Calcs_Pre_2060_Q_Rev03.gsm* in Appendix C includes the calculated radionuclide inventories for each of the screening times indexed to the year 2060. An activity correction factor for ^{79}Se is used to correct the erroneous half-life that was used in the PWR and BWR activity calculations (Appendix B). As noted at the bottom of Table 4-5, the ^{113}Cd inventory given for sludge batches 2 and 3 appears to be incorrect (the specific activity of ^{113}Cd makes it very unlikely that this value can be correct). It is plausible that this inventory should have been assigned to ^{113m}Cd. For this reason the ^{113}Cd inventory in Table 4-5 was assigned to ^{113m} Cd for the GoldSim calculations (Appendix C). This change in the input data remains to be verified (see Assumption 4, TBV-7772).

6.2.4 Accounting for Sorption and Solubility

For groundwater scenarios, elements are grouped into three sorption classes: high (H), medium (M), and low (L). Different modes of transport to the accessible environment may sort chemical elements according to sorption class (Table 6-2). The screening analysis allows for the possibility that any of the identified modes of transport may dominate at any time. Under some conditions, fracture flow may allow highly sorbing elements to be transported by colloids while low-sorbing and medium-sorbing elements travel in solution (Table 6-2, first row after header). Under more restrictive fracture-flow conditions, highly sorbing elements may attach to fracture walls and colloids may be filtered out, so that highly sorbing elements are discriminated against while medium-sorbing and low-sorbing elements travel in solution (Table 6-2, second row). Matrix flow discriminates in favor of low-sorbing elements due to the prolonged intimate contact of the groundwater with the rock matrix, during which medium-sorbing and highly sorbing elements are likely to sorb to the fracture walls or to colloids, which are likely to be filtered out (Table 6-2, last row). The sorption class combinations identified in Table 6-2 are used to form screening sets as described in Table 6-5.

Table 6-2. How Flow Conditions May Discriminate According to Sorptivity in the Groundwater Scenarios

Groundwater Flow Conditions	Favored Sorption Classes
Fracture flow, rich in colloids	High, Medium, and Low
Fracture flow, low in colloids	Medium and Low
Matrix flow (no colloids)	Low

The sorption classes given by the columns of Table 6-3 are assumed for the groundwater scenarios. The rationale for this assumption, which is strong enough to justify a claim that further confirmation is not required, is as follows. With the exception of some adjustments (to be detailed below), the classification corresponds to the NCRP assignment of freshwater sorption adjustment factors in a report that addresses screening techniques for releases of radioactive materials to the environment (NCRP 1996 [DIRS 101882], Table 6.1).

NCRP-123 assigns dimensionless adjustment factors of 0, 0.1, 1, and 10 to adjust the dose contributions from radionuclides in shoreline deposits (NCRP 1996 [DIRS 101882], pp. 69 and 70). Initial classifications are made here by assigning a correspondence as follows: the "Low" sorption class (L) corresponds to the 0 and 0.1 adjustment factors from the NCRP report; "Medium" (M) corresponds to an adjustment factor of 1; "High" (H) corresponds to an adjustment factor of 10. The NCRP derived the sorption adjustment factors from summary data on sorption to sediments at freshwater and marine shorelines.

The NCRP freshwater adjustment factors are used as an initial basis for the sorption classifications because NCRP freshwater values provide a rough but consistent indicator of sorptivity under freshwater conditions. Corroboration of this assumption is provided by YMP-generated sorption-coefficient distributions recommended for unsaturated and saturated conditions (CRWMS M&O 2001 [DIRS 154024], Tables 2a and 2b). The recommended sorption-coefficient distributions are consistent with the classifications derived from NCRP-123 for chlorine, iodine, and technetium (Low); carbon, nickel, neptunium, protactinium, selenium, strontium, and uranium (Medium); and actinium, americium, lead, plutonium, samarium, thorium, and zirconium (High). Note also that, although cesium, niobium, and radium were assigned sorption adjustment factors of 1 in the NCRP report (NCRP 1996 [DIRS 101882]), it is more consistent with recommended site-specific sorption values to assign cesium, niobium, and radium to the High sorption class. Although NCRP-123 (NCRP 1996 [DIRS 101882]) gives sorption adjustment factor of 0.1 for cadmium, cadmium was placed in the High sorption class due to evidence (EPA 1999 [DIRS 147475], Vol. II, Table 5.4) that indicates that the range of cadmium sorptivity more closely resembles the range of other elements assigned to the High sorption class (CRWMS M&O 2001 [DIRS154024], Tables 2a and 2b). Tin, which was assigned a sorption adjustment factor of 1 in the NCRP report, could reasonably have been placed in either the High or Medium classes based on the distributions presented by *Unsaturated Zone and Saturated Zone Transport Properties (U0100)* (CRWMS M&O 2001 [DIRS 154024], Tables 2a and 2b). Tin was placed in the High sorption class due to evidence that tin is highly sorbing compared to selenium and uranium under a range of geochemical conditions (Ticknor et al. 1996 [DIRS 159212], Abstract, p. 24, Table 11; Crowe and Vaniman 1985 [DIRS 159215], pp. 33 through 37).

It is recognized that sorptivity may vary depending on water chemistry, temperature, nature of the surrounding rock, and other variables. Class assignments are insensitive to uncertainties in sorptivity because only a rough division into three sorption classes has been done. The results of the screening analysis are insensitive to uncertainties in class assignments because the most important radionuclides have high enough radionuclide-screening products that they will not be screened out regardless of their assigned class. At worst, this assumption could lead marginally important radionuclides to be improperly screened out.

Table 6-3. Solubility and Sorption Classes for the Screening Analysis

Solubility Class	Sorption Class		
	Low (L)	**Medium (M)**	**High (H)**
High (H)	Ar, Cl, H, Rn, Fr,I, K, Kr, At, Rb, Tc, Na, Re, Ru	C, Os Se, Sr	Cs
Medium (M)	Mo, Rh, Sb,Te	Ag, Ba, Ca, Bi Eu, Gd, La, V, Zn Ni, Np, U, Be, Ho, Si, Tl	Ac, Am, Cf, Bk Cm, Pd, Pm, Pu, Ra, Sm, Th, Tm, Ce, Co, Fe, In, Ir, Lu, Mn, Nd, Po, Tb, Y, Pr
Low (L)	P	Pa, Pt	Cd, Nb, Pb, Sn, Zr, Hf, Ta

The solubility classes given by Table 6-3 are assumed for the groundwater scenarios. The solubility classifications roughly reflect the ability of solubility limits to restrict mobilization and transport to the accessible environment. It is recognized that solubility may vary over several orders of magnitude depending on water chemistry, temperature, composition of the surrounding rock, and other variables. Rough definitions of the solubility classes are: High (H): greater than or equal to 0.1 mol/L (or mol/kg); Medium (M): less than 0.1 but greater than 10^{-6} mol/L (or mol/kg), Low (L): less than or equal to 10^{-6} mol/L (or mol/kg). The rationale for the class assignments is provided in the following paragraphs.

For the most important elements, other YMP documents provide corroborating information for the class assignments. For some of the less important elements, due to their apparent lack of importance to repository performance, little YMP work has been done to estimate solubility under site-specific conditions. In these cases, approximate solubilities for plausible controlling solids were used. Class assignments are not sensitive to uncertainties in solubility limits because the solubility classes span several orders of magnitude. The results of the screening analysis are insensitive to uncertainties in class assignments because the most important radionuclides have high enough radionuclide-screening products that they will not be screened out regardless of their assigned class. Table 6-4 provides solubility class assignments and rationale.

In the groundwater scenarios, solubility affects the ability of an element in the waste form to mobilize within the degraded waste package and transport through groundwater to the accessible environment. The greater the solubility of an element, the greater the likelihood that its isotopes will be mobilized sufficiently to affect repository performance. For this analysis, elements are grouped into three solubility classes: high (H), medium (M), and low (L). The solubility and sorption classes are used to form screening sets as described in Table 6-5. The three solubility classes serve to divide the elements into sets based on alternative low-solubility cutoffs. Thus, with no consideration of solubility, all three classes are included: H, M, and L (see the first row of Table 6-5). A relatively high solubility cutoff discounts only the least soluble elements, leaving H and M solubility elements to be considered together (Table 6-5, second row). The most restrictive sets consider only the most soluble elements as possible contributors to dose (Table 6.5, last row). Within each screening set, no further account is taken of differences in solubility. In effect, within each screening set, solubility limits do not apply. Instead, the screening analysis represents each radionuclide in proportion to its fraction of the inventory, not in accordance with solubility limits that might apply to the element in question.

Table 6-4. Solubility Class Assignments and Rationales

Element	Rationale for Solubility Class Assignment
High (> ~0.1 mol/L)	
Ar, Kr, Rn	Transport of noble gasses is not restricted by solubility limits because they can travel in the gaseous phase.
Cl	Forms naturally occurring, highly soluble ionic compounds with alkali metals, for example, KCl (sylvite) and NaCl (halite) (Weast 1978 [DIRS 128733], B-150, B-165; Pauling 1970 [DIRS 157543], Figure 13-3, Section 13-4).
H, Na, K, Rb	Form compounds with halogens, for example, NaCl, KCl (sylvite), RbCl, and HCl, which are highly soluble (Weast 1978 [DIRS 128733], B-123, B-150, B-157; Pauling 1970 [DIRS 157543], Figure 13-3, Section 13-4).
C, Cs, I, Sr, Tc, Re, At, Fr	Highly soluble (BSC 2001 [DIRS 155455], pp. 54 and 55). Re has analogous chemistry to Tc (Cotton 1999 [DIRS 157545], Section 18-D). At is assigned to this group by analogy to I and Fr is assigned by analogy to Cs.
Os, Ru	The solubility of OsO_4 is about (6.44g/100g) $\times$ (I,000g/L) / (254.2g/mol) = 0.25 mol/L. RuO_4 is slightly soluble in water (Lide 2006 [DIRS 178081], pp. 4-44 to 4-101).
Se	Highly soluble, most likely solubility of 0.1 mol/L (CRWMS M&O 1998 [DIRS 100362], Table 6-32, p. 6-84).

Table 6-4. Solubility Class Assignments and Rationales (Continued)

Element	Rationale for Solubility Class Assignment
Medium (> ~10^{-6} mol/L; < ~0.1 mol/L)	
Mo	With naturally occurring molybdite (MoO_3) as the controlling solid, in cold water, solubility = (0.1 g/100 cc) / (143.94 g/mol) × 1,000 cc/L = 7 × 10^{-3} mol/L (Weast 1978 [DIRS 128733], p. B-139; CRWMS M&O 2001 [DIRS 154629], Section 6.3.4).
Ag	With naturally occurring horn sliver (AgCl) as the controlling solid, in cold water, solubility = (8.9 × 10^{-5} g/100 cc)/(143.32 g/mol) × 1,000 cc/L = 6.2 × 10^{-6} mol/L (Weast 1978 [DIRS 128733], pp. B-52, B-53, and B-162).
Ba	Taking naturally occurring barite ($BaSO_4$) as controlling, the solubility of Ba in cold water is about (2 × 10^{-4} g/100 cc) / (233.4 g/mol) × 1,000 cc/L = 9 × 10^{-2} mol/L (Weast 1978 [DIRS 128733], pp. B-11and B-99), which is on the upper end of the M class. According to another source, $BaSO_4$ has a solubility of less than about 10^{-2} mol/L (Pauling 1970 [DIRS 157543], Section 13-4), which places barium solidly in the M class.
Be	$Be(OH)_2$ is slightly soluble in water and alkali; soluble in acid. BeO is insoluble in water and slightly soluble in alkali (Lide 2006 [DIRS 178081], pp. 4-44 to 4-101)
Ca	Taking $CaCO_3$ as the controlling solid, note that J-13 water is saturated or nearly so in $CaCO_3$ and has 13 mg/L Ca, that is, 13 mg/L / [(1,000 mg/g) × (40 g/mol)] = 3.3 × 10^{-4} mol/L (DTN: MO0006J13WTRCM.000 [DIRS 151029]). Also, the solubility of $CaCO_3$ in cold water is about (0.0014 g/100 cc) / (100.09 g/mol) × 1,000 cc/L= 1.4 × 10^{-4} mol/L (Weast 1978 [DIRS 128733], p. B-105). One could argue that near saturation would inhibit the dissolution of calcium in the waste form. However, calcium is assigned to M because the M class spans several orders of magnitude and because percolating unsaturated storm water could transport calcium.
La, Ce, Pm, Pr, Eu, Ho, Lu, Nd, Tb, Tm, Y	Lanthanides have similar chemical properties (Cotton 1999 [DIRS 157545], Section 19.1) and gadolinium is assigned to M. Y has similar chemistry to the lanthanides (Cotton 1999 [DIRS 157545], Section 19.1); $Y(OH)_3$ is insoluble in water and Y_2O_3 is soluble in dilute acid (Lide 2006 [DIRS 178081], p. 4-44 to 4-101).
Gd	Taking $GdOHCO_3$ as the controlling solid gives a solubility of about 10^{-6} mol/L at neutral pH and normal atmospheric partial pressure of CO_2 (CRWMS M&O 1997 [DIRS 100222], Table C-1).
Ni, Co, Fe, Mn, V, Ta	Log uniform distribution from 1.4 × 10^{-6} to 3.1 mol/L (mean = $\sqrt{(1.4 \times 10^{-6} \times 3.1)}$ = 2.1 × 10^{-3} mol/L) (CRWMS M&O 2000 [DIRS 143569], Table 19, p. 41). The solubility of $CoCO_3$ in water at 20°C is about (0.00014 g/100g) × (I,000 g/L) / (118 g/mol) = 1.2 × 10^{-5} mol/L. The solubility of $Fe(OH)_2$ is about (0.000052 g/100g) × (I,000 g/L) / (89.8 g/mol) = 5.8 × 10^{-6} mol/L. The solubility of $Mn(OH)_2$ is about (0.00034 g/100g) × (I,000 g/L) / (88.9 g/mol) = 3.8 × 10^{-5} mol/L (Lide 2006 [DIRS 178081], pp. 4-44 to 4-101).
Np	Solubility 4.28 × 10^{-5} mol/L at pH 7 and CO_2 fugacity 10^{-3} bar (BSC 2001 [DIRS 155455], Table 14).
U	Solubility 2.04 mg/L at pH 7 and 30°C (BSC 2001 [DIRS 155455], Table 10). For approximate atomic weight 238, this is (2.04 mg/L) / (238 g/mol) × (10^{-3} g/mg) = 8.6 × 10^{-6} mol/L.
Ac, Bk, Cf	Actinides have similar chemical properties (Cotton 1999 [DIRS 157545], Section 20.1), and thorium, uranium, neptunium, plutonium, and americium are assigned to M.
Am	A solubility of 1.8 × 10^{-6} mol/L at pH 7 and CO_2 fugacity of 10^{-3} bar is suggested for americium (BSC 2001 [DIRS 155455], Table 17).
Cm, Sm	Assigned to M as americium analogues (CRWMS M&O 2000 [DIRS 143569], p. 40).
In, Tl	In_2O_3 is insoluble in water (Lide 2006 [DIRS 178081], pp. 4-44 to 4-101).
Ir, Rh	Ir_2O_3 is insoluble in water (Lide 2006 [DIRS 178081], pp. 4-44 to 4-101).
Pd	Log uniform distribution from 9.4 × 10^{-6} to 9.4 × 10^{-2} mol/L (CRWMS M&O 1998 [DIRS 100362], Table 6-32).
Pu	Solubility 2.22 × 10^{-4} mol/kg at pH 7 and CO_2 fugacity 10^{-3} bar (BSC 2001 [DIRS 155455], Table 16).
Ra	Solubility 2.3 × 10^{-6} mol/L is recommended (BSC 2001 [DIRS 155455], p. 54, Table 19).

Table 6-4. Solubility Class Assignments and Rationales (Continued)

Element	Rationale for Solubility Class Assignment
Sb, Bi	The solubility of Sb_2O_5 is about (0.3 g/100g) × 1,000 g/L) / (333.5 g/mol) = 0.009 mol/L. $Bi(OH)_3$ and Bi_2O_3 are insoluble in water (Lide 2006 [DIRS 178081], pp. 4-44 to 4-101).
Si	The concentration of Si in J-13 well water is about 28.5 mg/L, i.e., about 1×10^{-3} mol/L (DTN: MO0006J13WTRCM.000).
Th	Solubility 1.0×10^{-5} mol/L is recommended (BSC 2001 [DIRS 155455], p. 54, Table 19).
Te, Po	Te oxides are insoluble in water (Lide 2006 [DIRS 178081], pp. 4-44 to 4-101).
Zn	The solubility of $Zn(OH)_2$ is about (0.000042 g/100g) x (1000 g/L) / (99.4 g/mol) = 4.2×10^{-6} mol/L.
Low (< ~10^{-6} mol/L)	
Pa	A log uniform distribution from 10^{-10} to 10^{-5} mol/L (mean = 8.68×10^{-7} mol/L) is given (BSC 2001 [DIRS 155455], p. 55, Table 19).
Pt	Platinum is chemically unreactive and is found in nature in native alloys (Pauling 1970 [DIRS 157543], Section 20-7). Because elemental platinum is insoluble even in hydrochloric and nitric acids (Weast 1978 [DIRS 128733], p. B-42.), platinum is placed in L.
Sn	Solubility 5.0×10^{-8} mol/L is suggested (CRWMS M&O 2000 [DIRS 143569], p. 42, Table 19).
Cd	Cadmium concentrations in natural waters saturated with respect to otavite ($CdCO_3$) may be as high as 0.25 ppm (or mg/kg) (Carroll et al. 1998 [DIRS 144731], p. 960 and Figure 3E), that is, 0.25 mg/kg / [(1,000 mg/g) × (112 g/mol)] = 2.2×10^{-6} mol/kg, though cadmium concentrations this high in natural waters are rare (Langmuir 1997 [DIRS 100051], Table 8.13). Taking otavite as the controlling solid, the solubility cited (2.2×10^{-6} mol/kg) would place cadmium roughly at the bottom of M. However, because a solid solution of otavite and calcite ($CaCO_3$) may greatly reduce cadmium solubility (Langmuir 1997 [DIRS 100051], pp. 14 and 15), cadmium is placed in L.
Nb, Ta	Solubility 1.0×10^{-7} mol/L is suggested (CRWMS M&O 2000 [DIRS 143569], p. 41, Table 19). Ta_2O_5 is insoluble in water and acid (Lide 2006 [DIRS 178081], p. 4-93).
Pb	Log uniform distribution from 10^{-10} to 10^{-5} mol/L (mean = $\sqrt{(10^{-10} \times 10^{-5})} = 3.2 \times 10^{-8}$ mol/L) (BSC 2001 [DIRS 155455], p. 55, Table 19).
Zr, Hf	Solubility 6.8×10^{-10} mol/L is suggested (CRWMS M&O 2000 [DIRS 143569], p. 41, Table 19). The chemistry of Hf is similar to Zr (Cotton 1999 [DIRS 157545], Section 18-A)
P	Forms insoluble phosphates; concentration of about 0.12 ppm in J-13 well water (Harrar 1990 [DIRS 100814], Table 4.2)

6.2.5 Determining the Screening Sets

The considerations given in Section 6.2.4 result in a rule for combining solubility and sorption classes into screening sets for the groundwater scenarios. That is: consider the combinations of the solubility groupings H, M, and L; H and M; and H with the sorption groupings H, M, and L; M and L; and L.

Table 6-5 provides descriptions of the nine resulting screening sets. The elements included in each screening set are given in Table 6-6.

Table 6-5. Groundwater Scenario Screening Set Descriptions

Solubility Class Combinations	Sorption Class Combinations		
	H, M, and L	**M and L**	**L**
H, M, and L	Colloidal transport is important; solubility limits do not inhibit mobilization or transport. Neither solubility limits nor sorption limit radionuclide transport.	Colloidal transport is not important, highly sorbing elements are immobilized, but medium sorbing elements are allowed to pass; solubility limits do not inhibit mobilization or transport.	Colloidal transport is not important, highly and moderately sorbing elements are immobilized, but low sorbing elements are allowed to pass; solubility limits do not inhibit mobilization or transport.
H and M	Colloidal transport is important but solubility limits inhibit mobilization of the least soluble elements.	Colloidal transport is not important, highly sorbing elements are immobilized, but medium sorbing elements are allowed to pass; however, solubility limits inhibit mobilization of the least soluble elements.	Colloidal transport is not important, highly and moderately sorbing elements are immobilized, but low sorbing elements are allowed to pass; however, solubility limits inhibit mobilization of the least soluble elements.
H	Colloidal transport is important but solubility limits inhibit mobilization of all but the most soluble elements.	Colloidal transport is not important, highly sorbing elements are immobilized, but medium sorbing elements are allowed to pass; however, solubility limits inhibit mobilization of all but the most soluble elements.	Colloidal transport is not important, highly and moderately sorbing elements are immobilized, but low sorbing elements are allowed to pass; however, solubility limits inhibit mobilization of all but the most soluble elements.

Table 6-6. Lists of Elements in Each Screening Set

Solubility Class Combinations	Sorption Class Combinations		
	H, M, and L	**M and L**	**L**
H, M, and L	Ac, Ag, Am, Ar, Ba, C, Ca, Cd, Cf, Cl, Cm, Cs, Eu, Gd, H, I, K, Kr, La, Mo, Nb, Ni, Np, Pa, Pb, Pd, Pm, Pt, Pu, Ra, Rb, Se, Sm, Sn, Sr, Tc, Th, Tm, U, Zr, Bk, Be, Ce, Co, Fe, Hf, Ho, In, Ir, Lu, Mn, Na, Nd, Os, Re, Rh, Ru, Sb, Si, Te, Tl, V, Zn, At, Bi, Fr, P, Po, Pr, Rn, Ta, Tb, Y	Ag, Ar, Ba, C, Ca, Cl, Eu, Gd, H, I, K, Kr, La, Mo, Ni, Np, Pa, Pt, Rb, Se, Sr, Tc, U, Rn, Fr, At, Na, Re, Ru, Te, Os, Rh, Sb, Bi, V, Zn, Be, Ho, Si, Tl, P	Ar, Cl, H, I K, Kr, Mo, Rb, Tc, Rn, Fr, At, Na, Re, Ru, Rh, Sb, P
H and M	Ac, Ag, Am, Ar, Ba, C, Ca, Cf, Cl, Cm, Cs, Eu, Gd, H, I, K, Kr, La, Mo, Ni, Np, Pd, Pm, Pu, Ra, Rb, Se, Sm, Sr, Tc, Th, Tm, U, Rn, Fr, At, Na, Re, Ru, Te, Os, Rh, Sb, Bi, V, Zn, Be, Ho, Si, Tl, Bk, Ce, Co, Fe, In, Ir, Lu, Mn, Nd, Po, Tb, Y	Ag, Ar, Ba, C, Ca, Cl, Eu, Gd, H, I, K, Kr, La, Mo, Ni, Np, Rb, Se, Sr, Tc, U, Rn, Fr, At, Na, Re, Ru, Te, Os, Rh, Sb, Bi, V, Zn, Be, Ho, Si, Tl	Ar, Cl, H, I, K, Kr, Mo, Rb, Tc, Rn, Fr, At, Na, Re, Ru, Rh, Sb,
H	Ar, C, Cl, Cs, H, I, K, Kr, Rb, Se, Sr, Tc, Rn, Fr, At, Na, Re, Ru, Te, Os,	Ar, C, Cl, H, I, K, Kr, Rb, Se, Sr, Tc, Rn, Fr, At, Na, Re, Ru, Te, Os	Ar, Cl, H, I, K, Kr, Rb, Tc, Rn, Fr, At, Na, Re, Ru

6.2.6 Operational Description of the Screening Software

RadNuScreen 1.0 is used to perform calculations, rankings, and screenings required for the screening analysis described in Section 6.2.1. The fundamental calculation performed by the software is to multiply the activity of a radionuclide by a screening factor. The resulting product may be called a screening product. As the basic screening operation, RadNuScreen 1.0 ranks radionuclides based on the magnitudes of the screening products, sums the screening products in rank order to form the cumulative screening product for each radionuclide, and applies a screening cutoff limit. The software performs the basic screening operation for two exposure scenarios (groundwater and eruptive) for each screening time (Section 6.2.3). For the groundwater scenarios, multiple repetitions of the basic screening operation are required to cover all of the screening sets (see Table 6.6). The user must execute separate RadNuScreen 1.0 runs for each waste form under consideration (Section 6.2.2).

RadNuScreen 1.0 requires the user to provide the inputs listed below. For further information on RadNuScreen 1.0, see *Software Management Report (SMR) FOR RadNuScreen 1.0* (BSC 2002 [DIRS 158525]).

- The activity of each radionuclide in each waste form at each screening time. These inventories were obtained from the compilation of the GoldSim decay results in the Excel workbooks `GoldSim_Cunnane_Input_and_Results_Q_Rev03.xls`, and also from `PWR_000-00C-MGR0-00100-000-00BATTACH_IX.xls`, and `BWR_000-00C-MGR0-00200-000-00aATTACH_XIII.xls` (see Appendix C).

- Groundwater and eruptive screening factors for each radionuclide under consideration. The groundwater and eruptive screening factors are presented in the Excel workbook `Site-Specific Screening Factors_01-30-2007.xls` (see Appendix C).

- Solubility and sorption classes for each radionuclide. Three solubility classes (High, Medium, and Low) and three sorption classes (High, Medium, and Low) are allowed.

- Compositions of the groundwater screening sets as combinations of solubility and sorption classes (see, for example, the column and row headers of Table 6-6).

- Coarse-screen and fine-screen cutoff levels (95% and 99% were used in the present screening analysis).

- Decay half-lives for each radionuclide and the half-life cutoff that RadNuScreen will use to discriminate between long- and short-lived radionuclides. Except for the optional ^{79}Se correction, RadNuScreen 1.0 uses half-lives only to exclude short-lived radionuclides from the groundwater screening. The specified half-lives and half-life cutoffs have no effect on the eruptive screening. The half-life cutoff was set equal to zero for the screening analyses described in this document to ensure that all radionuclides that are likely to contribute to dose are considered in the screening analysis regardless of their half-lives.

The RadNuScreen output files are included in three folders in Appendix C (BWR PWR MOX UserWorkbooks, HLW UserWorkbooks, and DOE SNF UserWorkbooks). Each of the files in these workbooks shows the RadNuScreen 1.0 input as well as the results. Because the radionuclide array dimensions in RadNuScreen 1.0 limit the list of radionuclides to two hundred or less, some radionuclides for which either the inventory and/or the screening factors were equal to zero were deleted from the RadNuScreen 1.0 input. The deleted radionuclides were from the following list: ^{109m}Ag, ^{110}Ag, ^{239}Am, ^{39}Ar, ^{42}Ar, ^{132}Ba, ^{243}Bk, ^{150}Gd, ^{232}Pa, ^{234m}Pa, ^{106}Rh, ^{91}Nb, ^{92}Nb, ^{240m}Np, ^{211}Po, ^{212}Po, ^{64}Zn, ^{96}Zr, ^{130}Te, and ^{210}Tl.

The results for radionuclides that are screened in at both the 95% and 99% screening product cutoff levels for the periods up to 10,000 years and from 10,000 to 1,000,000 years are compiled in the Excel workbook `Screening SummaryREV02.xls` (Appendix C).

6.3 RESULTS

6.3.1 10,000-Year Period

The screening results for the 10,000-year period, which were produced using RadNuScreen 1.0, are provided in Table 6-7. Appendix C (a compact disc) provides Excel workbook files that list the inputs for RadNuScreen 1.0 and provide detailed results for every waste form and screening time; Appendix C lists the contents of the compact disc. A file (`Screening SummaryREV02.xls`) that summarizes the results for each waste form is also included. The formal screening was conducted using a screening-product cutoff of 0.95. The results listed for a 0.99 cutoff allow the reader to identify the marginally important radionuclides. The marginally important radionuclides might not have been screened out, had inputs or assumptions been significantly different. The rightmost two columns give the unions of the groundwater and eruptive sets. The results for the union of the groundwater and eruptive sets in Table 6-7 show that ^{227}Ac, ^{217}At, ^{244}Cm, ^{245}Cm, ^{221}Fr, ^{166m}Ho, ^{63}Ni, ^{236}Np, ^{233}Pa, ^{210}Pb, ^{241}Pu, ^{242}Pu, ^{223}Ra, ^{226}Ra, ^{228}Ra, ^{126}Sb, ^{230}Th, ^{232}Th, ^{235}U, and ^{90}Y are identified as marginally significant for the 10,000-year period.

6.3.2 Times Beyond the 10,000-Year Period up to 1 Million Years

The screening results from RadNuScreen 1.0 for times beyond the 10,000-year regulatory period, up to 1 million years after emplacement, are provided in Table 6-8. Appendix C (a compact disc) provides Excel workbook files that list the inputs for RadNuScreen 1.0 and provide detailed results for every waste form and screening time; Appendix C lists the contents of the compact disc. A file (`Screening SummaryREV02.xls`) that summarizes the results for each waste form is also included. The formal screening was conducted using a screening-product cutoff of 0.95. The results listed for a 0.99 cutoff allow the reader to identify the marginally important radionuclides. The rightmost two columns give the unions of the groundwater and eruptive sets. The results for the union of the groundwater and eruptive sets in Table 6-8 show that ^{241}Am, ^{217}At, ^{245}Cm, ^{221}Fr, ^{94}Nb, ^{236}Np, ^{233}Pa, ^{224}Ra, ^{126}Sb, ^{228}Th, and ^{93}Zr are identified as marginally significant for the period between 10,000 years and 1,000,000 years.

6.4 OTHER SCREENING FACTORS CONSIDERED AND REJECTED

In the course of developing the screening analysis, two alternative sets of screening factors were considered and rejected. First, unadjusted screening factors directly from NCRP-123 (NCRP 1996 [DIRS 101882]) were considered. It was found that the NCRP screening factors, which were not intended to apply specifically to a sparsely populated arid environment, overemphasized some pathways (in particular, consumption of fish, milk, and soil), as can be easily seen in retrospect from the adjustment factors calculated in Appendix C.

Second, a hybrid set of screening factors, based on biosphere dose conversion factors from Yucca Mountain viability-assessment and site-recommendation studies, where available, and NCRP screening factors wherever YMP-generated dose conversion factors were unavailable, was considered. The presumed advantage of the hybrid approach was that the forty or so most important radionuclides would be represented by YMP-generated screening factors and the NCRP factors would apply only to the less important radionuclides. However, it was found that differences in methods used in the various sources, such as treatments of radionuclide buildup in soil and the relative importance of exposure pathways, precluded the development of an internally consistent set of screening factors.

Table 6-7. Screening Results for the 10,000-Year Period

Radionuclide	Screening Results by Transport Scenario and Screening Product Cutoff Fraction					
	Groundwater Scenarios		Eruptive Igneous Scenario		Union of Sets for Groundwater and Eruptive Scenarios	
	0.95	0.99	0.95	0.99	0.95	0.99
^{225}Ac	^{225}Ac	^{225}Ac			^{225}Ac	^{225}Ac
^{227}Ac		^{227}Ac		^{227}Ac		^{227}Ac
^{241}Am	^{241}Am	^{241}Am	^{241}Am	^{241}Am	^{241}Am	^{241}Am
^{243}Am	^{243}Am	^{243}Am	^{243}Am	^{243}Am	^{243}Am	^{243}Am
^{217}At		^{217}At				^{217}At
^{14}C	^{14}C	^{14}C			^{14}C	^{14}C
^{36}Cl	^{36}Cl	^{36}Cl			^{36}Cl	^{36}Cl
^{244}Cm		^{244}Cm		^{244}Cm		^{244}Cm
^{245}Cm		^{245}Cm		^{245}Cm		^{245}Cm
^{135}Cs	^{135}Cs	^{135}Cs			^{135}Cs	^{135}Cs
^{137}Cs	^{137}Cs	^{137}Cs	^{137}Cs	^{137}Cs	^{137}Cs	^{137}Cs
^{221}Fr		^{221}Fr				^{221}Fr
^{166m}Ho		^{166m}Ho				^{166m}Ho
^{129}I	^{129}I	^{129}I			^{129}I	^{129}I
^{63}Ni		^{63}Ni				^{63}Ni
^{236}Np		^{236}Np				^{236}Np
^{237}Np	^{237}Np	^{237}Np		^{237}Np	^{237}Np	^{237}Np
^{239}Np	^{239}Np	^{239}Np			^{239}Np	^{239}Np

Table 6-7. Screening Results for the 10,000-Year Period (Continued)

Radionuclide	Screening Results by Transport Scenario and Screening Product Cutoff Fraction					
	Groundwater Scenarios		Eruptive Igneous Scenario		Union of Sets for Groundwater and Eruptive Scenarios	
	0.95	0.99	0.95	0.99	0.95	0.99
^{231}Pa	^{231}Pa	^{231}Pa		^{231}Pa	^{231}Pa	^{231}Pa
^{233}Pa		^{233}Pa				^{233}Pa
^{210}Pb		^{210}Pb				^{210}Pb
^{210}Po	^{210}Po	^{210}Po		^{210}Po	^{210}Po	^{210}Po
^{238}Pu	^{238}Pu	^{238}Pu	^{238}Pu	^{238}Pu	^{238}Pu	^{238}Pu
^{239}Pu	^{239}Pu	^{239}Pu	^{239}Pu	^{239}Pu	^{239}Pu	^{239}Pu
^{240}Pu	^{240}Pu	^{240}Pu	^{240}Pu	^{240}Pu	^{240}Pu	^{240}Pu
^{241}Pu		^{241}Pu		^{241}Pu		^{241}Pu
^{242}Pu		^{242}Pu		^{242}Pu		^{242}Pu
^{223}Ra		^{223}Ra				^{223}Ra
^{225}Ra	^{225}Ra	^{225}Ra		^{225}Ra	^{225}Ra	^{225}Ra
^{226}Ra		^{226}Ra		^{226}Ra		^{226}Ra
^{228}Ra		^{228}Ra				^{228}Ra
^{126}Sb		^{126}Sb				^{126}Sb
^{79}Se	^{79}Se	^{79}Se			^{79}Se	^{79}Se
^{126}Sn	^{126}Sn	^{126}Sn	^{126}Sn	^{126}Sn	^{126}Sn	^{126}Sn
^{90}Sr	^{90}Sr	^{90}Sr	^{90}Sr	^{90}Sr	^{90}Sr	^{90}Sr
^{99}Tc	^{99}Tc	^{99}Tc		^{99}Tc	^{99}Tc	^{99}Tc
^{229}Th	^{229}Th	^{229}Th	^{229}Th	^{229}Th	^{229}Th	^{229}Th
^{230}Th		^{230}Th		^{230}Th		^{230}Th
^{232}Th		^{232}Th				^{232}Th
^{232}U	^{232}U	^{232}U		^{232}U	^{232}U	^{232}U
^{233}U	^{233}U	^{233}U	^{233}U	^{233}U	^{233}U	^{233}U
^{234}U	^{234}U	^{234}U	^{234}U	^{234}U	^{234}U	^{234}U
^{235}U		^{235}U				^{235}U
^{236}U	^{236}U	^{236}U			^{236}U	^{236}U
^{238}U	^{238}U	^{238}U			^{238}U	^{238}U
^{90}Y		^{90}Y				^{90}Y
Counts:	26	45	11	24	26	45

Source: `Screening SummaryREV02.xls` in Appendix C.

Table 6-8. Screening Results for Times beyond 10,000 Years and up to 1 Million Years

Radionuclide	Screening Results by Transport Scenario and Screening Product Cutoff Fraction					
	Groundwater Scenarios		Eruptive Igneous Scenario		Union of Sets for Groundwater and Eruptive Scenarios	
	0.95	0.99	0.95	0.99	0.95	0.99
^{225}Ac	^{225}Ac	^{225}Ac			^{225}Ac	^{225}Ac
^{227}Ac	^{227}Ac	^{227}Ac	^{227}Ac	^{227}Ac	^{227}Ac	^{227}Ac
^{241}Am		^{241}Am		^{241}Am		^{241}Am
^{243}Am	^{243}Am	^{243}Am	^{243}Am	^{243}Am	^{243}Am	^{243}Am
^{217}At		^{217}At				^{217}At
^{210}Bi	^{210}Bi	^{210}Bi		^{210}Bi	^{210}Bi	^{210}Bi
^{14}C	^{14}C	^{14}C			^{14}C	^{14}C
^{36}Cl	^{36}Cl	^{36}Cl			^{36}Cl	^{36}Cl
^{245}Cm		^{245}Cm		^{245}Cm		^{245}Cm
^{135}Cs	^{135}Cs	^{135}Cs		^{135}Cs	^{135}Cs	^{135}Cs
^{221}Fr		^{221}Fr				^{221}Fr
^{129}I	^{129}I	^{129}I	^{129}I	^{129}I	^{129}I	^{129}I
^{94}Nb				^{94}Nb		^{94}Nb
^{236}Np		^{236}Np		^{236}Np		^{236}Np
^{237}Np	^{237}Np	^{237}Np	^{237}Np	^{237}Np	^{237}Np	^{237}Np
^{239}Np	^{239}Np	^{239}Np			^{239}Np	^{239}Np
^{231}Pa	^{231}Pa	^{231}Pa	^{231}Pa	^{231}Pa	^{231}Pa	^{231}Pa
^{233}Pa		^{233}Pa				^{233}Pa
^{210}Pb	^{210}Pb	^{210}Pb	^{210}Pb	^{210}Pb	^{210}Pb	^{210}Pb
^{210}Po	^{210}Po	^{210}Po	^{210}Po	^{210}Po	^{210}Po	^{210}Po
^{239}Pu	^{239}Pu	^{239}Pu	^{239}Pu	^{239}Pu	^{239}Pu	^{239}Pu
^{240}Pu	^{240}Pu	^{240}Pu	^{240}Pu	^{240}Pu	^{240}Pu	^{240}Pu
^{242}Pu	^{242}Pu	^{242}Pu	^{242}Pu	^{242}Pu	^{242}Pu	^{242}Pu
^{223}Ra	^{223}Ra	^{223}Ra			^{223}Ra	^{223}Ra
^{224}Ra		^{224}Ra				^{224}Ra
^{225}Ra	^{225}Ra	^{225}Ra		^{225}Ra	^{225}Ra	^{225}Ra
^{226}Ra	^{226}Ra	^{226}Ra	^{226}Ra	^{226}Ra	^{226}Ra	^{226}Ra
^{228}Ra	^{228}Ra	^{228}Ra	^{228}Ra	^{228}Ra	^{228}Ra	^{228}Ra
^{222}Rn	^{222}Rn	^{222}Rn			^{222}Rn	^{222}Rn
^{126}Sb		^{126}Sb				^{126}Sb
^{79}Se	^{79}Se	^{79}Se			^{79}Se	^{79}Se
^{126}Sn	^{126}Sn	^{126}Sn	^{126}Sn	^{126}Sn	^{126}Sn	^{126}Sn
^{99}Tc	^{99}Tc	^{99}Tc	^{99}Tc	^{99}Tc	^{99}Tc	^{99}Tc

Table 6-8. Screening Results for Times beyond 10,000 Years and up to 1 Million Years (Continued)

Radionuclide	Screening Results by Transport Scenario and Screening Product Cutoff Fraction					
	Groundwater Scenarios		Eruptive Igneous Scenario		Union of Sets for Groundwater and Eruptive Scenarios	
	0.95	0.99	0.95	0.99	0.95	0.99
^{228}Th		^{228}Th				^{228}Th
^{229}Th	^{229}Th	^{229}Th	^{229}Th	^{229}Th	^{229}Th	^{229}Th
^{230}Th	^{230}Th	^{230}Th	^{230}Th	^{230}Th	^{230}Th	^{230}Th
^{232}Th	^{232}Th	^{232}Th	^{232}Th	^{232}Th	^{232}Th	^{232}Th
^{232}U	^{232}U	^{232}U		^{232}U	^{232}U	^{232}U
^{233}U	^{233}U	^{233}U	^{233}U	^{233}U	^{233}U	^{233}U
^{234}U	^{234}U	^{234}U	^{234}U	^{234}U	^{234}U	^{234}U
^{235}U	^{235}U	^{235}U		^{235}U	^{235}U	^{235}U
^{236}U	^{236}U	^{236}U		^{236}U	^{236}U	^{236}U
^{238}U	^{238}U	^{238}U	^{238}U	^{238}U	^{238}U	^{238}U
^{93}Zr		^{93}Zr		^{93}Zr		^{93}Zr
Counts:	33	42	20	30	33	43

Source: `Screening SummaryREV02.xls` in Appendix C.

6.5 UNCERTAINTIES

Screening radionuclides at 95% of the cumulative radionuclide-screening product under the identified release scenarios is believed to be appropriate for TSPA. Screening at 95% means that the ranked radionuclides that contributed up to 95% of the maximum cumulative radionuclide-screening product for each waste form and screening set are considered potentially important (see Section 6.2.1 for further explanation). Choosing a high but not excessively conservative cutoff serves the purpose of this analysis, which is to screen out radionuclides that are unlikely to significantly contribute to radiation dose.

The radionuclide screening analysis has been performed against a backdrop of several previous Yucca Mountain TSPAs and reviews by the NRC and an international peer review panel (Riotte 2001 [DIRS 156782]). The results of the radionuclide screening analysis are not sensitive to uncertainties in input values or assumptions because the results of the screening analysis are partly known ahead of time (based on other TSPAs and on previous revisions of this screening analysis). Screening out a radionuclide known to be important or a failure to screen out a radionuclide not previously suspected of being at least marginally important would be viewed skeptically. Before finalization of the screening analysis, an inquiry into the unexpected result would lead either to an explanation and confirmation of the unexpected result, or to a discovery that some fault with the inputs or the screening method required correction.

The worst-case consequence of uncertainties in the inputs or assumptions is that marginally important radionuclides could be inappropriately screened out. To highlight radionuclides that are of marginal importance, and might have made the 95% cut under a different set of assumptions (such as solubility- and sorption-class assignments; screening factors; and characteristics of the average and outlying waste forms), a finer screening was conducted at a screening-product cutoff fraction of 99%. The marginally significant radionuclides for the period up to 10,000 years are listed at the end of Section 6.3.1. For the period beyond 10,000 years up to a million years, the marginally significant radionuclides are listed at the end of Section 6.3.2. These marginally significant radionuclides can be organized into three groups:

(1) Those radionuclides that are marginally significant for one of the two periods mentioned above but screened in for the other period (^{227}Ac, ^{241}Am, ^{210}Pb, ^{242}Pu, ^{226}Ra, ^{228}Ra, ^{230}Th, ^{232}Th, ^{235}U)

(2) Those radionuclides that have half lives less than 180 days and are included with a longer-lived parent (see discussion in Section 6.6.2) that is screened in (^{217}At, ^{221}Fr, ^{233}Pa, ^{223}Ra, ^{126}Sb, ^{90}Y)

(3) The remaining radionuclides (^{244}Cm, ^{245}Cm, ^{166m}Ho, ^{94}Nb, ^{63}Ni, ^{236}Np, ^{241}Pu, ^{224}Ra, ^{228}Th, ^{93}Zr).

The radionuclides in group 3 are discussed below; those in groups 1 and 2 are not discussed because they are included with the set of screened-in radionuclides in Section 7.

^{244}Cm has a half life of 18.1 years and is identified as marginally significant for the MOX and bounding BWR and PWR fuels at the 100-year screening time. Given the groundwater travel time and low probability of eruptive events, it is unlikely that ^{244}Cm will be released to the biosphere within the first few hundred years after closure of the repository; after that its inventory is insignificant. As discussed in Section 6.6.2, ^{245}Cm and ^{241}Pu have been added to the list of screened-in radionuclides. ^{236}Np is identified as marginally significant only for an eruptive scenario involving the West Valley HLW glass waste form. Given that the West Valley HLW glass is a small fraction of the HLW glass inventory, the screen-out result for ^{236}Np appears to be appropriate. Because both ^{228}Th and ^{224}Ra will be in secular equilibrium with ^{232}Th (which is screened in) during the post-10,000-year time period, for which they are marginally significant, their biological effects are included. ^{94}Nb, ^{63}Ni, and ^{93}Zr have been considered in earlier TSPAs (see Table 6-1). The results of these analyses are consistent with screening out these radionuclides in the current analysis. ^{166m}Ho is identified as marginally significant only for the bounding BWR inventory in the groundwater scenarios. It has not been identified as potentially significant by the NRC (Section 6.7.1) or the international peer review panel (Section 6.7.2).

In summary, examination of the specific radionuclides identified as marginally significant in this analysis indicates that screening at the 95% cumulative screening product level is appropriate.

6.6 ADDITIONAL RADIONUCLIDES RECOMMENDED

6.6.1 Separate Groundwater Protection Standard

EPA regulations (40 CFR 197.30 [DIRS 173176]) and the separate groundwater protection standard in 10 CFR 63.331 [DIRS 173273] set limits on:

(1) The combined activity of ^{226}Ra and ^{228}Ra in groundwater

(2) Gross alpha activity (including ^{226}Ra, but excluding radon and uranium)
(3) Dose from combined beta and photon emitting radionuclides in groundwater.

The first item requires the inclusion of ^{226}Ra and ^{228}Ra in the list of radionuclides that must be considered in the radionuclide inventory and tracked for TSPA. (Note: As shown in Tables 6-7 and 6-8, both of these radionuclides are screened in for the period up to a million years.)

The second item is concerned only with alpha decay. The screening analysis used dose considerations to identify the important radionuclides, including alpha emitters. Because dose is the best measure of the relative importance of alpha emitters from the human perspective, the same screening is appropriate to identify the radionuclides to be included in a gross-alpha calculation. However, some of the screened-in radionuclides will be in secular equilibrium with short-lived daughter products that were screened out as primary contributors (secular equilibrium occurs when the disintegration rate of a daughter radionuclide is equal to that of its parent). To show compliance with the gross-alpha regulation, it will be necessary to include appropriate equilibrium activity contributions for the short-lived decay products. The short-lived products will not need to be transported in the TSPA and their equilibrium activities can be computed from the activities of the parents, so it is not necessary to list them here or to include them in the radionuclide inventory (see Section 6.6.2). Long-lived decay products of important radionuclides are screened either in or out. If they have been screened in, their alpha activities and those of their short-lived daughters will be counted in the gross-alpha calculation. If they have been screened out, they need not be considered in the gross-alpha calculation because the screening analysis showed them and their short-lived daughters to be unimportant.

The third item is concerned with dose from drinking contaminated groundwater. This pathway was included in the screening analysis, so no further screening to identify potentially important contributors is necessary.

6.6.2 Precursors of Other Recommended Radionuclides

Some radionuclides that are precursors of important radionuclides are not necessarily identified by the screening analysis. It is important to identify and include such radionuclides because their decay will contribute to the inventory of the daughter radionuclides that are identified as important in the screening analysis. Also, because the models used for assessing the biological effects of screened-in radionuclides include short-lived radionuclides together with the first precursor radionuclide in the decay chain that has a half-life greater than 180 days (BSC 2004 [DIRS 169460], Section 6.3.5), the screened-in radionuclides with half-lives less than 180 days can be deleted if the pertinent precursor radionuclide is already screened in. If the pertinent precursor is not screened in, it should be added to the list if its decay will contribute to the inventory of a daughter radionuclide that is screened in.

Table 6-9 provides a summary of the radionuclides screened radionuclides from Tables 6-7 and 6-8 in accordance to the 95% cutoff.

Table 6-9. Summary of Screened Radionuclides

Radionuclide	Nominal, Human-Intrusion, and Intrusive Igneous Scenarios		Eruptive Igneous Scenario	
	10^2 yrs to 10^4 yrs	10^4 yrs to 10^6 yrs	10^2 yrs to 10^4 yrs	10^4 yrs to 10^6 yrs
^{225}Ac	^{225}Ac	^{225}Ac		
^{227}Ac		^{227}Ac		^{227}Ac
^{241}Am	^{241}Am		^{241}Am	
^{243}Am	^{243}Am	^{243}Am	^{243}Am	^{243}Am
^{210}Bi		^{210}Bi		
^{14}C	^{14}C	^{14}C		
^{36}Cl	^{36}Cl	^{36}Cl		
^{135}Cs	^{135}Cs	^{135}Cs		
^{137}Cs	^{137}Cs		^{137}Cs	
^{129}I	^{129}I	^{129}I		^{129}I
^{237}Np	^{237}Np	^{237}Np		^{237}Np
^{239}Np	^{239}Np	^{239}Np		
^{231}Pa	^{231}Pa	^{231}Pa		^{231}Pa
^{210}Pb		^{210}Pb		^{210}Pb
^{210}Po	^{210}Po	^{210}Po		^{210}Po
^{238}Pu	^{238}Pu		^{238}Pu	
^{239}Pu	^{239}Pu	^{239}Pu	^{239}Pu	^{239}Pu
^{240}Pu	^{240}Pu	^{240}Pu	^{240}Pu	^{240}Pu
^{242}Pu		^{242}Pu		^{242}Pu
^{223}Ra		^{223}Ra		
^{225}Ra	^{225}Ra	^{225}Ra		
^{226}Ra		^{226}Ra		^{226}Ra
^{228}Ra		^{228}Ra		^{228}Ra
^{222}Rn		^{222}Rn		
^{79}Se	^{79}Se	^{79}Se		
^{126}Sn	^{126}Sn	^{126}Sn	^{126}Sn	^{126}Sn
^{90}Sr	^{90}Sr		^{90}Sr	
^{99}Tc	^{99}Tc	^{99}Tc		^{99}Tc
^{229}Th	^{229}Th	^{229}Th	^{229}Th	^{229}Th
^{230}Th		^{230}Th		^{230}Th
^{232}Th		^{232}Th		^{232}Th
^{232}U	^{232}U	^{232}U		
^{233}U	^{233}U	^{233}U	^{233}U	^{233}U
^{234}U	^{234}U	^{234}U	^{234}U	^{234}U
^{235}U		^{235}U		

Table 6-9. Summary of Screened Radionuclides (Continued)

Radionuclide	Nominal, Human-Intrusion, and Intrusive Igneous Scenarios		Eruptive Igneous Scenario	
	10^2 yrs to 10^4 yrs	10^4 yrs to 10^6 yrs	10^2 yrs to 10^4 yrs	10^4 yrs to 10^6 yrs
^{236}U	^{236}U	^{236}U		
^{238}U	^{238}U	^{238}U		^{238}U
Counts:	**26**	**33**	**11**	**20**

Source: `Screening SummaryREV02.xls` in Appendix C.

Table 6-10 provides a systematic examination of the radionuclides identified in Table 6-9 to identify the additional precursor radionuclides that should be included and to delete those short-lived radionuclides that can be screened out because the pertinent longer-lived precursors are included. The additional radionuclides in the last column should be accounted for in the inventory, either by direct inclusion, or by appropriate augmentation of the daughter product inventory. Table 7-1 reflects the changes to the list of screened-in radionuclides that result from the discussion in Table 6-10.

Table 6-10. Evaluation of Precursor Radionuclides

Nuclide Examined	Discussion	Changes
^{225}Ac	Decays from ^{229}Th (^{229}Th → ^{225}Ra → ^{225}Ac). ^{225}Ac and ^{225}Ra have half lives less than 180 days. ^{229}Th has a half life greater than 180 days and is screened in.	Delete ^{225}Ac
^{227}Ac	Daughter of ^{231}Pa, which is screened in. Because its half-life is greater than 180 days (see table note), it is not deleted.	—
^{241}Am	^{245}Cm→^{241}Pu→^{241}Am. ^{245}Cm has a half-life much greater than that of ^{241}Am and can provide a source of ^{241}Am. After a few thousand years, ^{241}Am is in secular equilibrium with ^{245}Cm (see table note). Also, ^{245}Bk→^{241}Am, but ^{245}Bk does not appear in the waste forms used for the screening analysis. Because ^{245}Cm is screened in at the 99% screening product cutoff level for the groundwater and eruptive scenarios and because its decay, and the decay of ^{241}Pu, will affect the inventory of ^{241}Am, it is recommended that both of these radionuclides be included.	Add ^{241}Pu and ^{245}Cm
^{243}Am	^{247}Bk→^{243}Am, but ^{247}Bk does not appear in the waste forms used for the screening analysis (see table note). Also, ^{247}Cm→^{243}Pu→ ^{243}Am. ^{243}Pu has a half-life less than 180 days and need not be included in the inventory because it is merely serving as a conduit for the decay of ^{247}Cm to ^{243}Am. ^{247}Cm has a half-life of more than 15 million years and therefore would provide a nearly constant source of ^{243}Am throughout the period of this analysis. However, ^{247}Cm does not appear in the waste forms used for the screening analysis except in DOE SNF and MOX fuel, where its activity is a very small fraction of the ^{243}Am activity throughout the period of analysis; therefore, ^{247}Cm need not be included in the inventory.	—
^{210}Bi	Decays from ^{210}Pb (^{210}Pb → ^{210}Bi). ^{210}Bi has a half-life less than 180 days. ^{210}Pb has a half-life greater than 180 days and is screened in.	Delete ^{210}Bi
^{212}Bi	Decays from ^{228}Th (^{228}Th → ^{224}Ra → ^{220}Rn → ^{216}Po → ^{212}Pb → ^{212}Bi). ^{224}Ra, ^{220}Rn, ^{216}Po, and ^{212}Pb have half-lives less than 180 days. ^{228}Th has a half-life greater than 180 days and is screened in.	Delete ^{212}Bi, ^{220}Rn, ^{224}Ra
^{14}C	Activation product; not produced by the decay of anything in the waste forms used for the screening analysis.	—
^{36}Cl	Activation product; not produced by the decay of anything in the waste forms used for the screening analysis.	—

Table 6-10. Evaluation of Precursor Radionuclides (Continued)

Nuclide Examined	Discussion	Additional Nuclides
^{135}Cs	Fission product; not produced by the decay of anything in the waste forms used for the screening analysis.	—
^{137}Cs	Fission product; not produced by the decay of anything in the waste forms used for the screening analysis.	—
^{129}I	Fission product; not produced by the decay of anything in the waste forms used for the screening analysis.	—
^{237}Np	Decay product of ^{241}Am, which is screened in. Also produced by decay of ^{237}U, which is produced by a minor branch of the decay of ^{241}Pu. ^{237}U has a half-life less than 180 days and need not be included in the initial inventory because it is merely serving as a conduit for the decay of ^{241}Pu to ^{237}Np. ^{241}Pu has a half-life greater than 180 days and is listed above as needed for the inventory.	—
^{239}Np	Decays from ^{243}Am (^{243}Am → ^{239}Np). ^{239}Np has a half-life less than 180 days. ^{243} Am has a half-life greater than 180 days and is screened in.	Delete ^{239}Np
^{231}Pa	^{235}U→^{231}Th→^{231}Pa. ^{231}Th has a half-life less than 180 days and need not be included in the initial inventory because it is merely serving as a conduit for the decay of ^{235}U to ^{231}Pa. ^{235}U is present in the waste forms used for the screening analysis for all waste forms and its inventory is needed to accurately project the inventory of ^{231}Pa, especially for times beyond 10,000 years. ^{235}U has a half-life greater than 180 days and is screened in.	—
^{210}Pb	^{226}Ra →^{210}Pb through a series of short-lived radionuclides (half-lives less than 180 days) that need not be included. ^{226}Ra has a half-life greater than 180 days and is screened in.	—
^{210}Po	Decays from ^{210}Pb (^{210}Pb→^{210}Bi→^{210}Po). Both ^{210}Po and ^{210}Bi have half-lives less than 180 days. ^{210}Pb has a half-life greater than 180 days and is screened in.	Delete ^{210}Po
^{238}Pu	^{242m}Am →^{242}Am→^{242}Cm→^{238}Pu. ^{242}Cm and ^{242}Am have half-lives less than 180 days and need not be included in the inventory because they are merely serving as a conduit for the decay of ^{242m}Am to ^{238}Pu. Also ^{242m}Am →^{238}Np→^{238}Pu. ^{238}Np has a half-life of less than 180 days and need not be included ^{242m}Am has a longer half-life than ^{238}Pu, so could conceivably provide a source of ^{238}Pu worth tracking in TSPA. However, although ^{242m}Am shows up in BWR, DOE SNF, HLW, and PWR waste forms, in each case, the ^{242m}Am activity is negligible compared to that of ^{238}Pu.	—
^{239}Pu	^{243}Am →^{239}Np→^{239}Pu. Np-239 has a half-life less than 180 days and need not be included. ^{243}Am is screened in. Also, ^{243}Cm→^{239}Pu. ^{243}Cm appears in BWR, DOE SNF, HLW, and PWR waste forms, but in each case, the ^{243}Cm activity is negligible compared to that of ^{239}Pu.	—
^{240}Pu	^{244}Cm→^{240}Pu. ^{244}Cm has a half-life (18.1 years) much shorter than that of ^{240}Pu. For that reason, its initial (i.e., at the first screening time) activity would have to be much greater than that of ^{240}Pu to significantly affect the activity of ^{240}Pu. This claim can be verified as follows. A necessary condition for the inventory of the parent radionuclide to significantly affect that of the daughter is that the number of atoms in initial inventory for the parent be at least comparable to that of the daughter. As it happens, the necessary condition is not met because the initial ^{244}Cm activity in the waste forms that were used for the screening analysis is less than the initial ^{240}Pu activity. Therefore, ^{244}Cm need not be included in the inventory.	—
^{242}Pu	^{246}Cm→^{242}Pu. ^{246}Cm has a half-life (4,760 years) much shorter than that of ^{242}Pu. For that reason, its activity would have to be much higher than that of ^{242}Pu to significantly affect the activity of ^{242}Pu. (See the discussion for ^{240}Pu for a justification of this claim.) As it happens, the initial ^{246}Cm activity in the waste forms that were used for the screening analysis is less than the initial ^{242}Pu activity. Therefore, ^{246}Cm need not be included in the inventory.	—

Table 6-10. Evaluation of Precursor Radionuclides (Continued)

Nuclide Examined	Discussion	Additional Nuclides
^{223}Ra	Decays from ^{231}Pa (^{231}Pa→^{227}Ac→^{227}Th and ^{223}Fr→^{223}Ra). The parent ^{231}Pa has a half-life greater than 180 days and is screened in. ^{223}Ra has a half-life less than 180 days.	Delete ^{223}Ra
^{224}Ra	See ^{212}Bi above.	Delete ^{224}Ra
^{225}Ra	See ^{225}Ac above.	Delete ^{225}Ra
^{226}Ra	Decay product of ^{230}Th, which is screened in. ^{226}Ra is retained because it has a half-life greater than 180 days.	—
^{228}Ra	Decay product of ^{232}Th, which has a very long half-life (1.4E10 years) and is screened in. ^{228}Ra is retained because it has a half-life greater than 180 days.	—
^{220}Rn	See ^{212}Bi above.	Delete ^{220}Rn
^{222}Rn	Decays from ^{226}Ra (^{226}Ra→^{222}Rn). ^{222}Rn has a half life-less than 180 days. ^{226}Ra has a half-life greater than 180 days and is screened in.	Delete ^{222}Rn
^{79}Se	Fission product; not produced by the decay of anything in the waste forms used for the screening analysis.	—
^{126}Sn	Fission product; not produced by the decay of anything in the waste forms used for the screening analysis.	—
^{90}Sr	Fission product; not produced by the decay of anything in the waste forms used for the screening analysis.	—
^{99}Tc	Fission product; not produced by the decay of anything in the waste forms used for the screening analysis.	—
^{227}Th	Produced by decay of ^{227}Ac, which is screened in. ^{227}Th has a half-life less than 180 days.	Delete ^{227}Th
^{228}Th	Produced by decay of ^{228}Ra, which is screened in.	—
^{229}Th	Decay product of ^{233}U, which is screened in.	—
^{230}Th	Decay product of ^{234}U, which is screened in.	—
^{232}Th	Decay product of ^{236}U, which is screened in.	—
^{234}Th	Produced by decay of ^{238}U, which is screened in. ^{234}Th has a half-life less than 180 days.	Delete ^{234}Th
^{232}U	Produced by decay of ^{236}Np (^{236}Np→^{236}Pu→^{232}U); ^{236}Np is marginally significant.	—
^{233}U	^{237}Np→^{233}Pa→^{233}U. ^{237}Np is screened in. ^{233}Pa has a half-life less than 180 days and need not be included.	—
^{234}U	^{238}U→^{234}Th→^{234}Pa→^{234}U. ^{238}U is screened in. ^{234}Pa and ^{234}Th have half-lives less than 180 days and need not be included in the inventory	—
^{236}U	Decay product of ^{240}Pu, which is screened in.	—
^{235}U	Produced by decay of ^{239} Pu. ^{239}Pu is screened in.	—
^{236}U	Produced by decay of ^{240} Pu. ^{240}Pu is screened in.	—
^{238}U	Decay product of ^{242}Pu, which is screened in.	—

NOTES: See Parrington et al. 1996 [DIRS 103896] for decay relationships. See Table 4-3 for half-lives.

"—" indicates no change to list of screened-in radionuclides.

6.7 RESPONSES TO COMMENTS FROM EXTERNAL REVIEWS

6.7.1 Nuclear Regulatory Commission

This section is carried forward from Revision 01. As has been mentioned above (Section 6.1), the NRC provided a constructive critique of the previous revision of the radionuclide screening analysis (Beckman 2001 [DIRS 156122], Section 5.3.2.1). Partial responses to NRC comments are scattered throughout the present analysis. The NRC comments are stated more fully here, and responses are provided.

Comment: "First, the product of the inventory and the inhalation and ingestion DCFs [dose conversion factors] for the radionuclide are not directly related to the risk that the radionuclide poses to the critical group, even when the solubility and transport properties in the geosphere of the radionuclide are accounted for. Processes that affect transport in the biosphere, such as uptake by plants and bioaccumulation, are not accounted for using this methodology. Also, the direct exposure pathway is not accounted for by this approach. Thus, radionuclides for which ground shine constitutes a significant exposure pathway, such as Nb-94 and Sn-126, could be inappropriately screened using this methodology."

Response: The use of the adjusted NCRP screening factors (Appendix A) answers this concern by accounting for the effects of the biosphere (including uptake by plants, bioaccumulation, and direct exposure). Furthermore, the relative contribution of each biosphere pathway is appropriately weighted by YMP-generated usage factors (Section 4.1.2).

Consistent with the NRC observation, ^{126}Sn is screened in for the groundwater and igneous eruptive scenarios (Tables 6-7 and 6-8). Despite inclusion of the direct exposure pathway in this screening analysis, ^{94}Nb is screened out for all scenarios and time periods. However, ^{94}Nb is of marginal significance for the eruptive scenarios (Tables 6-7 and 6-8). An examination of Table 6-6 will confirm that niobium and tin appear in only one groundwater screening set owing to their high sorptivity and low solubility. Thus, the only way for ^{126}Sn and ^{94}Nb to be screened in is to prevail in competition with all other radionuclides.

Comment: "Second, the grouping of radionuclides based on solubility and transport properties appears to be too broad. Dividing the radionuclides into only two groups of solubility classes and three groups of transport classes can lead to the grouping of radionuclides that do not really behave similarly under repository conditions and the masking of potentially important radionuclides. For example, Se-79, which has been screened from the analysis, is grouped in the soluble and moderately sorbing transport group. This group also contains elements such as Np and U, which have significantly larger DCFs than Se. However, Se is more soluble than Np and U by several orders of magnitude and also is transported much more quickly than Np and U. Thus, Se could pose a much greater risk to the critical group than Np or U, especially at early times, but be screened from the analysis."

Response: The Revision 01 analysis reevaluated and revised the solubility and sorption classifications, using YMP studies for corroboration wherever possible, and introduced an intermediate solubility class (Section 6.2.4). The revised solubility and sorption classifications are retained in the current revision. One effect of the revised groundwater transport classifications is that Se is in the high solubility class, while uranium and neptunium are in the intermediate solubility class (Section 6.2.4). Although selenium is now classed separately from uranium and neptunium, ^{79}Se is screened in for the groundwater scenario in the time period up to 10,000 years and also for the 10,000-year to 1,000,000-year time period (Tables 6-7, 6-8, and 7-1).

Comment: "Also, there does not seem to be any proposed methodology to investigate the effect of certain radionuclides such as Se-79 that have been identified in previous DOE and NRC TSPAs as important but have not been identified as important using the proposed methodology."

Response: As discussed in the response to the preceding comment, ^{79}Se is screened in based on the results of the current screening analysis. The more general aspect of this comment is addressed in the last paragraph of Section 7.

Comment: "Finally, the inventory abstraction AMR [analysis/model report] does not indicate how radionuclides not considered important to performance in themselves, but that generate daughter products important to performance, will be accounted for."

Response: Significant sources of the potentially important radionuclides that were identified by the screening analysis are discussed in Section 6.6.2 and listed in Table 6-10. For further discussion on a related topic, see the response to the second comment in Section 6.7.2.

6.7.2 International Peer Review Panel

In the summer of 2001, an international panel reviewed site recommendation documents at the request of the DOE. The panel was jointly organized by the Nuclear Energy Agency of the Organisation for Economic Cooperation and Development, and the International Atomic Energy Agency of the United Nations. The final report (OECD 2002 [DIRS 158098], Section 3.3) provides comments on the radionuclide screening that was performed for site recommendation.

Comment: "The [international review team] notes that some radionuclides (such as Cl-36 and Cs-135) that feature as important in other international studies [OECD 1997 [DIRS 103445] were screened out after the TSPA-1995…. For instance, Cl-36 has been screened out because it is not a fission product. However, it is produced by neutron activation of contaminating Cl in the fuel. It has been shown to be an important contributor to dose in, for instance, the Canadian program (Johnson et al. 1995 [DIRS 158070])."

Response: A study that was cited by the international review team (OECD 1997 [DIRS 103445], Section 2.11) identifies the radionuclides that contributed most to dose rate in the "reference" cases of ten repository performance assessment studies. The ten studies vary with respect to waste form, geologic media, repository concept, and purpose of the assessment, so there is no reason to expect precisely the same radionuclides to be important for every study. Nevertheless, there are many similarities in influential variables such as initial waste inventories, geological processes, and characteristics of the biosphere, which make it useful to compare the results of the ten studies with the results of the present screening. For comparisons of results, take the screening for the groundwater scenarios as the "reference" case for the present screening. Of the 20 radionuclides collectively identified by the ten studies, 18 were screened in for groundwater scenarios during either or both the 10,000-year period and the period between

10,000 years and 1,000,000 years: ^{227}Ac, ^{243}Am, ^{14}C, ^{36}Cl, ^{135}Cs, ^{129}I, ^{237}Np, ^{231}Pa, ^{239}Pu, ^{240}Pu, ^{242}Pu, ^{223}Ra , ^{226}Ra, ^{79}Se, ^{99}Tc, ^{229}Th, ^{233}U, and ^{236}U. The two radionuclides (^{94}Nb and ^{107}Pd) that were identified as important by one or more of the ten studies but screened out by the present analysis are discussed below.

One of the ten studies found ^{94}Nb to be a major contributor to dose. The current analysis shows it to be a marginally significant radionuclide for the eruptive scenarios. ^{94}Nb is a low-yield fission product (Parrington et al. 1996 [DIRS 103896]), and is produced as a neutron-activation product of the niobium present in zirconium-based cladding.

One of the ten studies found ^{107}Pd to be an important contributor to dose. ^{107}Pd is a low-yield fission product (Parrington et al. 1996 [DIRS 103896]) with a relatively low groundwater-screening factor. In the present screening analysis, ^{107}Pd is screened out for all scenarios and times, and is not identified as marginally important by the fine-screen test.

Although ^{245}Cm, ^{246}Cm, and ^{59}Ni were not mentioned in the NRC or international reviews, the NRC included them in its iterative performance assessment. None of the ten studies under discussion (OECD 1997 [DIRS 103445], Table 2), which includes the NRC iterative performance assessment, found ^{245}Cm, ^{246}Cm, or ^{59}Ni to be important contributors to dose. In the current screening analysis, ^{245}Cm was found to be marginally significant for groundwater and eruptive scenarios.

Comment: "Furthermore, it is noted that the biosphere dose conversion factors used in screening out radionuclides did not properly account for short-lived daughters of long-lived parents when determining whether to screen out the parent."

Response: For the groundwater screening, direct contributions from radionuclides with half-lives less than a user-specified half-life cutoff are not included. As described in Section 6.2.6, the half-life cutoff was set equal to zero for the RadNuScreen runs conducted for this revision. The adjusted NCRP screening factors allow for radioactive in-growth during a 30-year period of radionuclide accumulation in the soil. For the eruptive screening, direct contributions from all radionuclides are accounted for regardless of longevity, and indirect contributions due to in-growth are accounted for by a 30-year soil accumulation period. Thus, the revised screening avoids the possibility that a radionuclide could be screened out because its short-lived decay products had not been accounted for, as was possible under the previous revision.

For a response to a related comment, see the response to the final NRC comment.

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7. CONCLUSIONS

The radionuclide screening analysis separately considers two different postclosure time periods: the 10,000-year period and the period from 10,000 years up to 1 million years after emplacement. Four release scenarios are considered: (1) the nominal scenario, (2) the human-intrusion scenario, (3) an intrusive igneous event, and (4) an eruptive igneous event. The screening analysis considers spent boiling water reactor fuel, spent pressurized water reactor fuel, U.S. Department of Energy spent nuclear fuel, and high-level radioactive waste. Average and outlying (that is, high burnup, high initial enrichment, low age, or otherwise exceptional) forms of each waste-form type are considered. The screening factors used for the analysis account for the influence of the biosphere and are consistent with the characteristics of the receptor based on the local population.

The screening analysis has shown that the radionuclides listed in Table 7-1 may substantially affect repository performance for the exposure scenarios and times listed. These radionuclides should be considered in TSPA-LA modeling. While the purpose of the analysis is to identify all of the radionuclides of major importance to dose and virtually all of the marginally important radionuclides, it is recognized that some radionuclides that could contribute a marginally significant fraction of the dose in unlikely circumstances might have been screened out. For this reason, a fine-screen test was conducted (Tables 6-7 and 6-8). See Section 6.5 for a discussion of the effect of uncertainties on the results of the screening analysis. It is noteworthy that two radionuclides (^{94}Nb and ^{245}Cm) that have been identified as potentially important in other TSPAs (Section 6.7) were also identified as marginally significant in this analysis.

The discussion in Sections 6.6.1 and 6.6.2 shows that, in addition to the radionuclides identified by the screening analysis, ^{245}Cm and ^{241}Pu should be included in the list of radionuclides considered in TSPA.

Table 7-1. Results of the Screening Analysis

Radionuclide	Nominal, Human-Intrusion, and Intrusive Igneous Scenarios		Eruptive Igneous Scenario	
	10^2 yrs to 10^4 yrs	10^4 yrs to 10^6 yrs	10^2 yrs to 10^4 yrs	10^4 yrs to 10^6 yrs
^{227}Ac		^{227}Ac		^{227}Ac
^{241}Am	^{241}Am		^{241}Am	
^{243}Am	^{243}Am	^{243}Am	^{243}Am	^{243}Am
^{14}C	^{14}C	^{14}C		
^{36}Cl	^{36}Cl	^{36}Cl		
^{245}Cm	Added to ensure that the effect of its decay on the inventory of ^{241}Am are included (see Section 6.6.2)			
^{135}Cs	^{135}Cs	^{135}Cs		
^{137}Cs	^{137}Cs		^{137}Cs	
^{129}I	^{129}I	^{129}I		^{129}I
^{237}Np	^{237}Np	^{237}Np		^{237}Np
^{231}Pa	^{231}Pa	^{231}Pa		^{231}Pa
^{210}Pb		^{210}Pb		^{210}Pb
^{238}Pu	^{238}Pu		^{238}Pu	
^{239}Pu	^{239}Pu	^{239}Pu	^{239}Pu	^{239}Pu
^{240}Pu	^{240}Pu	^{240}Pu	^{240}Pu	^{240}Pu
^{241}Pu	Added to ensure that the effect of its decay on the inventory of ^{241}Am and ^{237}Np are included (see Section 6.6.2)			
^{242}Pu		^{242}Pu		^{242}Pu
^{226}Ra		^{226}Ra		^{226}Ra
^{228}Ra		^{228}Ra		^{228}Ra
^{79}Se	^{79}Se	^{79}Se		
^{126}Sn	^{126}Sn	^{126}Sn	^{126}Sn	^{126}Sn
^{90}Sr	^{90}Sr		^{90}Sr	
^{99}Tc	^{99}Tc	^{99}Tc		^{99}Tc
^{229}Th	^{229}Th	^{229}Th	^{229}Th	^{229}Th
^{230}Th		^{230}Th		^{230}Th
^{232}Th		^{232}Th		^{232}Th
^{232}U	^{232}U	^{232}U		
^{233}U	^{233}U	^{233}U	^{233}U	^{233}U
^{234}U	^{234}U	^{234}U	^{234}U	^{234}U
^{235}U		^{235}U		
^{236}U	^{236}U	^{236}U		
^{238}U	^{238}U	^{238}U		^{238}U
Counts:	**22**	**26**	**11**	**19**

DTN: MO0701RLTSCRNA.000.

NOTE: The counts in the last row do not include ^{245}Cm and ^{241}Pu.

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8.4 OUTPUT DATA, LISTED BY DATA TRACKING NUMBER

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8.5 SOFTWARE CODES

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APPENDIX A

SCREENING FACTORS FOR GROUNDWATER SCENARIOS

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APPENDIX A
SCREENING FACTORS FOR GROUNDWATER AND IGNEOUS SCENARIOS

A.1 DEVELOPMENT OF PATHWAY SCREENING FACTORS

The following sections describe the development of screening factors for each pathway component from the NCRP-123 (NCRP 1996 [DIRS 101882], Table C.1) that is appropriate to represent the exposure of the receptor in the Yucca Mountain region. The total screening factor is the sum of the products of the screening factors for individual pathways. Screening factors were developed separately for the groundwater and igneous scenarios.

A.1.1 Screening Factors for Ingestion Pathways

Screening factors for ingestion pathways from NCRP-123 (NCRP 1996 [DIRS 101882]) are used as the basis of ingestion screening factors developed in the screening analysis. The screening factors for inhalation and external exposure were developed separately, consistent with, and based on the methods used in, the biosphere model (Sections A.1.2 and A.1.3).

The generic screening factors for ingestion are modified by multiplying them by the usage adjustment factors and the dose coefficient adjustment factors. The adjustment factors are applied to the primary radionuclide and to all contributing decay products that are listed in NCRP-123 (NCRP 1996 [DIRS 101882], Table C.1) (also see Excel file `Site-Specific Screening Factors.xls` in Appendix C).

The usage factors that are built into the NCRP ingestion screening factors, i.e., the quantities of water or food products consumed, are not necessarily appropriate for local conditions, especially with respect to consumption of foodstuffs that are produced locally. The NCRP screening factors for ingestion are thus adjusted here by replacing the generic usage factors (NCRP 1996 [DIRS 101882], Table 7.1) with usage factors developed in YMP documents (Section 4.1.2). Similarly, the dose coefficients used in the NCRP screening models were adjusted to match the dose coefficients used in the current biosphere model (BSC 2004 [DIRS 169460]). The dose coefficients that are used to convert radionuclide exposure to doses in the current biosphere model are more recent than the dose coefficients used in NCRP-123 (NCRP 1996 [DIRS 101882]). Therefore, the dose coefficients used in NCRP-123 (NCRP 1996 [DIRS 101882]) were replaced with the corresponding dose coefficients from FGR-13 (EPA 2000 [DIRS 153733]). For three radionuclides, ^{244}Pu, ^{252}Cf, and ^{248}Cm, dose coefficients from the ICRP-72 database (ICRP 1996 [DIRS 152446]) were used because they were not included in FGR-13. Table A-1 lists the water and food consumption rates used in NCRP-123 (NCRP 1996 [DIRS 101882]) and the consumption rates of locally produced food and water that are used in the biosphere model (BSC 2004 [DIRS 169460]) and correspond to site-specific conditions. The adjustment factor is the ratio of these consumption rates.

Table A-1. Adjustment Factors for Groundwater and Igneous Scenarios

Pathway Description	Applicable Scenarios	NCRP Report 123 Consumption [a]	Amargosa Valley Consumption [b]	Adjustment Factor
Consumption of drinking water (L/yr)	Groundwater	800	730.5	0.913
Consumption of fish (kg/yr)	Groundwater	20	0.23	0.012
Consumption of vegetables (kg/yr)	Groundwater and Igneous	200	21.42 [c]	0.106
Consumption of milk (L/yr)	Groundwater and Igneous	300	4.66	0.016
Consumption of meat (kg/yr)	Groundwater and Igneous	100	8.57 [d]	0.086
Inadvertent ingestion of soil (kg/yr)	Groundwater and Igneous	0.365	0.0365	0.100

[a] NCRP 1996 [DIRS 101882], Table 7.1.
[b] BSC 2005 [DIRS 172827], Section 7.1.2; DTN: MO0407SPACRBSM.002 [DIRS 170677].
[c] Calculated as a sum of leafy vegetable, other vegetable, fruit, and grain consumption rates.
[d] Calculated as a sum of meat, poultry, and egg consumption.

The dose coefficient adjustment factor for a radionuclide is a ratio of the FGR-13 dose coefficients and the dose coefficient that was used in NCRP-123 (NCRP 1996 [DIRS 101882]) to develop generic screening factors.

Table A-2 provides a complete list of the radionuclides considered in the screening calculations and their decay products along with the corresponding ingestion dose coefficients from NCRP-123 (NCRP 1996 [DIRS 101882]) and FGR-13 (EPA 2000 [DIRS 153733]) as well as the FGR-13 inhalation dose coefficients and dose coefficients for external exposure that are used in this analysis (Sections A.1.2 and A.1.3) to develop site-specific screening factors for inhalation of suspended contaminated soil particles and for external exposure to contaminated soil. The table includes the decay products of radionuclides of interest, as listed in NCRP-123 (NCRP 1996 [DIRS 101882], Tables B.1 and C.1). The dose coefficients for internal intakes used in the calculations of screening factors are for adults and represent committed effective doses for the 50-year commitment period. Inhalation dose coefficients are the highest of those available for any given radionuclide. The dose coefficients for external exposure used in the calculations of the screening factors for the groundwater scenario are for the soil contaminated to an infinite depth; the dose coefficients used for the volcanic scenario are for the contaminated ground surface.

Table A-2. Dose Coefficients Used in the Calculation of Screening Factors

Groundwater Scenario						Igneous Scenario					
Radionuclide	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^3)**	**Radionuclide**	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^2)**
^{225}Ac		3.81E-08	3.85E-08	8.49E-06	3.09E-19	**^{225}Ac**		3.81E-08	3.85E-08	8.49E-06	1.47E-17
^{227}Ac	^{227}Ac	2.26E-06	3.23E-07	1.56E-04	2.40E-21	**^{227}Ac**		2.26E-06	3.23E-07	1.56E-04	1.41E-19
	^{227}Th	1.27E-08	9.02E-09	1.04E-05	2.57E-18	**^{228}Ac**		4.50E-10	4.01E-10	1.46E-08	9.38E-16
^{228}Ac		4.50E-10	4.01E-10	1.46E-08	3.03E-17	**^{108}Ag**		0.00E+00	Not listed	Not listed	8.95E-17
^{108}Ag		0.00E+00	Not listed	Not listed	6.12E-19	**^{108m}Ag**		2.05E-09	2.36E-09	3.78E-08	1.54E-15
^{108m}Ag		2.05E-09	2.36E-09	3.78E-08	4.83E-17	**^{109m}Ag**		0.00E+00	Not listed	Not listed	7.54E-18
^{109m}Ag		0.00E+00	Not listed	Not listed	5.49E-20	**^{110}Ag**		0.00E+00	Not listed	Not listed	1.63E-16
^{110}Ag		0.00E+00	Not listed	Not listed	1.27E-18	**^{110m}Ag**		2.89E-09	2.79E-09	1.23E-08	2.58E-15
^{110m}Ag		2.89E-09	2.79E-09	1.23E-08	8.67E-17	**^{239}Am**		2.62E-10	2.39E-10	2.37E-10	2.08E-16
^{239}Am		2.62E-10	2.39E-10	2.37E-10	4.73E-18	**^{241}Am**		5.79E-07	2.04E-07	9.64E-05	2.33E-17
^{241}Am		5.79E-07	2.04E-07	9.64E-05	1.99E-19	**^{242}Am**	^{242}Am	3.85E-10	2.96E-10	1.97E-08	1.61E-17
^{242}Am	^{242}Am	3.85E-10	2.96E-10	1.97E-08	2.41E-19		^{242}Cm	2.31E-08	1.17E-08	5.92E-06	7.03E-19
	^{242}Cm	2.31E-08	1.17E-08	5.92E-06	6.89E-22	**^{242m}Am**		5.54E-07	1.91E-07	9.22E-05	2.26E-18
^{242m}Am		5.54E-07	1.91E-07	9.22E-05	7.71E-21	**^{243}Am**		5.75E-07	2.03E-07	9.57E-05	4.80E-17
^{243}Am		5.75E-07	2.03E-07	9.57E-05	6.66E-19	**^{245}Am**		4.41E-11	6.23E-11	5.62E-11	4.12E-17
^{245}Am		4.41E-11	6.23E-11	5.62E-11	7.13E-19	**^{246}Am**		5.28E-11	5.78E-11	6.96E-11	6.79E-16
^{246}Am		5.28E-11	5.78E-11	6.96E-11	1.97E-17	**^{39}Ar**		0.00E+00	Not listed	Not listed	2.53E-18
^{39}Ar		0.00E+00	Not listed	Not listed	4.30E-21	**^{42}Ar**		Not listed	Not listed	Not listed	Not listed
^{42}Ar		Not listed	Not listed	Not listed	Not listed	**^{217}At**	^{217}At	0.00E+00	Not listed	Not listed	2.92E-19
^{217}At	^{217}At	0.00E+00	Not listed	Not listed	8.86E-21		^{213}Bi	1.75E-10	1.98E-10	3.20E-08	1.68E-16
	^{213}Bi	1.75E-10	1.98E-10	3.20E-08	3.83E-18		^{209}Tl	0.00E+00	Not listed	Not listed	1.92E-15

Table A-2. Dose Coefficients Used in the Calculation of Screening Factors (Continued)

Groundwater Scenario						Igneous Scenario					
Radionuclide	Radionuclide and Decay Products	NCRP-123 Ingestion Dose Factor (Sv/Bq)	FGR-13 Ingestion Dose Coefficient (Sv/Bq)	FGR-13 Inhalation Dose Coefficient (Sv/Bq)	FGR-13 External Dose Coefficient (Sv/s per Bq/m^3)	Radionuclide	Radionuclide and Decay Products	NCRP-123 Ingestion Dose Factor (Sv/Bq)	FGR-13 Ingestion Dose Coefficient (Sv/Bq)	FGR-13 Inhalation Dose Coefficient (Sv/Bq)	FGR-13 External Dose Coefficient (Sv/s per Bq/m^2)
	^{209}Tl	0.00E+00	Not listed	Not listed	6.56E-17		^{209}Pb	5.31E-11	5.67E-11	6.10E-11	3.19E-18
	^{209}Pb	5.31E-11	5.67E-11	6.10E-11	4.04E-21		^{213}Po	0.00E+00	Not listed	Not listed	0.00E+00
	^{213}Po	0.00E+00	Not listed	Not listed	0.00E+00		^{209}Pb	5.31E-11	5.67E-11	6.10E-11	3.19E-18
	^{209}Pb	5.31E-11	5.67E-11	6.10E-11	4.04E-21	**^{218}At**	^{218}At	0.00E+00	0.00E+00	0.00E+00	3.65E-18
^{218}At	^{218}At	0.00E+00	0.00E+00	0.00E+00	2.61E-20		^{214}Bi	1.07E-10	1.12E-10	1.54E-08	1.44E-15
	^{214}Bi	1.07E-10	1.12E-10	1.54E-08	4.99E-17		^{210}Pb	8.02E-07	6.96E-07	5.61E-06	2.13E-18
	^{214}Po	0.00E+00	Not listed	Not listed	2.59E-21		^{210}Bi	1.93E-09	1.31E-09	1.33E-07	3.51E-17
	^{210}Pb	8.02E-07	6.96E-07	5.61E-06	1.06E-20		^{210}Po	2.14E-07	1.21E-06	4.27E-06	8.07E-21
	^{210}Bi	1.93E-09	1.31E-09	1.33E-07	2.92E-20	**^{219}At**		Not listed	Not listed	Not listed	Not listed
	^{210}Po	2.14E-07	1.21E-06	4.27E-06	2.64E-22	**^{132}Ba**		Not listed	Not listed	Not listed	Not listed
^{219}At		Not listed	Not listed	Not listed	Not listed	**^{133}Ba**		9.50E-10	1.53E-09	1.03E-08	3.73E-16
^{132}Ba		Not listed	Not listed	Not listed	Not listed	**^{137m}Ba**		0.00E+00	Not listed	Not listed	5.78E-16
^{133}Ba		9.50E-10	1.53E-09	1.03E-08	9.74E-18	**^{10}Be**		1.71E-09	1.14E-09	3.46E-08	3.41E-18
^{137m}Ba		0.00E+00	Not listed	Not listed	1.81E-17	**^{210}Bi**	^{210}Bi	1.93E-09	1.31E-09	1.33E-07	3.51E-17
^{10}Be		1.71E-09	1.14E-09	3.46E-08	5.38E-21		^{210}Po	2.14E-07	1.21E-06	4.27E-06	8.07E-21
^{210}Bi	^{210}Bi	1.93E-09	1.31E-09	1.33E-07	2.92E-20	**^{211}Bi**		0.00E+00	Not listed	Not listed	4.40E-17
	^{210}Po	2.14E-07	1.21E-06	4.27E-06	2.64E-22	**^{212}Bi**		2.21E-10	2.59E-10	3.32E-08	2.25E-16
^{211}Bi		0.00E+00	Not listed	Not listed	1.27E-18	**^{213}Bi**		1.75E-10	1.98E-10	3.20E-08	1.68E-16
^{212}Bi	^{212}Bi	2.21E-10	2.59E-10	3.32E-08	5.96E-18	**^{214}Bi**		1.07E-10	1.12E-10	1.54E-08	1.44E-15
	^{208}Tl	0.00E+00	Not listed	Not listed	1.17E-16	**^{215}Bi**		Not listed	Not listed	Not listed	Not listed
^{213}Bi		1.75E-10	1.98E-10	3.20E-08	3.83E-18	**^{243}Bk**		Not listed	Not listed	Not listed	Not listed
^{214}Bi		1.07E-10	1.12E-10	1.54E-08	4.99E-17	**^{249}Bk**	^{249}Bk	1.89E-09	9.70E-10	4.06E-07	5.36E-21

Table A-2. Dose Coefficients Used in the Calculation of Screening Factors (Continued)

Groundwater Scenario						Igneous Scenario					
Radionuclide	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^3)**	**Radionuclide**	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^2)**
^{215}Bi		Not listed	Not listed	Not listed	Not listed		^{249}Cf	7.02E-07	3.52E-07	1.68E-04	3.15E-16
^{243}Bk		Not listed	Not listed	Not listed	Not listed	**^{250}Bk**	^{250}Bk	1.33E-10	1.37E-10	2.09E-09	8.41E-16
^{249}Bk	^{249}Bk	1.89E-09	9.70E-10	4.06E-07	2.01E-23		^{250}Cf	3.19E-07	1.57E-07	7.36E-05	5.33E-19
	^{249}Cf	7.02E-07	3.52E-07	1.68E-04	9.21E-18	**^{14}C**		5.64E-10	5.81E-10	5.73E-09	1.28E-20
^{250}Bk		1.33E-10	1.37E-10	2.09E-09	2.81E-17	**^{41}Ca**		2.67E-10	1.93E-10	1.81E-10	0.00E+00
^{14}C		5.64E-10	5.81E-10	5.73E-09	5.90E-23	**^{45}Ca**		8.56E-10	7.10E-10	3.64E-09	3.78E-20
^{41}Ca		2.67E-10	1.93E-10	1.81E-10	0.00E+00	**^{109}Cd**		2.22E-09	2.00E-09	8.16E-09	1.66E-17
^{45}Ca		8.56E-10	7.10E-10	3.64E-09	2.86E-22	**^{113}Cd**		2.47E-08	2.47E-08	1.20E-07	5.82E-20
^{109}Cd		2.22E-09	2.00E-09	8.16E-09	6.55E-20	**^{113m}Cd**		2.33E-08	2.30E-08	1.10E-07	1.77E-18
^{113}Cd		2.47E-08	2.47E-08	1.20E-07	5.25E-22	**^{139}Ce**		3.67E-10	2.63E-10	1.92E-09	1.43E-16
^{113m}Cd		2.33E-08	2.30E-08	1.10E-07	3.23E-21	**^{142}Ce**		Not listed	Not listed	Not listed	Not listed
^{139}Ce		3.67E-10	2.63E-10	1.92E-09	3.11E-18	**^{144}Ce**		8.18E-09	5.23E-09	5.27E-08	1.84E-17
^{142}Ce		Not listed	Not listed	Not listed	Not listed	**^{249}Cf**		7.02E-07	3.52E-07	1.68E-04	3.15E-16
^{144}Ce	^{144}Ce	8.18E-09	5.23E-09	5.27E-08	3.46E-19	**^{250}Cf**		3.19E-07	1.57E-07	7.36E-05	5.33E-19
	^{144}Pr	4.93E-11	5.06E-11	1.83E-11	1.43E-18	**^{251}Cf**		7.14E-07	3.59E-07	1.71E-04	1.13E-16
^{249}Cf		7.02E-07	3.52E-07	1.68E-04	9.21E-18	**^{252}Cf**		1.73E-07	9.00E-08	2.00E-05	5.24E-19
^{250}Cf		3.19E-07	1.57E-07	7.36E-05	4.45E-22	**^{36}Cl**		8.36E-10	9.29E-10	3.80E-08	1.12E-17
^{251}Cf		7.14E-07	3.59E-07	1.71E-04	2.57E-18	**^{242}Cm**		2.31E-08	1.17E-08	5.92E-06	7.03E-19
^{252}Cf		1.73E-07	9.00E-08	2.00E-05	7.28E-22	**^{243}Cm**		4.03E-07	1.49E-07	6.94E-05	1.18E-16
^{36}Cl		8.36E-10	9.29E-10	3.80E-08	1.33E-20	**^{244}Cm**		3.25E-07	1.23E-07	5.70E-05	6.44E-19
^{242}Cm		2.31E-08	1.17E-08	5.92E-06	6.89E-22	**^{245}Cm**		5.94E-07	2.08E-07	9.85E-05	8.05E-17
^{243}Cm		4.03E-07	1.49E-07	6.94E-05	2.86E-18	**^{246}Cm**		5.90E-07	2.05E-07	9.72E-05	5.76E-19

Table A-2. Dose Coefficients Used in the Calculation of Screening Factors (Continued)

Groundwater Scenario						Igneous Scenario					
Radionuclide	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^3)**	**Radionuclide**	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^2)**
^{244}Cm		3.25E-07	1.23E-07	5.70E-05	4.80E-22	**^{247}Cm**		5.43E-07	1.91E-07	9.00E-05	2.99E-16
^{245}Cm		5.94E-07	2.08E-07	9.85E-05	1.64E-18	**^{248}Cm**		2.17E-06	7.70E-07	3.60E-04	4.40E-19
^{246}Cm		5.90E-07	2.05E-07	9.72E-05	4.44E-22	**^{250}Cm**		1.24E-05	4.40E-06	2.10E-03	0.00E+00
^{247}Cm		5.43E-07	1.91E-07	9.00E-05	8.85E-18	**^{58}Co**		9.86E-10	7.49E-10	2.12E-09	9.23E-16
^{248}Cm		2.17E-06	7.70E-07	3.60E-04	3.35E-22	**^{60}Co**		7.09E-09	3.42E-09	3.07E-08	2.30E-15
^{250}Cm		1.24E-05	4.40E-06	2.10E-03	0.00E+00	**^{134}Cs**		1.95E-08	1.92E-08	2.04E-08	1.48E-15
^{58}Co		9.86E-10	7.49E-10	2.12E-09	3.00E-17	**^{135}Cs**		1.92E-09	2.00E-09	8.53E-09	2.69E-20
^{60}Co		7.09E-09	3.42E-09	3.07E-08	8.24E-17	**^{137}Cs**	^{137}Cs	1.35E-08	1.36E-08	3.92E-08	2.99E-18
^{134}Cs		1.95E-08	1.92E-08	2.04E-08	4.76E-17		^{137m}Ba	0.00E+00	0.00E+00	0.00E+00	5.78E-16
^{135}Cs		1.92E-09	2.00E-09	8.53E-09	1.72E-22	**^{150b}Eu**		1.72E-09	1.28E-09	1.26E-07	1.41E-15
^{137}Cs	^{137}Cs	1.35E-08	1.36E-08	3.92E-08	4.47E-21	**^{152}Eu**		1.92E-09	1.37E-09	9.35E-08	1.07E-15
	^{137m}Ba	0.00E+00	0.00E+00	0.00E+00	1.81E-17	**^{154}Eu**		2.99E-09	2.04E-09	1.11E-07	1.17E-15
^{150}Eu		1.72E-09	1.28E-09	1.26E-07	4.37E-17	**^{155}Eu**		5.03E-10	3.26E-10	1.25E-08	5.35E-17
^{152}Eu		1.92E-09	1.37E-09	9.35E-08	3.54E-17	**^{55}Fe**		1.52E-10	3.31E-10	7.81E-10	0.00E+00
^{154}Eu		2.99E-09	2.04E-09	1.11E-07	3.89E-17	**^{221}Fr**	^{221}Fr	0.00E+00	0.00E+00	0.00E+00	2.84E-17
^{155}Eu		5.03E-10	3.26E-10	1.25E-08	8.67E-19		^{213}Bi	1.75E-10	1.98E-10	3.20E-08	1.68E-16
^{55}Fe		1.52E-10	3.31E-10	7.81E-10	0.00E+00		^{209}Tl	0.00E+00	0.00E+00	0.00E+00	1.92E-15
^{221}Fr	^{221}Fr	0.00E+00	0.00E+00	0.00E+00	7.56E-19	**^{223}Fr**	^{223}Fr	2.34E-09	2.36E-09	1.21E-08	7.76E-17
	^{213}Bi	1.75E-10	1.98E-10	3.20E-08	3.83E-18		^{223}Ra	1.29E-07	1.04E-07	8.68E-06	1.21E-16
	^{209}Tl	0.00E+00	0.00E+00	0.00E+00	6.56E-17	**^{150}Gd**		Not listed	Not listed	Not listed	Not listed
	^{209}Pb	5.31E-11	5.67E-11	6.10E-11	4.04E-21	**^{152}Gd**		2.63E-08	4.11E-08	1.90E-05	0.00E+00
^{223}Fr	^{223}Fr	2.34E-09	2.36E-09	1.21E-08	9.71E-19	**^{153}Gd**		3.94E-10	2.79E-10	2.40E-09	9.24E-17

Table A-2. Dose Coefficients Used in the Calculation of Screening Factors (Continued)

Groundwater Scenario						Igneous Scenario					
Radionuclide	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^3)**	**Radionuclide**	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^2)**
	^{223}Ra	1.29E-07	1.04E-07	8.68E-06	2.96E-18	**^{3}H**		1.73E-11	1.92E-11	2.62E-10	0.00E+00
^{150}Gd		Not listed	Not listed	Not listed	Not listed	**^{174}Hf**		0.00E+00	Not listed	Not listed	Not listed
^{152}Gd		2.63E-08	4.11E-08	1.90E-05	0.00E+00	**^{182}Hf**	^{182}Hf	2.91E-09	3.02E-09	3.08E-07	2.23E-16
^{153}Gd		3.94E-10	2.79E-10	2.40E-09	1.14E-18		^{182}Ta	2.12E-09	1.54E-09	1.04E-08	1.19E-15
^{3}H		1.73E-11	1.92E-11	2.62E-10	0.00E+00	**^{166m}Ho**		2.19E-09	1.98E-09	2.86E-07	1.65E-15
^{174}Hf		0.00E+00	Not listed	Not listed	Not listed	**^{129}I**		1.24E-07	1.06E-07	3.59E-08	1.96E-17
^{182}Hf	^{182}Hf	2.91E-09	3.02E-09	3.08E-07	6.17E-18	**^{113m}In**		2.28E-11	2.85E-11	2.10E-11	2.43E-16
	^{182}Ta	2.12E-09	1.54E-09	1.04E-08	4.02E-17	**^{115}In**		3.25E-08	3.25E-08	3.89E-07	3.57E-19
^{166m}Ho		2.19E-09	1.98E-09	2.86E-07	5.17E-17	**^{192}Ir**		1.92E-09	1.37E-09	6.63E-09	7.76E-16
^{129}I		1.24E-07	1.06E-07	3.59E-08	5.14E-20	**^{192m}Ir**	^{192m}Ir	3.33E-10	3.08E-10	3.91E-08	1.47E-16
^{113m}In		2.28E-11	2.85E-11	2.10E-11	7.13E-18		^{192}Ir	1.92E-09	1.37E-09	6.63E-09	7.76E-16
^{115}In		3.25E-08	3.25E-08	3.89E-07	1.90E-21	**^{194}Ir**		1.65E-09	1.33E-09	5.57E-10	1.81E-16
^{192}Ir		1.92E-09	1.37E-09	6.63E-09	2.29E-17	**^{40}K**		5.02E-09	6.16E-09	8.48E-08	2.03E-16
^{192m}Ir	^{192m}Ir	3.33E-10	3.08E-10	3.91E-08	3.68E-18	**^{42}K**		3.99E-10	4.36E-10	3.56E-10	3.97E-16
	^{192}Ir	1.92E-09	1.37E-09	6.63E-09	2.29E-17	**^{81}Kr**		0.00E+00	0.00E+00	0.00E+00	5.99E-18
^{194}Ir		1.65E-09	1.33E-09	5.57E-10	2.81E-18	**^{85}Kr**		0.00E+00	Not listed	Not listed	1.05E-17
^{40}K		5.02E-09	6.16E-09	8.48E-08	5.33E-18	**^{138}La**		1.53E-09	1.09E-09	1.56E-07	1.13E-15
^{42}K		3.99E-10	4.36E-10	3.56E-10	9.84E-18	**^{176}Lu**		2.39E-09	1.78E-09	1.50E-07	4.57E-16
^{81}Kr		0.00E+00	0.00E+00	0.00E+00	1.48E-19	**^{54}Mn**		7.09E-10	7.22E-10	3.27E-09	7.89E-16
^{85}Kr		0.00E+00	Not listed	Not listed	7.23E-20	**^{93}Mo**		2.36E-10	3.16E-09	2.32E-09	3.88E-18
^{138}La		1.53E-09	1.09E-09	1.56E-07	4.04E-17	**^{100}Mo**		Not listed	Not listed	Not listed	Not listed
^{176}Lu		2.39E-09	1.78E-09	1.50E-07	1.25E-17	**^{22}Na**		2.96E-09	3.18E-09	2.91E-08	2.05E-15

Table A-2. Dose Coefficients Used in the Calculation of Screening Factors (Continued)

Groundwater Scenario						Igneous Scenario					
Radionuclide	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^3)**	**Radionuclide**	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^2)**
^{54}Mn		7.09E-10	7.22E-10	3.27E-09	2.60E-17	**^{91}Nb**		Not listed	Not listed	Not listed	Not listed
^{93}Mo	^{93}Mo	2.36E-10	3.16E-09	2.32E-09	2.23E-21	**^{92}Nb**		Not listed	Not listed	Not listed	Not listed
	^{93m}Nb	1.92E-10	1.24E-10	1.77E-09	3.94E-22	**^{93m}Nb**		1.92E-10	1.24E-10	1.77E-09	6.82E-19
^{100}Mo		Not listed	Not listed	Not listed	Not listed	**^{94}Nb**		2.17E-09	1.74E-09	4.88E-08	1.49E-15
^{22}Na		2.96E-09	3.18E-09	2.91E-08	6.90E-17	**^{95}Nb**		7.35E-10	5.88E-10	1.75E-09	7.27E-16
^{91}Nb		Not listed	Not listed	Not listed	Not listed	**^{95m}Nb**	^{95m}Nb	8.30E-10	5.66E-10	8.81E-10	5.91E-17
^{92}Nb		Not listed	Not listed	Not listed	Not listed		^{95}Nb	7.35E-10	5.88E-10	1.75E-09	7.27E-16
^{93m}Nb		1.92E-10	1.24E-10	1.77E-09	3.94E-22	**^{144}Nd**			Not listed	Not listed	Not listed
^{94}Nb		2.17E-09	1.74E-09	4.88E-08	4.88E-17	**^{59}Ni**		6.51E-11	6.30E-11	4.44E-10	0.00E+00
^{95}Nb		7.35E-10	5.88E-10	1.75E-09	2.37E-17	**^{63}Ni**		1.88E-10	1.52E-10	1.26E-09	0.00E+00
^{95m}Nb	^{95m}Nb	8.30E-10	5.66E-10	8.81E-10	1.57E-18	**^{235}Np**		8.45E-11	5.30E-11	6.27E-10	2.86E-18
	^{95}Nb	7.35E-10	5.88E-10	1.75E-09	2.37E-17	**^{236m}Np**		2.34E-07	1.74E-08	7.95E-06	1.11E-16
^{144}Nd		Not listed	Not listed	Not listed	Not listed	**^{237}Np**		6.38E-07	1.07E-07	4.97E-05	2.52E-17
^{59}Ni		6.51E-11	6.30E-11	4.44E-10	0.00E+00	**^{238}Np**	^{238}Np	1.26E-09	9.12E-10	3.48E-09	5.32E-16
^{63}Ni		1.88E-10	1.52E-10	1.26E-09	0.00E+00		^{238}Pu	5.10E-07	2.28E-07	1.08E-04	6.26E-19
^{235}Np		8.45E-11	5.30E-11	6.27E-10	1.51E-20	**^{239}Np**		1.13E-09	7.99E-10	1.03E-09	1.54E-16
^{236m}Np		2.34E-07	1.74E-08	7.95E-06	2.23E-18	**^{240}Np**		5.87E-11	8.22E-11	9.06E-11	1.24E-15
^{237}Np		6.38E-07	1.07E-07	4.97E-05	3.73E-19	**^{240m}Np**		0.00E+00	Not listed	Not listed	3.86E-16
^{238}Np		1.26E-09	9.12E-10	3.48E-09	1.74E-17	**^{186}Os**		Not listed	Not listed	Not listed	Not listed
^{239}Np		1.13E-09	7.99E-10	1.03E-09	3.69E-18	**^{194}Os**	^{194}Os	4.02E-09	2.43E-09	8.50E-08	9.58E-19
^{240}Np		5.87E-11	8.22E-11	9.06E-11	3.89E-17		^{194}Ir	1.65E-09	1.33E-09	5.57E-10	1.81E-16
^{240m}Np		0.00E+00	Not listed	Not listed	1.02E-17	**^{32}P**		2.51E-09	2.40E-09	3.89E-09	8.52E-17

Table A-2. Dose Coefficients Used in the Calculation of Screening Factors (Continued)

Groundwater Scenario						Igneous Scenario					
Radionuclide	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^3)**	**Radionuclide**	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^2)**
^{186}Os		Not listed	Not listed	Not listed	Not listed	**^{231}Pa**		1.42E-06	4.79E-07	2.30E-04	3.78E-17
^{194}Os	^{194}Os	4.02E-09	2.43E-09	8.50E-08	5.01E-21	**^{232}Pa**		9.22E-10	6.75E-10	2.33E-09	8.80E-16
	^{194}Ir	1.65E-09	1.33E-09	5.57E-10	2.81E-18	**^{233}Pa**		1.33E-09	8.78E-10	3.86E-09	1.86E-16
^{32}P		2.51E-09	2.40E-09	3.89E-09	1.09E-19	**^{234}Pa**		5.57E-10	5.24E-10	4.16E-10	1.80E-15
^{231}Pa	^{231}Pa	1.42E-06	4.79E-07	2.30E-04	9.44E-19	**^{234m}Pa**	^{234m}Pa	0.00E+00	0.00E+00	0.00E+00	1.08E-16
	^{227}Ac	2.26E-06	3.23E-07	1.56E-04	2.40E-21		^{234}Pa	5.57E-10	5.24E-10	4.16E-10	1.80E-15
^{232}Pa		9.22E-10	6.75E-10	2.33E-09	2.87E-17	**^{205}Pb**		3.44E-10	2.78E-10	8.53E-10	2.08E-19
^{233}Pa		1.33E-09	8.78E-10	3.86E-09	5.04E-18	**^{209}Pb**		5.31E-11	5.67E-11	6.10E-11	3.19E-18
^{234}Pa		5.57E-10	5.24E-10	4.16E-10	5.83E-17	**^{210}Pb**		8.02E-07	6.96E-07	5.61E-06	2.13E-18
^{234m}Pa	^{234m}Pa	0.00E+00	0.00E+00	0.00E+00	5.28E-19	**^{211}Pb**		1.64E-10	1.78E-10	1.20E-08	9.49E-17
	^{234}Pa	5.57E-10	5.24E-10	4.16E-10	5.83E-17	**^{212}Pb**		8.35E-09	5.98E-09	1.90E-07	1.35E-16
^{205}Pb		3.44E-10	2.78E-10	8.53E-10	4.39E-23	**^{214}Pb**	^{214}Pb	1.54E-10	1.39E-10	1.47E-08	2.40E-16
^{209}Pb		5.31E-11	5.67E-11	6.10E-11	4.04E-21		^{214}Bi	1.07E-10	1.12E-10	1.54E-08	1.44E-15
^{210}Pb		8.02E-07	6.96E-07	5.61E-06	1.06E-20		^{210}Pb	8.02E-07	6.96E-07	5.61E-06	2.13E-18
^{211}Pb		1.64E-10	1.78E-10	1.20E-08	1.56E-18	**^{107}Pd**		5.82E-11	3.71E-11	5.87E-10	0.00E+00
^{212}Pb		8.35E-09	5.98E-09	1.90E-07	3.46E-18	**^{145}Pm**		1.49E-10	1.16E-10	8.43E-09	2.63E-17
^{214}Pb	^{214}Pb	1.54E-10	1.39E-10	1.47E-08	6.65E-18	**^{146}Pm**		1.15E-09	9.07E-10	4.44E-08	7.18E-16
	^{214}Bi	1.07E-10	1.12E-10	1.54E-08	4.99E-17	**^{147}Pm**		3.98E-10	2.61E-10	6.98E-09	2.81E-20
^{107}Pd		5.82E-11	3.71E-11	5.87E-10	0.00E+00	**^{210}Po**		2.14E-07	1.21E-06	4.27E-06	8.07E-21
^{145}Pm		1.49E-10	1.16E-10	8.43E-09	1.25E-19	**^{211}Po**		0.00E+00	Not listed	Not listed	7.41E-18
^{146}Pm		1.15E-09	9.07E-10	4.44E-08	2.21E-17	**^{212}Po**		0.00E+00	Not listed	Not listed	0.00E+00
^{147}Pm		3.98E-10	2.61E-10	6.98E-09	2.30E-22	**^{213}Po**	^{213}Po	0.00E+00	Not listed	Not listed	0.00E+00

Table A-2. Dose Coefficients Used in the Calculation of Screening Factors (Continued)

Groundwater Scenario						Igneous Scenario					
Radionuclide	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^3)**	**Radionuclide**	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^2)**
^{210}Po		2.14E-07	1.21E-06	4.27E-06	2.64E-22		^{209}Pb	5.31E-11	5.67E-11	6.10E-11	3.19E-18
^{211}Po		0.00E+00	Not listed	Not listed	2.40E-19	**^{214}Po**		0.00E+00	Not listed	Not listed	7.91E-20
^{212}Po		0.00E+00	Not listed	Not listed	0.00E+00	**^{215}Po**	^{215}Po	0.00E+00	Not listed	Not listed	1.68E-19
^{213}Po	^{213}Po	0.00E+00	Not listed	Not listed	0.00E+00		^{211}Pb	1.64E-10	1.78E-10	1.20E-08	9.49E-17
	^{209}Pb	5.31E-11	5.67E-11	6.10E-11	4.04E-21		^{211}Bi	0.00E+00	Not listed	Not listed	4.40E-17
^{214}Po		0.00E+00	Not listed	Not listed	2.59E-21		^{207}Tl	0.00E+00	Not listed	Not listed	5.56E-17
^{215}Po	^{215}Po	0.00E+00	Not listed	Not listed	5.06E-21		^{211}Po	0.00E+00	Not listed	Not listed	7.41E-18
	^{211}Pb	1.64E-10	1.78E-10	1.20E-08	1.56E-18	**^{216}Po**	^{216}Po	0.00E+00	Not listed	Not listed	1.61E-20
	^{211}Bi	0.00E+00	Not listed	Not listed	1.27E-18		^{212}Pb	8.35E-09	5.98E-09	1.90E-07	1.35E-16
	^{207}Tl	0.00E+00	Not listed	Not listed	1.23E-19		^{212}Bi	2.21E-10	2.59E-10	3.32E-08	2.25E-16
	^{211}Po	0.00E+00	Not listed	Not listed	2.40E-19		^{208}Tl	0.00E+00	Not listed	Not listed	2.97E-15
^{216}Po	^{216}Po	0.00E+00	Not listed	Not listed	5.26E-22	**^{218}Po**	^{218}Po	0.00E+00	Not listed	Not listed	8.64E-21
	^{212}Pb	8.35E-09	5.98E-09	1.90E-07	3.46E-18		^{214}Pb	1.54E-10	1.39E-10	1.47E-08	2.40E-16
	^{212}Bi	2.21E-10	2.59E-10	3.32E-08	5.96E-18		^{214}Bi	1.07E-10	1.12E-10	1.54E-08	1.44E-15
	^{208}Tl	0.00E+00	Not listed	Not listed	1.17E-16		^{214}Po	0.00E+00	Not listed	Not listed	7.91E-20
^{218}Po	^{218}Po	0.00E+00	Not listed	Not listed	2.85E-22		^{210}Pb	8.02E-07	6.96E-07	5.61E-06	2.13E-18
	^{214}Pb	1.54E-10	1.39E-10	1.47E-08	6.65E-18		^{210}Bi	1.93E-09	1.31E-09	1.33E-07	3.51E-17
	^{214}Bi	1.07E-10	1.12E-10	1.54E-08	4.99E-17		^{210}Po	2.14E-07	1.21E-06	4.27E-06	8.07E-21
	^{214}Po	0.00E+00	Not listed	Not listed	2.59E-21		^{218}At	0.00E+00	0.00E+00	0.00E+00	3.65E-18
	^{210}Pb	8.02E-07	6.96E-07	5.61E-06	1.06E-20		^{214}Bi	1.07E-10	1.12E-10	1.54E-08	1.44E-15
	^{210}Bi	1.93E-09	1.31E-09	1.33E-07	2.92E-20		^{214}Po	0.00E+00	Not listed	Not listed	7.91E-20
	^{210}Po	2.14E-07	1.21E-06	4.27E-06	2.64E-22		^{210}Pb	8.02E-07	6.96E-07	5.61E-06	2.13E-18

Table A-2. Dose Coefficients Used in the Calculation of Screening Factors (Continued)

Groundwater Scenario						Igneous Scenario					
Radionuclide	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^3)**	**Radionuclide**	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^2)**
	^{214}Bi	1.07E-10	1.12E-10	1.54E-08	4.99E-17		^{210}Bi	1.93E-09	1.31E-09	1.33E-07	3.51E-17
	^{214}Po	0.00E+00	Not listed	Not listed	2.59E-21		^{210}Po	2.14E-07	1.21E-06	4.27E-06	8.07E-21
	^{210}Pb	8.02E-07	6.96E-07	5.61E-06	1.06E-20	**^{144}Pr**		4.93E-11	5.06E-11	1.83E-11	1.63E-16
	^{210}Bi	1.93E-09	1.31E-09	1.33E-07	2.92E-20	**^{144m}Pr**	^{144m}Pr	0.00E+00	Not listed	Not listed	1.05E-17
	^{210}Po	2.14E-07	1.21E-06	4.27E-06	2.64E-22		^{144}Pr	4.93E-11	5.06E-11	1.83E-11	1.63E-16
^{144}Pr		4.93E-11	5.06E-11	1.83E-11	1.43E-18	**^{193}Pt**		4.49E-11	3.10E-11	6.70E-10	1.54E-19
^{144m}Pr	^{144m}Pr	0.00E+00	Not listed	Not listed	6.45E-20	**^{236}Pu**		1.89E-07	8.69E-08	3.98E-05	7.36E-19
	^{144}Pr	4.93E-11	5.06E-11	1.83E-11	1.43E-18	**^{238}Pu**		5.10E-07	2.28E-07	1.08E-04	6.26E-19
^{193}Pt		4.49E-11	3.10E-11	6.70E-10	3.38E-23	**^{239}Pu**		5.62E-07	2.51E-07	1.19E-04	2.84E-19
^{236}Pu		1.89E-07	8.69E-08	3.98E-05	9.71E-22	**^{240}Pu**		5.62E-07	2.51E-07	1.19E-04	6.01E-19
^{238}Pu		5.10E-07	2.28E-07	1.08E-04	6.25E-22	**^{241}Pu**	^{241}Pu	1.07E-08	4.75E-09	2.29E-06	1.72E-21
^{239}Pu		5.62E-07	2.51E-07	1.19E-04	1.41E-21		^{241}Am	5.79E-07	2.04E-07	9.64E-05	2.33E-17
^{240}Pu		5.62E-07	2.51E-07	1.19E-04	6.03E-22	**^{242}Pu**		5.33E-07	2.38E-07	1.13E-04	4.98E-19
^{241}Pu	^{241}Pu	1.07E-08	4.75E-09	2.29E-06	2.84E-23	**^{243}Pu**		8.71E-11	8.52E-11	8.66E-11	2.27E-17
	^{241}Am	5.79E-07	2.04E-07	9.64E-05	1.99E-19	**^{244}Pu**		5.30E-07	2.40E-07	1.10E-04	4.16E-19
^{242}Pu		5.33E-07	2.38E-07	1.13E-04	5.32E-22	**^{246}Pu**	^{246}Pu	4.93E-09	2.83E-09	4.76E-09	1.23E-16
^{243}Pu		8.71E-11	8.52E-11	8.66E-11	3.82E-19		^{246}Am	5.28E-11	5.78E-11	6.96E-11	6.79E-16
^{244}Pu	^{244}Pu	5.30E-07	2.40E-07	1.10E-04	2.92E-22	**^{223}Ra**		1.29E-07	1.04E-07	8.68E-06	1.21E-16
	^{240}mNp	0.00E+00	0.00E+00	0.00E+00	1.02E-17	**^{224}Ra**		7.41E-08	6.45E-08	3.36E-06	9.15E-18
^{246}Pu	^{246}Pu	4.93E-09	2.83E-09	4.76E-09	2.77E-18	**^{225}Ra**	^{225}Ra	7.09E-08	9.95E-08	7.73E-06	1.07E-17
	^{246}Am	5.28E-11	5.78E-11	6.96E-11	1.97E-17		^{225}Ac	3.81E-08	2.40E-08	8.50E-06	1.47E-17
^{223}Ra		1.29E-07	1.04E-07	8.68E-06	2.96E-18	**^{226}Ra**	^{226}Ra	2.25E-07	2.80E-07	9.51E-06	6.11E-18

Table A-2. Dose Coefficients Used in the Calculation of Screening Factors (Continued)

Groundwater Scenario						Igneous Scenario					
Radionuclide	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^3)**	**Radionuclide**	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^2)**
^{224}Ra		7.41E-08	6.45E-08	3.36E-06	2.53E-19		^{214}Pb	1.54E-10	1.39E-10	1.47E-08	2.40E-16
^{225}Ra		7.09E-08	9.95E-08	7.73E-06	4.63E-20		^{214}Bi	1.07E-10	1.12E-10	1.54E-08	1.44E-15
^{226}Ra	^{226}Ra	2.25E-07	2.80E-07	9.51E-06	1.56E-19		^{210}Pb	8.02E-07	6.96E-07	5.61E-06	2.13E-18
	^{214}Pb	1.54E-10	1.39E-10	1.47E-08	6.65E-18	**^{228}Ra**	^{228}Ra	2.76E-07	6.97E-07	1.60E-05	0.00E+00
	^{214}Bi	1.07E-10	1.12E-10	1.54E-08	4.99E-17		^{228}Ac	4.50E-10	4.01E-10	1.46E-08	9.38E-16
	^{210}Pb	8.02E-07	6.96E-07	5.61E-06	1.06E-20		^{208}Tl	0.00E+00	Not listed	Not listed	2.97E-15
^{228}Ra	^{228}Ra	2.76E-07	6.97E-07	1.60E-05	0.00E+00	**^{87}Rb**		1.29E-09	1.47E-09	1.52E-08	7.32E-20
	^{228}Ac	4.50E-10	4.01E-10	1.46E-08	3.03E-17	**^{187}Re**		4.32E-12	5.12E-12	4.20E-11	0.00E+00
	^{212}Pb	8.35E-09	5.98E-09	1.90E-07	3.46E-18	**^{102}Rh**		2.73E-09	2.58E-09	1.75E-08	2.02E-15
	^{208}Tl	0.00E+00	Not listed	Not listed	1.17E-16	**^{106}Rh**		0.00E+00	Not listed	Not listed	3.45E-16
^{87}Rb		1.29E-09	1.47E-09	1.52E-08	6.51E-22	**^{217}Rn**		Not listed			
^{187}Re		4.32E-12	5.12E-12	4.20E-11	0.00E+00	**^{218}Rn**	^{218}Rn	0.00E+00	0.00E+00	0.00E+00	7.24E-19
^{102}Rh		2.73E-09	2.58E-09	1.75E-08	6.52E-17		^{214}Po	0.00E+00	0.00E+00	0.00E+00	7.91E-20
^{106}Rh		0.00E+00	Not listed	Not listed	6.66E-18	**^{219}Rn**	^{219}Rn	0.00E+00	Not listed	Not listed	5.28E-17
^{217}Rn		Not listed	Not listed	Not listed	Not listed		^{215}Po	0.00E+00	Not listed	Not listed	1.68E-19
^{218}Rn	^{218}Rn	0.00E+00	0.00E+00	0.00E+00	2.28E-20		^{211}Pb	1.64E-10	1.78E-10	1.20E-08	9.49E-17
	^{214}Po	0.00E+00	0.00E+00	0.00E+00	2.59E-21		^{211}Bi	0.00E+00	Not listed	Not listed	4.40E-17
^{219}Rn	^{219}Rn	0.00E+00	Not listed	Not listed	1.53E-18		^{207}Tl	0.00E+00	Not listed	Not listed	5.56E-17
	^{215}Po	0.00E+00	Not listed	Not listed	5.06E-21		^{211}Po	0.00E+00	Not listed	Not listed	7.41E-18
	^{211}Pb	1.64E-10	1.78E-10	1.20E-08	1.56E-18	**^{220}Rn**	^{220}Rn	0.00E+00	Not listed	Not listed	3.69E-19
	^{211}Bi	0.00E+00	Not listed	Not listed	1.27E-18		^{216}Po	0.00E+00	Not listed	Not listed	1.61E-20
	^{207}Tl	0.00E+00	Not listed	Not listed	1.23E-19		^{212}Pb	8.35E-09	5.98E-09	1.90E-07	1.35E-16

Table A-2. Dose Coefficients Used in the Calculation of Screening Factors (Continued)

Groundwater Scenario						Igneous Scenario					
Radionuclide	Radionuclide and Decay Products	NCRP-123 Ingestion Dose Factor (Sv/Bq)	FGR-13 Ingestion Dose Coefficient (Sv/Bq)	FGR-13 Inhalation Dose Coefficient (Sv/Bq)	FGR-13 External Dose Coefficient (Sv/s per Bq/m^3)	Radionuclide	Radionuclide and Decay Products	NCRP-123 Ingestion Dose Factor (Sv/Bq)	FGR-13 Ingestion Dose Coefficient (Sv/Bq)	FGR-13 Inhalation Dose Coefficient (Sv/Bq)	FGR-13 External Dose Coefficient (Sv/s per Bq/m^2)
	^{211}Po	0.00E+00	Not listed	Not listed	2.40E-19		^{212}Bi	2.21E-10	2.59E-10	3.32E-08	2.25E-16
^{220}Rn	^{220}Rn	0.00E+00	Not listed	Not listed	1.15E-20		^{208}Tl	0.00E+00	Not listed	Not listed	2.97E-15
	^{216}Po	0.00E+00	Not listed	Not listed	5.26E-22	**^{222}Rn**	^{222}Rn	0.00E+00	Not listed	Not listed	3.82E-19
	^{212}Pb	8.35E-09	5.98E-09	1.90E-07	3.46E-18		^{214}Pb	1.54E-10	1.39E-10	1.47E-08	2.40E-16
	^{212}Bi	2.21E-10	2.59E-10	3.32E-08	5.96E-18		^{214}Bi	1.07E-10	1.12E-10	1.54E-08	1.44E-15
	^{208}Tl	0.00E+00	Not listed	Not listed	1.17E-16		^{214}Po	0.00E+00	Not listed	Not listed	7.91E-20
^{222}Rn	^{222}Rn	0.00E+00	Not listed	Not listed	1.17E-20		^{210}Pb	8.02E-07	6.96E-07	5.61E-06	2.13E-18
	^{214}Pb	1.54E-10	1.39E-10	1.47E-08	6.65E-18		^{210}Bi	1.93E-09	1.31E-09	1.33E-07	3.51E-17
	^{214}Bi	1.07E-10	1.12E-10	1.54E-08	4.99E-17		^{210}Po	2.14E-07	1.21E-06	4.27E-06	8.07E-21
	^{214}Po	0.00E+00	Not listed	Not listed	2.59E-21		^{218}At	0.00E+00	0.00E+00	0.00E+00	3.65E-18
	^{210}Pb	8.02E-07	6.96E-07	5.61E-06	1.06E-20		^{214}Bi	1.07E-10	1.12E-10	1.54E-08	1.44E-15
	^{210}Bi	1.93E-09	1.31E-09	1.33E-07	2.92E-20		^{210}Pb	8.02E-07	6.96E-07	5.61E-06	2.13E-18
	^{210}Po	2.14E-07	1.21E-06	4.27E-06	2.64E-22		^{210}Bi	1.93E-09	1.31E-09	1.33E-07	3.51E-17
	^{214}Bi	1.07E-10	1.12E-10	1.54E-08	4.99E-17		^{210}Po	2.14E-07	1.21E-06	4.27E-06	8.07E-21
	^{210}Pb	8.02E-07	6.96E-07	5.61E-06	1.06E-20	**^{106}Ru**	^{106}Ru	1.00E-08	7.01E-09	6.60E-08	0.00E+00
	^{210}Po	2.14E-07	1.21E-06	4.27E-06	2.64E-22		^{106}Rh	0.00E+00	0.00E+00	0.00E+00	3.45E-16
^{106}Ru		1.00E-08	7.01E-09	6.60E-08	0.00E+00	**^{125}Sb**		9.30E-10	1.13E-09	1.19E-08	4.08E-16
^{125}Sb		9.30E-10	1.13E-09	1.19E-08	1.22E-17	**^{126}Sb**		3.23E-09	2.46E-09	3.24E-09	2.71E-15
^{126}Sb		3.23E-09	2.46E-09	3.24E-09	8.60E-17	**^{126m}Sb**	^{126m}Sb	3.47E-11	3.60E-11	1.96E-11	1.54E-15
^{126m}Sb		3.47E-11	3.60E-11	1.96E-11	4.67E-17		^{126}Sb	3.23E-09	2.46E-09	3.24E-09	2.71E-15
^{79}Se		1.55E-09	2.89E-09	6.77E-09	8.21E-23	**^{79}Se**		1.55E-09	2.89E-09	6.77E-09	1.65E-20
^{32}Si	^{32}Si	8.58E-10	5.62E-10	1.14E-07	1.60E-22	**^{32}Si**	^{32}Si	8.58E-10	5.62E-10	1.14E-07	2.51E-20

Table A-2. Dose Coefficients Used in the Calculation of Screening Factors (Continued)

Groundwater Scenario						Igneous Scenario					
Radionuclide	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^3)**	**Radionuclide**	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^2)**
	^{32}P	2.51E-09	2.40E-09	3.89E-09	1.09E-19		^{32}P	2.51E-09	2.40E-09	3.89E-09	8.52E-17
^{145}Sm	^{145}Sm	3.04E-10	2.17E-10	2.93E-09	2.92E-19	**^{145}Sm**	^{145}Sm	3.04E-10	2.17E-10	2.93E-09	5.58E-17
	^{145}Pm	1.49E-10	1.16E-10	8.43E-09	1.25E-19		^{145}Pm	1.49E-10	1.16E-10	8.43E-09	2.63E-17
^{146}Sm		3.46E-08	5.45E-08	2.54E-05	0.00E+00	**^{146}Sm**		3.46E-08	5.45E-08	2.54E-05	0.00E+00
^{147}Sm		3.15E-08	4.95E-08	2.31E-05	0.00E+00	**^{147}Sm**		3.15E-08	4.95E-08	2.31E-05	0.00E+00
^{148}Sm		Not listed	Not listed	Not listed	Not listed	**^{148}Sm**		Not listed	Not listed	Not listed	Not listed
^{149}Sm		Not listed	Not listed	Not listed	Not listed	**^{149}Sm**		Not listed	Not listed	Not listed	Not listed
^{151}Sm		1.35E-10	9.80E-11	9.19E-09	3.62E-24	**^{151}Sm**		1.35E-10	9.80E-11	9.19E-09	3.55E-21
^{113}Sn	^{113}Sn	1.09E-09	7.38E-10	3.95E-09	1.42E-19	**^{113}Sn**	^{113}Sn	1.09E-09	7.38E-10	3.95E-09	1.64E-17
	^{113m}In	2.28E-11	2.85E-11	2.10E-11	7.13E-18		^{133m}In	2.28E-11	2.85E-11	2.10E-11	2.43E-16
^{119m}Sn		5.22E-10	3.44E-10	3.33E-09	1.13E-20	**^{119m}Sn**		5.22E-10	3.44E-10	3.33E-09	7.51E-18
^{121}Sn		3.00E-10	2.28E-10	2.49E-10	9.18E-22	**^{121}Sn**		3.00E-10	2.28E-10	2.49E-10	8.86E-20
^{121m}Sn		6.01E-10	3.82E-10	1.50E-08	7.70E-21	**^{121m}Sn**	^{121m}Sn	6.01E-10	3.82E-10	1.50E-08	3.62E-18
^{123}Sn		3.25E-09	2.10E-09	1.29E-08	2.84E-19		^{121}Sn	3.00E-10	2.28E-10	2.49E-10	8.86E-20
^{126}Sn	^{126}Sn	6.55E-09	4.77E-09	1.55E-07	6.97E-19	**^{123}Sn**		3.25E-09	2.10E-09	1.29E-08	6.50E-17
	^{126m}Sb	3.47E-11	3.60E-11	1.96E-11	4.67E-17	**^{126}Sn**	^{126}Sn	6.55E-09	4.77E-09	1.55E-07	4.83E-17
^{90}Sr		3.10E-08	2.77E-08	1.57E-07	3.46E-21		^{126m}Sb	3.47E-11	3.60E-11	1.96E-11	1.54E-15
^{182}Ta		2.12E-09	1.54E-09	1.04E-08	4.02E-17		^{126}Sb	3.23E-09	2.46E-09	3.24E-09	2.71E-15
^{160}Tb		2.26E-09	1.61E-09	8.28E-09	3.50E-17	**^{90}Sr**		3.10E-08	2.77E-08	1.57E-07	1.64E-18
^{98}Tc		1.83E-09	1.97E-09	4.50E-08	4.32E-17	**^{182}Ta**		2.12E-09	1.54E-09	1.04E-08	1.19E-15
^{99}Tc		6.64E-10	6.42E-10	1.33E-08	5.81E-22	**^{160}Tb**		2.26E-09	1.61E-09	8.28E-09	1.05E-15
^{123}Te		5.75E-10	4.40E-09	3.93E-09	2.49E-20	**^{98}Tc**		1.83E-09	1.97E-09	4.50E-08	1.34E-15

Table A-2. Dose Coefficients Used in the Calculation of Screening Factors (Continued)

Groundwater Scenario						Igneous Scenario					
Radionuclide	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^3)**	**Radionuclide**	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^2)**
^{123m}Te		1.20E-09	1.38E-09	5.07E-09	3.07E-18	**^{99}Tc**		6.64E-10	6.42E-10	1.33E-08	6.49E-20
^{125m}Te		9.06E-10	8.72E-10	4.13E-09	5.97E-20	**^{123}Te**		5.75E-10	4.40E-09	3.93E-09	1.43E-17
^{127}Te		1.84E-10	1.69E-10	1.40E-10	1.43E-19	**^{123m}Te**		1.20E-09	1.38E-09	5.07E-09	1.33E-16
^{127m}Te		2.28E-09	2.34E-09	9.79E-09	2.24E-20	**^{125m}Te**		9.06E-10	8.72E-10	4.13E-09	2.68E-17
^{128}Te		Not listed	Not listed	Not listed	Not listed	**^{127}Te**		1.84E-10	1.69E-10	1.40E-10	1.03E-17
^{130}Te		Not listed	Not listed	Not listed	Not listed	**^{127m}Te**		2.28E-09	2.34E-09	9.79E-09	8.61E-18
^{227}Th	^{227}Th	1.27E-08	9.02E-09	1.04E-05	2.57E-18	**^{128}Te**		Not listed	Not listed	Not listed	Not listed
	^{223}Ra	1.29E-07	1.04E-07	8.68E-06	2.96E-18	**^{130}Te**		Not listed	Not listed	Not listed	Not listed
^{228}Th	^{228}Th	6.55E-08	7.20E-08	3.97E-05	3.85E-20	**^{227}Th**	^{227}Th	1.27E-08	9.02E-09	1.04E-05	9.81E-17
	^{224}Ra	7.41E-08	6.45E-08	3.36E-06	2.53E-19		^{223}Ra	1.29E-07	1.04E-07	8.68E-06	1.21E-16
	^{212}Pb	8.35E-09	5.98E-09	1.90E-07	3.46E-18	**^{228}Th**		6.55E-08	7.20E-08	3.97E-05	2.13E-18
	^{208}Tl	0.00E+00	Not listed	Not listed	1.17E-16	**^{229}Th**		4.80E-07	5.00E-07	2.39E-04	7.90E-17
^{229}Th		4.80E-07	5.00E-07	2.39E-04	1.55E-18	**^{230}Th**		7.75E-08	2.14E-07	1.02E-04	6.37E-19
^{230}Th		7.75E-08	2.14E-07	1.02E-04	5.73E-21	**^{231}Th**		4.40E-10	3.36E-10	3.34E-10	1.56E-17
^{231}Th		4.40E-10	3.36E-10	3.34E-10	1.72E-19	**^{232}Th**		3.69E-07	2.31E-07	1.10E-04	4.55E-19
^{232}Th	^{232}Th	3.69E-07	2.31E-07	1.10E-04	2.44E-21	**^{234}Th**		5.30E-09	3.40E-09	7.69E-09	7.50E-18
	^{228}Ra	2.76E-07	6.97E-07	1.60E-05	0.00E+00	**^{204}Tl**		7.88E-10	1.19E-09	1.90E-08	1.08E-17
	^{228}Ac	4.50E-10	4.01E-10	1.46E-08	3.03E-17	**^{206}Tl**		Not listed	Not listed	Not listed	6.07E-17
	^{212}Pb	8.35E-09	5.98E-09	1.90E-07	3.46E-18	**^{207}Tl**		Not listed	Not listed	Not listed	5.56E-17
	^{208}Tl	0.00E+00	Not listed	Not listed	1.17E-16	**^{208}Tl**		Not listed	Not listed	Not listed	2.97E-15
^{234}Th		5.30E-09	3.40E-09	7.69E-09	1.14E-19	**^{209}Tl**		Not listed	Not listed	Not listed	1.92E-15
^{204}Tl		7.88E-10	1.19E-09	1.90E-08	2.08E-20	**^{171}Tm**		1.64E-10	1.07E-10	2.13E-09	5.56E-19

Table A-2. Dose Coefficients Used in the Calculation of Screening Factors (Continued)

Groundwater Scenario						**Igneous Scenario**					
Radionuclide	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^3)**	**Radionuclide**	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^2)**
^{206}Tl		Not listed	Not listed	Not listed	6.76E-20	**^{232}U**	^{232}U	1.31E-07	3.36E-07	3.70E-05	8.08E-19
^{207}Tl		Not listed	Not listed	Not listed	1.23E-19		^{208}Tl	0.00E+00	Not listed	Not listed	2.97E-15
^{208}Tl		Not listed	Not listed	Not listed	1.17E-16	**^{233}U**		2.88E-08	5.13E-08	9.59E-06	6.00E-19
^{209}Tl	^{209}Tl	Not listed	Not listed	Not listed	6.56E-17	**^{234}U**		2.82E-08	4.95E-08	9.40E-06	5.86E-19
	^{209}Pb	5.31E-11	5.67E-11	6.10E-11	4.04E-21	**^{235}U**		2.73E-08	4.67E-08	8.47E-06	1.40E-16
^{171}Tm		1.64E-10	1.07E-10	2.13E-09	5.04E-21	**^{236}U**		2.67E-08	4.69E-08	8.74E-06	5.03E-19
^{232}U	^{232}U	1.31E-07	3.36E-07	3.70E-05	4.25E-21	**^{237}U**		1.15E-09	7.61E-10	1.88E-09	1.24E-16
	^{228}Th	6.55E-08	7.20E-08	3.97E-05	3.85E-20	**^{238}U**		2.58E-08	4.45E-08	8.04E-06	4.24E-19
	^{224}Ra	7.41E-08	6.45E-08	3.36E-06	2.53E-19	**^{240}U**	^{240}U	1.28E-09	1.11E-09	5.82E-10	3.20E-18
	^{212}Pb	8.35E-09	5.98E-09	1.90E-07	3.46E-18		^{240m}Np	0.00E+00	0.00E+00	0.00E+00	3.86E-16
	^{212}Bi	2.21E-10	2.59E-10	3.32E-08	5.96E-18	**^{50}V**		Not listed	Not listed	Not listed	Not listed
	^{208}Tl	0.00E+00	Not listed	Not listed	1.17E-16	**^{90}Y**		3.93E-09	2.69E-09	1.50E-09	1.10E-16
^{233}U		2.88E-08	5.13E-08	9.59E-06	6.77E-21	**^{91}Y**		3.71E-09	2.37E-09	8.93E-09	7.46E-17
^{234}U		2.82E-08	4.95E-08	9.40E-06	1.84E-21	**^{64}Zn**		Not listed	Not listed	Not listed	Not listed
^{235}U	^{235}U	2.73E-08	4.67E-08	8.47E-06	3.53E-18	**^{65}Zn**		3.72E-09	3.94E-09	2.25E-09	5.39E-16
	^{231}Th	4.40E-10	3.36E-10	3.34E-10	1.72E-19	**^{93}Zr**	^{93}Zr	3.03E-10	1.11E-09	2.51E-08	0.00E+00
^{236}U		2.67E-08	4.69E-08	8.74E-06	9.53E-22		^{93m}Nb	1.92E-10	1.24E-10	1.77E-09	6.82E-19
^{237}U		1.15E-09	7.61E-10	1.88E-09	2.58E-18	**^{95}Zr**	^{95}Zr	1.21E-09	9.61E-10	5.84E-09	7.02E-16
^{238}U	^{238}U	2.58E-08	4.45E-08	8.04E-06	4.27E-22		^{95}Nb	7.35E-10	5.88E-10	1.75E-09	7.27E-16
	^{234}Th	5.30E-09	3.40E-09	7.69E-09	1.14E-19	**^{96}Zr**		Not listed	Not listed	Not listed	Not listed
	^{234m}Pa	0.00E+00	0.00E+00	0.00E+00	5.28E-19						
^{240}U		1.28E-09	1.11E-09	5.82E-10	5.95E-21						

Table A-2. Dose Coefficients Used in the Calculation of Screening Factors (Continued)

Groundwater Scenario						Igneous Scenario					
Radionuclide	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^3)**	**Radionuclide**	**Radionuclide and Decay Products**	**NCRP-123 Ingestion Dose Factor (Sv/Bq)**	**FGR-13 Ingestion Dose Coefficient (Sv/Bq)**	**FGR-13 Inhalation Dose Coefficient (Sv/Bq)**	**FGR-13 External Dose Coefficient (Sv/s per Bq/m^2)**
^{50}V		Not listed	Not listed	Not listed	Not listed						
^{90}Y		3.93E-09	2.69E-09	1.50E-09	2.15E-19						
^{91}Y		3.71E-09	2.37E-09	8.93E-09	2.03E-19						
^{64}Zn		Not listed	Not listed	Not listed	Not listed						
^{65}Zn		3.72E-09	3.94E-09	2.25E-09	1.88E-17						
^{93}Zr	^{93}Zr	3.03E-10	1.11E-09	2.51E-08	0.00E+00						
	^{93m}Nb	1.92E-10	1.24E-10	1.77E-09	3.94E-22						
^{95}Zr		1.21E-09	9.61E-10	5.84E-09	2.27E-17						
^{96}Zr		Not listed	Not listed	Not listed	Not listed						

Source: NCRP 1996 [DIRS 101882]; EPA 2000 [DIRS 153733].

NOTE: For ^{244}Pu, ^{252}Cf and ^{248}Cm, dose coefficients from the ICRP-72 database (ICRP 1996 [DIRS 152446]) were used because they were not included in FGR-13.

A.1.2 Screening Factors for Inhalation and External Exposure Pathways

The site-specific screening factors for inhalation and external exposure were calculated based on the methods used in the biosphere model (BSC 2004 [DIRS 169460], Sections 6.4.8.1 and 6.4.7.1). The calculations were carried out in Excel file `Site-Specific Screening Factors.xls` included in Appendix C.

The screening factor for external exposure to soil for the groundwater scenario was calculated as:

$$SF_{soil,\,ext,\,gw} = C_{soil}\;\; D\,U_{soil,\,ext}\;\; DF_{soil,\,ext} \qquad \text{(Eq. A-1)}$$

where

$SF_{soil,\ ext,gw}$ = groundwater screening factor for external exposure to radionuclides in soil (Sv/yr per Bq/m^3)

C_{soil} = radionuclide concentration in soil (Bq/kg), calculated as explained in Equation A-4

D = surface soil density (kg/m^3)

$U_{soil,\ ext}$ = groundwater usage factor for soil exposure (number of hours of soil exposure per year) (hr)

$DF_{soil,\ ext}$ = dose coefficient for exposure to soil contaminated to an infinite depth (Sv/hr per Bq/m^3).

Equation A-1 uses dose coefficient for exposure to soil contaminated to infinite depth, consistent with the approach used in the biosphere model (BSC 2004 [DIRS 169460], Section 6.4.7.1).

The screening factor for external exposure to soil for the igneous scenario was calculated as

$$SF_{soil,\,ext,\,ign} = C_{soil}\;\; D\;d\;U_{soil,\,ext}\;\; DF_{soil,\,ext} \qquad \text{(Eq. A-2)}$$

where

$SF_{soil,\ ext,\ ign}$ = igneous screening factor for external exposure to radionuclides in soil (Sv/yr per Bq/m^3)

C_{soil} = radionuclide concentration in soil (Bq/kg)

D = surface soil density (kg/m^3)

d = depth of contaminated layer

$U_{soil,\ ext}$ = igneous usage factor for soil exposure (number of hours of soil exposure per year) (hr)

$DF_{soil, ext}$ = dose coefficient for exposure to contaminated soil surface (Sv/hr per Bq/m^2).

Equation A-2 uses dose coefficient for exposure to contaminated soil surface, consistent with the approach used in the biosphere model (BSC 2004 [DIRS 169460], Section 6.5.5.1). Because these coefficients are expressed in Sv/s per Bq/m^2, the radionuclide concentration in soil is calculated per unit surface area. This is accomplished by multiplying in Equation A-2 the volume activity concentration ($C_{soil} \times D$) by the depth of contaminated layer, d. The depth of contaminated layer is assumed equal to 1 cm (NCRP 1996 [DIRS 101882], p. 68).

The average surface soil density used in the biosphere model (BSC 2004 [DIRS 169460]) is 1,500 kg/m^3 (DTN: MO0609SPASRPBM.0004 [DIRS 177742]). The same value is used in this analysis.

The receptor used in the biosphere model (BSC 2004 [DIRS 169460]) spends time in four mutually exclusive environments (active outdoors, inactive outdoors, asleep indoors, and active indoors) while in a contaminated area. The soil exposure time is calculated as the sum of time spent outdoors (active and inactive) and 0.4 times time spent indoors (asleep and active). The factor of 0.4 is the highest building-shielding factor for the radionuclides included in this analysis (NCRP 1999 [DIRS 155894], Appendix C). The receptor, in turn, is a composite of four population groups (non-workers, commuters, outdoor workers, and indoor workers). The soil exposure time is thus also weighted by the fraction of population that belongs to a given population group. The population fraction and the times spent in receptor environments were obtained from *Characteristics of the Receptor for the Biosphere Model* (BSC 2005 [DIRS 172827], Tables 7-1 and 7-2; DTN: MO0407SPACRBSM.002 [DIRS 170677]). The data and the calculated weighted soil exposure time are shown in Tables A-3 and A-4 for the groundwater and igneous scenarios, respectively.

Table A-3. Calculation of Soil Exposure Time for Groundwater Scenario

Population group	Fraction of Population	Time Spent in an Environment, hr/day				Soil Exposure Time
		Active Outdoors	Inactive Outdoors	Asleep Indoors	Active Indoors	
Non-workers	0.392	0.3	1.2	8.3	12.2	9.7
Commuters	0.392	0.3	1.4	8.3	6	7.4
Outdoor workers	0.055	3.1	4	8.3	6.6	13.1
Indoor workers	0.161	0.3	1.3	8.3	12.1	9.8
Population-weighted time in environment, h		0.5	1.4	8.3	9.4	9.0
Weighted soil exposure time, h/y						3,285.3

Source: DTN: MO0407SPACRBSM.002 [DIRS 170677].

NOTE: See Excel file `Site-Specific Screening Factors.xls`, worksheet `Additional Calculations`, in Appendix C.

Table A-4. Calculation of Soil Exposure Time for Igneous Scenario

Population group	Fraction of Population	Time Spent in an Environment, hr/day				Soil Exposure Time
		Active Outdoors	Inactive Outdoors	Asleep Indoors	Active Indoors	
Non-workers	0.392	0.3	1.2	8.3	12.2	9.7
Commuters	0.125	0.3	2	8.3	5.1	7.7
Outdoor workers	0.055	3.1	4.2	8.3	6.4	13.2
Indoor workers	0.428	0.3	1.5	8.3	11.9	9.9
Population-weighted time in environment, h		0.5	1.6	8.3	10.9	9.7
Weighted soil exposure time, hr/yr						3,545.4

Source: DTN: MO0407SPACRBSM.002 [DIRS 170677].

NOTE: See Excel file `Site-Specific Screening Factors.xls`, worksheet `Additional Calculations`, in Appendix C.

The screening factor for inhalation was calculated as:

$$SF_{soil,\,inh} = C_{soil}\, U_{soil,\,inh}\; DF_{inh} \qquad \text{(Eq. A-3)}$$

where

$SF_{soil,inh}$ = screening factor for inhalation of resuspended soil particles (Sv/Bq)

C_{soil} = radionuclide concentration in soil (Bq/kg)

$U_{soil,\, ext}$ = usage factor for soil exposure (mass of soil inhaled annually) (kg/yr)

$DF_{soil,\, ext}$ = dose coefficient for inhalation (Sv/Bq).

The mass of soil inhaled annually was calculated as a weighted average of mass inhaled in individual receptor environments with weights being the weighted time spent in these environments, as shown in Tables A-3 and A-4 for the groundwater and igneous scenarios, respectively. Calculations of the mass of inhaled soil are shown in Tables A-5 and A-6 for the two scenarios considered in this analysis.

Table A-5. Calculation of Mass of Inhaled Soil for Groundwater Scenario

Parameter	Active Outdoors	Inactive Outdoors	Asleep Indoors	Active Indoors	Mass Inhaled
Mass loading, mg/m^3	3	0.06	0.03	0.1	
Weighted time in environment [a]	0.5	1.4	8.3	9.4	
Breathing rate, m^3/hr	1.57	1.08	0.39	1.08	
Mass inhaled, kg/day	2.14×10^{-6}	9.39×10^{-8}	9.71×10^{-8}	1.02×10^{-6}	3.35×10^{-6}
Total mass inhaled, kg/yr					1.22×10^{-3}

Source: DTNs: MO0407SPACRBSM.002 [DIRS 170677] and MO0605SPAINEXI.003 [DIRS 177172].

[a] See Table A-3.

NOTE: See Excel file `Site-Specific Screening Factors.xls`, worksheet `Additional Calculations`, in Appendix C.

Table A-6. Calculation of Mass of Inhaled Soil for Igneous Scenario

Parameter	Active Outdoors	Inactive Outdoors	Asleep Indoors	Active Indoors	Mass Inhaled
Mass loading, mg/m^3	6	0.12	0.2	0.06	
Weighted time in environment [a]	0.5	1.6	8.3	10.9	
Breathing rate, m^3/hr	1.57	1.08	0.39	1.08	
Mass inhaled, kg/day	4.28×10^{-6}	2.07×10^{-7}	6.47×10^{-7}	7.04×10^{-7}	5.83×10^{-6}
Total mass inhaled, kg/yr					2.13×10^{-3}

Source: DTNs: MO0407SPACRBSM.002 [DIRS 170677] and MO0605SPAINEXI.003 [DIRS 177172].

[a] See Table A-4.

NOTE: See Excel file `Site-Specific Screening Factors.xls`, worksheet `Additional Calculations`, in Appendix C.

Radionuclide concentration in soil in Equations A-1 to A-3 was calculated from an equation that was used to develop the generic screening factor for soil ingestion (NCRP 1996 [DIRS 101882], Equation 8.6a), corrected in the case of the groundwater scenario for the depth of surface soil, as described below:

$$C_{soil} = \frac{SF_{soil\ ing}}{U_{soil\ ing} DF_{ing} DC} \qquad \text{(Eq. A-4)}$$

where

$SF_{soil,inh}$ = screening factor for soil ingestion (Sv/y per Bq/m^3)

$U_{soi\ ing}$ = usage factor for soil ingestion (mass of ingested soil (kg/yr)

DF_{ing} = dose coefficient for ingestion (Sv/Bq)

DC = surface soil depth correction factor (used only for the groundwater scenario).

Screening factors for soil ingestion were obtained from NCRP-123 (NCRP 1996 [DIRS 101882], Table C.1). The mass of ingested soil used in calculation of the generic screening factor is 0.365 kg/yr (NCRP 1996 [DIRS 101882], Table 7.1).

The radionuclide concentration in ingested soil is calculated in NCRP-123 by assuming that the contaminated layer is 1 cm in thickness (NCRP 1996 [DIRS 101882], p. 68). This thickness is consistent with the thickness of the contaminated layer for the igneous scenario. The thickness of surface soil contaminated by irrigation water (groundwater scenario) is assumed in the biosphere model (BSC 2004 [DIRS 169460]) to correspond to the tillage depth. The average tillage depth used in the biosphere model (BSC 2004 [DIRS 169460]) is 0.175 m (DTN: MO0403SPAAEIBM.002 [DIRS 169392]). The inhalation and external exposure originate from irrigated soil. For consistency with the biosphere model (BSC 2004 [DIRS 169460]), the radionuclide concentration in surface soil used for estimating inhalation and external exposure site-specific screening factors for groundwater scenario was adjusted to 0.175 m by using the surface soil depth correction factor equal to the ratio of these two soil thicknesses (i.e., equal to 17.5).

The calculation of pathway screening factors for groundwater and igneous scenarios is shown in Excel file `Site-Specific Screening Factors.xls` (Appendix C). The file includes additional information that was used during the development of the screening factors.

A.2 TOTAL SCREENING FACTORS FOR GROUNDWATER AND IGNEOUS SCENARIOS

The total groundwater screening factor for a radionuclide is a sum of the pathway screening factors for ingestion of water, soil, and contaminated food products, as well as inhalation of resuspended contaminated soil and external exposure to radionuclides in soil. The pathway screening factors and the total screening factors are presented in Table A-7. Additional details regarding incorporation of the decay products into the calculation of the screening factors are provided in the Excel file `Site-Specific Screening Factors.xls` in Appendix C.

The total igneous screening factor for a radionuclide is a sum of the pathway screening factors for ingestion of soil and contaminated food products, as well as inhalation of resuspended contaminated soil and external exposure to radionuclides deposited on the soil surface. The pathway screening factors and the total screening factors are presented in Table A-8. Additional details regarding incorporation of the decay products into the calculation of the screening factors are provided in the Excel file `Site-Specific Screening Factors.xls` in Appendix C.

Table A-7. Site-Specific Groundwater Screening Factors

Radionuclide	Screening Factors, Sv/yr per Bq/m^3									
	Water Ingestion	Fish Ingestion	Vegetable Ingestion	Milk Ingestion	Meat Ingestion	Soil Ingestion	Total Ingestion	Inhalation	External Exposure	All-Pathway
^{225}Ac	2.77E-08	3.25E-11	1.62E-09	1.88E-13	1.91E-12	3.64E-12	2.9E-08	1.5E-12	8.1E-13	**2.9E-08**
^{227}Ac	2.35E-07	1.10E-09	3.40E-08	3.63E-12	5.08E-11	1.38E-08	2.8E-07	1.3E-08	2.9E-09	**3.0E-07**
^{228}Ac	2.77E-10	1.13E-14	5.15E-14	1.33E-18	2.52E-23	9.81E-16	2.8E-10	6.8E-17	2.1E-12	**2.8E-10**
^{108}Ag	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{108m}Ag	1.68E-09	5.43E-12	2.59E-10	8.05E-11	5.62E-11	1.38E-10	2.2E-09	4.2E-12	7.9E-08	**8.1E-08**
^{109m}Ag	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{110}Ag	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{110m}Ag	2.03E-09	5.77E-12	2.69E-10	8.40E-11	5.71E-11	6.57E-12	2.4E-09	5.5E-14	5.7E-09	**8.1E-09**
^{239}Am	1.67E-10	2.62E-14	2.15E-13	1.42E-17	4.77E-19	1.10E-15	1.7E-10	2.1E-18	6.0E-13	**1.7E-10**
^{241}Am	1.48E-07	1.42E-09	2.11E-08	2.35E-12	8.15E-11	1.27E-08	1.8E-07	1.1E-08	3.4E-10	**2.0E-07**
^{242}Am	2.11E-10	4.83E-14	4.10E-12	3.88E-16	4.78E-15	6.27E-14	2.2E-10	5.9E-14	4.4E-14	**2.2E-10**
^{242m}Am	1.39E-07	1.31E-09	1.99E-08	2.20E-12	7.68E-11	1.14E-08	1.7E-07	1.1E-08	1.3E-11	**1.8E-07**
^{243}Am	1.48E-07	1.38E-09	2.12E-08	2.36E-12	8.17E-11	1.27E-08	1.8E-07	1.1E-08	1.2E-09	**2.0E-07**
^{245}Am	3.87E-11	1.02E-15	1.23E-17	3.07E-24	2.78E-40	5.09E-17	3.9E-11	8.8E-20	1.6E-14	**3.9E-11**
^{246}Am	2.50E-11	2.14E-16	9.26E-26	1.19E-39	0.00E+00	1.53E-17	2.5E-11	3.5E-20	1.5E-13	**2.5E-11**
^{39}Ar	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{42}Ar	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{217}At	1.1E-15	2.2E-20	9.7E-22	2.7E-25	8.2E-36	9.2E-22	1.1E-15	2.2E-22	5.2E-19	**1.1E-15**
^{218}At	5.0E-14	1.3E-16	5.7E-16	1.1E-17	1.4E-16	2.2E-16	5.1E-14	2.3E-18	3.1E-16	**5.2E-14**
^{219}At	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{132}Ba	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{133}Ba	1.12E-09	1.39E-12	1.69E-10	4.25E-12	2.35E-12	4.51E-11	1.3E-09	5.8E-13	8.0E-09	**9.3E-09**
^{137m}Ba	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{10}Be	8.52E-10	2.61E-11	1.29E-10	1.35E-14	4.57E-11	7.34E-11	1.1E-09	4.3E-12	9.6E-12	**1.1E-09**

Table A-7. Site-Specific Groundwater Screening Factors (Continued)

Radionuclide	Screening Factors, Sv/yr per Bq/m^3									
	Water Ingestion	Fish Ingestion	Vegetable Ingestion	Milk Ingestion	Meat Ingestion	Soil Ingestion	Total Ingestion	Inhalation	External Exposure	All-Pathway
^{210}Bi	1.02E-09	3.05E-12	3.00E-09	5.55E-11	8.75E-10	5.66E-11	5.0E-09	3.9E-13	3.9E-14	**5.0E-09**
^{211}Bi	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{212}Bi	1.39E-10	8.76E-16	5.77E-21	2.73E-28	0.00E+00	1.04E-16	1.4E-10	2.6E-17	1.4E-12	**1.4E-10**
^{213}Bi	9.19E-11	4.55E-16	1.58E-23	3.87E-33	0.00E+00	6.00E-17	9.2E-11	1.9E-17	3.2E-14	**9.2E-11**
^{214}Bi	2.87E-11	6.26E-17	2.02E-36	0.00E+00	0.00E+00	1.47E-17	2.9E-11	3.9E-18	1.8E-13	**2.9E-11**
^{215}Bi	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{243}Bk	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{249}Bk	7.03E-10	5.08E-12	9.81E-11	1.08E-14	1.84E-13	5.31E-11	8.6E-10	4.8E-11	3.6E-11	**9.4E-10**
^{250}Bk	8.94E-11	3.08E-15	8.05E-16	2.72E-21	2.56E-31	1.75E-16	8.9E-11	5.1E-18	1.0E-12	**9.0E-11**
^{14}C	4.23E-10	6.63E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.1E-09	0.0E+00	0.0E+00	**7.1E-09**
^{41}Ca	1.39E-10	4.41E-11	1.94E-10	2.13E-11	1.92E-11	1.23E-11	4.3E-10	2.2E-14	0.0E+00	**4.3E-10**
^{45}Ca	5.15E-10	1.34E-10	8.35E-11	1.20E-11	1.07E-11	1.08E-12	7.6E-10	1.1E-14	1.2E-14	**7.6E-10**
^{109}Cd	1.48E-09	8.60E-11	3.28E-10	2.24E-11	1.47E-11	8.74E-12	1.9E-09	6.8E-14	7.9E-12	**1.9E-09**
^{113}Cd	1.83E-08	1.14E-09	2.46E-08	5.59E-10	3.86E-10	1.60E-09	4.7E-08	1.5E-11	9.4E-13	**4.7E-08**
^{113m}Cd	1.71E-08	1.06E-09	1.37E-08	3.83E-10	2.71E-10	7.70E-10	3.3E-08	7.0E-12	3.0E-12	**3.3E-08**
^{139}Ce	1.90E-10	1.48E-12	2.46E-11	3.78E-14	3.44E-14	3.44E-13	2.2E-10	4.8E-15	1.1E-10	**3.3E-10**
^{142}Ce	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{144}Ce	3.82E-09	3.24E-11	5.14E-10	7.85E-13	7.12E-13	1.42E-11	4.4E-09	2.7E-13	1.3E-10	**4.5E-09**
^{249}Cf	2.56E-07	2.02E-09	3.65E-08	4.05E-12	1.68E-10	2.16E-08	3.2E-07	2.0E-08	1.6E-08	**3.5E-07**
^{250}Cf	1.17E-07	9.06E-10	1.63E-08	1.68E-12	7.17E-11	4.93E-09	1.4E-07	4.4E-09	3.9E-13	**1.4E-07**
^{251}Cf	2.62E-07	2.08E-09	3.77E-08	4.14E-12	1.72E-10	2.21E-08	3.2E-07	2.0E-08	4.4E-09	**3.5E-07**
^{252}Cf	6.65E-08	5.03E-10	8.91E-09	9.70E-13	3.88E-11	7.81E-10	7.7E-08	3.3E-10	1.8E-13	**7.7E-08**
^{36}Cl	6.80E-10	2.17E-10	3.33E-08	1.17E-08	3.24E-08	5.89E-11	7.8E-08	4.6E-12	2.3E-11	**7.8E-08**
^{242}Cm	8.32E-09	6.99E-11	1.14E-09	1.18E-13	1.56E-12	1.82E-11	9.6E-09	1.8E-11	3.0E-14	**9.6E-09**
^{243}Cm	1.08E-07	1.02E-09	1.54E-08	1.67E-12	2.31E-11	6.66E-09	1.3E-07	5.9E-09	3.5E-09	**1.4E-07**

Table A-7. Site-Specific Groundwater Screening Factors (Continued)

Radionuclide	Screening Factors, Sv/yr per Bq/m^3									
	Water Ingestion	Fish Ingestion	Vegetable Ingestion	Milk Ingestion	Meat Ingestion	Soil Ingestion	Total Ingestion	Inhalation	External Exposure	All-Pathway
^{244}Cm	8.99E-08	8.27E-10	1.26E-08	1.35E-12	1.88E-11	4.54E-09	1.1E-07	4.0E-09	4.9E-13	**1.1E-07**
^{245}Cm	1.50E-07	1.45E-09	2.18E-08	2.39E-12	3.30E-11	1.30E-08	1.9E-07	1.2E-08	2.8E-09	**2.0E-07**
^{246}Cm	1.49E-07	1.40E-09	2.12E-08	2.37E-12	3.28E-11	1.29E-08	1.8E-07	1.2E-08	7.7E-13	**2.0E-07**
^{247}Cm	1.38E-07	1.33E-09	2.00E-08	2.19E-12	3.01E-11	1.20E-08	1.7E-07	1.1E-08	1.5E-08	**2.0E-07**
^{248}Cm	5.51E-07	5.30E-09	7.98E-08	8.82E-12	1.22E-10	4.97E-08	6.9E-07	4.4E-08	6.0E-13	**7.3E-07**
^{250}Cm	3.21E-06	3.02E-08	4.56E-07	5.07E-11	6.99E-10	2.77E-07	4.0E-06	2.5E-07	0.0E+00	**4.2E-06**
^{58}Co	5.48E-10	3.58E-11	6.59E-11	6.96E-12	1.37E-10	5.09E-13	7.9E-10	2.8E-15	5.7E-10	**1.4E-09**
^{60}Co	2.51E-09	2.33E-10	4.80E-10	5.77E-11	1.20E-09	5.79E-11	4.5E-09	9.9E-13	3.9E-08	**4.3E-08**
^{134}Cs	1.44E-08	8.49E-09	2.74E-09	1.10E-09	7.68E-09	1.38E-10	3.5E-08	2.8E-13	9.5E-09	**4.4E-08**
^{135}Cs	1.43E-09	9.22E-10	9.26E-10	2.27E-10	1.61E-09	1.25E-10	5.2E-09	1.0E-12	3.0E-13	**5.2E-09**
^{137}Cs	1.01E-08	6.26E-09	4.96E-09	1.33E-09	9.50E-09	6.25E-10	3.3E-08	3.4E-12	2.3E-08	**5.6E-08**
^{150}Eu	9.51E-10	1.45E-11	1.35E-10	4.28E-13	1.98E-11	6.11E-11	1.2E-09	1.1E-11	5.8E-08	**5.9E-08**
^{152}Eu	9.77E-10	1.56E-11	1.45E-10	4.43E-13	2.08E-11	4.50E-11	1.2E-09	5.9E-12	3.2E-08	**3.3E-08**
^{154}Eu	1.50E-09	2.35E-11	2.12E-10	6.57E-13	3.04E-11	5.19E-11	1.8E-09	5.4E-12	2.7E-08	**2.9E-08**
^{155}Eu	2.37E-10	3.65E-12	3.33E-11	1.01E-13	4.78E-12	5.25E-12	2.8E-10	3.9E-13	3.9E-10	**6.7E-10**
^{55}Fe	2.39E-10	1.48E-11	3.27E-11	5.07E-13	7.09E-11	3.05E-12	3.6E-10	1.4E-14	0.0E+00	**3.6E-10**
^{221}Fr	1.1E-11	1.7E-16	8.5E-18	2.0E-21	6.3E-32	8.2E-18	1.1E-11	2.0E-18	6.2E-14	**1.1E-11**
^{223}Fr	7.25E-10	2.72E-13	6.30E-12	3.51E-13	3.59E-13	1.57E-14	7.3E-10	2.5E-15	1.6E-14	**7.3E-10**
^{150}Gd	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{152}Gd	3.00E-08	2.88E-10	4.35E-09	1.41E-11	6.56E-10	2.66E-09	3.8E-08	2.4E-09	0.0E+00	**4.0E-08**
^{153}Gd	2.00E-10	1.71E-12	2.73E-11	8.36E-14	3.82E-12	6.38E-13	2.3E-10	1.0E-14	7.2E-11	**3.1E-10**
^{3}H	1.42E-11	4.34E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.4E-11	0.0E+00	0.0E+00	**1.4E-11**
^{174}Hf	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{182}Hf	2.18E-09	2.75E-11	3.43E-10	3.62E-13	9.79E-12	2.81E-10	2.8E-09	3.8E-11	7.9E-08	**8.2E-08**
^{166m}Ho	1.49E-09	5.51E-09	2.13E-10	6.88E-13	3.18E-11	1.27E-10	7.4E-09	3.5E-11	9.2E-08	**9.9E-08**

Table A-7. Site-Specific Groundwater Screening Factors (Continued)

Radionuclide	Screening Factors, Sv/yr per Bq/m^3									
	Water Ingestion	Fish Ingestion	Vegetable Ingestion	Milk Ingestion	Meat Ingestion	Soil Ingestion	Total Ingestion	Inhalation	External Exposure	All-Pathway
^{129}I	7.73E-08	9.73E-10	1.46E-08	6.11E-09	3.37E-08	6.67E-09	1.4E-07	4.3E-12	9.0E-11	**1.4E-07**
^{113m}In	1.71E-11	1.22E-13	6.69E-19	2.91E-24	1.39E-44	1.88E-17	1.7E-11	2.6E-20	1.3E-13	**1.7E-11**
^{115}In	2.37E-08	7.48E-08	3.53E-09	3.73E-11	1.03E-09	2.00E-09	1.1E-07	4.6E-11	3.2E-12	**1.1E-07**
^{192}Ir	9.77E-10	2.22E-12	1.22E-10	1.22E-14	1.65E-11	1.00E-12	1.1E-09	9.3E-15	4.6E-10	**1.6E-09**
^{192m}Ir	2.28E-10	7.13E-13	1.39E-10	8.42E-15	1.13E-11	9.71E-11	4.8E-10	5.2E-12	4.3E-08	**4.3E-08**
^{194}Ir	9.57E-10	7.79E-14	3.28E-12	2.88E-16	5.39E-15	1.05E-14	9.6E-10	8.4E-18	6.1E-13	**9.6E-10**
^{40}K	4.48E-09	1.41E-08	3.94E-09	1.03E-09	4.10E-09	3.93E-10	2.8E-08	1.0E-11	9.4E-09	**3.8E-08**
^{42}K	3.09E-10	1.63E-11	4.45E-13	1.02E-13	5.15E-16	2.19E-15	3.3E-10	3.4E-18	1.4E-12	**3.3E-10**
^{81}Kr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{85}Kr	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{138}La	7.81E-10	7.54E-12	1.14E-10	3.76E-13	1.77E-11	6.84E-11	9.9E-10	1.9E-11	7.0E-08	**7.1E-08**
^{176}Lu	1.29E-09	1.03E-11	1.91E-10	6.13E-13	2.87E-11	1.12E-10	1.6E-09	1.8E-11	2.2E-08	**2.3E-08**
^{54}Mn	5.30E-10	7.61E-11	8.94E-11	1.74E-12	7.85E-12	2.14E-12	7.1E-10	1.9E-14	2.1E-09	**2.8E-09**
^{93}Mo	2.32E-09	7.24E-12	8.90E-10	4.78E-11	3.33E-11	2.05E-10	3.5E-09	3.8E-13	4.3E-12	**3.5E-09**
^{100}Mo	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{22}Na	2.35E-09	1.36E-11	3.57E-10	6.68E-10	1.84E-09	2.80E-11	5.3E-09	4.9E-13	1.7E-08	**2.2E-08**
^{91}Nb	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{92}Nb	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{93m}Nb	8.85E-11	8.17E-12	1.38E-11	1.30E-15	2.82E-16	4.14E-12	1.1E-10	1.1E-13	3.6E-13	**1.2E-10**
^{94}Nb	1.24E-09	1.20E-10	2.06E-10	1.99E-14	4.19E-15	1.12E-10	1.7E-09	6.0E-12	8.7E-08	**8.9E-08**
^{95}Nb	4.31E-10	2.21E-11	4.37E-11	4.72E-15	8.91E-16	2.00E-13	5.0E-10	1.1E-15	2.2E-10	**7.2E-10**
^{95m}Nb	4.11E-10	4.17E-12	1.38E-11	1.51E-15	1.63E-16	3.98E-14	4.3E-10	1.7E-16	2.4E-11	**4.5E-10**
^{144}Nd	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{59}Ni	4.60E-11	1.45E-12	1.24E-11	1.44E-11	4.98E-12	3.97E-12	8.3E-11	5.4E-14	0.0E+00	**8.3E-11**
^{63}Ni	1.11E-10	3.53E-12	2.77E-11	3.27E-11	1.11E-11	8.90E-12	1.9E-10	1.4E-13	0.0E+00	**1.9E-10**

Table A-7. Site-Specific Groundwater Screening Factors (Continued)

Radionuclide	Screening Factors, Sv/yr per Bq/m^3									
	Water Ingestion	Fish Ingestion	Vegetable Ingestion	Milk Ingestion	Meat Ingestion	Soil Ingestion	Total Ingestion	Inhalation	External Exposure	All-Pathway
^{235}Np	3.89E-11	3.39E-13	5.37E-12	2.63E-15	3.71E-13	2.01E-13	4.5E-11	4.5E-15	1.6E-12	**4.7E-11**
^{236m}Np	1.29E-08	1.20E-10	2.39E-09	1.00E-12	1.40E-10	1.12E-09	1.7E-08	9.8E-10	4.0E-09	**2.2E-08**
^{237}Np	7.81E-08	7.33E-10	1.49E-08	6.25E-12	8.48E-10	6.71E-09	1.0E-07	6.0E-09	6.5E-10	**1.1E-07**
^{238}Np	6.61E-10	4.08E-13	9.30E-12	5.17E-15	1.43E-13	1.88E-14	6.7E-10	1.4E-16	1.0E-11	**6.8E-10**
^{239}Np	5.81E-10	3.98E-13	9.09E-12	5.27E-15	1.70E-13	1.77E-14	5.9E-10	4.4E-17	2.3E-12	**5.9E-10**
^{240}Np	4.35E-11	6.12E-16	6.15E-21	8.48E-30	0.00E+00	3.50E-17	4.3E-11	7.4E-20	4.6E-13	**4.4E-11**
^{240m}Np	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{186}Os	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{194}Os	1.78E-09	1.95E-11	3.48E-10	1.32E-12	3.68E-11	7.10E-11	2.3E-09	3.1E-12	1.5E-09	**3.7E-09**
^{32}P	1.75E-09	8.91E-09	1.33E-10	1.44E-10	3.93E-10	3.25E-13	1.1E-08	1.0E-15	4.1E-13	**1.1E-08**
^{231}Pa	3.39E-07	1.09E-09	5.80E-08	1.38E-11	2.10E-11	3.69E-08	4.3E-07	3.4E-08	1.6E-09	**4.7E-07**
^{232}Pa	4.88E-10	6.40E-14	3.69E-12	9.55E-16	9.41E-17	8.79E-15	4.9E-10	5.8E-17	1.0E-11	**5.0E-10**
^{233}Pa	6.63E-10	9.87E-13	6.01E-11	1.64E-14	2.04E-14	2.25E-13	7.2E-10	1.9E-15	3.6E-11	**7.6E-10**
^{234}Pa	3.61E-10	1.05E-14	9.27E-14	7.01E-18	4.27E-23	1.41E-15	3.6E-10	2.1E-18	4.4E-12	**3.7E-10**
^{234m}Pa	1.37E-15	4.00E-20	3.53E-19	2.63E-23	1.61E-28	5.27E-21	1.4E-15	8.0E-24	1.6E-17	**1.4E-15**
^{205}Pb	2.07E-10	1.95E-11	3.03E-11	4.77E-13	1.80E-12	1.78E-11	2.8E-10	1.0E-13	7.8E-14	**2.8E-10**
^{209}Pb	3.71E-11	1.60E-14	3.55E-16	1.99E-19	6.04E-30	7.37E-17	3.7E-11	1.5E-19	1.5E-16	**3.7E-11**
^{210}Pb	5.07E-07	4.79E-08	7.44E-08	1.16E-09	4.31E-09	2.95E-08	6.6E-07	4.6E-10	1.2E-11	**6.6E-07**
^{211}Pb	7.33E-11	5.74E-15	3.37E-26	8.60E-39	0.00E+00	4.24E-17	7.3E-11	5.5E-18	1.0E-14	**7.3E-11**
^{212}Pb	4.25E-09	5.77E-12	4.14E-12	3.67E-14	5.77E-17	2.51E-14	4.3E-09	1.5E-15	4.0E-13	**4.3E-09**
^{214}Pb	8.14E-11	2.77E-15	1.35E-30	1.96E-47	0.00E+00	4.43E-17	8.1E-11	1.0E-17	2.8E-13	**8.2E-11**
^{107}Pd	2.74E-11	8.80E-14	1.02E-11	3.07E-14	8.74E-14	2.36E-12	4.0E-11	7.1E-14	0.0E+00	**4.0E-11**
^{145}Pm	8.53E-11	7.97E-13	1.25E-11	3.87E-14	1.80E-12	4.44E-12	1.0E-10	6.2E-13	1.3E-10	**2.4E-10**
^{146}Pm	6.63E-10	6.17E-12	9.29E-11	2.82E-13	1.35E-11	1.58E-11	7.9E-10	1.5E-12	1.1E-08	**1.1E-08**
^{147}Pm	1.92E-10	1.73E-12	2.67E-11	8.05E-14	3.71E-12	2.30E-12	2.3E-10	1.2E-13	5.6E-14	**2.3E-10**

Table A-7. Site-Specific Groundwater Screening Factors (Continued)

Radionuclide	Screening Factors, Sv/yr per Bq/m^3									
	Water Ingestion	Fish Ingestion	Vegetable Ingestion	Milk Ingestion	Meat Ingestion	Soil Ingestion	Total Ingestion	Inhalation	External Exposure	All-Pathway
^{210}Po	8.78E-07	2.28E-08	1.15E-07	2.37E-09	3.97E-08	1.58E-09	1.1E-06	1.1E-11	9.6E-15	**1.1E-06**
^{211}Po	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{212}Po	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{213}Po	1.37E-20	5.65E-24	1.26E-25	6.80E-29	2.20E-39	2.67E-26	1.4E-20	5.5E-29	5.3E-26	**1.4E-20**
^{214}Po	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{215}Po	6.0E-17	4.7E-21	2.8E-32	7.1E-45	0.0E+00	3.5E-23	6.0E-17	4.5E-24	1.6E-20	**6.0E-17**
^{216}Po	1.7E-14	2.3E-17	1.6E-17	1.4E-19	2.3E-22	1.0E-19	1.7E-14	7.2E-21	2.4E-17	**1.7E-14**
^{218}Po	9.8E-12	3.6E-15	5.2E-14	9.4E-16	1.2E-14	2.1E-14	9.9E-12	2.1E-16	3.2E-14	**9.9E-12**
^{144}Pr	1.12E-11	1.42E-16	3.85E-40	0.00E+00	0.00E+00	5.85E-18	1.1E-11	4.0E-21	4.6E-15	**1.1E-11**
^{144m}Pr	6.47E-12	8.03E-17	1.65E-40	0.00E+00	0.00E+00	2.46E-18	6.5E-12	1.7E-21	2.0E-15	**6.5E-12**
^{193}Pt	2.27E-11	2.46E-13	8.13E-12	2.36E-14	6.51E-14	1.59E-12	3.3E-11	6.6E-14	4.8E-14	**3.3E-11**
^{236}Pu	6.30E-08	5.82E-10	8.86E-09	4.50E-13	6.30E-11	8.28E-10	7.3E-08	7.3E-10	2.6E-13	**7.4E-08**
^{238}Pu	1.67E-07	1.59E-09	2.39E-08	1.32E-12	1.80E-10	1.30E-08	2.1E-07	1.2E-08	9.9E-13	**2.2E-07**
^{239}Pu	1.84E-07	1.75E-09	2.63E-08	1.46E-12	1.99E-10	1.56E-08	2.3E-07	1.4E-08	2.4E-12	**2.4E-07**
^{240}Pu	1.84E-07	1.75E-09	2.63E-08	1.46E-12	1.99E-10	1.56E-08	2.3E-07	1.4E-08	1.0E-12	**2.4E-07**
^{241}Pu	3.49E-09	3.27E-11	4.83E-10	3.01E-14	3.75E-12	3.55E-10	4.4E-09	3.2E-10	5.2E-12	**4.7E-09**
^{242}Pu	1.75E-07	1.64E-09	2.49E-08	1.39E-12	1.91E-10	1.52E-08	2.2E-07	1.4E-08	9.4E-13	**2.3E-07**
^{243}Pu	5.81E-11	3.71E-15	4.71E-15	3.65E-20	2.77E-25	1.66E-16	5.8E-11	3.2E-19	2.1E-14	**5.8E-11**
^{244}Pu	1.74E-07	1.67E-09	2.52E-08	1.41E-12	1.90E-10	1.50E-08	2.2E-07	1.3E-08	1.8E-08	**2.5E-07**
^{246}Pu	2.06E-09	5.15E-12	1.23E-10	7.31E-15	7.38E-13	2.99E-13	2.2E-09	9.6E-16	6.5E-11	**2.3E-09**
^{223}Ra	7.36E-08	3.24E-10	4.75E-09	2.76E-10	2.83E-10	1.13E-11	7.9E-08	1.8E-12	8.9E-12	**7.9E-08**
^{224}Ra	4.69E-08	8.01E-11	1.21E-09	7.03E-11	3.80E-11	2.26E-12	4.8E-08	2.3E-13	2.5E-13	**4.8E-08**
^{225}Ra	7.30E-08	3.71E-10	5.26E-09	3.05E-10	3.37E-10	1.40E-11	7.9E-08	2.1E-12	1.8E-13	**7.9E-08**
^{226}Ra	2.05E-07	3.15E-09	5.11E-08	1.82E-09	2.62E-09	3.22E-08	3.0E-07	1.4E-09	9.9E-08	**4.0E-07**
^{228}Ra	5.07E-07	7.84E-09	8.66E-08	3.81E-09	5.19E-09	1.28E-08	6.2E-07	5.6E-10	3.8E-08	**6.6E-07**

Table A-7. Site-Specific Groundwater Screening Factors (Continued)

Radionuclide	Screening Factors, Sv/yr per Bq/m^3									
	Water Ingestion	Fish Ingestion	Vegetable Ingestion	Milk Ingestion	Meat Ingestion	Soil Ingestion	Total Ingestion	Inhalation	External Exposure	All-Pathway
^{87}Rb	1.04E-09	6.81E-10	6.83E-10	2.66E-10	1.07E-09	9.24E-11	3.8E-09	1.8E-12	1.1E-12	**3.8E-09**
^{187}Re	3.79E-12	1.36E-11	2.41E-12	1.16E-13	8.13E-13	3.20E-13	2.1E-11	5.0E-15	0.0E+00	**2.1E-11**
^{102}Rh	1.90E-09	1.74E-10	2.83E-10	6.75E-12	3.81E-11	2.55E-11	2.4E-09	3.3E-13	1.8E-08	**2.0E-08**
^{106}Rh	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{217}Rn	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{218}Rn	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**0.0E+00**
^{219}Rn	1.3E-13	1.0E-17	6.2E-29	1.6E-41	0.0E+00	7.8E-20	1.3E-13	1.0E-20	3.6E-17	**1.3E-13**
^{220}Rn	6.2E-12	8.2E-15	6.1E-15	5.3E-17	8.6E-20	3.8E-17	6.2E-12	2.6E-18	9.0E-15	**6.2E-12**
^{222}Rn	6.3E-11	1.1E-14	7.2E-11	1.3E-12	1.6E-11	3.8E-11	1.9E-10	3.8E-13	5.7E-11	**2.5E-10**
^{106}Ru	5.12E-09	1.45E-11	7.13E-10	7.08E-13	9.61E-11	2.46E-11	6.0E-09	4.4E-13	0.0E+00	**6.0E-09**
^{125}Sb	8.21E-10	2.52E-11	1.17E-10	5.85E-13	8.12E-12	1.06E-11	9.8E-10	2.1E-13	3.2E-09	**4.2E-09**
^{126}Sb	1.81E-09	1.66E-11	1.14E-10	6.86E-13	7.18E-12	2.90E-13	1.9E-09	7.3E-16	2.8E-10	**2.2E-09**
^{126m}Sb	8.81E-12	1.19E-16	5.67E-38	0.00E+00	0.00E+00	4.57E-18	8.8E-12	4.8E-21	1.6E-13	**9.0E-12**
^{79}Se	2.04E-09	1.33E-10	8.19E-10	2.40E-10	3.36E-09	1.81E-10	6.8E-09	8.1E-13	1.4E-13	**6.8E-09**
^{32}Si	4.14E-10	1.15E-11	4.17E-09	8.76E-10	2.38E-09	1.78E-10	8.0E-09	1.4E-11	1.8E-10	**8.2E-09**
^{145}Sm	1.56E-10	1.15E-12	2.14E-11	6.56E-14	3.01E-12	9.26E-13	1.8E-10	4.9E-14	3.3E-11	**2.2E-10**
^{146}Sm	4.03E-08	3.08E-10	5.74E-09	1.88E-11	8.64E-10	3.47E-09	5.1E-08	3.1E-09	0.0E+00	**5.4E-08**
^{147}Sm	3.59E-08	2.89E-10	5.22E-09	1.71E-11	7.95E-10	3.15E-09	4.5E-08	2.8E-09	0.0E+00	**4.8E-08**
^{148}Sm	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{149}Sm	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{151}Sm	7.29E-11	5.59E-13	1.01E-11	3.38E-14	1.56E-12	5.52E-12	9.1E-11	9.9E-13	5.7E-15	**9.2E-11**
^{113}Sn	5.42E-10	4.05E-10	7.25E-11	3.58E-12	4.82E-11	8.44E-13	1.1E-09	8.4E-15	2.2E-10	**1.3E-09**
^{119m}Sn	2.53E-10	2.12E-10	4.23E-11	1.84E-12	2.48E-11	9.23E-13	5.3E-10	1.7E-14	8.4E-13	**5.4E-10**
^{121}Sn	1.67E-10	5.59E-12	9.77E-13	4.96E-14	3.32E-14	2.43E-15	1.7E-10	5.1E-18	2.7E-16	**1.7E-10**
^{121m}Sn	2.79E-10	2.63E-10	2.11E-10	3.95E-12	5.45E-11	2.04E-11	8.3E-10	1.5E-12	1.1E-11	**8.4E-10**

Table A-7. Site-Specific Groundwater Screening Factors (Continued)

Radionuclide	Screening Factors, Sv/yr per Bq/m^3									
	Water Ingestion	Fish Ingestion	Vegetable Ingestion	Milk Ingestion	Meat Ingestion	Soil Ingestion	Total Ingestion	Inhalation	External Exposure	All-Pathway
^{123}Sn	1.53E-09	1.19E-09	2.21E-10	1.00E-11	1.38E-10	2.59E-12	3.1E-09	3.0E-14	9.7E-12	**3.1E-09**
^{126}Sn	3.47E-09	3.27E-09	3.04E-09	5.43E-11	7.49E-10	3.01E-10	1.1E-08	1.9E-11	8.3E-08	**9.4E-08**
^{90}Sr	2.04E-08	3.80E-10	1.34E-08	1.29E-09	9.19E-09	1.25E-09	4.6E-08	1.4E-11	4.3E-12	**4.6E-08**
^{182}Ta	1.13E-09	2.84E-11	1.40E-10	3.72E-14	4.92E-14	1.67E-12	1.3E-09	2.2E-14	1.2E-09	**2.5E-09**
^{160}Tb	1.17E-09	6.55E-12	1.37E-10	4.43E-13	1.95E-11	1.14E-12	1.3E-09	1.1E-14	6.9E-10	**2.0E-09**
^{98}Tc	1.47E-09	9.04E-12	1.84E-08	5.02E-10	6.92E-11	1.29E-10	2.1E-08	5.6E-12	7.9E-08	**9.9E-08**
^{99}Tc	4.68E-10	3.00E-12	5.90E-09	1.65E-10	2.24E-11	4.06E-11	6.6E-09	1.6E-12	1.0E-12	**6.6E-09**
^{123}Te	3.21E-09	4.05E-10	1.23E-09	2.97E-11	5.64E-10	2.76E-10	5.7E-09	4.7E-13	4.3E-11	**5.8E-09**
^{123m}Te	1.01E-09	1.02E-10	1.35E-10	3.39E-12	6.41E-11	1.61E-12	1.3E-09	1.1E-14	9.9E-11	**1.4E-09**
^{125m}Te	6.33E-10	5.31E-11	7.42E-11	1.94E-12	3.63E-11	4.82E-13	8.0E-10	4.4E-15	9.2E-13	**8.0E-10**
^{127}Te	1.17E-10	1.90E-13	8.36E-14	1.06E-15	2.99E-18	6.34E-16	1.2E-10	1.0E-18	1.5E-14	**1.2E-10**
^{127m}Te	1.69E-09	1.65E-10	2.20E-10	5.74E-12	1.06E-10	2.46E-12	2.2E-09	2.0E-14	6.5E-13	**2.2E-09**
^{128}Te	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{130}Te	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{227}Th	6.49E-09	7.92E-11	5.32E-10	1.54E-13	3.47E-12	1.63E-12	1.1E-08	6.6E-12	2.8E-11	**1.1E-08**
^{228}Th	5.24E-08	1.64E-09	1.20E-08	1.64E-10	1.40E-10	9.30E-10	6.7E-08	5.4E-10	8.2E-09	**7.6E-08**
^{229}Th	3.61E-07	1.15E-08	5.24E-08	1.44E-11	4.02E-10	3.13E-08	4.6E-07	2.9E-08	2.7E-09	**4.9E-07**
^{230}Th	1.56E-07	4.76E-09	2.25E-08	6.00E-12	1.70E-10	1.35E-08	2.0E-07	1.2E-08	1.0E-11	**2.1E-07**
^{231}Th	2.44E-10	2.63E-13	1.31E-12	3.32E-16	3.60E-16	3.44E-15	2.5E-10	6.5E-18	4.9E-14	**2.5E-10**
^{232}Th	1.66E-07	5.33E-09	5.93E-08	6.34E-10	1.05E-09	4.50E-08	2.8E-07	1.4E-08	8.6E-08	**3.8E-07**
^{234}Th	2.46E-09	3.47E-11	2.27E-10	6.18E-14	1.48E-12	7.70E-13	2.7E-09	3.3E-15	7.2E-13	**2.7E-09**
^{204}Tl	8.69E-10	2.61E-09	2.10E-10	2.09E-11	1.94E-10	1.50E-11	3.9E-09	4.6E-13	7.3E-12	**3.9E-09**
^{206}Tl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{207}Tl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{208}Tl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**

Table A-7. Site-Specific Groundwater Screening Factors (Continued)

Radionuclide	Screening Factors, Sv/yr per Bq/m^3									
	Water Ingestion	**Fish Ingestion**	**Vegetable Ingestion**	**Milk Ingestion**	**Meat Ingestion**	**Soil Ingestion**	**Total Ingestion**	**Inhalation**	**External Exposure**	**All-Pathway**
^{209}Tl	4.29E-13	1.84E-16	4.00E-18	2.16E-21	6.86E-32	8.33E-19	4.3E-13	1.7E-21	2.7E-14	**4.6E-13**
^{171}Tm	7.74E-11	5.93E-13	1.05E-11	3.34E-14	1.51E-12	7.18E-13	9.1E-11	2.7E-14	9.4E-13	**9.2E-11**
^{232}U	2.34E-07	7.67E-10	3.90E-08	8.03E-10	2.14E-09	2.56E-08	3.0E-07	8.1E-09	7.2E-08	**3.8E-07**
^{233}U	3.74E-08	1.19E-10	5.53E-09	1.19E-10	3.21E-10	3.21E-09	4.7E-08	1.1E-09	1.2E-11	**4.8E-08**
^{234}U	3.69E-08	1.13E-10	5.26E-09	1.15E-10	3.16E-10	3.16E-09	4.6E-08	1.1E-09	3.3E-12	**4.7E-08**
^{235}U	3.44E-08	1.08E-10	4.96E-09	1.06E-10	2.93E-10	2.93E-09	4.3E-08	1.0E-09	6.4E-09	**5.0E-08**
^{236}U	3.37E-08	1.07E-10	4.89E-09	1.09E-10	3.01E-10	2.99E-09	4.2E-08	1.1E-09	1.7E-12	**4.3E-08**
^{237}U	5.56E-10	3.20E-13	2.41E-11	5.65E-13	9.64E-13	4.90E-14	5.8E-10	2.3E-16	4.6E-12	**5.9E-10**
^{238}U	3.31E-08	1.03E-10	4.93E-09	1.02E-10	2.82E-10	2.97E-09	4.1E-08	9.6E-10	1.1E-09	**4.4E-08**
^{240}U	7.92E-10	4.79E-14	1.49E-12	2.16E-14	1.78E-16	6.25E-15	7.9E-10	6.3E-18	9.3E-16	**7.9E-10**
^{50}V	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{90}Y	1.94E-09	1.50E-12	3.59E-11	1.28E-13	1.58E-12	6.85E-14	2.0E-09	7.3E-17	1.5E-13	**2.0E-09**
^{91}Y	1.75E-09	1.10E-11	1.98E-10	6.35E-13	2.74E-11	1.34E-12	2.0E-09	9.7E-15	3.2E-12	**2.0E-09**
^{64}Zn	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**
^{65}Zn	2.90E-09	8.04E-10	4.88E-10	1.97E-10	2.81E-09	9.11E-12	7.2E-09	1.0E-14	1.2E-09	**8.4E-09**
^{93}Zr	8.03E-10	7.58E-11	1.19E-10	3.89E-15	8.81E-15	7.33E-11	1.1E-09	3.1E-12	3.2E-13	**1.1E-09**
^{95}Zr	7.03E-10	4.48E-11	8.17E-11	2.59E-15	5.65E-15	5.88E-13	8.3E-10	6.8E-15	3.9E-10	**1.2E-09**
^{96}Zr	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0E+00**

Table A-8. Site-Specific Volcanic Screening Factors

Radionuclide	Screening Factors, Sv/yr per Bq/m^3							
	Vegetable Ingestion	Milk Ingestion	Meat Ingestion	Soil Ingestion	Total Ingestion	Inhalation	External Exposure	All-pathway
^{225}Ac	8.1E-04	8.5E-08	8.3E-07	1.8E-06	8.1E-04	2.8E-05	2.67E-06	**8.5E-04**
^{227}Ac	1.7E-02	1.7E-06	2.3E-05	6.7E-03	2.4E-02	2.3E-01	1.13E-05	**2.5E-01**
^{228}Ac	2.6E-08	1.9E-13	3.5E-18	4.9E-10	2.6E-08	1.3E-09	4.41E-06	**4.4E-06**
^{108}Ag	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{108m}Ag	1.2E-04	3.9E-05	2.7E-05	6.9E-05	2.6E-04	7.8E-05	1.73E-01	**1.7E-01**
^{109m}Ag	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{110}Ag	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{110m}Ag	1.3E-04	3.9E-05	2.6E-05	3.3E-06	2.0E-04	1.0E-06	1.17E-02	**1.2E-02**
^{239}Am	1.1E-07	3.1E-12	1.0E-13	5.7E-10	1.1E-07	3.9E-11	1.89E-06	**2.0E-06**
^{241}Am	1.1E-02	1.1E-06	3.9E-05	6.3E-03	1.7E-02	2.1E-01	2.79E-03	**2.3E-01**
^{242}Am	2.0E-06	1.8E-10	2.3E-09	3.2E-08	2.08E-06	1.1E-06	2.00E-07	**3.4E-06**
^{242m}Am	1.0E-02	1.0E-06	3.5E-05	5.5E-03	1.6E-02	1.9E-01	2.51E-04	**2.0E-01**
^{243}Am	1.1E-02	1.1E-06	3.9E-05	6.4E-03	1.7E-02	2.1E-01	5.78E-03	**2.3E-01**
^{245}Am	6.1E-12	2.1E-19	1.7E-35	2.5E-11	3.1E-11	1.6E-12	6.47E-08	**6.5E-08**
^{246}Am	4.6E-20	4.1E-35	0.0E+00	7.4E-12	7.4E-12	6.3E-13	3.36E-07	**3.4E-07**
^{39}Ar	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{42}Ar	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{217}At	4.9E-16	5.1E-20	1.5E-30	4.5E-16	9.4E-16	4.0E-15	1.46E-12	**1.5E-12**
^{218}At	2.78E-10	5.23E-12	6.39E-11	1.15E-10	4.6E-10	4.2E-11	3.41E-10	**8.5E-10**
^{219}At	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{132}Ba	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{133}Ba	8.5E-05	2.0E-06	1.1E-06	2.3E-05	1.1E-04	1.1E-05	2.11E-02	**2.1E-02**
^{137m}Ba	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{10}Be	6.3E-05	6.2E-09	2.2E-05	3.6E-05	1.2E-04	7.7E-05	4.14E-04	**6.1E-04**

Table A-8. Site-Specific Volcanic Screening Factors (Continued)

Radionuclide	Screening Factors, Sv/yr per Bq/m^3							
	Vegetable Ingestion	**Milk Ingestion**	**Meat Ingestion**	**Soil Ingestion**	**Total Ingestion**	**Inhalation**	**External Exposure**	**All-pathway**
^{210}Bi	1.5E-03	2.7E-05	4.5E-04	2.9E-05	2.03E-03	7.4E-06	3.22E-06	**2.0E-03**
^{211}Bi	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{212}Bi	2.9E-15	1.2E-23	0.0E+00	5.2E-11	5.2E-11	4.6E-10	1.72E-07	**1.7E-07**
^{213}Bi	7.8E-18	1.4E-28	0.0E+00	3.1E-11	3.1E-11	3.5E-10	9.97E-08	**1.0E-07**
^{214}Bi	9.9E-31	0.0E+00	0.0E+00	7.4E-12	7.4E-12	7.2E-11	3.68E-07	**3.7E-07**
^{215}Bi	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{243}Bk	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{249}Bk	5.0E-05	5.2E-09	8.7E-08	2.7E-05	7.74E-05	9.0E-04	8.81E-05	**1.1E-03**
^{250}Bk	2.3E-07	2.2E-11	9.3E-10	7.4E-08	3.02E-07	2.4E-06	2.07E-06	**4.8E-06**
^{14}C	1.4E-05	1.0E-06	6.4E-06	3.5E-09	2.2E-05	2.4E-09	2.97E-10	**2.2E-05**
^{41}Ca	1.0E-04	1.0E-05	9.9E-06	6.1E-06	1.3E-04	4.0E-07	0.00E+00	**1.3E-04**
^{45}Ca	4.2E-05	5.7E-06	5.1E-06	5.5E-07	5.3E-05	2.0E-07	1.12E-07	**5.3E-05**
^{109}Cd	1.6E-04	1.0E-05	7.1E-06	4.3E-06	1.9E-04	1.2E-06	1.38E-04	**3.3E-04**
^{113}Cd	1.3E-02	2.8E-04	1.9E-04	7.8E-04	1.4E-02	2.7E-04	7.07E-06	**1.4E-02**
^{113m}Cd	6.7E-03	1.8E-04	1.3E-04	3.9E-04	7.4E-03	1.3E-04	1.14E-04	**7.6E-03**
^{139}Ce	1.2E-05	1.8E-08	1.6E-08	1.7E-07	1.2E-05	8.8E-08	3.60E-04	**3.7E-04**
^{142}Ce	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{144}Ce	2.6E-04	3.7E-07	3.3E-07	7.0E-06	2.7E-04	5.0E-06	9.52E-05	**3.7E-04**
^{249}Cf	1.8E-02	1.9E-06	8.2E-05	1.1E-02	2.9E-02	3.5E-01	3.62E-02	**4.2E-01**
^{250}Cf	7.9E-03	8.4E-07	3.4E-05	2.6E-03	1.1E-02	8.4E-02	3.34E-05	**9.5E-02**
^{251}Cf	1.9E-02	2.0E-06	8.2E-05	1.1E-02	3.0E-02	3.7E-01	1.34E-02	**4.1E-01**
^{252}Cf	4.6E-03	4.4E-07	1.8E-05	4.0E-04	5.0E-03	6.3E-03	8.97E-06	**1.1E-02**
^{36}Cl	1.7E-02	5.9E-03	1.6E-02	2.9E-05	3.9E-02	8.3E-05	1.34E-03	**4.0E-02**
^{242}Cm	5.4E-04	5.3E-08	7.4E-07	9.1E-06	5.5E-04	3.2E-04	2.11E-06	**8.8E-04**
^{243}Cm	7.9E-03	8.0E-07	1.1E-05	3.4E-03	1.1E-02	1.1E-01	1.04E-02	**1.3E-01**

Table A-8. Site-Specific Volcanic Screening Factors (Continued)

Radionuclide	Screening Factors, Sv/yr per Bq/m^3							
	Vegetable Ingestion	Milk Ingestion	Meat Ingestion	Soil Ingestion	Total Ingestion	Inhalation	External Exposure	All-pathway
^{244}Cm	6.5E-03	6.5E-07	8.8E-06	2.3E-03	8.8E-03	7.6E-02	4.73E-05	**8.5E-02**
^{245}Cm	1.1E-02	1.1E-06	1.6E-05	6.7E-03	1.8E-02	2.2E-01	9.90E-03	**2.5E-01**
^{246}Cm	1.1E-02	1.1E-06	1.5E-05	6.6E-03	1.7E-02	2.2E-01	7.13E-05	**2.4E-01**
^{247}Cm	9.8E-03	1.0E-06	1.4E-05	6.0E-03	1.6E-02	2.0E-01	3.60E-02	**2.5E-01**
^{248}Cm	4.2E-02	4.2E-06	5.8E-05	2.4E-02	6.6E-02	7.9E-01	5.30E-05	**8.6E-01**
^{250}Cm	2.3E-01	2.4E-05	3.3E-04	1.4E-01	3.7E-01	4.6E+00	0.00E+00	**5.0E+00**
^{58}Co	3.3E-05	3.3E-06	6.5E-05	2.5E-07	1.0E-04	5.0E-08	1.19E-03	**1.3E-03**
^{60}Co	2.4E-04	2.8E-05	5.8E-04	2.9E-05	8.8E-04	1.8E-05	7.49E-02	**7.6E-02**
^{134}Cs	1.4E-03	5.2E-04	3.6E-03	6.7E-05	5.6E-03	5.0E-06	1.99E-02	**2.5E-02**
^{135}Cs	4.7E-04	1.1E-04	7.7E-04	6.3E-05	1.4E-03	1.9E-05	3.23E-06	**1.4E-03**
^{137}Cs	2.5E-03	6.4E-04	4.4E-03	3.1E-04	7.84E-03	6.3E-05	4.86E-02	**5.6E-02**
^{150b}Eu	6.7E-05	2.1E-07	9.6E-06	3.1E-05	1.1E-04	2.1E-04	1.29E-01	**1.3E-01**
^{152}Eu	7.1E-05	2.1E-07	9.8E-06	2.3E-05	1.0E-04	1.1E-04	6.86E-02	**6.9E-02**
^{154}Eu	1.0E-04	3.1E-07	1.4E-05	2.6E-05	1.4E-04	9.9E-05	5.72E-02	**5.7E-02**
^{155}Eu	1.7E-05	4.8E-08	2.2E-06	2.6E-06	2.2E-05	7.0E-06	1.64E-03	**1.7E-03**
^{55}Fe	1.7E-05	2.4E-07	3.4E-05	1.5E-06	5.2E-05	2.5E-07	0.00E+00	**5.2E-05**
^{221}Fr	8.1E-19	1.5E-29	0.0E+00	3.2E-12	3.17E-12	3.6E-11	1.46E-08	**1.5E-08**
^{223}Fr	3.1E-06	1.6E-07	1.7E-07	7.7E-09	3.44E-06	4.4E-08	5.52E-08	**3.5E-06**
^{150}Gd	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{152}Gd	2.2E-03	6.8E-06	3.1E-04	1.3E-03	3.8E-03	4.2E-02	0.00E+00	**4.6E-02**
^{153}Gd	1.4E-05	4.0E-08	1.8E-06	3.2E-07	1.6E-05	1.9E-07	4.06E-04	**4.2E-04**
^{3}H	6.9E-08	1.5E-08	2.8E-08	1.2E-11	1.1E-07	1.2E-11	0.00E+00	**1.1E-07**
^{174}Hf	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{182}Hf	1.8E-04	1.6E-07	4.5E-06	1.4E-04	3.25E-04	7.1E-04	1.70E-01	**1.7E-01**
^{166m}Ho	1.1E-04	3.2E-07	1.5E-05	6.2E-05	1.8E-04	6.2E-04	1.97E-01	**2.0E-01**

Table A-8. Site-Specific Volcanic Screening Factors (Continued)

Radionuclide	Screening Factors, Sv/yr per Bq/m^3							
	Vegetable Ingestion	Milk Ingestion	Meat Ingestion	Soil Ingestion	Total Ingestion	Inhalation	External Exposure	All-pathway
^{129}I	7.3E-03	2.9E-03	1.6E-02	3.3E-03	3.0E-02	7.9E-05	2.37E-03	**3.2E-02**
^{113m}In	3.3E-13	1.7E-19	7.6E-40	9.4E-12	9.7E-12	4.9E-13	3.07E-07	**3.1E-07**
^{115}In	1.7E-03	1.7E-05	4.9E-04	1.0E-03	3.2E-03	8.4E-04	4.23E-05	**4.1E-03**
^{192}Ir	6.0E-05	5.9E-09	7.9E-06	4.9E-07	6.9E-05	1.6E-07	1.06E-03	**1.1E-03**
^{192m}Ir	6.8E-05	4.1E-09	5.5E-06	5.0E-05	1.24E-04	9.6E-05	1.06E-01	**1.1E-01**
^{194}Ir	1.6E-06	7.9E-11	1.5E-09	5.1E-09	1.6E-06	1.5E-10	2.66E-06	**4.3E-06**
^{40}K	2.0E-03	5.1E-04	2.0E-03	2.0E-04	4.7E-03	1.9E-04	2.49E-02	**3.0E-02**
^{42}K	2.2E-07	2.4E-08	1.1E-10	1.1E-09	2.5E-07	6.1E-11	3.75E-06	**4.0E-06**
^{81}Kr	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{85}Kr	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{138}La	5.8E-05	1.8E-07	7.9E-06	3.4E-05	1.0E-04	3.4E-04	1.36E-01	**1.4E-01**
^{176}Lu	9.6E-05	2.9E-07	1.3E-05	5.6E-05	1.7E-04	3.3E-04	5.52E-02	**5.6E-02**
^{54}Mn	4.5E-05	8.2E-07	3.8E-06	1.0E-06	5.0E-05	3.2E-07	4.28E-03	**4.3E-03**
^{93}Mo	4.4E-04	2.3E-05	1.6E-05	9.9E-05	5.8E-04	5.1E-06	4.68E-04	**1.1E-03**
^{100}Mo	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{22}Na	1.8E-04	3.2E-04	8.7E-04	1.4E-05	1.4E-03	9.0E-06	3.46E-02	**3.6E-02**
^{91}Nb	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{92}Nb	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{93m}Nb	6.9E-06	6.4E-10	1.3E-10	2.1E-06	9.0E-06	2.1E-06	4.37E-05	**5.5E-05**
^{94}Nb	1.0E-04	9.6E-09	2.0E-09	5.5E-05	1.6E-04	1.1E-04	1.80E-01	**1.8E-01**
^{95}Nb	2.2E-05	2.2E-09	4.2E-10	9.6E-08	2.2E-05	2.0E-08	4.57E-04	**4.8E-04**
^{95m}Nb	7.0E-06	6.7E-10	7.1E-11	2.0E-08	7.01E-06	3.2E-09	5.33E-05	**6.0E-05**
^{144}Nd	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{59}Ni	6.1E-06	7.1E-06	2.4E-06	1.9E-06	1.8E-05	9.6E-07	0.00E+00	**1.8E-05**
^{63}Ni	1.4E-05	1.6E-05	5.5E-06	4.3E-06	4.0E-05	2.5E-06	0.00E+00	**4.3E-05**

Table A-8. Site-Specific Volcanic Screening Factors (Continued)

Radionuclide	Screening Factors, Sv/yr per Bq/m^3							
	Vegetable Ingestion	Milk Ingestion	Meat Ingestion	Soil Ingestion	Total Ingestion	Inhalation	External Exposure	All-pathway
^{235}Np	2.7E-06	1.3E-09	1.7E-07	1.0E-07	3.0E-06	8.3E-08	2.08E-05	**2.4E-05**
^{236m}Np	1.2E-03	4.7E-07	6.4E-05	5.5E-04	1.8E-03	1.8E-02	1.35E-02	**3.3E-02**
^{237}Np	7.4E-03	2.9E-06	4.0E-04	3.4E-03	1.1E-02	1.1E-01	3.04E-03	**1.2E-01**
^{238}Np	5.3E-06	1.9E-09	5.7E-08	4.3E-07	5.81E-06	1.4E-05	2.11E-05	**4.1E-05**
^{239}Np	4.6E-06	2.0E-09	6.1E-08	9.2E-09	4.7E-06	8.3E-10	6.81E-06	**1.2E-05**
^{240}Np	3.0E-15	3.7E-25	0.0E+00	1.8E-11	1.8E-11	1.4E-12	1.06E-06	**1.1E-06**
^{240m}Np	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{186}Os	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{194}Os	1.7E-04	6.3E-07	1.8E-05	3.6E-05	2.28E-04	5.7E-05	6.79E-03	**7.1E-03**
^{32}P	6.7E-05	6.7E-05	1.8E-04	1.6E-07	3.1E-04	1.9E-08	2.22E-05	**3.4E-04**
^{231}Pa	2.9E-02	6.8E-06	9.0E-06	1.5E-02	4.4E-02	5.1E-01	4.61E-03	**5.6E-01**
^{232}Pa	1.8E-06	3.2E-10	3.1E-11	4.2E-09	1.8E-06	1.0E-09	2.13E-05	**2.3E-05**
^{233}Pa	3.0E-05	7.7E-09	9.6E-09	1.1E-07	3.1E-05	3.5E-08	9.14E-05	**1.2E-04**
^{234}Pa	4.6E-08	1.1E-12	6.3E-18	7.0E-10	4.7E-08	3.9E-11	9.20E-06	**9.2E-06**
^{234m}Pa	1.7E-13	4.2E-18	2.3E-23	2.6E-15	1.74E-13	1.5E-16	3.69E-11	**3.7E-11**
^{205}Pb	1.6E-05	2.3E-07	8.3E-07	8.9E-06	2.6E-05	1.9E-06	2.56E-05	**5.3E-05**
^{209}Pb	1.7E-10	1.8E-14	5.3E-25	3.6E-11	2.1E-10	2.7E-12	7.86E-09	**8.1E-09**
^{210}Pb	3.7E-02	5.5E-04	2.0E-03	1.5E-02	5.5E-02	8.4E-03	1.74E-04	**6.3E-02**
^{211}Pb	1.7E-20	2.9E-34	0.0E+00	2.2E-11	2.2E-11	1.0E-10	4.45E-08	**4.5E-08**
^{212}Pb	2.1E-06	7.6E-09	1.1E-11	1.3E-08	2.1E-06	2.9E-08	1.12E-06	**3.2E-06**
^{214}Pb	8.5E-08	1.3E-09	4.6E-09	3.3E-08	1.23E-07	1.9E-08	5.76E-07	**7.2E-07**
^{107}Pd	5.3E-06	1.5E-08	4.1E-08	1.1E-06	6.5E-06	1.3E-06	0.00E+00	**7.7E-06**
^{145}Pm	6.1E-06	1.8E-08	8.7E-07	2.2E-06	9.2E-06	1.1E-05	1.90E-03	**1.9E-03**
^{146}Pm	4.6E-05	1.3E-07	6.2E-06	7.9E-06	6.1E-05	2.7E-05	2.40E-02	**2.4E-02**
^{147}Pm	1.3E-05	3.9E-08	1.7E-06	1.2E-06	1.6E-05	2.2E-06	4.89E-07	**1.9E-05**

Table A-8. Site-Specific Volcanic Screening Factors (Continued)

Radionuclide	Screening Factors, Sv/yr per Bq/m^3							
	Vegetable Ingestion	Milk Ingestion	Meat Ingestion	Soil Ingestion	Total Ingestion	Inhalation	External Exposure	All-pathway
^{210}Po	5.7E-02	1.1E-03	1.8E-02	7.9E-04	7.7E-02	2.0E-04	2.03E-08	**7.7E-02**
^{211}Po	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{212}Po	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{213}Po	6.3E-20	6.6E-24	1.9E-34	1.3E-20	7.57E-20	9.7E-22	2.77E-18	**2.8E-18**
^{214}Po	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{215}Po	1.4E-26	2.4E-40	0.0E+00	1.7E-17	1.74E-17	8.2E-17	7.30E-14	**7.3E-14**
^{216}Po	8.4E-12	3.0E-14	4.4E-17	5.2E-14	8.52E-12	1.3E-13	4.48E-11	**5.3E-11**
^{218}Po	2.6E-08	4.7E-10	5.9E-09	1.1E-08	4.26E-08	3.9E-09	6.73E-08	**1.1E-07**
^{144}Pr	1.9E-34	0.0E+00	0.0E+00	2.9E-12	2.9E-12	7.3E-14	3.56E-08	**3.6E-08**
^{144m}Pr	8.0E-35	0.0E+00	0.0E+00	1.2E-12	1.23E-12	3.1E-14	1.62E-08	**1.6E-08**
^{193}Pt	3.9E-06	1.2E-08	3.2E-08	8.3E-07	4.8E-06	1.3E-06	1.58E-05	**2.2E-05**
^{236}Pu	4.4E-03	2.1E-07	2.9E-05	4.1E-04	4.9E-03	1.3E-02	1.35E-05	**1.8E-02**
^{238}Pu	1.2E-02	6.2E-07	8.4E-05	6.3E-03	1.8E-02	2.1E-01	6.61E-05	**2.3E-01**
^{239}Pu	1.3E-02	6.9E-07	9.6E-05	8.0E-03	2.1E-02	2.7E-01	3.50E-05	**2.9E-01**
^{240}Pu	1.3E-02	6.9E-07	9.6E-05	8.0E-03	2.1E-02	2.7E-01	7.40E-05	**2.9E-01**
^{241}Pu	2.5E-04	1.4E-08	1.8E-06	1.8E-04	4.28E-04	5.9E-03	4.19E-05	**6.3E-03**
^{242}Pu	1.2E-02	6.5E-07	8.8E-05	7.6E-03	2.0E-02	2.5E-01	6.11E-05	**2.7E-01**
^{243}Pu	2.3E-09	4.7E-15	3.4E-20	8.4E-11	2.4E-09	6.0E-12	8.62E-08	**8.9E-08**
^{244}Pu	1.3E-02	6.5E-07	8.9E-05	7.7E-03	2.0E-02	2.5E-01	5.13E-05	**2.7E-01**
^{246}Pu	6.1E-05	3.3E-09	3.3E-07	1.5E-07	6.20E-05	1.8E-08	1.59E-04	**2.2E-04**
^{223}Ra	2.4E-03	1.3E-04	1.2E-04	5.7E-06	2.7E-03	3.4E-05	2.56E-05	**2.7E-03**
^{224}Ra	6.0E-04	2.8E-05	1.6E-05	1.1E-06	6.4E-04	4.1E-06	6.17E-07	**6.5E-04**
^{225}Ra	3.1E-03	1.4E-04	1.6E-04	8.7E-06	3.37E-03	8.1E-05	6.91E-06	**3.5E-03**
^{226}Ra	2.5E-02	8.7E-04	1.3E-03	1.6E-02	4.30E-02	2.5E-02	2.00E-01	**2.7E-01**
^{228}Ra	4.3E-02	1.8E-03	2.6E-03	6.3E-03	5.40E-02	1.0E-02	7.03E-02	**1.3E-01**

Table A-8. Site-Specific Volcanic Screening Factors (Continued)

Radionuclide	Screening Factors, Sv/yr per Bq/m^3							
	Vegetable Ingestion	Milk Ingestion	Meat Ingestion	Soil Ingestion	Total Ingestion	Inhalation	External Exposure	All-pathway
^{87}Rb	3.4E-04	1.3E-04	5.3E-04	4.7E-05	1.0E-03	3.4E-05	8.95E-06	**1.1E-03**
^{187}Re	1.2E-06	5.7E-08	4.0E-07	1.7E-07	1.8E-06	9.6E-08	0.00E+00	**1.9E-06**
^{102}Rh	1.4E-04	3.2E-06	1.8E-05	1.2E-05	1.8E-04	5.9E-06	3.70E-02	**3.7E-02**
^{106}Rh	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{217}Rn	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{218}Rn	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	0.0E+00	0.00E+00	**0.0E+00**
^{219}Rn	3.1E-23	5.2E-37	0.0E+00	3.9E-14	3.91E-14	1.9E-13	2.09E-10	**2.1E-10**
^{220}Rn	3.0E-09	1.1E-11	1.7E-14	1.9E-11	3.02E-09	4.9E-11	1.69E-08	**2.0E-08**
^{222}Rn	3.6E-05	6.3E-07	8.0E-06	1.9E-05	6.38E-05	7.0E-06	1.22E-04	**1.9E-04**
^{106}Ru	3.6E-04	3.4E-07	4.6E-05	1.2E-05	4.19E-04	7.9E-06	2.26E-03	**2.7E-03**
^{125}Sb	5.9E-05	2.8E-07	3.9E-06	5.2E-06	6.8E-05	3.9E-06	7.26E-03	**7.3E-03**
^{126}Sb	5.9E-05	3.1E-07	3.3E-06	1.4E-07	6.2E-05	1.3E-08	6.13E-04	**6.8E-04**
^{126m}Sb	9.0E-09	4.6E-11	4.8E-10	2.4E-11	9.53E-09	2.1E-12	4.69E-07	**4.8E-07**
^{79}Se	4.0E-04	1.2E-04	1.6E-03	9.1E-05	2.2E-03	1.5E-05	2.01E-06	**2.2E-03**
^{32}Si	2.1E-03	4.5E-04	1.2E-03	9.1E-05	3.85E-03	2.5E-04	1.01E-02	**1.4E-02**
^{145}Sm	1.1E-05	3.1E-08	1.4E-06	4.6E-07	1.26E-05	8.9E-07	4.41E-04	**4.5E-04**
^{146}Sm	2.9E-03	9.1E-06	4.2E-04	1.7E-03	5.0E-03	5.7E-02	0.00E+00	**6.2E-02**
^{147}Sm	2.7E-03	8.1E-06	3.8E-04	1.6E-03	4.6E-03	5.1E-02	0.00E+00	**5.6E-02**
^{148}Sm	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{149}Sm	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{151}Sm	5.2E-06	1.6E-08	7.5E-07	2.8E-06	8.7E-06	1.8E-05	3.84E-07	**2.7E-05**
^{113}Sn	3.8E-05	1.7E-06	2.3E-05	4.2E-07	6.24E-05	1.5E-07	5.68E-04	**6.3E-04**
^{119m}Sn	2.1E-05	8.6E-07	1.2E-05	4.7E-07	3.4E-05	3.2E-07	3.98E-05	**7.5E-05**
^{121}Sn	5.0E-07	1.5E-08	9.8E-09	1.2E-09	5.3E-07	9.3E-11	1.82E-09	**5.3E-07**
^{121m}Sn	1.3E-04	2.2E-06	2.7E-05	1.5E-05	1.79E-04	2.8E-05	3.78E-04	**5.9E-04**

Table A-8. Site-Specific Volcanic Screening Factors (Continued)

Radionuclide	Screening Factors, Sv/yr per Bq/m^3							
	Vegetable Ingestion	Milk Ingestion	Meat Ingestion	Soil Ingestion	Total Ingestion	Inhalation	External Exposure	All-pathway
^{123}Sn	1.1E-04	4.9E-06	6.6E-05	1.3E-06	1.8E-04	5.6E-07	1.54E-04	**3.4E-04**
^{126}Sn	1.6E-03	2.6E-05	3.7E-04	1.6E-04	2.13E-03	3.5E-04	2.39E-01	**2.4E-01**
^{90}Sr	6.9E-03	6.4E-04	4.4E-03	6.3E-04	1.3E-02	2.5E-04	1.44E-04	**1.3E-02**
^{182}Ta	7.1E-05	1.7E-08	2.3E-08	8.7E-07	7.2E-05	4.1E-07	2.59E-03	**2.7E-03**
^{160}Tb	7.0E-05	2.1E-07	9.2E-06	5.6E-07	8.0E-05	2.0E-07	1.39E-03	**1.5E-03**
^{98}Tc	9.0E-03	2.5E-04	3.5E-05	6.2E-05	9.3E-03	1.0E-04	1.63E-01	**1.7E-01**
^{99}Tc	2.9E-03	8.3E-05	1.2E-05	2.0E-05	3.0E-03	3.0E-05	7.90E-06	**3.1E-03**
^{123}Te	6.2E-04	1.4E-05	2.8E-04	1.4E-04	1.1E-03	8.6E-06	1.72E-03	**2.8E-03**
^{123m}Te	6.7E-05	1.6E-06	3.0E-05	7.8E-07	9.8E-05	2.0E-07	2.90E-04	**3.9E-04**
^{125m}Te	3.7E-05	9.3E-07	1.6E-05	2.4E-07	5.5E-05	8.0E-08	2.84E-05	**8.3E-05**
^{127}Te	4.2E-08	2.0E-10	5.4E-13	3.1E-10	4.3E-08	1.8E-11	7.32E-08	**1.2E-07**
^{127m}Te	1.1E-04	2.7E-06	5.0E-05	1.2E-06	1.6E-04	3.6E-07	1.74E-05	**1.8E-04**
^{128}Te	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{130}Te	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{227}Th	1.9E-03	7.1E-05	7.8E-05	1.0E-05	2.07E-03	1.2E-04	7.60E-05	**2.3E-03**
^{228}Th	3.6E-03	8.7E-07	2.4E-05	2.3E-04	3.9E-03	8.9E-03	2.63E-05	**1.3E-02**
^{229}Th	2.6E-02	6.8E-06	1.9E-04	1.6E-02	4.1E-02	5.2E-01	9.50E-03	**5.8E-01**
^{230}Th	1.1E-02	2.9E-06	8.0E-05	6.6E-03	1.8E-02	2.2E-01	7.59E-05	**2.4E-01**
^{231}Th	6.7E-07	1.0E-10	1.0E-10	1.7E-09	6.7E-07	1.2E-10	3.00E-07	**9.7E-07**
^{232}Th	1.2E-02	3.2E-06	8.6E-05	7.5E-03	2.0E-02	2.5E-01	5.69E-05	**2.7E-01**
^{234}Th	1.1E-04	2.9E-08	7.1E-07	3.9E-07	1.1E-04	6.2E-08	3.32E-06	**1.1E-04**
^{204}Tl	1.0E-04	9.9E-06	9.1E-05	7.4E-06	2.1E-04	8.3E-06	2.58E-04	**4.8E-04**
^{206}Tl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{207}Tl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{208}Tl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**

Table A-8. Site-Specific Volcanic Screening Factors (Continued)

Radionuclide	Screening Factors, Sv/yr per Bq/m^3							
	Vegetable Ingestion	**Milk Ingestion**	**Meat Ingestion**	**Soil Ingestion**	**Total Ingestion**	**Inhalation**	**External Exposure**	**All-pathway**
^{209}Tl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{171}Tm	5.4E-06	1.5E-08	7.3E-07	3.5E-07	6.5E-06	4.9E-07	7.04E-06	**1.4E-05**
^{232}U	1.8E-02	3.6E-04	1.0E-03	9.2E-03	2.85E-02	7.1E-02	1.13E-01	**2.1E-01**
^{233}U	2.7E-03	5.5E-05	1.5E-04	1.6E-03	4.5E-03	2.1E-02	7.29E-05	**2.6E-02**
^{234}U	2.6E-03	5.5E-05	1.5E-04	1.6E-03	4.4E-03	2.1E-02	7.11E-05	**2.5E-02**
^{235}U	2.6E-03	5.0E-05	1.4E-04	1.5E-03	4.2E-03	1.9E-02	1.70E-02	**4.0E-02**
^{236}U	2.4E-03	5.2E-05	1.4E-04	1.5E-03	4.1E-03	1.9E-02	6.09E-05	**2.3E-02**
^{237}U	1.2E-05	2.5E-07	4.1E-07	2.5E-08	1.3E-05	4.2E-09	1.53E-05	**2.8E-05**
^{238}U	2.4E-03	4.8E-05	1.3E-04	1.4E-03	4.0E-03	1.8E-02	5.12E-05	**2.2E-02**
^{240}U	7.4E-07	5.3E-09	4.0E-11	3.1E-09	7.51E-07	1.1E-10	4.21E-06	**5.0E-06**
^{50}V	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{90}Y	1.8E-05	4.8E-08	5.9E-07	3.4E-08	1.8E-05	1.3E-09	5.38E-06	**2.4E-05**
^{91}Y	1.0E-04	3.0E-07	1.3E-05	6.4E-07	1.2E-04	1.7E-07	7.73E-05	**1.9E-04**
^{64}Zn	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**
^{65}Zn	2.5E-04	9.7E-05	1.3E-03	4.6E-06	1.6E-03	1.8E-07	2.40E-03	**4.0E-03**
^{93}Zr	5.9E-05	1.9E-09	4.1E-09	3.7E-05	9.60E-05	5.7E-05	3.83E-05	**1.9E-04**
^{95}Zr	4.7E-05	1.7E-09	2.7E-09	4.7E-07	4.78E-05	1.6E-07	1.66E-03	**1.7E-03**
^{96}Zr	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	**0.0E+00**

APPENDIX B
CORRECTION OF ^{79}SE ACTIVITIES

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APPENDIX B
CORRECTION OF ^{79}SE ACTIVITIES

The first section below derives a generic correction factor for an activity calculation that was originally performed with an erroneous half-life or decay constant. The second section applies the generic correction factor to the present screening analysis to compute correction factors for ^{79}Se activity during the regulatory period and at 1 million years.

B.1 DERIVATION OF THE CORRECTION FACTOR

Assuming the number of nuclei, N_0, is correct in the activity calculations at time zero, the old (incorrect) and new (corrected) activities are given by:

$$\begin{aligned} A_{\mathrm{old}}(t) &= \lambda_{\mathrm{old}} N_0 \exp(-\lambda_{\mathrm{old}}\ t) \\ &= \frac{\ln 2}{\tau_{\mathrm{old}}} N_0 \exp(-\frac{\ln 2}{\tau_{\mathrm{old}}}\ t\ ) \end{aligned}$$

and

$$\begin{aligned} A_{\mathrm{new}}(t) &= \lambda_{\mathrm{new}} N_0 \exp(-\lambda_{\mathrm{new}}\ t) \\ &= \frac{\ln 2}{\tau_{\mathrm{new}}} N_0 \exp(-\frac{\ln 2}{\tau_{\mathrm{new}}}\ t\ ) \end{aligned}$$

where and λ_{old} and λ_{new} are the old and new decay constants, τ_{old} and τ_{new} are the old and new half-lives, and t is the decay time. The correction factor is:

$$\begin{aligned} F(t) &= \frac{A_{\mathrm{new}}(t)}{A_{\mathrm{old}}(t)} \\ &= \frac{\tau_{\mathrm{old}}}{\tau_{\mathrm{new}}} \exp[(\ln 2\ )(\frac{1}{\tau_{\mathrm{old}}} - \frac{1}{\tau_{\mathrm{new}}})\ t\ ] \end{aligned}$$

B.2 APPLICATION TO ^{79}SE IN THE PRESENT ANALYSIS

For ^{79}Se, τ_{old} is 330,000 years in the BWR and PWR inventory calculations for the selected screening times. More recent data (Baum et al. 2002 [DIRS 175238]) show that τ_{new} is 2.9×10^5 years. Although the correction factor is small given this half-life datum, it is used to adjust the PWR and BWR ^{79}Se inventories in the RadNuScreen runs (Appendix C).

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APPENDIX C

ELECTRONIC FILES GENERATED IN THIS ANALYSIS

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APPENDIX C
ELECTRONIC FILES GENERATED IN THIS ANALYSIS

Figures C-1 and C-2 provide a directory listing of the folders that contain electronic files generated in this analysis. These files are included on a compact disc that accompanies this document.

The files shown in Figure C-1 are the RadNuScreen 1.0 results by waste form for the periods up to 10,000 years and for the period from 10,000 years to 1,000,000 years. The first two worksheets in each workbook provide the inputs, while the remaining worksheets provide the outputs. The workbook `Screening SummaryREV02.xls` compiles and summarizes the results from the other workbooks.

Figure C-2 shows the Excel files used to calculate the screening factors, the Excel files that were used to provide input to GoldSim, and the files that show the radionuclide inventory at each of the screening times for each of the waste forms. Two revisions (Revision 03 and Revision 04) of the GoldSim run files and the associated Excel files (`GoldSim_Cunnane_Input_and_Results_Q_Rev03.xls` and `GoldSim_Cunnane_Input_and_Results_Q_Rev04.xls`) are included in the Figure C-2 folder. The Revision 03 files were generated when GoldSim V 8.02.500 was run on a workstation with Windows NT Server (CPU QWS 151635). Because a review comment pointed out that GoldSim V 8.02.500 was qualified only under the Windows 2000 operating system, it was rerun under Windows 2000 on the computer identified as Master 06 to generate the Revision 04 files. Comparison of the Revision 03 and Revision 04 outputs, as compiled in the Excel files identified above, showed that the Revision 03 output that was used as input to the RadNuScreen did not change. For this reason, the RadNuScreen runs were not redone using the Revision 04 outputs from the GoldSim runs.

```
                                    FigC-1.txt
 Volume in drive Z is New Volume
 Volume Serial Number is 683C-0946

 Directory of Z:\global\Cunnane\SCI-PRO-003 Backcheck\Figure C-1

02/15/2007  11:11 AM    <DIR>          .
02/15/2007  11:11 AM    <DIR>          ..
02/14/2007  04:26 PM    <DIR>          BWR PWR MOX UserWorkbooks
02/14/2007  04:31 PM    <DIR>          DHLW UserWorkbooks
02/14/2007  04:27 PM    <DIR>          DSNF UserWorkbooks
02/14/2007  04:32 PM    <DIR>          Results Summary
               0 File(s)              0 bytes

 Directory of Z:\global\Cunnane\SCI-PRO-003 Backcheck\Figure C-1\BWR PWR MOX
UserWorkbooks

02/14/2007  04:26 PM    <DIR>          .
02/14/2007  04:26 PM    <DIR>          ..
02/05/2007  02:37 PM           160,768 BWR Av 10k.xls
02/05/2007  02:38 PM         1,148,416 BWR Av 1M.xls
02/05/2007  02:44 PM         1,159,680 BWR Max 10k.xls
02/05/2007  02:48 PM         1,151,488 BWR Max 1M.xls
02/09/2007  07:35 AM         1,385,984 MOX 10k.xls
02/09/2007  07:37 AM         1,333,760 MOX 1M.xls
02/05/2007  02:58 PM         1,345,024 PWR Av 10k.xls
02/05/2007  03:01 PM         1,116,160 PWR Av 1M.xls
02/05/2007  03:06 PM         1,350,144 PWR Max 10k.xls
02/05/2007  03:08 PM         1,307,136 PWR Max 1M.xls
              10 File(s)     11,458,560 bytes

 Directory of Z:\global\Cunnane\SCI-PRO-003 Backcheck\Figure C-1\DHLW UserWorkbooks

02/14/2007  04:31 PM    <DIR>          .
02/14/2007  04:31 PM    <DIR>          ..
02/09/2007  07:09 AM         1,175,040 DHLW Hanford 10k.xls
02/13/2007  10:38 AM         1,123,840 DHLW Hanford 1M.xls
02/13/2007  10:17 AM         1,140,224 DHLW Hanford 1M_Zr93 to Nb93m.xls
02/09/2007  07:12 AM         1,177,600 DHLW INEEL 10k.xls
02/09/2007  07:13 AM         1,138,688 DHLW INEEL 1M.xls
02/09/2007  07:15 AM         1,169,408 DHLW LaBs 10k.xls
02/09/2007  07:16 AM         1,134,592 DHLW LaBs 1M.xls
02/09/2007  07:17 AM         1,177,600 DHLW SRS 10k.xls
02/09/2007  07:19 AM         1,138,176 DHLW SRS 1M.xls
02/09/2007  07:20 AM         1,187,840 DHLW WVDP 10k.xls
02/13/2007  10:38 AM         1,132,032 DHLW WVDP 1M.xls
02/13/2007  10:14 AM         1,148,416 DHLW WVDP 1M_Zr93 to Nb93m.xls
              12 File(s)     13,843,456 bytes

 Directory of Z:\global\Cunnane\SCI-PRO-003 Backcheck\Figure C-1\DSNF UserWorkbooks

02/14/2007  04:27 PM    <DIR>          .
02/14/2007  04:27 PM    <DIR>          ..
02/09/2007  07:23 AM         1,178,624 DSNF Av 10k.xls
02/09/2007  07:24 AM         1,138,688 DSNF Av 1M.xls
02/09/2007  07:26 AM         1,181,184 DSNF Max 10k.xls
02/09/2007  07:27 AM         1,141,248 DSNF Max 1M.xls
02/09/2007  07:28 AM         1,184,768 DSNF UCrbde 10k.xls
02/09/2007  07:30 AM         1,142,272 DSNF UCrbde 1M.xls
               6 File(s)      6,966,784 bytes

 Directory of Z:\global\Cunnane\SCI-PRO-003 Backcheck\Figure C-1\Results Summary

02/14/2007  04:32 PM    <DIR>          .
                                       Page 1
```

Figure C-1. Directory Listing of RadNuScreen 1.0 Files Generated in This Analysis

```
                                        FigC-1.txt
02/14/2007  04:32 PM    <DIR>          ..
02/13/2007  04:39 PM           116,224 Screening SummaryREV02.xls
               1 File(s)        116,224 bytes

     Total Files Listed:
              29 File(s)     32,385,024 bytes
              14 Dir(s)  465,499,971,584 bytes free
```

Page 2

Figure C-1. Directory Listing of RadNuScreen 1.0 Files Generated in This Analysis (Continued)

```
                              figc2.txt
 Volume in drive Z is New Volume
 Volume Serial Number is 683C-0946

 Directory of Z:\global\Cunnane\SCI-PRO-003 Backcheck\Figure C-2

03/02/2007  01:42 PM    <DIR>          .
03/02/2007  01:42 PM    <DIR>          ..
09/05/2006  03:56 PM           140,800 BWR_000-00C-MGR0-00200-000-00aATTACH_XIII.XLS
02/08/2007  04:51 PM         3,557,325 Decay_Calcs_Post_2060_Q_Rev03.gsm
02/20/2007  10:24 AM         3,557,326 Decay_Calcs_Post_2060_Q_Rev04.gsm
02/08/2007  04:50 PM         3,421,664 Decay_Calcs_Pre_2060_Q_Rev03.gsm
02/20/2007  10:19 AM         3,421,665 Decay_Calcs_Pre_2060_Q_Rev04.gsm
02/08/2007  04:49 PM         2,320,896 GoldSim_Cunnane_Input_and_Results_Q_Rev03.xls
02/20/2007  10:24 AM         3,417,088 GoldSim_Cunnane_Input_and_Results_Q_Rev04.xls
01/29/2007  12:26 PM           143,872 InitialRadInvData_JCC010207.xls
12/07/2006  04:36 PM         1,117,696 McClure et al _50-0G-CR.out.xls
09/11/2006  02:04 PM           474,112 PWR_000-00C-MGR0-00100-000-00BATTACH_IX.XLS
02/15/2007  11:21 AM           707,584 Site-Specific Screening
Factors_01-30-2007.xls
              11 File(s)     22,280,028 bytes

     Total Files Listed:
              11 File(s)     22,280,028 bytes
               2 Dir(s)  431,402,676,224 bytes free

                                Page 1
```

Figure C-2. Directory of Radionuclide Inventory, GoldSim, and Screening Factor Files

Scientific Analysis/Calculation Administrative Change Notice

QA: QA
Page 1 of 2

Complete only applicable items.

1. Document Number:	ANL-WIS-MD-000006	**2. Revision:**	REV 02	**3. ACN:**01	
4. Title:	Radionuclide Screening				
5. No. of Pages Attached:	5				

6. Approvals:

Preparer:	for Jim Cunnane Ernest Hardin Print Name and Sign	5/18/07 Date
Checker:	Christine Stockman Print name and sign	5/18/07 Date
QCS/Lead Lab QA Reviewer:	Bruce Foster Print name and sign	5/18/07 Date
Responsible Manager:	Geoff Freeze Print name and sign	5/18/07 Date

7. Affected Pages	**8. Description of Change:**
Change History	The Change History for REV02 ACN01A has been added as follows: Added CR 7925 to the set of applicable CRs and implemented changes to address DOE Deliverable Review Comments.
1-1	Omission of CR 7925 from the set of applicable CRs in Section 1. 3rd paragraph. Change the third paragraph in Section 1. page 1-1 to add CR 7925 as follows: The purpose of this revision (Revision 02) is to update the radionuclide inventory and screening factor input data (Condition Reports (CRs) 5925, 5600, and 7925). Consistent with this purpose, the current revision incorporates the content of previous revisions that has not been updated or superseded.
1-2	Correct technical work plan (TWP) title in Section 1. page 1-2. The first two lines in the first paragraph on page 1-2 are changed to delete the word *Postclosure* from the TWP title as follows: This document was prepared in accordance with *Technical Work Plan for Waste Form Testing and Modeling* (BSC 2006 [DIRS 177389]), with the following exceptions:

Scientific Analysis/Calculation Administrative Change Notice

Complete only applicable items.

1. Document Number:	ANL-WIS-MD-000006	**2. Revision**:	REV 02	**3. ACN**:01	

4. Title:	Radionuclide Screening
3-1	Definition of the function of the RadNuScreen Version 1.0 software. A sentence has been added to the last paragraph in Section 3.1 to provide a cross reference to Section 6.2.6 where the function of the RadNuScreen Version 1.0 software is described. This paragraph is revised as follows: This analysis also used RadNuScreen Version 1.0 (RadNuScreen V1.0 [DIRS 157983], STN: 10732-1.0-00). RadNuScreen V1.0 is qualified baseline software. It was obtained from Software Configuration Management and installed on a Dell Optiplex GX 260 personal computer (Serial No. HZ5N921) in accordance with Section 4.1 of IT-PRO-0011, *Software Management.* RadNuScreen 1.0 is appropriate for this application because it was designed specifically for use in radionuclide screening analyses. The functions of the RadNuScreen 1.0 software are described in Section 6.2.6. The software was used with Excel 2000 9.0.6923 SP-3 and the Windows 2000 (Version 5.0, Build 2195, Service Pack 4) operating system. This software was used within the documented validation range (BSC 2002 [DIRS 158525], Section 2.5). Input and output workbook files are provided in Appendix C. Except for the Screening Summary file, which is an output summary, the first two worksheets in each workbook file provide the inputs, while the remaining worksheets provide the outputs. There are no limitations on the output due to the use of RadNuScreen V1.0.

01	Completely revise: (1) drop the inventory projections (the old Attachments I and II) to simplify the organization of the analysis and because of an updated CSNF waste stream is expected after the approval of this analysis; (2) revise the screening method to include (a) an intermediate solubility class, (b) external exposure, and (c) effects of the biosphere. Change bars are not used due to extensive revision. This revision (01) fulfills the commitments regarding radionuclide screening that were made in response to Technical Error Report TER-02-0064 (see AP-15.3Q, Control of Technical Product Errors.
02	This is a complete revision of the document. This revision addresses Condition Reports 5925 and 5600 by updating the radionuclide inventory and screening factor input data. Consistent with this purpose the current revision incorporates the content of previous revisions that has not been updated or superseded. Change tracking is not used because the changes in the document are too extensive.
02 ACN01	Added CR 7925 to the set of applicable CRs and implemented changes to address DOE Deliverable Review Comments.

1. PURPOSE

The waste forms under consideration for disposal in the repository at Yucca Mountain contain scores of radionuclides. It would be impractical and highly inefficient to model all of these radionuclides in a total system performance assessment (TSPA). Thus, the purpose of this radionuclide screening analysis is to remove from further consideration (screen out) radionuclides that are unlikely to significantly contribute to radiation dose to the public from a nuclear waste repository at Yucca Mountain. The remaining nuclides (those screened in) are recommended for consideration in TSPA modeling for license application. This analysis also covers radionuclides that may not be screened in based on dose, but need to be included in TSPA modeling for other reasons. For example, U.S. Environmental Protection Agency (EPA) and U.S. Nuclear Regulatory Commission (NRC) regulations require consideration of the combined activity of ^{226}Ra and ^{228}Ra in groundwater (40 CFR 197.30 [DIRS 173176], 10 CFR 63.331 [DIRS 173176]). In addition, parent radionuclides (e.g., ^{245}Cm and ^{241}Pu) that contribute to the inventory of the screened-in progeny should be included in TSPA modeling.

The radionuclide screening analysis considers two different postclosure time periods: the period up to 10,000 years and the period after 10,000 years up to 1 million years after emplacement. For the purposes of the screening analysis, four modeling cases are considered within the nominal and disruptive scenario classes: (1) nominal, which entails long-term degradation of disposal containers and waste forms, (2) human-intrusion, (3) intrusive igneous, and (4) eruptive igneous. Because the first three cases require groundwater transport, they are called groundwater scenarios below. The screening analysis considers the following waste form types: commercial spent nuclear fuel (CSNF) from light water reactors; U.S. Department of Energy (DOE) spent nuclear fuel (SNF), excluding navy spent fuel, which is not considered in this analysis; and high-level waste (HLW) in the form of borosilicate glass. Within these waste form types, average and outlying (high-burnup, high-initial enrichment, low-age, or otherwise exceptional) waste forms are considered.

The purpose of this revision (Revision 02) is to update the radionuclide inventory and screening factor input data (Condition Reports (CRs) 5925, 5600, and 7925). Consistent with this purpose, the current revision incorporates the content of previous revisions that has not been updated or superseded.

In a review of Revision 00 of this radionuclide screening analysis, the NRC found that “processes that affect transport in the biosphere, such as uptake by plants and bioaccumulation are not accounted for,” and that “the direct exposure pathway is not accounted for” (Beckman 2001 [DIRS 156122], Section 5.3.2.1). The NRC also found that the solubility and sorption classes were too broadly defined, noting, for example, that Se is in the same solubility and sorptivity groups as neptunium and uranium, yet is “more soluble than neptunium and uranium by several orders of magnitude” (Beckman 2001 [DIRS 156122], Section 5.3.2.1). This revision includes the responses to the specific concerns raised by the NRC and other reviewers that were documented in Revision 01 (BSC 2002 [DIRS 160059]). As does Revision 01 (BSC 2002 [DIRS 160059]), this revision uses screening factors that take into account various environmental transport and exposure pathways in the biosphere. It also retains the three solubility and sorption classes used in Revision 01 (BSC 2002 [DIRS 160059]) to better segregate the radionuclides into appropriate groups for radionuclide screening.

This document was prepared in accordance with *Technical Work Plan for Waste Form Testing and Modeling* (BSC 2006 [DIRS 177389]), with the following exceptions:

- The procedure used for this scientific analysis was SCI-PRO-005, *Scientific Analyses and Calculations*.
- Inputs were managed in accordance with SCI-PRO-004, *Managing Technical Product Inputs.*
- Although it was not identified in Section 9 of the technical work plan (TWP) (BSC 2006 [DIRS 177389]), GoldSim V 8.02.500 (see Section 3.1) was used for radionuclide inventory decay calculations.

These deviations from the TWP are justified because SCI-PRO-005 superseded LP-SIII.9Q-BSC and SCI-PRO-004 superseded LP-3.15Q-BSC, which were the corresponding procedures identified in the TWP (BSC 2006 [DIRS 177389], Section 4.2). Current revisions of applicable procedures were used. Also, the use of GoldSim V 8.02.500 is justified because an application was needed to calculate the radionuclide inventories at selected decay times up to one million years after emplacement, and the radionuclide transport module in GoldSim V 8.02.500 is qualified and suitable for performing the needed calculations.

3. USE OF SOFTWARE

3.1 SOFTWARE APPROVED FOR QUALITY ASSURANCE WORK

This section identifies and describes the controlled and baselined software (as defined in IM-PRO-003, *Software Management*) used in this analysis and how the requirements of SCI-PRO-005 (Attachment 2, Section 3) were satisfied for the use of this software.

This analysis used GoldSim Version 8.02.500 (GoldSim V. 8.02.500 [DIRS 174650], STN: 10344-8.02-05), run under Windows 2000 on the computer identified as Master06, to do radionuclide inventory decay calculations for selected times up to a million years. These calculations were performed using the radionuclide transport module within the range of use of GoldSim V. 8.02.500. This software was selected because it is qualified baseline software and the radionuclide transport module in GoldSim V. 8.02.500 simulates radioactive decay and is suitable for calculating the radionuclide inventories at the selected decay times. It was obtained from Software Configuration Management and installed on a workstation with Windows NT Server (CPU QWS-151635) in accordance with Section 6.1 of IM-PRO-003. The GoldSim run files are included in Appendix C and are discussed in Section 6.2.3. The use of GoldSim V. 8.02.500, as described above, was consistent with the intended use and within the documented validation range of the software. There are no limitations on the output due to the use of the GoldSim V. 8.02.500 software.

This analysis also used RadNuScreen Version 1.0 (RadNuScreen V1.0 [DIRS 157983], STN: 10732-1.0-00). RadNuScreen V1.0 is qualified baseline software. It was obtained from Software Configuration Management and installed on a Dell Optiplex GX 260 personal computer (Serial No. HZ5N921) in accordance with Section 4.1 of IT-PRO-0011, *Software Management.* RadNuScreen 1.0 is appropriate for this application because it was designed specifically for use in radionuclide screening analyses. The functions of the RadNuScreen 1.0 software are described in Section 6.2.6. The software was used with Excel 2000 9.0.6923 SP-3 and the Windows 2000 (Version 5.0, Build 2195, Service Pack 4) operating system. This software was used within the documented validation range (BSC 2002 [DIRS 158525], Section 2.5). Input and output workbook files are provided in Appendix C. Except for the Screening Summary file, which is an output summary, the first two worksheets in each workbook file provide the inputs, while the remaining worksheets provide the outputs. There are no limitations on the output due to the use of RadNuScreen V1.0.

3.2 COMMERCIAL OFF-THE-SHELF SOFTWARE USED

This section identifies and describes the exempt software (as defined in IM-PRO-003, Section 2) used in this analysis and how the requirements of SCI-PRO-005 (Attachment 2, Section 3) were satisfied for the use of this software.

Microsoft Excel 2003 (11.8033.8036) SP2, a commercially available spreadsheet software package, was used to process radionuclide inventory data and GoldSim and RadNuScreen inputs and results. Excel is appropriate for these uses because the calculations require simple mathematical expressions and operations that are available as standard functions in Excel. The specific standard functions of Excel that were used for calculations are described at the point of use (Appendices A and C). These standard functions of Excel are exempt from the software