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Evaluation of Short-Term Risks for Operable Unit 7-13/14

Wayne Schofield
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Idaho National Engineering and Environmental Laboratory
Bechtel BWXT Idaho, LLC

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Idaho National Engineering and Environmental Laboratory
Environmental Restoration Project
Idaho Falls, Idaho 83415

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ABSTRACT

To satisfy the requirements of the Federal Facilities Agreement and Consent Order with the State of Idaho and the U. S. Environmental Protection Agency, the Department of Energy is conducting the Waste Area Group 7 Operable Unit 13/14 Comprehensive Remedial Investigation/Feasibility Study at the Idaho National Engineering and Environmental Laboratory. The Comprehensive Environmental Response, Compensation, and Liability Act governs these activities, which involve assessments of contaminants of concern, risk factors, and potential technologies employed during remediation.

In support of the feasibility study, this report presents the short-term risks for four alternatives that are being evaluated for the stabilization or retrieval and disposal of transuranic waste buried in the Subsurface Disposal Area at the Idaho National Engineering and Environmental Laboratory's Radioactive Waste Management Complex. The purpose of the risk assessment is to assess short-term risks and effectiveness for each alternative in protecting human health and the environment during the preconstruction, construction, operational, and decontamination and decommissioning phases until Comprehensive Environmental Response, Compensation, and Liability Act response objectives have been achieved.

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ACRONYMS

CEDE	committed effective dose equivalent
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CRF	cancer risk factor
D&D	decontamination and decommissioning
DOE	U.S. Department of Energy
DOL	Department of Labor
EPA	U.S. Environmental Protection Agency
FS	feasibility study
HE	heavy equipment
HEO	heavy-equipment operator
ILCR	incremental lifetime cancer risk
INEEL	Idaho National Engineering and Environmental Laboratory
IRA	Interim Risk Assessment
ISG	in situ grouting
ISV	in situ vitrification
MEI	maximally exposed individual
MHRF	mechanical hazard risk factor
ORNL	Oak Ridge National Laboratory
OU	operable unit
QA	quality assurance
RA	risk assessment
RCT	radiological control technician
RWMC	Radioactive Waste Management Complex
RWTF	Radioactive Waste Treatment Facility
SDA	Subsurface Disposal Area

TRU	transuranic
TRUPACT II	transuranic package container II
WAG	waste area group
WIPP	Waste Isolation Pilot Plant

Evaluation of Short-Term Risks for Operable Unit 7-13/14

1. INTRODUCTION

This risk assessment (RA) supports the feasibility study (FS), which is designed and conducted to identify, develop, and evaluate different scientific approaches that could serve as remedial alternatives—cleanup actions—that will bring the area known as Waste Area Group 7 (WAG 7) back to conditions acceptable by U.S. Environmental Protection Agency (EPA) risk criteria.

As the second half of a remedial investigation/feasibility study and a primary document in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process, an FS must first identify and then evaluate the alternatives that could be used to clean up the waste identified as posing a risk to human health and the environment. Therefore, the purpose of the WAG 7 FS is to develop a comprehensive, defensible, and balanced analysis of remedial alternatives that adequately addresses the risks associated with the waste sites contained within the Radioactive Waste Management Complex (RWMC) area. Specifically, the FS develops and evaluates alternatives that will remedy the WAG 7 risks.

Nine evaluation criteria have been developed by EPA to address the CERCLA requirements and the additional technical and policy considerations that have proven to be important for selecting remedial alternatives. These evaluation criteria serve as the basis for conducting the detailed analyses during the FS and for subsequently selecting an appropriate remedial action. The evaluation criteria are:

- Overall protection of human health and the environment
- Compliance with applicable or relevant and appropriate requirements
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume
- Short-term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance.

This assessment examines in detail one of the nine criteria, specifically the short-term risks associated with the selected alternatives that will be used to stabilize or retrieve buried transuranic (TRU) waste from the Subsurface Disposal Area (SDA) at the RWMC. The purpose of the RA is to assess the short-term effectiveness of each alternative in protecting human health and the environment during preconstruction, construction, operation, and decontamination and decommissioning (D&D) phases until response objectives have been met.

Short-term effectiveness measures the impacts associated with implementing an alternative. One category of impacts is risks to workers. This category assesses impacts on nonremediation and remediation workers from mechanical hazards associated with implementing the alternative and from exposure to hazardous substances, including radioactive material and radiation fields. Also included, but presented separately, are impacts on workers who support remedial activities but are not part of the remediation staff. These workers may be exposed to materials released during remedial activities, including excavation, waste packaging, and waste processing, or from radiation fields attributed to waste handling and staging. Results include radiological risks (collective dose equivalent and fatal cancer risk) and Occupational Safety and Health Administration-type accident rates.

Another category of impacts is risks to the public. The public can be impacted through releases of hazardous substances from waste handling and processing activities or from offsite waste transportation. Transportation risks include traffic fatalities and radiation risk from routine and accidental exposures to radioactive material.

Short-term effectiveness does not measure residual risks associated with materials remaining at the site or from materials disposed at other sites—these risks are measured under long-term effectiveness.

2. WASTE AREA GROUP 7 INTERIM RISK ASSESSMENT AND BASELINE RISK ASSESSMENT

The results of the Interim Risk Assessment (IRA) and contaminant screening for Operable Unit (OU) 7-13/14, the combined OU 7-13 TRU pits and trenches and OU 7-14 WAG 7 Comprehensive Remedial Investigation/Feasibility Study, are presented in *Interim Risk Assessment and Contaminant Screening for the Waste Area Group 7 Remedial Investigation* (Becker et al. 1998).

The IRA and contaminant screening described in the report are snapshots of the current understanding of the nature and extent of contamination and potential risks associated with WAG 7. Lacking a completed and approved Baseline Risk Assessment, information gleaned from the IRA was used as baseline information required to calculate short-term effectiveness in support of the RA for the FS.

3. ALTERNATIVES EVALUATION RISK ASSESSMENT

This section presents the remedial alternatives; the potential receptors, pathways, and exposure parameters; and the conceptual and mathematical models for the analyses. As stated above, this RA evaluates the short-term effectiveness of the process alternatives (i.e., the risks associated with implementing each alternative).

3.1 Description of Alternatives

The risks from four alternatives have been estimated in the following sections of this document. The four alternatives include:

- Surface barrier alternative—this alternative requires the placement of a long-term, multilayer, low-permeability cap over the SDA. The cap design includes a low-permeability layer to control surface water infiltration and a biotic barrier to prevent intrusion into the waste by burrowing animals and deep-rooted plants. The cap design also includes a gas collection layer to address future volatile organic compound releases from the buried waste. As described in detail in the FS, the cap design for the Idaho National Engineering and Environmental Laboratory (INEEL) CERCLA Disposal Facility landfill was selected.

- In situ grouting (ISG) alternative—this alternative involves application of ISG technology to stabilize buried waste and contaminated soils in place. In situ thermal desorption will be performed as a preconditioning step before performing active ISG operations on the selected pits and trenches. Application of the ISG alternative would include placement of a protective cover over the entire SDA as described above in the surface barrier alternative.

- In situ vitrification (ISV) alternative—this alternative involves application of ISV technology to treat and stabilize buried waste and contaminated soil. In situ thermal desorption will be performed as a preconditioning step before performing active ISV operations on the selected pits and trenches. Application of the ISV alternative would include placement of a protective cover over the entire SDA as described above in the surface barrier alternative.

- Full retrieval, ex situ treatment, on-Site, or off-Site disposal alternative—in this alternative, the waste is retrieved and treated as required for either onsite or offsite disposal. During retrieval activities, high-level waste and possibly spent nuclear fuel may be encountered. If encountered, the material will be moved to a separate cell, grouted, and left in the pit or trench. Application of this alternative would include placement of a protective cover over the entire SDA as described above in the surface barrier alternative. For this alternative, the processed materials are either disposed of on-Site, if classified non-TRU, or, if classified as TRU, shipped to the Waste Isolation Pilot Plant (WIPP) for disposal. Transportation alternatives evaluated here include truck-only transport. The transportation scenarios evaluated are discussed in Appendix A of this RA.

Institutional controls would be added to these alternatives to restrict access and future land uses. Environmental monitoring, cap integrity monitoring, and maintenance (e.g., repair of any observable degradation such as cracks, erosion, or biotic intrusion) would be conducted on an annual basis, and provisions would be established for access restrictions (e.g., fencing) and maintenance.

3.2 Potential Receptors, Pathways, and Exposure Parameters

This subsection provides the basis for the RA, including assumptions, exposure pathways, receptors, mathematical models, and exposure parameters (i.e., the values used in the models to assess the risks).

Remedial action risks are associated with implementing remedial action alternatives and are delivered over the duration of the remediation. Short-term human health impacts are closely related to exposure duration. Exposure duration is the amount of time a receptor may be exposed to hazards associated with the waste itself, or during the removal and subsequent disposal of the waste. Specifically, the exposure duration is the amount of time that a person is exposed to hazards associated with waste or the retrieval and subsequent disposal of waste. Simply stated, the longer the exposure time, the greater the risk. Short-term environmental impacts are related primarily to the extent of physical disturbance of habitat.

Short-term risks include normal and off-normal conditions that may expose remediation workers, nonremediation workers, and the public to hazardous constituents. Normal exposure hazards include exposure to mechanical injuries or penetrating radiation during the construction, operational, and D&D phases of a selected alternative. Off-normal conditions that may be a significant risk contributor for selected alternatives may include fatalities from mechanical hazards, radiological exposures from a criticality event, inhalation of a radiological or hazardous constituent, or offsite transportation accidents.

Some of these risks are quantifiable; others can only be addressed qualitatively at this early stage of the investigation. While regulators prefer quantifiable data, qualitative evaluations often provide very useful differentiations between alternatives relative to short-term risks. In some cases, the need to quantify some of the short-term risks is unnecessary.

Short-term risks are usually lifetime cancer risks associated with exposure to ionizing radiation illnesses and mechanical injuries and fatalities associated with construction and operational activities. This RA estimates risks delivered to three groups of individuals: remediation workers, nonremediation workers, and the general public. Remediation workers are those placed at risk by a specific component of a process alternative while implementing that component (e.g., process equipment operators, operators, laborers, transportation workers, construction workers, and health and safety staff). Nonremediation workers are those at the RWMC who are not directly working in support of remediating the SDA but are providing support services. The general public living near the INEEL site is at risk from the release of radioactive material from process effluent if effluents are left unabated. The general public living next to or sharing the offsite transport route for the waste materials is at risk from direct radiation associated with transport containers and the accidental release of waste material during a transportation accident.

To estimate risks from normal operations for each of the selected alternatives, this RA examines three distinct remedial alternative components: preconstruction, construction support, and processing alternatives. Other risks evaluated for applicable alternatives from normal operations include movement of retrieved material onsite to the Radioactive Waste Treatment Facility (RWTF) and subsequent onsite disposal and TRU shipments offsite to WIPP. The RWTF is described in detail in the facility description section of the FS. Risks evaluated from off-normal events include a Melt Expulsion Event during ISV, worker exposure because of a radiological incident within the primary containment during retrieval actions, and a transportation accident while transporting TRU material from the INEEL to WIPP. These components represent the operations that have the potential for contributing significantly to the remedial action risks. Each component is briefly described in the following list:

- Preconstruction and construction support: some degree of preconstruction activity will be accomplished, and support facility construction will be evaluated for each alternative. The more elaborate the processing and operational requirements are, the more extensive the support facilities must be. The exposure mode associated with this component is mechanical injury and fatalities and external radiation exposure from the nearby storage areas and onsite disposal operations.

- Facility operations: each alternative requires a labor force to invoke it or operate the facility. This work force is exposed to varying levels of ambient radiation, depending on their tasks within the facility. These workers also are exposed to mechanical hazards. Also, the public living near the site could potentially be exposed to radioactive material if releases occurred during operational activities. For applicable alternatives, workers onsite and the offsite public could be exposed to varying levels of radiation from a criticality event during waste removal or stabilization. During ISV and retrieval operations, workers may be exposed to radiological constituents from an off-normal event.

- Transportation: this will be evaluated for the retrieval alternative only. Waste will be retrieved from the pits and trenches within the SDA, placed in a transport container (probably a B-25 metal bin), and transported to the RWTF for segregation and classification. Workers will be exposed to varying levels of radiation during waste packaging, staging, and movement operations. Waste that is categorized as non-TRU will be disposed of onsite. TRU classified waste will be packaged in 55-gal drums, placed in a transuranic package container II (TRUPACT II), and shipped offsite to WIPP for final disposal. The RADTRAN5 computer model is used to assess radiological and nonradiological risks to workers and the public from transporting waste from the INEEL to WIPP.

- Decommissioning: decontamination and decommissioning operations have been separated from other operations. Workers are exposed to both radiological and mechanical risks during D&D phases required by some of the alternatives.

It should be noted that the components are developed for conceptual purposes to provide a basis for the RA and the FS comparative evaluations. Additional sections of this RA describe the exposure pathways.

3.2.1 Assumptions for Analysis of Remedial Action Risks

The assessments of remedial action risks require a number of assumptions. Assumptions have been made for each element of the assessment: exposure scenarios, receptors, exposure models, and exposure parameters. The assumptions are documented in the following list:

- Transuranium isotopes of concern include Np-236, Np-237, Pu-238, Pu-239, Pu-240, Pu-242, Pu-244, Am-241, Am-243, Cm-243, Cm-245, Cm-246, Cm-247, Cm-248, Cm-250, Bk-247, Cf-249, and Cf-251. According to the IRA, U.S. Department of Energy (DOE)/ID-10566(DOE-ID 1998), and values established in the preliminary Baseline Risk Assessment, the following radionuclides and curie quantities represent the "best estimates" of inventory currently within the pits and trenches at the SDA (see Table 1). More appropriate values for Ni-59, Co-60, and Cs-137 were obtained from Table 3-1 presented in *Subsurface Disposal Area Waste Identification (1952–1970 emphasis)* (EG&G 1990), which provides an estimate of the low-level waste buried with the TRU waste in the selected pits and trenches requiring excavation. For completeness, the values reported in Table 2 include in-growth of daughter products.

Table 3-1. 1999 inventory of concern.

Radionuclide	1999 Inventory (Ci)	Fraction of Total	Radionuclide	1999 Inventory (Ci)	Fraction of Total
Ac-227	5.12E-07	2.31E-13	Pu-240	1.71E+04	7.70E-03
Am-241	1.83E+05	8.42E-02	Pu-241	9.74E+05	4.39E-01
Am-243	1.34E+02	6.04E-05	Pu-242	1.65E+01	7.43E-06
Ba-137m[a]	5.93E+02	2.67E-04	Ra-226	6.00E+01	2.70E-05
C-14	5.00E+02	2.25E-04	Ra-228	1.08E-05	4.86E-12
Cl-36	1.11E+00	5.00E-07	Sr-90	4.52E+05	2.04E-01
Co-60[a]	7.09E+02	3.19E-04	Tc-99	6.05E+01	2.73E-05
Cm-244	5.24E+04	2.36E-02	Th-228	1.02E+01	4.59E-06
Cs-137[a]	6.26E+02	2.82E-04	Th-229	6.81E-06	3.07E-12
I-129	1.58E-01	7.12E-08	Th-230	3.13E-02	1.41E-08
Nb-94	1.00E+03	4.50E-04	Th-232	1.34E+00	6.04E-07
Ni-59[a]	1.50E+03	6.76E-04	U-233	1.51E+00	6.80E-07
Np-237	2.64E+00	1.19E-06	U-234	6.74E+01	3.04E-05
Pa-231	8.64E-04	3.89E-10	U-235	5.54E+00	2.50E-06
Pb-210	5.10E-07	2.30E-13	U-236	2.86E+00	1.29E-06
Pu-238	1.71E+04	7.70E-03	U-238	1.17E+02	5.27E-05
Pu-239	6.49E+04	2.92E-02	Y-90	4.52E+05	2.04E-01
			Total	**2.22E+06**	**1.00E+00**

a. EG&G, 1990, *Subsurface Disposal Area Waste Identification (1952–1970 emphasis),* EG&G-WM-8727, Rev. 2, January 1990.

Table 3-2. 1999 inventory decayed to 2002.

Radionuclide	2002 Decayed Inventory (Ci)	Fraction of Inventory	Radionuclide	2002 Decayed Inventory (Ci)	Fraction of Inventory
Ac-225	4.21E-04	2.08E-10	Po-213	4.12E-04	2.04E-10
Ac-227	9.54E-05	4.72E-11	Po-214	5.99E+01	2.97E-05
Ac-228	4.07E-01	2.01E-07	Po-215	9.12E-05	4.51E-11
Am-241	1.87E+05	9.23E-02	Po-216	3.62E+00	1.79E-06
Am-243	1.34E+02	6.63E-05	Po-218	5.99E+01	2.97E-05
At-217	4.21E-04	2.08E-10	Pu-238	1.67E+04	8.27E-03
Ba-137m	5.53E+02	2.74E-04	Pu-239	6.49E+04	3.21E-02
Bi-210	5.29E+00	2.62E-06	Pu-240	1.71E+04	8.47E-03
Bi-211	9.12E-05	4.51E-11	Pu-241	8.43E+05	4.17E-01
Bi-212	3.63E+00	1.80E-06	Pu-242	1.65E+01	8.17E-06
Bi-213	4.21E-04	2.08E-10	Ra-223	9.12E-05	4.51E-11
Bi-214	5.99E+01	2.97E-05	Ra-224	3.62E+00	1.79E-06
C-14	5.00E+02	2.47E-04	Ra-225	4.26E-04	2.11E-10

Table 3-2. (continued).

Radionuclide	2002 Decayed Inventory (Ci)	Fraction of Inventory	Radionuclide	2002 Decayed Inventory (Ci)	Fraction of Inventory
Cl-36	1.11E+00	5.50E-07	Ra-226	5.99E+01	2.97E-05
Cm-244	4.67E+04	2.31E-02	Ra-228	4.07E-01	2.01E-07
Co-60	4.78E+02	2.37E-04	Rn-219	9.12E-05	4.51E-11
Cs-137	5.85E+02	2.89E-04	Rn-220	3.62E+00	1.79E-06
Fr-221	4.21E-04	2.08E-10	Rn-222	5.99E+01	2.97E-05
Fr-223	1.32E-06	6.51E-13	Sr-90	4.20E+05	2.08E-01
I-129	1.58E-01	7.82E-08	Tc-99	6.05E+01	3.00E-05
Nb-94	1.00E+03	4.95E-04	Th-227	9.15E-05	4.53E-11
Ni-59	1.50E+03	7.43E-04	Th-228	3.61E+00	1.79E-06
Np-237	2.82E+00	1.40E-06	Th-229	4.35E-04	2.15E-10
Np-239	1.34E+02	6.63E-05	Th-230	3.31E-02	1.64E-08
Pa-231	1.22E-03	6.01E-10	Th-231	5.54E+00	2.74E-06
Pa-233	2.81E+00	1.39E-06	Th-232	1.34E+00	6.63E-07
Pa-234	1.87E-01	9.27E-08	Th-234	1.17E+02	5.79E-05
Pa-234m	1.17E+02	5.79E-05	Tl-207	9.10E-05	4.50E-11
Pb-209	4.21E-04	2.08E-10	Tl-208	1.30E+00	6.45E-07
Pb-210	5.32E+00	2.63E-06	Tl-209	9.08E-06	4.50E-12
Pb-211	9.12E-05	4.51E-11	U-233	1.51E+00	7.48E-07
Pb-212	3.63E+00	1.79E-06	U-234	6.75E+01	3.34E-05
Pb-214	5.99E+01	2.97E-05	U-235	5.54E+00	2.74E-06
Po-210	4.34E+00	2.15E-06	U-236	2.86E+00	1.42E-06
Po-211	2.49E-07	1.23E-13	U-238	1.17E+02	5.79E-05
Po-212	2.32E+00	1.15E-06	Y-90	4.20E+05	2.08E-01
			Total	**2.02E+06**	**1.00E+00**

- A nuclear criticality is a concern when processing radiological waste that contains high levels of fissile materials that could become concentrated and formed into a favorable geometry. The only alternative where a criticality is a concern is during retrieval activities and ancillary support operations.

  During retrieval activities, it may be possible to concentrate fissile radionuclides by excavation and repackaging operations or excavating an intact overloaded drum. It is currently assumed that most of the waste containers are in various stages of decomposition, if not completely decomposed. The integrity of the containers may range from completely disintegrated to structurally sound. Changing the waste environment (excavating and retrieving an overloaded drum) may increase the fissile mass density, increase moderation, or create a more favorable geometry for a criticality event. Changing one or all of these criticality parameters may increase the likelihood of a criticality accident during active retrieval and support operations.

Based on the inventory of concern, the potential for a criticality event cannot be summarily dismissed. A criticality during retrieval may be possible, however, unlikely. Therefore, a simple calculation can be performed to assess the potential for a criticality event. There are three potential fissile radionuclides of concern buried within the SDA. They are Pu-239, U-233, and U-235. Sufficient quantities of each of these radionuclides are present so that if distributed in an optimum geometry with optimal reflection and moderation, a critical condition may occur or approach a K_{eff} of 1. The following table was prepared to address the potential criticality conditions. As shown, if the limiting fissile radionuclide of concern (U-235) was distributed in volume of approximately $6 \times 6 \times 6$ m at 100% enrichment with optimal geometry, reflection, and moderation, a K_{eff} of 1 could be achieved. However, these are very unrealistic conditions. It is uncertain as to the enrichment and location of each of the fissile radionuclides, and it is highly unlikely that the fissile nuclides could be placed into an optimum geometry with optimal reflection and moderation to achieve a K_{eff} approaching 1. It also is highly unlikely that all of the SDA inventory for a fissile radionuclide would be placed in the minimum calculated volume shown in Table 3 below. Because of these uncertainties and at this early stage of the FS, a credible criticality event cannot be assessed or quantified but should be evaluated further for a selected alternative if found applicable.

Table 3-3. ARH-600 minimum critical concentrations for selected fissile radionuclides.

Radionuclide	Form	Total Curies Buried in the SDA	Specific Activity (Ci/g)	Minimum Critical Concentration @ 100% Enrichment (g/L) (ARH-600)	Minimum Volume @ 100% Enrichment (m^3)
Pu-239	$Pu(NO_3)_4$-Water	6.49E+04	6.13E-02	7.8	1.35E+02
U-233	UO_2F_2	1.51E+00	9.48E-03	11.25	1.42E-02
U-235	UO_2F_2	5.54E+00	2.15E-06	11.8	2.18E+02

SDA = Subsurface Disposal Area

- Worker and public exposures to hazardous contaminants are also a concern. Currently, there is not enough defensible or quantifiable information about the quantities and location of buried hazardous materials within the SDA pits and trenches. The alternatives in which workers could be potentially exposed to hazardous contaminants include ISG, ISV, and retrieval. Before quantifying exposure to workers, a sampling and analysis program should be initiated to collect information and quantify data about hazardous contaminants in the SDA pits and trenches. At this point in the FS, it will be assumed that worker exposure risks from hazardous contaminants would be overshadowed by those presented by radiological and mechanical risks until further sampling and analysis can be performed.

- There are approximately 114,083 yd^3 (87,233 m^3) of assorted waste and 200,964 yd^3 (153,665 m^3) of contaminated soils consisting of overburden, underburden, side burden, endburden, and interstitial soils that will be retrieved from all of the identified TRU pits and trenches in the SDA (total volume = 240,898 m^3). It is further assumed that 10% of the total TRU waste volume is composed of TRU-contaminated large metallic objects, or 6,358 m^3. Though in all probability, most of the metal uncovered during retrieval operations may be classified as low-level waste, it was conservatively assumed that the metals would be classified as TRU to maximize the risk for stabilization and shipment of this waste stream. The remaining volume of associated waste and contaminated soils has been segregated into two additional waste streams, a TRU-contaminated waste and soil composite with an associated volume of 171,497 m^3 and a non-TRU-contaminated waste and soil composite with an associated volume of 63,044 m^3 (see Table 4).

- For all shielding and TRUPACT II loading calculations, the assumed density for the waste and soil composite and the large metallic pieces is 2.0 g/cm^3 and 7.86 g/cm^3, respectively. Contact dose rates were actually calculated at a distance of 1 in. from the surface of the modeled containers. This is the approximate distance that the center chamber of a survey meter can achieve.

- It is realized that some of the retrieved waste will be either mixed TRU or mixed non-TRU, which will require treatment at the RWTF. However, for this analysis, it will be assumed that all of the retrieved waste will fall into two major categories: TRU or non-TRU. During the retrieval process, it will further be assumed that the buried waste (e.g., combustibles, sludge, nonmetals, glass, concrete or bricks, and salts) will be mixed with the various burdens and interstitial soils to become a waste and soil composite to create one waste stream (TRU waste and soil composite). Non-TRU-contaminated waste and soil composites will comprise a second waste stream (non-TRU waste and soil composite). The remaining waste stream will comprise large metallic waste (e.g., trucks, cranes, and large vessels). Metals will be segregated as much as possible, size reduced, and packaged as TRU-contaminated waste for conservatism (TRU-metal). Table 4 presents the results.

Table 3-4. Transuranic and nontransuranic waste breakdown.

Waste Stream	Total Volume (yd^3)	Total Volume (m^3)	TRU Volume (m^3)	Non-TRU Volume (m^3)
Before retrieval				
Waste	114,083	87,233	63,576	23,657
Contaminated soils	200,964	153,665		
After retrieval				
Waste-soil composite	306,732	234,540	171,497	63,044
Large metallic waste	8,315	6,358	6,358	

TRU = transuranic

- A packing fraction of 50% will be assumed for the metal components, and 100% will be assumed for all other TRU-contaminated waste material. For conservatism, it will be assumed that all excavated soil and waste will require packaging and disposal thus maximizing the amount of containers requiring disposal. Tables 5 and 6 present the packaged volumes and number of packages requiring disposal.

Table 3-5. Onsite waste movement.

Waste Stream	Volume (m^3)	Packaging Fraction	Compaction Fraction	Packaged Volume (m^3)	Packaged B-25 Bins	Packaged 55-gal Drums
Retrieval face to RWTF						
TRU + Non-TRU waste-soil composite	234,541	1.00	1.00	234,541	73,988	NA
TRU metal	6,358	0.50	1.00	12,716	NA	61,083
From RWTF to onsite disposal area						
Non-TRU waste-soil composite	63,044	1.00	1.00	63,044	19,888	NA

RWTF = Radioactive Waste Treatment Facility
TRU = transuranic

Table 3-6. Onsite and offsite shipped waste breakdown.

Waste Stream	Volume (m^3)	Packaging Fraction	Compaction Fraction	Packaged Volume (m^3)	Packaged 55-Gal Drums	Number of WIPP Shipments[a]
From RWTF to TRUPACT II loading area						
TRU waste-soil composite	171,497	1.00	1.00	171,497	823,809	29,422
Large TRU metallic waste	6,358	0.50	1.00	12,716	61,083	1,454
Total	**177,855**			**184,213**	**884,892**	**30,876**

a. Assumes three TRUPACT IIs per shipment (total of forty-two 55-gal drums) with the exception of shipped soil composites, which assumes two TRUPACT IIs per shipment (twenty-eight 55-gal drums).

RWTF = Radioactive Waste Treatment Facility
TRU = transuranic
TRUPACT = transuranic package containers
WIPP = Waste Isolation Pilot Plant

- To perform dose calculations for the different handling and shipping scenarios, a source term concentration must first be calculated for the three waste streams (e.g., TRU waste and soil composite, large TRU metallic waste, and non-TRU waste and soil composite). For conservatism, it will be assumed that the entire radionuclide inventory presented in Table 2 would be distributed throughout the TRU waste volumes presented in Tables 4 and 5. For the assumed non-TRU waste and soil composite, the same analogy applies with one exception; TRU radionuclides have been eliminated from the inventory (see Tables 7, 8, and 9).

Table 3-7. Transuranic waste and soil composite waste stream radionuclide concentrations.

Radionuclide	2002 Decayed Inventory (Ci)	Fraction of Inventory	TRU Waste and Soil Matrix (Ci/m^3)	Radionuclide	2002 Decayed Inventory (Ci)	Fraction of Inventory	TRU Waste and Soil Matrix (Ci/m^3)
Ac-225	4.21E-04	2.08E-10	2.45E-09	Po-213	4.12E-04	2.04E-10	2.40E-09
Ac-227	9.54E-05	4.72E-11	5.56E-10	Po-214	5.99E+01	2.97E-05	3.49E-04
Ac-228	4.07E-01	2.01E-07	2.37E-06	Po-215	9.12E-05	4.51E-11	5.32E-10
Am-241	1.87E+05	9.23E-02	1.09E+00	Po-216	3.62E+00	1.79E-06	2.11E-05
Am-243	1.34E+02	6.63E-05	7.81E-04	Po-218	5.99E+01	2.97E-05	3.49E-04
At-217	4.21E-04	2.08E-10	2.45E-09	Pu-238	1.67E+04	8.27E-03	9.74E-02
Ba-137m	5.53E+02	2.74E-04	3.23E-03	Pu-239	6.49E+04	3.21E-02	3.78E-01
Bi-210	5.29E+00	2.62E-06	3.08E-05	Pu-240	1.71E+04	8.47E-03	9.98E-02
Bi-211	9.12E-05	4.51E-11	5.32E-10	Pu-241	8.43E+05	4.17E-01	4.92E+00
Bi-212	3.63E+00	1.80E-06	2.11E-05	Pu-242	1.65E+01	8.17E-06	9.62E-05
Bi-213	4.21E-04	2.08E-10	2.45E-09	Ra-223	9.12E-05	4.51E-11	5.32E-10
Bi-214	5.99E+01	2.97E-05	3.49E-04	Ra-224	3.62E+00	1.79E-06	2.11E-05
C-14	5.00E+02	2.47E-04	2.91E-03	Ra-225	4.26E-04	2.11E-10	2.49E-09
Cl-36	1.11E+00	5.50E-07	6.47E-06	Ra-226	5.99E+01	2.97E-05	3.49E-04
Cm-244	4.67E+04	2.31E-02	2.72E-01	Ra-228	4.07E-01	2.01E-07	2.37E-06
Co-60	4.78E+02	2.37E-04	2.79E-03	Rn-219	9.12E-05	4.51E-11	5.32E-10
Cs-137	5.85E+02	2.89E-04	3.41E-03	Rn-220	3.62E+00	1.79E-06	2.11E-05
Fr-221	4.21E-04	2.08E-10	2.45E-09	Rn-222	5.99E+01	2.97E-05	3.49E-04
Fr-223	1.32E-06	6.51E-13	7.67E-12	Sr-90	4.20E+05	2.08E-01	2.45E+00
I-129	1.58E-01	7.82E-08	9.21E-07	Tc-99	6.05E+01	3.00E-05	3.53E-04
Nb-94	1.00E+03	4.95E-04	5.83E-03	Th-227	9.15E-05	4.53E-11	5.33E-10
Ni-59	1.50E+03	7.43E-04	8.75E-03	Th-228	3.61E+00	1.79E-06	2.10E-05
Np-237	2.82E+00	1.40E-06	1.64E-05	Th-229	4.35E-04	2.15E-10	2.53E-09
Np-239	1.34E+02	6.63E-05	7.81E-04	Th-230	3.31E-02	1.64E-08	1.93E-07
Pa-231	1.22E-03	6.01E-10	7.08E-09	Th-231	5.54E+00	2.74E-06	3.23E-05
Pa-233	2.81E+00	1.39E-06	1.64E-05	Th-232	1.34E+00	6.63E-07	7.81E-06
Pa-234	1.87E-01	9.27E-08	1.09E-06	Th-234	1.17E+02	5.79E-05	6.82E-04
Pa-234m	1.17E+02	5.79E-05	6.82E-04	Tl-207	9.10E-05	4.50E-11	5.30E-10
Pb-209	4.21E-04	2.08E-10	2.45E-09	Tl-208	1.30E+00	6.45E-07	7.60E-06
Pb-210	5.32E+00	2.63E-06	3.10E-05	Tl-209	9.08E-06	4.50E-12	5.30E-11
Pb-211	9.12E-05	4.51E-11	5.32E-10	U-233	1.51E+00	7.48E-07	8.80E-06
Pb-212	3.63E+00	1.79E-06	2.11E-05	U-234	6.75E+01	3.34E-05	3.94E-04
Pb-214	5.99E+01	2.97E-05	3.49E-04	U-235	5.54E+00	2.74E-06	3.23E-05
Po-210	4.34E+00	2.15E-06	2.53E-05	U-236	2.86E+00	1.42E-06	1.67E-05
Po-211	2.49E-07	1.23E-13	1.45E-12	U-238	1.17E+02	5.79E-05	6.82E-04

Table 3-7. (continued).

Radionuclide	2002 Decayed Inventory (Ci)	Fraction of Inventory	TRU Waste and Soil Matrix (Ci/m³)	Radionuclide	2002 Decayed Inventory (Ci)	Fraction of Inventory	TRU Waste and Soil Matrix (Ci/m³)
Po-212	2.32E+00	1.15E-06	1.35E-05	Y-90	4.20E+05	2.08E-01	2.45E+00
				Total	**2.02E+06**	**1.00E+00**	**1.18E+01**

TRU = transuranic

Table 3-8. Transuranic metal waste stream radionuclide concentrations.

Radionuclide	2002 Decayed Inventory (Ci)	Fraction of Inventory	TRU Metal (Ci/m³)	Radionuclide	2002 Decayed Inventory (Ci)	Fraction of Inventory	TRU Metal (Ci/m³)
Ac-225	4.21E-04	2.08E-10	6.62E-08	Po-213	4.12E-04	2.04E-10	6.47E-08
Ac-227	9.54E-05	4.72E-11	1.50E-08	Po-214	5.99E+01	2.97E-05	9.42E-03
Ac-228	4.07E-01	2.01E-07	6.39E-05	Po-215	9.12E-05	4.51E-11	1.43E-08
Am-241	1.87E+05	9.23E-02	2.93E+01	Po-216	3.62E+00	1.79E-06	5.70E-04
Am-243	1.34E+02	6.63E-05	2.11E-02	Po-218	5.99E+01	2.97E-05	9.42E-03
At-217	4.21E-04	2.08E-10	6.62E-08	Pu-238	1.67E+04	8.27E-03	2.63E+00
Ba-137m	5.53E+02	2.74E-04	8.70E-02	Pu-239	6.49E+04	3.21E-02	1.02E+01
Bi-210	5.29E+00	2.62E-06	8.31E-04	Pu-240	1.71E+04	8.47E-03	2.69E+00
Bi-211	9.12E-05	4.51E-11	1.43E-08	Pu-241	8.43E+05	4.17E-01	1.33E+02
Bi-212	3.63E+00	1.80E-06	5.70E-04	Pu-242	1.65E+01	8.17E-06	2.60E-03
Bi-213	4.21E-04	2.08E-10	6.61E-08	Ra-223	9.12E-05	4.51E-11	1.43E-08
Bi-214	5.99E+01	2.97E-05	9.42E-03	Ra-224	3.62E+00	1.79E-06	5.70E-04
C-14	5.00E+02	2.47E-04	7.86E-02	Ra-225	4.26E-04	2.11E-10	6.70E-08
Cl-36	1.11E+00	5.50E-07	1.75E-04	Ra-226	5.99E+01	2.97E-05	9.42E-03
Cm-244	4.67E+04	2.31E-02	7.35E+00	Ra-228	4.07E-01	2.01E-07	6.40E-05
Co-60	4.78E+02	2.37E-04	7.52E-02	Rn-219	9.12E-05	4.51E-11	1.43E-08
Cs-137	5.85E+02	2.89E-04	9.19E-02	Rn-220	3.62E+00	1.79E-06	5.70E-04
Fr-221	4.21E-04	2.08E-10	6.62E-08	Rn-222	5.99E+01	2.97E-05	9.42E-03
Fr-223	1.32E-06	6.51E-13	2.07E-10	Sr-90	4.20E+05	2.08E-01	6.61E+01
I-129	1.58E-01	7.82E-08	2.49E-05	Tc-99	6.05E+01	3.00E-05	9.52E-03
Nb-94	1.00E+03	4.95E-04	1.57E-01	Th-227	9.15E-05	4.53E-11	1.44E-08
Ni-59	1.50E+03	7.43E-04	2.36E-01	Th-228	3.61E+00	1.79E-06	5.67E-04
Np-237	2.82E+00	1.40E-06	4.44E-04	Th-229	4.35E-04	2.15E-10	6.83E-08
Np-239	1.34E+02	6.63E-05	2.11E-02	Th-230	3.31E-02	1.64E-08	5.21E-06
Pa-231	1.22E-03	6.01E-10	1.91E-07	Th-231	5.54E+00	2.74E-06	8.71E-04
Pa-233	2.81E+00	1.39E-06	4.42E-04	Th-232	1.34E+00	6.63E-07	2.11E-04
Pa-234	1.87E-01	9.27E-08	2.94E-05	Th-234	1.17E+02	5.79E-05	1.84E-02

Table 3-8. (continued).

Radionuclide	2002 Decayed Inventory (Ci)	Fraction of Inventory	TRU Metal (Ci/m^3)	Radionuclide	2002 Decayed Inventory (Ci)	Fraction of Inventory	TRU Metal (Ci/m^3)
Pa-234m	1.17E+02	5.79E-05	1.84E-02	Tl-207	9.10E-05	4.50E-11	1.43E-08
Pb-209	4.21E-04	2.08E-10	6.61E-08	Tl-208	1.30E+00	6.45E-07	2.05E-04
Pb-210	5.32E+00	2.63E-06	8.37E-04	Tl-209	9.08E-06	4.50E-12	1.43E-09
Pb-211	9.12E-05	4.51E-11	1.43E-08	U-233	1.51E+00	7.48E-07	2.37E-04
Pb-212	3.63E+00	1.79E-06	5.70E-04	U-234	6.75E+01	3.34E-05	1.06E-02
Pb-214	5.99E+01	2.97E-05	9.42E-03	U-235	5.54E+00	2.74E-06	8.71E-04
Po-210	4.34E+00	2.15E-06	6.83E-04	U-236	2.86E+00	1.42E-06	4.50E-04
Po-211	2.49E-07	1.23E-13	3.92E-11	U-238	1.17E+02	5.79E-05	1.84E-02
Po-212	2.32E+00	1.15E-06	3.65E-04	Y-90	4.20E+05	2.08E-01	6.61E+01
				Total	**2.02E+06**	**1.00E+00**	**3.18E+02**

TRU = transuranic

Table 3-9. Nontransuranic waste and soil composite waste stream radionuclide concentrations.

Radionuclide	2002 Decayed Inventory (Ci)	Fraction of Inventory	Non-TRU Waste and Soil Composite (Ci/m^3)	Radionuclide	2002 Decayed Inventory (Ci)	Fraction of Inventory	Non-TRU Waste and Soil Composite (Ci/m^3)
Ac-225	4.21E-04	2.42E-10	6.67E-09	Po-213	4.12E-04	2.36E-10	6.53E-09
Ac-227	9.54E-05	5.48E-11	1.51E-09	Po-214	5.99E+01	3.44E-05	9.50E-04
Ac-228	4.07E-01	2.34E-07	6.45E-06	Po-215	9.12E-05	5.24E-11	1.45E-09
Am-241	0.00E+00	0.00E+00	0.00E+00	Po-216	3.62E+00	2.08E-06	5.75E-05
Am-243	0.00E+00	0.00E+00	0.00E+00	Po-218	5.99E+01	3.44E-05	9.50E-04
At-217	4.21E-04	2.42E-10	6.67E-09	Pu-238	0.00E+00	0.00E+00	0.00E+00
Ba-137m	5.53E+02	3.18E-04	8.77E-03	Pu-239	0.00E+00	0.00E+00	0.00E+00
Bi-210	5.29E+00	3.04E-06	8.38E-05	Pu-240	0.00E+00	0.00E+00	0.00E+00
Bi-211	9.12E-05	5.24E-11	1.45E-09	Pu-241	8.43E+05	4.84E-01	1.34E+01
Bi-212	3.63E+00	2.08E-06	5.75E-05	Pu-242	0.00E+00	0.00E+00	0.00E+00
Bi-213	4.21E-04	2.42E-10	6.67E-09	Ra-223	9.12E-05	5.24E-11	1.45E-09
Bi-214	5.99E+01	3.44E-05	9.50E-04	Ra-224	3.62E+00	2.08E-06	5.75E-05
C-14	5.00E+02	2.87E-04	7.93E-03	Ra-225	4.26E-04	2.45E-10	6.76E-09
Cl-36	1.11E+00	6.38E-07	1.76E-05	Ra-226	5.99E+01	3.44E-05	9.50E-04
Cm-244	4.67E+04	2.69E-02	7.41E-01	Ra-228	4.07E-01	2.34E-07	6.45E-06
Co-60	4.78E+02	2.75E-04	7.58E-03	Rn-219	9.12E-05	5.24E-11	1.45E-09
Cs-137	5.85E+02	3.36E-04	9.27E-03	Rn-220	3.62E+00	2.08E-06	5.75E-05
Fr-221	4.21E-04	2.42E-10	6.67E-09	Rn-222	5.99E+01	3.44E-05	9.50E-04
Fr-223	1.32E-06	7.56E-13	2.09E-11	Sr-90	4.2E+05	2.41E-01	6.66E+00

Table 3-9. (continued).

Radionuclide	2002 Decayed Inventory (Ci)	Fraction of Inventory	Non-TRU Waste and Soil Composite (Ci/m^3)	Radionuclide	2002 Decayed Inventory (Ci)	Fraction of Inventory	Non-TRU Waste and Soil Composite (Ci/m^3)
I-129	1.58E-01	9.08E-08	2.51E-06	Tc-99	6.05E+01	3.48E-05	9.60E-04
Nb-94	1.00E+03	5.75E-04	1.59E-02	Th-227	9.15E-05	5.26E-11	1.45E-09
Ni-59	1.50E+03	8.62E-04	2.38E-02	Th-228	3.61E+00	2.07E-06	5.72E-05
Np-237	0.00E+00	0.00E+00	0.00E+00	Th-229	4.35E-04	2.50E-10	6.89E-09
Np-239	1.34E+02	7.70E-05	2.13E-03	Th-230	3.31E-02	1.90E-08	5.25E-07
Pa-231	1.22E-03	6.98E-10	1.93E-08	Th-231	5.54E+00	3.18E-06	8.79E-05
Pa-233	2.81E+00	1.62E-06	4.46E-05	Th-232	1.34E+00	7.70E-07	2.13E-05
Pa-234	1.87E-01	1.08E-07	2.97E-06	Th-234	1.17E+02	6.72E-05	1.86E-03
Pa-234m	1.17E+02	6.72E-05	1.86E-03	Tl-207	9.10E-05	5.23E-11	1.44E-09
Pb-209	4.21E-04	2.42E-10	6.67E-09	Tl-208	1.30E+00	7.49E-07	2.07E-05
Pb-210	5.32E+00	3.06E-06	8.44E-05	Tl-209	9.08E-06	5.22E-12	1.44E-10
Pb-211	9.12E-05	5.24E-11	1.45E-09	U-233	1.51E+00	8.68E-07	2.40E-05
Pb-212	3.63E+00	2.08E-06	5.75E-05	U-234	6.75E+01	3.88E-05	1.07E-03
Pb-214	5.99E+01	3.44E-05	9.50E-04	U-235	5.54E+00	3.18E-06	8.79E-05
Po-210	4.34E+00	2.50E-06	6.89E-05	U-236	2.86E+00	1.64E-06	4.54E-05
Po-211	2.49E-07	1.43E-13	3.95E-12	U-238	1.17E+02	6.72E-05	1.86E-03
Po-212	2.32E+00	1.34E-06	3.68E-05	Y-90	4.20E+05	2.41E-01	6.66E+00
				Total	**1.74E+06**	**1.00E+00**	**2.75E+01**

TRU = transuranic

- Waste stabilization and processing (ISV and Waste Treatment Facility) normal operational releases will be captured by a high-efficiency particulate air filtered off-gas system, maintained below acceptable EPA air emission guidance levels, and are negligible based on the use of best available technology emission controls. The release point for the heating, ventilation, and air conditioning exhaust is out of an engineered stack.

- During normal ISV, waste retrieval and processing, and Waste Treatment Facility operations, operators are not in contact with the waste or off-gas plume, which eliminates exposure from inhaling contaminants and dermal contact with contaminants. Operators are protected from any airborne releases of material during normal processing and retrieval operations through equipment design and personal protective equipment. Inhalation calculations were only performed for off-normal events.

- Offsite individuals who have the potential for exposure to airborne contaminants from a transportation accident would be exposed through the inhalation pathway only.

- For assessing transportation hazards, RADTRAN5 computer model default values are used to the fullest extent practical.

- Routine exposure to nonremediation workers (office workers at the RWMC) from radiological constituents will be negligible for this assessment. Engineering and administrative controls would minimize this type of radiological exposure.

- Two drivers are required, and driver inspections are made every 2 hours or 100 mi.

- A maximum of three TRUPACT IIs (two soil matrices) with a total fissionable material limit of <7 curies/drum can be carried by each truck. A maximum of 14 drums, weighing a maximum of 1,000 lb each and totaling a maximum of 7,265 lb, are loaded into each TRUPACT II. At the assumed densities for the waste and soil composite and the metallic items, loading weight restrictions are maintained.

- There are 260 working days/year, and work will progress for all alternatives based on a 40-hour week or 2,080 hours/year.

- The preferred transportation route from the INEEL to WIPP was chosen by TRANSNET. The preferred route leaves the INEEL by way of Highway 20 to Atomic City, Idaho. From Atomic City, Idaho, the route continues southeast on Highway 26 to Pocatello, Idaho. From Pocatello, Idaho, the route continues south on I-15 to Ogden, Utah. At Ogden, Utah, the route continues east on I-80 to Cheyenne, Wyoming. From Cheyenne, Wyoming, the route continues south on I-25 through Denver, Colorado, to Santa Fe, New Mexico. From Santa Fe, New Mexico, the route continues south on Highway 285 to Carlsbad, New Mexico. From Carlsbad, New Mexico, the route continues east on Highway 180 to WIPP.

3.2.2 Exposure Scenarios for Remedial Action Risks

The following exposure scenarios apply to this RA:

- Exposure from normal operations

  - Direct external radiation exposure to both construction, remediation, and transportation workers and collocated workers

  - Exposure of mechanical injuries to construction and remediation workers

  - Direct external radiation exposure to the general public from transportation shipments.

- Exposure from off-normal operations

  - Internal radiological exposures to remediation workers, collocated workers, and the general public from off-normal operations

  - Nonradiological fatalities to construction, remediation, and transportation workers and the general public from off-normal operations or transportation accidents.

As shown, except for off-normal events and transportation accidents, the risks from airborne radioactive material have not been assessed for normal operations within the designated safety envelope for each of the alternatives based on the assumptions made above. The effluent treatment system for applicable alternatives will preclude the releases of radiological constituents, eliminating this pathway. Also, nonremediation workers (collocated workers outside the SDA) are no longer viable receptors during normal operations since the only possible exposure pathway was through inhalation of radioactive material.

3.2.3 Receptors for Remedial Action Risks

Receptors for remedial action risks are described below. Each of the following descriptions includes the alternative components that apply to that receptor:

- Collocated workers and nonremediation workers: collocated workers are those individuals who are placed at risk because of their proximity or downwind location to waste stabilization operations. For example, a collocated worker or nonremediation worker (e.g., clerical staff, RWMC management, or technicians) may be exposed to a plume released during an accident or to increased levels of ambient radiation from waste removal and recovery operations. The level of risk to which these individuals are exposed depends on their proximity to the operations, length of exposure time, and the type of hazard.

- Remediation workers: remediation workers are those individuals who are placed at risk from the tasks that they themselves are performing. For example, an individual operating process equipment is exposed to the ambient radiation fields in that operating zone. The level of risk to which these individuals are exposed depends on their proximity to the waste, length of time of exposure to the hazard, and the type of hazard.

- Transportation workers: transportation workers (truck drivers for offsite shipments) are a subcategory of remediation workers. They have been broken out because the model used to assess impacts from transporting waste develops estimates specifically for these individuals. The magnitude of these impacts depends on the level of contaminants in the transported waste, the degree of shielding provided by transport containers, the worker's proximity to the waste shipments, and the duration of transport, including stops.

- Members of the public: since no particulate radioactive material will be released from normal waste processing, the public is only impacted during off-normal events and waste transportation accidents. For transportation scenarios, the offsite individuals live along the transport route or, in the case of truck transport, share the roadway with the trucks. The transportation model assessed collective and maximum individual risks from exposure to contaminants during transport, including the accidental release of waste material.

3.2.4 Exposure Models for Remedial Action Risks

This section presents the exposure models used to estimate the remedial action risks. The section has been divided into subsections for each alternative component-exposure mode-receptor combination.

Preconstruction, construction, facility operations, D&D, and mechanical injury or construction and remediation workers—the risk from mechanical injury, both for injuries and fatalities, is based on a risk conversion factor developed by the Department of Labor (DOL). This conversion factor translates hours worked to risk from a mechanical hazard. Equation 1 provides the expression for the risk.

$$\text{Risk} = \text{MHRF} \times \text{T} \qquad (1)$$

where

MHRF = mechanical hazard risk factor, injuries, or fatalities/person-hours worked

T = person-hours worked during facility preconstruction and construction.

Processing, direct radiation, and remediation workers—the direct radiation exposure to personnel from waste processing, handling, and storage is based on estimates of ambient radiation dose rates for different work zones within the facility or complex. These dose rates are multiplied by the total person-hours worked within that zone to estimate the dose equivalent. Equation 2 is used to estimate the risk from the dose equivalent estimate.

$$H_E = (DR)(T) \qquad (2)$$

where

H_E = collective effective dose equivalent for work zone (person-mrem)

DR = dose rate for applicable work zone analyzed (mrem/hour)

T = number of person-hours worked in work zone.

Ambient radiation levels have been assumed for each alternative for workers during the preconstruction, construction, operation, and D&D phases. These levels are based on ambient levels that have previously existed at the RWMC. The active operational phases for each alternative have been broken down into two discrete work zones or activities: Zone 1 and Zone 2, where Zone 1 is considered to be the hottest, radiologically. The operational phase for each alternative would include active ISG, ISV, or retrieval operations that pertain to waste stabilization or retrieval activities. The dose rates for these two operational zones are 5.0 mR/hour and 2.0 mR/hour, respectively. During the preconstruction, construction, and D&D phases, ambient radiation levels will be assumed to be 0.025, 0.025, and 0.05 mR/hour, respectively.

The dose delivered to personnel supporting the loading and movement of waste packages is assessed differently. Equation 3 provides the expression, which is the product of the package (or truck) dose rate for a given operation, the number of packages handled or trucks processed, and the time that an individual is exposed. Dose rates from 55-gal drums, B-25 bins, shipping TRUPACT IIs, and loaded trucks were calculated based on the inventory presented in Tables 6–8 using MicroShield, Version 5. Supporting analyses are included as Appendix B.

$$H_E = (DR)(P)(N)(T) \qquad (3)$$

where

H_E = collective effective dose equivalent for transportation support operation (person-rem)

DR = dose rate for transportation support operation (mrem/hour)

P = number of packages or trucks for operation

N = number of workers involved in transportation support operation

T = number of hours required to perform the transportation activity.

The risk from exposure to ionizing radiation is measured in incremental lifetime fatal cancers. Equation 4 calculates the risk.

$$ILCR = (H_E)(CRF) \quad (4)$$

where

ILCR = incremental lifetime cancer risk

CRF = cancer risk factor, ILCR/mrem.

The magnitude of the transportation impacts is calculated by RADTRAN5, a component of the TRANSNET computer model system. The TRANSNET system is operated by Sandia National Laboratory and includes routing models (HIGHWAY and INTERSTATE for truck transport and INTERLINE for rail transport) and an impact model (RADTRAN5). RADTRAN5 assesses both radiological and nonradiological impacts.

3.2.5 Exposure Parameters for Remedial Action Risks

This section tabulates the exposure parameters used in the quantitative assessment. Similar sets of parameters (e.g., risk factors and exposure durations) have been grouped together. References for the parameter values also have been provided.

The risk factor for radiological exposures was obtained from the BIER V report, *Health Effects of Exposure to Low Levels of Ionizing Radiation* (BEIR V 1990), and is reported in risk/person-rem of exposure (see Table 10).

Table 3-10. Risk factors.

Parameter	Value	Units	Reference
CRF	6.30E-04	Per person-rem	BIER V
MHRF (injury)	7.01E-05	Injuries/person-hour	DOL
MHRF (fatality)	1.57E-07	Fatalities/person-hour	DOL

CRF = cancer risk factor
DOL = Department of Labor
MHRF = mechanical hazard risk factor

Risk factors for injuries and deaths caused by construction and transportation hazards were obtained from the DOL Bureau of Labor Statistics for year 2000 http://www.bls.gov (see Table 10). The basis for the values is presented in Table C-1 in Appendix C.

Construction activities analyzed by the DOL included residential and nonresidential building construction, heavy construction (e.g., road, water, sewer, and utilities), and special trade contractors (e.g., plumbing, heating, air conditioning, painting, electrical, masonry, carpentry, roofing, siding, concrete, and miscellaneous trades). Transportation and public utilities included railroad, trucking, warehousing, storage, communications, transportation services, and miscellaneous trucking and transportation activities.

3.2.6 Operations Exposure Durations

Exposure durations or person-hours worked have been estimated by alternative (see Table 11) based on the rationale provided in Appendix D. The RWTF values have been combined with the values calculated for the retrieval alternative because retrieval is the only alternative that would use such a facility.

Table 3-11. Exposure durations based on person-hours worked.

Activity	Surface Barrier	ISG	ISV	Retrieval-RWTF
Preconstruction	8.58E+04	6.44E+04	1.81E+05	6.03E+05
Construction	1.65E+05	2.04E+05	1.65E+05	1.05E+07
Facility operations Zone 1	1.90E+05	2.40E+05	3.16E+06	1.94E+07
Facility operations Zone 2	7.48E+05	2.40E+05	4.40E+05	6.90E+05
D&D	1.96E+04	3.15E+05	1.96E+04	4.94E+06

D&D = decontamination and decommissioning
ISG = in situ grouting
ISV = in situ vitrification
RWTF = Radioactive Waste Treatment Facility

3.2.7 Ancillary Support Operations (Retrieval Alternative Only)

To calculate final risk for the retrieval alternative, several other ancillary operations were analyzed in addition to preconstruction, construction, facility operations, and D&D activities. These include the movement of loaded B-25s from the retrieval area to lag storage, the movement of loaded B-25s from lag storage to the RWTF, the movement of B-25s from the RWTF to onsite disposal, the movement of 55-gal drums from the RWTF to the TRUPACT II loading area, the loading of 55-gal drums into TRUPACT IIs, and the loading and securing of TRUPACT IIs for offsite shipment. Radiological exposures in person-rem and exposure duration in person-hours are reported in Tables 12–19.

3.2.8 Maximally Exposed Individual Calculations

Maximally exposed individual (MEI) calculations were performed for only three of the selected alternatives: ISV and retrieval, off-Site waste transportation, and disposal. Because of the design and lack of a credible waste exposure route, it is assumed that the surface barrier alternative and the ISG alternative will not provide a credible exposure mechanism to workers. Maximally exposed individual calculations assume that the analyzed activity occurs outside of the designated safety envelope for that activity.

3.2.8.1 In Situ Vitrification Operations Maximally Exposed Individual. The worst-case unmitigated accident scenario established for the ISV alternative was a Melt Expulsion Event. This scenario was analyzed and presented in detail in the report, *Evaluation of In-Situ Vitrification for the Operable Unit 7-13/14* (Thomas and Treat 2002). The unmitigated dose to the MEI was reported at 37,000-rem 50-year committed effective dose equivalent (50-year CEDE). However, if ISV is selected as the preferred alternative, the melt would be covered with 10 ft of soil, and thermal desorption would be used. Use of these mandatory mitigating controls would reduce the MEI exposure by a minimum of

1/1,000 or 3.7-rem 50-year CEDE. The lifetime cancer risk calculated for this receptor is presented in Table 20.

3.2.8.2 Retrieval Operations Maximally Exposed Individual. The worst-case scenario established for the retrieval alternative is a worker who is exposed to a high concentration of airborne radiological activity. The following assumptions drive the analysis:

- A heavy-equipment operator (HEO) who is operating the retrieval excavator inadvertently uncovers a large pocket of highly contaminated material resulting in the resuspension of large amounts of contaminated particulate material.
- It is assumed that the HEO uncovered a pocket of Pu-239-contaminated soil. The soil contains 1/10 of the entire SDA inventory, or 6.49E+03 Ci.
- One percent of the material is resuspended into a volume of 27 m^3, and 1% of the resuspended material is respirable, resulting in a respirable concentration of 2.40E-02 Ci/m^3.
- The HEO is wearing an air-supplied hood with a protection factor of 10,000.
- Upon hearing the alarm from the constant air monitor, it takes the HEO 3 minutes to exit the primary containment area.
- The ventilation system is effective in retaining the particulate matter, and receptors outside the primary containment structure are not exposed.

Equation 5 provides the 50-year CEDE inhalation dose for the HEO.

$$D_{CEDE} = (RC)(1/PF)(BR)(ET)(DCR)(CF) \quad (5)$$

where

D_{CEDE} = 50-year CEDE from inhalation

RC = respirable concentration

PF = protection factor for an air-supplied hood (10,000)

BR = standard man breathing rate (3.47E-04 m^3/second)

ET = exposure time (180 seconds)

DCR = inhalation dose conversion factor for Pu-239 (3.30E + 02 rem/µCi—obtained from *Internal Dose Conversion Factors for Calculation of Dose to the Public* [DOE 1988a])

CF = conversion factor

then

D_{CEDE} = 49.5 rem = (2.40E-02 Ci/m^3)(1/10,000)(3.47E-04 m^3/second)(180 seconds)(3.30E + 02 rem/µCi)(1.0E + 06 µCi/Ci).

The lifetime cancer risk calculated for this receptor is presented in Table 20.

Table 3-12. Estimated radiological exposure from onsite package handling operations.

Labor	Number of Workers	Number of Handling Operations (per Package)	Number of Packages	Package Type	Time/Package (Minutes)	Modeling Distance	Dose Rate (mR/h)	Exposure (Person-rem)
Retrieval face to RWTF (TRU + non-TRU waste soil composite)								
Laborer	1	3	73,988	B-25	5	Package @ Contact	5.2	9.62E+01
HE operator	1	3	73,988	B-25	15	Page @ 3 ft	2.2	1.22E+02
RCT	1	2	73,988	B-25	5	Package @ Contact	5.2	6.41E+01
Retrieval face to RWTF (TRU metal)								
Laborer	1	3	61,083	55-gal drum	5	Package @ Contact	16.9	2.58E+02
HE operator	1	3	61,083	55-gal drum	15	Page @ 3 ft	1.6	7.33E+01
RCT	1	2	61,083	55-gal drum	5	Package @ Contact	16.9	1.72E+02
From RWTF to onsite disposal area (non-TRU soils waste composite)								
Laborer	1	2	19,888	B-25	5	Package @ Contact	18.2	6.03E+01
HE operator	1	1	19,888	B-25	15	Page @ 3 ft	6.0	2.98E+01
RCT	1	1	19,888	B-25	5	Package @ Contact	18.2	3.02E+01
							Total	**9.06E+02**

HE = heavy-equipment
RCT = radiological control technician
RWTF = Radioactive Waste Treatment Facility
TRU = transuranic

Table 3-13. Estimated occupational exposure duration from onsite package handling operations.

Labor	Number of Workers	Number of Handling Operations (per Package)	Number of Packages	Package Type	Handling Time/Package (Minutes)	Exposure Duration (Person-Hours)
Retrieval face to RWTF (TRU + non-TRU waste and soil composite)						
Laborer	1	3	73,988	B-25	5	1.85E+04
HE operator	1	3	73,988	B-25	15	5.55E+04
RCT	1	2	73,988	B-25	5	1.23E+04
Retrieval face to RWTF (TRU metal)						
Laborer	1	3	61,083	55-gal drum	5	1.53E+04
HE operator	1	3	61,083	55-gal drum	15	4.58E+04
RCT	1	2	61,083	55-gal drum	5	1.02E+04
From RWTF to onsite disposal area (non-TRU waste and soil composite)						
Laborer	1	2	19,888	B-25	5	3.31E+03
HE operator	1	1	19,888	B-25	15	4.97E+03
RCT	1	1	19,888	B-25	5	1.66E+03
					Total	**1.68E+05**

HE = heavy-equipment
RCT = radiological control technician
RWTF = Radioactive Waste Treatment Facility
TRU = transuranic

Table 3-14. Estimated radiological exposure from onsite 55-gal drum handling operations (transuranic waste and soil composites and metals).

Labor	Number of Workers	Number of Handling Operations (per Package)	Number of Packages	Package Type	Handling Time/Package (Minutes)	Modeling Distance	Dose Rate (mR/h)	Exposure (Person-rem)
From RWTF to the TRUPACT II loading station (TRU waste and soil)								
Laborer	1	2	823,809	55-gal drum	5	Package @ Contact	5.2	7.14E+02
HE operator	1	2	823,809	55-gal drum	15	Page @ 3 ft	0.5	2.06E+02
RCT	1	2	823,809	55-gal drum	5	Package @ Contact	5.2	7.14E+02
From RWTF to the TRUPACT II loading station (TRU metals)								
Laborer	1	2	61,083	55-gal drum	5	Package @ Contact	16.9	1.72E+02
HE operator	1	2	61,083	55-gal drum	15	Page @ 3 ft	1.6	4.89E+01
RCT	1	2	61,083	55-gal drum	5	Package @ Contact	16.9	1.72E+02
							Total	**2.03E+03**

HE = heavy-equipment
RCT = radiological control technician
RWTF = Radioactive Waste Treatment Facility
TRU = transuranic
TRUPACT = transuranic package containers

Table 3-15. Estimated occupational exposure duration from onsite 55-gal drum handling operations (transuranic waste and soil composites and metals).

Labor	Number of Workers	Number of Handling Operations (per Package)	Number of Packages	Package Type	Time/Package (Minutes)	Exposure Duration (Person-Hours)
From RWTF to the TRUPACT II loading station (TRU waste and soils)						
Laborer	1	2	823,809	55-gal drum	5	1.37E+05
HE operator	1	2	823,809	55-gal drum	15	4.12E+05
RCT	1	2	823,809	55-gal drum	5	1.37E+05
From RWTF to the TRUPACT II loading station (TRU metals)						
Laborer	1	2	61,083	55-gal drum	5	1.02E+04
HE operator	1	2	61,083	55-gal drum	15	3.05E+04
RCT	1	2	61,083	55-gal drum	5	1.02E+04
					Total	**7.37E+05**

HE = heavy-equipment
RCT = radiological control technician
RWTF = Radioactive Waste Treatment Facility
TRU = transuranic
TRUPACT = transuranic package containers

Table 3-16. Estimated radiological exposure from loading transuranic package container IIs (transuranic waste and soil composite).

Labor	Number of Workers	Type	Number of Packages	Exposure Time (Minutes)	Number of Shipments	Modeling Distance	Dose Rate (mR/h)	Exposure (Person-rem)
Loading 55-gal drums into TRUPACT IIs								
Laborer	1	55-gal drum	823,809	5	NA	Drum @ Contact	5.2	3.57E+02
RCT	1	55-gal drum	823,809	5	NA	Drum @ Contact	5.2	3.57E+02
HE operator	1	55-gal drum	823,809	5	NA	Drum @ 3 ft	0.5	3.43E+01
Loading TRUPACT IIs on Truck								
Laborer	1	TRUPACT II	2	30	29,422	TRUPACT II @ Contact	0.2	5.88E+00
RCT	1	Truck	1	10	29,422	Truck @ 3 ft	0.2	9.81E-01
HE operator	1	TRUPACT II	2	30	29,422	TRUPACT II @ 3 ft	0.2	5.88E+00
Supervisor	1	Truck	1	30	29,422	Loaded truck @ 10 ft	0.04	5.88E-01
Shipping coordinator	1	Truck	1	15	29,422	Loaded truck @ 10 ft	0.04	2.94E-01
QA waste acceptance	1	Truck	1	15	29,422	Loaded truck @ 10 ft	0.04	2.94E-01
						Total		**7.62E+02**

a. Dose rates calculated at distances from loaded TRUPACT II shipments included cumulative dose rates from each TRUPACT II, or for TRU waste and soil two times the dose rate calculated for one TRUPACT II.

HE = heavy-equipment
QA = quality assurance
RCT = radiological control technician
TRU = transuranic
TRUPACT = transuranic package containers

Table 3-17. Estimated occupational exposure duration from loading transuranic package container IIs (transuranic waste and soil composite).

Labor	Number of Workers	Type	Number of Packages	Handling Time (Minutes)	Number of Shipments	Exposure Duration (Person-Hours)
Loading 55-gal drums into TRUPACT IIs						
Laborer	1	Drum	823,809	5	NA	6.87E+04
RCT	1	Drum	823,809	5	NA	6.87E+04
HE operator	1	Drum	823,809	5	NA	6.87E+04
Loading TRUPACT IIs on truck						
Laborer	1	TRUPACT II	2	30	29,422	2.94E+04
RCT	1	Truck	1	10	29,422	4.90E+03
HE operator	1	TRUPACT II	2	30	29,422	2.94E+04
Supervisor	1	Truck	1	30	29,422	1.47E+04
Shipping coordinator	1	Truck	1	15	29,422	7.36E+03
QA waste acceptance	1	Truck	1	15	29,422	7.36E+03
					Total	**2.99E+05**

HE = heavy-equipment
QA = quality assurance
RCT = radiological control technician
TRUPACT = transuranic package containers

Table 3-18. Estimated radiological exposure from loading transuranic package II containers (metals).

Labor	Number of Workers	Type	Number of Packages	Exposure Time (Minutes)	Number of Shipments	Modeling Distance	Dose Rate (mR/h	Exposure (Person-rem)
Loading 55-gal drums into TRUPACT IIs								
Laborer	1	Drum	61,803	5	NA	Drum @ Contact	16.9	8.70E+01
RCT	1	Drum	61,803	5	NA	Drum @ Contact	16.9	8.70E+01
HE operator	1	Drum	61,803	5	NA	Drum @ 3 ft	1.6	8.24E+00
Loading TRUPACT IIs on truck								
Laborer	1	TRUPACT II	2	30	1,454	TRUPACT II @ Contact	0.6	8.72E+00
RCT	1	Truck	1	10	1,454	Truck @ 3 ft	0.9	2.18E+00
HE operator	1	TRUPACT II	2	30	1,454	TRUPACT II @ 3 ft	0.9	1.31E+01
Supervisor	1	Truck	1	30	1,454	Loaded truck @ 10 ft	0.2	1.45E+00
Shipping coordinator	1	Truck	1	15	1,454	Loaded truck @ 10 ft	0.2	7.27E-01
QA waste acceptance	1	Truck	1	15	1,454	Loaded truck @ 10 ft	0.2	7.27E-01
							Total	**2.09E+02**

a. Dose rates calculated at distances from loaded TRUPACT II shipments included cumulative dose rates from each TRUPACT II, or for TRU metals three times the dose rate calculated for one TRUPACT II.

HE = heavy-equipment
QA = quality assurance
RCT = radiological control technician
TRU = transuranic
TRUPACT = transuranic package containers

Table 3-19. Estimated occupational exposure duration from loading transuranic package II containers (metals).

Labor	Number of Workers	Type	Number of Packages	Handling Time (Minutes)	Number of Shipments	Exposure Duration (Person-Hours)
Loading 55-gal drums into TRUPACT IIs						
Laborer	1	55-gal drum	61,803	5	NA	5.15E+03
RCT	1	55-gal drum	61,803	5	NA	5.15E+03
HE operator	1	55-gal drum	61,803	5	NA	5.15E+03
Loading TRUPACT IIs on truck						
Laborer	1	TRUPACT II	2	30	1,454	1.45E+03
RCT	1	Truck	1	10	1,454	2.42E+02
HE operator	1	TRUPACT II	2	30	1,454	1.45E+03
Supervisor	1	Truck	1	30	1,454	7.27E+02
Shipping coordinator	1	Truck	1	15	1,454	3.64E+02
QA waste acceptance	1	Truck	1	15	1,454	3.64E+02
					Total	**2.01E+04**

HE = heavy-equipment
QA = quality assurance
RCT = radiological control technician
TRUPACT = transuranic package containers

Table 3-20. Total risk (cancer and mechanical injuries or fatalities) by alternative.

Risk	Surface Barrier	ISG	ISV	Retrieval, Ex Situ Treatment, or Disposal
Facility operational activities				
MEI cancer risk	NA	NA	2.33E-03	3.12E-02
Cancer risk (population)	1.55E+00	1.07E+00	1.05E+01	6.23E+01
Injury risk (population)	8.47E+01	7.45E+01	2.78E+02	2.53E+03
Fatality risk (population)	1.90E-01	1.67E-01	6.23E-01	5.67E+00
Onsite package movement and storage				
Cancer risk (population)	NA	NA	NA	1.85E+00
Injury risk (population)	NA	NA	NA	6.34E+01
Fatality risk (population)	NA	NA	NA	1.42E-01
Preparation of TRUPACT IIs for offsite shipment				
Cancer risk (population)	NA	NA	NA	5.97E-01
Injury risk (population)	NA	NA	NA	2.24E+01
Fatality risk (population)	NA	NA	NA	5.01E-02
Transportation of TRUPACT IIs from INEEL to WIPP				
MEI cancer risk (incident free)	NA	NA	NA	2.39E-06
MEI cancer risk (accident-severity class 2)				3.81E-03
Cancer risk (transportation crew + incident free + vehicle stops + accident) (population)	NA	NA	NA	2.34E+00
Occupational fatality risk (population)	NA	NA	NA	1.93E+00
Public fatality risk (population)	NA	NA	NA	6.82E+00

INEEL = Idaho National Engineering and Environmental Laboratory
ISG = in situ grouting
ISV = in situ vitrification
MEI = maximally exposed individual
TRUPACT = transuranic package containers
WIPP = Waste Isolation Pilot Plant

3.2.8.3 Transportation Accident Maximally Exposed Individual (Retrieval Alternative Only). RADTRAN5 was used to calculate the MEI for the public during waste transportation. The MEI was calculated at 3.80E-03 rem for all incident-free shipments. The MEI for a transportation accident was calculated at 5.91E + 00 rem, including the inhalation, cloud shine, and ground shine pathways. The numerical results for Severity Class 2 were chosen for the final MEI values because Severity Class 2 has the highest probably of occurrence. Results from the farming scenario were calculated and included in Appendix A but were not reported in Table 20. All results for the transportation analysis can be found in Appendix A. The lifetime cancer risk calculated for these receptors is presented in Table 20.

4. SHORT-TERM EXPOSURE RISKS

This section presents the short-term risk results. Tables 21 and 22 present the collective dose equivalent and cancer risk to plant operators. Table 23 presents injury and fatality risks to plant operators from mechanical operations within each facility. Tables 24–27 present the radiological cancer risks and risks from mechanical injury and fatality for onsite movements of B-25s and 55-gal drums, as well as risks from TRUPACT II loading in preparation for offsite shipment. Tables 28–30 present the cancer risks and the risks of fatality from nonradiological transportation impacts from the shipment of TRUPACT IIs from the INEEL to WIPP.

Table 20 presents the qualitative results of the short-term RA for each of the selected alternatives. The results are presented separately in terms of latent cancer risks, mechanical injury, and fatality risks for each of the selected alternatives. It is inappropriate to sum all of the risks for an alternative since this would portray a skewed representation of the total risk for that alternative. The risk from a mechanical injury will always be much greater than the risk from a mechanical fatality or from a latent cancer risk when calculated over a project's anticipated timeline.

As presented, ex situ retrieval and waste disposal onsite and offsite will present not only the greatest challenges but also will present the greatest short-term risks to workers and the general public. Short-term risks calculated for the ISV alternative are less than those for the retrieval or ex situ treatment disposal alternative but are greater than those presented for the ISG and surface barrier alternatives. Ex situ retrieval and ISV will require additional engineering and administrative controls to properly maintain short-term effectiveness. In terms of short-term risks, the risks presented from performing surface barrier and ISG activities are comparable.

As stated previously, all offsite transportation analyses are presented separately in Appendix A.

Table 4-1. Estimated collective dose equivalent (person-rem) from operational activities.

Activity	Ambient Dose Rate (mR/h)	Surface Barrier (Person-Hours)	Surface Barrier (Person-rem)	ISG (Person-Hours)	ISG (Person-rem)	ISV (Person-Hours)	ISV (Person-rem)	Retrieval-RWTF (Person-Hours)	Retrieval-RWTF (Person-rem)
Preconstruction	0.025	8.58E+04	2.15E+00	6.44E+04	1.61E+00	1.81E+05	4.53E+00	6.03E+05	1.51E+01
Construction	0.025	1.65E+05	4.13E+00	2.04E+05	5.10E+00	1.65E+05	4.13E+00	1.05E+07	2.63E+02
Operations Zone 1	5	1.90E+05	9.50E+02	2.40E+05	1.20E+03	3.16E+06	1.58E+04	1.94E+07	9.70E+04
Operations Zone 2	2	7.48E+05	1.50E+03	2.40E+05	4.80E+02	4.40E+05	8.80E+02	6.90E+05	1.38E+03
D&D	0.05	1.96E+04	9.80E-01	3.15E+05	1.58E+01	1.96E+04	9.80E-01	4.94E+06	2.47E+02
Total		**1.21E+06**	**2.45E+03**	**1.06E+06**	**1.70E+03**	**3.97E+06**	**1.67E+04**	**3.61E+07**	**9.89E+04**

D&D = decontamination and decommissioning
ISG = in situ grouting
ISV = in situ vitrification
RWTF = Radioactive Waste Treatment Facility

Table 4-2. Cancer risk for facility operational activities.

Activity	Cancer Risk Factor	Surface Barrier (Person-rem)	Surface Barrier Risk	ISG (Person-rem)	ISG Risk	ISV (Person-rem)	ISV Risk	Retrieval-RWTF (Person-rem)	Retrieval-RWTF Risk
Preconstruction	6.30E-04	2.15E+00	1.35E-03	1.61E+00	1.01E-03	4.53E+00	2.85E-03	1.51E+01	9.51E-03
Construction	6.30E-04	4.13E+00	2.60E-03	5.10E+00	3.21E-03	4.13E+00	2.60E-03	2.63E+02	1.66E-01
Operations Zone 1	6.30E-04	9.50E+02	5.99E-01	1.20E+03	7.56E-01	1.58E+04	9.95E+00	9.70E+04	6.11E+01
Operations Zone 2	6.30E-04	1.50E+03	9.45E-01	4.80E+02	3.02E-01	8.80E+02	5.54E-01	1.38E+03	8.69E-01
D&D	6.30E-04	9.80E-01	6.17E-04	1.58E+01	9.95E-03	9.80E-01	6.17E-04	2.47E+02	1.56E-01
Total		**2.46E+03**	**1.55E+00**	**1.70E+03**	**1.07E+00**	**1.67E+04**	**1.05E+01**	**9.89E+04**	**6.23E+01**

D&D = decontamination and decommissioning
ISG = in situ grouting
ISV = in situ vitrification
RWTF = Radioactive Waste Treatment Facility

Table 4-3. Mechanical injury and fatality risk for facility operational activities.

Activity	Mechanical Risk Factor	Surface Barrier (Person-Hours)	Surface Barrier Risk	ISG (Person-Hours)	ISG Risk	ISV (Person-Hours)	ISV Risk	Retrieval-RWTF (Person-Hours)	Retrieval-RWTF Risk
Risk of injury									
Preconstruction	7.01E-05	8.58E+04	6.01E+00	6.44E+04	4.51E+00	1.81E+05	1.27E+01	6.03E+05	4.23E+01
Construction	7.01E-05	1.65E+05	1.16E+01	2.04E+05	1.43E+01	1.65E+05	1.16E+01	1.05E+07	7.36E+02
Operations Zone 1	7.01E-05	1.90E+05	1.33E+01	2.40E+05	1.68E+01	3.16E+06	2.22E+02	1.94E+07	1.36E+03
Operations Zone 2	7.01E-05	7.48E+05	5.24E+01	2.40E+05	1.68E+01	4.40E+05	3.08E+01	6.90E+05	4.84E+01
D&D	7.01E-05	1.96E+04	1.37E+00	3.15E+05	2.21E+01	1.96E+04	1.37E+00	4.94E+06	3.46E+02
Total		**1.21E+06**	**8.47E+01**	**1.06E+06**	**7.45E+01**	**3.97E+06**	**2.78E+02**	**3.61E+07**	**2.53E+03**
Risk of fatality									
Preconstruction	1.57E-07	8.58E+04	1.35E-02	6.44E+04	1.01E-02	1.81E+05	2.84E-02	6.03E+05	9.47E-02
Construction	1.57E-07	1.65E+05	2.59E-02	2.04E+05	3.20E-02	1.65E+05	2.59E-02	1.05E+07	1.65E+00
Operations Zone 1	1.57E-07	1.90E+05	2.98E-02	2.40E+05	3.77E-02	3.16E+06	4.96E-01	1.94E+07	3.05E+00
Operations Zone 2	1.57E-07	7.48E+05	1.17E-01	2.40E+05	3.77E-02	4.40E+05	6.91E-02	6.90E+05	1.08E-01
D&D	1.57E-07	1.96E+04	3.08E-03	3.15E+05	4.95E-02	1.96E+04	3.08E-03	4.94E+06	7.76E-01
Total		**1.21E+06**	**1.90E-01**	**1.06E+06**	**1.67E-01**	**3.97E+06**	**6.23E-01**	**3.61E+07**	**5.67E+00**

D&D = decontamination and decommissioning
ISG = in situ grouting
ISV = in situ vitrification
RWTF = Radioactive Waste Treatment Facility

Table 4-4. Collective dose equivalent and cancer risk for onsite package movement (retrieval only).

Labor	Collective Dose Equivalent (Person-rem)	Cancer Risk
All (laborers, HE operators, RCTs)	2.94E+03	1.85E+00

HE = heavy-equipment
RCT = radiological control technician

Table 4-5. Mechanical injury and fatality risk for onsite package movement (retrieval only).

Labor	Collective Person-Hours	Risk of Injury	Risk of Fatality
All (laborers, HE operators, RCTs)	9.05E+05	6.34E+01	1.42E-01

HE = heavy-equipment
RCT = radiological control technician

Table 4-6. Collective dose equivalent and cancer risk for offsite shipments and preparation and loading transuranic package container IIs (retrieval only).

Labor	Collective Dose Equivalent, (Person-rem)	Cancer Risk
All (laborers, RCTs, HE operators, supervisors, shipping coordinators QA)	9.47E+02	5.97E-01

HE = heavy-equipment
QA = quality assurance
RCT = radiological control technician

Table 4-7. Mechanical injury and fatality risk for offsite shipments and preparation and loading transuranic package container IIs (retrieval only).

Labor	Collective Person-Hours	Risk of Injury	Risk of Fatality
All (laborers, RCTs, HE operators, supervisors, shipping coordinators QA)	3.19E+05	2.24E+01	5.01E-02

HE = heavy-equipment
QA = quality assurance
RCT = radiological control technician

Table 4-8. Estimated offsite transportation (Idaho National Engineering and Environmental Laboratory-Waste Isolation Pilot Plant) dose equivalents (retrieval only).

Waste Stream	Transportation Crew (Person-rem)	Incident Free to the Public (Person-rem)	Maximally Exposed Individual Incident Free Dose (rem)	Dose to Public from Transport Vehicle Stops (Person-rem)	Transportation Accident (Person-rem)	Maximally Exposed Individual Transportation Accident Dose (Severity Class 2) (rem)	Sum of Incident Free and Stops (Person-rem)
TRU waste and soils	4.50E+02	1.49E+02	3.54E-03	2.76E+03	6.37E+01	1.46E-01	2.91E+03
TRU metals	3.30E+01	1.10E+01	2.62E-04	2.04E+02	3.31E+01	5.91E+00	2.15E+02
Total	**4.83E+02**	**1.60E+02**	**3.80E-03**	**2.96E+03**	**9.68E+01**	**6.01E+00**	**3.12E+03**

TRU = transuranic

Table 4-9. Offsite transportation (Idaho National Engineering and Environmental Laboratory-Waste Isolation Pilot Plant) cancer risks (retrieval only).

Waste Stream	Transportation Crew Cancer Risk	Incident Free Cancer Risk to the Public	Maximally Exposed Individual Risk	Cancer Risk to Public from Transport Vehicle Stops	Cancer Risk from Transportation Accident	Maximally Exposed Individual Transportation Accident Risk	Sum of Incident Free and Stop Risks
TRU waste and soils	2.84E-01	9.39E-02	2.23E-06	1.74E+00	4.01E-02	9.20E-05	1.83E+00
TRU metals	2.08E-02	6.93E-03	1.65E-07	1.29E-01	2.09E-02	3.72E-03	1.35E-01
Total	**3.04E-01**	**1.01E-01**	**2.39E-06**	**1.87E+00**	**6.10E-02**	**3.81E-03**	**1.97E+00**

TRU = transuranic

Table 4-10. Offsite transportation (Idaho National Engineering and Environmental Laboratory-Waste Isolation Pilot Plant) nonradiological fatality risks (retrieval only).

Waste Stream	Public, Nonradiological Risks (Normal Transportation)	Occupational, Nonradiological Risks (Accidents During Transportation)	Public, Nonradiological Risks (Accidents During Transportation)
TRU waste and soil	0.00E+00	1.84E+00	6.50E+00
TRU metals	0.00E+00	9.10E-02	3.21E-01
Total	**0.00E+00**	**1.93E+00**	**6.82E+00**

TRU = transuranic

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