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Environmental and Other Evaluations of Alternatives for Long-Term Management of Stored INEL Transuranic Waste

February 1979

MASTER

U.S. Department of Energy
Assistant Secretary for Energy Technology
Office of Nuclear Waste Management

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U.S. Department of Energy
Assistant Secretary for Energy Technology
Office of Nuclear Waste Management
Washington, D.C. 20545

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1. INTRODUCTION

1.1 PURPOSE

The objective of the study reported in this document is to provide preliminary evaluations of alternatives for long-term management of transuranic-contaminated waste (TRU waste)^(a) stored at the Radioactive Waste Management Complex (RWMC) at the Idaho National Engineering Laboratory (INEL).^(b) The evaluations include environmental effects, costs, radiological risk to the public, and hazards to workers. This document is intended to provide supporting evaluations for the Draft Environmental Impact Statement, Waste Isolation Pilot Plant, Carlsbad, New Mexico (DOE 1979). Applicable portions are summarized and included as part of that Environmental Impact Statement (EIS). The summarized portions relate to the effects in Idaho of several alternatives for managing the TRU waste stored at the INEL.

There is also a large quantity of transuranic waste buried in pits and trenches at the RWMC.^(c) For perspective and completeness, the buried waste is described, along with the stored waste, in this

-
- (a) See the Glossary in Appendix H for definitions of transuranic waste and other specialized terms as used in this document. See Appendix G for a list of the abbreviations used in this document.
 - (b) Records show that the stored waste, whose management is the subject of this document, is contaminated with transuranic radionuclides to levels of greater than 10 nCi/g of waste. As such, the waste properly falls within the definition of transuranic-contaminated solid waste (TRU waste) specified by the Department of Energy (ERDA 1973a). Note: Use of the value of 10 nCi/g to define transuranic waste is being reviewed and may be revised. The potential effects of such a revision are not addressed in this document.
 - (c) Some of the buried waste is contaminated to levels of less than 10 nCi/g; some is essentially free from transuranics. Since it may be impractical to sort the buried waste into greater than 10 and less than 10 nCi/g portions, the term, TRU waste, is applied to all the waste discussed herein unless the text indicates otherwise.

document. However, alternatives for managing the buried TRU waste are not discussed in this document. Management of both types of TRU waste is the subject of a technical alternatives study (DOE 1978a) and of a Draft Programmatic Environmental Impact Statement, in preparation (See Subsection 7.3). Hereafter, in this document, the term TRU waste refers to the stored waste only, unless the context indicates otherwise.

1.2 BACKGROUND

Established in 1949 by the Atomic Energy Commission (AEC) for the construction, operation, and testing of nuclear facilities, reactors, and equipment, the Idaho National Engineering Laboratory (INEL) occupies 894 square miles of semiarid plain in southeastern Idaho.

The Radioactive Waste Management Complex (RWMC) at the INEL was put into operation in 1952 as a controlled area for burial of solid radioactive waste generated by INEL operations. Since 1954, waste contaminated with transuranic radionuclides also has been received at the RWMC from the Rocky Flats Defense Production Plant near Golden, Colorado, and from other operations of the Atomic Energy Commission (AEC) and its successor agencies. In addition, a limited amount of waste (predominantly nontransuranic) generated by universities, hospitals, and private research organizations was accepted through 1964.

From 1954 until 1970, the TRU-contaminated waste was buried in pits and trenches at the RWMC and was covered with soil. Presently, an additional cover of highly compacted clay is being placed as a moisture barrier. About 2,000,000 ft³ of TRU waste is currently buried at the RWMC. (Approximately 2,200,000 ft³ of TRU waste was originally buried. However, experimental projects for retrieving buried waste have reduced the total to approximately 2,000,000 ft³.) Beta-gamma emitting, nontransuranic waste was intermixed in the pits and trenches with the TRU waste and is estimated to total 500,000 ft³. The buried waste is discussed only for background. This document does not develop alternatives for the management of buried waste.

The TRU waste received since 1970 (the subject of this document) has been placed in retrievable aboveground storage. Containers of waste are stacked on asphalt pads. The entire stack of containers is then covered successively with plywood, plastic sheeting, and soil. It is estimated that by the beginning of 1985, about 2,000,000 ft³ of TRU waste will be in aboveground storage at the RWMC.

Environmental monitoring (Dolenc and Janke 1977, Hedahl and Janke 1978) over the last several years has not identified any near-term hazards from the TRU waste currently buried or stored at the RWMC. However, the objective of the study reported here is to identify and evaluate feasible technical alternatives for long-term management of the stored waste. (The buried and stored TRU waste differ from one another with respect to retrieval, handling, and associated hazards. Therefore, the two types of waste require separate evaluations and may involve different alternatives for long-term management.) The results of the evaluation are presented here in a format that permits meaningful comparisons among the alternatives. The document does not present recommendations.

A number of factors, such as environmental effects, risks to the public, hazards to workers, technical feasibility, and costs, are important in making decisions regarding the long-term management of the INEL TRU waste.^(a) The decisions must also be compatible with the overall Department of Energy (DOE) program for waste management. The factors that are amenable to technical evaluation are addressed in this document.

(a) The term, INEL TRU waste, is used throughout this report for simplicity. However, the reader should note that: (1) not all TRU waste currently buried or stored at the INEL originated from INEL operations (most is from the Rocky Flats Defense Plant), (2) not all future waste stored at the INEL will be INEL-generated waste, and (3) buried and stored waste will not necessarily remain at the INEL.

At the time of this study, the alternatives presented here were considered to be leading or representative candidates for implementation and to represent applications of current technology. Improvements in technology and changes in regulations governing waste management may lead to modifications of the methods for implementing these alternatives. Before a decision is made for long-term management of INEL TRU stored waste, a Programmatic EIS, covering both buried and stored waste, will be prepared (see Subsection 7.3.2). The statement will assess in detail the potential effects of the most acceptable methods for implementing the alternatives presented in this document.

It is anticipated that any long-term management alternative selected as a result of this and other studies would be implemented starting in 1985 or as soon thereafter as practicable. Research and development studies to assist in selecting an alternative are presently being conducted.

1.3 SCOPE OF THE STUDY

This study identifies and evaluates long-term management alternatives for TRU waste presently stored at the INEL, but does not evaluate alternatives for buried TRU waste. The study also considers stored waste expected to be received prior to implementing a long-term management method. Because of the many uncertainties in the rate of receipt, stored waste that might be received after implementation of an alternative is not included in the study. However, the possible impacts of this waste are briefly discussed in Appendix C.

The study addresses three possibilities with respect to the availability of a federal repository: (1) a federal repository^(a) will be available in 1985; (2) a federal repository will be available,

(a) Hereafter, the terms, "a federal repository" and "the Federal Repository", are used to indicate a geologic repository not located at the INEL.

but will be delayed by 20 yr (in the expectation that improved technology for waste management will be developed in the intervening 20 yr); and (3) a federal repository will not be available.

The third possibility, no federal repository, would require permanent waste disposal in Idaho. However, no waste stored or disposed of at other DOE locations would be shipped to Idaho for disposal.

The data base developed and described for the present study includes: (1) the present environment of the INEL and the RWMC, (2) the RWMC and its operations, (3) the environmental effects from current operations, (4) the effects of current operations on workers and the public, and (5) the previous or current studies of TRU waste management. (This data base is discussed in Sections 3 through 6 and in Subsections 7.2 and 7.3.) No experimental studies or other efforts were made to develop basic scientific data. Rather, the study involved using existing data, as well as data from ongoing projects, to develop waste management concepts and to conduct preliminary evaluations of these concepts. The experimental project most closely linked with this study is the Transuranic Storage Area (TSA) reentry studies, described in Subsection 4.4.3.

Detailed guidelines for this study are listed in Subsection 7.4.1. Of particular importance are the time periods selected for evaluating the various effects of the alternatives.

The long-term management alternatives for the stored INEL TRU waste are described in Sections 8, 9, and 10. Section 12 outlines the environmental effects while Section 13 evaluates the short- and long-term risks for the alternatives. Hazards to operating personnel are addressed in Section 14, and Section 15 examines the monetary costs of the alternatives. Implementation requirements, including land acquisition and use, necessary compliance documents, technical development

studies, and required environmental and safety studies are identified in Section 16. Section 17 is a summary comparison of all alternatives studied.

1.4 NEED FOR A FEDERAL REPOSITORY

Large quantities of solid TRU waste, generated by the DOE and its predecessor agencies in support of the U. S. weapons program, are stored at several locations in the United States. The weapons program is continuing, although at a lower level than in the past. A method of permanent disposal of the waste generated at these facilities is needed.

A major portion of the national inventory of stored defense TRU waste is presently located at the RWMC. The TRU waste volume as of December 31, 1977, is approximately 1,200,000 ft³ in retrievable aboveground storage, and 2,000,000 ft³ in shallow-land burial. These volumes represent approximately 75% and 20%, respectively, of the total DOE inventory of the two classes mentioned. Additional TRU waste is continually being placed into storage at the RWMC. It is estimated that, by the beginning of 1985, the total volume in storage will reach about 2,000,000 ft³.

Commitments, made by the AEC and its successor agencies, for removing the waste from Idaho are given in Appendix A. Development of a repository is required to meet the commitments, although scheduled removal has been delayed to the late 1980s because of the unavailability of a federal repository.

A federal repository is also required to alleviate the need for expanding the RWMC or establishing another waste storage location at the INEL. Waste volume projections indicate that the present RWMC land area will be filled to capacity in the mid-1980s. A repository would receive the waste presently stored at the RWMC and would accommodate the waste generated in the future.

2. SUMMARY

2.1 BACKGROUND

This study identifies, develops, and evaluates, in a preliminary manner, alternatives for long-term management of TRU waste stored at the Radioactive Waste Management Complex (RWMC) at the INEL. The evaluations concern waste currently at the RWMC and waste expected to be received by the beginning of the year 1985. The effects of waste that might be received after that date are addressed in Appendix C. The technology required for managing the waste, the environmental effects, the risks to the public, the radiological and nonradiological hazards to workers, and the estimated costs are discussed.

2.2 ENVIRONMENTAL CHARACTERISTICS OF THE INEL AND THE RWMC

The INEL encompasses 894 square miles of semiarid plain at an average elevation of approximately 5,000 ft above mean sea level. The plain extends across southern Idaho and is characterized by soil of relatively shallow depths underlain by basalt rock.

The RWMC, Site 14, and the Lemhi Range site considered in this study are located within the boundaries of the INEL. The closest major population center is Idaho Falls, 30 miles from the eastern boundary of the INEL. The population living within a 50-mile radius of the INEL is approximately 117,000. Land uses in the surrounding area (50-mile radius) include urban, industrial, irrigated farming, and dry land farming. In addition, a small area of the INEL is used to graze sheep and cattle in the spring and fall.

The climate at the INEL is semiarid. The prevailing weather is dry, sunny, and breezy. Annual precipitation averages 8.5 in. Relative humidity ranges from an average monthly minimum of 15% in August to 89% in February and December. Tornadoes are rare in this region,

and those occurring tend to be small and cause little damage. Ten funnel clouds (vortex clouds that do not reach the ground) and two tornadoes (which caused no damage) have been documented at the INEL.

Located entirely on the eastern Snake River Plain, the INEL adjoins mountains to the northwest that provide the northern boundary of the plain. The INEL area is underlain by a succession of Pliocene, Pleistocene, and recent basaltic lava flows.

The Snake River Plain has been aseismic during the historic record. However, the absence of earthquakes or microseisms does not eliminate the possibility that the earth's crust in this region contains stored elastic strain. Such strain might be released by slippage along a dormant fault, to produce an earthquake.

No surface streams exit the INEL. The water supply source for the INEL is the groundwater contained in the Snake River Plain Aquifer. The general direction of flow of the aquifer is from northeast to southwest. The depth to the aquifer beneath the INEL varies from 200 ft in the northeast corner to 900 ft in the southwest corner.

The vegetation mosaic of the INEL consists primarily of sagebrush, lanceleaf rabbitbrush, and a variety of grasses. Small mammals are abundant. The pronghorn antelope is the predominant big game mammal. Sage grouse and pheasants are the only resident game birds. The only endangered species occasionally observed at the INEL are the peregrine falcon and the bald eagle. The INEL has been designated a National Environmental Research Park. Here scientists from throughout the nation can study environmental changes caused by man's activities and can develop information to assist in land use decisions.

The environmental characteristics of the RWMC are generally similar to those of the INEL. The depth to the Snake River Plain Aquifer below the RWMC is approximately 580 ft. The RWMC is located near two features of geologic or hydrologic interest in this study: (1) the

Arco Rift Zone, an area of recurring volcanic activity over recent geologic time periods; and (2) the Big Lost River, the principal surface water feature of the INEL.

2.3 THE RWMC AND ITS OPERATIONS

The Radioactive Waste Management Complex (RWMC) was established in the southwestern corner of the INEL in 1952 as a controlled area for burial of solid radioactive waste generated by INEL operations. It encompasses about 144 acres. Since 1954, waste contaminated with transuranic radionuclides has been received from defense-related activities at the Rocky Flats Defense Production Plant and from other operations of the Atomic Energy Commission and its successor agencies. The waste consists of contaminated materials associated with a variety of nuclear operations. Such materials include laboratory equipment, process equipment, protective clothing, maintenance tools, and building materials. In terms of activity, the principal radionuclides in the TRU waste are plutonium-238, -239, -240, -241, and -242, and americium-241.

Approximately 2,200,000 ft³ of TRU waste was buried in pits and trenches at the RWMC between 1954 and 1970. Additionally, about 500,000 ft³ of beta/gamma waste was mingled with the buried TRU waste.

Since 1970, about 1,100,000 ft³ of TRU waste has been received and stored retrievably on aboveground asphalt pads at the RWMC. This waste has been covered with successive layers of plywood, plastic sheeting, and soil. As a result of experimental retrieval projects, an additional 165,000 ft³ of TRU waste has been retrieved from the pits and trenches and placed on the pads. By 1985, an additional 800,000 ft³ is expected to be received and stored. This will result in a total of approximately 2,000,000 ft³ of (stored) TRU waste on the pads and approximately 2,000,000 ft³ of (buried) TRU waste in the pits and trenches.

The containers (metal bins and drums, and wooden boxes) for the stored waste are generally in good condition. These containers were intended to be retrievable in a contamination-free condition for at least 20 yr. However, the containers for the buried waste have deteriorated badly. Steel drums have corroded through; wood and cardboard containers have rotted or disintegrated. Some of the waste, such as large pieces of equipment, was buried without containers. As a result of the deterioration of the containers, some of the soil immediately adjacent to the buried waste has become contaminated. The contamination level of most of this soil is very low.

2.4 EFFECTS OF CURRENT OPERATIONS

The effects of current RWMC operations on workers, the public, and the environment are minimal. There are no normal releases of TRU contamination. Four TRU waste handling accidents have been recorded at the RWMC since the present management procedures were established in 1970. Only one of these accidents resulted in a release of contamination. A forklift penetrated a drum, resulting in the spill of a small amount of contaminated waste. The spilled waste was easily retrieved, repackaged, and the local area quickly decontaminated. There were no significant radiation doses to personnel.

Surface and subsurface water samples are routinely collected at the RWMC. The only significant TRU contamination detected in water samples was in 1962 and 1969, when local flooding of the RWMC occurred. The floodwaters came in contact with buried waste in partially filled pits and trenches. The highest alpha activity measured in the runoff water was 1×10^{-4} ^(a) nCi/ml, which is much less than the maximum concentrations allowed by DOE standards for water released to

(a) This number is expressed in scientific notation, which is explained in Appendix F.

an uncontrolled area. These flood waters, and perhaps wind transport, are believed to be responsible for the spread of TRU contamination to the drainage depression at the northeastern perimeter of the RWMC. TRU contamination has been detected up to 8200 ft from the RWMC, which is still well within the INEL boundary. The maximum contamination levels found in surface soils (0-5 cm) were 2048 nCi Am-241/m², 1377 nCi Pu-239/m², and 32 nCi Pu-238/m². These levels were found at the northeastern perimeter of the RWMC.

Subsurface migration of radionuclides from the buried TRU waste is being monitored. Samples indicate the migration to date is limited to a few inches at the soil-waste interface. The USGS has reported detectable concentrations of radionuclides in subsurface sediments at the 110- and 240-ft depths. However, these statistically positive results were suspected to have resulted from contamination of drilling cores from surface sources. Subsequent drilling using strict anticontamination controls did not identify any radionuclides in these sedimentary layers.

The study of uptake of radionuclides by animal and plant species at the RWMC has begun recently. Results to date indicate that the concentrations of Pu-238, Pu-239, and Am-241 in deer mice tissues are low. Many of the samples were near or below the minimum detection limit for the radionuclides.

The RWMC is a controlled area. Consequently, the potential for direct radiation exposure to the public is minimized and is localized within the controlled area. The workers are exposed to low levels of radiation. The highest annual whole-body dose of recent record was 1.87 rem. However, this dose resulted mainly from the handling and disposal of beta/gamma waste received from current INEL operations. The maximum annual whole-body dose received during operations for receiving and storing TRU waste is estimated to be 0.4 rem. These doses are well below the DOE standard of 5 rem/yr.

2.5 WASTE MANAGEMENT ALTERNATIVES STUDIED

Six alternatives, designated 1 through 6, were studied for long-term management of the stored TRU waste (Alternatives for long-term management of the buried TRU waste are being studied in connection with a Draft Programmatic Environmental Impact Statement for INEL TRU waste, in preparation.) These alternatives are identified in the simplified decision tree in Figure 2-1. For convenience, Table 2-1 lists the waste management alternatives, and concepts within these alternatives, that were developed and evaluated.

Additional alternatives and concepts were identified, but were not studied because they appeared to be less desirable. These alternatives and concepts, and reasons for not studying them, are discussed in Appendix B.

The six major alternatives derive from three different premises: (1) a Federal Repository will be available as scheduled, assumed for this study to be in 1985; (2) a Federal Repository will be available in the year 2005, and (3) a Federal Repository will not be available, and the waste must remain at the INEL. Of the alternatives listed in Figure 2-1 and Table 2-1, Alternative 3 falls into the first category; Alternatives 4 and 6, the second, and Alternatives 1, 2, and 5, the third.

In Alternative 1, the TRU waste would be left in place as is. The present cover of plywood, polyvinyl sheeting, and 3 ft of soil over the waste would be maintained. The present environmental surveillance at the RWMC would be continued, with improved procedures incorporated as they are developed. All these procedures would be continued for 100 yr, the assumed minimum duration of societal control over such activities. It was conservatively assumed that, after the 100-yr period, reliance would be placed entirely on the current waste confinement system (containers, soil covering) for isolation from man and protection of the environment.

Fig. 2-1 Alternatives and concepts studied for long-term management of stored INEL TRU waste.

TABLE 2-1

ALTERNATIVES AND CONCEPTS STUDIED FOR LONG-TERM
MANAGEMENT OF STORED INEL TRU WASTE

Alternative	Concept	Description
1		<u>Leave As Is</u>
2		<u>Provide Improved Confinement</u>
	2-a	Above and Around
	2-b	Above, Around, and Below
	2-c	Immobilization
3		<u>Retrieve As Scheduled, Process, Ship To Federal Repository</u>
		Direct-Control Retrieval, SP(a)
4		<u>Retrieve As Scheduled, Process, Store 20 Years, Ship To Federal Repository</u>
		Direct-Control Retrieval, SP
5		<u>Retrieve As Scheduled, Process, Deep Rock Disposal - Shaft Access (In Lemhi Range)</u>
	5-a	Direct-Control Retrieval, SP
	5-b	Direct-Control Retrieval, CPT(b)
	5-c	Direct-Control Retrieval, PKG(c)
5		<u>Retrieve As Scheduled, Process, Deep Rock Disposal - Tunnel Access (In Lemhi Range)</u>
	5-d	Direct-Control Retrieval, SP
	5-e	Direct-Control Retrieval, CPT
	5-f	Direct-Control Retrieval, PKG
5		<u>Retrieve As Scheduled, Process, Engineered Shallow-Land Disposal (At Site 14)</u>
	5-g	Direct-Control Retrieval, SP
	5-h	Direct-Control Retrieval, CPT
	5-i	Direct-Control Retrieval, PKG
5		<u>Retrieve As Scheduled, Process, Disposal In Engineered Surface Facility (Near RWMC)</u>
	5-j	Direct-Control Retrieval, SP
	5-k	Direct-Control Retrieval, CPT
	5-l	Direct-Control Retrieval, PKG
6		<u>Delay Retrieval 20 Years, Process, Ship To Federal Repository</u>
		Direct-Control Retrieval, SP

- (a) SP - Slagging Pyrolysis and Packaging
 (b) CPT - Compaction, Immobilization, and Packaging
 (c) PKG - Packaging Only

In Alternative 2, the TRU waste would be left in place, but engineered confinement would be added. Three concepts were studied as ways of providing this additional protection. For all three concepts of improved confinement, the present maintenance and surveillance at the RWMC would be continued for 100 yr, as in Alternative 1, with improved procedures incorporated as they are developed.

In Alternative 3, the TRU waste would be retrieved as scheduled (beginning in 1985 and requiring 10 yr), incinerated and immobilized by slagging pyrolysis, packaged, and shipped by rail to the Federal Repository. Each of these operations (retrieval, processing, and shipment) was evaluated as a separate module. The combination of the three modules constitutes Alternative 3.

In Alternative 4, the TRU waste would be retrieved as scheduled (beginning in 1985 and requiring 10 yr), processed by slagging pyrolysis, packaged, stored in a precast concrete facility at the RWMC for 20 yr, and shipped to the (delayed) Federal Repository in 2005.

In Alternative 5, the waste would be retrieved as scheduled (beginning in 1985 and requiring 10 yr), processed, and disposed of on the INEL. The concepts within Alternative 5 differ in the type of processing and in the method and location of disposal. Processing operations, or modules, studied were the following: (1) slagging pyrolysis and packaging; (2) compaction, immobilization, and packaging; or (3) packaging only. Disposal modules studied were: (1) deep rock disposal in the Lemhi Range with access by a shaft; (2) deep rock disposal in the Lemhi Range with access by a tunnel; (3) engineered shallow-land disposal at Site 14 (both massive and "less massive" engineered structures were evaluated); or (4) disposal in an engineered surface facility near the RWMC.

In Alternative 6, retrieval would be delayed for 20 yr (to the year 2005). Processing would involve slagging pyrolysis and packaging. The TRU waste would then be shipped to the Federal Repository. Except for the 20-yr delay in retrieval, this alternative is identical to Alternative 3.

Large uncertainties exist in future rates of waste generation, in national waste management policies of the future, and in waste management practices that might be in effect after implementation begins for the selected TRU waste management alternative. Therefore, the evaluations and facility layouts for this study do not reflect the effects of TRU waste that might be received at the RWMC after the start of the campaign (1985). These effects are discussed in Appendix C.

2.6 ENVIRONMENTAL EFFECTS OF ALTERNATIVES

For each alternative and concept, the potential radiological and nonradiological effects on the environment were evaluated. These effects would derive from the following phases: site preparation and construction, plant operation, and decontamination and decommissioning after completion of the waste management campaign.

2.6.1 Nonradiological Effects. Tables 2-2 and 2-3 summarize quantifiable nonradiological effects expected during the construction phase and operations phase, respectively. These summary tables highlight only some of the major effects. For example, pollutant emissions are summarized by giving only the estimates for particulates, because that is the only air pollutant on the INEL that is now near the allowable limits.

For all alternatives and concepts except Alternative 1, air quality would be impacted by increased emissions from construction equipment and increased generation of dust. These impacts would be minor and would occur only during the construction phase. None of the air pollutants would exceed offsite standards.

Several aspects of construction activities could cause adverse impacts when occurring near surface waters. Such activities include: (1) withdrawal of water for use in construction or for human intake; (2) discharge of wastewater such as sanitary wastewater; (3) gravel or clay mining from stream or lake bottoms; and (4) erosion of construction areas by surface runoff and resultant siltation of streams.

TABLE 2-2

SUMMARY OF QUANTITATIVE NONRADIOLOGICAL IMPACTS
(CONSTRUCTION PHASE)

Concept	Usage (10^3yd^3)		Particulate Emissions (10^3lbs)(a)	Labor (man- years)	Diesel Fuel Usage (10^3gal)
	Clay	Concrete			
1	0	0	0	0	0
2-a	30	0	9.5	16	86
2-b	30	13	13	54	120
2-c	0	0	3.2	20	29
3	0	2	46	500	410
4	0	8	48	510	440
5-a	0	4	82	570	740
5-b	0	4	75	530	680
5-c	0	4	66	410	600
5-d	0	7	82	570	740
5-e	0	7	75	530	680
5-f	0	7	66	410	600
5-g	420	510	56	530	510
LMV(b)	120	16	54	520	490
5-h	360	430	49	490	450
LMV	160	20	47	480	430
5-i	990	1200	40	370	370
LMV	320	43	38	360	350
5-j	43	380	54	520	490
5-k	42	360	47	470	430
5-l	120	1100	38	360	350
6	0	2	46	500	410
See Tables	12-6	12-6	12-2	12-1	12-1

(a) From diesel-powered construction equipment; assumes all construction proceeding simultaneously.

(b) LMV identifies use of the less massive variation of the engineered shallow-land disposal facility at Site 14.

TABLE 2-3

SUMMARY OF QUANTITATIVE NONRADIOLOGICAL IMPACTS
(OPERATIONS PHASE)

Concept	Particulate Emissions (10 ³ lb/yr)(a)	Land Usage (acres)	Employment(b)		Energy Used	
			Jobs	(10 ⁶ \$/yr)	Diesel (10 ³ gal/yr)	Electric (10 ⁶ kwh/yr)
1-a	0	(c)	10	0.16	0	0
2-a	0	(c)	10	0.16	0	0
2-b	0	(c)	10	0.16	0	0
2-c	0	(c)	10	0.16	0	0
3	0.95	1.9	230	3.9	88	25
4	4.3	9.4	250	4.0	100	25
5-a	11	210	270	4.5	160	28
5-b	11	210	130	2.0	160	9.6
5-c	19	210	120	1.8	220	9.6
5-d	10	210	270	4.3	150	27
5-e	10	210	120	1.8	150	8.6
5-f	17	210	110	1.7	200	7.6
5-g	3.9	250	250	4.0	92	25
LMV(d)	2.2	170	240	4.0	92	25
5-h	4.1	240	110	1.5	94	6.7
LMV	2.4	190	100	1.5	94	6.7
5-i	5.6	410	110	1.5	110	3.9
LMV	3.9	230	100	1.5	110	3.9
5-j	7.7	36	260	4.0	92	25
5-k	7.9	35	110	1.5	94	6.7
5-l	8.5	96	110	1.5	100	3.8
6	0.95	1.9	230	3.9	88	25
See Tables	12-7	12-3	12-9	12-9	12-9	12-9

(a) From diesel vehicles or slagging pyrolysis facility stack, only.

(b) Direct employment only; income in 1977 dollars.

(c) No incremental land usage beyond area in the RWMC currently in use.

(d) LMV identifies use of the less massive variation of the engineered shallow-land disposal facility at Site 14.

Increased noise levels from construction would be localized. Impacts on vegetation would be limited to removal of natural vegetation from the construction site and from INEL areas used for extraction of construction materials, such as clay, gravel, and basalt. Habitat and cover for wildlife would also be reduced, but even the concept resulting in the maximum habitat loss would affect only about 400 acres, or 0.07% of the total acreage of the INEL. Use of the Lemhi Range disposal sites could result in removing an additional 8,000 acres of grazing land in the form of a buffer zone. No other conflicts were identified with any known plans or policy related to land use adjacent to or within the boundaries of the INEL.

Construction of waste management facilities would result in long-term or irreversible commitment of some natural resources. In particular, the engineered shallow-land disposal facility (except for the less massive variation) and the engineered surface disposal facility would require large quantities of concrete. Construction would also require the commitment of nonrenewable energy resources, such as petroleum products. Commitment of labor hours and funds for design and construction would be unrecoverable.

Construction of any of the waste management facilities would not detract significantly from the existing aesthetic quality of the INEL. Retrieval and process facilities constructed at the RWMC would be visible from a public roadway. The slagging pyrolysis facility stack would be particularly prominent.

Added employment during construction or operation of any of the facilities would not be expected to have a major socioeconomic impact. In June 1978, total INEL employment was approximately 9400 people. By comparison, the maximum direct employment during construction of waste management facilities would be 435 people. During the operational phase, direct employment would be an estimated 273 people. Idaho Falls would be the major city impacted by influx of

construction or operational personnel. However, completion of existing construction projects during the 1985 time frame would provide a pool of available workers without a major influx of personnel. No major impacts on housing, schools, hospitals, or recreational facilities were identified.

Although archaeological artifacts have been collected in the vicinity of each of the three onsite disposal locations studied, no detailed archaeological surveys have been made. INEL operating procedures require protection of antiquities. Reconnaissance would be made by a qualified archaeologist prior to and during excavation for construction.

2.6.2 Radiological Effects. Two time periods were considered in evaluating the effects of the normal operational releases of radionuclides: (1) the period of up to 100 yr following implementation of an alternative or concept; and (2) the post 100-yr period. (Accidental releases of radionuclides were evaluated as part of the risk analysis in the study.)

For all alternatives and concepts, the radiological dose commitments^(a) to the general public from normal operational releases would be a very small fraction of the natural background dose. The whole-body dose from natural background radiation in southeastern Idaho is about 150 mrem/yr. For any of the alternatives or concepts, the maximum whole-body dose commitment to an individual, resulting from one year of normal operation, was calculated to be 1.9×10^{-7} mrem (see Table 2-4). The dose commitments to the population living within 50 miles are summarized in Table 2-5.

(a) Hereafter, the term "dose" is often used for brevity. However, it should be understood that dose commitment is meant, evaluated as described in Appendix E.

TABLE 2-4

MAXIMUM INDIVIDUAL LIFETIME DOSE COMMITMENTS RESULTING
FROM ONE YEAR OF NORMAL OPERATION OF WASTE MANAGEMENT FACILITIES

Alternative/ Concept	Maximum Individual Dose Commitment (mrem) to Organ or Tissue				
	Whole Body	Lung	Bone	Liver	Kidney
1	0	0	0	0	0
2	0	0	0	0	0
3,4,5-a, 5-d,5-g,5-j	1.9×10^{-7}	3.5×10^{-3}	3.6×10^{-3}	2.7×10^{-3}	1.3×10^{-3}
5-b,5-c,5-e, 5-f,5-h,5-i, 5-k,5-l	2.6×10^{-8}	4.9×10^{-4}	5.0×10^{-4}	3.7×10^{-4}	1.8×10^{-4}
6	1.6×10^{-7}	3.4×10^{-3}	3.4×10^{-3}	2.5×10^{-3}	1.2×10^{-3}

TABLE 2-5

LIFETIME POPULATION DOSE COMMITMENTS RESULTING FROM
ONE YEAR OF NORMAL OPERATION OF WASTE MANAGEMENT FACILITIES

Alternative/ Concept	Lifetime Population Dose Commitment To Organ or Tissue (man-rem)				
	Whole Body	Lung	Bone	Liver	Kidney
1	0	0	0	0	0
2	0	0	0	0	0
3,4,5-a, 5-d,5-g,5-j	2.3×10^{-6}	3.3×10^{-2}	3.3×10^{-2}	2.5×10^{-2}	1.2×10^{-2}
5-b,5-c,5-e, 5-f,5-h,5-i, 5-k,5-l	3.2×10^{-7}	4.5×10^{-3}	4.6×10^{-3}	3.4×10^{-3}	1.7×10^{-3}
6	2.4×10^{-6}	3.8×10^{-2}	3.8×10^{-2}	2.9×10^{-2}	1.4×10^{-2}

2.7 RADIOLOGICAL RISKS TO THE PUBLIC

The same time periods were considered in evaluating the radiological effects on the public from uncontrolled (accidental or nature-caused) releases of radionuclides: (1) the period of up to 100 yr following implementation of an alternative or concept, and (2) the post 100-yr period. The following potential causes of release were studied: process and handling accidents, natural disasters (e.g., earthquakes), and airplane crashes. The release consequences were calculated for all the operational steps, or modules, making up each alternative or concept.

For each alternative and concept, the radiological risk was estimated for the short-term period. Risk was defined as the probability that a release of radioactive material will occur, multiplied by the consequences of the release in terms of the radiation dose commitment received. For the long-term period, only the dose commitment for scenarios of uncontrolled release was calculated. Estimates of long-term probabilities were considered to be too uncertain to be reliable.

Table 2-6 summarizes the dose and risk from short-term (up to 100 yr) release scenarios for all alternatives and concepts. For brevity, only calculations involving dose to the lung, the organ of maximum dose, are presented. The scenario of greatest importance in all instances is lava flow over the waste, leading to possible airborne release of a fraction of the radionuclides present. (Even for Alternatives 3 through 6, involving retrieval of the waste, the lava flow scenario is predominant because of the possibility of lava flow disrupting waste that would not yet have been retrieved. For simplicity, however, the short-term lava flow scenario for Alternatives 3 through 6 has been deleted from the table.) The operational scenarios of greatest import (Alternatives 3 through 6) are (1) an explosion in the slagging pyrolysis facility, and (2) a fire in the retrieval facility. The population risk from even the dominant scenario (10 man-rem/yr) would be small compared with that from natural background radiation to the same population (24,000 man-rem/yr).

TABLE 2-6

SUMMARY OF EFFECTS FROM SHORT-TERM RELEASE SCENARIOS(a,b,c,d,e)

Alternative/Concept	Maximum Dose to Maximum Individual (rem)	Total Risk to Maximum Individual (rem/yr)	Maximum Population Dose (man-rem)	Total Risk to Population (man-rem/yr)
1	1×10^2	6×10^{-3}	2×10^5	1×10^1
2-a	2×10^1	6×10^{-5}	4×10^4	1×10^{-1}
2-b	2×10^0	6×10^{-5}	4×10^3	1×10^{-1}
2-c	1×10^0	6×10^{-5}	2×10^3	1×10^{-1}
3	1×10^{-1}	2×10^{-6}	2×10^2	3×10^{-3}
4	1×10^{-1}	2×10^{-6}	2×10^2	3×10^{-3}
5-a,5-d,5-g(f),5-j	1×10^{-1}	2×10^{-6}	2×10^2	3×10^{-3}
5-b,5-e,5-h(f),5-k	6×10^{-3}	5×10^{-7}	1×10^1	1×10^{-3}
5-c,5-f,5-i(f),5-l	6×10^{-3}	6×10^{-7}	1×10^1	1×10^{-3}
6	1×10^{-1}	2×10^{-6}	2×10^2	3×10^{-3}
Natural Background Radiation		180×10^{-3}		24,000

(a) Effects reported here are for lung dose only.

(b) Short-term accidents include release scenarios occurring no more than 100 yr into the future for Alternative 1 and 2. For Alternatives 3 through 6, entries include only campaign-related events. Entries do not include possible releases due to natural events or aircraft impacts disrupting waste still unretrieved during retrieval campaign (10-yr period). Inclusion of such events would cause entries to be similar to those for Alternative 1 for that time period. For Alternative 4, entries listed do not include release scenarios for natural events occurring while processed waste is in storage during 1985-2005. Inclusion of such events would have little effect. For Alternative 6, entries listed pertain to time after campaign starts in 2005. From 1985 through 2005, entries for Alternative 1 would apply. For Alternative 5, only releases occurring prior to or during emplacement (10-yr period) are included.

(c) Release scenarios involving sabotage have been evaluated in a related study. The results of that study have been published in a preliminary report that is classified.

(d) Effects of possible releases occurring at the Federal Repository are not included for Alternatives 3, 4, and 6, because these effects are being evaluated in other DOE projects.

(e) See Subsections 7.4.1 and 13.2 for additional explanations of scope and assumptions.

(f) Entries apply to either more massive or less massive variation of the engineered shallow-land disposal facility at Site 14.

A summary of projected effects from long-term (greater than 100 yr) release scenarios for each alternative or concept is given in Table 2-7. All entries are calculated values of population dose to the lung for the dominant release scenario, which is either lava flow over the waste or a volcanic eruption up through the waste. The maximum estimated population dose is 4×10^5 man-rem. Double entries at a given time indicate the effects before and after hypothesized times of complete deterioration of confinement for disposal. For simplicity, such deterioration was assumed to occur instantaneously rather than gradually. The indicated times of confinement deterioration are highly conjectural.

The supplement following Table 2-7 presents the same data points in graphic form, with connecting curves through the points. The increase in dose between zero and one hundred years is due to the assumed population growth during the first hundred years. Also indicated is the level of natural background radiation, the population dose that is certain to accrue each year. (No effort was made to estimate the possible decay of background radiation.) By comparison, the curves for the waste management alternatives represent doses from highly unlikely volcanic action events.

Entries in Tables 2-6 and 2-7 have generally been rounded to one significant figure. The uncertainties of the calculated doses and risks are estimated generally to be factors of one to two orders of magnitude, both upward and downward. Such uncertainties do not have a major impact on the significance of doses and risks that are already extremely small.

The train crews involved in shipping the waste to the Federal Repository would comprise approximately 90 people. These people would receive a population dose of about 1 man-rem/yr. The calculated dose to all crew members would be well below published standards. The general public along the route would receive a population dose of about 0.05 man-rem/yr.

TABLE 2-7
SUMMARY OF CONSEQUENCES FROM LONG-TERM RELEASE SCENARIOS(a)

Alternative/ Concept	YEARS AFTER 1985								
	0	100		400		2000		25000	
		BCF(b)	ACF(c)	BCF	ACF	BCF	ACF	BCF	ACF
1	2x10 ⁵	4x10 ⁵		3x10 ⁵		1x10 ⁵		4x10 ⁴	
2-a	4x10 ⁴ (d)	8x10 ⁴ (d)	4x10 ⁵	3x10 ⁵		1x10 ⁵		4x10 ⁴	
2-b	4x10 ⁴ (d)	8x10 ⁴ (d)	4x10 ⁵	3x10 ⁵		1x10 ⁵		4x10 ⁴	
2-c	2x10 ³	4x10 ³		3x10 ³	3x10 ⁵	1x10 ⁵		4x10 ⁴	
3	No long-term management of stored TRU waste at the INEL (e)								
4	No long-term management of stored TRU waste at the INEL (e)								
5-a through 5-f (Lemhi Range)	4x10 ¹ (d)	8x10 ¹ (d)		6x10 ¹ (d)		2x10 ¹ (d)		8x10 ⁰ (d)	
5-g through 5-i (Site 14)(f)	4x10 ² (d)	8x10 ² (d)		6x10 ² (d)		2x10 ² (d)	8x10 ¹ (d)	4x10 ⁴	
5-g through 5-i (LMV)(g,h)	1x10 ³ (d)	2x10 ³ (d)		1.5x10 ³ (d)	5x10 ² (d)	1x10 ⁵		4x10 ⁴	
5-j through 5-l (RWMC)(e)	4x10 ² (d)	8x10 ² (d)		6x10 ² (d)		2x10 ² (d)	8x10 ¹ (d)	4x10 ⁴	
6	No long-term management of stored TRU waste at the INEL (e)								

- (a) All entries are the calculated values of population dose to the lung, in man-rem, for the dominant release scenario.
- (b) BCF = Before Confinement Failure.
- (c) ACF = After Confinement Failure.
- (d) Explosive volcanic eruption is dominant release scenario. For all other entries, lava flow is dominant release scenario.
- (e) Long-term effects of disposal of TRU waste at the Federal Repository are being evaluated in other DOE-sponsored studies.
- (f) Resistance to explosive volcanic eruption assumed to be a factor of 100 better than that for Concepts 2-a and 2-b, as long as facility has not disintegrated.
- (g) Resistance to explosive volcanic eruption assumed to be a factor of 40 better than that for Concepts 2-a and 2-b, as long as facility has not disintegrated.
- (h) LMV identifies the use of the less massive variation of the engineered shallow-land disposal facility at Site 14.

Supplement to Table 2-7
(Summary of Consequences from Long-Term Release Scenarios)

Health effects experienced by the public as a consequence of the waste management operations and of uncontrolled releases were projected. No short-term health effects (occurring within about one year of the exposure) would be expected. Long-term effects (typically occurring several years after exposure) could occur. However such effects, both somatic and genetic, would not be expected statistically. That is, (1) the mathematically expected number of effects is nearly zero, and (2) the most probable number of effects is zero.

2.8 HAZARDS TO THE WORKERS

Both radiological and nonradiological hazards to the workers who would implement each alternative or concept were evaluated on a preliminary basis. The nonradiological hazards evaluated were those leading to common industrial accidents such as falls, burns, and electric shock. For each alternative and concept, the projected numbers of injuries and fatalities from such accidents are given in Table 2-8. As might be expected, the greatest numbers of projected injuries and fatalities are associated with the alternatives and concepts that would involve retrieval and processing of the waste (Alternatives 3 through 6). Construction and operation of the slagging pyrolysis facility would contribute a major portion of such injuries for concepts containing this module. However, these numbers of injuries are no higher than those expected in similar industrial operations of the same level of effort.

Radiological hazards that were evaluated include the exposure of workers to radiation and possible contamination by radioactive materials. Hazards associated with normal operations and hazards associated with potential accidents were both considered.

Conservative estimates of radiation exposures to the workers during normal operations are summarized in Table 2-9. Summed over the workers involved, the largest exposures in man-rem would accrue to

TABLE 2-8

PROJECTED NONRADIOLOGICAL INJURIES AND FATALITIES TO WASTE MANAGEMENT WORKERS

Alternative or Concept	Manpower Commitment in Various Activities(a) (10 ⁶ man-hours)					Estimated Number of Injuries(b)					Estimated Number of Fatalities(b)				
	Construction	Retrieval	Processing	Disposal/Storage	Surveillance	Construction	Retrieval	Processing	Disposal/Storage	Surveillance	Construction	Retrieval	Processing	Disposal/Storage	Surveillance
1	N/A(c)	N/A	N/A	N/A	2.1(1)	N/A	N/A	N/A	N/A	4.4	N/A	N/A	N/A	N/A	0
2-a	0.03(6)	N/A	N/A	N/A	2.1(1)	0.4	N/A	N/A	N/A	4.4	<0.1(d)	N/A	N/A	N/A	0
2-b	0.11(6,2)	N/A	N/A	N/A	2.1(1)	0.9	N/A	N/A	N/A	4.4	<0.1	N/A	N/A	N/A	0
2-c	0.04(2)	N/A	N/A	N/A	2.1(1)	0.2	N/A	N/A	N/A	4.4	<0.1	N/A	N/A	N/A	0
3	1.0(6)	0.8(3)	4.1(7)	NI(e)	N/A	15	7.8	75	NI	N/A	0.2	0.1	0.4	NI	N/A
4	1.2(6)	0.8(3)	4.1(7)	0.1(4)+NI	0.2(1)	18	7.8	75	1+NI	0.4	0.2	0.1	0.4	0+NI	0
5-a	1.3(6,8)	0.8(3)	4.1(7)	0.7(8)	2.1(1)	22	7.8	75	18	4.4	0.3	0.1	0.4	0.4	0
5-b	1.2(6,8)	0.8(3)	1.0(5)	0.7(8)	2.1(1)	20	7.8	12	18	4.4	0.3	0.1	<0.1	0.4	0
5-c	1.0(6,8)	0.8(3)	0.8(4)	0.7(8)	2.1(1)	17	7.8	8	18	4.4	0.3	0.1	0	0.4	0
5-d	1.3(6,8)	0.8(3)	4.1(7)	0.5(8)	2.1(1)	22	7.8	75	13	4.4	0.3	0.1	0.4	0.3	0
5-e	1.2(6,8)	0.8(3)	1.0(5)	0.5(8)	2.1(1)	20	7.8	12	13	4.4	0.3	0.1	<0.1	0.3	0
5-f	1.0(6,8)	0.8(3)	0.8(4)	0.5(8)	2.1(1)	17	7.8	8	13	4.4	0.3	0.1	0	0.3	0
5-g (f)	1.4(6)	0.8(3)	4.1(7)	0.1(4)	2.1(1)	21	7.8	75	1	4.4	0.2	0.1	0.4	0	0
LMV	1.2(6)	0.8(3)	4.1(7)	0.1(4)	2.1(1)	18	7.8	75	1	4.4	0.2	0.1	0.4	0	0
5-h	1.3(6)	0.8(3)	1.0(5)	0.1(4)	2.1(1)	19	7.8	12	1	4.4	0.2	0.1	<0.1	0	0
LMV	1.1(6)	0.8(3)	1.0(5)	0.1(4)	2.1(1)	16	7.8	12	1	4.4	0.2	0.1	<0.1	0	0
5-i	1.1(6)	0.8(3)	0.8(4)	0.3(4)	2.1(1)	16	7.8	8	3	4.4	0.2	0.1	0	0	0
LMV	0.8(6)	0.8(3)	0.8(4)	0.3(4)	2.1(1)	12	7.8	8	3	4.4	0.1	0.1	0	0	0
5-j	1.4(6)	0.8(3)	4.1(7)	0.1(4)	2.1(1)	21	7.8	75	1	4.4	0.2	0.1	0.4	0	0
5-k	1.3(6)	0.8(3)	1.0(5)	0.1(4)	2.1(1)	19	7.8	12	1	4.4	0.2	0.1	<0.1	0	0
5-l	1.1(6)	0.8(3)	0.8(4)	0.3(4)	2.1(1)	16	7.8	8	3	4.4	0.2	0.1	0	0	0
6	1.0(6)	0.8(3)	4.1(7)	NI	0.4(1)	15	7.8	75	NI	0.8	0.2	0.1	0.4	NI	0

Alternative or Concept	Hazards of Truck Shipment				Hazards of Rail Shipment				Totals (For All Activities)	
	Truck-Miles(g)	Accidents	Injuries	Fatalities	Car-Miles	Accidents	Injuries	Fatalities	Injuries	Fatalities
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4.4	0
2-a	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4.8	<0.1
2-b	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5.3	<0.1
2-c	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4.6	<0.1
3	2.7x10 ³	<0.1	<0.1	<0.1	5.3x10 ⁶	0.7	2	0.1	100+NI	0.8+NI
4	2.7x10 ³	<0.1	<0.1	<0.1	5.3x10 ⁶	0.7	2	0.1	104+NI	0.8+NI
5-a	1.8x10 ⁵	0.3	0.2	<0.1	N/A	N/A	N/A	N/A	127	1.2
5-b	1.5x10 ⁵	0.3	0.1	<0.1	N/A	N/A	N/A	N/A	62	0.8
5-c	1.6x10 ⁵	0.3	0.1	<0.1	N/A	N/A	N/A	N/A	55	0.8
5-d	1.8x10 ⁵	0.3	0.2	<0.1	N/A	N/A	N/A	N/A	122	1.1
5-e	1.5x10 ⁵	0.3	0.1	<0.1	N/A	N/A	N/A	N/A	57	0.7
5-f	1.6x10 ⁵	0.3	0.1	<0.1	N/A	N/A	N/A	N/A	50	0.7
5-g	1.2x10 ⁵	0.2	0.1	<0.1	N/A	N/A	N/A	N/A	109	0.7
LMV	1.2x10 ⁵	0.2	0.1	<0.1	N/A	N/A	N/A	N/A	106	0.7
5-h	1.0x10 ⁵	0.2	<0.1	<0.1	N/A	N/A	N/A	N/A	44	0.3
LMV	1.0x10 ⁵	0.2	<0.1	<0.1	N/A	N/A	N/A	N/A	41	0.3
5-i	1.1x10 ⁵	0.2	<0.1	<0.1	N/A	N/A	N/A	N/A	39	0.3
LMV	1.1x10 ⁵	0.2	<0.1	<0.1	N/A	N/A	N/A	N/A	35	0.2
5-j	4.2x10 ³	<0.1	<0.1	<0.1	N/A	N/A	N/A	N/A	109	0.7
5-k	3.9x10 ³	<0.1	<0.1	<0.1	N/A	N/A	N/A	N/A	44	0.3
5-l	4.0x10 ³	<0.1	<0.1	<0.1	N/A	N/A	N/A	N/A	39	0.3
6	2.7x10 ³	<0.1	<0.1	<0.1	5.3x10 ⁶	0.7	2	0.1	101+NI	0.8+NI

(a) Numbers in parentheses refer to comparable industries for which accident rates were used (see Table 14-2).

(b) Actual calculated values are reported. Fractional values have meaning only for comparison purposes. Nonzero results less than 0.1 are shown to indicate small hazard.

(c) N/A = Not Applicable.

(d) < = Less than.

(e) NI = Not Included (relates to operations at the Federal Repository).

(f) LMV = Use of the less massive variation of engineered shallow-land disposal at Site 14.

(g) Includes mileage from retrieval to processing facility and from processing to onsite disposal or storage facility.

TABLE 2-9
ESTIMATED WORKER DOSES FROM NORMAL OPERATIONS (man-rem)(a)

Alternative/ Concept	Retrieval		Processing		Transfer and Onsite Truck Shipment		Disposal/Storage		Maintenance/Surveillance		Total Dose for Concept
	Number of Workers	Total Dose (man-rem)	Number of Workers	Total Dose (man-rem)	Number of Workers	Total Dose (man-rem)	Number of Workers	Total Dose (man-rem)	Number of Workers ^(b)	Total Dose (man-rem)	
1	N/A ^(c)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	10	5	5
2-a	N/A	N/A	N/A	N/A	N/A	N/A	8 ^(d)	<1 ^(e)	10	5	5
2-b	N/A	N/A	N/A	N/A	N/A	N/A	27 ^(d)	<1	10	5	5
2-c	N/A	N/A	N/A	N/A	N/A	N/A	10 ^(d)	<1	10	5	5
3	39	88	195	205	2	<<1 ^(f)	NI ^(g)	NI	N/A	N/A	293+NI
4	39	88	195	205	3	<<1	15+NI	34+NI	10	1	328+NI
5-a	39	88	195	205	4	4	39	74	10	5	376
5-b	39	88	50	52	4	4	39	74	10	5	223
5-c	39	88	40	42	4	4	39	74	10	5	213
5-d	39	88	195	205	4	4	31	56	10	5	358
5-e	39	88	50	52	4	4	31	56	10	5	205
5-f	39	88	40	42	4	4	31	56	10	5	195
5-g	39	88	195	205	2	3	19	7	10	5	308
LMV ^(h)	39	88	195	205	2	3	10	7	10	5	308
5-h	39	88	50	52	2	3	17	7	10	5	155
LMV	39	88	50	52	2	3	8	7	10	5	155
5-i	39	88	40	42	2	3	28	7	10	5	145
LMV	39	88	40	42	2	3	19	7	10	5	145
5-j	39	88	195	205	2	<<1	21	7	10	5	305
5-k	39	88	50	52	2	<<1	19	7	10	5	152
5-l	39	88	40	42	2	<<1	30	7	10	5	142
6	39	44	195	102	2	<<1	NI	NI	10	1	147+NI

(a) Total estimated operations-related exposure to whole body for duration of operations.

(b) Surveillance personnel for 10 yr for Alternative 4, 20 yr for Alternative 6, and 100 yr for Alternatives 1, 2, and 5.

(c) N/A = Not applicable.

(d) Covering, grouting and immobilization personnel working for 2 yr.

(e) < = Less than.

(f) << = Much less than.

(g) NI = Not included in this estimate (applies to Federal Repository workers).

(h) LMV = Use of less massive variation of engineered shallow-land disposal at Site 14.

workers in operations for waste retrieval and for slagging pyrolysis. All normal operational doses would be expected to be well below the standard of 5 rem/yr.

A number of potential accidents were considered for their radiological effects on the workers. It was concluded that, by use of suitable equipment and by adherence to safe operating procedures, the hazard from radiological accidents could be controlled to within normally accepted levels.

2.9 COSTS OF ALTERNATIVES

Cost estimates for the alternatives and concepts studied are summarized in Table 2-10. All estimates are based on 1978 dollars. Included are capital costs, operating and maintenance (O&M) costs, and costs for D&D of facilities. Some of the indirect capital costs, such as site characterization and environmental preparation, are not included. Where applicable, the costs of shipping the waste to the Federal Repository (or to any other disposal site studied) and of long-term management of the waste at the Federal Repository are included. The latter cost was assumed to be applied as a one-time acceptance cost upon receipt of the waste at the Federal Repository. Although the cost would not be assessed in this manner, the item was included here in the interest of presenting more complete estimates.

The cost estimates are not considered budgetary cost estimates, because they are based on the limited amount of preconceptual design performed during the study. The estimates have large associated uncertainties. No positive statement of the uncertainties can be given. However, experience indicates that uncertainties of as much as a factor of two are not unusual in this type of estimate. Despite the uncertainty, the cost estimates are useful for comparisons of alternatives and concepts.

TABLE 2-10

SUMMARY OF ESTIMATED COSTS(a)

Alter- native or Concept	Capital Cost	Total O&M Cost	Shipment Costs		Cost at Federal Reposi- tory	D&D Cost	Total Cost
			Onsite	Offsite			
1	0.1	60	N/A(b)	N/A	N/A	N/A	60
2-a	1.0	60	N/A	N/A	N/A	N/A	61
2-b	2.9	60	N/A	N/A	N/A	N/A	63
2-c	11.3	60	N/A	N/A	N/A	N/A	71
3	136	135	N/A	9	77	14	371
4	140	149	0.4	9	77	14	389
5-a	161	201	0.5	N/A	N/A	14	377
5-b	106	119	0.9	N/A	N/A	8	234
5-c	95	135	0.5	N/A	N/A	7	238
5-d	161	201	0.7	N/A	N/A	14	377
5-e	106	119	1.1	N/A	N/A	8	234
5-f	96	135	0.6	N/A	N/A	7	239
5-g	295	203	0.5	N/A	N/A	14	513
LMV(c)	155	199	0.5	N/A	N/A	14	369
5-h	211	121	0.7	N/A	N/A	8	341
LMV	102	117	0.7	N/A	N/A	8	228
5-i	420	139	0.5	N/A	N/A	7	567
LMV	107	135	0.5	N/A	N/A	7	250
5-j	227	204	0.4	N/A	N/A	14	445
5-k	176	122	0.5	N/A	N/A	8	307
5-l	329	140	0.4	N/A	N/A	7	476
6	136	147	N/A	9	77	14	383

(a) All costs are in millions of mid-July 1978 dollars.

(b) N/A = Not Applicable.

(c) LMV identifies the use of the less massive variation of the engineered shallow-land disposal facility at Site 14.

Table 2-10 indicates that the lowest costs would be associated with Alternatives 1 and 2, ranging from \$60 million to \$71 million. The cost to retrieve and process the waste and to ship it to the Federal Repository and dispose of it there would range from \$371 million to \$389 million (Alternatives 3, 4, and 6). The range of costs reflects the impact of a 20-yr delay, but it does not include the effects of inflation. The cost of retrieval, processing, and onsite disposal would range from \$228 million to \$567 million, depending on the methods of processing and of disposal.

2.10 COMPARISONS

The alternatives and concepts studied for long-term management of the stored TRU waste were compared on the basis of environmental effects, risk to the public, hazards to workers, costs, and other factors. Competing modules (e.g., slagging pyrolysis versus compaction and immobilization) were also compared.

The results of the comparisons are discussed in Section 17. Because Section 17 is not lengthy, and because the discussion of comparisons could not readily be abridged without hazard of misinterpretation, that discussion is not summarized here. Therefore, the reader is referred to Section 17 for the full text of the comparisons.

3. PRESENT ENVIRONMENT OF THE INEL (INCLUDING RWMC, SITE 14, AND LEMHI RANGE)

The environmental setting of the alternative disposal sites studied for long-term management of TRU waste stored at the INEL is described in this section. The four disposal sites, i.e., RWMC (present location of the waste), Site 14, and the two sites in the Lemhi Range, are within the INEL boundaries. General descriptions of the environmental characteristics of the INEL are given in the following subsections. Where there are local differences among these locations within the INEL, the differences are described. However, the information is preliminary, and the exact facility locations at Site 14 and the Lemhi Range have not yet been determined. Local variations may result in slightly different environments from those described here. Detailed studies and exploration to determine the geologic and hydrologic characteristics of Site 14 and the Lemhi Range sites would be required before implementation.

3.1 GEOGRAPHICAL SETTING

The INEL is located at the foot of the Lost River, Lemhi, and Beaverhead mountain ranges along the western edge of the Eastern Snake River Plain in southeastern Idaho. Most of the INEL lies in Butte County, although it also extends into Bingham, Bonneville, Jefferson, and Clark counties. The relative location of the INEL within Idaho is shown in the upper left corner of Figure 3-1.

The four sites within the INEL are also identified on Figure 3-1. The Lemhi Range sites are located at the northwest edge of the INEL at the base of the Lemhi Mountain Range; Site 14 is located in the central area of the INEL; and the RWMC is located in the southwestern part of the INEL.

Fig. 3-1 Location and principal features of the INEL.

3.2 TOPOGRAPHY

The Eastern Snake River Plain is relatively flat, with an average elevation of 4900 ft above mean sea level (MSL). Within the INEL, elevations generally range from 4750 ft to 5200 ft (See Figure 3-2). Exceptions include the Twin Buttes in the southeastern part of the INEL and the Lemhi Mountain Range, which extends into the northwestern area of INEL. The Twin Buttes reach an elevation of approximately 6400 ft, and the Lemhi Range within the INEL reaches a maximum elevation of approximately 6300 ft.

Most of the INEL slopes slightly toward the northeast (see Figure 3-2). A broad topographic ridge extends from the twin buttes in a northward direction through the INEL. This ridge effectively separates the drainage of the mountain ranges on the north and west of the INEL from the Snake River, which flows from north to south on the eastern edge of the plain. Natural drainage on the INEL is to the four playas in the northwestern part of the INEL (see Sub-section 3.5).

The RWMC has an average elevation of about 5000 ft above MSL and slopes to the northeast. Site 14 has an average elevation of approximately 4800 ft and slopes to the northwest. The Lemhi Range sites are located at elevations of approximately 5300 ft (tunnel access) and 4950 ft (shaft access).

3.3 CLIMATE AND METEOROLOGY (Yanskey, Marker, and Richter 1966)^(a)

The National Oceanic and Atmospheric Administration (NOAA) has operated a meteorological observation program at the INEL since 1949. In addition to recording day-to-day weather data and providing daily

(a) The referenced report (Yanskey, Marker, and Richter 1966) covers the time period from 1954 to 1966. Data since 1966 have been collected and will be incorporated in a report to be published in 1979.

Fig. 3-2 Topographic map of the INEL.

operational forecasts for the INEL, the NOAA staff maintains an extensive research and development (R&D) program to improve the reliability of prediction and measurement of meteorological parameters that influence operations on the INEL. A number of meteorological stations are located throughout the INEL to measure simultaneously the variation of several meteorological parameters, such as temperature, wind speed, and wind direction, up to a height of 250 ft above the ground.

The climate at the INEL is semiarid, with steppe characteristics. The topographic features that affect the INEL weather patterns are the northeast-southwest orientation of the plain and the mountain ranges to the north and west.

The orientation of the plain on which the INEL is situated and the trend of the mountain-ranges tend to channel the prevailing west winds of this latitude so that a southwest to northeast flow near the surface predominates over most of the INEL. Air masses entering the Snake River Plain first must cross mountain barriers, where a large percentage of air moisture is precipitated. Annual rainfall at the INEL is therefore light.

Meteorological and climatological data summarized in this section are from NOAA's monitoring program and include: temperature, wind, precipitation, evaporation, relative humidity, and severe weather conditions.

3.3.1 Temperature. During the 22-yr period of record, the extremes of temperatures have varied from a low of -43°F in January to a high of 103°F in July. During winter the average maximum temperature is approximately 27°F , with an average minimum of approximately 3°F . The summer data indicate an average maximum temperature of 87°F and an average minimum of about 50°F . Normal weather at the INEL includes adiabatic lapse conditions (temperature decrease with height) during daylight hours and inversion conditions (temperature increase with height) from about sunset until shortly after sunrise. Winds and clouds associated with stormy weather may prevent

nighttime inversion. Daytime inversions may occur during the season of lowest sun angle (winter), and later if snow cover exists. Annual averages show lapse conditions 52% of the time and inversion conditions 48% of the time.

3.3.2 Wind. The INEL is in a belt of prevailing westerly winds, which locally are channeled by topography into a prevailing southwest to northeast direction. During the summer months a very sharp diurnal reversal in wind direction occurs. Winds blowing from the southwest (upslope) predominate during daylight hours, and northeasterly winds persist at night. The reversal normally occurs a few hours after sunrise and again shortly after sunset.

Wind roses (Figure 3-3) are recorded at the Central Facilities Area (CFA) in the southern portion of the INEL, approximately 5 miles northeast of the RWMC. The wind roses indicate the percentage of time that the wind blows from a given direction and the associated wind speeds. The wind roses are similar for the four seasons. However, there is a fundamental difference between the winds in winter and in the other three seasons. Winter winds are controlled almost exclusively by either large-scale weather systems or by stagnation, and show no significant diurnal characteristics. Winds in the other three seasons show diurnal characteristics in response to relatively strong local buoyancy forces resulting from heating of the ground. The absence of mountain-valley wind circulation in winter allows a high frequency of calms during periods of high atmospheric pressure.

The average hourly windspeed is a minimum of about 5 mph in December and a maximum of 9 mph in April and May. The highest maximum hourly-average speed was 51 mph (measured at the 20-ft level at the CFA) from the west-southwest. Calm conditions prevail 11% of the time.

Strong wind gusts can occur in the immediate vicinity of thunderstorms. These gusts are usually quite localized and of short duration. The highest instantaneous speed recorded at 20 ft above the ground at CFA was 78 mph from the west-southwest.

Fig. 3-3 INEL Central Facilities Area (CFA) 20-ft-level wind roses (January 1950-May 1962).

3.3.3 Precipitation. The average annual precipitation at the INEL is 8.5 in. Maximum precipitation occurs during May and June and the minimum in July. There have been 13 occurrences of 1.0 in. of rain or more in a 24-hr period during the 22 yr of record. The greatest was 1.73 in. in June 1954. Only once has more than 0.5 in. of rain fallen in 1 hr. That was 1.19 in. in 1 hr on June 10, 1969. Snowfall ranges from a low of about 12 in./yr to a high of about 45 in./yr. The average annual snowfall of 28.5 in. occurs primarily during November through April, although snow occasionally falls during May, June, September, and October.

3.3.4 Evaporation. The potential annual evaporation from a saturated ground surface at the INEL is approximately 36 in. During the warmest month, the potential daily rate is approximately 0.25 in. During the coldest months evaporation is small and may be insignificant. Actual evaporation rates are much lower than potential rates because the ground surface is rarely saturated. Evapotranspiration by the sparse native vegetation of the Snake River Plain is estimated at 6 to 9 in./yr. Times when the greatest quantity of precipitation water is available for infiltration (late-winter to spring rain or snow) coincide with times of relatively low evapotranspiration rates (Mundorff, Crosthwaite, and Kilburn 1964).

3.3.5 Relative Humidity. The relative humidity at the INEL ranges from a monthly average minimum of 15% in August to a monthly average maximum of 89% in February and December. On a daily basis, humidity reaches a maximum just before sunrise at a time of minimum temperature, and reaches a minimum late in the afternoon near the time of maximum temperature. Large variations in relative humidity occur as a result of summer thunderstorms and large-scale storms, which occur predominantly from late fall through spring.

3.3.6 Severe Weather Conditions. On the average, two or three thunderstorm days occur during each of the months from June through August. The surface effects from thunderstorms over the Snake River Plain are usually much less severe than are experienced east of the

Rocky Mountains or even in the mountains surrounding the plain. Although small hail frequently accompanies the thunderstorms, damage from hail has not occurred at the INEL.

Ten funnel clouds (vortex clouds that do not reach the ground) and two tornadoes (which caused no damage) have been documented at the INEL since 1954.

3.4 GEOLOGY AND SEISMOLOGY (ERDA 1977c, DOE 1978a, and Kuntz 1978)

3.4.1 The INEL. The Snake River Plain cuts a 50- to 100-mile-wide swath through the Rocky Mountains across the State of Idaho. The 12,000-ft-high peaks of the adjacent snow-tipped mountains are a sharp contrast to the plain that rises gently from 2,300 ft in the west to 6,000 ft in the east. Bordering ranges consist of Paleozoic and Mesozoic rocks folded and intruded and later uplifted along normal faults during Basin and Range tectonism. These ranges terminate abruptly against both sides of the low-lying basalt- and sediment-filled Snake River Plain. A generalized geologic map of the Eastern Snake River Plain is shown in Figure 3-4. A map of INEL soils is shown in Figure 3-5 and described in Table 3-1.

Except for small areas along the mountain fronts and three rhyolite domes, all of which are $500,000 \pm 200,000$ yr old, the entire INEL area is underlain by a succession of Pliocene, Pleistocene, and Recent basaltic lava flows. The basalt was formed chiefly from fluid (low viscosity--approximately 1 poise), high temperature (1652 to 2282°F), pahoehoe-type lavas. The flows have been extruded from rifts and from volcanoes whose locations are rift-controlled. The flows form layers of hard rock whose thickness varies from 10 to 100 ft. The physical characteristics and horizontal distribution of the flows also vary. Unconsolidated material, cinders, and breccia are interbedded with the basalt. The beds are nearly horizontal, with no significant structural deformation evident. The approximately 6 mile-wide Arco Rift Zone extends 30 miles southeastward from the north margin of the Snake River Plain at Arco to the longitudinal axis of the plain near Atomic City. The Arco Rift Zone is the locus

Fig. 3-4 Generalized geologic map of the eastern Snake River Plain, Idaho and vicinity.

TABLE 3-1

CLASSIFICATION OF SOILS ON THE INEL
BY MAPPING UNITS (SEE FIGURE 3-5)

Mapping Unit	Description
B1, B2, B3, B4, B5, B6, B8, B9C, B10J, C1, C3	Thin loam over deep sands and gravels with low water-holding capacity (surface glacial till underlying surface loam) and limestone alluvium.
E1, E2, E3, E4, E5, E6J, E7J, E8J	Sandy loams derived largely from aeolian sands. Strongly calcareous including cemented calcium carbonates. Overlies basalt rock. Low water-holding capacity and stony to rocky (north of INEL).
F1	Playas in the sinks area. Clay loam over low permeability clay at root zone. Strongly calcareous.
F2, F3, F4, F5, F6, F7	Similar to F1 with high sodic alkalinity.
G	Irrigation limitations slight. Soil is deep, well drained, laminated clay loam. Moderately calcareous. Slightly sodic. (Lacustrine sediments in a playa east and south of Howe.)
H, HJ	Sandy loam surface, low permeability clay at root zone. Sand dunes in places. (At north end of the Big Lost River flood plain continuing to Mud Lake including remnants of prehistoric Lake Terreton.)
L1, L10Bi, L11Bi	Very shallow soils, very steep slopes, very rocky, mixed geologic materials of hills and mountains.
W2, W3, W4, W5, W7, W8, W9, W11Bi, W12B	Thin loess-covered basalt plains on western border of INEL. Small areas surrounded by bare basalt. Stoniness to rockiness.
W10, W13J, W14Bi	Similar to the other W mapping unit soils, however, more rockiness.
Z1, Z2, Z3	Stream bottoms of the Big Lost River on the INEL. Moderate depth of soil and moderate water-holding capacity. In some areas the soil is shallow and has low water-holding capacity.
Z4, Z5	Lower alluvial plains of the Little Lost River. Only slight limitations in these soils.

of extensional fractures, a graben structure, rifts, and numerous basalt volcanoes. The youngest basalt flows in the Arco Rift Zone are approximately 10,500 to 12,000 yr old. It is inferred that these basalt rocks are underlain by geologically older volcanic and sedimentary rocks, perhaps ranging from Cambrian to Tertiary ages. Rhyolitic volcanic rocks, ranging in age from approximately 4 million to 10 million yr, are exposed along the north and south margins of the eastern Snake River Plain. These rocks are presumed to underlie basalt beneath the INEL. The most recent volcanic activity in the region occurred at the present site of the Craters of the Moon National Monument, approximately 25 miles southwest of the INEL, about 1,500 to 2,000 yr ago. This area lies outside the Arco Rift Zone.

The U.S. Geological Survey (USGS) conducted a microearthquake study in 1968-1969 to determine whether the Arco or Howe faults, located a few miles from the INEL boundary, or possibly other faults in the region are sources of microearthquakes. No seismic activity was detected in the vicinity of the INEL. However, the absence of microearthquakes does not eliminate the possibility that the earth's crust in this region contains stored elastic strain. Such strain might be released, by slippage along a dormant fault, to produce an earthquake.

Since October 1972, three vertical-motion recording seismographs have been in operation. This seismograph network is capable of detecting microseisms from strain accumulation along faults in the mountains. It will also detect any microseisms that would precede a resumption of volcanism on the eastern Snake River Plain. To date, the seismic network has detected microseisms occurring in adjacent mountains and distant locations. However, no seismic activity has been identified as originating beneath the INEL.

Additional discussion concerning seismic activity at the INEL is presented in Subsection 13.4.2.1.3.

3.4.2 The RWMC. At the RWMC, the depth of the surface soil ranges from 3 to 25 ft. The average depth is about 15 ft. Beneath the surficial sedimentary layer are successive layers of basalt and sedimentary deposits. Figure 3-6 shows a typical geologic cross section through the RWMC.

The RWMC lies at the edge of the Arco Rift Zone. Although the most recent basalt flows occurred in this zone from 10,500 to 12,000 yr ago, the basalt flows at the actual location of the RWMC are older. The ages of these flows have been estimated at $200,000 \pm 100,000$ yr and $40,000 \pm 20,000$ yr (EG&G 1977). A study to determine the recurrence interval of the basalt flows at the RWMC is currently being conducted by the USGS. The study is scheduled to be completed by July 1979.

3.4.3 Site 14. Site 14 is the designation given to an area located in the approximate center of the INEL. The geology of this site has been investigated briefly by boring shallow test holes and drilling one test well. Although drilling in the area has been limited, Figure 3-7 shows the expected geology. There is an area of at least 7 square miles where surface sediments may be greater than 100 ft thick. The test well showed upper sediments extending down 332 ft. Much of this upper sediment zone contains silt and clay with good ion exchange properties. Such sediments would be relatively effective in adsorbing and retaining radionuclides. Because of this large sedimentary deposit, Site 14 was selected for further investigations for waste disposal operations.

Site 14 is located within 2 miles of a postulated volcanic rift zone. Volcanic eruptions near Site 14 have not occurred in over 100,000 yr.

3.4.4 Lemhi Range. The northern portion of the INEL includes a small part of the Lemhi Mountain Range. This range forms part of the northern extension of the Basin and Range physiographic province. It is over 50 miles long and, for the most part, is composed of Paleozoic

Fig. 3-6 Geologic cross section north to south through the RWMC.

Fig. 3-7 East-west cross section of subsurface strata across Site 14.

calcareous rocks. This range runs NW-SE; only the southeastern-most extension of the range is part of the INEL. This is the only part of the INEL that does not lie on the Snake River Plain.

On the eastern side of the INEL portion of the Lemhi Range are Pleistocene (less than one million years old) basalts, and Recent (less than 10 thousand years old) windblown, alluvial, playa, and lake bed deposits, as shown in Detail A of Figure 3-4. In the upper reaches of the gullies, this material is coarse enough to be characterized as talus. This alluvial material may be 50 ft or more thick in places. At elevations higher than about 5000 to 5200 ft above MSL, silicic volcanic rocks are exposed. These rocks, probably Miocene (11 million to 25 million years old), are primarily welded tuff, but include some ash beds and rhyolite flows. The contact between the volcanics and the sedimentary rocks is very irregular, but generally occurs within one mile of the INEL boundary in this portion of the Lemhi Range. This contact, as well as the sedimentary rocks, strikes north-northwest and dips $40-45^{\circ}$ to the east. The strike is parallel to the main trend of the range as a whole. To the south of this portion of the Lemhi Range on the INEL, the alluvium lies directly upon the calcareous rocks without any intervening silicic volcanic outcrops.

The sedimentary rocks represent the Carboniferous period (270 million to 350 million years old). Within the INEL, the exposed rocks are primarily fossiliferous, massively bedded limestone. To the north and west of the INEL boundary, this lithic sequence includes some thick beds of dolomite and some quartzite layers. There is also some thin interbedded shale. These rocks presumably underlie the limestone exposed within the INEL portion of the Lemhi Range, although at exactly what depth is uncertain.

Two Lemhi Range sites were chosen for: (1) deep rock disposal with shaft access, and (2) deep rock disposal with tunnel access. The shaft entrances have been preliminarily located on a limestone outcrop. Because the Carboniferous deposits are many thousands of feet thick, a shaft of any reasonable depth at this location would be

entirely in these rocks. The tunnel entrances are located in the silicic volcanic rock. From the location of the surface contact, it is estimated that the tunnels would pass from the volcanic rocks into the limestone near the midpoint of the tunnels.

The rift zones on the Snake River Plain appear to be extensions of the range-front faults in the adjoining mountains. This suggests that the basin and range structures continue beneath the plain. Tectonic development in the plain, however, is expressed in the form of volcanic rift zones and associated eruptions. In the Lemhi Range, tectonic development is expressed generally in the form of range front faults. Therefore, volcanism would not be as likely in the Lemhi Range as on the Snake River Plain.

The Lemhi Range is bordered by fault zones along both sides, and the range is terminated by the fault or hinge zone that marks the northern boundary of the Snake River Plain. None of these zones have been located exactly in this area. Based on field evidence and the age of the faulted structure, the last fault movement in the Lemhi Range is postulated to have occurred between 4,000 and 30,000 yr ago (Malde 1971). The surface evidence indicates that the limestone near the volcanic contact has not been significantly faulted since the volcanic rocks were emplaced.

3.5 HYDROLOGY (ERDA 1977c, EG&G 1977, and DOE 1978a)

3.5.1 The INEL. Surface water at the INEL consists mainly of three streams draining through intermountain valleys - Big Lost River, Little Lost River, and Birch Creek. These three drainages terminate in the four playas in the north-central part of the INEL (Figure 3-8). No surface streams exit the INEL.

Except for evaporation losses, all flow of the Big Lost River entering the Snake River Plain is recharged to the subsurface. Recharge effects from the Big Lost River are very pronounced in the Snake River Plain Aquifer and in the perched water beneath the river.

Fig. 3-8 Map of the INEL showing river systems.

The Snake River Plain Aquifer is approximately 200 miles long by 30 to 60 miles wide. Groundwater flow lines for the aquifer are depicted in Figure 3-9. The aquifer is composed of thin basalt flows with interbedded layers of sediments. Most of the aquifer permeability occurs along the upper and lower edges of the basaltic flows, which have large irregular fracture fissures and other voids. The aquifer thickness is not known, because no wells have been drilled deep enough to pass through it. Most evidence indicates that the aquifer is between 1,000 and 5,000 ft thick in the INEL region. The depth to the aquifer under the INEL varies from 200 ft in the northeast corner to 900 ft in the southwest corner. Average flow rates in the aquifer are difficult to assess. Tracer studies at the INEL indicate natural flow rates in the range of 5 to 20 ft/day, with an average near 10 ft/day. However, these local measurements are not necessarily representative of velocities throughout the aquifer.

As shown in Figure 3-9, groundwater flows generally southwest in the aquifer to the discharge areas. About 6,500,000 acre-ft are discharged by the aquifer annually into irrigation wells, into springs near Hagerman, and in a region west of Pocatello.

3.5.2 The RWMC. The most important element of the surface water hydrology near the RWMC is the Big Lost River. Its closest proximity to the RWMC is 2 miles to the northwest. A flood control system was constructed on the Big Lost River in 1958. This system consists of earth-filled embankments, which can divert part of the flow of the river near the southwestern corner of the INEL (see Figure 3-8). During flooding, flow is diverted to the spreading area.

The largest flood since construction of the system was in 1965. During this flood, the entire spreading area was not utilized. If an exceptionally large flood were to occur, water would leave the spreading area over a weir and flow out of the INEL. The U.S. Geological Survey has used mathematical models to project the effectiveness of

Fig. 3-9 Location of the INEL, the Snake River Plain, and generalized groundwater flowlines hypothesized for the Snake River Plain Aquifer.

the flood control system (Carrigan 1972). This analysis of streamflow data indicated that floods in the Big Lost River would overtop the diversion embankments about once every 55 yr on the average. If the capacity of the diversion channels to the spreading area were doubled, the diversion embankments would not be overtopped by a 300-yr flood (a flood with an expected return period of 300 yr).

In 1962 and 1969, local runoff led to the collection of surface water in depressions in the RWMC.^(a) Water from the runoff in February 1962 flooded Pits 2 and 3 and Trenches 24 and 25, all of which were open to receive additional waste. Immediately after this local flooding, dikes were constructed around the perimeter of the RWMC. In January 1969, large snow drifts tended to block the existing drainage system. Winter rains and thawing snow caused runoff from the local basin to overflow the old dike and flood Pit 10 and Trenches 48 and 49, which were open. As a result of this flood, a more extensive diking system was constructed to protect the RWMC from runoff in the local drainage basin. The improved dikes and ditches were designed to withstand a major local flood, even in the presence of deep snow drifts. The ditches are wide enough that large drifts can be cleared with heavy equipment. The pits, trenches, and diking system are shown on Figure 3-10.

In 1971, the RWMC was graded to provide drainage channels for surface water. An outlet pipe with a flap valve was placed through the dike in the northeast corner of the RWMC to allow surface water to flow outward and to prevent outside surface water from entering.

(a) Only the buried waste was flooded. Aboveground storage of TRU waste was not initiated until 1970.

Fig. 3-10 Plot plan of the Subsurface Disposal Area (SDA) showing pits, wells, and trenches.

The depth to the Snake River Plain Aquifer at the RWMC is approximately 580 ft. A geologic section of the RWMC, indicating the location of the aquifer and sedimentary layers vs depth from the surface, is shown in Figure 3-6. Zones of perched water exist above the aquifer at various locations within the INEL. Perched water has been found beneath the RWMC.

3.5.3 Site 14. The surface hydrology of Site 14 is typical of the INEL in general. The distance to the nearest surface drainage channel is approximately 5 miles. Although the elevation of Site 14 is lower than the RWMC, the potential for flooding is expected to be much less than at the RWMC.

During well drilling at Site 14, groundwater was encountered at a depth of 303 ft. However, basalt containing a large quantity of water was not encountered until a depth of about 490 ft was reached. The water in the well then rose to a depth of within 260 ft from the surface of the ground. This is the approximate depth of the regional water table in that area. These facts indicate that the sediments have invaded the basalts and reduced their permeability, forming a relatively impervious zone above the Snake River Plain Aquifer in the Site 14 area.

3.5.4 Lemhi Range. At elevations of approximately 4950 ft and 5300 ft, these sites are high enough to be safe from any flooding of the Big Lost River or Birch Creek.

Test wells have not been drilled in the area. This part of the INEL does not lie directly over the Snake River Plain Aquifer, but is believed to be hydrologically coupled to the aquifer. Some recharge to the aquifer occurs from groundwater flow in alluvial fan deposits extending from mountains surrounding the plain. In many instances, these alluvial fan deposits spread over the boundary of the plain itself.

3.6 ECOLOGY (ERDA 1977c, McBride et al 1978)

The type of soil, meager rainfall, and extended drouth periods limit the INEL vegetation to mainly sagebrush, perennial herbs, and a variety of grasses. Extensive surveys of INEL vegetation were carried out in 1952, 1958, and 1967 using 150 permanent transects established and maintained for this purpose (Harniss and West 1973). The results of this work were used to prepare a map of INEL vegetation types (Figure 3-11).

The INEL has only a few trees, located principally along the Big Lost River. The most prominent ground cover is a mixture of vegetation consisting of sagebrush (Artemesia tridentata), lanceleaf rabbitbrush (Crysothamnus viscidiflorus), and a variety of grasses. Approximately 80% of the station exhibits this type of ground cover.

Other types of vegetation found on the INEL are as follows:

- (a) Grasses: Agropyron spicatum (bluebunch wheatgrass), Hordeum jubatum, Sitanion hystrix, Oryzopsis hymenoides (Indian ricegrass), Stipa Agropyran smithii (bluestem wheatgrass), Agropyron cristatum (crested wheatgrass), Agropyron dasystachyun (thickspike wheatgrass), Agropyron deseriarun, Elymus cinereus (giant wildrye grass)
- (b) Shrubs: Atriplex confertifolia (shadscale), Chrysothamnus nauseosus (rubber rabbitbrush), Gutierrezia sarothrae (matchbush), Chambatiaria millefolium (fernbush), Tetradymia spinosa, Atriplex nuttallii (Nuttall's saltbush), Eurotia lanata (winterfat), Artemisia tripartika (three-tipped sagebrush), Atriplex talcata
- (c) Trees: Juniperus utahensis (juniper), Populus angustifolia (cottonwood), Salix sp. (willow), Juniperus osteosperma (juniper)

1. *Artemisia tridentata*/*Agropyron dasystachyum*
2. *Artemisia tridentata*/*Agropyron spicclum*/*Chrysothamus Viscidiflorus*
3. *Artemisia tridentata*/*Eruotia lanota*/*Chrysothamus Viscidiflorus*
4. *Artemisia tridentata*/*Sitanion hystrix*
5. *Artemisia tripartite*/*Agropyron spicatum*/*Chrysothamus Viscidiflorus*
6. *Juniperus osteosperma*/*Agropyron spicatum*
7. *Eurotia lanata* - *Atriplex flacata*
8. *Atriplex falcata*
9. *Eorotia lanata*
10. *Elymus cinereus*
11. *Agropyron smithii*
12. *Agropyron desertorum*
13. Playas
14. Recent lava flows

Fig. 3-11 Distribution of vegetation at the INEL (Harniss and West 1973).

- (d) Other: Opuntia polyacantha (prickly pear cactus), Rosa sp. (rose), Iva axillaris (poverty weed).

The vegetation of the INEL supports a variety of wildlife consisting mainly of small mammals, birds, reptiles, and a few large mammals. The small mammals include chipmunks, ground squirrels, several species of mice, kangaroo rats, pygmy rabbits, and jack-rabbits. The pronghorn antelope inhabits the INEL during the entire year. However, many of the antelope are migratory and winter south of the INEL and summer north of it. Antelope are occasionally born on the station in the spring as the herds move northward into Birch Creek valley. Coyotes and bobcats are seen frequently. Sage grouse and pheasants are the only resident game birds on the INEL; however, hunting is not permitted. In addition to raptors and other indigenous and introduced species of birds, some migrant species pass over the area. These include doves, larks, hawks, ducks, geese, and golden and bald eagles. The only endangered species occasionally observed at the INEL are the bald eagle and the peregrine falcon. The reptiles consist mainly of lizards and a few species of snakes.

Domestic sheep and cattle are allowed to graze on the perimeter areas of the INEL in the early spring and fall.

Aquatic life on the INEL is limited and depends mainly upon the flow of the Big Lost River. The riverbed is quite permeable. During several months of the year, and even during some entire years, the river does not flow. However, during spring runoff and periods of high rainfall, the diversion system (southern boundary of the site) and the Big Lost River Sinks (northern area of the site) support waterfowl during periods of water accumulation. This normally occurs less than two or three months in the spring, but, depending on annual conditions, water flow and accumulation may be sustained for several months. The small liquid waste disposal ponds at the Test Reactor Area (TRA) (see Figure 3-1) are also a habitat for a small number of water-seeking animals. These waters also attract various species of

ducks, the great blue heron, and a variety of smaller shore birds. Fish species observed in the Big Lost River on the INEL include rainbow trout, mountain whitefish, eastern brook trout, Kokanee salmon, and the shorthead sculpin (Overton, Grove, and Johnson 1976).

3.7 ARCHAEOLOGY (ERDA 1977c)

The INEL operating procedures prescribe measures for assuring protection of any antiquities or historic sites on the INEL, as required by the Antiquities Act of 1906 and the Historic Sites Act of 1936. These procedures are applied to avoid loss of archaeological and historical values found at the INEL. Archaeological surveys of the INEL were performed during 1967-1969 and again in 1970-1972. These surveys have disclosed evidence that man has been in the region of Eastern Idaho for perhaps 10,000 to 12,000 yr. The locating and surveying of sites and the preservation of antiquities are continuing.

Fossils of prehistoric mammals have been found in excavations at the INEL. It is postulated that the fossils are from camels and mastodons that inhabited the region during the latter part of the Pleistocene epoch about 35,000 yr ago. One fossil taken from carbonaceous strata encountered during well drilling at approximately 100 ft below land surface is over 40,000 yr old. Areas of special archaeological interest have been identified outside the west and northwest boundaries of the RWMC and in the vicinity of Site 14.

The State of Idaho Historic Preservation Officer and the State Archaeologist were contacted to determine the State's interest in the preservation of cultural resources and archeological findings at the INEL. The Idaho Historic Preservation Officer stated that, except for EBR-I, which is designated a National Historic Landmark, he knows of no other historic sites on the INEL worthy of preservation. The State Archaeologist recommended that, for each major construction project at the INEL, a consulting archaeologist be retained to evaluate and protect cultural resources unearthed. This is being

done. To protect any archaeological resources that may exist on the INEL, the Idaho Operations Office of the DOE, in complying with all appropriate federal regulations, has implemented a number of actions. These actions are summarized as follows:

- (a) Announced to all employees and contractors that collection, without permit, of archaeological items at INEL is prohibited by law.
- (b) In 1961 and 1962, assisted in issuance of permits by the Department of Interior (DOI) for archaeological surveys, excavations, and collections of archaeological resources by Idaho State University. These permits have been renewed.
- (c) Erected signs at the INEL warning against improper appropriation, excavation, injury to or destruction of ruins, monuments, or objects of antiquity.
- (d) Entered into an agreement with the National Park Service (NPS), through which the NPS has surveyed a construction area at the RWMC.
- (e) Stipulated in all construction contracts that if, in the course of excavations for structures, archaeological resources are uncovered, the work will be stopped until appropriate evaluations are made.

3.8 LAND USE

The various nuclear facilities and numerous support facilities use only a small percentage of the total INEL land area. The facilities are widely separated and were sited for maximum safety. Antelope and mammals roam the INEL freely. A large area of the INEL is used for grazing sheep in the spring and fall. Usage is controlled by

issuance of grazing permits. These areas are shown in Figure 3-12. However, grazing does not occur within 2 miles of any nuclear facility. Large mammals are excluded from the immediate facility areas by security fences.

3.9 POPULATION CHARACTERISTICS AND ECONOMIC SETTING

The nearest populated area to the INEL is Atomic City, located less than 1 mile from the southern INEL boundary, with about 25 residents. In 1970, the population residing within a 50-mile radius approximated 117,000 (U.S. Bureau of the Census 1973). The projected population is discussed in Subsection 12.4.7. The population distribution around the INEL, as a function of distance and direction, is shown in Figure 3-13. Figure 3-14 shows the location of the major population centers within a 50-mile radius of the Central Facilities Area of the INEL. Table 3-2 shows the population (U.S. Bureau of the Census 1973) of counties within a 50-mile radius of the INEL. Table 3-3 shows the number of people living in cities within these counties.

The growth characteristics of the cities and towns around the INEL are similar to those of the rest of the state. According to the "Idaho Economic Atlas", published by the Idaho Bureau of Mines and Geology, the trend has been migration from rural to urban areas (Caldwell 1970). The net result of migration trends near the INEL is movement away from the INEL boundaries and toward the cities of Idaho Falls, Blackfoot, and Pocatello. There is also movement toward some small towns outside the 30-mile radius and, in some instances, outside the 50-mile radius.

The population growth assumption used for this study (see Subsections 7.4.1.3 and 7.4.1.5) was a (geometric) growth rate of 1%/yr until the year 2085, with a constant population thereafter. This projection yields 50-mile radius populations of about 136,000, 150,000, 166,000, 183,000, and 367,000 in 1985, 1995, 2005, 2015, and 5, respectively.

Fig. 3-12 Permit grazing areas within the INEL.

Fig. 3-14 INEL vicinity map centered at the Central Facilities Area (CFA).

TABLE 3-2

COUNTY POPULATIONS WITHIN 50-MILE RADIUS OF CFA

<u>Counties</u>	<u>Population</u>
Bannock (a)	42,183
Bingham	23,474
Blaine	360
Bonneville	40,959
Butte	2,966
Clark	62
Custer	602
Jefferson	5,973
Lemhi	22
Power	221
TOTAL	<hr/> 116,822 ~ 117,000

Source: 1970 U. S. Census (U.S. Bureau of the Census 1973)

(a) Includes residents of the city of Pocatello, which is located just outside the 50-mile radius of the CFA.

TABLE 3-3

CITY POPULATIONS WITHIN 50-MILE RADIUS OF CFA
(Cities with Population over 300)

<u>Cities</u>	<u>Population</u>
Aberdeen	1,542
Ammon	2,553
Arco	1,244
Blackfoot	8,716
Chubbuck	2,927
Firth	362
Idaho Falls	35,776
Lewisville	468
Mackay	539
Menan	545
Pocatello (a)	38,826
Roberts	393
Shelley	2,674

Source: 1970 U. S. Census (U.S. Bureau of the Census 1973)

(a) Pocatello is located just outside the 50-mile radius of the CFA, but is included because part of the city lies within 50 miles of the RWMC.

The economy of the region is supported by the activities at the INEL. In June 1978, total INEL employment was approximately 9400 people, about 80% of whom were assigned to onsite activities. The remaining 20% are employed in support activities in Idaho Falls. Other major industries in the region include agriculture, food processing, tourism, and phosphate mining.

4. THE RWMC AND ITS OPERATIONS

4.1 HISTORY AND CURRENT LAYOUT

The Radioactive Waste Management Complex (RWMC) was established in 1952 in the southwest corner of the INEL, approximately 3.5 miles north of the INEL boundary. The RWMC was required for the disposal of solid radioactive waste originating from Atomic Energy Commission operations.

The RWMC was originally 13 acres in area. This was expanded to 88 acres in 1957 and to its present area of 144 acres in 1970. It presently consists of the Subsurface Disposal Area (SDA), the Transuranic Storage Area (TSA), and the Transuranic Disposal Area (TDA). The TDA is located within the boundaries of the SDA. These areas are shown in Figure 4-1. Support facilities within the RWMC include the Waste Volume Reduction Facility (WVRF) and the Decontamination Facility South (DFS).

The SDA covers approximately 88 acres and is surrounded by a wire fence. Until 1970, TRU waste (and beta-gamma waste) was buried here in pits and trenches.^(a) There is generally a minimum of 2 ft of soil below the waste and a minimum of 3 ft of soil over it. A 2-ft layer of compacted clay is being placed over the soil cover as protection against water intrusion. Most of the center lines of the trenches and boundaries of the pits are identified with brass data plates embedded in concrete markers.

(a) This buried waste is not the subject of this study. The buried waste is described here for perspective and to give the reader some background in past TRU waste management.

SDA - Subsurface Disposal Area
TDA - Transuranic Disposal Area
TSA - Transuranic Storage Area

Fig. 4-1 Layout of the Radioactive Waste Management Complex (RWMC).

The TSA is a 56-acre area, established in 1970 for 20-yr retrievable storage of waste contaminated with more than 10 nCi transuranic radionuclides per gram of waste. (This waste is the subject of this study.) The TSA is surrounded by a security fence and has an intrusion alarm system. Asphalt pads, approximately 150 by 700 ft, have been constructed. These pads slope toward the center and from one end to the other to facilitate drainage during waste emplacement. The runoff is monitored for radioactivity.

The TDA is a small area within the SDA, established in 1972 for surface disposal of waste containing less than 10 nCi transuranic activity per gram of waste. (TRU waste containing more than 10 nCi/g activity is stored on the TSA.) The TDA uses existing space within the SDA that is not suitable for subsurface disposal because of near-surface basalt outcroppings. An asphalt pad was constructed at this location. Waste containers are stacked on the pad and covered with soil. The low-activity TRU waste is considered to be disposed. The management of this waste is not within the scope of the current study.

There are two additional waste management areas within the RWMC. One area, within the SDA, is currently used for disposal of beta-gamma waste. This waste is not intermixed with TRU waste. The other area, within the TSA, consists of a number of storage vaults for transuranic waste having radiation levels that preclude direct handling. A relatively small quantity of this type of waste (termed intermediate-level transuranic waste) is present. Management of both these types of waste lies outside the scope of this study. A limited amount of TRU-contaminated waste is stored elsewhere at the INEL (Argonne National Laboratory-West). (See ERDA 1977c, p II-163-179.) Management of this waste is also outside the scope of this study.

4.2 OPERATIONS FOR MANAGING TRU WASTE

Since 1954, TRU waste has been received at the RWMC, primarily from the Rocky Flats operation near Golden, Colorado. TRU waste has also been received from INEL facilities and other DOE-sponsored facilities, such as Mound Laboratory, Bettis Atomic Power Laboratory, and Argonne National Laboratory. A limited amount of waste (predominantly nontransuranic) was received through 1964 from sources such as universities, hospitals, and private research foundations.

Changes in waste management practices at the RWMC have occurred over the years. Early shipments (1954 to 1957) of TRU waste were buried with INEL beta-gamma waste in SDA trenches. As the volume of TRU waste received from Rocky Flats and other offsite sources increased, the use of SDA pits for burial was begun. From 1958 to November 1963, waste containers were stacked in the pits. In November 1963, dumping of the waste into pits was begun. Dumping was continued until 1969, when the receipt of waste again increased. At that time, the policy of stacking the waste in the pits was reinstituted because of concern for container integrity and the need to conserve RWMC space. Since November 1970, when aboveground retrievable storage was started, TRU waste has been stored on the TSA. The TSA-stored waste is the subject of this study. (The buried waste is described for background only.)

TRU waste to be stored on the TSA is received in government-owned ATMX rail cars or commercial truck trailers. The waste is contained in 4 x 4 x 7-ft fiberglass-covered plywood boxes, 55-gal steel drums with polyethylene liners, or 4 x 5 x 6-ft steel bins, all of which are stacked on the asphalt pads. (Some of the waste placed earlier on the TSA was stored in containers of nonstandard sizes.) The containers are intended for 20-yr integrity. The containers are stacked in layers with a sheet of 1/2-in. plywood separating each layer. When a stack has reached a height of approximately 16 ft, a cover consisting of 5/8-in. plywood, nylon-reinforced polyvinyl sheeting, and about 3 ft of soil is emplaced. See Figure 4-2.

Fig. 4-2 Storage of transuranic waste on the TSA pads at the RMWC.

Until 1972, the plywood boxes placed on the TSA were not covered with fiberglass. Such boxes constitute approximately 25% of the boxes placed on the TSA through the end of 1977. Because boxes currently received are fiberglass-covered, it is estimated that, by 1985, this percentage will have been reduced to 15%. Similarly, until 1972, the steel drums placed on the TSA had no polyethylene liners. The 90-mil polyethelene liners provide additional containment for the TRU waste and additional assurance of container integrity for the 20-yr intended life. Such drums constitute about 44% of the drums on the TSA as of the end of 1977. Because drums currently received are lined, it is estimated that, by 1985, this percentage will have dropped to about 30%.

NOTE: The percentages given for the unlined drums represent an update of the corresponding percentages listed in the alternatives document for INEL TRU waste (DOE 1978a).

4.3 DESCRIPTION OF TRU WASTE

4.3.1 Physical Description. The TRU waste is composed of several categories: evaporator sludge; filter sludge; decontamination and decommissioning (D&D) materials (lumber, concrete, etc); laboratory equipment (fume hoods, glassware, etc.); process equipment (tanks, pumps, etc.); protective clothing; and maintenance tools. The waste may be hazardous chemically as well as radiologically. The buried waste, in particular, is suspected of containing toxic chemicals, pyrophoric materials, and other materials that present nonradiological hazards.

4.3.2 Volumes (DOE 1978a). The volumes of buried and stored TRU waste and of associated materials are summarized in Table 4-1. Estimates are given for both the volumes emplaced and the volumes at the time assumed for retrieval (1985). The volume of waste is based on

the size of the waste container shipped and not necessarily the volume of actual waste. The estimated uncertainties in the waste volumes range from 10% to 30%. The remainder of this subsection explains the entries in the table.

TABLE 4-1

SUMMARY OF APPROXIMATE VOLUMES OF TRU WASTE AND ASSOCIATED MATERIALS

<u>Waste</u>	<u>Total Emplaced, (ft³)</u>	<u>Inventory Projected to January 1, 1985 (ft³)</u>
Buried TRU Waste	2,200,000	2,000,000
Buried Beta-Gamma Waste (Intermixed With TRU Waste)	500,000	500,000
Contaminated Soil (Associated with Buried TRU Waste)	0	3,750,000
Stored TRU Waste	1,200,000 through December 31, 1977	2,000,000

Before 1970, TRU waste, totaling about 2,200,000 ft³, was buried in the SDA. Included were approximately 195,000 drums, 6000 boxes, and 13,000 cartons. Approximately 165,000 ft³ of the total buried waste has been retrieved in experimental projects. (The experimental retrieval projects are the In-Drum Retrieval (IDR) Project and the Early-Waste Retrieval (EWR) Project.) Thus, the volume of buried TRU waste has been reduced from the original 2,200,000 ft³ to 2,035,000 ft³, or approximately 2,000,000 ft³.

Of the buried waste, an estimated 9% is actually uranium waste--essentially free from transuranics. (About 2×10^5 Kg of U-238 and 1.3×10^2 Kg of U-235 are included in the buried waste. However, the activity is only about 67 Ci, or about 0.03% of the total activity of the buried TRU waste. In the stored waste, U-235 and U-238 comprise a fraction of less than 10^{-8} of the total activity.) Twenty-six percent of the buried waste is nitrate salts of low TRU content. Nitrate salts have a higher leachability and a greater potential than the TRU waste to migrate from the immediate burial location.

Before 1970, an estimated 500,000 ft³ of beta-gamma waste was buried in the SDA, along with the TRU waste.

Most of the cardboard cartons, wooden boxes, and metal drums originally containing the buried waste have deteriorated. Furthermore, some of the waste, such as large pieces of equipment, was buried without containers. As a result, some of the soil adjacent to the waste has become contaminated. If the buried TRU waste were retrieved, it is estimated that 3,750,000 ft³ of contaminated soil would require retrieval.^(a) The retrieval operations themselves would contribute to the increased volume of soil that would become contaminated.

The TRU waste received since 1970 (approximately 1,100,000 ft³ through the end of 1977) has been stored aboveground on the TSA. Through the end of 1977, an additional 100,000 ft³ of TRU waste had been stored on the TSA as a result of experimental projects for retrieving the buried TRU waste. The 1,200,000 ft³ of waste is

(a) The 3,750,000 ft³ of contaminated soil is based on experience from the Early Waste Retrieval (EWR) project. Experimental results indicated an approximate ratio of contaminated soil to waste of 1.5:1. Thus, $1.5 \times (2,000,000 \text{ ft}^3 \text{ of TRU waste} + 500,000 \text{ ft}^3 \text{ of beta-gamma waste}) = 3,750,000 \text{ ft}^3$ of contaminated soil.

stored in approximately 83,000 drums, 5000 boxes, and 170 bins. It is estimated that, by the beginning of 1985, about 2,000,000 ft³ of TRU waste will be in aboveground storage. Included in this total is the additional 65,000 ft³ from 1978 experimental retrieval projects. Waste projections beyond 1985 are discussed in Appendix C.

Beta-gamma waste, as such, is not mixed with the stored TRU waste. However, there are small quantities of beta-gamma emitting radionuclides in the stored waste. The radiation levels produced at the surface of the steel bins average 50 mR/hr. For drums, the average is 3 mR/hr; for boxes, about 1 mR/hr.

4.3.3 Radionuclide Content. Shown in Table 4-2 are the inventories of the principal radionuclides (on the basis of TRU content) of the buried and stored TRU waste. For buried waste, the data are listed both at the time of emplacement (1954 through 1970) and as decayed to 1985. For stored waste, values at the time of receipt are given for waste placed on the TSA through 1977 and for the total inventory projected to 1985. The estimates and calculations for the projected inventory take into account both radioactive decay and an assumption of increased waste compaction in the future by the waste generators.

No detailed listing is available for the quantities of radionuclides present in the beta-gamma waste that is intermixed with the buried TRU waste. Table 4-3 gives the distribution of beta-gamma radionuclides in the beta-gamma waste currently being disposed in the SDA (see the last paragraph of Subsection 4.1). This distribution is presented as an example of what the distribution might have been in the pre-1970 buried beta-gamma waste at the time of disposal. Decay adjustment of the distribution to 1985 is also given in Table 4-3.

TABLE 4-2

RADIONUCLIDE CONTENT OF BURIED AND STORED TRU WASTE

Transuranic Radionuclide	Half-Life(a), Years	Buried Waste(b)				Stored Waste			
		Emplaced		As of January 1, 1985		Emplaced (through Dec. 31, 1977)		As of January 1, 1985	
		Curies	Percent	Curies	Percent	Curies	Percent	Curies	Percent
Americium-241	458	48,007	18.98	46,548	37.06	45,740	26.90	133,284	31.91
Plutonium-238	86.4	571.4	0.22	462	0.37	16,120	9.48	44,223	10.59
Plutonium-239	24,390	21,043	8.32	19,789	15.76	11,720	6.89	34,230	8.19
Plutonium-240	6,580	4,860	1.92	4,564	3.63	2,856	1.68	8,071	1.93
Plutonium-241	13.2	178,425	70.55	54,234	43.18	91,940	54.08	194,092	46.46
Plutonium-242	379,000	0.2	<0.01	0.2	<0.01	0.2	<0.01	0.2	<0.01
Uranium-233	162,000	0.5	<0.01	0.5	<0.01	527	0.31	1,486	0.36
Curium-244	17.6	0	0	0	0	1,113	0.65	2,343	0.56
Total Radio- activity		252,907	100	125,598	100	170,016	100	417,729	100
Total Weight of TRU, g		381,000		356,900		280,116		787,140	
Total Waste Volume, ft ³		2,200,000		2,000,000		1,200,000		2,000,000	
Transuranic Activity, Ci/ft ³		0.115		0.063		0.14		0.21	

(a) Values are taken from the Radiological Health Handbook (Bureau of Radiological Health 1970).

(b) Does not include the beta-gamma waste present.

TABLE 4-3
ESTIMATED DISTRIBUTION OF RADIONUCLIDES
IN THE BETA-GAMMA WASTE

<u>RADIONUCLIDE</u>	<u>HALF-LIFE</u>	<u>% AT TIME OF DISPOSAL</u>	<u>% AT BEGIN- NING OF 1985</u>
Chromium-51	27.7 d(a)	49.9	0
Cobalt-60	5.27 yr(b)	19.8	50
Zirconium-95	64 d	6.9	0
Iron-59	44.6 d	5.8	0
Cobalt-58	70.8 d	5.6	0
Manganese-54	312.5 d	4.8	0
Zirconium-Niobium-95	64 d-3.5 d	1.8	0
Cerium-141	32.5 d	1.4	0
Ruthenium-103	39.4 d	0.5	0
Nickel-59	8 x 10 ⁴ yr	0.3	15
Cerium-144	284.4 d	0.2	0
Cesium-137	30.17 yr	0.2	10
Strontium-90	29 yr	0.2	10
Ruthenium-106	368 d	0.1	0
Others Identified	~3 yr	0.1	0
Mixed Activation Products	~5 yr	1.2	3
Mixed Fission Products	~30 yr	0.1	10
Unidentified Beta-Gamma	~3 yr	1.1	2
		100.0	100.0

(a) d = days

(b) yr = years

4.3.4 History of Waste Container Damage. There have been several incidents of TRU waste container damage during shipment to INEL and during handling of the waste containers at the RWMC. Container damage incidents during the TRU waste shipment are listed in Table 4-4. Incidents during waste handling at the RWMC are listed in Table 4-5. Only one incident led to release of contamination. No spread of contamination resulted.

4.4 RELATED CURRENT PROJECTS

4.4.1 RWMC Improvements. Several RWMC improvements have been proposed or are currently being implemented. The improvements include the addition of analytical facilities, improved utility and security systems, improved personnel radiation monitors, and a clay cover over the buried TRU waste.

4.4.2 Waste Processing R&D Studies. A study of waste incinerators with application to the buried TRU waste was completed in 1977 (FMC 1977). The objective of the incinerator study was to evaluate the available processes and to identify the one that appeared most promising for further study for processing the buried TRU waste. Most of the recommendations in the referenced study apply also to the stored TRU waste. Additional details of the study are given in Subsection B.4.2 of Appendix B.

Waste treatment by slagging pyrolysis was considered the most desirable method to process the buried waste before shipment to a federal repository. The major advantages of this incineration process are that it will accept waste as retrieved from the pits and trenches with minimum requirements for segregation of the waste, and that only minimal size reduction of the waste material is required.

Slagging pyrolysis was the only process found to meet or exceed all the processing and acceptance criteria specified in the incineration study (FMC 1977). Based on the FMC study and on the positive

TABLE 4-4

ACCIDENTS OR INCIDENTS(a) - OFFSITE SHIPMENTS TO RWMC

<u>Item</u>	<u>Date</u>	<u>Location</u>	<u>Incident Description</u>	<u>Effects</u>
(1)	3/25/70	Blackfoot, ID	Seal missing on a truck trailer.	Load intact, no other problem.
(2)	6/15/71	Unknown	Opened ATMX car, evidence of fire on piggyback trailer inside (charred wood). Not known if there were signs of fire on casks themselves.	No breach, no contamination or radiation release.
(3)	8/7/73	Blackfoot, ID	Derailment during switching of ATMX car.	No release, no apparent damage.
(4)	3/31/76 9/21/76	Unknown	Opened ATMX car, found evidence of hard bump: some wooden blocking was broken and 4-5 waste containers were dented.	No breach, no breakage.

(a) All incidents are reported to safety personnel. Reports are on file at DOE Health and Safety, Idaho Operations Office, Idaho Falls, Idaho.

TABLE 4-5

ACCIDENTS OR INCIDENTS - TRU WASTE HANDLING AT RWMC

<u>Item</u>	<u>Date</u>	<u>Incident Description</u>	<u>Effects</u>
(1)	12/14/72	Puncturing of barrel and inner liner from Rocky Flats. Barrel did not contain TRU waste.	No contamination.
(2)	7/9/75	Solid sewage sludge drum generated internal pressure causing bulging of the lid. Drums were repacked in overpack containers	No contamination.
(3)	1976	Partial drum penetration by fork-lift. No breach of inner liner.	No contamination.
(4)	1/9/78	Drum penetration by forklift; a small portion of contents were spilled onto the cargo container floor.	Small amount of local contamination. The contamination was immediately contained and the drum replaced in an overpack container. There was no airborne activity. After recontainment, the area was thoroughly surveyed, and no contamination was found.

results of formulating a slagging pyrolysis concept for treatment of buried TRU waste (Dodson, Hopper, and McCormack 1978; Kaiser Engineers 1977), this process was selected by the DOE for further development for treating the INEL TRU waste. The slagging pyrolysis process is described in Section 9.

The conceptual facility for slagging pyrolysis would involve application of existing technologies for use at the RWMC. However, special development studies would be required to ensure control of the radiological and chemical hazards in the INEL TRU waste. Because of these development needs and the decision to perform additional studies of the slagging pyrolysis process, a number of supportive R&D studies are underway. Considerable interaction with other DOE laboratories, as well as with commercial chemical and waste processing companies, is expected in the course of these studies.

The supportive R&D studies include an ongoing instrumentation development study concerned with monitoring and assaying waste input and effluents for curie content, fissile material content, radiation levels, and waste composition. Handling systems are being studied for waste inspection, transfer, size reduction, remote operation, packaging, and D&D. Components, such as refractory liners, waste-heat recovery systems for heating primary combustion air, and off-gas control systems, are being investigated. Studies are underway concerning slag characteristics (e.g., leach rates), incinerator input/output relationships for waste of varying compositions, and radionuclide behavior in the incinerator. Regulatory requirements and administrative guidelines are being investigated concerning radiological and environmental control.

4.4.3 TSA Reentry Studies (Bishoff 1978). To determine the degree of deterioration of stored TRU waste containers at TSA (with a 20-yr intended life), Cell 6 and Cell 1 (see Figure 3-10), were penetrated. Steel drums and plywood boxes, stored between 1970 and 1973, were removed. Air monitors indicated no release of airborne contaminants during the penetration.

There was free rust on the lids of some of the drums. Some drums showed signs of rust or corrosion on the lockrings. Generally, the drums that had been stored vertically had more rust than those stored horizontally. However, out of the 70 horizontal drums removed, two showed signs of bad rusting and corrosion. These two drums appeared to have leaked from the top. Neither drum had completely rusted through. Both drums contained evaporated salts from the Rocky Flats Plant. Nondestructive examination of the drums is planned to provide further information on which to base an estimate of drum longevity.

All plywood boxes, both with and without fiberglass covering, showed no significant signs of deterioration.

5. ENVIRONMENTAL EFFECTS FROM CURRENT OPERATIONS OF TRU WASTE MANAGEMENT

5.1 RADIOACTIVE EMISSIONS

TRU waste is received in Department of Transportation (DOT) containers and is monitored before shipment, during unloading operations, and while stored. This monitoring consists of direct radiation surveys, smears and swipes, and air monitoring during unloading and emplacement. The only TRU contamination identified to date resulted from incidents outside the normal operations (see Subsection 4.3.4) and from past flooding and possible wind resuspension (see Subsection 5.4).

The air at the RWMC is constantly monitored for radioactive emissions to ensure personnel safety. Six low volume air samplers (1 cfm) surround the SDA perimeter and provide a constant surveillance on radioactive emissions to the atmosphere. Four high-volume air samplers (10-40 cfm) are operated in the predominant wind paths from the areas where waste handling is conducted. Additional air monitors are currently being installed. The air filters are routinely collected and analyzed to determine the amount and type of activity present. The most recent monitoring report (Hedahl and Janke 1978) indicates that all measured concentrations of radionuclides in air were below standards for uncontrolled areas (ERDA 1977a).

5.2 AIR QUALITY

There are no major activities at the RWMC that seriously impact the local or regional air quality. The primary source of pollutants is from motor vehicle exhaust, combustion of fuel oils for heating, and nonradioactive dust from RWMC operations.

Airborne particulate matter has been routinely monitored at the RWMC since 1976. The annual average RWMC concentration of airborne particulate matter for 1977 is $77 \times 10^3 \text{ ng/m}^3$. (This average particulate concentration is normal for earth moving operations.) This compares with a 1977 average of $57 \times 10^3 \text{ ng/m}^3$ at the INEL boundaries and $50 \times 10^3 \text{ ng/m}^3$ at locations off the INEL in eastern Idaho. The EPA annual standard is $60 \times 10^3 \text{ ng/m}^3$ (40 CFR Part 50). Although the EPA standard is exceeded at the RWMC, the average concentration of airborne particulates at the INEL site boundaries is below the EPA standard.

5.3 SURFACE WATER

Surface water samples from rainfall or snowmelt (when present) are routinely collected (Hedahl and Janke 1978). Table 5-1 lists the results from analyses of the water samples taken in 1977. For the isotopes measured, the highest detected concentrations ranged from 1 to 5 orders of magnitude below the DOE standards for uncontrolled areas (ERDA 1977a). Gross alpha measurements were near the detection limits. Therefore, no additional analyses for plutonium or americium identification were made.

On two occasions (1962 and 1969), unusually rapid snow melting and rain caused local flooding at the RWMC. The flood water came in contact with buried TRU and other waste in partially filled pits and trenches. Low concentrations of contaminants were measured in the runoff water (e.g., $1 \times 10^{-2} \text{ nCi/ml}$ beta activity and $1 \times 10^{-4} \text{ nCi/ml}$ alpha activity). See Subsections 5.4 and 5.5 for further discussion.

5.4 GROUND SURFACE CONTAMINATION

Soil samples are currently collected at the surface and at 6 and 12 in. depths at 25 locations within the SDA. Soil samples are analyzed for plutonium, major gamma emitters, and, when indicated by gross alpha analysis, americium. The primary purpose of the surface

TABLE 5-1
1977 SURFACE WATER SAMPLING

Radio-isotope	Highest Concentrations Detected in Samples			DOE Standard for Uncontrolled Areas(a)
	Date	Location	Concentration (nCi/ml)	
Am-241	5-24-77	SDA	2.5×10^{-5}	4×10^{-3}
Ag-110m	5-20-77	SDA	6.0×10^{-7}	3×10^{-2}
Ce-141	5-24-77	TDA	5.6×10^{-5}	9×10^{-2}
Ce-144	5-24-77	TDA	2.9×10^{-4}	1×10^{-2}
Co-60	5-20-77	TDA	1.8×10^{-6}	5×10^{-2}
Cr-51	5-20-77	SDA	5.3×10^{-6}	2
Cs-134	6-12-77	TSA	1.9×10^{-6}	9×10^{-3}
Cs-137	5-24-77	TDA	1.0×10^{-4}	2×10^{-2}
K-40	5-20-77	TDA	1.5×10^{-4}	2×10^{-2}
Mn-54	5-20-77	SDA	1.4×10^{-6}	1×10^{-1}
Nb-95	5-24-77	TDA	5.7×10^{-4}	1×10^{-1}
Ra-226	5-20-77	SDA	4.7×10^{-6}	3×10^{-5}
Ru-103	5-24-77	TDA	1.4×10^{-4}	8×10^{-2}
Ru-106	6-12-77	TDA	3.0×10^{-5}	1×10^{-2}
Sb-125	5-20-77	TDA	6.2×10^{-6}	1×10^{-1}
Ta-128	5-20-77	Control(b)	1.1×10^{-5}	4×10^{-2}
Th-232	5-20-77	TDA	1.0×10^{-5}	2×10^{-3}
Zr-95	5-24-77	TDA	3.4×10^{-4}	6×10^{-2}

(a) Source: ERDAM-0524 (ERDA 1977a).

(b) The control sample was taken in the Big Lost River 2 miles from the RWMC.

soil analyses is to determine whether the past burial and current storage operations at the RWMC are contributing to plutonium contamination of the surface soil and, if so, to what degree.

Figure 5-1 shows the sampling locations and plutonium concentrations within the SDA for 1977. The soil samples show statistically significant plutonium content. The higher plutonium concentrations are located in the northeastern section of the SDA (the area of lowest elevation).

Plutonium and americium contamination levels in surface (0 - 5 cm) soils outside the RWMC are shown in Figure 5-2. Flooding in 1962 and 1969 (see Section 5.3) and wind transport appear to be the primary mechanisms that transported these nuclides out of the SDA. The contamination levels of plutonium drop off sharply with distance from the SDA. The maximum distances from the SDA perimeter at which concentrations of Am-241, Pu-239, and Pu-238 could be detected above background were approximately 8200, 7900, and 3300 ft, respectively, still well within the INEL boundary.

5.5 SUBSURFACE MIGRATION OF RADIONUCLIDES

Current practices at the RWMC are designed to minimize the possibility of subsurface migration of radionuclides. Drainage of surface water is being improved by grading and by adding 2 ft of compacted clay above the trenches and pits for buried waste. The sorptive capacity of the soil, plus that in the rock interstices, would minimize movement of contaminants to the regional aquifer 580 ft below, the nearest stock watering well 10 miles away, or the nearest private water supply 18 miles away. The visitors center at EBR-I (2 miles from the RWMC) is supplied with drinking water from a well. However, EBR-I is not in the aquifer flow path from the RWMC.

Radiochemical analyses of samples taken in subsurface sediment beds at the 110- and 240-ft depths and from the groundwater have shown instances of detectable contamination (Barracough et al. 1976). Of

Fig. 5-1 Soil sampling locations and plutonium concentrations in the Subsurface Disposal Area (SDA).

Fig. 5-2 Isopleths of contamination (nCi/m²) in surface soils near the Subsurface Disposal Area (SDA) in 1974.

the 58 sedimentary samples taken, 27 showed detectable radioactivity, but at levels detectable only by the most sensitive radiochemical methods. Because of the techniques inherent in the drilling operations, such levels could have arisen through contamination of the drilling cores from surface sources.

In 1975, drilling was conducted at two additional locations inside the RWMC, near the locations where earlier samples showed statistically positive quantities of waste nuclides. The object of this study was to use improved coring techniques and improved anticontamination measures to sample the sedimentary layers at the 110- and 240-ft levels for radionuclides. Analytical procedures of high sensitivity were used (Burgus and Maestes 1976) on samples taken from these sedimentary layers. The analysis showed no waste nuclide radioactivity. Because of the extensive measures taken in this study to minimize extraneous contamination of cores, high confidence is placed in the results.

Studies have recently been made of the migration of transuranics in the soil immediately below the RWMC (Humphrey and Tingey 1978). Most of the soil samples were taken from below Pit No. 2. (See Subsection 3.5.2, Figure 3-10). This pit was completely flooded in 1962 while it was still open. Flooding occurred again in 1969 before the most recent improvement in the diking system was completed and before emplacement of the clay cover was begun. These studies showed a maximum concentration of transuranic radionuclides of 1.1×10^{-8} Ci/g (11 nCi/g) of soil at a depth of about 4 in. below the bottom of the pit. One foot below the bottom of the pit (and still above the basalt), the concentration was smaller by a factor of about one hundred. Between this depth and the basalt, the sample concentrations ranged from about 1×10^{-12} Ci/g down to about 1×10^{-15} Ci/g, the approximate limit of reliable detection. Subsurface monitoring is continuing in order to detect any migration to the aquifer that might occur.

Although most of the transuranics in the waste are believed to be insoluble, the potential effects of water on the soluble portion were studied. Water entering the pits and trenches would leach out the soluble species of plutonium and americium. The dissolved transuranics would tend to be adsorbed by the sediment and basalt layers as they moved downward. Most of the adsorption would be expected to occur in the sedimentary layers. Experiments (Fried et al. 1976) using basalt from the INEL have shown that intrusion of radionuclides into the aquifer would also be minimized by retention in the basalt.

5.6 GROUNDWATER

The United States Geological Survey (USGS) and the Radiological and Environmental Sciences Laboratory (RESL) of the DOE monitor the Snake River Plain Aquifer. Chemical and radiological analyses are made of the groundwater samples from locations within the INEL and offsite. Groundwater level measurements and other hydrologic and geologic data are obtained for the aquifer and reported by the USGS.

Wells numbered 87 through 90, located around the periphery of the SDA, are shown in Figure 5-3. These wells are used to sample the aquifer at depths approximately 600 ft below the ground surface. Aquifer samples have also been drawn from the RWMC production well, and perched water samples from Well No. 92 (about 214 ft deep). Well No. 92 is located within the SDA. (See Figure 5-3).

The results of the sampling provide a record of the radionuclide content of the subsurface water in and around the RWMC. In studies conducted from 1972 to 1974, plutonium and americium were detected in aquifer samples drawn from Wells No. 87 through No. 90 (Barracough et al. 1976). Perched water samples (from Well No. 92) also indicated the presence of plutonium. Tests for the presence of americium were not conducted. All measured concentrations of americium (in the periphery wells) and plutonium were several orders of magnitude below the standards in ERDAM-0524 (ERDA 1977a) and the regulations of the

- ▲ RWMC Production Well
- Monitoring Wells

Fig. 5-3 Topographic map and well monitoring locations at the RWMC.

State of Idaho. In a 1975 study (Polzer, Percival, and Barraclough 1976), aquifer samples from the RWMC production well showed no positive indications of plutonium or americium. Samples drawn in 1976 (Dolenc and Janke 1977) and 1977 (Hedahl and Janke 1978) from all of these wells gave no positive indications of plutonium or americium.

Detectable tritium was present in very low concentrations in 1977 in all the water samples from three wells to the north and east of the SDA (Wells 87 and 90 and the production well). Tritium was not detected in any water sample from Well 88 but was detected in one sample from Well 89. The tritium is attributed to discharge from the Idaho Chemical Processing Plant (ICPP) and the Test Reactor Area (TRA), not from the RWMC (Hedahl and Janke 1978).

5.7 FLORA AND FAUNA

The loss of grazing or wildlife habitat as a consequence of current waste management facilities has a small effect on the fauna in the area. Some small rodents could burrow down to the buried wastes and ingest or spread contamination to the surface. However, this source of surface contamination is probably very small and is not distinguishable from the soil contamination attributed to past flooding at the RWMC (see Section 5.4). Predatory animals conceivably could consume contaminated rodents, but again the individual effect is probably very small.

Studies by RESL to investigate radionuclide uptake and movement within the RWMC ecosystem began in FY 1978. Selected animals are being implanted with thermoluminescent dosimeter (TLD) chips and ear tagged for recognition. (These procedures do not result in permanent damage to the animal.) Attempts are made to recapture as many animals as possible, so that the TLD chips can be analyzed by the RESL Dosimetry Laboratory.

Tissue sampling is underway mainly from small mammals trapped in the RWMC during the spring and summer months, when animal activity is highest. Bone, muscle, stomach, lung, and skin samples are collected, pooled, and analyzed for transuranic nuclides, Sr-90, and gamma-emitting isotopes. The objective is to determine buildup of radionuclides within these tissues and to estimate the role of small burrowing mammals in bringing transuranic, activation, and fission products to the surface. Preliminary results from these studies indicate that the concentrations of Pu-238, Pu-239, and Am-241 in deer mice tissues are low, with many of the samples near or below the minimum detection limit for the radionuclides. The results of the studies to date are summarized in Table 5-2.

Plant species growing in the RWMC are being identified and listed. Species are being analyzed for specific radioactive isotopes, which will provide information on plant uptake and possible transfer of radionuclides.

5.8 NONRADIOLOGICAL EFFECTS

Nonradiological effects include the impacts caused by: (1) earth moving operations at the RWMC (primarily dust and motor vehicle exhaust), (2) the commitment of land, and (3) the commitment of resources. Air quality impacts caused by the earth-moving operations are discussed in Section 5.2.

Storage and burial of TRU and beta-gamma waste at the RWMC preclude other uses of the land. However, final cover and protection methods have been postulated that will minimize the environmental impact resulting from the long-term commitment of this land area (see Subsections 12.2.5 and 12.3.5). Impacts due to the loss of wildlife habitat are discussed in Section 5.7.

The commitment of resources includes the construction materials for RWMC facilities and the use of oil and fuel for equipment and heating.

TABLE 5-2

Pu-238, Pu-239, Am-241 CONCENTRATIONS IN DEER MICE TISSUES COLLECTED NEAR THE INEL SUBSURFACE DISPOSAL AREA

	Pu-238		Pu-239		Am-241	
	Max	Avg $\pm$ SD ^(a)	Max	Avg $\pm$ SD	Max	Avg $\pm$ SD
pCi/g wet						
Perimeter transect (N = 14) ^(b)						
Hides	4.05	0.08 $\pm$ 0.16 ^(c)	25	0.63 $\pm$ 1.26 ^(c)	4.5	0.26 $\pm$ 0.29 ^(c)
Gastrointestinal Tract	40.5	0.05 $\pm$ 0.12 ^(c)	2,072	0.22 $\pm$ 0.51 ^(c)	274.0	0.09 $\pm$ 0.08 ^(c)
Lungs	0.05	BDL ^(d)	0.20	BDL	0.08	BDL
Carcass	0.07	0.01 $\pm$ 0.02	0.33	0.04 $\pm$ 0.09	0.08	0.02 $\pm$ 0.04
50 m north transect (N = 4)						
Hides	0.01	0.005 $\pm$ 0.005	0.14	0.06 $\pm$ 0.05	0.14	0.08 $\pm$ 0.05
Gastrointestinal Tract	0.09	0.02 $\pm$ 0.05	0.48	0.13 $\pm$ 0.23	0.59	0.14 $\pm$ 0.23
Lungs	BDL	BDL	0.11	0.05 $\pm$ 0.05	0.01	BDL
Carcass	BDL	BDL	0.02	0.01 $\pm$ 0.01	0.01	BDL
100 m northeast transect (N = 8)						
Hides	0.005	BDL	0.12	0.02 $\pm$ 0.04	0.58	0.10 $\pm$ 0.21
Gastrointestinal Tract	0.005	BDL	0.08	0.02 $\pm$ 0.03	0.32	0.06 $\pm$ 0.10
Lungs	0.05	BDL	0.17	BDL	0.05	BDL
Carcass	0.01	BDL	0.005	BDL	0.03	0.005 $\pm$ 0.010
350 m northeast transect (N = 8)						
Hides	0.001	BDL	0.03	0.01 $\pm$ 0.01	0.07	0.02 $\pm$ 0.02
Gastrointestinal Tract	0.001	BDL	0.02	0.010 $\pm$ 0.005	0.07	0.03 $\pm$ 0.03
Lungs	0.09	0.02 $\pm$ 0.03	5.7	0.17 $\pm$ 0.28	0.31	BDL
Carcass	0.001	BDL	0.001	BDL	0.01	0.005 $\pm$ 0.005

(a) SD = Standard Deviation

(b) N = Number of sampling locations. Tissue samples from each location were composites from an average of 9.5 mice.

(c) Sample with maximum concentration not included in average.

(d) BDL = At least one-half of the samples were below detection limits.

6. EFFECTS OF CURRENT TRU WASTE MANAGEMENT ON THE WORKERS AND ON THE PUBLIC

6.1 RADIOLOGICAL DOSE TO WORKERS

6.1.1 External. The work force for storage and disposal operations at the RWMC ranges from 15 to 20 people. Included are equipment operators, health physics technicians, laborers, and supervisors. The personnel involved in the emplacement of TRU waste are also involved in the emplacement of nontransuranic beta-gamma waste received from onsite operations. Radiation dosimetry exposure records are kept for each individual at the RWMC. Since these dosimetry records are for cumulative exposure, regardless of the location within the RWMC where the exposure occurred, separate personnel exposure records are not available for TRU-waste-only operations.

Health physics monitoring indicates that most personnel exposure results from handling and disposal of nontransuranic INEL waste. The radiation from many of these waste packages often exceeds several R/hr, while the radiation 6 ft from drums or boxes of TRU waste is generally less than 1 mR/hr.

Radiation dose records from 1976 and 1977 were examined as the most representative of current operations. These records indicate that the individual annual dose for operating personnel ranged from 40 mrem to 1870 mrem. During 1976 the average individual radiation dose for 14 workers was 694 mrem, while the average individual annual dose in 1977 was 710 mrem for 17 workers. A worker could thus expect to receive approximately 700 mrem/yr whole body dose if assigned to the RWMC full time. However, only a relatively small portion of this total would be attributed to handling TRU waste.

A preliminary estimate of exposure due to handling TRU waste alone was made using an average radiation of 1 mR/hr at 6 ft from most of the drums and from the boxes of TRU waste. When the waste

containers are stacked, additive effects could result in peak radiation exposure rates on the order of 10 mR/hr at 6 ft from the face of the stack. More typically, the radiation level during emplacement operations would be on the order of 1 mR/hr. From available information, it was estimated that an individual would receive a dose of 10 to 20 mrem during a full week of receiving, handling, and storing the TRU waste. Based on the current rate of TRU waste receipt, 25 weeks of operation per yr are required for TRU storage and handling operations. With 25 weeks of operation per yr, an individual would receive an annual dose of about 400 mrem. This dose would be received by only two or three individuals. Emplacement of TRU waste is essentially a one-man operation, with support personnel provided on an as-needed basis.

These estimated doses, as well as the actual exposures, are well below the ERDAM-0524 (ERDA 1977a) standard of 5000 mrem/yr for whole-body dose. The operating contractor at the RWMC has an active ALAP (as low as practicable) program to minimize radiation exposure. To achieve this goal, the operating contractor limits individual exposure time and uses shielding and distance to reduce personnel exposure, whenever possible. In addition, the radiation exposure guides are continually assessed and future changes will, in all probability, be downward.

6.1.2 Internal. During normal handling and storage of TRU waste, there has been no identifiable TRU contamination available for inhalation or ingestion. (Recorded incidents during handling of TRU waste are listed in Subsection 4.3.4. Only one incident resulted in loss of containment, and no effects on workers were identified.) Packages are monitored for loose contamination before shipment and on receipt at the RWMC. The air is continually sampled by air monitors during unloading and emplacement activities. No airborne TRU activity has ever been detected during these operations. In addition, a whole-body count is required of all RWMC workers at least annually. Bio-assay samples are also routinely analyzed. The water supply for the

RWMC operations personnel is supplied by the RWMC production well. However, there has been no transuranic contamination of this water source.

In the EWR and IDR projects for experimental retrieval of buried waste, workers may be susceptible to airborne contamination. Strict contamination control measures are practiced during these operations. Continuous monitoring of the air is normal operating practice, as is the taking of smears and swipes of exposed surfaces. In the IDR program, anticontamination clothing is worn including coveralls, safety shoes, shoe covers, gloves, and hard hats. Respirators are carried by each worker. In the EWR program, workers are completely protected by bubble suits with supplied air since the retrieved waste containers are in a more deteriorated condition than those in the IDR project. Since contaminants are likely to become airborne during the operations for these projects, workers supply routine bioassay samples. During 1977, bioassay samples indicated that four individuals might have had a low level of internal exposure from transuranics. However, these statistically positive bioassay results were so low that it was impossible to assign dose estimates. Further samples were analyzed to determine uptake and elimination rates. Again, because of the very low levels of possible internal deposition and the variability between samples, no dose estimates could be made. Follow-up sampling and analyses are underway.

6.2 RADIATION EFFECTS ON THE PUBLIC

Radiation effects on the public from RWMC operations are indistinguishable from the effects due to natural background radiation. The RWMC is a controlled area. Members of the public are prohibited from uncontrolled entrance to the facility. Signs and barricades are provided at the RWMC access road at the EBR-I area. A cyclone fence surrounding the TSA is equipped with intrusion alarms to preclude unauthorized entry. A barbed wire fence surrounds the Subsurface Disposal Area. The entrance gate is kept locked, and entry is administratively controlled. DOE security guards make regular inspections

of the facility. The closest public accesses to the RWMC are the EBR-I National Landmark, approximately 2 miles northeast, and U. S. Highway 20, approximately 3.5 miles north. Consequently, the potential for direct radiation exposure to the public is minimized and localized within the controlled area.

The fence around the RWMC precludes grazing on land that may be contaminated. Hunting is not allowed on the INEL. The small rodents and the predatory and game animals at the INEL do not enter directly into the human food chain. The desert vegetation is not harvested or used by humans, further precluding the entrance of contamination into the food chain.

Resuspension of surficial contamination represents a possible route to man for the alpha-emitting radionuclides. Snow cover greatly reduces the chance of resuspension from late fall to early spring of each year. Measurements by alpha spectrometry on samples of airborne dust have shown plutonium-238 and plutonium-239 concentrations at CFA during the most probable times for resuspension to be less than 1×10^{-14} nCi/m³. Continuous exposure to this concentration for 6 months would result in inhalation of no more than 0.036 pCi of each isotope and a total lung dose of less than 0.05 mrem. The longest credible exposure period for a member of the public is a brief stopover at the rest station at the Lost River bridge on U. S. Highway 20. The potential dose at this rest station is less than 0.002 mrem.

7. IDENTIFICATION OF ALTERNATIVES FOR INEL TRU WASTE MANAGEMENT

This section reviews communications between state and federal officials concerning the INEL TRU waste and discusses earlier and ongoing studies of INEL waste management. Guidelines and terminology formulated for the present study are presented. The waste management alternatives studied are briefly described. Detailed descriptions of the alternatives may be found in Sections 8 through 10.

7.1 COMMUNICATIONS BETWEEN THE FEDERAL GOVERNMENT AND THE GOVERNMENT OF THE STATE OF IDAHO CONCERNING LONG-TERM MANAGEMENT OF INEL TRU WASTE

Since 1969, DOE and its predecessor organizations (ERDA and AEC) have been in communication with officials of the State of Idaho concerning long-term management of TRU waste at the INEL. Interest was first focused on this subject after the Rocky Flats fire in 1969, when contaminated TRU solid waste resulting from the cleanup operations was shipped to the INEL. The INEL had been receiving Rocky Flats waste since 1954. The publicity from the fire caused Idaho officials to raise questions concerning the safety of the Rocky Flats waste in Idaho. The AEC made a commitment in 1970 to place top priority on shipment of the waste to a federal repository. A summary of the communications and copies of official correspondence are presented in Appendix A.

7.2 THE NATIONAL ACADEMY OF SCIENCES/NATIONAL RESEARCH COUNCIL STUDIES

The Committee on Radioactive Waste Management of the National Research Council (NRC) has been conducting independent evaluations of current and future plans for the handling of radioactive solid waste. Two studies with possible implications at the INEL are summarized here.

7.2.1 Shallow Land Burial of Low-Level Radioactive Waste.

The National Academy of Sciences Select Committee on Radioactive Waste Management evaluated current and future low-level radioactive waste management practices at DOE-controlled burial sites, including the INEL. Summaries of recommendations and conclusions from this report (NAS-NRC 1976) that are pertinent to TRU waste management at the INEL include:

- (1) Exhumation of (low-level TRU) waste originally buried without any intent of later retrieval is a potentially very hazardous operation. Such exhumation should not be made unless there is a credible reason to believe that (a) a significant radiation hazard could arise from leaving the waste where it is, and (b) the wastes can be exhumed safely. As a corollary to this recommendation, radioactive waste should not be exhumed and put into temporary engineered storage where the material must await a final decision on permanent disposal.
- (2) DOE has set an upper limit for burial of transuranic waste of 10 nCi/g of waste. This criterion should be evaluated further in light of more recent data on the biological and ecological effects of low levels of radiation.
- (3) A permanent final repository for solid waste contaminated with transuranic nuclides must be established without delay.
- (4) Burial sites should be monitored continually with periodic reports to the public.
- (5) A careful study should be made of the actual rate of migration of transuranic nuclides under a wide variety of field conditions.

7.2.2 Management of Radioactive Waste at Hanford (NRC 1978).

The National Academy of Sciences Select Committee on Radioactive Waste Management also evaluated current and future radioactive waste management practices at Hanford, Washington. The interested reader is referred to this document (NAS-NRC 1978). The principal conclusion concerning TRU waste is that most soils and sediments containing dispersed radionuclides should be left in place, rather than be exhumed, unless and until a major hazard to the environment can be demonstrated. However, because seismic, volcanic, and hydrologic conditions at the INEL are significantly different from those at Hanford, the conclusions of the study may not be applicable to waste management at the INEL.

7.3 THE DOE ALTERNATIVES STUDY AND EIS FOR INEL TRU WASTE

7.3.1 DOE Alternatives Study for INEL TRU Waste. The DOE has recently completed a report entitled, Alternatives for Long-Term Management of Defense Transuranic Waste at the Idaho National Engineering Laboratory (DOE 1978a). The study identified, developed, and evaluated alternatives for long-term management of both the buried TRU waste and the stored TRU waste at the INEL. The technology required for managing the waste, the risks to the public, the radiological hazards to workers, and the estimated costs are discussed.

The initial step in the study was a review of current waste management technology, including current projects related to the RWMC. Particular attention was given to experimental retrieval projects, waste treatment projects, and investigations of subsurface migration of radionuclides. Based on this review, three long-term management alternatives were identified for the buried TRU waste and two alternatives were identified for the stored waste. These alternatives are summarized in Table 7-1.

TABLE 7-1

ALTERNATIVES AND CONCEPTS IDENTIFIED IN THE
DOE ALTERNATIVES STUDY FOR INEL TRU WASTE

<u>Buried Waste</u>		
<u>Alternatives</u>	<u>Concepts</u>	<u>Description</u>
I		<u>Retain Existing Procedures</u>
II		<u>Provide Engineered Containment</u>
	II-A	Cover
	II-B	Cover and walls
	II-C	Cover, walls, and floor
	II-D	Encapsulation
III		<u>Retrieve, Process, Ship</u>
	III-A	Direct retrieval, Molten Salt Incineration (MSI)
	III-B	Direct retrieval, In-Drum Incineration (IDI)
	(a)	Direct retrieval, Slagging Pyrolysis (SP)
	III-C	Remote retrieval, MSI
	III-D	Remote retrieval, IDI
	(a)	Remote retrieval, SP
(a)		<u>Retrieve, Ship</u>
<u>Stored Waste</u>		
1		<u>Retrieve, Ship</u>
2		<u>Retrieve, Treat, Ship</u>
	2-a	MSI
	2-b	IDI
	(a)	SP

(a) These alternatives or concepts were developed in the appendices of the alternatives document, rather than in the main body of the report.

In the case of waste processing by slagging pyrolysis, development studies were underway during preparation of the alternatives document. Therefore, slagging pyrolysis was not included in the body of the report but rather in an appendix.

This referenced study of alternatives provides the basic information for both the EIS described in Subsection 7.3.2 and the present evaluations of alternatives reported in this document. However, both follow-up documents are updating the concepts of the referenced study.

7.3.2 Environmental Impact Statement for INEL TRU Waste Management. An environmental impact statement is currently in preparation for alternatives for TRU waste management at the RWMC. Both buried and stored TRU waste will be addressed. The projected completion date of the draft EIS is late in CY 1979. The study is analyzing the environmental impact, risks, costs, and implications of selected major alternatives.

The EIS is a formal, in-depth study. The results of experimental environmental studies, currently in progress, will be incorporated into the EIS. More detail will be provided on fewer management concepts than is the case for the environmental studies presented in the present document.

7.4 THE CURRENT STUDY

7.4.1 Guidelines for the Study. For the purposes of the present study, the guidelines discussed below were formulated and followed to provide a common baseline. It was recognized that revisions in regulations and in national policies for waste management, occurring during and after the study and the report preparation, could result in a departure from these guidelines. Thus, concepts developed under the present guidelines could require modification before implementation.

7.4.1.1 General

- (1) The study shall identify and evaluate alternatives, and concepts within these alternatives, for long-term management of TRU waste stored at the RWMC. (Included is the TRU waste that is expected to be received until 1985 for storage.)

NOTE: The buried TRU waste is not considered in this study.

- (2) Because of large uncertainties in waste generation rates and in waste management policies and practices after the start of the campaign, the principal evaluations and facilities layouts shall not reflect the effects of managing TRU waste that may be received after the start of the campaign. These effects shall be addressed separately (see Appendix C).
- (3) The study shall address three scenarios: (1) a federal repository will be available; (2) a federal repository will be available, but will be delayed by 20 years; and (3) a federal repository will not be available.
- (4) Implementation of any long-term waste management alternative shall be assumed to commence in 1985 or as soon thereafter as practicable.

NOTE: In this document, all references to operations occurring in the year 1985 are made only for the purposes of the study and should be understood in the context of this guideline. No assurance can be given that the operations will,

in fact, occur in 1985, even if such operations are selected for implementation.

- (5) Any concept that proposes retrieval, processing, and disposal of the waste shall be capable of completion within an operating period of approximately 10 yr.

NOTE: The requirement to complete the campaign within 10 yr is an arbitrary constraint imposed only for convenience in the present study. Longer campaigns, perhaps up to 40 yr, appear to be feasible. A longer campaign would reduce the processing rate requirements. Table 7-2 presents comparisons of processing rates, given various lengths of campaigns. The numbers in Table 7-2 can be derived from the information in the guidelines of Subsection 7.4.1.2.

- (6) For the purpose of performing the shipment analyses in this study, the Federal Repository shall be assumed to be located near Carlsbad, New Mexico.
- (7) Except for possible shipment to the Federal Repository, no disposal shall be contemplated outside of the INEL.
- (8) Facilities for disposal of retrieved waste at the INEL shall be designed to allow the removal of waste for a period of 40 yr following initial emplacement, after which disposal may be irretrievable.

TABLE 7-2

PROCESSING RATES^(a,b,c) FOR
STORED WASTE FOR SEVERAL LENGTHS OF CAMPAIGN

Length of Campaign (yr)	Processing Feed Rate for Stored Waste ^(d) (ft ³ /yr)
5	442,200
10	221,100
20	110,550
30	73,700
40	55,275

- (a) Processing rates do not include coal, bark, makeup soil, or concrete.
- (b) 220 operating days/yr.
- (c) Rates are identical for all methods of processing.
- (d) Volumes of waste to be processed each year are averages and include the anticipated volumes of waste generated by retrieval and processing operations and by related decontamination and decommissioning (D&D) operations (See Subsection 7.4.1.2.).
-

- (9) For any concept that proposes not shipping the waste to a Federal Repository, maintenance and surveillance efforts shall be assumed to continue for 100 yr after implementation of the concept.

NOTE: This time period has been recommended (EPA 1978) as the limit for assumed reliance on institutional control for protection of radioactive waste. All disposal facilities would be designed to provide passive isolation for the radionuclides for time periods far in excess of the 100-yr period.

- (10) Concepts that would require development of new technology (as opposed to applications of present technology) before their implementation shall not be considered.

NOTE: Even for the case of delaying retrieval by 20 yr, the development of no new technology is assumed in this study. There is no guarantee that significant new technology for TRU waste management will develop within a 20-yr time frame. Furthermore, the form that any such development might take is a matter of conjecture and is not amenable to study for a document such as this.

- (11) All facilities shall be designed so that all effluents will be limited to levels consistent with the requirements of existing regulations.

- (12) All facilities shall be designed to limit radiation exposures to operating personnel to levels consistent with the requirements of existing regulations.
- (13) The waste shall be monitored to provide an assessment of plutonium content after retrieval, during processing, and after packaging.
- (14) Any contaminated soil intermixed with the stored waste shall be treated in the same manner as the TRU waste.
- (15) Concepts proposing retrieval of the stored waste must provide a facility in which the air surrounding the waste is maintained at a subatmospheric pressure during waste retrieval.

NOTE: Because the stored waste is packaged in special containers, maintaining subatmospheric pressure surrounding the waste may not be needed during retrieval. Implementation of this requirement, or lack thereof, will be based upon continuing evaluation of the integrity of the storage containers. In the present study, it was conservatively assumed that the subatmospheric pressure would be required.

- (16) Any processing of retrieved waste shall be performed at or near the RWMC.
- (17) No concept shall be studied that proposes reclamation of fissile material.

- (18) Any facility for treating or packaging the TRU waste must provide double containment, supplying progressively lower pressures in the direction of increasing contamination.
- (19) Transfer of unprocessed waste shall be by a damage-resistant vehicle, with a sealable inner liner. Shipment of processed waste within the INEL shall be over a committed roadway and shall be by conventional semitrailers.
- (21) All waste shipped to the Federal Repository shall be processed to satisfy the Draft Acceptance Criteria of the Waste Isolation Pilot Plant (WIPP) (see Appendix D).

NOTE: The draft acceptance criteria in Appendix D are subject to change, which in turn could affect the selection of the method of processing the INEL TRU waste.

- (22) All waste shipped to the Federal Repository shall be contained to meet Department of Transportation (DOT) requirements. The use of ATMX 600 rail cars shall be assumed.

NOTE: This study shall not address the availability of the ATMX 600 rail cars for shipment of INEL TRU waste at the time of interest. Furthermore, it is recognized that these cars may not satisfy the shipping regulations in effect at the start of the campaign. In that event, the ATMX cars would be replaced with cars that would comply with the regulations in effect at that time.

7.4.1.2 Waste Inventory and Characteristics

- (1) The volume and radionuclide content of the waste projected through January 1, 1985, (see Tables 4-1 and 4-2) shall be used in the study. Other characteristics assumed for the waste shall be those given in Subsection 4.3.
- (2) Waste retrieval and processing operations for the stored waste shall be assumed to generate an additional 200,000 ft³ of waste, such as contaminated hand tools and protective clothing. An estimated 45,000 ft³ of waste requiring disposal would result from D&D of the retrieval and treatment facilities for stored waste.

NOTE: It is recognized that the quantities of self-generated waste and of D&D waste would depend, to some extent, on the methods of retrieval and processing selected. However, the magnitude of this effect on the total quantity of waste to be managed is expected to be less than 5%. Therefore, no allowance for these small differences in waste quantities was included in the evaluations in this study.

- (3) The following combustible/noncombustible volume ratios shall be assumed: stored TRU waste, 25/75; self-generated waste, 95/5; D&D waste, 5/95.
- (4) The following values for density, in lb/ft³, shall be assumed: stored TRU waste, 35 overall (13 for combustible and 42.33 for noncombustible);

self-generated waste, 8.4 overall (8 for combustible and 16 for noncombustible); D&D waste, 50 overall (15 for combustible and 51.84 for noncombustible).

NOTE: The density for each noncombustible portion listed was estimated based on the overall density, the density of combustibles, and the percentage of combustibles. (For self-generated waste only, it was the overall density that was calculated.) The numbers of significant digits shown above for such derived values do not reflect the accuracy of the values, but are retained to ensure a closed materials balance.

- (5) The radionuclide compositions for the self-generated waste and the D&D waste shall be assumed to be the same as the TRU waste from which they originated.
- (6) For calculating releases of radionuclides, the particle size of airborne radionuclides shall be assumed conservatively to be 1 micron activity median aerodynamic diameter (AMAD) for accidental releases and 0.3 micron AMAD for normal operational releases.

7.4.1.3 Risk Analysis

- (1) The risk analysis shall address radiological risks to the public from accidental releases. Normal operational releases shall be considered in the environmental impact analysis. See Guideline (4) in Subsection 7.4.1.5.

- (2) The analysis shall summarize both radiological and nonradiological hazards to the workers.
- (3) For concepts that propose shipping the waste to the Federal Repository, the risk analysis shall extend from retrieval through receipt at the Federal Repository.

NOTE: The radiological effects associated with long-term management at the Federal Repository are being evaluated in other studies. The Repository risks and long-term radiological effects, when evaluated, should be added to the risks and long-term radiological effects analyzed in this study, to obtain the total risk and effects for Alternatives 3, 4, and 6.

- (4) For concepts that propose leaving the waste in place, with or without engineered confinement, the risk analysis shall cover two time periods: (a) the 100-yr period following implementation, and (b) the post-100-yr period.
- (5) For concepts that propose retrieval, processing, and disposal within the INEL, the risk analysis shall cover: (a) the operations from retrieval through emplacement at the disposal site, (b) the ensuing period to 100 yr, and (c) the post-100-yr period.
- (6) For concepts that propose delaying retrieval for 20 yr or retrieving and storing 20 yr before shipment to the Federal Repository, the risk analysis

shall cover: (a) the 20-yr delay period, and
(b) the operations from retrieval through receipt
at the Federal Repository.

- (7) Risks associated with the D&D of any facilities proposed in the study shall be analyzed.
- (8) Estimates of the frequency of occurrence of postulated incidents shall be based, where possible, on experience gained in handling of waste and in experimental retrieval projects at the RWMC.
- (9) Risks associated with sabotage shall not be addressed in this study.
- (10) The average compositions of the waste, summarized in Tables 4-2 and 4-3, shall be used for the dose and risk calculations.
- (11) Demographic projections shall be based on 1978 population estimates, with a 1% (geometric) increase per year until the year 2085. After 2085, the population shall be assumed to remain constant.

7.4.1.4 Cost Estimates

- (1) The time periods evaluated in the cost studies shall be the same as those for the risk evaluations in Subsection 7.4.1.3, with the following exceptions: (a) no costs shall be assessed for time periods beyond 100 yr after implementation, and (b) the costs assumed to be assessed for long-term management at the Federal Repository shall be included.

- (2) Estimates of direct capital costs shall be based on prices in mid-July 1978, the date of the beginning of the study.
- (3) The cost of labor and materials in estimates of Operating and Maintenance (O&M) costs shall be based on 1977 data for the INEL, escalated to mid-July 1978.
- (4) Facility cost estimates shall not include such site services as utilities, water, and sewerage beyond the "5 ft line" around the facility.
- (5) Costs associated with D&D of any facilities proposed by the study shall be included in the estimates.
- (6) Shipment costs shall be based on transporting the waste from the RWMC to the location of concern.
- (7) The cost of DOT-approved shipping containers shall be included where applicable.
- (8) The cost of ATMX rail cars, assumed to be government-owned, shall not be included.

7.4.1.5 Environmental

- (1) The environmental aspects of the project shall be described using available data.
- (2) No field study, testing, or surveys (outside of those ongoing or already planned and funded) shall be conducted during the period of the study.

- (3) The time periods evaluated for the environmental study shall be the same as those evaluated for the risk study.
- (4) Only normal operational releases shall be considered in the environmental impact analysis. Accidents shall be analyzed in the risk analysis. See Guideline (1) in Subsection 7.4.1.3.
- (5) Shipments shall meet Department of Transportation requirements. These requirements preclude normal operational releases. Accidents associated with shipments shall be discussed in the risk analysis.
- (6) Dose estimates shall be based on the current (1978) data bank of meteorological characteristics and transfer coefficients.
- (7) Demographic projections shall be based on 1978 population estimates, with a 1% (geometric) increase per year until the year 2085. After 2085, the population shall be assumed to remain constant.
- (8) Descriptions of archaeological and historical remnants shall be derived from available data. The National Register of Historic Places shall be consulted along with the State Historic Preservation Officer and the State Archaeologist.

7.4.2 Terminology. In the discussion and evaluation of long-term management of TRU waste, the term "alternative", "concept", and "module" is used. For the present document, these terms are defined as follows:

- (1) Alternative: a general method of managing the TRU waste. For example, Alternative 5 is "Retrieve as Scheduled, Process, and Dispose of on the INEL".
- (2) Concept: a more specific method for implementing an alternative through the use of a series of modules, defined below. A concept is composed of one or more modules. For example, in Alternative 5, Concept 5-a would entail direct-control retrieval, incineration by slagging pyrolysis, packaging, and deep rock disposal (shaft access) in the Lemhi Range.
- (3) Module: a specific operation, such as direct-control retrieval or slagging pyrolysis.

7.4.3 Alternatives and Concepts Studied. Alternatives and concepts studied in this document are identified in the simplified decision tree presented in Figure 7-1 and in Table 7-3.

The six major alternatives studied for managing stored TRU waste stem from three possibilities: (1) a Federal Repository will be available as scheduled, in 1985, (2) a Federal Repository will be available, but will be delayed until the year 2005, and (3) a Federal Repository will not be available. Alternative 3 falls into the first category; Alternatives 4 and 6, into the second category; and Alternatives 1, 2, and 5, into the third.

In Alternative 1, the TRU waste would be left in place, as is. Existing management procedures (e.g., monitoring of the environment for evidence of migration of the waste, maintenance of the cover over the waste, and maintenance of security systems) would be continued and upgraded for 100 yr, the assumed minimum duration of societal control. A description of Alternative 1 is found in Subsection 8.1.

Fig. 7-1 Alternatives and concepts studied for long-term management of stored INEL TRU waste.

TABLE 7-3

ALTERNATIVES AND CONCEPTS STUDIED FOR LONG-TERM MANAGEMENT
OF STORED INEL TRU WASTE

Alternatives	Concepts	Description
1		<u>Leave As Is</u>
2		<u>Provide Improved Confinement</u>
	2-a	Above and Around
	2-b	Above, Around, and Below
	2-c	Immobilization
3		<u>Retrieve As Scheduled, Process, Ship To Federal Repository</u>
		Direct-Control Retrieval, SP(a)
4		<u>Retrieve As Scheduled, Process, Store 20 Years, Ship To Federal Repository</u>
		Direct-Control Retrieval, SP
5		<u>Retrieve As Scheduled, Process, Deep Rock Disposal - Shaft Access (In Lemhi Range)</u>
	5-a	Direct-Control Retrieval, SP
	5-b	Direct-Control Retrieval, CPT(b)
	5-c	Direct-Control Retrieval, PKG(c)
5		<u>Retrieve As Scheduled, Process, Deep Rock Disposal - Tunnel Access (In Lemhi Range)</u>
	5-d	Direct-Control Retrieval, SP
	5-e	Direct-Control Retrieval, CPT
	5-f	Direct-Control Retrieval, PKG
5		<u>Retrieve As Scheduled, Process, Engineered Shallow-Land Disposal (At Site 14)</u>
	5-g	Direct-Control Retrieval, SP
	5-h	Direct-Control Retrieval, CPT
	5-i	Direct-Control Retrieval, PKG
5		<u>Retrieve As Scheduled, Process, Disposal In Engineered Surface Facility (Near RWMC)</u>
	5-j	Direct-Control Retrieval, SP
	5-k	Direct-Control Retrieval, CPT
	5-l	Direct-Control Retrieval, PKG
6		<u>Delay Retrieval 20 Years, Process, Ship To Federal Repository</u>
		Direct-Control Retrieval, SP

(a) SP - Slagging Pyrolysis and Packaging

(b) CPT - Compaction, Immobilization, and Packaging

(c) PKG - Packaging Only

In Alternative 2, the TRU waste would also be left in place, but improved confinement would be added. Concepts within this alternative differ in the methods or combinations of methods for accomplishing the improved confinement. Alternative 2 is described in detail in Subsection 8.2.

In Alternative 3, the TRU waste would be retrieved as scheduled (beginning in 1985), processed, and shipped to the Federal Repository. Only one concept for Alternative 3 was studied: direct-control retrieval, followed by slagging pyrolysis, packaging, and shipment by rail to the Federal Repository. Reasons are given at the beginning of Section 9 for studying only these retrieval, processing, and shipment methods for alternatives (3, 4, and 6) involving waste disposal at the Federal Repository. Alternative 3 is described in Subsection 9.1.

In Alternative 4, the TRU waste would be retrieved as scheduled (beginning in 1985), processed by slagging pyrolysis and packaging, stored at the INEL for 20 yr, and shipped to the (delayed) Federal Repository in the year 2005. Alternative 4 is discussed in Subsection 9.2.

In Alternative 5, the waste would be retrieved as scheduled in 1985, processed, and disposed of on the INEL. The concepts studied differ in the type of processing and the method and location of disposal. Processing modules may be one of the following: (1) slagging pyrolysis and packaging; (2) compaction, immobilization, and packaging; or (3) packaging only. Disposal modules include: (1) deep rock disposal in the Lemhi Range with access by a shaft, (2) deep rock disposal in the Lemhi Range with access by a tunnel, (3) engineered shallow-land disposal at Site 14, or (4) disposal in an engineered surface facility near the RWMC. All combinations of processing modules with disposal modules were studied. Alternative 5 is described further in Section 10.

The onsite disposal modules were developed by first selecting a broad set of the most technically appealing disposal methods. Then each method was matched with an attractive disposal location, for that method, on the INEL. Although many different combinations of methods and locations could have been studied (see Appendix B for further discussion), the modules selected for detailed analysis are representative of the preferred disposal methods and onsite locations.

In Alternative 6, retrieval would be delayed for 20 yr (to the year 2005). Processing would involve slagging pyrolysis and packaging, and the TRU waste would be shipped to the Federal Repository. Alternative 6 is described in detail in Subsection 9.3. Except for the 20-yr delay in retrieval, this alternative is identical to Alternative 3.

Possible interactions between management methods for the stored TRU waste and the buried TRU waste are mentioned in Section 11. The estimated environmental effects of the alternatives and concepts studied are presented in Section 12. Radiological risks to the public are estimated in Section 13. Both radiological and nonradiological hazards to the workers are estimated in Section 14, and costs in Section 15. Section 16 discusses the requirements for implementation. The effects of implementing the various alternatives, concepts, and modules are compared in Section 17.

7.4.4 Alternatives and Concepts Identified But Not Studied.

While the six alternatives studied for stored waste do not include all possible combinations of concepts and modules, they are representative alternatives within the limits of the study guidelines (Subsection 7.4.1). The number of possible alternatives and concepts is so large as to preclude developing and evaluating each to the depth of detail presented in Sections 8 through 16. Therefore, a number of alternatives, concepts, and ideas that were identified but not studied

further in the main body of the document are discussed briefly in Appendix B. These alternatives, concepts, and ideas include:

(1) leave in place options, (2) retrieval methods, (3) processing methods, (4) immobilization methods, (5) storage methods, (6) methods for shipment, (7) methods and locations for onsite disposal, and (8) other miscellaneous options.

8. ALTERNATIVES INVOLVING LEAVE-IN-PLACE MANAGEMENT

This section discusses the alternatives and concepts developed for leaving the stored waste in place. (See Figure 7-1.) In Alternative 1, the waste would be left as is. In Alternative 2, improved confinement would be provided for the waste.

For these alternatives, existing waste management procedures, such as maintenance, surveillance, and security, would be retained or upgraded as necessary. These procedures would be modified to suit the revised containment of Alternative 2. Guideline (9) in Subsection 7.4.1.1 specifies that the waste management procedures would be continued for 100 yr after implementation in 1985.

8.1 ALTERNATIVE 1: LEAVE STORED TRU WASTE IN PLACE AS IS

8.1.1 General Procedures. In Alternative 1, the cover of plywood, polyvinyl sheeting, and about 3 ft of earth over the stored TRU waste, described in Subsection 4.2, would be maintained. The current practice of periodic visual inspection would be continued to detect settling in the storage mound, to detect damaged fences and signs, and to survey general conditions. Procedures would be periodically reviewed and updated.

8.1.2 Monitoring and Sampling Procedures. The present environmental monitoring and sampling procedures (Hedahl and Janke 1978, Harness and Passmore 1976a) covering the area within the RWMC would be continued and expanded. Monitoring would be continually improved to identify any long-term local changes in the concentration of radionuclides in the air, water, and soil. Measurements and reporting of conditions outside the perimeter of the RWMC, currently performed by the Radiological and Environmental Sciences Laboratory (RESL) of the DOE, would be continued. The present procedures are described in the following paragraphs. These procedures would be kept current with developing technology and would be expanded as required.

Radiation surveys of the ground surface would be continued to ensure that the general area of the RWMC would not present a radiological hazard. Cumulative radiation exposure data would be gathered.

The current soil sampling program at the RWMC involves tests for detecting plutonium at the surface and at depths of 6 and 12 in. Studies are made of the potential for horizontal migration near the ground surface and for vertical migration downward below the surface.

Air monitors are presently installed at several locations around the perimeter of the RWMC to determine the airborne concentration of radionuclides. Analyses have shown that the predominant radionuclides are cobalt-60 and cesium-137. At no time in the past 4 yr has the recorded air concentration exceeded 10% of the allowable controlled-area concentration given in ERDAM-0524 (ERDA 1977a). The results of the air sampling program at the RWMC are given in Subsection 5.1, Harness and Passmore (1976a), Harness and Passmore (1976b), Dolenc and Janke (1977), and Hedahl and Janke (1978).

The lack of surface water near the RWMC restricts water sampling activities to collecting runoff from rainfall or melting snow. These samples are analyzed for contamination. The water sampling results are presented in the same four reports listed above for air sampling results and in Subsection 5.3.

Recently initiated monitoring by the RESL detects the accumulation of radionuclides in plants or animals. (See Subsection 5.7.) Knowledge of how various radioisotopes pass through the human food chain is used to guide the sampling. Food crops grown in offsite areas are monitored to determine the uptake of radioisotopes from soils. Soil samples are collected from burrows of small animals and are analyzed for the presence of radionuclides. The samples analyzed to date have generally contained quantities of radionuclides that are either below or only slightly above the limits of detection.

Currently, moisture monitoring is accomplished by lowering a combination neutron source and thermal neutron detector into perforated pipes driven through the soil to the basalt and by recording the reflected thermal neutron flux. A record is thereby provided of the amount of moisture contained in the subsurface soil. To date, no abnormal moisture trends have been detected.

Wells No. 87 through 89, located around the periphery of the RWMC, and Well No. 90, located within the RWMC (see Figure 5-3), are used to sample the aquifer at depths of approximately 600 ft below the ground surface. Aquifer samples have also been drawn from the RWMC production well. Perched water samples have been drawn from Well No. 92 (about 214 ft deep), which is located within the Subsurface Disposal Area (SDA). The results of the sampling provide a record of the radionuclide content of the subsurface water in and around the RWMC (see Subsection 5.6).

Monitoring of the environmental parameters within portions of the TSA pads, initiated in early 1974, would be continued. Dew point and temperature measuring probes have been placed at various depths inside the arrays of waste containers (Hedahl and Janke 1978). Metal corrosion coupons were placed throughout the stacked waste in March of 1975. These coupons consist of painted metal strips that are intended to provide information concerning the possible corrosion of the steel drums. In April of 1978, several coupons were retrieved from Cell 6 of TSA (see Figure 3-10). The condition of the retrieved coupons was comparable to the condition of the steel drums removed from Cell 6 in the TSA reentry study (see Subsection 4.4.3). As on the drums, fairly large amounts of free rust were also found on the coupons. The coupons also exhibited small areas of corrosion.

The containers of stored waste would eventually deteriorate, allowing the soil cover to settle. The average density of the stored waste and containers is estimated to be 35 lb/ft^3 . As the waste and soil cover compacts and settles, it is assumed that the average density of the waste and containers would eventually reach the natural

soil density of about 80 lb/ft³. Therefore, the waste would settle to a little less than half the present height. Waste has been stored to a height of approximately 16 ft. The settled height of the waste, including the original 3-ft soil cover, is estimated to be a minimum of 10 ft. Thus, after settling of the waste, the top of the mound of soil would still be well above the surrounding area, thereby providing drainage.

8.2 ALTERNATIVE 2: LEAVE STORED TRU WASTE IN PLACE AND PROVIDE IMPROVED ENGINEERED CONFINEMENT

This alternative considers the means of providing additional in-place protection against penetration of water and intrusion by animals and plant roots. Two concepts for constructing confinement barriers for the waste, designated 2-a (above and around) and 2-b (above, around, and below), are discussed within this alternative. One immobilization concept (2-c) is also discussed. These concepts are illustrated in Figure 8-1. The block flow diagrams are shown in Figure 8-2.

8.2.1 Concept 2-a. In this concept, an additional 10-ft cover of compacted clay, plus a 3-ft cover of basalt riprap, would be built up over the existing mounds on the TSA pads (Figure 8-1). The clay would be placed in layers, each of which would be compacted. Clay is composed of small particles that pack closely together, inhibiting water penetration. Clay also expands and contracts without cracking when wet, thereby retaining its flexibility and resistance to penetration by water. If observations indicate that clay might not be satisfactory for the 10-ft mound, bentonite, a locally available colloidal clay, would be used. Independent laboratory tests of bentonite have indicated excellent resistance to moisture penetration.

The clay mound would be sloped to provide drainage. Three feet of crushed basalt riprap would then be layered over the clay to serve as an erosion deterrent. Both clay and basalt are available near the RWMC.

Concept 2-a Confinement Above & Around

Typical section through the TSA pad showing mound and riprap cover.

Concept 2-b Confinement Above, Around, & Below

Concept 2-a with grout seal of sediment under asphalt pad.

Concept 2-c

Immobilization with grout injection.

Fig. 8-1. Typical sections through waste and confinement for Alternative 2.

Fig. 8-2. Block flow diagram for Alternative 2.

As discussed in Subsection 8.1.2, the containers of stored waste would eventually deteriorate, allowing the soil to settle. The settled height of the waste, including the original 3-ft soil cover and the 13-ft clay and basalt cover just described, is estimated to be a minimum of 23 ft. Thus, after settling of the waste, the top of the clay and basalt cover would be well above the surrounding area, thereby providing drainage.

8.2.2 Concept 2-b. This concept would include the clay and riprap cover described for Concept 2-a. Increased isolation would be provided by pressure-grout sealing of the sediments beneath the asphalt pad. Downward migration of the waste would thus be minimized as long as the grout remained intact. Assurance cannot be given that the grout would remain intact for the thousands of years required for the radionuclides to decay to very low levels. By placing the grout several feet below the asphalt pad, the ion retention properties of the sediment would serve to slow the downward migration of radionuclides.

The technique of pressure-grouting was recognized and used in the 19th century (Karol 1968). Early grouting projects undoubtedly used solids for grouting material. Sodium silicate, or water glass, the first chemical pressure-grout additive, was introduced in the early 20th century. It was used extensively through the 1960s. In specific applications, it is still in use. With the advent of new chemical additives in the 1950s, chemical pressure-grout has become more widely used. This grout is frequently injected into dry, granular, stratified, or fractured formations to increase their strength. However, most chemical grouting applications are related to blocking water flow or moisture penetration, such as preventing water from seeping through sand under waterfront structures or blocking the flow of water into mine shafts and tunnels (Epstein and Barvenik 1975).

Pressure-grouting is accomplished by forcing pipes into the soil, often to depths of several hundred feet, and pumping grout through the pipes into the soil as the pipes are withdrawn. In soil or rock formations too dense to permit the grout pipes to be forced through them, holes are drilled and the pipes inserted into the holes. As a pipe is withdrawn, pumping continues, and the grout is forced outward around the end of the pipe, often to a distance of several feet. When the end of the pipe has reached the surface, pumping is stopped. The pipe is then reinserted into the soil a predetermined distance from its first location, and pumping is restarted. By repeating these operations, a solid wall, or curtain, of grout is formed in the soil or rock. Application of pressure-grouting to seal the sediments beneath the waste in Concept 2-b would be accomplished as described in the following paragraphs.

Two parallel rows of sheet piling, 6 ft apart, would be driven down into the sediment on each side of the TSA pad. Excavation of the sediment between the sheet piling would produce a trench along each side of the asphalt pad. Bridging would be used to prevent collapse of the piling into the trench. The bottom of the trench would be several feet below the depth at which the grout pipes are to be inserted. The grout would be inserted between 10 and 20 ft below grade. The exact depth would be determined by preliminary studies on the depth and ion-exchange properties of the sediment, the amount of ion-exchange capability desired, and the depth to the basalt beneath the TSA. At the RWMC, the average sediment thickness is about 15 ft. If basalt is encountered at shallower depths, grout will be injected directly above the basalt.

The grout pipes would be forced through the sediment without drilling. The pipes would be inserted horizontally to the centerline of the pad from each side, so that the grout would form a complete seal under the pad. The grout would be made up of a mixture of portland cement, finely divided clay, and one or more of the commercially available chemical additives used to improve viscosity and aid in penetration. When the grouting in one section is completed, the sheet

piling would be removed to form the walls for a new section of the trench. The portion of the trench where the grouting is complete would be filled with concrete. The trench would be continued around each end of the TSA pad, so that the grout and the concrete-filled trenches would form an impervious barrier under the waste.

The grouting would be done before the emplacement of the clay and riprap cover. The clay would extend out over the concrete-filled trenches, so that no water could enter the sediment enclosed by the concrete-filled trenches and the grout floor.

8.2.3 Concept 2-c. In this concept, the waste would be immobilized in place by injecting grout into the waste and into the sediment beneath the pad. The waste would thereby be encased in a massive, impermeable block of grout. The grout injection would be accomplished as described in the following paragraphs.

Several grout pipes would be forced through the 3-ft soil cover, the waste, the asphalt pad, and several feet of the sediment below. Figure 8-1 shows typical pipe locations. Pressure-grouting would be performed as described in Concept 2-b until the ends of the pipes had been withdrawn to the elevated surface of the soil cover. The grout pipes would then be relocated to an adjacent area and again forced downward into the underlying sediments. The procedure would be repeated until the entire TSA pad area had been treated.

The grout would form a solid mass around the waste containers, and inside any breached containers. The grout would not penetrate sound waste containers. However, the containers themselves would be surrounded by the grout. This immobilization method would make any future retrieval extremely difficult.

Any waste that might have been pushed downward by the grout pipes would also be immobilized in the grout. During insertion and withdrawal, the grout pipes would be provided with external containment to prevent the spread of contamination. The optimum grout mix and grout hole spacing would be determined in a test area.

The same grout materials would be used as those described in the previous subsection. Presently, assurance cannot be given that the grout would remain intact for the thousands of years required for the radionuclides to decay to very low levels. Tests to determine the leachability, permeability, and structural stability of grouted volumes of soil are planned for FY 1979 and 1980. Changes in these characteristics with time will also be measured.

9. ALTERNATIVES INVOLVING RETRIEVAL, PROCESSING, AND SHIPMENT TO THE FEDERAL REPOSITORY

This section discusses the methods studied for (1) retrieval of TRU waste stored at the RWMC, (2) onsite processing, (3) packaging, and (4) shipment to the Federal Repository. Several options were considered for each of these operations, but only one option for each was evaluated further. A general layout of the current storage area and of the facilities developed for the waste management alternatives appears in Figure 9-1. The facilities to implement the alternatives have been designed, on a preconceptual basis, so that the retrieval, processing, and shipping could be completed in a 10-yr campaign. See Guideline (5) in Subsection 7.4.1.1.

For retrieval, three methods were considered for handling the waste containers: (1) manual handling by operators; (2) handling by operator-controlled equipment (direct control); and (3) handling by remote-controlled equipment. The first method was not evaluated further because of unnecessary radiological exposure to the workers and the length of time required for retrieval. The third method was not examined further because the results of the TSA reentry study (see Subsection 4.4.3) indicate that no significant overall advantages would accrue from remote-controlled handling of the stored TRU waste.

Four means were considered for providing confinement during waste retrieval operations: (1) open air retrieval (no confinement); (2) use of a plastic-coated fabric structure supported by internal air pressure, to provide weather protection; (3) use of a moveable, solid-frame structure operating at ambient pressure; and (4) use of a moveable, solid-frame structure, but operating at subatmospheric pressure. The fourth method was studied because, of the methods considered, only it would provide positive control against possible release of contamination. See Guideline (15) in Subsection 7.4.1.1.

Fig. 9-1 Site plan for facilities for retrieval, onsite processing, and shipping to the Federal Repository.

Four processing options were considered: (1) ship as is; (2) repackage only; (3) compact, immobilize, and package; and (4) incinerate and package. Waste shipped to the Federal Repository would have to satisfy the acceptance criteria at the repository. Draft acceptance criteria were published in July 1977 (see Appendix D). These criteria, which are subject to change, were used as a basis for selecting a processing method to be studied for these alternatives (3, 4, and 6). The criteria effectively limit the waste to 20 vol% combustibles and 10 wt% gas producers. Because approximately 25 vol% of the stored INEL TRU waste is combustible, incineration of the waste would be necessary to satisfy the draft criteria. Evaluations of incineration methods (FMC 1977, Kaiser Engineers 1977), discussed in Subsection B.4.2 of Appendix B, have concluded that slagging pyrolysis is the most promising method for processing the RWMC TRU waste (see Subsection 4.4.2). Therefore, the slagging pyrolysis process was selected for study here.

The packaging for the slag product was assumed to be 55-gal steel drums because of availability and past experience with handling this type of container.

Rail shipment of the waste was assumed because of its expected cost advantage over shipment by truck.

Thus, the sequence of operations selected for study was (1) retrieval with operator-controlled equipment inside a moveable, solid-frame structure at subatmospheric pressure; (2) processing by slagging pyrolysis with the slag packaged in 55-gal drums; and (3) rail shipment to the Federal Repository. These operations and their effects are discussed briefly in the following subsections.

9.1 SHIPMENT AS SCHEDULED

This section discusses Alternative 3, in which the TRU waste stored on the TSA pads would be retrieved, processed, and shipped to the Federal Repository, as scheduled.

9.1.1 Retrieval. The sequence of retrieval activities is illustrated in Figure 9-2. One retrieval building would be sufficient to meet the 10-yr retrieval guideline. Retrieval rates would match the flow rates in Figure 9-9.

The retrieval building (see Figure 9-3) would be a mobile, single-walled structure. Below ambient air pressure would be maintained within the building. See Guideline (15) in Subsection 7.4.1.1. Thus, air leakage would be directed inward, precluding the escape of contaminants to the environment. The negative pressure differential would be maintained by the ventilation system. All air removed by the ventilation system would pass through a series of roughing filters and one bank of High Efficiency Particulate Air (HEPA) filters. Each of the filters would remove successively smaller particles. A seal mechanism would seal the building with the TSA pad during retrieval operations. The building would be equipped with retractable wheels to support its weight during relocation operations. The wheels would be similar to those used in industry to facilitate moving large, heavy objects. Moveable, channel-shaped steel tracks would be provided to permit the building to be moved on a year-round basis. One production transfer air lock, a vehicle air lock, a personnel air lock, and two emergency personnel exits would be provided through the building walls.

The retrieval building would be erected on an asphalt pad that would form an extension to the TSA pad. After the building has been erected, most of the soil covering the waste would be removed from the area to be covered by the building. The building would then be moved over this area; and the remainder of the soil, the polyvinyl, and the plywood cover would be removed.

Operators would control the retrieval equipment from environmentally protected cabs located on the equipment. Preliminary calculations indicate that shielding of operators would not be required. However, if necessary, removable shields would be mounted on the retrieval equipment.

Fig. 9-2 Block flow diagram for retrieval of stored TRU waste.

Fig. 9-3 Plan of retrieval building for stored TRU waste.

The waste containers would be monitored and examined to confirm their integrity. Intact, uncontaminated containers would be placed directly into the transfer vehicle. Deteriorated or damaged containers would be enclosed in a sealed transfer container before being placed in the transfer vehicle.

Transfer of waste from the retrieval facility to the processing facility would be made in low-speed transfer vehicles comprised of semitrailers, pulled by conventional tractors over committed roadways within the RWMC. Each semitrailer would be equipped with a van body. The van body would be designed to resist rupture in the event of an accident and would have a removable stainless steel liner. To provide a high degree of stability, the trailer would have a low center of gravity. To further guard against overturning, the truck speed would be limited by a governor to 20 mph.

When loading or unloading at a facility air lock, the van body would be sealed to the air lock entrance. An airtight extension of the air lock would thereby be formed. Contamination of the exterior of the vehicle would not be expected.

9.1.2 Processing. This subsection describes the facility, equipment, and process for the chemical stabilization, volume reduction, and immobilization of stored TRU waste. The slagging pyrolysis process, discussed below, would accomplish these goals in one operation. The molten slag product would then be cast and packaged in a form that could be shipped to the Federal Repository without further treatment.

9.1.2.1 Operating Experience with Slagging Pyrolysis.

Because large-scale incineration of TRU waste is still in the developmental stage, this subsection briefly reviews the operating experience, both nuclear and nonnuclear, with slagging pyrolysis. The slagging pyrolysis process was originally developed as a commercial method

to generate a gas of low Btu content from nonradioactive municipal or industrial waste. A 76 ton^(a) per day pilot plant began operation in the U.S. in 1971. Three plants, each capable of incinerating about 190 to 220 tons of municipal and industrial waste per day, have been built in Europe. These plants are located in Luxemburg, Luxemburg; Frankfurt, Germany; and Grasse, France.

A 220-lb/hr slagging pyrolysis unit for incinerating radioactive waste is now operating in Belgium. Contaminated waste has been processed in this incinerator with good results. The unit will be modified in 1979 to process TRU waste. Contract negotiations are being conducted with the Belgian government to obtain data from the process. These data from the modified unit would be used in the design of an incinerator for processing the INEL TRU Waste.

9.1.2.2 Conceptual Processing of INEL TRU Waste by Slagging Pyrolysis. A conceptual flow diagram for processing of the stored TRU waste by slagging pyrolysis is presented in Figure 9-4. The preliminary layout for a facility incorporating the necessary functions is shown in Figures 9-5, 9-6, and 9-7. One slagging unit would be incorporated into the facility. This unit would have a capacity of 41 tons/day of waste and makeup soil. (Current data indicate that approximately 1.5 lb of soil per lb of waste is required to assure proper slagging characteristics.)

9.1.2.2.1 Preprocessing. Retrieved stored waste would be transferred from the TSA to the receiving air lock of the processing facility. All operations in the facility, from waste entry through the air lock to packaging of the output product, would be remotely controlled. After passing through the air lock, each container would

(a) short ton (2000 lb)

Fig. 9-4 Block flow diagram for processing TRU waste by slagging pyrolysis.

COOLING
TOWER

Fig. 9-5 Plan for ground level for slagging pyrolysis facility for stored TRU waste.

Fig. 9-6 Plan for second level for slagging pyrolysis facility for stored TRU waste.

Fig. 9-7 Cross section of slagging pyrolysis facility for stored TRU waste.

be monitored for radiation levels and for gross transuranic content. Should the monitoring indicate the need for special handling, the container would be routed to a special handling area. Criticality alarms would be strategically located throughout the facility.

If the incoming waste volume exceeded the incineration capability, unopened containers would be placed in a temporary storage area. This waste would be used to provide a continuous flow of waste to the incinerator during minor interruptions in the receipt of waste at the processing facility. Under normal operating conditions, incoming waste would be dumped onto a conveyor. Any transfer containers would then be returned to the waste retrieval area for reuse.

Drums and other containers would be opened (probably by sawing or ripping operations) and dumped. The inclusion of complete drums in the feed would seriously reduce the incineration rate. The waste would be visually examined for potentially large or hazardous items. Large items would be reduced in size to a maximum dimension of about 3 ft. Suspect items would be removed for special handling.

The waste would be blended to achieve some uniformity of the feed material. Incinerator operation would be impaired if large quantities of noncombustible materials were fed into it without blending with combustible materials. Additionally, a certain minimum proportion of makeup soil (approximately 1.5 parts of soil to 1 part of waste by weight) is required. The soil contains aluminosilicates needed to form a glass-like slag and ensure minimum leachability.

The decision to add combustibles or soil would be made during the visual inspection of the feed material.

9.1.2.2.2 Incineration. Figure 9-8 is a process flow diagram of the slagging pyrolysis and off-gas treatment processes. The incinerator would be a vertical furnace composed of a gasifier and

a secondary combustion chamber. Solid waste material would be fed into a hopper at the top and introduced into the gasifier through a sealed air lock. Solids from the off-gas treatment system would also be introduced in this manner. The air lock would prevent blowback of contaminated gas.

The gasifier would have three vertical zones: the drying zone, the pyrolysis zone, and the combustion zone. The combustion zone, operating at about 3000°F, would be refractory lined and could be mounted on rails and provided with flanges to facilitate removal for rebricking.

Because of the relatively low heat content of the TRU waste material, it would be necessary to add supplementary heat to the gasifier to produce a molten slag. This heat would be produced primarily by adding coal and bark to the process feed and by using combustion air preheated to 1900°F. Even if most of the supplementary heat were supplied by fuel oil, it would be necessary to add some quantity of a bulky solid fuel to increase porosity of the feed and enhance the flow of gases upward through the charge of materials. Coal and wood bark would be used as the bulky solid fuel. They would be added to the waste feed stream. Storage would be provided for these materials so that they could be added as needed. The coal and bark add a small amount of ash to the slag.

In the molten slag portion of the gasifier, water would flow through a cooling jacket around the slag to prevent deterioration of the metal walls of the vessel. The slag would be cooled considerably by this water. Therefore, fuel oil would be burned above the slag surface to prevent further loss of heat by radiation. Excess air and fuel oil would be added there to ensure complete combustion of the waste gas from the gasifier.

Fig. 9-8 Process flow diagram for slagging pyrolysis and gas cleaning system.

Molten slag would be conveyed through a heated conduit from the gasifier (primary combustor) to the slag-casting chamber, where it would be cast into molds. Gases and particulate matter would leave the top of the gasifier at approximately 1100°F through an outlet plenum and pass into the secondary combustion chamber. Here the oxygen-deficient exit gases would be mixed with secondary combustion air, which would be introduced tangentially into this refractory-lined chamber. The high temperatures in the secondary combustion chamber would cause the inert materials to melt and to leave the bottom of the chamber as a molten slag. This slag would be conveyed to the slag casting chamber in the same manner as the slag from the gasifier.

9.1.2.2.3 Output Packaging. The slag would be poured into molds and moved to a cooling chamber. After cooling, the castings would be removed from their molds and transferred to an assay and inventory station. Any defective castings would be returned to the incinerator feed stream for remelting. From the assay and inventory station, acceptable castings would be packaged into steel drums. The drums would be labeled and consigned to the storage room for eventual shipment to the Federal Repository. At the time of shipment, the drums would be monitored to ensure that they meet the requirements for levels of surface radiation and contamination. Contaminated drums would be routed to a decontamination cell. A drum exceeding the radiation level for shipping would have a radiation shield placed around it. Drums would then be loaded into ATMX railroad cars, 74 containers per carload.

9.1.2.2.4 Off-Gas Treatment. An effective off-gas treatment system for the slagging incinerator would be used to minimize environmental releases of particulates, aerosols, and volatile compounds. Airborne solid and aerosol material would contain the greatest quantity of radioactive substances in the effluent gas stream; therefore, the greatest attention would be given to removing this material. Neutralization of nonradioactive chemical products, such as

HCl and SO_x, would also be provided. All airborne releases would be limited to levels complying with standards set by the DOE, the Environmental Protection Agency, and other governmental agencies.

The off-gas treatment system considered the most promising at this time is a dry process called the aqueous carbonate process (Estcourt et al. 1978). This is essentially a spray drying process in which sodium carbonate dissolved in water is sprayed into the off-gas stream. The temperature of the entering off-gas stream would be maintained high enough to allow total evaporation of the water and still result in a superheated gas stream. The spray dryer would: (1) remove particulate material from the incinerator by impingement upon droplets or sodium carbonate particles, and (2) remove gaseous HCl and SO_x by chemical reactions with the sodium carbonate.

Particulate matter in the gas stream leaving the spray dryer would be removed before the gas is discharged to the atmosphere. This would be accomplished by four particle-collection devices arranged in series: a cyclone, a cross-flow sintered metal filter, a full-flow sintered metal filter, and two HEPA filters. Each of these removes successively smaller particles. All collected solids would be recycled to the incinerator feed stream. Contaminated HEPA filter elements would also be fed into the incinerator.

9.1.2.2.5 Flow Rates and Volumes. Figure 9-9 presents the estimated quantities and flow rates for stored waste. This information has been developed from the data in Table 4-1 and the guidelines for waste characteristics in Subsection 7.4.1.2. The facility was assumed to operate 24 hr/day for 220 days/yr.

The amounts of coal and bark fed to the incinerator were determined by a simultaneous mass and energy balance such that the total feed would have a heating value and moisture content comparable to that from operation of existing slagging pyrolysis incinerators for municipal waste. It was found that, for each lb of combined waste and makeup soil, 0.43 lb of coal and 0.70 lb of bark were required.

ESTIMATED QUANTITIES AND FLOW RATES FOR SLAGGING PYROLYSIS PROCESSING OF STORED TRU WASTE TO BE SENT TO THE FEDERAL REPOSITORY(a,b)

	Combus- tibles	Noncom- bustibles	Makeup soil	Coal	Bark	Fuel Oil	Ash	Air	Waste Gases	Total
1 WASTE FEED										
ft ³ /day	314	691	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1005
tons/day	1.82	14.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	16.4
10 ³ ft ³ /10 yr	691	1520	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2211
10 ³ tons/10 yr	4	32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	36
2 MAKEUP SOIL										
ft ³ /day	N/A	N/A	615	N/A	N/A	N/A	N/A	N/A	N/A	615
tons/day	N/A	N/A	24.6	N/A	N/A	N/A	N/A	N/A	N/A	24.6
3 FUEL										
ft ³ /day	N/A	N/A	N/A	704	1435	49.8	N/A	N/A	N/A	2189
tons/day	N/A	N/A	N/A	17.6	28.7	1.32	N/A	N/A	N/A	47.6
4 AIR										
10 ⁶ ft ³ /day	N/A	N/A	N/A	N/A	N/A	N/A	N/A	15.1	N/A	15.1
tons/day	N/A	N/A	N/A	N/A	N/A	N/A	N/A	578	N/A	578
5 PROCESS FEED										
ft ³ /day	314	691	615	704	1435	49.8	N/A	N/A	N/A	3809
tons/day	1.82	14.6	24.6	17.6	28.7	1.32	N/A	N/A	N/A	88.6
6 STACK EFFLUENT										
10 ⁶ ft ³ /day	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	16.3	16.3
tons/day	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	625	625
7 SLAG OUTPUT										
ft ³ /day	N/A	166	280	N/A	N/A	N/A	23	N/A	N/A	469
tons/day	N/A	14.6	24.6	N/A	N/A	N/A	1.98	N/A	N/A	41.2
8 TRANSPORTATION										
Containers/day	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	64
Railroad cars/day	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1

N/A Not Applicable

(a) Length of Campaign is 10 yr, 220 days/yr.

(b) Includes all the self-generated waste and 1/4 the D&D waste. Other D&D waste was assumed not processed.

Fig. 9-9 Flow rates for retrieval, onsite processing, and shipping stored TRU waste to the Federal Repository.

The slag would consist of: (1) all the makeup soil and the non-combustible waste, since these components do not burn, and (2) ash produced from combustible waste, coal, and bark. By weight, an estimated 5% of the combustible waste, 9% of the coal, and 1% of the bark would remain as ash. The overall slag density was assumed to be 175 lb/ft³.

Fuel oil, air, and off-gas flow rates were determined by Andco-Torrax, an incinerator vendor (Shea 1978). The calculations were made with a computer program that has been used for the design of existing slagging pyrolysis incinerators. Simultaneous mass and energy balances are used for the various portions of the process.

Part of the heat from the off-gas leaving the secondary combustion chamber would be captured in a waste heat boiler. The steam from this boiler could be used for heating or for generating electricity. The amount of steam to be produced and its use would be considered during detailed design.

The slag would be cast and placed into Department of Transportation Specification (DOT Spec) 17C 55-gal drums without liners. Each drum would hold about 7.4 ft³ of slag and when full, would weigh approximately 1360 lb including the weight of the drum.

9.1.2.3 Facility. The slagging pyrolysis facility, shown in Figures 9-5, 9-6, and 9-7, would be a reinforced concrete structure designed with three separate air zones. The outer zone would surround the second zone, which would surround the innermost zone, which would comprise the waste processing areas. Each zone would be equipped with its own ventilation system to maintain progressively lower pressures between the outside atmosphere and the innermost zone. All air removed by the ventilation systems would first pass through roughing filters having efficiencies of 30% and 90% and then through HEPA filters. Air from the innermost and middle zones would pass through two HEPA filter banks; air from the outer zone, through only one HEPA filter bank.

The facility would be subdivided generally into processing areas and support areas. The support areas, located in the outer zone, would provide space for administrative functions, conference rooms, and storage. The processing areas would be located in the two inner zones, with the areas of highest probable contamination being located within the innermost zone. Thus, potential air leakage within the facility would be directed from the area of least probable contamination into the area of greatest probable contamination. The innermost zone would contain such functions as transfer container opening and emptying, open waste handling and transfer operations, slagging pyrolysis, slagging pyrolysis off-gas treatment, and other operations presenting a high probability of the presence of contamination. The middle zone would contain compartments, corridors, and operating galleries that, although normally not contaminated, would be adjacent to areas of probable contamination.

There would normally be no personnel in the innermost zone. Air locks would be provided between the middle zone and the innermost zone to permit access for maintenance and repair by personnel wearing bubble suits and supplied with breathing air from a central source. Passage between the middle and outer zone would be through monitoring portals.

9.1.3 Offsite Shipment. ATMX rail cars would be used to ship the processed stored waste to the Federal Repository. To calculate the cost and risks of waste shipment, it was necessary to assume a specific route. The assumed route, shown in Figure 9-10, is one of several possible routes. The actual route that would be followed has not yet been selected. Denver, Colorado, is the major population center along the assumed route, with Pueblo, Colorado, and Colorado Springs, Colorado, next in size. The remainder of the route is primarily through rural areas of low population density. A one-way trip of approximately 1400 miles would require about 6 days.

Based upon the allowable net weight per ATMX car (101,300 lb), it was calculated that about 74 drums could be placed in each car. The estimated shipment rate would be about 190 cars/yr.

9.1.4 Disposal at the Federal Repository. A description of the Federal Repository and the waste management methods to be used there lies outside the scope of this document. Design studies for the repository are underway in other DOE-sponsored programs.

9.1.5 Decontamination and Decommissioning. The retrieval and processing facilities would be designed to make decontamination and decommissioning (D&D) as simple and inexpensive as feasible. Included would be such features as use of easily decontaminated surfaces, equipment designed for dismantling into easily handled components, and a processing building arrangement permitting use of key equipment during decommissioning.

The interior surface of the retrieval building, all equipment located inside the building, and the transfer containers would probably become contaminated during operations. Dismantling and shipment to the Federal Repository is assumed to be required. All retrieval facility materials destined for the Federal Repository would be processed through the processing facility.

Decommissioning of the processing facility would be conducted so that the slagging pyrolysis unit and associated equipment, along with the heating and ventilating system, would remain in service until late in the D&D campaign. This equipment would be used to reduce the volume of D&D waste.

Much of the equipment within the inner portion of the processing facility would probably be so contaminated that decontamination and recovery would not be practical. The processing equipment would be reduced in volume as much as possible, packaged, and shipped to the Federal Repository. The remaining equipment in the processing facility would probably be decontaminable, permitting normal disposal. It would probably be possible to decontaminate such equipment as cell doors and the heating and ventilating equipment. Construction materials

would be decontaminated by removing a surface layer. Some miscellaneous equipment, located outside the inner areas of the building, would probably not be decontaminable and would require packaging and shipment.

The total volume of D&D waste to be shipped, including D&D waste from the retrieval and processing facilities, would be approximately 45,000 ft³. See Guideline (2) in Subsection 7.4.1.2.

9.2 SHIPMENT DELAYED 20 YEARS

In Alternative 4, retrieval and processing of the stored waste would proceed as scheduled. However, for this study, a 20-yr delay was assumed in the availability of the Federal Repository. The processed waste would be stored onsite for 20 yr before shipment to the Repository. All the steps in this alternative are identical to those of Alternative 3 (see Subsection 9.1) with the addition of storage between processing and shipment.

The storage facility would consist of two aboveground engineered buildings located near the processing facility, as shown in Figure 9-11. The storage facility would resemble a large warehouse complex and would be designed to protect the processed waste for the 20-yr period. The buildings would be constructed of precast concrete panels as shown in Figure 9-12. This type of building is exceptionally strong and relatively low in cost. Each building would be approximately 192 x 384 x 20 ft high.

The use of precast, prestressed concrete panels in constructing low-cost permanent buildings is well established. These buildings are constructed in the following manner: the panels are approximately 8 ft wide; of the desired length; and contain prestressed, high-tensile steel wire. They are cast and are transported to the construction site after being properly aged. Steel plates are imbedded in each

Fig. 9-11 Location and arrangement for 20-yr storage of processed waste.

Fig. 9-12 Perspective of buildings for 20-yr storage of processed waste.

edge of each panel, and the plates are welded together during erection. The roof and walls are formed from the same type of panels. The steel plates in the roof slabs are welded to those in the wall panels to form a completely sealed structure.

Ventilation for the building would be provided by a system that provides a minimum of four air changes per hour in the working areas while the building is being filled with containers of waste. Air would be introduced into the building through a HEPA filter system and exhausted through a second system containing one stage of HEPA filters. Both systems would be provided with fire protection. After the building has been filled with waste containers, the ventilation system blowers would be shut off and the doors sealed. Subsequent ventilation, to control moisture, would be provided by natural convection through the filter system.

The waste containers would be delivered to the storage facility and stacked on end five high, with sheets of plywood between layers. Conventional material handling equipment would be used to stack the drums. The building would be designed to withstand a snow loading of at least 30 lb/ft² and to be tornado resistant. The facility also would be designed to meet the requirements of the Uniform Building Code (UBC 1961), and the DOE level of "Improved Risk". Security measures and the concrete building construction would protect the waste from vandalism and access by unauthorized personnel. In addition, the building would prevent the possible spread of contamination in the unlikely event of container leakage.

After the waste has been removed at the conclusion of the interim storage period, the building would be decontaminated, if necessary, and used for other purposes. To facilitate decontamination, the internal surfaces would have been coated at the time of construction

with an appropriate paint or resin to seal cracks and pores. The building would be dismantled at the end of its useful life, and the area would be returned to its natural state.

9.3 RETRIEVAL DELAYED 20 YEARS

In Alternative 6, retrieval and processing of the stored waste would be delayed 20 yr and begin in the year 2005. The Federal Repository was assumed to be available at that time so that the waste could be shipped to the Repository directly after processing.

This alternative is identical to Alternative 3 except for the 20-yr delay of all facilities and operations. If waste continued to be stored at the TSA during the 1985 to 2005 period, there would be more waste to retrieve, process, and ship when operations begin in 2005 than there would have been in 1985. Because waste generation rates have not been projected beyond 1987, the effects of this waste are not addressed here. See Appendix C for a discussion of the impact of waste received after January 1, 1985. In this study, the facilities required by this alternative were designed to retrieve, process, and ship only the waste expected to have accumulated by 1985. If waste continues to be stored on the pads at the TSA after 1985, either the capacity of the facilities described in Subsection 9.1 would be increased or the retrieval campaign would be extended past the stipulated 10-yr period. The latter seems the more logical approach, in view of the uncertainties in the receiving rates beyond 1985.

There are significant uncertainties associated with planning for a 20 yr delay. If the ongoing monitoring and surveillance program for the stored waste were to detect accelerated degradation of the waste containers, the delay of the retrieval for 20 yr would have to be reevaluated. Excessive deterioration of the stored waste containers

might result in a requirement for improved containment during retrieval. If the degradation of the containers were detected early enough, the retrieval and processing facilities could possibly be placed in operation before a significant number of containers failed. This subject is discussed in greater detail in Subsection B.5.3 in Appendix B.

10. ALTERNATIVES INVOLVING RETRIEVAL, PROCESSING, AND DISPOSAL ON THE INEL

In Alternative 5, the TRU waste would be retrieved from its present location, processed, and shipped to a disposal facility on the INEL. Because there are three processing modules (methods) and four disposal modules (methods), there are 12 possible combinations within this alternative. The 12 concepts for Alternative 5 are listed in Table 7-3.

Retrieval would begin in 1985 or as soon thereafter as practicable. Unlike Alternatives 3 and 4, which anticipate shipping the processed waste to the Federal Repository, the waste would be shipped to a disposal facility on the INEL after processing.

10.1 RETRIEVAL OF STORED WASTE

The retrieval module would be identical to that for Alternative 3, described in Subsection 9.1.1.

10.2 PROCESSING THE STORED WASTE

Three methods were analyzed for processing the stored waste under Alternative 5. They are: (1) incineration by slagging pyrolysis, followed by packaging; (2) compaction, immobilization, and packaging; and (3) packaging only.

10.2.1 Incineration and Packaging. This processing module applies to Concepts 5-a, 5-d, 5-g and 5-j in Table 7-3. However, these concepts have different disposal methods and locations.

The slagging pyrolysis facility and operations are described in Subsection 9.1.2. Incineration in Alternative 5 is identical to that in Alternative 3. The flow rates are given in Figure 10-1.

ESTIMATED QUANTITIES AND FLOW RATES FOR SLAGGING PYROLYSIS PROCESSING OF STORED TRU WASTE FOR DISPOSAL AT THE INEL (a,b)

	Combus- tibles	Noncom- bustibles	Makeup soil	Coal	Bark	Fuel Oil	Ash	Air	Waste Gases	Total
1 WASTE FEED										
ft ³ /day	314	691	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1005
tons/day	1.82	14.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	16.4
10 ³ ft ³ /10 yr	691	1520	N/A	N/A	N/A	N/A	N/A	N/A	N/A	221
tons/10 yr	4	32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	36
2 MAKEUP SOIL										
ft ³ /day	N/A	N/A	615	N/A	N/A	N/A	N/A	N/A	N/A	615
tons/day	N/A	N/A	24.6	N/A	N/A	N/A	N/A	N/A	N/A	24.6
3 FUEL										
ft ³ /day	N/A	N/A	N/A	704	1435	49.8	N/A	N/A	N/A	2189
tons/day	N/A	N/A	N/A	17.6	28.7	1.32	N/A	N/A	N/A	47.6
4 AIR										
10 ⁶ ft ³ /day	N/A	N/A	N/A	N/A	N/A	1.32	N/A	15.1	N/A	15.1
tons/day	N/A	N/A	N/A	N/A	N/A	1.32	N/A	578	N/A	578
5 PROCESS FEED										
ft ³ /day	314	691	615	704	1435	49.8	N/A	N/A	N/A	3809
tons/day	1.82	14.6	24.6	17.6	28.7	1.32	N/A	N/A	N/A	88.6
6 STACK GASES										
10 ⁶ ft ³ /day	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	16.3	16.3
tons/day	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	625	625
7 SLAG OUTPUT										
ft ³ /day	N/A	166	280	N/A	N/A	N/A	23	N/A	N/A	469
tons/day	N/A	14.6	24.6	N/A	N/A	N/A	1.98	N/A	N/A	41.2
8 TRANSPORTATION										
Containers/day	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	64
Truckloads/day	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.3

N/A Not Applicable

(a) Length of Campaign is 10 yr, 220 days/yr.

(b) Includes all the self-generated waste and 1/4 the D&D waste. Other D&D waste was assumed not processed.

Fig. 10-1 Process flow and flow rates for slagging pyrolysis of stored TRU waste.

10.2.2 Compaction, Immobilization and Packaging. This subsection describes the processing operation for Concepts 5-b, 5-e, 5-h, and 5-k (see Table 7-3). These concepts have different disposal methods and locations, but share the compaction, immobilization, and packaging process. In a facility designed for this purpose, the waste would be compacted within fiberboard containers. Four of the containers would be cast into a concrete block. This casting would accomplish both the immobilization and the packaging functions. Flow rates are given in Figure 10-2.

The facility layout is depicted in Figures 10-3 through 10-5. A block flow diagram of the process is shown in Figure 10-6. The transfer vehicle from the retrieval area would bring the waste containers into the receiving area. The containers would be removed from the transfer vehicle by a bridge crane. The crane would place the containers either in a temporary storage area or on a transfer cart. The containers would be monitored for radiation level and for gross transuranic content. The containers and cart would be raised to the upper level of the facility by an elevator. There the contents of the container would be dumped on an inspection conveyor. On the upper level, large items obviously requiring size reduction would be removed from the conveyor by a monorail hoist, then taken to the size reduction equipment. The remaining waste would be inspected visually. Hazardous items would be removed by a bridge-mounted manipulator for special handling.

The conveyor would dump the remaining waste into a feed bin through a screen. Items too large to pass through the screen would be taken to the size reduction equipment by the bridge-mounted manipulator. Other manipulators would be located near the size reduction equipment to aid in piece location and transfer between items of equipment. A separate conveyor would take the output from the size reduction equipment to a feed bin separate from that fed by the inspection conveyor. This bin would contain primarily large, solid chunks of material. The bin fed by the inspection conveyor would contain some large solid pieces, but the bulk of its contents would be small trash.

N/A Not Applicable

(a) Includes all self-generated waste and 1/4 of D&D waste. Other D&D waste is assumed not processed.

(b) Length of campaign is 10 yr, 220 days/yr.

(c) Includes volume of containers.

Fig. 10-2 Process flow and flow rates for compaction and immobilization of stored TRU waste.

Fig. 10-3 Plan of ground level of compaction and immobilization facility for stored TRU waste.

Fig. 10-4 Plan of second level of compaction and immobilization facility for stored TRU waste.

- 4 WASTE TRANSFER CART ELEVATOR
- 26 LARGE BOX LIFT MONORAIL HOIST
- 27 MANIPULATOR
- 28 SCREENED WASTE PARTICLES STORAGE BIN

Fig. 10-5 Cross section of compaction and immobilization facility.

Fig. 10-6 Block flow diagram for compaction, immobilization, and packaging.

A 30-in. diameter by 40-in. long fiberboard container would be placed into the female-mold portion of the compactor, which would be located beneath the outlet parts of the two feed bins. To gain efficiency in filling the containers, large pieces of waste from the size reduction feed bin would be fed into the container first. Smaller pieces of waste from the inspection feed bin would then be fed into the container to fill the void spaces. Compaction would be accomplished by a hydraulically actuated piston. Successive filling and compacting would compress the waste into a solid cylinder within the fiberboard container. It was estimated that the compaction operation would reduce the overall volume of waste by about 40%. Therefore, the compaction operation would reduce the waste input of about 2.2 million ft^3 to about 1.3 million ft^3 . The flow rate from the compaction operation would be about 250 filled fiberboard containers per week.

When full, the fiberboard container would be moved to a capping station. It would then leave the compaction area and enter the immobilization area, where it would be placed in a form with three other containers. Concrete would be added, completely encasing the four fiberboard containers. The form would be vibrated during filling to eliminate voids. The casting operation would generate about 63 concrete blocks per week.

After the concrete pouring is complete, a bridge crane would be used to place the form on a transfer cart, which would take the form to a storage area. There the concrete would be allowed to cure for about 20 days, hardening into a block. The blocks would be about 63 in. square and 43 in. high, and would weigh about 8700 lb. When curing is complete, the blocks would be monitored for contamination. Any contamination would be removed prior to loading. The blocks would then be moved by the bridge crane to a truck for shipment to the disposal location.

As with the slagging pyrolysis facility (Subsection 9.1.2.3), the compaction facility would be a reinforced concrete structure with three separate air zones, each based on the potential level of contami-

nation. All inlet air would pass through a single bank of HEPA filters. All air removed by the ventilation systems would pass through roughing filters having 30% and 90% efficiencies, and then through HEPA filters. Air from the innermost and middle zones would pass through two HEPA filter banks in series; and air from the outer zone, through one HEPA filter bank.

10.2.3 Packaging Only. This section describes the processing operation for Concepts 5-c, 5-f, 5-i, and 5-l. (Refer to Table 7-3.) These concepts have different disposal methods and locations, but share the packaging process.

In a facility designed for this purpose, the waste would be reduced in size, if necessary, and then placed in new 55-gal drums. Material flow rates are given in Figure 10-7.

The facility layout is depicted in Figures 10-8 through 10-10. A block flow diagram of the process is shown in Figure 10-11. The receiving area, monitor station, elevator, inspection conveyor, feed storage bins, and size reduction areas would all be the same as in the facility described in the previous subsection. The main difference would be that the material from the bins would be fed into steel drums and that there would be no compaction. The drums would be the final containers, so there would be no encapsulation in concrete. The drum filling would take place on a rotating platform with four indexed positions: (1) load empty drum onto platform, (2) fill drum, (3) fasten lid on drum, and (4) unload filled drum.

The filled drums would be removed from the filling area to a monitoring and decontamination area through an airlock. From there they would go to a palletizing area where the drums would be strapped onto pallets, two layers of 6 drums each per pallet. The pallets would be loaded onto trucks using forklifts, or stored for later shipment.

Fig. 10-7 Process flow and flow rates for packaging only of stored TRU waste.

Fig. 10-8 Plan of ground level of packaging-only facility.

Fig. 10-9 Plan of second level of packaging-only facility.

4. WASTE TRANSFER CART ELEVATOR
8. FULL DRUM TRANSFER MONORAIL
11. AIR LOCK
12. MONITORING & DECONTAMINATION ROOM
19. INSPECTION CONVEYOR
20. SCREENING HOPPER
21. SCREENED WASTE PARTICLES STORAGE BIN
22. ELEVATOR HOIST
23. LARGE BOX LIFT MONORAIL HOIST
24. MANIPULATOR

Fig. 10-10 Cross section of packaging-only facility.

Fig. 10-11 Block flow diagram of packaging-only process.

10.3 ONSITE SHIPMENT

Onsite shipment of processed waste would be accomplished using semitrailers pulled by standard, highway truck tractors. The trucks would travel over an asphalt-surfaced road that would be committed to traffic associated with shipment of the TRU waste. To reduce the probability of accidents, the trucks would be limited to a speed of 35 mph and would travel only 12 hr/day, primarily during daylight hours.

The cast slag from slagging pyrolysis would be shipped in DOT Spec 17C, 55-gal capacity drums without plastic liners. Each drum would weigh about 1360 lb. Fifty drums would be loaded onto a low-boy semitrailer. Because the semitrailers would travel only on a committed roadway at controlled speeds, normal highway load limits would not govern.

The compacted waste would be contained in cylinders that are 30 in. diameter by 40 in. long. Four cylinders would be immobilized within a 63-in. square, 43-in. tall block of concrete, as described in Subsection 10.2.2. Each block would weigh about 8700 lb. Four blocks would be loaded onto a semitrailer. Again, travel over a committed road would waive weight limits.

The packaged waste would be shipped in DOT Spec 17C, 55-gal capacity drums without plastic liners. Each drum would weigh about 260 lb. To reduce the truck loading and unloading times, the drums would be strapped onto pallets, 12 drums/pallet. Twelve pallets would be loaded on a semitrailer for shipment.

Table 10-1 summarizes the parameters for onsite shipment. Due to rounding of the numbers of semitrailers and of trips/semitrailer, multiplication of the shipment rates by the container volumes will not exactly equal the total waste volume to be shipped.

TABLE 10-1

SUMMARY OF DAILY ONSITE SHIPMENT OF PROCESSED STORED WASTE

Waste From:	Destination								
	Deep Rock, Disposal Shaft Access			Deep Rock Disposal, Tunnel Access			Site 14		
	60 miles/round trip			60 miles/round trip			40 miles/round trip		
	Containers Per Semi-trailer	Number of Semitrailers In Operation	Round Trips Per Semi-trailer	Containers Per Semi-trailer	Number of Semitrailers In Operation	Round Trips Per Semi-trailer	Containers Per Semi-trailer	Number of Semitrailers In Operation	Round Trips Per Semi-trailer
Slagging Pyrolysis and Packaging	48(a)	2	1	48(a)	2	1	48(a)	1	2
Compact Immobilize and Package	8(h)	2	1	8(h)	2	1	8(b)	1	2
Package Only	144(c)	2	1	144(c)	2	1	144(c)	1	2

(a) Each container holds 7.4 ft³ of cast slag.

(b) Each container holds 65.36 ft³ of compacted waste.

(c) Each container holds 5.9 ft³ of packaged waste.

10.4 DISPOSAL

Four disposal modules were analyzed. In two of the modules, the processed waste would be placed in vaults or rooms mined out of the calcareous rocks in the Lemhi Mountain Range. These rocks are not part of the formation in which the Snake River Plain Aquifer is located. The two modules differ primarily in the access to the underground workings - shaft or tunnel. The third module involves engineered shallow-land disposal in lacustrine sediments at an area on the INEL known as Site 14. Two design versions of this module were studied, affording different degrees of protection for the waste. The fourth module is disposal of the waste in an aboveground concrete structure near the RWMC.

For all disposal methods and locations studied, the volumes, including containers, to be disposed of would be: (1) 1.3 million ft^3 from the incineration process, (2) 1.9 million ft^3 from the compaction and immobilization process and, (3) 3.4 million ft^3 from the packaging-only process.

10.4.1 Deep Rock Disposal - Shaft Access. Concepts 5-a, 5-b, and 5-c involve deep rock disposal in the Lemhi Range with shaft access. This module requires construction of two shafts to a subsurface repository in which the waste would be stored. The repository would be similar in design, but smaller and less complex than the Waste Isolation Pilot Plant proposed by DOE as a Federal Repository.

The surface facilities and shaft entrances would be located on the INEL in the lower reaches of the Lemhi Range, as shown in Figures 3-2 and 3-4. For this study, the site has been tentatively located in the southern half of Section 27, Township 6 N, Range 30 E. Selection of an actual site would take place after the area had been thoroughly investigated by core drilling. Because the presence of water would be a detriment to long-term container integrity, the core holes would be tested for water in formation before proceeding with

this disposal module. Reports concerning old mines in other areas of the Lemhi Range indicate that water might be a serious problem in the limestone in which the vault area would be located.

The geology of this area is briefly described in Subsection 3.4.4. The upper hundred feet or less of the shafts would probably be in quaternary alluvial fan material. Both shafts would be lined with concrete for their entire length. The majority of the length of the shafts, as well as the mine, would be located in carboniferous rocks. These rocks are mostly limestones and dolomites. The selection of the layer for the mine, and its exact depth below the surface, would depend upon the drilling results.

To protect the waste from possible surface effects, the vault area would be located a minimum of 800 ft below ground. For this report, it was assumed that the shafts would be 800 ft long. The Snake River Plain in the vicinity of the proposed site is about 200 ft below the elevation at the entrances of the shafts. The vault area would therefore be at least 600 ft below the surface of the plain.

After waste emplacement and a 30-yr retrievability period, the shafts would be filled with rock and plugged with concrete.

10.4.1.1 Assumptions. Little information is available on ground conditions or groundwater problems in the area of interest. For this study, the following assumptions were made. Detailed onsite studies might lead to modification of these assumptions.

- (1) No unusual groundwater problems will be encountered in the underground workings.
- (2) Minimal ground support will be needed in the rock type selected.

- (3) Ventilation will be provided by input fans at the surface and controlled underground by brattices and overpasses. In the vault rooms, the air will be distributed by fans and ducts.
- (4) Because of the volume of air involved, the exhaust will not normally pass through HEPA filters, but will bypass them. Whenever the radiation level in the exhaust increases significantly, a radiation monitor in the exhaust stream will activate a motor to close a door in this bypass and direct the exhaust air through the HEPA filters. Input and exhaust fans will be sized to ensure that the inflow air will be at a higher pressure than the exhaust. Thus, air flow will be toward the exhaust system.
- (5) Rock excavation will proceed at approximately the same rate as emplacement of waste, so that one room will be ready when the previous room has been filled.
- (6) Emplacement of waste will be carried out over a 10-yr period from the date of start. The workings will be maintained for 30 yr after final emplacement for possible reentry and waste removal. See Guideline (8) in Subsection 7.4.1.1.

10.4.1.2 Mining Method. Excavation would be by conventional mining methods. The rock strength is estimated to be above the practical limit for continuous mining machines. Rock-boring machines were not considered due to the number of sharp corners in the tunnels. Diesel powered, rubber-tired mine equipment would be used for maneuverability and adaptability. Load-haul-dump equipment would haul the rock to the man/materials (m/m) shaft station for loading into the skip. Water would be used for drilling and for wetting down the rock to comply with applicable mining laws. All tunnels would be driven on a +1/2% slope to facilitate drainage of mine water to a sump for pumping to the surface. The tunnels would be interconnected at predetermined points to facilitate ventilation. This would also allow the

passage of mining equipment from one tunnel to the other. A room-and-pillar system would be used for the waste vault area. Both rooms and pillars would be 20 ft wide. The entire roof area would be rock bolted with wire mesh. In addition, rock bolting on the sides of openings might be required.

10.4.1.3 Surface Facilities. The repository would require both surface and subsurface facilities. The surface facilities, shown on Figure 10-12, are:

- (1) waste receiving and handling building,
- (2) administration facility,
- (3) maintenance building,
- (4) mine building,
- (5) warehouse and shops,
- (6) sewage treatment facility,
- (7) transformer yard, and
- (8) rock dump area.

The waste receiving and handling building would provide the capability to receive and handle the incoming waste. It would also contain facilities to decontaminate containers and equipment and to repackage damaged containers. A health physics area and change rooms would also be provided. A plan of this building is shown in Figure 10-13. The waste hoist and the exhaust fans and filters are also located in this building.

The administration facility would contain administrative office space, a supply storage area, and repair and maintenance facilities for uncontaminated equipment. It would also contain alarm and communications equipment, an emergency power supply, and guard facilities.

The mine building would be located at the man/materials (m/m) shaft. It would contain the m/m hoist, the input ventilation equipment for the mine, and the air compressors. Rock excavated from

Fig. 10-12 Site plan for surface facilities for deep rock disposal - shaft access.

Fig. 10-13 Plan of waste facility for deep rock disposal - shaft access.

the mine would be brought to the surface via the m/m shaft only. About 60% of the excavated rock might be used later for backfill. If the remainder is found useful as a construction material at some other location within the INEL, it could be released for that purpose.

10.4.1.4 Underground Facilities. Underground facilities would include two shafts, drifts or tunnels to the mining and vault areas, the vaults or rooms in which the waste would be placed, a maintenance area, and an area containing eating and sanitary facilities for the workers. The initial construction phase would comprise the two shafts, the drifts or tunnels, the ventilation system, and sufficient vault capacity to accommodate the output of one year of operation of the process facility. Subsequent to the initial phase, additional vault space would be mined incrementally, as part of the operating and maintenance activities, to keep pace with the process facility output.

Figure 10-14 is a sketch of the underground layout and also shows the ventilation flow. Table 10-2 lists the approximate volumes of rock to be excavated and the estimated emplacement rates for the three waste processing modules. The emplacement rates are based upon the assumption that the underground facilities would be in operation 52 weeks/yr, as opposed to the 220 operating days/yr at the process facility. Therefore, the waste emplacement rate can not be related directly to the containers/day output from the process facilities as shown on Figures 10-1, 10-2 and 10-7.

The m/m shaft would provide the means for removing excavated rock from the mine and bringing in men and materials. It would also contain electrical cables and accommodate the mine intake air supply. The waste shaft would be used only for bringing in waste and for exhausting the air. Both shafts would be concrete lined for their entire depth, and would have a finished inside diameter of 12 ft. Both shafts would be equipped with two drum hoists and head frames of suitable capacity. The m/m shaft would also be equipped with a skip

Fig. 10-14 Plan and ventilation flow of underground facility for deep rock disposal shaft access.

TABLE 10-2

SIZE REQUIREMENTS FOR DEEP ROCK DISPOSAL FACILITY - SHAFT ACCESS

Item	Processing Concept		
	Slagging Pyrolysis and Packaging	Compaction, Immobilization, and Packaging	Packaging Only
Volumes to be Mined, 10^6 ft ³	3.2	3.9	6.0
Disposal Volume, Rooms (b)	10	14	25
Excavation Rate (a)			
Rooms/yr (b)	1.0	1.4	2.5
Ft of Tunnel/yr	71	97	168
Container	55-gal drum	Concrete block 63 in. x 63 in. x 43 in. high	55-gal drum
Handling Unit	pallet	block	pallet
Containers/Handling Unit	6	1	12
Weight of Handling Unit, lb	8,160	8,700	3,120
Waste Emplacement Rate (c)			
Containers/week	270	38	719
Handling Units/week	45	38	60

(a) Assumed length of campaign is 10 yr, following 30-month mine opening

(b) Assumed room size: 500 x 20 x 18 ft

(c) Based on 52 weeks/yr operation

pocket for rock removal at the underground station and a rock bin at the surface. The shaft separation would depend on the exploratory core drilling results, but would not be less than 300 ft. Tunnels about 750 ft long would connect the shafts to the vault area. These tunnels would be 10 ft square, as would the tunnels within the vault area. The vaults or rooms would be about 20 ft wide and about 500 ft long. About 18 ft of usable storage height would be provided.

A forklift would remove the waste from the waste hoist cage at the underground station and place it on a diesel-powered, rubber-tired truck for transfer to the vault area. This truck would be of standard mine design. In the vault where waste is being emplaced, another forklift would unload the truck and put the waste in its final position.

The maintenance area would be near the base of the m/m shaft. Only limited maintenance operations, such as of mining equipment and waste transporters, would be conducted underground. First-aid facilities and a lunch area with restrooms would also be located in this area.

10.4.2 Deep Rock Disposal - Tunnel Access. Concepts 5-d, 5-e, and 5-f involve deep rock disposal with tunnel access in the southeast portion of the Lemhi Mountain Range in the northwest part of the INEL. (The geology of this area is presented in Subsection 3.4.4. The tunnel entrance location is shown in Figures 3-2 and 3-4.) This module requires construction of two tunnels and a subsurface repository for the waste. The repository would be identical to that described in Subsection 10.4.1.4.

After waste emplacement and a 30-yr retrievability period, the tunnels would be filled with rock and plugged with concrete.

10.4.2.1 Location and Rock Units Involved. For purposes of this study, the disposal vault area was tentatively located in the southeastern quarter of Section 10 of Township 6 N, Range 30 E. Selection of an actual disposal location would take place only after the area had been thoroughly investigated. Based on experience at the

lead and silver mines elsewhere in the Lemhi Range, there is a possibility that limestone in the proposed vault area would be water saturated. Because this would be undesirable, the vault area would be explored by core drilling and hole testing before proceeding further with this disposal concept.

Two parallel tunnels would be required, each about 5000 ft long. Their entrances would be located about 5275 ft above sea level in the southeastern quarter of Section 11 of Township 6 N, Range 30 E. The vault area would be located approximately 5300 ft above sea level, and would be more than 800 ft below the ground surface. If needed at a later date, additional vault area could be located on lower levels.

The tunnel mouth and approximately the outer half of the tunnel would be located in silicic volcanic rocks of Pliocene age. This petrologic sequence is composed mostly of rhyolites and welded tuffs, which are quite porous. Excavation of these rocks would be comparatively easy, but ceiling support would be required for much of the tunnel. The vault area and approximately the last half of the access tunnel would be located in carboniferous sedimentary rocks. These rocks consist primarily of limestones and dolomites, with interbedded shale layers. Excavation in these rocks would be slower than in the volcanic rocks, but much less roof support would be required.

10.4.2.2 General Description. The Lemhi Range disposal facility would consist of a surface facility, two tunnels approximately 5000 ft long each, and an underground vault area. Figure 10-15 shows a cross section of the proposed facility. The assumptions used for this disposal module are the same as those listed in Subsection 10.4.1.1 for the deep rock disposal-shaft access module. The mining method for tunnel access is similar to the method for shaft access, given in Subsection 10.4.1.2. The major difference is that the tunnels to the vault area would be sloped upward on a + 1/2% slope, so that drainage of any moisture would be toward tunnel entrances. Passageways within the vault area would also be sloped so as to permit any moisture to drain out of the mine. Thus, there would

Fig. 10-15 Cross section of facility for deep rock disposal - tunnel access.

be no sump within the mine and no need for pumping to remove water. Any water drainage from the vault would be collected at the tunnel entrances and monitored for radioactivity before release.

10.4.2.3 Surface Facilities. Figure 10-16 shows the surface facilities. There is presently insufficient flat area for the administration building and waste transfer building to be located as shown. This area would be built up with rock excavated from the tunnel and vault area. After this area has been built up, the rock excavated by mining would be hauled north and dumped in a spoil area.

Figure 10-17 is a plan of the waste transfer building for loading and unloading. Forklifts would remove containers of waste from the transfer vehicle and place them on the mine trucks to be hauled to the vault area. Trucks would pass through an airlock enroute to and from each tunnel. A constant flow of air into and out of the mine would thereby be maintained. The air intake would be located where it would not pick up exhaust air.

10.4.2.4 Underground Facilities. The underground facilities would include the two access tunnels and the vault area (Figure 10-18). No maintenance or eating facilities would be provided underground. The initial construction phase would comprise the two access tunnels and sufficient vault capacity to accommodate the output from one year of operation of the process facility. Subsequent to the initial phase, additional vault space would be mined incrementally, as part of the operating and maintenance activities, to keep pace with the process facility output.

Volumes and emplacement rates are given in Table 10-3. The emplacement rates are based on the assumption that the underground facilities would be operated 52 weeks/yr, as opposed to the 220 operating days/yr at the process facility. Therefore, the waste emplacement rate cannot be related directly to the containers/day output from the process facilities, as shown on Figures 10-1, 10-2, and 10-7.

Fig. 10-16 Site plan for surface facilities for deep rock disposal - tunnel access.

Fig. 10-17 Plan of waste transfer building for deep rock disposal - tunnel access.

Fig. 10-18 Plan and ventilation flow for underground facility for deep rock disposal - tunnel access.

TABLE 10-3

SIZE REQUIREMENTS FOR DEEP ROCK DISPOSAL FACILITY - TUNNEL ACCESS

Item	Processing Concept		
	Slagging Pyrolysis and Packaging	Compaction, Immobilization, and Packaging	Packaging Only
Volumes to be Mined(a), 10 ⁶ ft ³	4.2	4.9	7.0
Disposal Volume, Rooms	10	14	25
Excavation Rate(b)			
Rooms/yr	1.0	1.4	2.5
Ft of Tunnel/yr	71	97	168
Container	55-gal drum	concrete block 63 in. x 63 in. x 43 in. high	55-gal drum
Handling Unit	pallet	block	pallet
Containers/Handling Unit	6	1	12
Weight of Handling Unit, lb	8160	8700	3120
Waste Emplacement Rate(c)			
Containers/week	270	38	719
Handling Units/week	45	38	60

(a) Includes two 5000 ft long access tunnels.

(b) Assumed length of campaign is 10 yr, following 30-month mine opening.

(c) Based on 52 weeks/yr operation.

Both tunnels would be 10 ft square. Their roofs would be rock bolted with wire mesh for their entire length. The waste tunnel would be used only for hauling waste into the mine and for exhaust air. The m/m tunnel would be used for rock removal, access for men and materials, and intake ventilation. Load-haul-dump equipment would haul the rock to the surface via the m/m tunnel and dump it in a spoil area. Trucks of standard mine design would transport the waste into the vault area via the waste tunnel. The vault area would be identical to the vault area with shaft access described in Subsection 10.4.1. Tunnels in the vault area would be 10 ft square. The rooms would be about 20 ft wide and about 500 ft long. About 18 ft of usable storage height would be provided. Pillar width would be 20 ft. Ventilation flow is shown in Figure 10-18.

10.4.3 Engineered Shallow-Land Disposal at Site 14. Concepts 5-g, 5-h, and 5-i involve shallow-land disposal of processed waste in engineered structures at Site 14. Table 10-4 lists the number of containers to be disposed of for each process module described in Subsection 10.2.

Two designs were developed for the engineered disposal structures. The baseline design contemplates massive structures intended to endure for thousands of years. However, the estimated cost for the massive structures is much larger than that for the deep rock disposal modules. Because of the very unfavorable cost of this design, a less massive variation of the design was also developed and is discussed in Subsection 10.4.3.6.

10.4.3.1 Site Description. Site 14 is described in Section 3. Figure 3-2 shows the location of Site 14. The location considered is about 1.5 miles east of Lincoln Boulevard and approximately 20 miles north of the Test Reactor Area (TRA). The area is in a slight depression. The elevation ranges from 4790 to 4795 ft above sea level, with the slope being upward to the southwest.

TABLE 10-4

SIZE REQUIREMENTS FOR ENGINEERED SHALLOW-LAND
DISPOSAL FACILITY AT SITE 14

	Process		
	Slagging Pyrolysis and Package	Compaction, Immobilization, and Packaging	Packaging Only
Container	55-gal drum	concrete block 63 in. x 63 in. x 43 in. high	55-gal drum
Approximate Number of Containers	140,800	19,800	374,000
Disposal Room Cross Section	12 ft wide 10 ft high	12 ft wide 12 ft high	12 ft wide 10 ft high
Total length of Disposal Rooms at Above Cross Section, ft	18,800	18,000	49,800
Number of Storage Structures Required ^(a)	6	5	14

(a) Each structure would be about 186 ft wide and 600 ft long, and would contain six disposal rooms.

10.4.3.2 Disposal Facility. The general arrangement of the disposal facility is shown in Figure 10-19. The facility consists of underground concrete structures arranged in a rectangular array. A cross section through a typical structure is shown in Figure 10-20. Each structure would be about 600 ft long, 186 ft wide, and 24 ft thick. It would be buried so that the top of the structure would be 15 ft below the original surface of the ground. Each structure would contain 6 rooms running the full length of the structure and having a cross section 12 ft wide and 10 or 12 ft high depending on the waste containers to be disposed. This room cross section would enable placement of standard drums 5 across and stacked 3 high, or placement of the concrete blocks 2 across and stacked 3 high. The structural configuration is typified by (1) high ratio of solid material (reinforced concrete) to void, (2) use of massive interlocking concrete blocks, and (3) use of a thick layer of natural material (bentonite, clay, and basalt riprap) to protect the concrete from the environment. This design would protect the waste against containment failure modes that might be anticipated over a prolonged period of time, including:

- (1) gradual deterioration of the concrete, followed by tensile failure and collapse into the void volumes;
- (2) failure due to a seismic event or any other occurrence causing relative displacement of the structure;
- (3) erosion or washing away of the protective cover, followed by deterioration and failure of the concrete structure; and
- (4) impact by large objects; e.g., aircraft.

The proposed structural arrangement would minimize the volumetric change under completely collapsed conditions. This would maintain the integrity of the basic structure and reduce the possibility of breaching the protective cover.

Fig. 10-19 Plan of shallow-land disposal facility for stored TRU waste at Site 14.

Fig. 10-20 Cross section through typical structure at Site 14.

The use of a structure built of interlocking blocks would provide a high degree of flexibility and would redistribute the stresses due to relative motion rather than crack or shear as might be expected in a rigid structure. An additional desirable feature results from the high percentage of overlap of the blocks spanning the tunnels. This arrangement would provide solid beam support, so that tensile stresses in the span would be small.

Protection from failure due to erosion, leakage, or impact would be provided by a minimum of 21 ft of clay, bentonite, and basalt covering the concrete structure. The basic approach would be to provide an outer layer that is highly resistant to the environment and to destructive events, and to underlie this layer with a thick impervious blanket to provide isolation and protection against moisture penetration. To provide improved drainage, the upper surface would be graded to provide a 10% slope from the centerline to a point 30 ft from the edge of the structure.

- To permit emplacement of waste containers, an asphalt ramp would be constructed, extending from the ground surface to the floor level of the rooms. A temporary office and vehicle maintenance building would be situated adjacent to the structures to provide space for administration activities and for servicing equipment assigned to the area.

A 24-ft wide asphalt roadway about 20 miles long would be constructed to permit shipment of the processed waste from the RWMC to Site 14. This committed roadway would not intersect the public roadway, but would pass beneath it by means of an underpass. The disposal area would also be connected to Lincoln Boulevard by a 24-ft wide asphalt roadway about 1.5 miles long. A 20-ft wide gravel roadway would be constructed around and between each structure to permit surveillance. The entire area would be surrounded by a 12-ft chain link fence.

10.4.3.3 Surveillance. To facilitate continued surveillance of the spaces within the structures, instrumentation would be installed during construction. Any abnormal increase in activity would be detected and corrected. This surveillance would be continued for a period of about 100 yr.

10.4.3.4 Waste Emplacement. Containers of processed waste would be transported to Site 14 using low-boy type trailers. The containers would be unloaded by forklifts and either placed on a temporary storage pad adjacent to the ramps leading to the rooms or placed in their final positions within the rooms. When each room is filled, it would be temporarily closed with a concrete barrier. Upon completion of the 40-yr operational and observational period (during which retrieval capability would be provided), the barrier would be replaced with a solid concrete plug and the ramp area completely filled.

10.4.3.5 Construction Techniques. The concrete blocks used for construction are too large to permit prefabrication and individual placement. Therefore, it would be necessary to provide forms and pour each block in place. This would be done by using moveable forms and by placing impermeable barriers on adjacent blocks to provide controlled separation between blocks. The initial construction phase would comprise site preparation, the 20-mile and 1.5-mile asphalt roadways, the gravel roadways, the chain link fence, the service facilities, and sufficient underground structures to accommodate the output from one year of operation of the process facility. Additional underground structures would be constructed incrementally, as part of the operating and maintenance activities, to keep pace with the process facility output.

10.4.3.6 Engineered Shallow-Land Disposal at Site 14 - Less Massive Variation. The less massive variation (LMV) of the engineered structures for shallow-land disposal differs from the previously discussed design, principally in the use of 8-in. walls, rather than approximately 8-ft walls. Only the significant differences between the two designs are discussed here.

The facility consists of underground concrete structures arranged in a rectangular array (Figure 10-21). Table 10-5 lists the number of containers to be disposed of for each processing method. A cross section through a typical structure is shown in Figure 10-22. Each structure would be about 500 ft long, 120 ft wide, and 14 ft thick. The top of the structure would be 15 ft below the original surface of the ground. Each structure would contain 6 rooms running the full length of the structure and having a cross section 16.8 ft wide and 12.5 or 11.5 ft high depending on the waste containers to be disposed. This room cross section would enable placement of standard drums 8 across and stacked 4 high, or placement of the concrete blocks 3 across and stacked 3 high.

The 500 ft structure would be subdivided by cross walls every 50 ft forming individual cells 50 ft long, 16.8 ft high, and 12.5 or 11.5 ft wide. The stacked waste container arrays would be surrounded by a layer of tar approximately 4 in. thick to provide an elastic waterproof coating. The structural configuration is typified by multiple containment layers (waste container, tar, and concrete) and a thick layer of natural material (bentonite, clay, and basalt riprap) to protect the concrete from the environment. This design would provide protection of the waste against the containment failure modes listed in Subsection 10.4.3.2.

The proposed structural arrangement would minimize the effects of volumetric changes under completely collapsed conditions. If a collapse resulted in a waste volume change of 50%, the top of the cover would still be at least 10 ft above the surrounding area, thereby providing drainage. Protection from failure due to erosion, leakage, or impact would be provided by the minimum of 21-ft layer of clay, bentonite, and rock covering the concrete structure.

The concrete rooms would be formed and poured in place. The roof slabs would be either poured onsite, or fabricated elsewhere and transported to the site as needed. The initial construction phase would

Fig. 10-21 Plan of shallow-land disposal facility (less massive variation) for stored TRU waste at Site 14.

TABLE 10-5

SIZE REQUIREMENTS FOR ENGINEERED SHALLOW-LAND DISPOSAL
FACILITY AT SITE 14 - LESS MASSIVE VARIATION

	Process		
	Slagging Pyrolysis and Packaging	Compaction, Immobilization, and Packaging	Packaging Only
Container	55-gal drum	concrete block 63 in. x 63 in. x 43 in. high	55-gal drum
Approximate Number of Containers	140,800	19,800	374,000
Disposal Room Cross Section	16.8 ft wide 12.5 ft high	16.8 ft wide 11.5 ft high	16.8 ft wide 12.5 ft high
Number of Storage Structures Required (a)	3	4	9

(a) Each structure would be 118 ft wide and 500 ft long, and would contain six disposal rooms.

Fig. 10-22 Cross section through typical structure (less massive variation) at Site 14.

comprise site preparation, the 20-mile and the 1.5-mile asphalt roadways, the gravel roadways, the chain link fence, the service facilities, and sufficient underground structures to accommodate the output from one year of operation of the process facility. Additional underground structures would be constructed incrementally, as part of the operating and maintenance activities, to keep pace with the process facility output.

10.4.4 Disposal in Engineered Surface Facility near the RWMC.

Concepts 5-j, 5-k, and 5-l involve disposal of processed waste in an engineered surface facility near the RWMC. The size of the facility would be based on disposal of stored waste processed by the three methods discussed in Subsection 10.2. Table 10-6 lists the number of containers to be disposed of for each processing method.

10.4.4.1 Site Description. The INEL and the RWMC are described in Section 3. Figure 10-23 shows the RWMC and the location of existing and proposed facilities and disposal areas. The location studied for the Engineered Surface Disposal Facility, is adjacent to the southeastern corner of the RWMC and extends outside and south of the existing RWMC fence. The elevation in this area ranges from 5010 to 5020 ft above sea level and slopes to the northwest. The surface soil is typically about 15 ft thick, with an underlying layer of basalt approximately 100 ft thick.

10.4.4.2 Disposal Facility. The Engineered Surface Disposal Facility would consist of elongated, earth-covered, concrete structures, arranged as shown in Figure 10-23. Each structure, including the cover material, would be approximately 820 ft long, 340 ft wide and 62 ft high (above ground level). Figure 10-24 shows the cross section of a typical structure. Figure 10-25 is an isometric cutaway illustrating the overall configuration.

Each structure would contain 15 disposal rooms. Each room would be 12 ft wide by 10 or 12 ft high depending on the waste containers to be disposed and extend the full length of the structure. The room

TABLE 10-6

SIZE REQUIREMENTS FOR ENGINEERED SURFACE DISPOSAL
FACILITY NEAR THE RWMC

	Process		
	Slagging Pyrolysis and Packaging	Compaction, Immobilization, and Packaging	Packaging Only
Container	55-gal drum	concrete block 63 in. x 63 in. x 43 in. high	55-gal drum
Approximate Number of Containers	140,800	19,800	374,000
Disposal Room Cross Section	12 ft wide 10 ft high	12 ft wide 12 ft high	12 ft wide 10 ft high
Total length of Disposal Rooms at Above Cross Section, ft	18,800	18,000	49,800
Number of Storage Structures Required	2.02 (use 2, 620 ft long)	2.0 (use 2, 600 ft long)	5.53 (use 6, 600 ft long)
Height of Structure, ft	62	72	62

Fig. 10-23 Plan for disposal in engineered structures for stored TRU waste near the RWMC.

Fig. 10-25 Isometric cutaway of engineered structure at surface disposal facility near the RWMC.

cross section would permit placement of 55-gal drums 5 across and 3 high, or concrete blocks 2 across and 3 high. The initial construction phase would comprise site preparation and construction of sufficient structures to accommodate the output from one year of operation of the processing facility. Additional structures would be constructed incrementally, as part of the operating and maintenance activities, to keep pace with the process facility output.

The structural configuration would have a high ratio of solid material (reinforced concrete) to void because of the use of massive interlocking concrete blocks rather than solid poured concrete. The site would be excavated to permit this massive structure to rest on basalt. A 12-ft layer of natural material (bentonite, clay, and basalt riprap) would protect the concrete from the environment. This design would provide protection for the waste against the containment failure modes that might be anticipated for a structure of this type under the local environmental conditions for a prolonged period of time, as discussed in Subsection 10.4.3.2. The maximum volumetric change under the completely collapsed condition would be only about 25%.

A structure built of interlocking blocks would provide a high degree of flexibility and would tend to redistribute stresses due to relative motion rather than to crack or shear as might be expected in a rigid structure. An additional desirable feature in this structural configuration results from the high percentage of overlap of the blocks spanning the void regions. This arrangement would provide solid beam support rather than simple point support. Thus, tensile stresses in the span would be small.

10.4.4.3 Surveillance. To facilitate continued surveillance of the spaces within the structures, instrumentation would be installed during construction. Any abnormal increase in radioactivity would be detected and corrected. The surveillance would be continued for a period of about 100 yr.

10.4.4.4 Waste Emplacement. To permit emplacement of waste containers, temporary earth-filled ramps would be constructed from the level of natural terrain to the level of the tunnels. The containers would be transferred from the processing facility to the disposal facility. Forklifts would be used to position the containers in the tunnels. As each tunnel is filled, it would be temporarily closed with a concrete barrier. At the end of the 40-yr operational and observational period during which retrieval capability would be provided, the temporary barrier would be removed and replaced with a solid, poured-in-place concrete plug. The end of the structure would then be covered with the same bentonite, clay, and basalt blanket described previously.

10.4.4.5 Construction Techniques. The concrete blocks used for construction are too large to permit prefabrication and individual placement. Therefore, it would be necessary to provide forms and pour each block in place. This would be done by using moveable forms and by placing impermeable barriers on adjacent blocks to provide controlled separation between blocks.

10.5 DECONTAMINATION AND DECOMMISSIONING

D&D of the retrieval and slagging pyrolysis facilities is discussed in Subsection 9.1.5. In many respects, D&D of the facility to compact, immobilize, and package the waste would be similar to D&D of the slagging facility. Equipment that is not decontaminable would be shipped to the disposal facility.

D&D of the facility for packaging the waste would be simpler than D&D of the other processing facilities. Again, equipment that could not be decontaminated would be shipped to the disposal facility.

It is anticipated that disposal service facilities, such as maintenance shops, would not become contaminated. Therefore, D&D would be relatively simple compared with D&D of retrieval or process facilities.

11. COMBINED MANAGEMENT OF BURIED TRU WASTE AND STORED TRU WASTE

As mentioned in Subsection 7.3, the DOE alternatives study for INEL TRU waste and the draft EIS for INEL TRU waste address both the buried TRU waste and the stored TRU waste. The selection of a particular alternative or concept for managing one type of TRU waste could affect the choice of alternative or concept for the other type. This subject is discussed in the studies just mentioned. Because the present study addresses only stored TRU waste, the topic of combined waste management is not addressed here. The existence of such considerations is simply called to the reader's attention.

12. ENVIRONMENTAL EFFECTS OF ALTERNATIVES FOR MANAGING TRU WASTE

12.1 INTRODUCTION AND APPROACH

This discussion of environmental effects is presented in three major parts. Subsection 12.2 discusses the potential impacts, basically all nonradiological, of preparing the sites and constructing the facilities described in Sections 8, 9, 10. Subsection 12.3 discusses the nonradiological impacts of operating the facilities and subsequently decontaminating and decommissioning (D&D) them. Subsection 12.4 discusses the radiological impacts of operations and D&D.

Whenever possible, the environmental effects are discussed generically. In cases for which a generic discussion would be inadequate, an effect (or impact) is discussed by module.

Each impact is generally discussed first in terms of the leave-in-place alternatives. Then four waste management operations are discussed in turn: retrieval, processing, storage (Alternative 4 only), and disposal. Each major subsection includes tabulations of effects by alternatives and modules. The summary, Subsection 12.5, is a final tabulation by waste management concept (combinations of various modules, as in Figure 7-1 and Table 7-3), and includes a recapitulation of unavoidable adverse impacts.

12.2 SITE PREPARATION AND CONSTRUCTION

The waste management alternatives are defined in Section 7, and the facilities in Sections 8 through 10. Effects are discussed in terms of the existing environment, described in Section 3. The facilities and other construction efforts would consist of improved confinement (Alternative 2), retrieval and processing facilities (Alternatives 3, 4, 5, and 6), a 20-yr storage facility (Alternative 4), waste disposal facilities (Alternative 5), and ancillary facilities associated with all of the above. Alternative 1 (leave-as-is) would not involve any additional construction.

12.2.1 Air Quality. The major air quality impacts associated with the construction of the facilities would result from construction vehicle emissions and equipment exhaust, and from generation of dust. Increased dust levels would result from vehicular traffic over gravel roads and construction areas as well as from wind-generated erosion of areas stripped of protective vegetative cover. Though some adverse air quality impact is likely to occur, there would be strict adherence to federal and state air quality standards. Mitigative measures that can reduce the effects include: (1) application of dust palliatives to roads and construction areas, (2) limitation of disturbances of vegetative cover to only those areas necessary for construction of facilities, and (3) use of erosion control and restorative procedures to minimize wind-generated dust.

Despite these mitigative actions, some minor but unavoidable adverse impact would occur during construction and for a limited period afterwards. Construction would require operation of a number of vehicles, heavy construction equipment (bulldozers, front end loaders, backhoes, earthmovers, etc), and other motor-driven equipment. Columns (1) and (2) of Table 12-1 show the estimated construction period for each facility and an estimate of the average number of equipment pieces used. Most of this equipment would be operated only during daylight hours. However, a disposal facility at a Lemhi site would be constructed using three shifts per day.

Table 12-2 lists estimated total contaminants emitted by the construction equipment (Duprey 1968). Because of the isolation of the INEL and the localized nature of the effects, there would be no adverse air quality impacts to the public. However, localized adverse air quality would affect construction workers at the site. Most construction-related air quality impacts would cease upon completion of the construction, but wind-generated dust might continue until protective vegetative cover had been reestablished. A 10-yr operating phase at any of the INEL disposal facilities would include continuing expansion of the disposal capacity, as discussed in Section 10 and footnote (b) of Table 12-1.

TABLE 12-1

CONSTRUCTION ACTIVITIES

	(1) Time (months)	(2) Pieces of Heavy Equipment Used (Average No.)	(3) Diesel Fuel Used (10 ³ gal)	(4) Construction Workers Avg.	(5) Max.
LEAVE AS IS	0	0	0	0	0
IMPROVED CONFINEMENT					
Above and Around	24	6	86	8	8
Above, Around	24	8	120	27	27
and Below	24	2	29	10	10
Immobilization					
RETRIEVAL FACILITY	9	10	54	50	75
PROCESS FACILITY(a)					
SP	20	30	360	275	325
CPT	20	25	300	250	300
PKG	18	20	220	200	250
DISPOSAL FACILITIES(b)					
Deep Rock Disposal					
Lemhi Site - Tunnel					
or Shaft Access(c)	30	12	220	21	21
Roadway	14	13	110	21	21
Engineered Shallow-					
Land Disposal at					
Site 14	9	6	32	25	35
LMV(d)	6	4	14	20	30
Roadway(e)	8	13	62	21	21
Engineered Surface					
Facility Near RWMC	9	12	65	25	35
Service Roads	1	13	8	21	21
20-YR RETRIEVABLE STORAGE	6	6	22	25	35

(a) SP: Slagging Pyrolysis and Packaging,
CPT: Compaction, Immobilization, and Packaging,
PKG: Packaging Only

(b) For disposal facilities, "time" for construction refers to site preparation and initial capacity only. Additional capacity would be added during operations phase (see Section 10).

(c) Construction effort at Lemhi Range would be approximately the same for either shaft access or tunnel access. First row of entries includes only the shaft or tunnel and a one-yr disposal capacity. Additional capacity would be constructed as needed and is added into operations activities. A similar approach was used for the other disposal facilities. A two-lane committed roadway 30 miles long would also be built. It is estimated that the construction period would extend over 18 months for this roadway but that activity would be suspended for 4 months during the winter.

(d) LMV refers to the less massive variation of the disposal facility.

(e) A committed roadway to Site 14 would be about 20 miles long.

TABLE 12-2

ESTIMATED TOTAL AIRBORNE CONTAMINANTS RELEASED BY EQUIPMENT DURING
CONSTRUCTION OF FACILITIES

Facility	Contaminant Released (10^3 lb)						Particulates
	Aldehydes(a)	CO	Hydrocarbons	NO _x	SO ₂	Acetic Acids(a)	
LEAVE AS IS	0	0	0	0	0	0	0
IMPROVED CONFINEMENT							
Above and Around	0.86	5.2	12	19	3.4	2.7	9.5
Above, Around, and Below	1.2	7.2	16	27	4.8	3.7	13
Immobilization	0.29	1.7	3.9	6.4	1.2	0.9	3.2
RETRIEVAL FACILITY	0.54	3.2	7.3	12	2.2	1.8	5.9
PROCESS FACILITY(b)							
SP	3.6	22	49	80	14	11	40
CPT	3.0	18	41	67	12	9.3	33
PKG	2.2	13	30	49	8.8	6.8	24
DISPOSAL FACILITIES							
Deep Rock Disposal							
Lemhi Site - Tunnel or Shaft							
Access	2.2	13	30	49	8.8	6.8	24
Roadway	1.1	6.6	15	24	4.4	3.4	12
Engineered Shallow-Land Disposal at							
Site 14	0.32	1.9	4.4	7.1	1.3	1.0	3.5
LMV(c)	0.14	0.84	1.9	3.1	0.56	0.43	1.5
Roadway	0.62	3.7	8.4	14	2.5	1.9	6.8
Engineered Surface Facility Near							
RWMC	0.65	3.9	8.8	14	2.6	2.0	7.2
Service Roads	0.08	0.48	1.1	1.8	0.32	0.25	0.88
20-YR RETRIEVABLE STORAGE	0.22	1.3	3.0	4.9	0.88	0.68	2.4

(a) From air oxidation of exhaust products of diesel fuel.

(b) SP: Slagging Pyrolysis and Packaging,
CPT: Compaction, Immobilization, and Packaging,
PKG: Packaging Only

(c) LMV identifies the use of the less massive variation of the engineered shallow-land disposal facility at Site 14.

12.2.2 Environmental Noise. Except for noise generated by public traffic crossing the INEL and the operations of some of the INEL facilities, ambient noise levels are generally very low and localized. Construction operations would result in an increase in ambient noise levels, in proportion to the number of machines operating and the length of the construction period. Table 12-1 lists these data.

Because of the isolation of the INEL, the increase in local ambient noise levels would not impact the public. Workers would be exposed to localized high noise levels but would be provided, by the contractor, with hearing protection in conformance with OSHA regulations. Noise would also impact local wildlife (see Subsection 12.2.3). Construction-related noise impacts are short term and would cease when construction activity was completed.

12.2.3 Terrestrial Environment. Construction-related effects on the terrestrial environment would include potential impacts to vegetation and wildlife. The primary impact would be vegetation removal for facility construction. Table 12-3 lists the vegetation types that would be affected and the acreage of land that would be committed for each module. Though some of the disturbed acreage could be revegetated, most of the area could not return to preexisting conditions until the D&D phase of the program.

Additional vegetation would be disturbed as a result of extraction of construction materials, such as clay, gravel and basalt, on the INEL. Potential material sites have not yet been identified but some material extraction might occur in the Big Lost River area and the playas to the north. Relative values of the acreage involved can be obtained by comparing the volumes of material required for each module (see Table 12-6 in Subsection 12.2.8). After material needs have been met, these sites could be rehabilitated and would eventually return to their previous state.

TABLE 12-3

VEGETATION TYPES AFFECTED AND ESTIMATED ACREAGE NEEDED FOR FACILITIES

Facility	Vegetation Community	Spoil (10 ³ yd ³)	Land Requirements (Acres)			
			Spoil	Facility	Roads	Total
LEAVE AS IS AND IMPROVED CONFINEMENT	Big Sagebrush	N/A	N/A	0	0	0
RETRIEVAL FACILITY	Big Sagebrush	N/A	N/A	0.5	0	0.5
PROCESS FACILITY						
SP(a)	Big Sagebrush	N/A	N/A	1.4	0	1.4
CPT	Big Sagebrush	N/A	N/A	1.8	0	1.8
PKG	Big Sagebrush	N/A	N/A	1.0	0	1.0
DISPOSAL FACILITIES(b)						
<u>Deep Rock Disposal Lemhi Site</u>						
<u>Shaft Access</u>						
SP	Juniper (Roadway: Sagebrush & playas)	96	4	1	200	205
CPT	Juniper (Roadway: Sagebrush & playas)	96	4	1	200	205
PKG	Juniper (Roadway: Sagebrush & playas)	222	9	1	200	210
<u>Deep Rock Disposal Lemhi Site Tunnel Access</u>						
SP	Juniper (Roadway: Sagebrush & playas)	115	5	1	200	206
CPT	Juniper (Roadway: Sagebrush & playas)	115	5	1	200	206
PKG	Juniper (Roadway: Sagebrush & playas)	245	10	1	200	211
<u>Engineered Shallow-Land Disposal at Site 14</u>						
SP	Sagebrush	770	95	22	136	253
LMV(c)	and	204	25	11	136	172
CPT	grasses	642	79	19	136	234
LMV		164	33	14	136	183
PKG		1800	223	52	136	411
LMV		542	67	28	136	231
<u>Engineered Surface Facility Near RWMC</u>						
SP	Big Sagebrush	169	21	11	2	34
CPT	Big Sagebrush	265	20	11	2	33
PKG	Big Sagebrush	492	61	31	2	94
20-YR RETRIEVABLE STORAGE	Big Sagebrush	N/A	N/A	7.5	0	7.5

(a) SP: Slagging Pyrolysis and Packaging,
CPT: Compaction, Immobilization, and Packaging,
PKG: Packaging Only

(b) The size of the disposal facilities depends on the volume of processed waste to be handled. This would be largest for the PKG output. Proportionality of SP and CPT spoils and acreages is not necessarily consistent because of the modularity of some disposal facilities (see Section 10).

(c) LMV identifies the use of the less massive variation of the engineered shallow-land disposal facility at Site 14.

Removing natural vegetative cover increases the potential for soil erosion by runoff and wind, and reduces habitat and cover for wildlife. Erosion can be minimized by standard control techniques, but habitat lost during construction would not be returned to its natural state until D&D.

The maximum amount of habitat that could be lost, taking the concept that would require the most acreage, is about 411 acres, or 0.07% of the total acreage of the INEL. This is the acreage required for Concept 5-i: retrieval, packaging only, and disposal in the engineered shallow-land disposal facility at Site 14. Although a Site 14 facility for disposal of the packaging output would be the largest of all those considered, the high acreage requirement is explained mostly by the need to dispose of spoils and by the land for a committed roadway. In Table 12-3 the spoils are assumed to be spread 5 ft deep, except in the Lemhi Range where an average depth of 15 ft is assumed. The committed roadways, whether to Site 14 (20 miles long) or to a Lemhi site (30 miles long), are assumed to have a fenced right-of-way 56 ft wide (24 ft asphalt pavement plus 16 ft width on each side for shoulders and easement).

The vegetation and wildlife in the area of the RWMC are described in Subsection 3.6. (See also McBride et al. 1978.) New facilities there could result in the loss of up to 90 acres of big sagebrush habitat but this is not considered a major impact because of the availability of similar habitat on the INEL. Also, much of this apparent loss would be within the RWMC itself--already a disturbed area.

The two Lemhi sites are located in the Juniperus osteosperma - Artemesia tridentata - Agropyron spicatum community dominated by dense stands of juniper trees, typical of higher elevations on the INEL. Since the presence of trees on the INEL site is limited, loss of part of this habitat would be more significant than loss of an equal area of sagebrush community. Although this juniper community is only a

small part of the INEL, it dominates the offsite areas to the northwest. The trees provide shelter and breeding areas for many species, including several species of raptors. A roadway to the Lemhi sites would traverse mainly sagebrush community but would also cross the Big Lost River and playa area. This area is characterized by cottonwood trees and other shrubs and by grass species not common in other areas of the INEL.

A committed roadway from the RWMC to Site 14 would also result in the loss of an estimated 136 acres of big sagebrush habitat.

As mentioned earlier, potential sources of construction material include the Big Lost River Valley and playa areas. These areas have been identified as potential nesting habitat for several species of raptors. Activities would be carefully planned to avoid adverse effects on the associated fauna.

Short-term impacts to wildlife would occur as a result of construction activity. Operation of heavy machinery would have localized effects on some animal species as they migrate away from disturbances. Nests, breeding areas, and foraging areas of some species would likely be affected. For the more sensitive species, such as the ferruginous hawk (status undetermined), prairie falcon (once a threatened species), and others, scheduling of construction to avoid periods of wildlife movements would help to minimize adverse impact. Most species would return to the area when construction and rehabilitation are complete.

12.2.4 Water Resources.

12.2.4.1 Surface Water. Surface water on the INEL is discussed in Subsection 3.5. The intermittent nature of the surface waters on the INEL reduces the likelihood of significant impacts to this resource.

Several aspects of construction activity could cause small adverse effects on surface waters: (1) withdrawal of water for use in construction, (2) discharge of wastewater, such as sanitary wastewater or water from ditch dewatering operations, (3) gravel or clay mining from stream or lake bottoms, (4) channelization or diversion of surface waters for flood control, and (5) erosion of construction areas by surface runoff and resultant siltation of streams.

Since surface water is seasonal and thus is unreliable, most water would be obtained from the more reliable groundwater sources. However, when convenient sources of surface water do exist, they might be used for such purposes as dust control or concrete mixing. Depending on the volume withdrawn, surface water flow could be reduced significantly, affecting downstream uses. The Big Lost River supports aquatic biota on the INEL, including rainbow trout and whitefish (Overton, Grove, and Johnson 1976). Fish kills on the site have been reported, caused by entrapment when water flow ceased. However, adverse impacts to biota from surface water withdrawals for construction purposes can be totally avoided if adequate planning is exercised or by using well water only.

Applicable federal and state water quality and effluent guidelines would be applied to the management of wastewater generated from construction activities. Sanitary wastewater would be treated before discharge to the environment.

Other water quality impacts could result from discharge of silt-laden ditchwater, siltation of the Big Lost River from soil erosion or construction activity near streams, and minor oil spills. Such impacts would be minimized by implementing good construction practices. The activity most likely to result in unavoidable adverse impacts to water quality would be construction in or near surface waters. The removal of gravel, soil, or clay from the Big Lost River or playa vicinity would likely result in increased silt loads. This activity would be quite likely since significant quantities of these materials

would be required and the best material (particularly clay) sites are located near the river or playas. Construction of access road stream crossings or construction in flood plain areas would also cause some impacts. These impacts can be mitigated by scheduling work for periods when surface runoff is absent, then by restoring the disturbed area and using erosion control techniques. Erosion might continue for a time after construction is complete, but the area would eventually return to its earlier condition.

The only potential long-term impact to surface water resources would be from inadequate drainage structures at roadway river crossings. Inadequate drainage would cause erosion and possible velocity blocks to fish passage for the life of such a roadway (approximately 40 yr). Proper design of drainage structures would reduce the likelihood of this problem.

12.2.4.2 Groundwater. The only groundwater impacts expected as a result of construction would be increased water consumption and potential impacts to water quality from wastewater discharge. During 1974, the total consumption of water from the 24 production wells on the INEL was 2.9×10^9 gal, which was 0.1% of the estimated total annual discharge of the Snake River Plain Aquifer (ERDA 1977c). The expected increase in water consumption would not appreciably affect the aquifer hydrology or downstream users.

Except for small volumes of sanitary wastewater, treated before discharge, no new wastewater discharges would be expected from construction activities. Therefore, no long-term water quality impacts would be expected.

12.2.5 Nonradiological Solid Waste Disposal. Construction of the waste management facilities would generate considerable nonradiological solid waste material: scrap metal and wood, discarded equipment parts, oily wastes, slash and timber, excess overburden, mining

spoils, and other construction debris. Disposal of this material must be done so as to avoid nuisance, hazard to health, and adverse environmental impacts.

The volume of waste is generally proportional to the level of construction activity (i.e., the duration, quantities of materials, number of workers, and pieces of equipment). Excavation for disposal facilities on the INEL could produce large amounts of overburden or mining spoils, as shown in Table 12-3. Since the Lemhi sites would be located in the foothills area, where the surficial material consists of alluvial deposits, some of the material from there might be suitable for construction of the committed roadway to the site. However, the roadway would be needed before most of the spoils would be available, so much of the material would still have to be disposed.

It is anticipated that all solid waste generated during construction of facilities would be disposed of on the INEL in sanitary landfills. To minimize environmental effects from these disposal facilities, all federal and state regulations regarding their siting and operation would be complied with. In conformance with the Federal Resource Recovery Act of 1970, amended by the Resource Conservation and Recovery Act of 1976, the compliance would include evaluation of possible reuse alternatives, such as use of Lemhi site spoils as discussed above.

Even with the best waste management practices and adherence to all applicable regulations, certain unavoidable adverse effects would likely occur from solid waste disposal. These include the commitment of land area for disposal activities and adverse aesthetic impacts from disposal site development. Any adverse impacts that would occur would be short term. Landfill sites would be revegetated after use.

12.2.6 Land Use Impacts. The INEL land is committed for the purpose of energy research and development and related program activities and is designated as a National Environmental Research Park. Approximately 95% of the 894 square miles in the research park has

been withdrawn from the public domain. The remainder of the land is owned and controlled by the DOE. A series of Public Land Orders (PLOs), dating back to 1946, have established the present research park boundary and uses. Lands originally under the control of the Bureau of Land Management (BLM) were withdrawn from the public domain under three principal Public Land Orders: PLO 318, 545, and 637, dated May 13, 1946; January 7, 1949; and April 7, 1950, respectively. Six other PLOs pertaining to INEL lands have been issued. These orders primarily concern transfer of managerial responsibilities and do not affect the basic purpose and intent of the original PLOs.

Each of the alternatives and concepts studied is located in the area that has been withdrawn from the public domain. The RWMC and the Lemhi sites lie in the area withdrawn under PLO 637. Site 14 is included in the area withdrawn under PLO 318. The PLOs, as interpreted, provide for nuclear energy research and development and related activities. Waste processing, storage, and disposal are considered related activities. Therefore, such activities would be consistent with the purpose of the orders, and land would be available for implementing the alternatives. No special legislation nor amendment to the PLOs would be necessary to pursue either short-term or long-term use of these lands for waste management.

Existing facilities on INEL lands are widely spaced for maximum safety. They occupy a very small percentage of the 894 square miles of available land. Examination of the existing facility locations, plans for new facilities and the TRU waste processing, storage, and disposal options, does not reveal any internal facility siting conflict.

Approximately 330,000 acres of the INEL are open to controlled grazing of cattle or sheep. (See Figure 3-12.) The areas allocated for grazing within the INEL boundary are mutually agreed upon by the

DOE and the Department of the Interior and the grazing permits are administered through the BLM. Grazing is prohibited within 2 miles of any nuclear facility, and livestock populations are controlled. Site 14 and the RWMC are not included in the grazing zone, but the RWMC is within 2 miles of the edge of the zone. Cattle frequently wander to the edge of the RWMC, but the area is fenced to exclude them. The Lemhi locations are within the grazing zone. Normal grazing patterns would not be seriously affected during the construction period but would be affected after the sites were in use, as discussed in Subsection 12.3.6.

Local, state, and federal agencies were consulted to determine if the alternatives and concepts studied would conflict with existing plans or policies. The Office of Budget and Policy Planning, State of Idaho, indicated that the state does not have plans or policies specifically related to land use either adjacent to or within the boundaries of the INEL. The East-Central Idaho Planning and Development Association (ECIPDA) is a regional economic planning agency serving a nine county region, most of which encompasses the INEL. The ECIPDA, like the State of Idaho, does not have any policies or plans that involve lands or activities near the INEL. Butte County, which encompasses most of the INEL land and all the potential locations studied for processing, storage, and disposal, is sparsely populated. The county does not have a policy plan, comprehensive plan, or zoning ordinance, so no plans or policies specifically related to land use are available from Butte County. The BLM continues to administer road and utility rights-of-way for facilities other than those at the INEL. The BLM has prepared a draft management plan for the Little Lost River-Birch Creek planning unit, which includes the northern portion of the INEL. The management plan emphasizes that effective range management is critical to the livelihood of local ranchers. The BLM suggests that economic stability for the livestock producers is an

important consideration in resolving grazing land conflicts. The Lemhi Range sites would be the only sites potentially in conflict with the BLM management plan.

All waste retrieval, processing, and storage options would have small requirements for land. The disposal options would be more land-intensive, as seen in Table 12-3. Additional lands, not quantified in the table, might be used during the construction period for material and equipment storage and for construction staging. None of the proposals would place pressure on the availability of land at the INEL. As noted, the most land-intensive waste management concept involves only 0.07% of the total INEL land area. None of the alternatives or concepts creates any particular conflict with onsite uses during construction.

12.2.7 Socioeconomic Impacts.

12.2.7.1 Employment and Economics. For perspective, Table 12-4 shows the projected number of man-years of construction labor needed for INEL construction programs already committed through Fiscal Year 1982. Construction employment is expected to peak in Fiscal Year 1980, decreasing gradually in 1981 and dropping significantly in 1982. The indicated decline of over 950 jobs in the last two years suggests that more than enough workers would be available for construction of waste management facilities. For operations to begin in 1985, construction of facilities would start in 1982 or 1983. The most labor-intensive concepts, 5-g or 5-j, would employ about 370 workers ("average" column in Table 12-1) or a maximum of 456 in the unlikely event that all the peaks occurred simultaneously. (Those concepts would involve facility construction for retrieval, slagging pyrolysis, and disposal in an engineered facility--about 530 man-years of effort on projects lasting 8 to 30 months.)

TABLE 12-4

INEL CONSTRUCTION LABOR PROJECTION 1977-1982 (MAN-YEARS)^(a)

	<u>FY1977</u>	<u>FY1978</u>	<u>FY1979</u>	<u>FY1980</u>	<u>FY1981</u>	<u>FY1982</u>
Construction Craft Labor	282	474	1024	1353	1282	486
Support Craft Labor	<u>50</u>	<u>84</u>	<u>181</u>	<u>239</u>	<u>192</u>	<u>86</u>
Total Craft Labor	332	558	1205	1592	1474	572

(a) Source: Population and Economic Trends and Projections (Bonneville Council of Governments 1974)

Because of scheduling problems or shortages in some skills, part of the construction force would be hired from outside the area. For convenience, these workers, and perhaps some local workers, might move closer to the construction site, so smaller cities in the immediate area, such as Arco and Atomic City, might experience a temporary influx of construction personnel.

In addition to the construction employment, secondary or indirect employment would be created. The indirect employment multiplier for construction work forces is normally about 1.5. That is, for each construction job created, an estimated 0.5 additional jobs arise in the supporting economy, resulting in an overall increase of 1.5 jobs. Applying this multiplier to the (average) entries in Table 12-1, construction for Concept 2-a would lead to an additional 4 jobs in the area, or up to 185 for Concepts 5-g and 5-j. These estimates should be regarded as upper limits, because of the current and projected levels of other construction work.

The total payroll at the INEL was \$112 million in 1976 and \$132.6 million in 1977. The estimated 1978 payroll is \$150 million. The DOE estimated that total program costs for FY 1978 would be \$294 million (Idaho Falls Chamber of Commerce 1978).

Total direct earnings of construction workers would be expected to be a maximum of about \$12 million for construction of waste management facilities, based on weighted 1978 wage rates for skilled and common construction labor in the area (LATA 1977). Additional income would be generated in local communities, primarily Idaho Falls. The earnings multiplier for the area is estimated to be about 2.2 (as opposed to the employment multiplier of 1.5), so associated indirect earnings would add about \$14 million.

12.2.7.2 Housing. Table 12-5 shows the housing characteristics of INEL employees in March 1978, as reflected in nearly 7000 responses to a DOE questionnaire (DOE 1978c). If half of the construction workers were new hires, the most labor-intensive concept could be

TABLE 12-5

HOUSING CHARACTERISTICS OF INEL EMPLOYEES (PERCENT)^(a)

	<u>Single Family</u>	<u>Duplex</u>	<u>Apart- ment</u>	<u>Room</u>	<u>Mobile Home</u>	<u>Rural</u>	<u>Total</u>
Own	58	(b)	(b)	(b)	5	4	68%
Rent	6	1	21	(b)	1	(b)	30%
Live with Parents	<u>1</u>	<u>0</u>	<u>(b)</u>	<u>0</u>	<u>(b)</u>	<u>(b)</u>	<u>2%</u>
TOTAL	65	2	21	(b)	7	5	100%

(a) Source: Summary of INEL Personnel Data (DOE 1978b).

(b) Less than 0.5% (totals may not check because of rounding).

expected to create a demand for 180 additional housing units, but with more emphasis on rented quarters and mobile homes than reflected in the table. The other half of the employment would assure continued occupancy of the same number of units, in a pattern closer to that in Table 12-5.

12.2.7.3 Social Services. The INEL employee questionnaire indicated that there were approximately 1.2 school-aged children per household. Assuming the same ratio for the construction employees, there would be a maximum increase of about 220 school children due to construction employment (assuming 50% immigration), or an increase of up to 330 if indirect employment is also considered. Nearly all schools are currently at capacity because of recent growth in the area. Several bond issues have been passed to increase capacity and facilities. By 1985, there might or might not be adequate space to handle the anticipated school children. The local school districts are undertaking expansion programs and continually plan for future growth.

Idaho Falls is the medical center for Southeastern Idaho. Riverview Hospital and Parkview Hospital are the two hospitals in Bonneville County. Butte, Fremont, Lemhi, Madison, and Teton Counties have hospitals; but Clark, Custer, and Jefferson Counties do not. Each county has a Health and Welfare Department that provides some basic health services.

The impact on local health facilities would not be expected to be significant. Population growth in smaller outlying communities and counties is projected to be small, with a small additional demand for health facilities. Some additional physicians and services would be required in Idaho Falls to maintain present service levels. Other services and facilities, such as police and fire protection, transportation, and water and sewer facilities, would have to be expanded to accommodate the projected growth. Most smaller communities would

not be noticeably affected. Idaho Falls, which would be expected to accommodate about 70% of the growth, would have to provide additional services. The increased tax base and revenue from new development would help to offset the new service and facility demands.

The anticipated population growth would not be expected to affect regional recreational facilities significantly. Tourism is a major sector of the local economy, and regional facilities reflect this. For example, Idaho Falls has a golf course, zoo, museum, numerous parks and playgrounds and a minor league baseball park.

12.2.8 Commitment of Resources. Construction of any of the waste management facilities would result in a long-term commitment of resources. Consumed energy resources would be almost exclusively petroleum products. Estimates of diesel fuel usage are shown in Table 12-1. There would also be other energy usage, by miscellaneous equipment and commuting by workers. Expected water usage would be low compared with current INEL uses and should not appreciably affect local resources.

Commitment of labor hours and of the funds for design and construction of the facilities would be irretrievable. Table 12-1 estimates the construction effort involved and Section 15 gives cost estimates for each concept studied.

Preliminary estimates for the quantities of most construction materials that would be used are given in Table 12-6. (The rationale for the less massive variation (LMV) of engineered shallow-land disposal at Site 14 is highlighted in this table.) Significant material usage would be required for the 20-mile roadway to Site 14 or for the 30-mile roadway to the Lemhi Range. Each mile of roadway would use 4,700 yd³ of crushed rock, nearly 1,200 yd³ of asphalt, and 10,560 lineal ft of fencing.

TABLE 12-6

ESTIMATED MAJOR REQUIREMENTS FOR CONSTRUCTION MATERIALS

Facility	Material (10 ³ yd ³)(a)				
	Concrete	Grout	Riprap	Bentonite	Clay
IMPROVED CONFINEMENT					
Above and Around	0	0	12	0	30
Above, Around, and Below	13	1	12	0	30
Immobilization	0	34	0	0	0
DISPOSAL FACILITIES(b,c)					
<u>Deep Rock Disposal</u>					
<u>Lemhi Site - Shaft Access</u>					
SP	2	0	0	0	0
CPT	2	0	0	0	0
PKG	2	0	0	0	0
<u>Deep Rock Disposal</u>					
<u>Lemhi Site - Tunnel Access</u>					
SP	5	0	0	0	0
CPT	5	0	0	0	0
PKG	5	0	0	0	0
<u>Engineered Shallow-Land</u>					
<u>Disposal at Site 14</u>					
SP	510	0	260	160	430
LMV	14	0	130	60	120
CPT	430	0	210	140	360
LMV	18	0	170	60	160
PKG	1200	0	600	380	990
LMV	41	0	340	170	320
<u>Engineered Surface</u>					
<u>Facility Near RWMC</u>					
SP	380	0	94	40	43
CPT	360	0	91	39	42
PKG	1100	0	270	120	130
20-YR RETRIEVABLE					
STORAGE	6	0	0	0	0

(a) All data rounded to two significant digits.

(b) The size of the disposal facilities depends on the volume of processed waste to be handled. This would be largest for the PKG output. Proportionality of SP and CPT usages is not necessarily consistent because of the modularity of some disposal facilities (See Section 10).

(c) SP: Slagging Pyrolysis and Packaging
 CPT: Compaction, Immobilization, and Packaging,
 PKG: Packaging Only
 LMV: Less massive variation of the disposal facility at Site 14

12.2.9 Archaeological and Historical Sites.

Formal archaeological surveys of the INEL were performed during 1967-1969 and 1970-1972. Fossils dating back 40,000 yr have been found. Recovered artifacts indicate man's presence in the area approximately 12,500 yr ago.

With assistance from the office of the Idaho State Archaeologist and with data from the previous surveys, archaeological sites were identified near the locations of the conceptual facilities. The archaeological sites include a lava tube with cultural materials, campsites, finds in blowouts and sinks, rock shelters, and pictographs. No attempt has been made to establish exact locations of the facilities considered, so the impact on these antiquities, resulting from construction, cannot be stated with certainty.

Regardless of the construction location, INEL operating procedures prescribe measures for assuring protection of antiquities and historic sites, as required by federal and state regulations.^(a) The regulations require, as a minimum, a site reconnaissance project before construction to determine the presence of antiquities and their value. Depending on the findings, further study might be necessary, followed by excavation and salvage operations if needed. During construction, a qualified archaeologist would be on call to monitor any unforeseen finds.

The conceptual sites considered are void of any known historical significance. The INEL Experimental Breeder Reactor I (EBR-I), now decommissioned, is listed on the National Register of Historic Places,

(a) Federal Historical and Archaeological Regulations: Antiquities Act of 1906, Historic Sites Act of 1935, Reservoir Salvage Act of 1960, National Historic Preservation Act of 1966, National Environmental Policy Act of 1969, Executive Order 11593. State of Idaho Regulations: Preservation of Historic Sites, 1975.

and was designated a National Historic Landmark in 1966. EBR-I is located near the access road to the RWMC, so construction activity at the RWMC could cause minor temporary disturbance to the viewing public. No other adverse impacts would be expected.

A review of the state register in the office of the State Historic Preservation Officer showed several historic sites listed on the INEL. Two of the sites are remnants from the Aboriginal American period. Neither is in the vicinity of the locations studied here. The state register also lists the INEL itself as playing an important role in atomic history. This listing identifies the total area of the INEL, but the state has not taken any action to designate it as a historic district.

12.2.10 Aesthetics. Figure 3-1 shows that the INEL is relatively undeveloped over most of its area. The site lies in the broad, flat upper Snake River Plain at the foot of the Lost River, Lemhi, and Beaverhead mountain ranges. The observable presence of man-made structures or disturbances in this setting impinges to varying degrees on individual aesthetic sensibilities. In this respect, the INEL site has been adversely impacted by past activities and facilities. Several facilities are in full view to motorists passing on a public highway. Only limited topographic barriers exist to shield these facilities from view.

Construction of the facilities studied here would not detract significantly from the existing aesthetic quality of the INEL. However, the new facilities would have some adverse impact. Retrieval and process facilities would be visible from the EBR-I site and possibly from the public roadway. This impact would persist only until the facilities were dismantled. The stack for the slagging pyrolysis facility would be particularly prominent, since there has been little development of the site south of U.S. 20 compared with the area north of this highway (Figure 3-1). The engineered surface disposal facilities might be visible from the highway. However, visual impact would

be minimized by considering aesthetic qualities in facility design. Adverse impacts would result from construction of the Lemhi site or Site 14 facilities, and from the committed roadways to these sites.

12.2.11 Environmentally Sensitive Areas. Areas generally considered environmentally sensitive include: surface waters, marshlands and wetlands, floodplains, groundwater recharge areas, forests and woodlands, prime agricultural lands, habitat for rare or endangered species, and archaeological and historical sites.

Surface waters on the INEL exist during only part of the year. Most flow of the major streams entering the site is lost by recharge to the groundwater. Impacts to surface water quality and biota could be avoided by scheduling construction activities near streams during dry months.

There are no true marshlands or wetlands on the site. However, the area known as the Big Lost River Sink or playa could be considered a floodplain or intermittent wetland. During seasons of high runoff, this area may support waterfowl. The vegetation in this area provides a habitat somewhat different from that of the surrounding sagebrush plain and tends to support a locally unique assemblage of species. (The spreading areas at the diversion dam west of the RWMC also support waterfowl in the spring of the year.) Of the conceptual facilities studied, only the committed roadway to the Lemhi Range would impinge on the playa. As discussed earlier, however, the need for construction aggregate, such as gravel or clay, may entail extraction from the playa area. If this were true, precautions would be taken to avoid or minimize adverse effects on this sensitive area.

The INEL is situated over the extensive Snake River Plain Aquifer. The Big and Little Lost Rivers and Birch Creek recharge to this aquifer at or near the INEL boundary, providing an important source of water to the system. No adverse impacts to this system would be anticipated from the construction being considered.

The Targhee and Challis National Forests border the INEL to the northwest. There would be no impact to these areas, however. The only trees on the site are located in the Big Lost River Valley and in the higher elevations of the Lemhi foothills and Twin Buttes. These few trees provide important habitat for raptors and other birds. Some trees would probably be lost if either of the Lemhi sites were developed. Road construction activity or gravel extraction in the Big Lost River or playa area could result in the loss of some trees so work would be planned to avoid this where practicable.

Any impacts on prime agricultural lands must be considered carefully. Because the INEL is a federal reserve, public use is restricted and there is little agricultural activity. Some areas within the INEL have agricultural potential (Figure 3-5), but, historically, agricultural ventures in the area have met with little success. Nevertheless, potential conflicts with future agricultural use should be considered.

Currently there are approximately 330,000 acres open to grazing on the INEL (Figure 3-12), but only the Lemhi sites overlap grazing areas. Initial effects, during construction, would affect only a very limited area, but would be more extensive later (see Subsection 12.3.6).

The peregrine falcon (Falco peragrinus) and the bald eagle (Haliaeetus leucocephalus) are the only rare or endangered species observed on the INEL. Only one sighting of the peregrine falcon has been documented, however, suggesting that this species is only an occasional migrant over the area and that construction of waste management facilities would not have an impact. The prairie falcon (Falco mexicanus) is a frequent resident of the INEL, seen throughout the year. This species was designated as a threatened species in 1974, but its status was changed when populations began to stabilize. Prairie falcons are sighted mostly in areas of native vegetation. Reductions in sagebrush habitat could affect this species. However, no significant effect would be anticipated because of the small areas

involved (Table 12-3). Another sensitive raptor species, the burrowing owl (Speotyto cunicularia), nests in lava burrows on the INEL. This species is classified as "status undetermined," along with the ferruginous hawk (Buteo regalis). The decline in the number of this latter species is attributed to recent low populations of the black-tail rabbit (Lepus californicus), its preferred prey. One of the most concentrated known nesting areas of the ferruginous hawk is the Little Lost River Valley. Impacts to these species would be avoided by careful planning. Because declines in many of these species could be partially attributed to extensive agricultural development and eradication of native vegetation, maintenance of the INEL as a federal reserve may be considered a beneficial impact to these and other species by preserving valuable habitat (Craig and Trost 1976, Craig 1977).

Archaeological and historical sites are considered nonrenewable resources. Their protection is given high priority. Subsection 12.2.9 discusses those cultural resources on the INEL that could be affected by construction activity. If the mitigative measures outlined in that section are enforced, no adverse impacts would be expected. Similarly, with attention to design of facilities proposed for the RWMC area, adverse impact to the Experimental Breeder Reactor I (EBR-I), a national historical monument, would be avoided.

12.2.12 Mitigation of Construction-Related Impacts. The most significant nonradiological environmental effects associated with construction of waste management facilities would be:

- (1) commitment of land area for construction of the facilities, disposal of solid waste and spoil material, and extraction of construction materials, such as gravel and clay;
- (2) loss of wildlife habitat from the above activities; and
- (3) secondary impacts resulting from the economic stimulation provided by the creation of construction jobs.

Most of the effects would be of short duration, ceasing when construction was completed. Other effects, such as the commitment of resources or potential disturbance to archeological sites, would be irreversible. The environmental impacts vary greatly with the alternative considered. The alternative judged as the preferred one overall may not be the one most environmentally acceptable. In that instance, certain adverse impacts would have to be accepted. Therefore, where possible, measures to avoid or minimize adverse impacts must be formulated.

Sound engineering, design, and construction practices help to minimize environmental impact. The practice of resource conservation and reuse concepts also reduce impacts. Adherence to state and federal regulations governing air quality, water quality, solid waste disposal, etc., ensures that environmental impacts that might occur would be within established standards. Some specific mitigative actions are listed below:

- (1) All sites disturbed as a result of construction activity, which are not to be committed for facilities (for example, gravel sites), would be restored to their natural state where possible.
- (2) Archaeological site reconnaissance surveys would be conducted to assess potential impacts from facility construction and to recommend procedures to mitigate impacts to important sites.
- (3) Design would include consideration of aesthetic impacts.
- (4) Impacts to environmentally sensitive areas would be minimized by considering wildlife movements and habitat loss in facility siting and construction scheduling.
- (5) Nonradiological construction hazards would be minimized by adherence to OSHA and other occupational safety regulations concerning construction projects (see Section 14).

12.2.13 Preoperational Requirements for Environmental Monitoring. Environmental monitoring and sampling procedures covering the RWMC and perimeter areas would be continued and updated as technology advances. These monitoring programs focus on detection of radiological contamination of the soil, air, water, and biota from RWMC and other INEL activities. Nonradiological parameters also are measured routinely. These include measurements of water level, water quality, and suspended particulates in the air. In addition, special studies are being conducted to learn more about the vegetation and wildlife on the INEL. The designation of the INEL as a National Environmental Research Park has encouraged scientists to study this relatively undisturbed area. Valuable information is being generated concerning the impact of man's activities on the cool desert ecosystem. Continuation of these studies will provide data useful in formulating mitigating actions before construction and afterwards in monitoring the impacts on the environment.

12.3 NONRADIOLOGICAL EFFECTS OF OPERATIONS AND OF DECONTAMINATION AND DECOMMISSIONING

This subsection describes the nonradiological environmental impacts expected from operation and from decontamination and decommissioning (D&D) of the waste management facilities. Facility operations are assumed to last 10 yr, and ensuing D&D (for retrieval, processing, or 20-yr storage facilities) to take 2 yr. The discussion considers each potential nonradiological environmental impact first in general terms, and then specifically, by alternative. The outline used in Subsection 12.2 is followed.

12.3.1 Air Quality. Nonradiological airborne effluents (emissions) from current operations at the INEL originate from three primary sources: combustion of fuel oils, calcination or solidification of liquid wastes at the Idaho Chemical Processing Plant (ICPP), and motor vehicle exhaust. Inconsequential releases occur from evaporation of organic solvents at shops and vapor drift from cooling towers. The major contaminants are the common industrial oxides of nitrogen, sulfur, and carbon.

Depending on the waste management alternative, operation and D&D activities would increase the quantity of nonradiological airborne effluents at the INEL site. Alternatives involving leaving the waste as is (Alternative 1), or improving confinement (Alternative 2), would have little or no effect on air quality. The greatest increase in airborne releases would come from retrieval, slagging pyrolysis, and transfer to and operation of a disposal facility on the INEL. The primary effects would be from vehicular exhaust from shipping and other vehicles, as well as stack emissions from the slagging pyrolysis facility. Table 12-7 lists estimated emission rates of several contaminants from diesel vehicular exhaust for waste management operations. Estimated stack emissions for the slagging pyrolysis unit are given in footnote (b) of the table.

The largest emissions in Table 12-7 are nitrogen oxides. The total of these oxides would be a maximum of about 55,000 lb/yr for retrieval, slagging pyrolysis, and disposal at the Lemhi site with shaft access (Concept 5-a). This total, which includes the slagging pyrolysis stack emissions, would amount to 250 lb/day (based on the assumed operating period of 220 days/yr). This would be a 5% to 9% increase over current NO_x discharges of 2800 to 4800 lb/day from other facilities and vehicles now operating at the INEL (ERDA 1977c). The highest observed concentration onsite has been $4.3 \times 10^{-6} \text{ g/m}^3$. The EPA standard is $100 \times 10^{-6} \text{ g/m}^3$ (40 CFR 50) so a 9% increase would neither contravene EPA standards nor cause any significant environmental impact. The maximum offsite concentration, at the nearest INEL boundary, would be about $3 \times 10^{-6} \text{ g/m}^3$ if Concept 5-a contributions were added to current emissions.

Sulfur can exist in the air in several compound forms: hydrogen sulfide, salts, oxides, and sulfuric acid. Ultimately, all forms are oxidized to sulfur trioxide which, when dissolved in water, forms sulfuric acid. Monitoring at the five INEL sampling sites indicates that current concentrations of sulfur trioxide are below the detection

TABLE 12-7

ESTIMATED AIR EMISSION RATES FROM VEHICULAR (DIESEL) EXHAUST

Facility/Operation	Contaminant (10 ³ lb/yr)						
	Alde- hydes	CO	Hydro- carbons	NO _x	SO ₂	Acetic Acid	Parti- culates
RETRIEVAL FACILITY	0.09	0.52	1.2	1.7	0.34	0.27	0.95
PROCESS FACILITY(a)							
SP(b)	0	0	0	0	0	0	0
CPT	0	0	0	0	0	0	0
PKG	0	0	0	0	0	0	0
DISPOSAL FACILITIES							
Deep Rock Disposal							
Lemhi Site							
Shaft Access							
SP(c)	0.94	5.7	12.7	21	3.7	2.9	10.4
CPT	0.94	5.7	12.7	21	3.7	2.9	10.4
PKG	1.7	9.8	22	36	6.4	5.0	18
Deep Rock Disposal							
Lemhi Site							
Tunnel Access							
SP	0.84	5.1	11	19	3.3	2.6	9.3
CPT	0.84	5.1	11	19	3.3	2.6	9.3
PKG	1.5	8.6	20	32	5.6	4.4	16
Engineered Shallow- Land Disposal at Site 14							
SP	0.26	1.6	3.5	5.8	1.0	0.80	2.9
LMV	0.11	0.63	1.4	2.3	0.42	0.32	1.2
CPT	0.28	1.7	3.8	6.2	1.1	0.90	3.1
LMV	0.13	0.75	1.7	2.7	0.50	0.39	1.4
PKG	0.42	2.5	5.7	9.3	1.7	1.3	4.6
LMV	0.27	1.6	3.6	5.8	1.1	0.82	2.9
Engineered Surface Facility Near RWMC							
SP	0.61	3.7	8.3	13	2.4	1.9	6.7
CPT	0.63	3.8	8.5	14	2.5	2.0	6.9
PKG	0.69	4.1	9.3	15	2.8	2.1	7.5
20-YR RETRIEVABLE STORAGE	0.30	1.8	4.0	6.7	1.2	0.92	3.3

- (a) SP: Slagging Pyrolysis and Packaging;
 CPT: Compaction, Immobilization, and Packaging;
 PKG: Packaging Only
 (No diesel equipment is operating for any of these modules)
- (b) Although there are no emissions from diesel exhaust, SP stack emissions would contribute 17,000 lbs/yr of NO_x; 3,000 lbs/yr SO₂; 1,000 lbs/yr of HCL; and 1.1 lb/yr of particulates.
- (c) Disposal operations vary with the volume of the output from the processing facility, being highest for the least-dense output of the package-only processing.

limit of 7.5×10^{-6} g/m³ (ERDA 1977c). The maximum offsite concentration of SO₂ that would be added by any waste management concept (again, Concept 5-a) would be less than 0.03×10^{-6} g/m³. When compared to the EPA standard (80×10^{-6} g/m³) it is clear that none of the waste management concepts would contravene the EPA standard or cause any significant effect.

Carbon monoxide becomes toxic at a level of 120 mg/m³. The EPA air quality standard is 10 mg/m³. The incremental increase in CO emissions that could result from operating activities would increase concentrations on the INEL.

Maximum particulate emissions would arise from Concept 5-c, totaling 19,000 lb/yr, or about 86 lb/day on a 220 day/yr operating schedule. This would inevitably affect particulate levels at the RWMC, which have recently been above EPA standards (see Subsection 5.2), but should not affect air quality at the site boundaries. Particulate levels at distant monitoring stations have historically exceeded those on the INEL and at its boundaries, presumably because of urban and agricultural activity (ERDA 1977c). Nevertheless, careful monitoring would be continued to assure that waste management operations did not impact offsite air quality.

No problems would be anticipated from any of the other airborne effluents listed in Table 12-7.

12.3.2 Environmental Noise. Increased noise levels over ambient conditions would occur in a localized area adjacent to the committed roadway for those concepts involving onsite transfer. Other modules involving trucking or vehicle movements would have similar effects. However, increased noise levels would impact only local wildlife, which would probably move away from the disturbance. Because of the isolation of the INEL, the public would not be affected by the increased noise levels.

12.3.3 Terrestrial Environment. Once construction of the facilities is completed and the disturbed areas rehabilitated, the effects of operations on the terrestrial environment would be minimal. The maximum acreage that would be committed for any alternative would be about 0.07% of the total acreage of the INEL. With the exception of disposal facilities, much of this land could be returned to its previous use. Operations and D&D would continue to cause local but temporary dispersal of some animal species. Adverse impacts from increased air pollutant levels on vegetation and wildlife would probably be minimal, though the impact of air pollutants on the steppe community is still unknown.

The alternatives of leaving the TRU waste in place do not require any operational activity, except for continued environmental monitoring. However, long-term effects on vegetation and wildlife could occur because of contact with the waste by plant roots or burrowing animals. The waste consists not only of radiologically hazardous substances, but also substances hazardous from a nonradiological standpoint. Many of these substances persist and could be transmitted to the environment through biological pathways. This threat would be reduced by the methods studied for improved confinement, but assurance of total confinement is not possible.

Alternatives that entail onsite shipment would disturb wildlife along the roadway. Effects from the noise would be minor, as just discussed, but road kills would be expected to occur. Because of the slow speed of the vehicles (35 mph), daytime operation, and the low traffic volume, the number of road kills would be small.

12.3.4 Water Resources.

12.3.4.1 Surface Waters. The surface water hydrology of the INEL is discussed in Subsections 3.5 and 12.2.4.1. There would be no discharges to nor withdrawals from surface waters during operations or D&D.

If the waste were left in place, current flood control practices would be continued or upgraded. It is not known what effect future flood control modifications would have on the aquatic environment.

12.3.4.2 Groundwater. Potential nonradiological impacts to the groundwater from operation and D&D activities include: adverse impacts to water quality from waste discharges, increased water consumption, and the possibility of nonradiological contamination from the hazardous substances in the waste.

Current INEL wastewater discharges on the Snake River Plain Aquifer can be detected over an area of about 25 square miles on the INEL. Elevated levels of dissolved solids in this area have been attributed to these wastewater discharges. Except for small volumes of sanitary wastewater, treated before discharge to the environment, the alternatives would not result in any new discharges. Therefore, long-term water quality impacts would not be expected.

It is not anticipated that the demand for water would be significant compared with the total water resource of the Snake River Plain Aquifer. The increased demand should not affect the availability of water for downgradient users.

Leaving the waste in place would continue the possibility that hazardous substances might contaminate the groundwater if flooding occurred and waste confinement failed. However, the substances would have to migrate nearly 600 ft through porous basalt and sedimentary layers before reaching the aquifer. Much of the hazardous material would be filtered out. Material that did reach the aquifer would be very dilute, well below 0.1 g/l for nitrates (DOE 1978a). The risks from flooding are discussed in Section 13.

12.3.5 Nonradiological Solid Waste Disposal. Most of the solid waste resulting from facility operations would not be contaminated and would, therefore, be consigned to existing sanitary landfills on the INEL. All concepts under Alternative 5 (disposal on the INEL) would continue to generate excavation spoils. The construction

phase includes only enough site preparation to handle about six months' output from the processing facility. Acreage for disposal of spoils, as given in Table 12-3, has been calculated to handle the total spoils, whether arising during construction or operations.

The greatest volume of solid waste to be considered would be that arising from D&D. Asphalt and gravel from D&D of a committed roadway could be recycled in theory, but it is more likely that most of the road would be adapted for other uses within the INEL. No radiological releases are expected during onsite transfer operations, so no decontamination should be necessary.

The retrieval facility, including most of its equipment, would be contaminated. The solid waste resulting from its D&D has been included in the estimates of waste to be processed, given in Sections 9 and 10. That is, the waste from D&D of the retrieval facility would be processed in the same way as the TRU waste would be processed. Solid waste resulting from D&D of a processing facility would require special planning and adherence to all applicable regulations. Uncontaminated materials and equipment would be reused or recycled.

12.3.6 Land Use. The committed land requirements during facility operation are given in Table 12-3 under construction impacts (Subsection 12.2.3). Areas required only for construction staging and for construction materials and equipment storage would be restored after the facilities were operational. All but the disposal facilities would be restored during D&D.

As discussed in Subsection 12.2.6, none of the facilities being considered competes with any planned land use except for the Lemhi sites, which would be located within currently allotted grazing areas. Surface facilities at a Lemhi site would occupy only about one acre (Table 12-3), but present policy would surround this area with a two-mile buffer to exclude cattle and sheep. Continuation of this policy would remove about 8,000 acres of grazing land, or about 2.5% of the total grazing area now administered on the INEL by the BLM (approximately 330,000 acres). If a Lemhi site were adopted, the buffer zone

might be judged unnecessary, because of the protection afforded by the deep rock disposal facility itself. Although livestock production is a major economic activity in the Lemhi Range area, only a small portion of that area lies within the INEL. Even a 2.5% loss of INEL grazing would have a smaller effect when taken in the context of adjoining public lands, which are also administered by the BLM.

12.3.7 Socioeconomic Impacts.

12.3.7.1 Employment and Economics. The potential employment impacts of operating the waste management alternatives studied can be placed in perspective by examining overall INEL employment and its recent variations in level. Table 12-8 shows that employment remained relatively constant from 1967 to 1974, but has grown substantially (43%) from 1975 to June 1978, when total employment was about 9400. The recent rapid growth rate is expected to level off in the near future.

TABLE 12-8
INEL EMPLOYMENT 1967-1978(a)

<u>Year</u>	<u>Minimum Employment</u>	<u>Maximum Employment</u>	<u>% Increase In Maximum</u>
1967	5526	6044	---
1968	5403	6027	-0.3
1969	5669	5996	-0.5
1970	5574	6016	0.3
1971	5324	6023	0.1
1972	5228	6237	3.6
1973	5665	6175	-1.0
1974	5872	6241	1.0
1975	6343	6561	5.1
1976	6298	7499	14.3
1977	7454	8632	15.1
1978(b)	8515	9406	9.0

(a) Source: Summary of INEL Personnel Data (DOE 1978b)

(b) Through June 1978

Table 12-9 shows the expected full-time operational employment for the various waste management modules. The leave-in-place alternatives would not require new employment, because the monitoring personnel shown in the table are already employed in that role. The balance of this subsection, therefore, deals only with the impacts from the other alternatives and concepts.

Operating employment from the other concepts would range from an estimated low of 97 new employees for the less massive variation of Concept 5-h (39 for retrieval, 50 for compaction, and 8 for disposal at Site 14) to 273 for Concept 5-a (39 for retrieval, 195 for slagging pyrolysis, and 39 for disposal - shaft access - in the Lemhi Range). These employment levels are lower than those estimated for the construction phase (see Table 12-1 and Subsection 12.2.7.1). Some individuals would probably transfer from the construction payroll to the operating payroll. (Both phases would require vehicle operators; and continued expansion of disposal capacity is really a continuation of earlier construction work.) At a maximum, the estimated new direct employment would be a 3% increase over June 1978 levels and impose a relatively small impact compared to the recent fluctuations shown in Table 12-8.

Indirect employment resulting from new operating employment would be greater than that from shorter-term construction payrolls. The normal multiplier for operating employment is about 2.5 (compared to the 1.5 used when discussing construction, in Subsection 12.2.7.1), implying the creation of 140 to 400 jobs in the supporting economy. The recent INEL personnel questionnaire (DOE 1978b) showed that about half of the current employees had been hired from out of state. A slightly lower immigration would be expected for the operating employees considered here, for the reasons discussed above. However, no data are available for predicting the immigrating fraction for the secondary employment.

The estimated payroll for the 97 to 273 new operating employees would total about \$1.6 to \$4.6 million/yr, as seen by summing the corresponding modules in Table 12-9. This would be 1% to 3% of the

TABLE 12-9

ESTIMATED RESOURCE USES DURING OPERATIONS PHASE

Facility	Direct Employment		Energy Usage	
	Number of Jobs	Annual Payroll(a) (10 ³ \$/yr)	Diesel Fuel (10 ³ gal/yr)	Electricity (10 ³ kwh/yr)
LEAVE AS IS AND IMPROVED CONFINEMENT(b)	10	160	0	0
RETRIEVAL FACILITY	39	624	88	600
PROCESS FACILITY(c)				
SP(d)	195	3,315	0	24,000
CPT	50	825	0	6,000
PKG	40	640	0	3,000
DISPOSAL FACILITIES				
Deep Rock Disposal				
Lemhi Site				
Shaft Access(e)				
SP	39	624	94	3,000
CPT	39	624	94	3,000
PKG	39	624	162	6,000
Deep Rock Disposal				
Lemhi Site				
Tunnel Access				
SP	31	496	84	2,000
CPT	31	496	84	2,000
PKG	31	496	142	4,000
Engineered Shallow				
Land Disposal at				
Site 14				
SP	19	304	26	130
LMV	10	160	11	130
CPT	17	272	28	100
LMV	8	128	13	100
PKG	28	448	42	260
LMV	19	304	27	260
Engineered Surface				
Facility Near RWMC				
SP	21	336	61	100
CPT	19	304	63	100
PKG	30	480	69	170
20-YR RETRIEVABLE STORAGE(f)	15	240	30	160

(a) 1978 rates, weighted according to estimated skills used: \$17K/yr for SP processing; \$16.5K/yr for CPT processing; \$16K/yr for all others.

(b) Employment is for monitoring personnel only and continues for 100 yr.

(c) SP: Slagging Pyrolysis and Packaging,
CPT: Compaction, Immobilization, and Packaging,
PKG: Packaging Only

(d) SP processing would also use 4,000 tons/yr of coal and 6,000 tons/yr of bark.

(e) Disposal operations vary with the volume of the output from processing.

(f) Employment and energy use would continue for 20 yr. All others would continue for 10 yr (except for monitoring disposal sites, which would continue for 100 yr).

1978 INEL payroll. Using the earnings multiplier of 2.2, the total economic impact on the area could be \$3.5 to \$10.1 million/yr, when secondary income is included.

The questionnaire developed by the INEL showed that the average employee household size was 3.1 persons. Assuming the same average household size, the new population (assuming 50% immigration) would be a maximum of 420 due to direct employment for waste management.

12.3.7.2 Housing. The first column of Table 12-10 shows the March 1978 residence pattern of INEL employees. Assuming the same general distribution for the employees needed to operate the waste management concepts being studied (still excluding the leave-in-place alternatives because of their negligible employment), local communities could expect the impacts shown in the center column of the table. The last column shows the possible total impact, including that from indirect employment.

TABLE 12-10
ESTIMATED RESIDENCE DISTRIBUTION OF NEW EMPLOYEES.

<u>City</u>	<u>Percent (a)</u>	<u>Direct Employment</u>	<u>Total New Employment</u>
Idaho Falls	66.5	64-182	160-455
Blackfoot	6.9	7-19	18-48
Pocatello	4.6	4-13	10-31
Shelley	3.4	3-9	8-23
Arco	2.6	3-7	8-18
Rigby	1.8	2-5	5-13
Ucon	1.6	2-4	5-10
Others	<u>12.6</u>	<u>12-34</u>	<u>30-85</u>
TOTALS	100%	97-273(b)	244-685

(a) Source: Summary of INEL Personnel Data (DOE 1978b).

(b) See Subsection 12.3.7.1 for range, low to high, of employment (excludes Alternatives 1 and 2, which involve only 10 direct employees).

Assuming a continuation of the existing patterns for residence location and housing style, discussed earlier (Table 12-5), the maximum housing demand would be for single-family units in Idaho Falls. That demand would be approximately 60 single-family units. Secondary employment would require additional housing, presumably proportionately. At most, an estimated 670 units would be required for direct plus indirect workers. This number is less than the number of units on the market in Idaho Falls, alone, in 1978. Thus, the housing impact appears to be within the capacity of local communities.

12.3.7.3 Social Services. Subsection 12.2.7.3 discusses the construction employment impacts on schools, medical care, fire and police protection, and recreation facilities. Direct employment during operations would place fewer demands on local social services than would arise during construction, because the number of employees would generally be smaller. However, impacts from the operating phase would last longer, and be larger overall, because of the higher employment multiplier (2.5 versus only 1.5 for the construction phase).

At an average of 1.2 school children/employee (DOE 1978b), the maximum impact would be the addition of 800 pupils to local schools, if all 670 new jobs (270 direct plus 400 indirect) were filled by immigrants. It is more likely that at least half the positions would be filled locally. In any case, some school expansion would be necessary under all except the leave-in-place alternatives. Proportional adjustments in other services would also be necessary. In no case do they exceed the scale of increased demands placed on local communities by the growth in recent years (Table 12-8).

12.3.8 Commitment of Resources. Operation and D&D of the alternative waste management facilities would result in both retrievable and irretrievable commitments of resources. Retrievable resources that would be committed for the life of the project include some land, uncontaminated equipment, and some building materials. These

resources could be reclaimed upon project termination. Irretrievable commitments would include land for disposal facilities, contaminated materials and facilities, labor hours, public funds, and energy.

Table 12-9 indicates the number of personnel required for each module considered for stored waste management. The most labor-intensive concepts are those that entail waste retrieval, processing, and onsite disposal. The leave-in-place alternatives involve the least labor for operations.

Estimated energy requirements for operating the facilities are also given in Table 12-9. The most energy-intensive activities are processing by slagging pyrolysis and onsite disposal. The slagging pyrolysis facility would use some wood bark, a locally available waste by-product of lumber processing. Currently, most waste bark is incinerated. The environmental impacts of bark utilization could be beneficial. Using a waste by-product as an alternate energy source would reduce the demand for other energy sources and reduce air quality impacts from the current incineration of bark.

12.3.9 Archaeological and Historical Sites. Measures assuring protection of antiquities and historic sites during construction should reduce the possibility of impacts during operation. Construction impacts are discussed in Subsection 12.2.9.

12.3.10 Aesthetics. Aesthetic impacts from operation and maintenance of facilities would be an extension of construction impacts for the life of the project. Additionally, a visible plume from the slagging facility stack could cause adverse aesthetic impact to passersby. Following termination of use of most of the facilities, previous aesthetic quality could be reestablished through D&D and rehabilitation of disturbed areas. However, the disposal facilities would impose long-term impact on aesthetics. Given the existing development on the INEL, this impact is considered minor.

12.3.11 Environmentally Sensitive Areas. The only operations that might adversely affect environmentally sensitive areas are activities at the Lemhi Range sites, transfer activities, and disposal of solid waste. Maintenance of a Lemhi site disposal facility would affect grazing if it were decided that a 2-mile buffer zone was needed. Transfer activities would cause localized disturbance to wildlife along roadways and potential increases in road kills. Solid waste disposal from operations and D&D could impact environmentally sensitive areas, so careful siting would be needed to minimize this impact.

The potential threat of contamination of the Snake River Plain Aquifer by hazardous agents in the waste would remain if Alternative 1 were selected. This potential would be reduced by the confinement concepts under Alternative 2.

12.3.12 Mitigation of Operational and D&D Impacts. Adverse operational and D&D environmental impacts would be minimized by adherence to all applicable federal and state regulations. Water and air pollution would be further avoided by employing state-of-the-art pollution control technology on potential effluents and emissions. Environmental monitoring would be maintained to detect radiological and nonradiological effects of operations and D&D activities. Restoration and rehabilitation, following or as a part of D&D activities, would help mitigate many long-term adverse impacts. To minimize energy consumption, operations design would include utilization of alternative energy sources; e.g., waste bark for use as fuel in the slagging pyrolysis facility. Additionally, latest state-of-the-art technology would be employed to ensure maximum energy efficiency.

12.3.13 Operational and D&D Environmental Monitoring Requirements. Environmental monitoring of radiological and nonradiological contaminants would be continued, with methodology updated as technology advanced. For concepts and alternatives involving disposal onsite or leaving waste in place, monitoring would continue for 100 yr as discussed in Section 7.4.1.

12.4 RADIOLOGICAL EFFECTS OF FACILITY OPERATIONS AND OF DECONTAMINATION AND DECOMMISSIONING

This section discusses the radiological effects of alternatives for long-term management of stored INEL TRU waste. Only the effects of normal operations are presented in this section. Accidental releases and attendant risks are discussed in Section 13, as are the effects of long-term mechanisms for release of radionuclides (e.g., erosion). The material in this subsection is organized in the following manner. Introductory material is presented in Subsection 12.4.1. The human exposure pathways and calculational models are presented in Subsection 12.4.2. The releases from facilities associated with each alternative are discussed in Subsection 12.4.3. The impact on land and water, impact on biota, radiological doses to individuals, and radiological doses to populations from these releases are then discussed in Subsections 12.4.4 through 12.4.7, respectively. The long-term environmental dose commitment is given in Subsection 12.4.8. Radiation dose from rail shipment of the processed TRU waste is given in Subsection 12.4.9. The projected health effects from all of these radiation doses are summarized in Subsection 12.4.10. Mitigation of radioactive release impacts and long-term monitoring requirements are discussed in Subsections 12.4.11 and 12.4.12, respectively.

12.4.1 Introduction. The assessment of environmental effects is based on expected airborne releases of small quantities of radioactive materials from retrieval, processing, storage, and disposal facilities. (No liquid effluents would be anticipated from normal operations.) Assessment of these effects is complicated by the fact that the expected releases would be in addition to waste discharges from other INEL facilities. Such discharges are discussed in the Environmental Impact Statement for INEL Waste Management Operations (ERDA 1977c). Furthermore, all INEL releases are superimposed on the natural levels of radioactivity present in soil, water, and air at the INEL. Also present is radioactivity from nuclear weapons testing conducted at the Nevada Test Site and elsewhere in the world. Most of the deposited fallout activity resulted from nuclear explosions in the

atmosphere in the early 1960s. However, one or more aboveground detonations has occurred in each of the last few years. A partial radiation dose assessment for two such events in 1976 has been published (Strong, Smith, and Johnson 1977).

12.4.2 Human Exposure Pathways. The analyses of radiological impacts considered the direct and indirect routes by which released radioactivity can be transported to man. The importance of each exposure route depends on many factors, including the chemical and biological behavior of the radioactive material, the distance to agricultural areas, agricultural management methods, recreation use patterns around the facility, and local meteorology and hydrology.

Figure 12-1 illustrates the potential human exposure pathways considered for airborne radioactive emissions released from waste management facilities. The models used to predict environmental transport of the airborne effluents and the resultant radiation doses to humans and biota are described in Appendix E. The principal pathway for the transuranic nuclides is inhalation of dispersed airborne effluents and resuspended material previously deposited on the ground. Direct radiation from the effluent plume and from material deposited on the ground is negligible for these alpha-emitting radionuclides. Uptake by crops and transfer from air or vegetation to animal tissue are also minor pathways because of small soil-to-plant and intestine-to-blood transfer factors for the transuranic elements.

No liquid effluents would be anticipated from normal operations of facilities for any of the waste management alternatives. Therefore, exposure pathways involving liquid discharges have not been considered in the analysis.

12.4.3 Releases of Radionuclides During Normal Operation and During Decontamination and Decommissioning.

12.4.3.1 Releases from Retrieval Facility. It is expected (although not certain) that the transuranic waste stored at the TSA will all be fully contained at the time of retrieval. (See Subsec-

Fig. 12-1 Potential exposure pathways for radionuclides released to the atmosphere.

tion 4.4.3.) Although the retrieval process would generate dust, the dust would probably not be a source of contamination within the facility or a source of radioactive waste effluents. However, for the purposes of this analysis, it was assumed that 1% of the containers (containing a representative fraction of the stored waste inventory) were breached before retrieval began. (There is no established technical basis for this value. It is considered to be reasonable, yet conservative.) It was further assumed that 0.1% of the activity in each breached container was released into the retrieval facility (Smith and Ross 1975). The fraction of the released activity which was assumed to become airborne within the facility, because of movement of machinery, containers, and personnel, was 1×10^{-4} (Mishima 1974; Mishima and Schwendiman 1970, 1973a, 1973b; Selby et al. 1973; Sehmel 1977; ORNL 1970b). Facility ventilation air would pass through one HEPA filter before discharge. The decontamination factor (DF) for the HEPA filter was estimated to be 10^3 for airborne particulates. Table 12-11 contains the average rates of release to the environment during retrieval between 1985 and 1995, and between 2005 and 2015 (delayed retrieval).

Radionuclide releases to the atmosphere during decommissioning of the retrieval facility would be expected to be less than 1% of those in Table 12-11. There would be a requirement to maintain radiation doses as low as practicable within the facility during operations. That requirement would limit the amount of internal contamination of the facility and thereby limit the decommissioning releases.

12.4.3.2 Releases from Slagging Pyrolysis Facility.

There are two sources of airborne radioactive effluents from a slagging pyrolysis facility. One is the dust generated when material is being prepared for pyrolysis. In estimating the release rate from this source, it was conservatively assumed that the maximum stable aerosol concentration of 100 mg/m^3 (Mishima and Schwendiman 1973b, Mishima 1974) was maintained at all times. The airborne dust would be carried by the building ventilation system to HEPA filters (two in series), which would reduce the effluent concentrations by a factor of

TABLE 12-11

AVERAGE NUCLIDE CONCENTRATIONS IN STORED WASTE AND AVERAGE
RELEASE RATES DURING RETRIEVAL

Nuclide	Radionuclide Content of Stored TRU Waste (Ci)	Average Release Rates to the Envi- ronment During Retrieval (pCi/sec)	
		Scheduled (1985-1995)	Delayed (2005-2015)
Pu-238	4.4×10^4	2.2×10^{-4}	2.0×10^{-4}
Pu-239	3.4×10^4	1.8×10^{-4}	1.8×10^{-4}
Pu-240	8.1×10^3	4.3×10^{-5}	4.3×10^{-5}
Pu-241	1.9×10^5	8.2×10^{-4}	2.8×10^{-4}
Pu-242	2.0×10^{-1}	1.0×10^{-9}	1.0×10^{-9}
Am-241	1.3×10^5	7.2×10^{-4}	7.0×10^{-4}
Cm-244	2.3×10^3	9.8×10^{-6}	3.5×10^{-6}
U-233	1.5×10^3	7.8×10^{-6}	7.8×10^{-6}

1×10^6 before discharge. (The value used for this factor is conservative and reflects possible minor bypass leakage around one filter. Filter testing at the time of installation and periodically during operation would minimize the possibility of bypass leakage.) The release rates are given in Table 12-12.

The second source of airborne effluents is the process off-gas, which contains particulate and (possibly) volatilized radionuclides. Release rates for these effluents also are given in Table 12-12. It was conservatively assumed that the off-gas treatment system would provide a decontamination factor of 10^5 for volatile species. (However, recent studies suggest that volatile radionuclides in the off-gas stream would be removed prior to release from the stack. The volatiles would be expected to condense and nucleate on off-gas particulate material or on equipment surfaces, as the temperature of the off-gas stream is reduced. In Table 12-12 the contribution from the volatiles is conservatively added directly into the average release rate total.) The off-gas stream would pass through the volatile off-gas treatment system, sintered metal filters, and two HEPA filter systems before discharge. The overall DF for particulates would be expected to be at least 10^8 . The effluent concentrations upstream of the filtration systems were based on an evaluation of probable off-gas concentrations (Christian, Kirstein, and Pence 1978), scaled for the size of the facility under consideration and the expected 1985 waste concentrations. The referenced calculations used a flow rate of $5.47 \text{ m}^3/\text{sec}$ through the secondary combustion chamber. The design flow rate reflects the daily mass of waste processed and is $3.7 \text{ m}^3/\text{sec}$ for a facility processing the stored TRU waste.

For the two processing periods studied, Tables 12-12 and 12-13 contain the projected release rates of radionuclides from both dust generation and system off-gas. Any volatile radioactive component would consist of oxides of the elements listed.

TABLE 12-12

AVERAGE RELEASE RATES FROM SLAGGING PYROLYSIS AND PACKAGING FACILITY,
(PROCESSING BETWEEN 1985 AND 1995)

Average Release Rates to the Environment During Processing (pCi/sec)				
Nuclide ^(a)	Preparation Cell	Processing Off-gas Stream		Total
	Particulate	Particulate	Volatile	
Pu-238	1.5×10^{-1}	5.9×10^{-1}	3.2×10^{-1}	1.1×10^0
Pu-239	1.2×10^{-1}	4.7×10^{-1}	2.6×10^{-1}	8.5×10^{-1}
Pu-240	2.8×10^{-2}	1.2×10^{-1}	6.1×10^{-2}	2.1×10^{-1}
Pu-241	5.3×10^{-1}	2.2×10^0	1.2×10^0	3.9×10^0
Pu-242	6.9×10^{-7}	2.8×10^{-6}	1.5×10^{-6}	5.0×10^{-6}
Am-241	4.7×10^{-1}	1.9×10^0	9.6×10^{-1}	3.3×10^0
Cm-244	6.5×10^{-3}	2.7×10^{-2}	1.3×10^{-2}	4.7×10^{-2}
U-233	5.2×10^{-3}	2.1×10^{-2}	2.0×10^{-2}	4.6×10^{-2}

(a) All radionuclides are assumed to be in the oxide form.

TABLE 12-13

AVERAGE RELEASE RATES FROM SLAGGING PYROLYSIS AND PACKAGING FACILITY
(PROCESSING BETWEEN 2005 AND 2015)

Average Release Rates to the Environment During Processing (pCi/sec)				
Nuclide ^(a)	Preparation Cell Particulate	Process Off-gas Stream		Total
		Particulate	Volatile	
Pu-238	1.3×10^{-1}	5.0×10^{-1}	2.7×10^{-1}	9.0×10^{-1}
Pu-239	1.2×10^{-1}	4.7×10^{-1}	2.6×10^{-1}	8.5×10^{-1}
Pu-240	2.8×10^{-2}	1.2×10^{-1}	6.1×10^{-2}	2.1×10^{-1}
Pu-241	1.8×10^{-1}	4.7×10^{-1}	4.2×10^{-1}	1.3×10^0
Pu-242	6.9×10^{-7}	2.8×10^{-6}	1.5×10^{-6}	5.0×10^{-6}
Am-241	4.6×10^{-1}	1.9×10^0	9.4×10^{-1}	3.3×10^0
Cm-244	2.3×10^{-3}	9.6×10^{-3}	4.8×10^{-3}	1.7×10^{-2}
U-233	5.2×10^{-3}	2.1×10^{-2}	2.0×10^{-2}	4.6×10^{-2}

(a) All radionuclides listed are assumed to be in the oxide form.

12.4.3.3 Releases from Compaction Facility. Generation of airborne dust containing radionuclides would be the only source of airborne releases from the compaction facility. The anticipated release rates are given in Table 12-14.

Health physics considerations would limit the amount of contamination within the building. Thus, the release rates during decommissioning would be limited to less than 1% of those in Table 12-14.

12.4.3.4 Releases from Packaging Facility. Airborne releases from a facility for packaging waste would result only from dust generation during operation. These releases would be about the same as for the compaction facility, given in Table 12-14.

12.4.3.5 Releases from Waste Disposal Facilities. No releases of radioactivity would be expected during normal operation of the waste disposal facilities or during transfer to them.

12.4.4 Contamination of Land and Water. One consequence of normal operation of the facilities described above would be the gradual buildup of released radioactivity in the environment. No liquid waste discharges would be anticipated, so this discussion centers on the accumulation of material deposited on the ground surface. The air-to-surface transport model described in Appendix E was used for all calculations. The results of computations of ground surface concentrations (the quantity S , in units of nCi/m^2) at the end of the 10-yr operating period are given in the several tables that follow.

Table 12-15 lists the maximum expected soil contamination following 10 yr of waste retrieval. For each nuclide, the average concentration within 50 miles of the representative site was calculated to be about 1/13 of the maximum value shown in the table. This maximum-to-average relationship holds for all tables in this subsection.

TABLE 12-14

AVERAGE RELEASE RATES FROM COMPACTION FACILITY

<u>Nuclide</u>	Average Release Rates to the Environment During Processing (pCi/sec)
	Following Scheduled Retrieval (1985-1995)
Pu-238	1.5×10^{-1}
Pu-239	1.2×10^{-1}
Pu-240	2.8×10^{-2}
Pu-241	5.3×10^{-1}
Pu-242	6.9×10^{-7}
Am-241	4.7×10^{-1}
Cm-244	6.5×10^{-3}
U-233	5.2×10^{-3}

TABLE 12-15

MAXIMUM SOIL CONTAMINATION RESULTING FROM AIRBORNE EFFLUENTS
FROM RETRIEVAL FACILITY

<u>Nuclide</u>	Maximum Soil Concentrations (a) (nCi/m ²)	
	Retrieval as Scheduled, <u>1985-1995</u>	Delayed Retrieval, <u>2005-2015</u>
Pu-238	4.8×10^{-5}	4.1×10^{-5}
Pu-239	4.1×10^{-5}	4.1×10^{-5}
Pu-240	9.5×10^{-6}	9.5×10^{-6}
Pu-241	1.4×10^{-4}	4.9×10^{-5}
Pu-242	2.4×10^{-10}	2.4×10^{-10}
Am-241	1.6×10^{-4}	1.5×10^{-4}
Cm-244	1.7×10^{-6}	6.2×10^{-7}
U-233	1.8×10^{-6}	1.8×10^{-6}

(a) These concentrations would be found only at the point of maximum air concentration (see Figure E-1). The average concentrations within a 50-mile circle around the retrieval facility would be 1/13 of the tabulated values.

Table 12-16 shows the maximum expected soil contamination following 10 yr of operating the slagging pyrolysis facility. Table 12-17 shows the maximum expected soil contamination expected from 10 yr of operating the waste compaction facility. Maximum soil contamination levels expected from 10 yr of operating a waste packaging facility would be about the same as those given above for the compaction facility.

The amount of surface soil contamination from normal operations would be independent of the time and method of shipment to the disposal site, and the location of the disposal site, whether at the Federal Repository or at the INEL. Table 12-18 summarizes the maximum expected soil contamination, by management alternative or concept.

For comparison, the concentrations of some natural and fallout radionuclides in soil are given in Table 12-19. The projected maximum total concentration of alpha-emitters resulting from any alternative is about 2 nCi/m^2 ; the corresponding average concentration would be about 0.15 nCi/m^2 . This average is about 10% of the mean concentration of alpha-emitting fallout radionuclides. The data also show that concentrations of major long-lived alpha-emitting fallout radionuclides are considerably smaller than the concentrations of naturally occurring alpha-emitters.

The radiological doses resulting from the projected concentrations of transuranic nuclides are discussed below. The implications of these soil concentration projections can best be understood in that context.

The radiological status of land in the RWMC and in adjacent areas must be discussed also in the context of anticipated future land use patterns. The expected continuation of the RWMC as a disposal area for fission product wastes (see Section 4) represents a long-term commitment of that land. This commitment is independent of the selection of a TRU waste management alternative.

TABLE 12-16

MAXIMUM SOIL CONTAMINATION RESULTING FROM AIRBORNE EFFLUENTS
FROM SLAGGING PYROLYSIS FACILITY

Nuclide	Maximum Soil Concentrations ^(a) (nCi/m ²)	
	1985-1995	2005-2015
Pu-238	3.8×10^{-1}	3.2×10^{-1}
Pu-239	3.2×10^{-1}	3.2×10^{-1}
Pu-240	7.7×10^{-2}	7.7×10^{-2}
Pu-241	1.1×10^0	3.9×10^{-1}
Pu-242	1.9×10^{-6}	1.9×10^{-6}
Am-241	1.2×10^0	1.2×10^0
Cm-244	1.4×10^{-2}	4.9×10^{-3}
U-233	1.7×10^{-2}	1.7×10^{-2}

(a) These concentrations would be found only at the point of maximum air concentration (see Figure E-1). The average concentrations within a 50-mile circle around the slagging pyrolysis facility would be 1/13 of the tabulated values.

TABLE 12-17

MAXIMUM SOIL CONTAMINATION RESULTING FROM AIRBORNE EFFLUENTS
FROM COMPACTION FACILITY

<u>Nuclide</u>	Maximum Soil Concentrations ^(a) (nCi/m ²)
	<u>1985-1995</u>
Pu-238	5.3×10^{-2}
Pu-239	4.4×10^{-2}
Pu-240	1.0×10^{-2}
Pu-241	1.6×10^{-1}
Pu-242	2.6×10^{-7}
Am-241	1.7×10^{-1}
Cm-244	1.9×10^{-3}
U-233	1.9×10^{-3}

(a) These concentrations would be found only at the point of maximum air concentration (see Figure E-1). The average concentrations within a 50-mile circle around the compaction facility would be 1/13 of the tabulated values.

TABLE 12-18

MAXIMUM SOIL CONTAMINATION RESULTING FROM NORMAL OPERATION
OF FACILITIES REQUIRED TO IMPLEMENT ALTERNATIVES

Management Alternative or Concept	Radionuclide Concentration ^(a) of Surface Soil (nCi/m ²)							
	Pu-238	Pu-239	Pu-240	Pu-241	Pu-242	Am-241	Cm-244	U-233
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3,4,5-a, 5-d,5-g,5-j	3.8x10 ⁻¹	3.2x10 ⁻¹	7.7x10 ⁻²	1.1x10 ⁰	1.9x10 ⁻⁶	1.2x10 ⁰	1.4x10 ⁻²	1.7x10 ⁻²
5-b,5-c,5-e, 5-f,5-h,5-i, 5-k,5-l	5.3x10 ⁻²	4.4x10 ⁻²	1.0x10 ⁻²	1.6x10 ⁻¹	2.6x10 ⁻⁷	1.7x10 ⁻¹	1.9x10 ⁻³	1.9x10 ⁻³
6	3.8x10 ⁻¹	3.2x10 ⁻¹	7.7x10 ⁻²	3.9x10 ⁻¹	1.9x10 ⁻⁶	1.2x10 ⁰	4.9x10 ⁻³	1.7x10 ⁻²

(a) These concentrations would be found only at the point of maximum air concentration (See Figure E-1). The average concentrations within a 50-mile circle around the RWMC would be 1/13 of the tabulated values.

TABLE 12-19

NATURAL AND FALLOUT RADIONUCLIDE CONCENTRATIONS IN INEL SOIL

Nuclide	Source	Average Concentration (nCi/m ²)
<u>Alpha Emitters</u>		
Pu-238	Fallout	0.15
Pu-239/ -240	Fallout	1.1
Am-241	Fallout	0.3
U-238	Natural	20
U-238 & alpha- beta emitting daughters	Natural	190
Th-232	Natural	30
Th-232 & alpha- beta emitting daughters	Natural	190
<u>Beta-Gamma Emitters</u>		
Cs-137	Fallout	110
Sr-90	Fallout	70
K-40	Natural	560
Beta-gamma emitting daughters of U-238	Natural	80
Beta-gamma emitting daughters of Th-232	Natural	140

- (a) The concentration shown for naturally occurring nuclides is only that in the top cm of the soil. The values for fallout nuclides are the total deposition, which is mainly distributed in the top 10 cm.

As a point of reference, a comparison of the soil radioactivity levels with the EPA screening level (EPA 1977) is appropriate. The EPA recommendation is that the group of people exposed to the highest radiation dose rate should not receive more than 1 mrad/yr to the pulmonary region of the lung or 3 mrad/yr to the bone. The derived soil screening level is 200 nCi/m^2 for particle sizes less than 2 microns in the top cm of soil (EPA 1977).

There are areas within and immediately adjacent to the Subsurface Disposal Area at the RWMC that now contain transuranic concentrations in excess of the screening level. These areas would not be released for unrestricted use without careful evaluation to assure that the EPA dose guideline, described above, could be met. This land has already been committed for an indefinite period for waste disposal. The waste retrieval and processing activities under consideration would result in some surface soil contamination, as described in the previous subsection. However, the maximum anticipated concentrations of transuranics in soil are less than 2% of the EPA screening value (EPA 1977). Thus, no radiological restrictions on land in the surrounding areas would result from transuranics released during normal operation of waste retrieval and processing facilities.

12.4.5 Radiological Impact on Biota. Both small and large mammals would have contact with air, soil, and vegetation bearing contaminants released during normal operation of waste retrieval and processing facilities. The small mammals include chipmunks, ground squirrels, kangaroo rats, mice, and rabbits. The large mammals include pronghorn antelope, deer, and domestic sheep and cattle.

The principal pathways by which airborne radioactivity can reach large animals are shown in Figure 12-1. Plutonium-238 and -239 have been detected in antelope lung tissue, reflecting both fallout and INEL releases. The annual lung dose to large animals from the transuranic nuclides released in waste processing would be less than 0.1 mrad. This dose addition would pose no threat to the health of individual animals or to the populations of these species.

Small mammals will also ingest contaminated soil, a pathway not shown in Figure 12-1. Plutonium-238, -239, and Am-241 have been found in small mammals residing in and near the Subsurface Disposal Area of the RWMC. (ERDA 1977a; Markham, Puphal, and Filer 1978). Doses to the lung and other tissues of small mammals (mainly mice) would be a maximum of 2-3 mrad/yr. This observation is based on measurement of mice now inhabiting the RWMC, where maximum soil concentrations of transuranics are up to 2000 nCi/m², or about 100 times larger than the highest soil concentrations expected from normal TRU waste management operations. Neither individual nor population effects would be expected among small mammals inhabiting areas with the anticipated soil contamination levels.

12.4.6 Maximum Radiation Doses^(a) to Individuals. The maximum annual radiation dose commitments for any individual as the result of normal operations of waste management facilities are discussed here. The inhalation and external radiation dose calculations assume that an individual resides at the point of maximum air concentration (and surface deposition) throughout the year. Few, if any, individuals would receive doses as large as the maximum values presented. Herdsmen tending domestic stock could be located at the point of maximum concentration for a part of the year. It is also possible that a few people could establish residence near the southern INEL boundary before startup of new waste management facilities. The maximum annual radiation dose commitment for either of these groups of people would be less than half of the dose commitments presented in this subsection.

For the two retrieval times considered, the maximum individual dose commitments from one year of stored waste retrieval operations are shown in Table 12-20.

(a) The radiation doses presented in Section 12 assume an average lifetime of 70 yr. Dose commitments were calculated by integrating over the time period from the initial exposure to the end of the remaining life of the individual (see Appendix E).

TABLE 12-20

MAXIMUM INDIVIDUAL LIFETIME DOSE COMMITMENT RESULTING FROM AIRBORNE
EFFLUENTS FROM ONE YEAR OF OPERATION OF WASTE RETRIEVAL FACILITY

Organ or Tissue	Maximum Lifetime Dose Commitment (mrem) Per Year of Retrieval Facility Operation	
	As Scheduled (1985-1995)	Delayed ^(a) (2005-2015)
Whole Body	2.4×10^{-11}	2.1×10^{-11}
Lung	4.5×10^{-7}	4.3×10^{-7}
Bone	4.6×10^{-7}	4.3×10^{-7}
Liver	3.4×10^{-7}	3.2×10^{-7}
Kidney	1.6×10^{-7}	1.6×10^{-7}

(a) Dose commitments for "Delayed" retrieval are lower than those for "As Scheduled" retrieval, primarily because of radioactive decay of Pu-241 during the 20-yr delay period.

The lifetime dose commitments resulting from one year of operation of a slagging pyrolysis facility are shown in Table 12-21. The whole-body dose commitments listed in the table are small because very little (60 KeV for a gamma ray release coincident with alpha decay of Am-241) of the decay energy is released as penetrating radiation.

The radiation dose commitments from airborne effluents from a compaction facility are shown in Table 12-22. The dose commitments from effluents from a waste packaging facility would be about the same as those for the compaction facility.

TABLE 12-21

MAXIMUM INDIVIDUAL LIFETIME DOSE COMMITMENT RESULTING FROM
AIRBORNE EFFLUENTS FROM ONE YEAR OF OPERATION OF
SLAGGING PYROLYSIS FACILITY

<u>Organ or Tissue</u>	<u>Maximum Lifetime Dose Commitment (mrem) Per Year of Slagging Pyrolysis Operation</u>	
	<u>As Scheduled (1985-1995)</u>	<u>Delayed^(a) (2005-2015)</u>
Whole Body	1.9×10^{-7}	1.6×10^{-7}
Lung	3.5×10^{-3}	3.4×10^{-3}
Bone	3.6×10^{-3}	3.4×10^{-3}
Liver	2.7×10^{-3}	2.5×10^{-3}
Kidney	1.3×10^{-3}	1.2×10^{-3}

(a) Dose commitments for "Delayed" are less than those for "As Scheduled" primarily because of radioactive decay of Pu-241 during the 20-yr delay period.

TABLE 12-22

MAXIMUM INDIVIDUAL LIFETIME DOSE COMMITMENT RESULTING FROM
AIRBORNE EFFLUENTS FROM ONE YEAR OF OPERATION OF
COMPACTION FACILITY

<u>Organ or Tissue</u>	<u>Maximum Lifetime Dose Commitment (mrem) Per Year of Compaction Facility Operation (1985- 1995)</u>
Whole Body	2.6×10^{-8}
Lung	4.9×10^{-4}
Bone	5.0×10^{-4}
Liver	3.7×10^{-4}
Kidney	1.8×10^{-4}

12.4.7 Radiation Doses to the Population During Operations and Decommissioning. The short-term (operating phase) radiation dose commitments to the population living within 50 miles of the waste management site are described in this subsection. The long-term dose commitments from environmental contamination associated with the waste management alternatives are discussed in Subsection 12.4.8.

The population doses to employees who work at the various INEL facilities are not included in this discussion. However, the dose commitment to this population group would be about 70% of the dose commitment to the populations living within a 50-mile radius of the waste management site. The calculations of 50-mile population dose commitments are based on 1970 census data (see Subsection 3.9), modified by an assumed growth rate guideline (see Guideline (7) in Subsection 7.4.1.5 and Appendix E).

Lifetime dose commitments per year of operation of the waste management facilities under consideration are presented below. Inhalation is the only important exposure pathway. (No liquid waste effluents are anticipated during normal operation; hence all the population dose commitments discussed below would result from airborne effluents from the facilities.) Whole-body doses are very small because the nuclides involved become localized in specific tissues and the principal emissions are of nonpenetrating radiation.

The lifetime population dose commitment resulting from the release of airborne effluents during one year of operation of the retrieval facility is shown in Table 12-23.

TABLE 12-23

LIFETIME POPULATION DOSE COMMITMENT RESULTING FROM
ONE YEAR OF OPERATION OF RETRIEVAL FACILITY

Organ or Tissue	Lifetime Population Dose Commitment (man-rem) Per Year of Facility Operation	
	As Scheduled (1985-1995)	Delayed (2005-2015)
Whole Body	2.9×10^{-10}	3.1×10^{-10}
Lung	4.1×10^{-6}	4.8×10^{-6}
Bone	4.2×10^{-6}	4.9×10^{-6}
Liver	3.1×10^{-6}	3.6×10^{-6}
Kidney	1.5×10^{-6}	1.8×10^{-6}

Tables 12-24 and 12-25 contain the lifetime population dose commitments from one year of operation of the slagging pyrolysis facility and compaction facility, respectively. The lifetime population dose commitments for the packaging facility would be about the same as those given in Table 12-25 for the compaction facility.

TABLE 12-24

LIFETIME POPULATION DOSE COMMITMENT RESULTING FROM ONE YEAR OF
OPERATION OF SLAGGING PYROLYSIS FACILITY

Organ or Tissue	Lifetime Population Dose Commitment (man-rem) Per Year of Facility Operation	
	As Scheduled (1985-1995)	Delayed (2005-2015)
Whole Body	2.3×10^{-6}	2.4×10^{-6}
Lung	3.3×10^{-2}	3.8×10^{-2}
Bone	3.3×10^{-2}	3.8×10^{-2}
Liver	2.5×10^{-2}	2.9×10^{-2}
Kidney	1.2×10^{-2}	1.4×10^{-2}

TABLE 12-25

LIFETIME POPULATION DOSE COMMITMENT RESULTING FROM ONE YEAR OF
OPERATION OF COMPACTION FACILITY

Organ or Tissue	Lifetime Population Dose Commitment (man-rem) Per Year of Facility Operation	
	(1985-1995)	
Whole Body	3.2×10^{-7}	
Lung	4.5×10^{-3}	
Bone	4.6×10^{-3}	
Liver	3.4×10^{-3}	
Kidney	1.7×10^{-3}	

12.4.8 Long-Term Environmental Dose Commitment. This subsection discusses the long-term dose commitment from normal operations of waste management facilities to: (1) the population living within 50 miles, and (2) the entire U.S. population. The long-term dose commitments result from the expected environmental contamination due to 10 yr of waste management facility operations. As can be seen from Table 12-18, the alternatives resulting in the largest amount of soil contamination from routine operations involve waste retrieval and slagging pyrolysis in 1985-1995. The lifetime dose commitments from inhalation of airborne materials during the 10-yr operating period were summarized in the previous subsection. The following discussion is confined to the long-term consequences of the contamination of the environment. The principal pathway of concern is inhalation of resuspended radionuclides from the soil contamination.

In estimating doses from resuspension of surface deposits, it was assumed that all radioactivity deposited was contained in the top cm of soil at the end of facility operations in 1995. The average areal concentrations are obtained by dividing the maximum values in Table 12-18 by 13, the peak-to-mean concentration ratio for the 50-mile circle. Three processes subsequently reduce the resuspendable surface activity: migration downward out of the top cm of soil, radioactive decay, and the resuspension process itself. Thus, the resuspension source term decreases exponentially with time (see Appendix E). The mass loading approach was used with the calculated source term to compute the air concentrations to which individuals within the 50-mile circle would be exposed at various times after 1995.

Table 12-26 contains the cumulative lifetime population dose commitments from retrieval and slagging pyrolysis of TRU waste for various times after 1985. The doses shown do not include the operational phase lifetime population dose commitments discussed in Section 12.4.7. Again, the population was assumed to grow exponentially at the rate of 1%/yr from 1985 to 2085 and to remain constant thereafter.

The maximum long-term whole-body and individual organ dose commitments are about 10 to 20 times those for the 10-yr operating period. These maxima are a very small fraction of the population dose from natural sources and are, in fact, less than the annual variation in population dose from natural sources. (No estimates were made of long-term decay of the sources of natural background radiation. However, such decay is believed to be relatively small over the million-year period studied.) During the first 10 yr, the average annual whole-body dose commitment for the population would be 4×10^{-5} man-rem. This dose commitment would be spread over a mean population of nearly 158,000 persons; hence, the average annual individual dose would be 2.5×10^{-7} mrem during that period.

TABLE 12-26

CUMULATIVE LIFETIME DOSE COMMITMENTS TO LOCAL POPULATION FOR VARIOUS TIMES AFTER 1995, FOR THE ALTERNATIVE RESULTING IN HIGHEST DOSES

Time (yr) After 1995	Cumulative Lifetime Population Dose Commitment To Organ or Tissue (man-rem) to Specified Year				
	Whole Body	Lung	Bone	Liver	Kidney
10	1.8×10^{-4}	5.5	3.0	2.4	1.1
20	3.4×10^{-4}	11	5.8	4.7	2.1
50	7.9×10^{-4}	25	13	11	4.9
100	1.4×10^{-3}	44	23	19	8.6
200	1.9×10^{-3}	61	32	27	12
500	2.1×10^{-3}	66	35	29	13
10^3	2.1×10^{-3}	66	35	29	13
10^4	2.1×10^{-3}	66	35	29	13
10^5	2.1×10^{-3}	66	35	29	13
10^6	2.1×10^{-3}	66	35	29	13

For comparison, the local cumulative whole-body and lung doses to the local population from natural sources are shown in Table 12-27. Figure 12-2 compares the 50-mile cumulative population dose commitments to lung tissue from normal operation of the worst-case alternative and from natural background radiation.

TABLE 12-27

CUMULATIVE LIFETIME DOSE COMMITMENTS TO LOCAL POPULATION
FROM NATURAL SOURCES FOR VARIOUS TIMES AFTER 1995

Time (Yr) After 1995	Cumulative Whole-Body and Lung Population Doses (man-rem) To Specified Year	
	Whole Body	Lung
10	2.1×10^5	3.0×10^5
20	4.5×10^5	6.3×10^5
50	1.3×10^6	1.8×10^6
100	3.4×10^6	4.9×10^6
200	8.8×10^6	1.2×10^7
500	2.5×10^7	3.5×10^7
10^3	5.3×10^7	7.4×10^7
10^4	5.5×10^8	7.4×10^8
10^5	5.5×10^9	7.4×10^9
10^6	5.5×10^{10}	7.4×10^{10}

The long-term environmental dose commitments for the U.S. population as the result of normal operation of the facilities were evaluated as described in Appendix E. Populations were again assumed to grow exponentially at 1%/yr until 2085 and to remain constant after that time. Table 12-28 contains the cumulative lifetime dose commitments for distant populations as the result of normal operations.

Fig. 12-2 Comparison of cumulative lung dose commitment for the population within 50 miles.

TABLE 12-28

CUMULATIVE LIFETIME DOSE COMMITMENTS FOR DISTANT POPULATIONS AT VARIOUS
TIMES AFTER 1995 FOR ALTERNATIVES RESULTING IN HIGHEST DOSES

Time (Yr) After 1995	Cumulative Lifetime Population Dose Commitment To Organ or Tissue (man-rem) to Specified Year				
	Whole Body	Lung	Bone	Liver	Kidney
10	8.2×10^{-4}	26	14	11	5.0
20	1.6×10^{-3}	50	27	22	9.8
50	3.7×10^{-3}	110	61	50	23
100	6.4×10^{-3}	200	110	88	40
200	9.0×10^{-3}	280	150	120	56
500	9.8×10^{-3}	310	160	130	61
10^3	9.8×10^{-3}	310	160	130	61
10^4	9.8×10^{-3}	310	160	130	61
10^5	9.8×10^{-3}	310	160	130	61
10^6	9.8×10^{-3}	310	160	130	61

12.4.9 Radiation Doses From Rail Shipment of the Processed TRU Waste. The transport of processed TRU waste to a disposal location onsite or offsite would result in doses to transportation workers, and to the general public near the route. This subsection discusses expected doses from the offsite shipment of waste by rail. The waste is assumed to be processed by slagging pyrolysis and packaged for delivery to the Federal Repository. Expected doses to onsite workers due to onsite transport of waste by truck are presented in Section 14.

Most of the radionuclides in the stored TRU waste are alpha-emitters. Because of the nature of alpha radiation, no external whole-body exposure would result from rail shipment of waste containing only alpha-emitters. However, small quantities of beta-gamma emitting radionuclides exist in the stored TRU waste. For this reason, rail shipment of the waste would result in small whole-body doses to the train crews and to the public near the route.

The radiation levels from the processed waste would generally be low enough to preclude the need for shielded containers. Preliminary calculations show that, averaged over all shipments, the dose rate at 6 ft from the external surface of the rail cars would be about 7×10^{-1} mR/hr (DOE 1978a). The value permitted by federal regulations is 10 mR/hr (49 CFR 173.393). A few of the containers might require shielding to meet this requirement. However, the number of containers in this category is expected to be insignificant.

Figure 9-10 illustrates the shipment route assumed for this study. A one-way trip would take 6 days. The train would be manned 24 hr/day. Each crew would consist of 5 members; shifts would be changed every 8 hr. The total number of crew members would be about 90 (6 days x 3 shifts/day x 5 members/shift). The estimated shipping rate is 190 rail cars/yr.

The population densities along the postulated railroad route were categorized as urban for the Denver-Boulder area, suburban for the Colorado Springs and Pueblo area, and rural for the remainder of the route. Distances through urban, suburban, and rural areas were estimated to be 35, 50, and 1326 miles, respectively.

External whole-body exposure from normal operational shipment of the waste could be received by the general public, passing traffic, station personnel, and train crews. The maximum annual dose to an individual crew member was calculated to be approximately 25 mrem (DOE 1978a). This is well below the allowable limit of 500 mrem/yr for individuals in unrestricted areas (10 CFR 20.105). In the same

dy, the dose to a railroad station employee was estimated to be

7 mrem/yr. The maximum dose to a member of the general public was estimated at 6×10^{-3} mrem/yr. Table 12-29 illustrates the expected population dose from external whole body exposure from shipment of 190 car loads of waste per yr. The shipments would take place at this rate for 10 yr in Alternatives 3, 4, and 6. The effect of the 20-yr delay in Alternatives 4 and 6 would be to reduce the calculated doses from external exposure by approximately a factor of 2.

TABLE 12-29

EXPECTED DOSE FROM EXTERNAL WHOLE-BODY EXPOSURE
DUE TO RAIL TRANSPORT OF STORED TRU WASTE

<u>Group</u>	<u>Annual Population Dose (man-rem/yr)</u>
General Public	0.05
Passing Traffic	<0.005
Station Personnel	0.1
Train Crews	1.0

12.4.10 Health Effects. The health effects of the individual and population doses presented previously are now discussed. The impacts on individuals, even those who receive the maximum doses, would be small. The maximum individual whole-body doses from normal operations, from soil contamination, and from shipping is calculated to be 2×10^{-7} mrem/yr, 3×10^{-6} mrem/yr, and 25 mrem/yr, respectively. These doses are approximately $10^{-7}\%$, $10^{-6}\%$, and 20%, respectively of the annual individual whole-body doses received from natural sources.

In estimating health effects, the population dose in man-rem has been used as a measure of the detriment to the exposed group. The population dose is the integral, over the appropriate range of doses, of the product of the number of individuals receiving a specific dose times that dose.

To estimate the maximum potential number of health effects that might result from normal operation of the highest-dose modules, the relationships in Table 12-30 were used (NAS-NRC 1972, United Nations 1972, ICRP 1966, and ICRP 1969). These are upper limits. A linear relationship between dose and health effects is assumed even at very low doses and dose rates (NRC 1975, Appendix 6; NAS-NRC 1972; United Nations 1972; NCRPM 1975).

For operation of retrieval and slagging pyrolysis facilities, Table 12-31 shows the cumulative maximum potential number of health effects as a function of time after 1985. These effects have been summed over all five tissues of concern. The values in Table 12-31 include the long-term effects of the resuspension of radionuclides that were deposited in soils from releases to the environment during the original 10-yr retrieval and processing campaign. The population group includes both local and distant populations.

The dose of concern for genetic effects is the gonadal dose, also called the genetically significant whole-body dose. Genetic effects were determined by multiplying the sum of the whole-body doses to local and distant populations by the genetic damage incident rate shown in Table 12-30. Less than one health effect is projected to result from normal operation of any combination of facilities considered, even when considering the whole population of the United States over a period of a million years.

The maximum potential number of health effects from shipping the waste to the Federal Repository was also estimated. The population group exposed to radiation during rail shipment of the waste includes

TABLE 12-30

MAXIMUM POTENTIAL NUMBER OF HEALTH EFFECTS
PER UNIT POPULATION DOSE^(a)

Organ or Tissue at Risk	Maximum Potential Health Effects (Number/man-rem population dose)		
	Total Incidence	Fatal	Nonfatal
Whole Body	4×10^{-4}	2×10^{-4}	2×10^{-4}
Lung	6×10^{-5}	6×10^{-5}	(b)
Bone	5×10^{-5}	3×10^{-5}	2×10^{-5}
Liver	3×10^{-5}	3×10^{-5}	(b)
Kidneys	1×10^{-5}	1×10^{-5}	(b)
Genetic Damage	3×10^{-4}	$3 \times 10^{-4}(c)$	(b)

(a) Source: NAS-NRC (1972), United Nations (1972), ICRP (1966), and ICRP (1969).

(b) All are assumed to be fatal.

(c) Assumes deaths are to fetuses in early steps of development.

TABLE 12-31

MAXIMUM CUMULATIVE POTENTIAL HEALTH EFFECTS
FROM IMPLEMENTATION OF ANY ALTERNATIVE

Maximum Cumulative Potential Health Effects			
Time (yr) After 1985	Cancers		
	Fatal	Nonfatal	Genetic
10	2.8×10^{-3}	3.4×10^{-4}	3.0×10^{-7}
20	5.4×10^{-3}	6.5×10^{-4}	5.8×10^{-7}
50	1.2×10^{-2}	1.5×10^{-3}	1.3×10^{-6}
100	2.2×10^{-2}	2.7×10^{-3}	2.4×10^{-6}
200	3.0×10^{-2}	3.6×10^{-3}	3.3×10^{-6}
500	3.3×10^{-2}	3.9×10^{-3}	3.6×10^{-6}
10^3	3.3×10^{-2}	3.9×10^{-3}	3.6×10^{-6}
10^4	3.3×10^{-2}	3.9×10^{-3}	3.6×10^{-6}
10^5	3.3×10^{-2}	3.9×10^{-3}	3.6×10^{-6}
10^6	3.3×10^{-2}	3.9×10^{-3}	3.6×10^{-6}

the general public in the vicinity of the railroad route, passing traffic, station personnel, and train crews. Health effects were determined by multiplying the whole-body population dose by the fatal and nonfatal incidence rates shown in Table 12-30. Less than one (2.3×10^{-3}) fatal and less than one (2.3×10^{-3}) nonfatal health effect are projected as a result of shipping the waste to the Federal Repository.

12.4.11 Mitigation of the Impacts of Operational Radioactivity Releases. The projected radiation doses to individuals and to the general population projected for the alternatives are small. The maximum individual whole-body dose from retrieval and processing options is only about 2×10^{-7} mrem/yr, or about one-billionth of the annual background dose of 150 mrem/yr. Population doses within 50 miles of the waste management site are an even smaller fraction of the annual background dose. These very small doses indicate that additional expenditures for filtration or other cleanup systems would be questionable. Individual whole-body doses from the shipment of waste to the Federal Repository is comparatively much higher than doses received from the retrieval, processing, and packaging alternatives. However, these doses, 25 mrem/yr to the maximum individual, are still only about 20% of the individual dose received from natural sources and 5% of the dose allowed by federal standards (10 CFR 20.105). Therefore, mitigative measures would probably not be necessary.

12.4.12 Requirements for Long-Term Monitoring. Monitoring of facility effluents and the local environment would be carried out throughout the operation and decommissioning phase of any alternative selected. This monitoring would provide detailed data of treatment system performance and of environmental radioactivity levels resulting from operations. It is expected that operational releases would not result in any environmental contamination above guidelines recently established (see Subsection 12.4.4).

12.5 SUMMARY

12.5.1 Nonradiological Environmental Effects. Environmental effects are inevitable from any action that changes the management of the stored TRU waste. On the other hand, concern has been expressed about the environment if no action is taken.

Earlier discussions in this section tabulated the estimates of nonradiological effects from the modules considered. Tables 12-32 and 12-33 summarize the major quantitative effects for construction and operations, respectively, for each concept.

Each column in each table ends with a reference to the more complete tabulation and accompanying discussion in Subsections 12.2 and 12.3. The summary tables highlight only some of the major effects. For example, pollutant emissions are summarized by giving only the estimates for particulates, because that is the only air pollutant on the INEL that is now near the allowable limits. More detailed data, for other pollutants, are given by module in the referenced tables.

Similarly, construction material usage is summarized only in terms of clay and concrete, because of the dominance of these materials, e.g., 990×10^3 yd³ of clay and 1200×10^3 yd³ of concrete for Concept 5-i (shallow disposal of the least-dense packaging output). The consequences of these material usages are reflected in the cost estimates of Section 15.

Socioeconomic effects are roughly proportional to changes in direct employment. The summary tables show this as man-years of effort for the short-term construction work but as new jobs for the longer-term operating phase. The direct effects (new employment, increased income) can be seen as benefits to the local economy, but the labor usage is an irreversible commitment of resources. Secondary employment would also cause increased demands for social services: schooling, health care, recreation, etc.

TABLE 12-32

SUMMARY OF QUANTITATIVE NONRADIOLOGICAL IMPACTS
(CONSTRUCTION PHASE)

Concept	Usage (10^3yd^3)		Particulate Emissions (10^3 lbs) (a)	Labor (man-years)	Diesel Fuel Usage (10^3 gal)
	Clay	Concrete			
1	0	0	0	0	0
2-a	30	0	9.5	16	86
2-b	30	13	13	54	120
2-c	0	0	3.2	20	29
3	0	2	46	500	410
4	0	8	48	510	440
5-a	0	4	82	570	740
5-b	0	4	75	530	680
5-c	0	4	66	410	600
5-d	0	7	82	570	740
5-e	0	7	75	530	680
5-f	0	7	66	410	600
5-g	420	510	56	530	510
LMV(b)	120	16	54	520	490
5-h	360	430	49	490	450
LMV	160	20	47	480	430
5-i	990	1200	40	370	370
LMV	320	43	38	360	350
5-j	43	380	54	520	490
5-k	42	360	47	470	430
5-l	120	1100	38	360	350
6	0	2	46	500	410
See Tables	12-6	12-6	12-2	12-1	12-1

(a) From diesel-powered construction equipment; assumes all construction proceeding simultaneously.

(b) LMV identifies use of the less massive variation of the engineered shallow-land disposal facility at Site 14.

TABLE 12-33

SUMMARY OF QUANTITATIVE NONRADIOLOGICAL IMPACTS
(OPERATIONS PHASE)

Concept	Particulate Emissions (10 ³ lb/yr) (a)	Land Usage (acres)	Employment (b)		Energy Used	
			Jobs	(10 ⁶ \$/yr)	Diesel (10 ³ gal/yr)	Electric (10 ⁶ kwh/yr)
1-a	0	(c)	10	0.16	0	0
2-a	0	(c)	10	0.16	0	0
2-b	0	(c)	10	0.16	0	0
2-c	0	(c)	10	0.16	0	0
3	0.95	1.9	230	3.9	88	25
4	4.3	9.4	250	4.0	100	25
5-a	11	210	270	4.5	160	28
5-b	11	210	130	2.0	160	9.6
5-c	19	210	120	1.8	220	9.6
5-d	10	210	270	4.3	150	27
5-e	10	210	120	1.8	150	8.6
5-f	17	210	110	1.7	200	7.6
5-g	3.9	250	250	4.0	92	25
LMV (d)	2.2	170	240	4.0	92	25
5-h	4.1	240	110	1.5	94	6.7
LMV	2.4	190	100	1.5	94	6.7
5-i	5.6	410	110	1.5	110	3.9
LMV	3.9	230	100	1.5	110	3.9
5-j	7.7	36	260	4.0	92	25
5-k	7.9	35	110	1.5	94	6.7
5-l	8.5	96	110	1.5	100	3.8
6	0.95	1.9	230	3.9	88	25
See Tables	12-7	12-3	12-9	12-9	12-9	12-9

(a) From diesel vehicles or slagging pyrolysis facility stack, only.

(b) Direct employment only; income in 1977 dollars.

(c) No incremental land usage beyond area in the RWMC currently in use.

(d) LMV identifies use of the less massive variation of the engineered shallow-land disposal facility at Site 14.

It has been noted, in Subsections 12.2.1 and 12.3.1, that none of the air pollutants would exceed existing offsite standards. Most of the effects are temporary, limited to the construction period, or ceasing after D&D. A significant portion of the land usage would be associated with the committed roadway to either Site 14 or to the Lemhi Range. Either roadway could be decommissioned (and the land restored to its previous condition), or dedicated to public usage over most of its length. Although an effect may be measurable, as listed in the summary tables, its impact may be almost unnoticeable, or within acceptable standards in terms of the gain to be achieved. These tradeoffs are a matter of judgement and public perception.

12.5.2 Radiological Environmental Impacts. The maximum individual doses resulting from normal operations of the waste management activities are summarized by alternative or concept in Table 12-34. The maximum radiation doses are very small. Doses for alternatives involving slagging pyrolysis are the highest. However, the annual whole-body dose from natural sources is approximately 150 mrem/yr, so the small increment of about 2×10^{-7} mrem associated with slagging pyrolysis is not significant.

The calculated doses are so small it would not be cost-effective to pursue mitigating actions beyond those already incorporated in the designs being evaluated. For example, the maximum individual whole-body dose for one year of operation for any of the alternatives is less than 2×10^{-7} mrem, compared to the annual natural background doses of 150 mrem (ERDA 1977c). In none of the concepts is there any cause for concern about significant radiological environmental impacts from normal operations. (Abnormal operations and long-term release scenarios are discussed in Sections 13 and 14.)

The annual population dose commitments associated with normal waste management operations are summarized by alternative or concept in Table 12-35.

TABLE 12-34

MAXIMUM INDIVIDUAL LIFETIME DOSE COMMITMENTS
RESULTING FROM ONE YEAR OF NORMAL OPERATION OF WASTE MANAGEMENT FACILITIES

Management Alternative or Concept	Maximum Individual Dose Commitment (mrem) to Organ or Tissue				
	Whole Body	Lung	Bone	Liver	Kidney
1	0	0	0	0	0
2	0	0	0	0	0
3,4,5-a, 5-d,5-g ^(a) ,5-j	1.9×10^{-7}	3.5×10^{-3}	3.6×10^{-3}	2.7×10^{-3}	1.3×10^{-3}
5-b,5-c,5-e, 5-b,5-h ^(a) ,5-i ^(a) , 5-k,5-l	2.6×10^{-8}	4.9×10^{-4}	5.0×10^{-4}	3.7×10^{-4}	1.8×10^{-4}
6	1.6×10^{-7}	3.4×10^{-3}	3.4×10^{-3}	2.5×10^{-3}	1.2×10^{-3}

(a) Values would be unchanged for the less massive variation of the engineered shallow-land disposal facility at Site 14.

TABLE 12-35

LIFETIME POPULATION DOSE COMMITMENTS RESULTING FROM
ONE YEAR OF NORMAL OPERATION OF WASTE MANAGEMENT FACILITIES

Alternative or Concept	Lifetime Population Dose Commitment to Organ or Tissue (man-rem)				
	Whole Body	Lung	Bone	Liver	Kidney
1	0	0	0	0	0
2	0	0	0	0	0
3,4,5-a, 5-d,5-g ^(a) ,5-j	2.3×10^{-6}	3.3×10^{-2}	3.3×10^{-2}	2.5×10^{-2}	1.2×10^{-2}
5-b,5-c,5-e, 5-f,5-h ^(a) ,5-i ^(a) , 5-k,5-l	3.2×10^{-7}	4.5×10^{-3}	4.6×10^{-3}	3.4×10^{-3}	1.7×10^{-3}
6	2.4×10^{-6}	3.8×10^{-2}	3.8×10^{-2}	2.9×10^{-2}	1.4×10^{-2}

(a) Values would be unchanged for the less massive variation of the engineered shallow-land disposal facility at Site 14.

The annual population dose commitments from operation of the waste management facilities can be compared with the annual population doses from external and internal radiation from natural sources. In 1985, the population of about 136,000 within 50 miles would all receive approximately 1.5×10^2 mrem/yr from natural sources. The estimated population dose would be about 2×10^4 man-rem in that year. The largest whole-body population dose from pursuit of any waste management alternative or concept would be about 2.4×10^{-6} man-rem, or 10 orders of magnitude lower than the population dose from natural sources.

The total lifetime population dose commitments from 10 yr of operation of the facilities, during the 1985-1995 or 2005-2015 time periods, are approximately ten times the values tabulated above. The largest projected total dose commitment is 2.4×10^{-5} man-rem. This value is 10 orders of magnitude lower than the population dose from natural sources received by the local population in the same 10-yr operating period.

12.5.3 Unavoidable Adverse Impacts. Unavoidable adverse environmental impacts associated with the proposals for managing radioactive waste vary in kind and intensity with the alternative studied. Those alternatives that would result in the greatest impact are those that would require the largest amount of construction and those that would be most labor and energy intensive.

Unavoidable construction impacts include the loss of up to 410 acres, depending on the alternative, for construction of facilities. This results in loss of habitat and commitment of this land until D&D. Additional habitat would be lost for a short time by such construction-related activities as material mining and construction staging.

Operation of some of the facilities would be moderately labor and energy intensive and would result in the commitment of valuable, non-renewable resources, including labor hours, energy, and public funds

(see Table 12-33)... Employment leading to population increases in the area could have adverse effects on public services. The potential for adverse air quality impacts would exist, but is not considered significant (see Subsections 12.2.1 and 12.3.1). There is also a slight possibility of contamination by hazardous wastes during operations.

Waste from D&D of a retrieval facility has been accounted for as input to waste processing. D&D of a processing facility, however, would generate additional waste, some of which would go into sanitary landfills. The contaminated waste would require special handling to be designed at the time the facility design itself was finalized.

Except for the long-term commitment of disposal areas, the above effects would all be nonradiological. In general, these are typical of any construction activity, and operation that consumes resources. The design, construction, and modes of operation, however, do not represent typical practices or costs; they are characterized by extreme precautions to overcome all conceivable radiological hazards. Incremental radiological effects still can be calculated, and have been in Subsection 12.4, but they are all so small that measurement would be impossible. The result is that normal operations and long-term effects would impose no adverse impacts on the public nor on biota on or off the INEL. Normal operations and long-term effects would impose no adverse radiological impacts on the public nor on biota on or off the INEL.

13. RADIOLOGICAL RISKS TO THE PUBLIC

13.1 ORGANIZATION OF SECTION

This section addresses the effects on the public of accidental or uncontrolled releases of radionuclides in the waste. Discussed in Subsection 13.2 are the purpose and scope; definitions of terms; assumptions and methodology for the analysis; and long-term hazard characteristics of the waste. Subsection 13.3 presents, in summary form, the results of the dose commitment and risk calculations for the alternatives, concepts, and modules described in Sections 8 through 10. For the short term (up to 100 yr), the results presented include maximum individual and population dose commitment, as well as maximum individual and population risk. For the long term (beyond 100 yr), maximum individual and population dose commitments are given.

Most of the remainder of the section (Subsections 13.4 through 13.10) discusses the release scenarios studied and the details of the evaluations. (The results of the evaluations are not repeated; the reader should refer back to Subsection 13.3.) Subsection 13.4 presents most of the event scenarios as part of the analysis of Alternative 1 (Leave As Is). Short-term risks and doses^(a) are calculated for airborne and for waterborne releases. Long-term effects (dose commitments) are then discussed for airborne and for waterborne releases. Discussions of subsequent alternatives, concepts, and modules refer to this initial discussion, and modifications of the release scenarios are included where appropriate. The same order of presentation is followed.

(a) Hereafter, the term "dose" is often used for brevity. However, it should be understood that dose commitment is meant, calculated as described in Appendix E.

Health effects estimated to result from the calculated exposures are discussed in Subsection 13.11. The environmental effects of radionuclide releases due to accidents and natural events are discussed in Subsection 13.12.

13.2 BACKGROUND

13.2.1 Purpose and Scope. The purpose of the risk analysis is to evaluate and compare the doses and risks to the public for the various alternatives, concepts, and modules studied. Accidental or uncontrolled releases of radioactive materials are evaluated in this section. Normal operational releases are addressed in Section 12. Radiological hazards to workers are addressed briefly in Section 14.

The scope of the analysis presented in this section is indicated by the guidelines of Subsection 7.4.1. The alternatives, concepts, and modules studied are identified in Figure 7-1.

The doses and risks to the public were estimated for the time period to 100 yr after implementing each waste management alternative or concept. These are referred to as short-term doses and risks. Depending on the concept or module being evaluated, the operational period could range from 10 to 30 yr (including a postulated 20-yr delay in retrieving the waste). For some concepts, a 30-yr retrievability phase of disposal was studied.

Long-term effects (dose commitments) - involving times more than 100 yr after implementation - were estimated for concepts in which the waste would be left in place or disposed on the INEL. Probabilities of events generating long-term effects are qualitatively discussed. However, long-term risks were not calculated because of the difficulty of reliably predicting probabilities and geologic characteristics into the far-distant future. Long-term effects at the Federal Repository are not included because they are being evaluated in other DOE projects.

13.2.2 Definition of Risk. The concept of risk involves not only the likelihood that a hazardous event will occur, but also the consequences, or extent of damage, if the event were to occur (NRC 1975). One way to define the risk to an individual from a potential accident is to calculate the absorbed radiation dose, in roentgen equivalent man (rem), and to multiply that dose by the estimated frequency or probability of the event in a given year.^(a) The product of these two terms is the risk, measured in rem/yr. The population risk, defined as the sum of the risks incurred by all individuals in a given geographic area, can be expressed in man-rem/yr.

The following example illustrates how risk to an individual can be calculated. An event resulting in a release yielding a calculated dose of 1 rem to an individual, with an expected frequency of four times per year, would have the following associated risk:

<u>Dose</u>	<u>Frequency</u>	<u>Risk</u>
-------------	------------------	-------------

$$1 \text{ rem/event} \times 4 \text{ events/yr} = 4 \text{ rem/yr}$$

Analysis of another event might show a larger potential dose and a lower frequency. If the calculated dose were 4 rem, and the expected frequency were once in 100 yr, or 10^{-2} events/yr, the risk would be:

<u>Dose</u>	<u>Frequency</u>	<u>Risk</u>
-------------	------------------	-------------

$$4 \text{ rem/event} \times 10^{-2} \text{ events/yr} = 0.04 \text{ rem/yr}$$

The risk associated with the first event (4 rem/yr) is 100 times that of the second event (0.04 rem/yr). The calculated risks in this analysis are especially useful for such comparisons.

(a) The discussion in Subsection 13.11 enables the interested reader to translate the stated definition of risk into one based on health effects.

Calculated radiological effects on the public, for a given hypothetical or actual release event or collection of events, are often reported using the terms "maximum individual dose," "maximum individual risk," "population dose," "population risk," and "time-integrated population risk." These terms are defined in this report as follows:

- (1) Maximum individual dose (rem) is that dose commitment incurred by an individual located in an unrestricted area who receives the maximum possible dose commitment as a result of the release of radioactive material.
- (2) Maximum individual risk (rem/yr) is calculated for a given release by multiplying the maximum individual dose commitment (rem/event) by the expected frequency of the release (events/yr).
- (3) Population dose (man-rem) is that dose commitment incurred by the surrounding population as a result of the release of radioactive material.
- (4) Population risk (man-rem/yr) is obtained by multiplying the population dose commitment for a given release by the expected frequency of the release (events/yr).
- (5) Time-integrated population risk involves the summation, or integration, of annual population risks over the duration of the operation presenting the risk. Factors representing population growth and decay of radionuclides in the waste are included in the calculations. The unit of time-integrated population risk is man-rem, because the risk is equal to the annual population risk, in man-rem/yr, summed over a specified number of years.

In this study, the first four measures of dose and risk were evaluated. Means are provided for evaluating the last measure listed,

as discussed in the following paragraphs. The specific assumptions and methods used to calculate these quantities are described in Appendix E.

Time-integrated values of population risk can be estimated by multiplying the annual risk by the factors indicated in Table 13-1. (These particular factors which are derived in Appendix E, apply only to dose commitment to the bone. Although factors were not derived for dose commitment to other organs, the calculation procedure would be similar to that discussed here and in Appendix E.) Because several factors are involved in the time-integration process, the factors in Table 13-1 are only approximate.

Calculations of short-term dose commitments and risks assumed that releases will occur in 1985. Except as noted in Subsections 13.5.3.3, 13.8.4.3.3, and 13.8.4.3.4, calculations of long-term dose commitments assumed that releases will occur in 2085. For the most significant release scenarios, the long-term dose commitments were also calculated for times as much as 25,000 yr into the future. Table 13-1 and Subsection 13.2.5 provide guidance for projecting release effects as much as 1,000,000 yr into the future.

TABLE 13-1

MULTIPLIERS FOR TIME-INTEGRATED RISK TO THE BONE

Time- Integration Interval (yr)	Population Risk Multiplier	Individual Risk Multiplier	Dominant Isotopes
1×10^1	1.0×10^1	9.9×10^0	Am-241, Pu-238, Pu-239
1×10^2	1.5×10^2	8.7×10^1	Am-241, Pu-238, Pu-239
1×10^3	1.4×10^3	5.3×10^2	Am-241, Pu-240, Pu-239
1×10^4	6.9×10^3	2.5×10^3	Am-241, Pu-240, Pu-239
1×10^5	2.2×10^4	8.4×10^3	Pu-240, Pu-239
2.5×10^5	2.3×10^4	8.4×10^3	Pu-239
1×10^6	2.3×10^4	8.4×10^3	Pu-239

13.2.3 Assumptions. A number of approximations and simplifying assumptions was used as bases in performing the risk analyses (see Subsections 7.4.1.3, 13.2.4, and 13.4 through 13.9). Therefore, the doses and risks presented in this report are best used for broad comparisons between concepts. Using the doses and risks as absolute numbers (as for comparisons with concepts from other waste management sites) should be done only with considerable caution.

In the accident studies, it was assumed that the release fraction would be the same for all nuclides present. In reality, selective processes and material properties, such as volatility, solubility, and chemical form, would promote the release of some nuclides and the retention of others.

Several assumptions are also implicit in the use of the man-rem concept for estimating the effects of population dose. A linear, nonthreshold relationship between dose and effect is assumed over the entire range of potential doses and dose rates (Taylor and Wyckoff 1976; ICRP 1965; NCRPM 1971, 1975; Casarett 1968; and NAS-NRC 1972). For a given organ (e.g., bone or lung), all persons are assumed equally radiosensitive. Somatic effects, such as cancer, are assumed proportional to the dose to the relevant organ.

The assumptions used for HEPA filter effectiveness were developed by examining several sources of HEPA performance data. Recommendations for filter decontamination factor (DF) in removing PuO_2 aerosols from an air stream varied widely, even though the same range of PuO_2 particle sizes was considered. The highest values of DF suggested nearly the ultimate in filter performance, while the lowest values reflected pessimistic and probably degraded performance. The HEPA filters referred to in the present study would be tested in place at least twice annually and changed at frequent intervals as needed. The DF values adopted for this study lie near the middle of the range identified: for a single-stage HEPA filter, 10^3 ; for a double stage, 10^6 .

13.2.4 Risk Analysis Methodology. Calculation of risk as defined in Subsection 13.2.2 requires evaluating the radiological dose from postulated releases and estimating the frequencies of occurrence. Individual operational steps in the alternatives, concepts, and modules were examined to identify potential events leading to releases. Hazards typically evaluated were operational hazards (equipment failures, operating errors, and utility outages); natural events (such as earthquakes, tornadoes, volcanic action, and floods); and aircraft crashes. Analyses were also performed for several highly unusual events, such as meteorite impact. In all instances, the risk from these unusual events was found to be much less than that from the dominant events listed in the results.

Where possible, the event frequencies or probabilities used were based on experience at the RWMC. Probabilities for other events were based on documented data sources for similar or related events. In some instances, no adequate data base exists for event probabilities. In such cases, engineering judgment was used.

The quantities of radionuclides released in the hypothetical accidents were estimated based on the inventory present and the fraction expected to become mobile under the assumed accident conditions. The previous discussion concerning data sources for probabilities also applies to release fractions.

The pathways by which the released radionuclides could reach man are discussed in Appendix E. The movement of radionuclides in the environment was considered to occur via atmospheric dispersion and transport or by a leaching process into the aquifer with subsequent transport through the groundwater. The more significant processes governing these pathways are identified in Figure 12-1. For most release scenarios, inhalation of airborne radioactive material (including resuspended material) was found to be the dominant pathway to man in the dose calculations. Because the waste consists mainly of alpha-emitting radionuclides, the external dose would be expected to be much smaller than the inhalation dose. Other pathways would also

be expected to have similarly small effects (Denham et al. 1973). However, uptake of deposited radionuclides through the food chain to man was also evaluated.

For scenarios involving transport via the Snake River Plain Aquifer, the dominant pathway was assumed to be drinking water. The known points of potential exposure are discussed in Section 5. The risk analysis supplements these actual well locations with two hypothetical wells, one 3 miles and one 80 miles from the RWMC, which could yield higher doses than for the actual locations.

The population distribution used in the evaluations includes those people residing within a 50-mile radius of the Central Facilities Area of the INEL (see Subsection 3.9). This population represents the general public. It was assumed that the current population will increase uniformly at a geometric rate of 1%/yr through the year 2085. After 2085, the population was assumed to remain constant (See Guideline (11) in Subsection 7.4.1.3).

The dose and risk to INEL workers not associated with waste management, represented by the current number of personnel during normal day-shift operations, were also evaluated. The dose and risk were found to be about 70% of those to the general public. These results were not included in the summary tables, which represent dose and risk to the general public only. Hazards to waste management workers are addressed briefly in Section 14.

Maximum individual short-term dose and risk and short-term population dose and risk were estimated for each alternative and concept for 1985, the year generally assumed for implementation. In calculating the doses for Alternative 6 (20-yr delay in retrieval), consideration was given to the decay of the radionuclides and to the estimated increase in population. No significant differences were observed between the values calculated for 1985 and the later year of implementation.

Estimation of long-term risks (greater than 100 yr) is much less certain than estimation of short-term risks. Probabilities and times of occurrence for rare geologic events and for processes in the distant future cannot be accurately predicted. For the long-term evaluations of this study, scenarios leading to waste dispersion were postulated and their consequences evaluated, generally based on a postulated release in the year 2085. If, under the worst circumstances, there would be no severe consequence, the given scenario was not considered further. However, if there would be severe consequences, a judgment about the relative likelihood of the event was sometimes found to be of value, in spite of the lack of reliable data for the probability of the scenario. (For example, based on geologic data, it is quite likely that lava will flow over the TSA within the next 50,000 yr. However, impact of a giant meteorite on the TSA pads would be highly unlikely even in a period of 1,000,000 yr.) The consequences were also estimated based on a postulated release occurring as much as 25,000 yr into the future.

13.2.5 Long-Term Hazard Characteristics of the INEL TRU Waste.

The INEL TRU waste is described in Subsection 4.3. The long-term hazard characteristics of the stored TRU waste, including decay daughter products, are described in the following paragraphs.

Total activity is not a valid measure of the relative hazard of the radionuclides in the stored waste. Radionuclides vary widely in radiotoxicity, with Pu-239 having a high specific toxicity. Pu-239 is present in the waste in sufficient quantity and has a half-life long enough to be considered the principal isotope of concern over the time period from somewhat less than 100 yr up to about 2.5×10^5 yr.

Table 13-2 gives the expected radionuclide composition of the stored INEL TRU waste in 1985. The total activity in the waste in 1985 will be approximately 12 times the Pu-239 activity.

The hazards of the other isotopes in the stored waste can be related to the hazard of Pu-239, as follows:

$$\text{Relative Hazard of Nuclide X} = \frac{\text{Concentration of Nuclide X}}{\text{Concentration of Pu-239}} \frac{[(MPC)_a]_{\text{Pu-239}}}{[(MPC)_a]_X} \quad (13-1)$$

The quantity $[(MPC)_a]_X$ refers to the maximum permissible concentration for nuclide X in air. While the relative hazard is not a reliable measure of risk, it provides a perspective on the time-dependence of the long-term hazards of the waste. For example, the total relative hazard for the waste in 1985, calculated using Equation 13-1 and the activity concentrations of Table 13-2, will be only about four times the Pu-239 hazard. (See Table 13-3 for results and calculational details.)

TABLE 13-2

AVERAGE RADIONUCLIDE COMPOSITION OF INEL TRU WASTE IN 1985

Radionuclide	Half-Life(a) (yr)	Total Activity (Ci)	Activity Concentration ($\mu\text{Ci/g}$ of Waste)
Pu-238	87.74	4.4×10^4	1.4×10^0
Pu-239	24,100	3.4×10^4	1.1×10^0
Pu-240	6537	8.1×10^3	2.5×10^{-1}
Pu-241	14.7	1.9×10^5	6.1×10^0
Pu-242	376,000	2.0×10^{-1}	6.3×10^{-6}
U-233	159,200	1.5×10^3	4.7×10^{-2}
Am-241	432	1.3×10^5	4.2×10^0
Cm-244	18.11	2.3×10^3	7.4×10^{-2}
TOTAL		$4.2 \times 10^5 \text{ Ci}$	13.2 $\mu\text{Ci/g}$ of waste

(a) Values are taken from Chart of Nuclides, 12th ed, General Electric (1977).

TABLE 13-3

RELATIVE HAZARD OF WASTE RADIONUCLIDES RELATIVE TO PLUTONIUM-239 IN 1985

Radio-nuclide	Most Restrictive Occupational (MPC) ^(a) ($\mu\text{Ci}/\text{cm}^3$)	Concentration of Radionuclide X Concentration of Pu-239	(MPC) _a Pu-239 (MPC) _a Radionuclide X	Relative Hazard, 1985 ^(b)
Pu-238	6×10^{-13}	1.3×10^0	1.0×10^0	1.3×10^0
Pu-239	6×10^{-13}	1.0×10^0	1.0×10^0	1.0×10^0
Pu-240	6×10^{-13}	0.24×10^{-1}	1.0×10^0	2.4×10^{-1}
Pu-241	3×10^{-11}	5.6×10^0	2.0×10^{-2}	1.1×10^{-1}
Pu-242	6×10^{-13}	5.9×10^{-6}	1.0×10^0	5.9×10^{-6}
U-233	4×10^{-11}	4.4×10^{-2}	1.5×10^{-2}	6.6×10^{-4}
Am-241	2×10^{-12}	3.8×10^0	3.0×10^{-1}	1.1×10^0
Cm-244	3×10^{-12}	6.8×10^{-2}	2.0×10^{-1}	1.4×10^{-2}
TOTAL				3.76 ~ 4

(a) (MPC)_a - Maximum permissible air concentration.

(b) Pu-239 hazard set at 1.0.

For time periods beyond 1985, the relative hazard of each nuclide changes due to radioactive decay. Many of the nuclides in Table 13-2 produce radioactive daughter products or chains of daughter products

that must be considered in evaluating the long-term hazard of the parent nuclides. For some nuclides and for some limited time periods, the ingrowth of high-hazard daughter nuclides results in an increase with time of the relative hazard. Table 13-4 illustrates the time dependence of the relative hazard of the parent and daughter nuclides in the stored waste.

The relative hazard of stored waste nuclides, including daughter products, as a function of time, is given in Table 13-5. The predominant hazards at 0 and 100 yr after 1985 result from Pu-238, Pu-239, and Am-241 and their daughter products. At 10^3 , 10^4 , and 10^5 yr, the predominant hazard is from Pu-239. At 10^6 yr, Am-241 predominates. The total relative hazard is reduced by about a factor of 3 after 10^3 yr, 5 after 10^4 yr, 50 after 10^5 yr, and 400 after 10^6 yr.

TABLE 13-4

CHANGE IN RELATIVE HAZARD OF RADIONUCLIDES
AS A FUNCTION OF TIME

Nuclide(a)	Time After 1985 (yr)					
	0 (b)	10^2	10^3	10^4	10^5	10^6
Pu-238	1.0	4.5×10^{-1}	7.7×10^{-4}	2.7×10^{-4}	1.5×10^{-3}	3.9×10^{-4}
Pu-239	1.0	1.0×10^0	9.7×10^{-1}	7.5×10^{-1}	7.2×10^{-2}	2.9×10^{-4}
Pu-240	1.0	1.0×10^0	9.0×10^{-1}	3.5×10^{-1}	1.5×10^{-4}	5.0×10^{-6}
Pu-241	1.0	5.2×10^{-1}	1.4×10^{-1}	2.2×10^{-4}	2.4×10^{-3}	5.9×10^{-3}
Pu-242	1.0	1.0×10^0	1.0×10^0	9.8×10^{-1}	8.4×10^{-1}	1.7×10^{-1}
U-233	1.0	1.0×10^0	1.0×10^0	9.6×10^{-1}	6.6×10^{-1}	1.3×10^{-2}
Am-241	1.0	8.5×10^{-1}	2.0×10^{-1}	4.6×10^{-4}	4.6×10^{-3}	6.9×10^{-3}
Cm-244	1.0	3.3×10^{-2}	1.3×10^{-2}	6.5×10^{-3}	7.0×10^{-7}	6.5×10^{-8}

(a) Includes decay daughter products of nuclide indicated.

(b) Relative hazard for all nuclides set at 1.0 for 0 yr after 1985.

TABLE 13-5

RELATIVE HAZARD OF WASTE RADIONUCLIDES AS A FUNCTION OF TIME

Nuclide	Relative Hazard ^(a) of Nuclide Parent and Daughters at Specified Time After 1985 (yr)					
	0	10 ²	10 ³	10 ⁴	10 ⁵	10 ⁶
Pu-238	1.3x10 ⁰	5.9x10 ⁻¹	1.0x10 ⁻³	3.4x10 ⁻⁴	2.0x10 ⁻³	5.1x10 ⁻⁴
Pu-239	1.0x10 ^{0(a)}	1.0x10 ⁰	9.7x10 ⁻¹	7.5x10 ⁻¹	7.2x10 ⁻²	2.9x10 ⁻⁴
Pu-240	2.4x10 ⁻¹	2.4x10 ⁻¹	2.2x10 ⁻¹	8.4x10 ⁻²	3.6x10 ⁻⁵	1.2x10 ⁻⁶
Pu-241	1.1x10 ⁻¹	5.7x10 ⁻²	1.5x10 ⁻²	2.4x10 ⁻⁵	2.6x10 ⁻⁴	6.5x10 ⁻⁴
Pu-242	5.9x10 ⁻⁶	5.9x10 ⁻⁶	5.9x10 ⁻⁶	5.8x10 ⁻⁶	5.0x10 ⁻⁶	1.0x10 ⁻⁶
U-233	6.6x10 ⁻⁴	6.6x10 ⁻⁴	6.6x10 ⁻⁴	6.3x10 ⁻⁴	4.4x10 ⁻⁴	8.6x10 ⁻⁶
Am-241	1.1x10 ⁰	9.4x10 ⁻¹	2.2x10 ⁻¹	5.1x10 ⁻⁴	5.1x10 ⁻³	7.6x10 ⁻³
Cm-244	1.4x10 ⁻²	4.6x10 ⁻⁴	1.8x10 ⁻⁴	9.1x10 ⁻⁵	9.8x10 ⁻⁹	9.1x10 ⁻¹⁰
TOTAL	3.8x10 ⁰	2.8x10 ⁰	1.4x10 ⁰	8.3x10 ⁻¹	8.0x10 ⁻²	9.1x10 ⁻³

(a) Pu-239 hazard set at 1.0x10⁰ in 1985 (0 yr after 1985).

It is also of interest to examine the activity of the waste as a function of time. As shown in Table 13-2, the total concentration of transuranic nuclides in 1985 will be about 13.2 $\mu\text{Ci/g}$ (13,200 nCi/g). This assumes that the activity of the most important transuranic daughter product (Am-241) would be at its peak value at that time. Table 13-6 shows the time dependence of the total concentration of transuranic nuclides in the stored waste. The predominant nuclides (including daughter products) are given in order of their concentration at each time. Between 10⁵ and 10⁶ yr after 1985, the con-

centration of transuranics will drop below 10 nCi/g, the current lower concentration limit for waste to be classified as transuranic-contaminated.

TABLE 13-6

TOTAL CONCENTRATIONS OF TRANSURANIC NUCLIDES IN THE
TRANSURANIC STORAGE AREA

<u>Time After 1985 (yr)</u>	<u>Predominant Nuclides</u>	<u>TSA Concentration (nCi/g)</u>
0	Pu-241, Am-241, Pu-238	13,200
10 ¹	Am-241, Pu-241, Pu-239	10,600
10 ²	Am-241, Pu-239, Pu-240	5,700
10 ³	Pu-239, Am-241, Pu-240	2,200
10 ⁴	Pu-239, Pu-240, Np-237	900
10 ⁵	Pu-239, Np-237, Pu-240	64
10 ⁶	Np-237, Pu-242	0.64

13.3 SUMMARY OF RESULTS

For the waste management alternatives, concepts, and modules studied, summary Tables 13-7 through 13-18 present the results of the dose and risk analyses.^(a) For alternatives and concepts that consist of more than one module, the results are given for each module (if the results have not been given previously).

Included in the tables are release fractions (RF), event frequencies, and decontamination factors (DF). The RF is the fraction of the total inventory of the waste that would be released to the environment, i.e., the fraction of all waste projected to be in storage (4.2×10^5 Ci in 1985). The DF is discussed in Subsection 13.2.3.

(a) Some of the results presented in these summary tables may differ somewhat from the corresponding results presented in the Draft Environmental Impact Statement, Waste Isolation Pilot Plant, Carlsbad, New Mexico. The present results represent a more recent, improved calculation.

TABLE 13-7

SUMMARY OF ACCIDENT EFFECTS FOR ALTERNATIVE 1: LEAVE AS IS

Releases	Release Fract.	Event Freq, yr ⁻¹	Maximum Individual						Population					
			Dose, rem			Risk, rem/yr			Dose, man-rem			Risk, man-re i/yr		
			Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung
AIRBORNE														
<u>Short-Term</u>														
Explosive														
Volcano	2x10 ⁻³	4x10 ⁻⁹	3x10 ⁻²	1x10 ¹	2x10 ¹	1x10 ⁻¹⁰	4x10 ⁻⁸	8x10 ⁻⁸	4x10 ¹	2x10 ⁴	4x10 ⁴	2x10 ⁻⁷	8x10 ⁻⁵	2x10 ⁻⁴
Earthquake	5x10 ⁻¹⁰	2x10 ⁻⁶	5x10 ⁻⁹	3x10 ⁻⁶	5x10 ⁻⁶	1x10 ⁻¹⁴	5x10 ⁻¹²	1x10 ⁻¹¹	1x10 ⁻⁵	5x10 ⁻³	1x10 ⁻²	2x10 ⁻¹¹	1x10 ⁻⁸	2x10 ⁻⁸
Mackay Dam(a)	6x10 ⁻⁶	2x10 ⁻³	4x10 ⁻⁸	8x10 ⁻⁵	2x10 ⁻⁴	8x10 ⁻¹¹	2x10 ⁻⁷	4x10 ⁻⁷	6x10 ⁻⁵	1x10 ¹	2x10 ¹	1x10 ⁻⁷	2x10 ⁻⁴	4x10 ⁻⁴
Lava Flow(b)	1x10 ⁻²	6x10 ⁻⁵	1x10 ⁻¹	7x10 ¹	1x10 ²	6x10 ⁻⁶	4x10 ⁻³	6x10 ⁻³	2x10 ²	1x10 ⁵	2x10 ⁵	1x10 ⁻²	6x10 ⁰	1x10 ¹
<u>Long-Term(c)</u>														
Lava Flow(b)	1x10 ⁻²	NC(d)	3x10 ⁻²	5x10 ¹	9x10 ¹	NC	NC	NC	1x10 ²	2x10 ⁵	4x10 ⁵	NC	NC	NC
10 ⁴ Yr(b)	1x10 ⁻²	NC	5x10 ⁻³	2x10 ¹	1x10 ¹	NC	NC	NC	2x10 ¹	1x10 ⁵	6x10 ⁴	NC	NC	NC
Erosion	Wind Pickup	NC	1x10 ⁻⁴	4x10 ⁻¹	8x10 ⁻¹	NC	NC	NC	5x10 ⁻¹	2x10 ³	4x10 ³	NC	NC	NC
Intrusion														
(Excavation fol-														
lowing Erosion:														
7x10 ⁻⁷ Cj														
Inhaled(e)	N/A(f)	NC	2x10 ⁻⁵	2x10 ⁻²	4x10 ⁻²	NC	NC	NC	7x10 ⁻²	1x10 ²	2x10 ²	NC	NC	NC
Intrusion (Farming)														
Ingestion														
(5x10 ⁻⁶ Ci/yr)	N/A	NC	8x10 ⁻⁵	2x10 ⁰	N/A	NC	NC	NC	8x10 ⁻⁴	2x10 ¹	N/A	NC	NC	NC
Inhalation														
(1x10 ⁻⁷ Ci/yr)(e)	N/A	NC	3x10 ⁻³	6x10 ¹	6x10 ¹	NC	NC	NC	3x10 ⁻²	5x10 ²	5x10 ²	NC	NC	NC
Tornado	3x10 ⁻³	NC	9x10 ⁻³	1x10 ¹	3x10 ¹	NC	NC	NC	4x10 ¹	6x10 ⁴	1x10 ⁵	NC	NC	NC
Mackay Dam(a)	1x10 ⁻⁴	NC	3x10 ⁻⁷	8x10 ⁻⁴	2x10 ⁻³	NC	NC	NC	1x10 ⁻³	3x10 ⁰	7x10 ⁰	NC	NC	NC
Earthquake	5x10 ⁻⁹	NC	2x10 ⁻⁸	2x10 ⁻⁵	4x10 ⁻⁵	NC	NC	NC	7x10 ⁻⁵	1x10 ⁻¹	2x10 ⁻¹	NC	NC	NC
WATERBORNE(g)														
<u>Short-Term</u>														
Mackay Dam(b)	1x10 ⁻⁴	2x10 ⁻³	3x10 ⁻⁹	1x10 ⁻⁴	N/A	6x10 ⁻¹²	2x10 ⁻⁷	N/A	1x10 ⁻⁹	3x10 ⁻⁵	N/A	2x10 ⁻¹²	6x10 ⁻⁸	N/A
<u>Long Term(c)</u>														
Mackay Dam	1x10 ⁻⁴	NC	3x10 ⁻⁹	1x10 ⁻⁴	N/A	NC	NC	NC	3x10 ⁻⁹	7x10 ⁻⁵	N/A	NC	NC	NC
River Channel Alteration(b)	1x10 ⁻²	NC	3x10 ⁻⁷	1x10 ⁻²	N/A	NC	NC	NC	3x10 ⁻⁷	7x10 ⁻³	N/A	NC	NC	NC
Groundwater Variation	1x10 ⁻⁴	NC	3x10 ⁻⁹	1x10 ⁻⁴	N/A	NC	NC	NC	3x10 ⁻⁹	7x10 ⁻⁵	N/A	NC	NC	NC
Glaciation, Climate Change, etc.(b)	1x10 ⁻²	NC	3x10 ⁻⁷	1x10 ⁻²	N/A	NC	NC	NC	3x10 ⁻⁷	7x10 ⁻³	N/A	NC	NC	NC

(a) Resuspension by wind pickup.

(b) Dominant event.

(c) Includes 1% population growth to 2085 and assumes 100 yr decay of radionuclides unless otherwise specified.

(d) NC = Not calculated because of the difficulty of reliably predicting probabilities and geologic characteristics into the distant future.

(e) Intake listed is that for maximum individual.

(f) N/A = Not applicable.

(g) Maximum individual doses and risks are based on use of 3-mile well; population doses and risks on use of 80-mile well. Because, in the analysis of waterborne releases, the maximum individual is not included in the population, dose and risk to maximum individual may be larger than those to population.

TABLE 13-8
SUMMARY OF ACCIDENT EFFECTS FOR CONCEPT 2-a: IMPROVE CONFINEMENT - ABOVE AND AROUND

Releases	Release Fract.	Event Freq, yr ⁻¹	Maximum Individual						POPULATION					
			Dose, rem			Risk, rem/yr			Dose, man-rem			Risk, man-rem/yr		
			Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung
AIRBORNE														
Short-Term														
Explosive														
Volcano	2x10 ⁻³	4x10 ⁻⁹	3x10 ⁻²	1x10 ¹	2x10 ¹	1x10 ⁻¹⁰	4x10 ⁻⁸	8x10 ⁻⁸	4x10 ¹	2x10 ⁴	4x10 ⁴	2x10 ⁻⁷	8x10 ⁻⁵	2x10 ⁻⁴
Earthquake	1x10 ⁻¹⁰	2x10 ⁻⁶	1x10 ⁻⁹	8x10 ⁻⁷	1x10 ⁻⁶	2x10 ⁻¹⁵	1x10 ⁻¹²	2x10 ⁻¹²	2x10 ⁻⁶	1x10 ⁻³	2x10 ⁻³	4x10 ⁻¹²	2x10 ⁻⁹	4x10 ⁻⁹
Mackey Dam(a)	1x10 ⁻⁷	2x10 ⁻³	8x10 ⁻¹⁰	2x10 ⁻⁶	4x10 ⁻⁶	2x10 ⁻¹²	4x10 ⁻³	8x10 ⁻⁹	1x10 ⁻⁶	2x10 ⁻³	4x10 ⁻³	2x10 ⁻⁹	4x10 ⁻⁶	8x10 ⁻⁶
Lava Flow(b)	1x10 ⁻⁴	6x10 ⁻⁵	1x10 ⁻³	7x10 ⁻¹	1x10 ⁰	6x10 ⁻⁸	4x10 ⁻⁵	6x10 ⁻⁵	2x10 ⁰	1x10 ³	2x10 ³	1x10 ⁻⁴	6x10 ⁻²	1x10 ⁻¹
Long-Term(c)														
Lava Flow(b)	1x10 ⁻²	NC(d)	3x10 ⁻²	5x10 ¹	9x10 ¹	NC	NC	NC	1x10 ²	2x10 ⁵	4x10 ⁵	NC	NC	NC
10 ⁴ yr(b)	1x10 ⁻²	NC	5x10 ⁻³	2x10 ¹	1x10 ¹	NC	NC	NC	2x10 ¹	1x10 ⁵	6x10 ⁴	NC	NC	NC
Erosion	Wind Pickup	NC	1x10 ⁻⁴	4x10 ⁻¹	8x10 ⁻¹	NC	NC	NC	5x10 ⁻¹	2x10 ³	4x10 ³	NC	NC	NC
Intrusion														
(Excavation fol-														
lowing Erosion:														
7x10 ⁻⁷ Ci/yr														
Inhaled(e)	N/A(f)	NC	2x10 ⁻⁵	2x10 ⁻²	4x10 ⁻²	NC	NC	NC	7x10 ⁻²	1x10 ²	2x10 ²	NC	NC	NC
Intrusion (Farming)														
Ingestion														
(5x10 ⁻⁶ Ci/yr)	N/A	NC	8x10 ⁻⁵	2x10 ⁰	N/A	NC	NC	NC	8x10 ⁻⁴	2x10 ¹	N/A	NC	NC	NC
Inhalation														
(1x10 ⁻⁷ Ci/yr)(e)	N/A	NC	3x10 ⁻³	6x10 ¹	6x10 ¹	NC	NC	NC	3x10 ⁻²	5x10 ²	5x10 ²	NC	NC	NC
Tornado	3x10 ⁻³	NC	9x10 ⁻³	1x10 ¹	3x10 ¹	NC	NC	NC	4x10 ¹	6x10 ⁴	1x10 ⁵	NC	NC	NC
Mackay Dam(a)	1x10 ⁻⁴	NC	3x10 ⁻⁷	8x10 ⁻⁴	2x10 ⁻³	NC	NC	NC	1x10 ⁻³	3x10 ⁰	7x10 ⁰	NC	NC	NC
Earthquake	5x10 ⁻⁹	NC	2x10 ⁻⁸	2x10 ⁻⁵	4x10 ⁻⁵	NC	NC	NC	7x10 ⁻⁵	1x10 ⁻¹	2x10 ⁻¹	NC	NC	NC
WATERBORNE(g)														
Short-Term														
Mackay Dam(b)	2x10 ⁻⁵	2x10 ⁻³	6x10 ⁻¹⁰	2x10 ⁻⁵	N/A	1x10 ⁻¹²	4x10 ⁻⁸	N/A	2x10 ⁻¹⁰	6x10 ⁻⁶	N/A	4x10 ⁻¹³	1x10 ⁻⁸	N/A
Long Term(c)														
Mackay Dam	1x10 ⁻⁴	NC	3x10 ⁻⁹	1x10 ⁻⁴	N/A	NC	NC	NC	3x10 ⁻⁹	7x10 ⁻⁵	N/A	NC	NC	NC
River Channel														
Alteration(b)	1x10 ⁻²	NC	3x10 ⁻⁷	1x10 ⁻²	N/A	NC	NC	NC	3x10 ⁻⁷	7x10 ⁻³	N/A	NC	NC	NC
Groundwater														
Variation	1x10 ⁻⁴	NC	3x10 ⁻⁹	1x10 ⁻⁴	N/A	NC	NC	NC	3x10 ⁻⁹	7x10 ⁻⁵	N/A	NC	NC	NC
Glaciation, Climate														
Change, etc.(b)	1x10 ⁻²	NC	3x10 ⁻⁷	1x10 ⁻²	N/A	NC	NC	NC	3x10 ⁻⁷	7x10 ⁻³	N/A	NC	NC	NC

(a) Resuspension by wind pickup.

(b) Dominant event.

(c) Includes 1% population growth to 2085 and assumes 100 yr decay of radionuclides unless otherwise specified.

(d) NC = Not calculated because of the difficulty of reliably predicting probabilities and geologic characteristics into the distant future.

(e) Intake listed is that for maximum individual.

(f) N/A = Not applicable.

(g) Maximum individual doses and risks are based on use of 3-mile well; population doses and risks on use of 80-mile well. Because, in the analysis of waterborne releases, the maximum individual is not included in the population, dose and risk to maximum individual may be larger than those to population.

TABLE 13-9

SUMMARY OF ACCIDENT EFFECTS FOR CONCEPT 2-b: IMPROVE CONFINEMENT - ABOVE, AROUND, AND BELOW

Releases	Release Fract.	Event Freq. yr ⁻¹	Maximum Individual						Population					
			Dose, rem			Risk, rem/yr			Dose, man-rem			Risk, man-rem/yr		
			Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung
AIRBORNE														
Short-Term														
Explosive														
Volcano	2x10 ⁻³	4x10 ⁻⁹	3x10 ⁻²	1x10 ¹	2x10 ¹	1x10 ⁻¹⁰	4x10 ⁻⁸	8x10 ⁻⁸	4x10 ¹	2x10 ⁴	4x10 ⁴	2x10 ⁻⁷	8x10 ⁻⁵	2x10 ⁻⁴
Earthquake	1x10 ⁻¹⁰	2x10 ⁻⁶	1x10 ⁻⁹	8x10 ⁻⁷	1x10 ⁻⁶	2x10 ⁻¹⁵	1x10 ⁻¹²	2x10 ⁻¹²	2x10 ⁻⁶	1x10 ⁻³	2x10 ⁻³	4x10 ⁻¹²	2x10 ⁻⁹	4x10 ⁻⁹
Mackay Dam(a)	1x10 ⁻⁷	2x10 ⁻³	8x10 ⁻¹⁰	2x10 ⁻⁶	4x10 ⁻⁶	2x10 ⁻¹²	4x10 ⁻⁹	8x10 ⁻⁹	1x10 ⁻⁶	2x10 ⁻³	4x10 ⁻³	2x10 ⁻⁹	4x10 ⁻⁶	8x10 ⁻⁶
Lava Flow(b)	1x10 ⁻⁴	6x10 ⁻⁵	1x10 ⁻³	7x10 ⁻¹	1x10 ⁰	6x10 ⁻⁸	4x10 ⁻⁵	6x10 ⁻⁵	2x10 ⁰	1x10 ³	2x10 ³	1x10 ⁻⁴	6x10 ⁻²	1x10 ⁻¹
Long-Term(c)														
Lava Flow(b)	1x10 ⁻²	NC(d)	3x10 ⁻²	5x10 ¹	9x10 ¹	NC	NC	NC	1x10 ²	2x10 ⁵	4x10 ⁵	NC	NC	NC
10 ⁴ yr(b)	1x10 ⁻²	NC	5x10 ⁻³	2x10 ¹	1x10 ¹	NC	NC	NC	2x10 ¹	1x10 ⁵	6x10 ⁴	NC	NC	NC
Erosion	Wind Pickup	NC	1x10 ⁻⁴	4x10 ⁻¹	8x10 ⁻¹	NC	NC	NC	5x10 ⁻¹	2x10 ³	4x10 ³	NC	NC	NC
Intrusion														
(Excavation fol-														
lowing Erosion:														
7x10 ⁻⁵ Ci														
Inhaled(e)	N/A(f)	NC	2x10 ⁻⁵	2x10 ⁻²	4x10 ⁻²	NC	NC	NC	7x10 ⁻²	1x10 ²	2x10 ²	NC	NC	NC
Intrusion (Farming)														
Ingestion														
(5x10 ⁻⁶ Ci/yr)	N/A	NC	8x10 ⁻⁵	2x10 ⁰	N/A	NC	NC	NC	8x10 ⁻⁴	2x10 ¹	N/A	NC	NC	NC
Inhalation														
(1x10 ⁻⁷ Ci/yr) (e)	N/A	NC	3x10 ⁻³	6x10 ¹	6x10 ¹	NC	NC	NC	3x10 ⁻²	5x10 ²	5x10 ²	NC	NC	NC
Tornado	3x10 ⁻³	NC	9x10 ⁻³	1x10 ¹	3x10 ¹	NC	NC	NC	4x10 ¹	6x10 ⁴	1x10 ⁵	NC	NC	NC
Mackay Dam(a)	1x10 ⁻⁴	NC	3x10 ⁻⁷	8x10 ⁻⁴	2x10 ⁻³	NC	NC	NC	1x10 ⁻³	3x10 ⁰	7x10 ⁰	NC	NC	NC
Earthquake	5x10 ⁻⁹	NC	2x10 ⁻⁸	2x10 ⁻⁵	4x10 ⁻⁵	NC	NC	NC	7x10 ⁻⁵	1x10 ⁻¹	2x10 ⁻¹	NC	NC	NC
WATERBORNE(g)														
Short-Term														
Mackay Dam(b)	5x10 ⁻⁶	2x10 ⁻³	1x10 ⁻¹⁰	6x10 ⁻⁶	N/A	2x10 ⁻¹³	1x10 ⁻⁸	N/A	6x10 ⁻¹¹	1x10 ⁻⁶	N/A	1x10 ⁻¹³	2x10 ⁻⁹	N/A
Long Term(c)														
Mackay Dam	1x10 ⁻⁴	NC	3x10 ⁻⁹	1x10 ⁻⁴	N/A	NC	NC	NC	3x10 ⁻⁹	7x10 ⁻⁵	N/A	NC	NC	NC
River Channel														
Alteration(b)	1x10 ⁻²	NC	3x10 ⁻⁷	1x10 ⁻²	N/A	NC	NC	NC	3x10 ⁻⁷	7x10 ⁻³	N/A	NC	NC	NC
Groundwater														
Variation	1x10 ⁻⁴	NC	3x10 ⁻⁹	1x10 ⁻⁴	N/A	NC	NC	NC	3x10 ⁻⁹	7x10 ⁻⁵	N/A	NC	NC	NC
Glaciation, Climate														
Change, etc.(b)	1x10 ⁻²	NC	3x10 ⁻⁷	1x10 ⁻²	N/A	NC	NC	NC	3x10 ⁻⁷	7x10 ⁻³	N/A	NC	NC	NC

(a) Resuspension by wind-pickup.

(b) Dominant event.

(c) Includes 1% population growth to 2085 and assumes 100 yr decay of radionuclides unless otherwise specified.

(d) NC = Not calculated because of the difficulty of reliably predicting probabilities and geologic characteristics into the distant future.

(e) Intake listed is that for maximum individual.

(f) N/A = Not applicable.

(g) Maximum individual doses and risks are based on use of 3-mile well; population doses and risks on use of 80-mile well. Because, in the analysis of waterborne releases, the maximum individual is not included in the population, dose and risk to maximum individual may be larger than those to population.

TABLE 13-10

SUMMARY OF ACCIDENT EFFECTS FOR CONCEPT 2-c: IMPROVE CONFINEMENT - IMMOBILIZATION

Releases	Release Fract.	Event Freq. yr ⁻¹	Maximum Individual						Population					
			Dose, rem			Risk, rem/yr			Dose, man-rem			Risk, man-rem/yr		
			Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung
AIRBORNE														
Short-Term														
Explosive														
Volcano	2x10 ⁻⁵	4x10 ⁻⁹	3x10 ⁻⁴	1x10 ⁻¹	2x10 ⁻¹	1x10 ⁻¹²	4x10 ⁻¹⁰	8x10 ⁻¹⁰	4x10 ⁻¹	2x10 ²	4x10 ²	2x10 ⁻⁹	8x10 ⁻⁷	1x10 ⁻⁶
Earthquake	5x10 ⁻¹²	2x10 ⁻⁶	5x10 ⁻¹¹	3x10 ⁻⁸	5x10 ⁻⁸	1x10 ⁻¹⁶	5x10 ⁻¹⁴	1x10 ⁻¹³	1x10 ⁻⁷	5x10 ⁻⁵	1x10 ⁻⁴	2x10 ⁻¹³	1x10 ⁻¹⁰	1x10 ⁻¹¹
Mackay Dam(a)	6x10 ⁻⁹	2x10 ⁻³	4x10 ⁻¹¹	8x10 ⁻⁸	2x10 ⁻⁷	8x10 ⁻¹⁴	2x10 ⁻¹⁰	4x10 ⁻¹⁰	6x10 ⁻⁸	1x10 ⁻⁴	2x10 ⁻⁴	1x10 ⁻¹⁰	2x10 ⁻⁷	1x10 ⁻⁷
Lava Flow(b)	1x10 ⁻⁴	6x10 ⁻⁵	1x10 ⁻³	7x10 ⁻¹	1x10 ⁰	6x10 ⁻⁸	4x10 ⁻⁵	6x10 ⁻⁵	2x10 ⁰	1x10 ³	2x10 ³	1x10 ⁻⁴	6x10 ⁻²	1x10 ⁻¹
Long-Term(c)														
Lava Flow(b)	1x10 ⁻⁴	NC(d)	3x10 ⁻⁴	5x10 ⁻¹	9x10 ⁻¹	NC	NC	NC	1x10 ⁰	2x10 ³	4x10 ³	NC	NC	NC
10 ⁴ yr(b)	1x10 ⁻²	NC	5x10 ⁻³	2x10 ¹	1x10 ¹	NC	NC	NC	2x10 ¹	1x10 ⁵	6x10 ⁴	NC	NC	NC
Erosion	Wind Pickup	NC	1x10 ⁻⁶	4x10 ⁻³	8x10 ⁻³	NC	NC	NC	5x10 ⁻³	2x10 ¹	4x10 ¹	NC	NC	NC
Intrusion														
(Excavation Fol-														
lowing Erosion:														
7x10 ⁻⁹ c)														
Inhaled(e)	N/A(f)	NC	2x10 ⁻⁷	2x10 ⁻⁴	4x10 ⁻⁴	NC	NC	NC	7x10 ⁻⁴	1x10 ⁰	2x10 ⁰	NC	NC	NC
Intrusion (Farming)														
Ingestion														
(8x10 ⁻⁶ Ci/yr)	N/A	NC	8x10 ⁻⁷	2x10 ⁻²	N/A	NC	NC	NC	8x10 ⁻⁶	2x10 ⁻¹	N/A	NC	NC	NC
Inhalation														
(2x10 ⁻⁷ Ci/yr)(e)	N/A	NC	3x10 ⁻⁵	6x10 ⁻¹	6x10 ⁻¹	NC	NC	NC	3x10 ⁻⁴	5x10 ⁰	5x10 ⁰	NC	NC	NC
Tornado	3x10 ⁻⁵	NC	9x10 ⁻⁵	1x10 ⁻¹	3x10 ⁻¹	NC	NC	NC	4x10 ⁻¹	6x10 ²	1x10 ³	NC	NC	NC
Mackay Dam(a)	1x10 ⁻⁷	NC	3x10 ⁻¹⁰	8x10 ⁻⁷	2x10 ⁻⁶	NC	NC	NC	1x10 ⁻⁶	3x10 ⁻³	7x10 ⁻³	NC	NC	NC
Earthquake	5x10 ⁻¹¹	NC	2x10 ⁻¹⁰	2x10 ⁻⁷	4x10 ⁻⁷	NC	NC	NC	7x10 ⁻⁷	1x10 ⁻³	2x10 ⁻³	NC	NC	NC
WATERBORNE(g)														
Short-Term														
Mackay Dam(b)	1x10 ⁻⁶	2x10 ⁻³	3x10 ⁻¹¹	1x10 ⁻⁶	N/A	6x10 ⁻¹⁴	2x10 ⁻⁹	N/A	1x10 ⁻¹¹	3x10 ⁻⁷	N/A	2x10 ⁻¹⁴	6x10 ⁻¹⁰	N/A
Long Term(c)														
Mackay Dam Failure	1x10 ⁻⁶	NC	3x10 ⁻¹¹	1x10 ⁻⁶	N/A	NC	NC	NC	3x10 ⁻¹¹	7x10 ⁻⁷	N/A	NC	NC	NC
River Channel														
Alteration(b)	1x10 ⁻⁴	NC	3x10 ⁻⁹	1x10 ⁻⁴	N/A	NC	NC	NC	3x10 ⁻⁹	7x10 ⁻⁵	N/A	NC	NC	NC
Groundwater														
Variation	1x10 ⁻⁶	NC	3x10 ⁻¹¹	1x10 ⁻⁶	N/A	NC	NC	NC	3x10 ⁻¹¹	7x10 ⁻⁷	N/A	NC	NC	NC
Glaciation, Climatic														
Change, etc.(b)	1x10 ⁻⁴	NC	3x10 ⁻⁹	1x10 ⁻⁴	N/A	NC	NC	NC	3x10 ⁻⁹	7x10 ⁻⁵	N/A	NC	NC	NC

(a) Resuspension by wind pickup.

(b) Dominant event.

(c) Includes 1% population growth to 2085 and assumes 100 yr decay of radionuclides unless otherwise specified.

(d) NC = Not calculated because of the difficulty of reliably predicting probabilities and geologic characteristics into the distant future.

(e) Intake listed is that for maximum individual.

(f) N/A = Not applicable.

(g) Maximum individual doses and risks are based on use of 3-mile well; population doses and risks on use of 80-mile well. Because, in the analysis of waterborne releases, the maximum individual is not included in the population, dose and risk to maximum individual may be larger than those to population.

TABLE 13-11

SUMMARY OF ACCIDENT EFFECTS: RETRIEVAL

Airborne Releases	Release Fract.	Decon. Factor	Event Freq. yr ⁻¹	Maximum Individual						Population					
				Dose, rem			Risk, rem/yr			Dose, man-rem			Risk, man-rem/yr		
				Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung
Short-Term															
Explosive Volcano(a)	2x10 ⁻³	1.0	4x10 ⁻⁹	3x10 ⁻²	1x10 ¹	2x10 ¹	1x10 ⁻¹⁰	4x10 ⁻⁸	8x10 ⁻⁸	4x10 ¹	2x10 ⁴	4x10 ⁴	2x10 ⁻⁷	8x10 ⁻⁵	2x10 ⁻⁴
Lava Flow(a,b)	1x10 ⁻²	1.0	6x10 ⁻⁵	1x10 ⁻¹	7x10 ¹	1x10 ²	6x10 ⁻⁶	4x10 ⁻³	6x10 ⁻³	2x10 ²	1x10 ⁵	2x10 ⁵	1x10 ⁻²	6x10 ⁰	1x10 ¹
Tornado	1x10 ⁻⁷	1.0	5x10 ⁻⁷	1x10 ⁻⁶	7x10 ⁻⁴	1x10 ⁻³	5x10 ⁻¹³	4x10 ⁻¹⁰	5x10 ⁻¹⁰	2x10 ⁻³	1x10 ⁰	2x10 ⁰	1x10 ⁻⁹	5x10 ⁻⁷	1x10 ⁻⁶
Dropped Container	7x10 ⁻¹⁰	10 ³	1x10 ⁻²	7x10 ⁻¹²	5x10 ⁻⁹	7x10 ⁻⁹	7x10 ⁻¹⁴	5x10 ⁻¹¹	7x10 ⁻¹¹	1x10 ⁻⁸	7x10 ⁻⁶	1x10 ⁻⁵	1x10 ⁻¹⁰	7x10 ⁻⁸	1x10 ⁻⁷
Fire(c)	4x10 ⁻⁷	10 ¹	1x10 ⁻³	6x10 ⁻⁷	3x10 ⁻⁴	4x10 ⁻⁴	6x10 ⁻¹⁰	3x10 ⁻⁷	4x10 ⁻⁷	8x10 ⁻⁴	4x10 ⁻¹	8x10 ⁻¹	8x10 ⁻⁷	4x10 ⁻⁴	8x10 ⁻⁴
Aircraft Impact With Fire	9x10 ⁻⁶	1.0	9x10 ⁻¹⁰	1x10 ⁻⁴	6x10 ⁻²	9x10 ⁻²	9x10 ⁻¹⁴	5x10 ⁻¹¹	8x10 ⁻¹¹	2x10 ⁻¹	9x10 ¹	2x10 ²	2x10 ⁻¹⁰	8x10 ⁻⁸	2x10 ⁻⁷
Transfer Accident	6x10 ⁻⁹	1.0	1x10 ⁻⁶	9x10 ⁻⁸	3x10 ⁻⁵	6x10 ⁻⁵	9x10 ⁻¹⁴	3x10 ⁻¹¹	6x10 ⁻¹¹	1x10 ⁻⁴	6x10 ⁻²	1x10 ⁻¹	1x10 ⁻¹⁰	6x10 ⁻⁸	1x10 ⁻⁷
Transfer Accident With Fire	6x10 ⁻⁷	1.0	3x10 ⁻⁷	9x10 ⁻⁶	3x10 ⁻³	6x10 ⁻³	3x10 ⁻¹²	9x10 ⁻¹⁰	2x10 ⁻⁹	1x10 ⁻²	6x10 ⁰	1x10 ¹	3x10 ⁻⁹	2x10 ⁻⁶	3x10 ⁻⁶

(a) These scenarios apply principally to waste remaining on the pads during the campaign and do not apply to retrieval operations, per se.

(b) Dominant event.

(c) Dominant event related to retrieval operations.

TABLE 13-12

SUMMARY OF ACCIDENT EFFECTS: SLAGGING PYROLYSIS AND PACKAGING

Airborne Releases	Release Fract.	Decon. Factor	Event Freq. yr ⁻¹	Maximum Individual						Population					
				Dose, rem			Risk, rem/yr			Dose, man-rem			Risk, man-rem/yr		
				Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung
SHORT-TERM															
Waste Preparation Area															
Dropped Container	7x10 ⁻¹⁰	10 ⁶	1x10 ⁻²	7x10 ⁻¹⁵	5x10 ⁻¹²	7x10 ⁻¹²	7x10 ⁻¹⁷	5x10 ⁻¹⁴	7x10 ⁻¹⁴	1x10 ⁻¹¹	7x10 ⁻⁹	1x10 ⁻⁸	1x10 ⁻¹³	7x10 ⁻¹¹	1x10 ⁻¹⁰
Fire	1x10 ⁻⁶	10 ³	1x10 ⁻²	1x10 ⁻⁸	7x10 ⁻⁶	1x10 ⁻⁵	1x10 ⁻¹⁰	7x10 ⁻⁸	1x10 ⁻⁷	2x10 ⁻⁵	1x10 ⁻²	2x10 ⁻²	2x10 ⁻⁷	1x10 ⁻⁴	2x10 ⁻⁴
Explosion	2x10 ⁻⁶	10 ³	1x10 ⁻³	2x10 ⁻⁸	1x10 ⁻⁵	2x10 ⁻⁵	2x10 ⁻¹¹	1x10 ⁻⁸	2x10 ⁻⁸	4x10 ⁻⁵	2x10 ⁻²	4x10 ⁻²	4x10 ⁻⁸	2x10 ⁻⁵	4x10 ⁻⁵
Pyrolysis Area															
Fire	1x10 ⁻⁸	10 ³	1x10 ⁻²	1x10 ⁻¹⁰	7x10 ⁻⁸	1x10 ⁻⁷	1x10 ⁻¹²	7x10 ⁻¹⁰	1x10 ⁻⁹	2x10 ⁻⁷	1x10 ⁻⁴	2x10 ⁻⁴	2x10 ⁻⁹	1x10 ⁻⁶	2x10 ⁻⁶
Explosion	1x10 ⁻⁵	10 ³	1x10 ⁻³	1x10 ⁻⁷	7x10 ⁻⁵	1x10 ⁻⁴	1x10 ⁻¹⁰	7x10 ⁻⁸	1x10 ⁻⁷	2x10 ⁻⁴	1x10 ⁻¹	2x10 ⁻¹	2x10 ⁻⁷	1x10 ⁻⁴	2x10 ⁻⁴
Explosion/Failed Confinement ^(a)	1x10 ⁻⁵	1.0	1x10 ⁻⁵	1x10 ⁻⁴	7x10 ⁻²	1x10 ⁻¹	1x10 ⁻⁹	7x10 ⁻⁷	1x10 ⁻⁶	2x10 ⁻¹	1x10 ²	2x10 ²	2x10 ⁻⁶	1x10 ⁻³	2x10 ⁻³
Tornado/Failed Off-Gas Duct	3x10 ⁻⁸	1.0	5x10 ⁻⁷	4x10 ⁻⁷	2x10 ⁻⁴	3x10 ⁻⁴	2x10 ⁻¹³	1x10 ⁻¹⁰	2x10 ⁻¹⁰	5x10 ⁻⁴	3x10 ⁻¹	4x10 ¹	2x10 ⁻¹⁰	1x10 ⁻⁷	2x10 ⁻⁷
Shipping Area															
Fire	1x10 ⁻⁹	10 ³	1x10 ⁻²	1x10 ⁻¹¹	7x10 ⁻⁹	1x10 ⁻⁸	1x10 ⁻¹³	7x10 ⁻¹¹	1x10 ⁻¹⁰	2x10 ⁻⁸	1x10 ⁻⁵	2x10 ⁻⁵	2x10 ⁻¹⁰	1x10 ⁻⁷	2x10 ⁻⁷
Tornado	1x10 ⁻⁸	1.0	5x10 ⁻⁷	1x10 ⁻⁷	7x10 ⁻⁵	1x10 ⁻⁴	5x10 ⁻¹⁴	3x10 ⁻¹¹	5x10 ⁻¹¹	2x10 ⁻⁴	1x10 ⁻¹	2x10 ⁻¹	1x10 ⁻¹⁰	5x10 ⁻⁸	1x10 ⁻⁷

(a) Dominant Event.

TABLE 13-13

SUMMARY OF ACCIDENT EFFECTS: SHIPMENT OF PROCESSED WASTE TO FEDERAL REPOSITORY

Airborne Releases	Release Fract.	Event Freq. yr ⁻¹	Maximum Individual						Population					
			Dose, rem			Risk, rem/yr			Dose, man-rem			Risk, man-rem/yr		
			Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung
Rural ^(a,b)	2×10^{-11}	4×10^{-7}	3×10^{-10}	1×10^{-7}	2×10^{-7}	1×10^{-16}	4×10^{-14}	8×10^{-14}	4×10^{-7}	2×10^{-4}	4×10^{-4}	2×10^{-13}	8×10^{-11}	2×10^{-10}
Suburban ^(c)	2×10^{-11}	2×10^{-8}	3×10^{-10}	1×10^{-7}	2×10^{-7}	6×10^{-18}	2×10^{-15}	4×10^{-15}	3×10^{-6}	2×10^{-3}	3×10^{-3}	6×10^{-14}	4×10^{-11}	6×10^{-11}
Urban ^(d)														

(a) Dominant event.

(b) Assumes a population density approximately the same as the INEL site.

(c) Assumes a population density of about 8 times the INEL site.

(d) Significant releases in urban accidents would not be expected, because speeds involved would not be sufficient to result in breach of ATMX railcar.

TABLE 13-14

SUMMARY OF ACCIDENT EFFECTS: COMPACTION AND IMMOBILIZATION

Airborne Releases	Release Fract.	Decon-Factor	Event Freq. yr ⁻¹	Maximum Individual						Population					
				Dose, rem			Risk, rem/yr			Dose, man-rem			Risk, man-rem/yr		
				Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung
<u>SHORT-TERM</u>															
<u>Waste Preparation Area</u>															
Dropped Container	7x10 ⁻¹⁰	10 ⁶	1x10 ⁻²	7x10 ⁻¹⁵	5x10 ⁻¹²	7x10 ⁻¹²	7x10 ⁻¹⁷	5x10 ⁻¹⁴	7x10 ⁻¹⁴	1x10 ⁻¹¹	7x10 ⁻⁹	1x10 ⁻⁸	1x10 ⁻¹³	7x10 ⁻¹¹	1x10 ⁻¹⁰
Fire	1x10 ⁻⁷	10 ³	1x10 ⁻²	1x10 ⁻⁹	7x10 ⁻⁷	1x10 ⁻⁶	1x10 ⁻¹¹	7x10 ⁻⁹	1x10 ⁻⁸	2x10 ⁻⁶	1x10 ⁻³	2x10 ⁻³	2x10 ⁻⁸	1x10 ⁻⁵	2x10 ⁻⁵
Explosion	2x10 ⁻⁶	10 ³	1x10 ⁻³	2x10 ⁻⁸	1x10 ⁻⁵	2x10 ⁻⁵	2x10 ⁻¹¹	1x10 ⁻⁸	2x10 ⁻⁸	4x10 ⁻⁵	2x10 ⁻²	4x10 ⁻²	4x10 ⁻⁸	2x10 ⁻⁵	4x10 ⁻⁵
<u>Compaction Area</u>															
Dropped Container	1x10 ⁻⁹	10 ⁶	8x10 ⁻³	1x10 ⁻¹⁴	7x10 ⁻¹²	1x10 ⁻¹¹	8x10 ⁻¹⁷	6x10 ⁻¹⁴	8x10 ⁻¹⁴	2x10 ⁻¹¹	1x10 ⁻⁸	2x10 ⁻⁸	2x10 ⁻¹³	8x10 ⁻¹¹	2x10 ⁻¹⁰
Fire (a)	4x10 ⁻⁷	10 ³	1x10 ⁻²	6x10 ⁻⁹	3x10 ⁻⁶	4x10 ⁻⁶	6x10 ⁻¹¹	3x10 ⁻⁸	4x10 ⁻⁸	8x10 ⁻⁶	4x10 ⁻³	8x10 ⁻³	8x10 ⁻⁸	4x10 ⁻⁵	8x10 ⁻⁵
Explosion	2x10 ⁻⁶	10 ³	1x10 ⁻³	2x10 ⁻⁸	1x10 ⁻⁵	2x10 ⁻⁵	2x10 ⁻¹¹	1x10 ⁻⁸	2x10 ⁻⁸	4x10 ⁻⁵	2x10 ⁻²	4x10 ⁻²	4x10 ⁻⁸	2x10 ⁻⁵	4x10 ⁻⁵

(a) Dominant Event.

TABLE 13-15

SUMMARY OF ACCIDENT EFFECTS: PACKAGING ONLY

Airborne Releases	Release Fract.	Decon. Factor	Event Freq. yr ⁻¹	Maximum Individual						Population					
				Dose, rem			Risk, rem/yr			Dose, man-rem			Risk, man-rem/yr		
				Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung
SHORT-TERM															
Waste Preparation Area															
Dropped Container	7x10 ⁻¹⁰	10 ⁶	1x10 ⁻²	7x10 ⁻¹⁵	5x10 ⁻¹²	7x10 ⁻¹²	7x10 ⁻¹⁷	5x10 ⁻¹⁴	7x10 ⁻¹⁴	1x10 ⁻¹¹	7x10 ⁻⁹	1x10 ⁻⁸	1x10 ⁻¹³	7x10 ⁻¹¹	1x10 ⁻¹⁰
Fire	1x10 ⁻⁷	10 ³	1x10 ⁻²	1x10 ⁻⁹	7x10 ⁻⁷	1x10 ⁻⁶	1x10 ⁻¹¹	7x10 ⁻⁹	1x10 ⁻⁸	2x10 ⁻⁶	1x10 ⁻³	2x10 ⁻³	2x10 ⁻⁸	1x10 ⁻⁵	2x10 ⁻⁵
Explosion	2x10 ⁻⁶	10 ³	1x10 ⁻³	2x10 ⁻⁸	1x10 ⁻⁵	2x10 ⁻⁵	2x10 ⁻¹¹	1x10 ⁻⁸	2x10 ⁻⁸	4x10 ⁻⁵	2x10 ⁻²	4x10 ⁻²	4x10 ⁻⁸	2x10 ⁻⁵	4x10 ⁻⁵
Packaging Area															
Dropped Container	4x10 ⁻¹⁰	10 ⁶	4x10 ⁻²	4x10 ⁻¹⁵	3x10 ⁻¹²	4x10 ⁻¹²	2x10 ⁻¹⁶	1x10 ⁻¹³	2x10 ⁻¹³	6x10 ⁻¹²	4x10 ⁻⁹	6x10 ⁻⁹	2x10 ⁻¹³	2x10 ⁻¹⁰	3x10 ⁻¹⁰
Fire (a)	4x10 ⁻⁷	10 ³	1x10 ⁻²	6x10 ⁻⁹	3x10 ⁻⁶	4x10 ⁻⁶	6x10 ⁻¹¹	3x10 ⁻⁸	4x10 ⁻⁸	8x10 ⁻⁶	4x10 ⁻³	8x10 ⁻³	8x10 ⁻⁸	4x10 ⁻⁵	8x10 ⁻⁵
Explosion	2x10 ⁻⁶	10 ³	1x10 ⁻³	2x10 ⁻⁸	1x10 ⁻⁵	2x10 ⁻⁵	2x10 ⁻¹¹	1x10 ⁻⁸	2x10 ⁻⁸	4x10 ⁻⁵	2x10 ⁻²	4x10 ⁻²	4x10 ⁻⁸	2x10 ⁻⁵	4x10 ⁻⁵
Shipping Area															
Dropped Container	4x10 ⁻¹⁰	10 ⁶	4x10 ⁻²	4x10 ⁻¹⁵	3x10 ⁻¹²	4x10 ⁻¹²	2x10 ⁻¹⁶	1x10 ⁻¹³	2x10 ⁻¹³	6x10 ⁻¹²	4x10 ⁻⁹	6x10 ⁻⁹	2x10 ⁻¹³	2x10 ⁻¹⁰	3x10 ⁻¹⁰
Fire (a)	4x10 ⁻⁷	10 ³	1x10 ⁻²	6x10 ⁻⁹	3x10 ⁻⁶	4x10 ⁻⁶	6x10 ⁻¹¹	3x10 ⁻⁸	4x10 ⁻⁸	8x10 ⁻⁶	4x10 ⁻³	8x10 ⁻³	8x10 ⁻⁸	4x10 ⁻⁵	8x10 ⁻⁵
Explosion	2x10 ⁻⁶	10 ³	1x10 ⁻³	2x10 ⁻⁸	1x10 ⁻⁵	2x10 ⁻⁵	2x10 ⁻¹¹	1x10 ⁻⁸	2x10 ⁻⁸	4x10 ⁻⁵	2x10 ⁻²	4x10 ⁻²	4x10 ⁻⁸	2x10 ⁻⁵	4x10 ⁻⁵
(a) Dominant Event.															

TABLE 13-16

SUMMARY OF ACCIDENT EFFECTS: ONSITE SHIPMENT FOR ALL PROCESSING MODULES

Airborne Releases	Release Fract.	Event Freq. yr ⁻¹	Maximum Individual						Population					
			Dose, rem			Risk, rem/yr			Dose, man-rem			Risk, man-rem/yr		
			Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung
SHORT-TERM														
Slagging Pyrolysis and Packaging														
Lemhi	3x10 ⁻¹⁰	4x10 ⁻⁶	3x10 ⁻⁹	2x10 ⁻⁶	4x10 ⁻⁶	1x10 ⁻¹⁴	8x10 ⁻¹²	2x10 ⁻¹¹	6x10 ⁻⁶	3x10 ⁻³	6x10 ⁻³	2x10 ⁻¹¹	1x10 ⁻⁸	2x10 ⁻⁸
Site 14	3x10 ⁻¹⁰	3x10 ⁻⁶	3x10 ⁻⁹	2x10 ⁻⁶	4x10 ⁻⁶	9x10 ⁻¹⁵	6x10 ⁻¹²	1x10 ⁻¹¹	6x10 ⁻⁶	3x10 ⁻³	6x10 ⁻³	2x10 ⁻¹¹	9x10 ⁻⁹	2x10 ⁻⁸
RWMC	3x10 ⁻¹⁰	4x10 ⁻⁸	3x10 ⁻⁹	2x10 ⁻⁶	4x10 ⁻⁶	1x10 ⁻¹⁶	8x10 ⁻¹⁴	2x10 ⁻¹³	6x10 ⁻⁶	3x10 ⁻³	6x10 ⁻³	2x10 ⁻¹³	1x10 ⁻¹⁰	2x10 ⁻¹⁰
Compaction, Immobilization, and Packaging														
Lemhi	1x10 ⁻⁸	4x10 ⁻⁶	1x10 ⁻⁷	7x10 ⁻⁵	1x10 ⁻⁴	4x10 ⁻¹³	3x10 ⁻¹⁰	4x10 ⁻¹⁰	2x10 ⁻⁴	1x10 ⁻¹	2x10 ⁻¹	8x10 ⁻¹⁰	4x10 ⁻⁷	8x10 ⁻⁷
Site 14	1x10 ⁻⁸	2x10 ⁻⁶	1x10 ⁻⁷	7x10 ⁻⁵	1x10 ⁻⁴	2x10 ⁻¹³	1x10 ⁻¹⁰	2x10 ⁻¹⁰	2x10 ⁻⁴	1x10 ⁻¹	2x10 ⁻¹	4x10 ⁻¹⁰	2x10 ⁻⁷	4x10 ⁻⁷
RWMC	1x10 ⁻⁸	3x10 ⁻⁸	1x10 ⁻⁷	7x10 ⁻⁵	1x10 ⁻⁴	3x10 ⁻¹⁵	2x10 ⁻¹²	3x10 ⁻¹²	2x10 ⁻⁴	1x10 ⁻¹	2x10 ⁻¹	6x10 ⁻¹²	3x10 ⁻⁹	6x10 ⁻⁹
Packaging Only														
Lemhi	4x10 ⁻⁸	4x10 ⁻⁶	4x10 ⁻⁷	2x10 ⁻⁴	4x10 ⁻⁴	2x10 ⁻¹²	8x10 ⁻¹⁰	2x10 ⁻⁹	8x10 ⁻⁴	4x10 ⁻¹	8x10 ⁻¹	3x10 ⁻⁹	2x10 ⁻⁶	3x10 ⁻⁶
Site 14	4x10 ⁻⁸	3x10 ⁻⁶	4x10 ⁻⁷	2x10 ⁻⁴	4x10 ⁻⁴	1x10 ⁻¹²	6x10 ⁻¹⁰	1x10 ⁻⁹	8x10 ⁻⁴	4x10 ⁻¹	8x10 ⁻¹	2x10 ⁻⁹	1x10 ⁻⁶	2x10 ⁻⁶
RWMC	4x10 ⁻⁸	3x10 ⁻⁸	4x10 ⁻⁷	2x10 ⁻⁴	4x10 ⁻⁴	1x10 ⁻¹⁴	6x10 ⁻¹²	1x10 ⁻¹¹	8x10 ⁻⁴	4x10 ⁻¹	8x10 ⁻¹	2x10 ⁻¹¹	1x10 ⁻⁸	2x10 ⁻⁸

TABLE 13-17

SUMMARY OF ACCIDENT EFFECTS: ONSITE DISPOSAL - OPERATIONAL PHASE

Airborne Releases	Release Fract.	Decon. Factor	Event Freq. yr ⁻¹	Maximum Individual						Population					
				Dose, rem			Risk, rem/yr			Dose, man-rem			Risk, man-rem/yr		
				Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung
DEEP ROCK DISPOSAL - LEMHI SITE - SHAFT ACCESS															
Slag	4x10 ⁻¹⁰	10 ³	9x10 ⁻⁵	4x10 ⁻¹²	3x10 ⁻⁹	5x10 ⁻⁹	4x10 ⁻¹⁶	3x10 ⁻¹³	5x10 ⁻¹³	8x10 ⁻⁹	4x10 ⁻⁶	8x10 ⁻⁶	7x10 ⁻¹³	4x10 ⁻¹⁰	7x10 ⁻¹⁰
Compacted	1x10 ⁻⁹	10 ³	8x10 ⁻⁵	1x10 ⁻¹¹	7x10 ⁻⁹	1x10 ⁻⁸	8x10 ⁻¹⁶	6x10 ⁻¹³	8x10 ⁻¹³	2x10 ⁻⁸	1x10 ⁻⁵	2x10 ⁻⁵	2x10 ⁻¹²	8x10 ⁻¹⁰	2x10 ⁻⁹
Packaged	4x10 ⁻⁸	10 ³	1x10 ⁻⁴	4x10 ⁻¹⁰	3x10 ⁻⁷	5x10 ⁻⁷	4x10 ⁻¹⁴	3x10 ⁻¹¹	5x10 ⁻¹¹	8x10 ⁻⁷	4x10 ⁻⁴	8x10 ⁻⁴	8x10 ⁻¹¹	4x10 ⁻⁸	8x10 ⁻⁸
DEEP ROCK DISPOSAL - LEMHI SITE - TUNNEL ACCESS(a)															
Slag	7x10 ⁻¹³	10 ³	1x10 ⁻²	7x10 ⁻¹⁵	5x10 ⁻¹²	9x10 ⁻¹²	7x10 ⁻¹⁷	5x10 ⁻¹⁴	9x10 ⁻¹⁴	1x10 ⁻¹¹	7x10 ⁻⁹	1x10 ⁻⁸	1x10 ⁻¹³	7x10 ⁻¹¹	1x10 ⁻¹⁰
Packaged	3x10 ⁻¹⁰	10 ³	4x10 ⁻²	3x10 ⁻¹²	2x10 ⁻⁹	4x10 ⁻⁹	1x10 ⁻¹³	8x10 ⁻¹¹	2x10 ⁻¹⁰	6x10 ⁻⁹	3x10 ⁻⁶	6x10 ⁻⁶	2x10 ⁻¹⁰	1x10 ⁻⁷	2x10 ⁻⁷
ENGINEERED SHALLOW-LAND DISPOSAL AT SITE 14(a,b)															
Slag	7x10 ⁻¹³	10 ³	1x10 ⁻²	7x10 ⁻¹⁵	5x10 ⁻¹²	9x10 ⁻¹²	7x10 ⁻¹⁷	5x10 ⁻¹⁴	9x10 ⁻¹⁴	1x10 ⁻¹¹	7x10 ⁻⁹	1x10 ⁻⁸	1x10 ⁻¹³	7x10 ⁻¹¹	1x10 ⁻¹⁰
Packaged	3x10 ⁻¹⁰	10 ³	4x10 ⁻²	3x10 ⁻¹²	2x10 ⁻⁹	4x10 ⁻⁹	1x10 ⁻¹³	8x10 ⁻¹¹	2x10 ⁻¹⁰	6x10 ⁻⁹	3x10 ⁻⁶	6x10 ⁻⁶	2x10 ⁻¹⁰	1x10 ⁻⁷	2x10 ⁻⁷
ENGINEERED SURFACE DISPOSAL NEAR THE RWMC(a)															
Slag	7x10 ⁻¹³	10 ³	1x10 ⁻²	7x10 ⁻¹⁵	5x10 ⁻¹²	9x10 ⁻¹²	7x10 ⁻¹⁷	5x10 ⁻¹⁴	9x10 ⁻¹⁴	1x10 ⁻¹¹	7x10 ⁻⁹	1x10 ⁻⁸	1x10 ⁻¹³	7x10 ⁻¹¹	1x10 ⁻¹⁰
Packaged	3x10 ⁻¹⁰	10 ³	4x10 ⁻²	3x10 ⁻¹²	2x10 ⁻⁹	4x10 ⁻⁹	1x10 ⁻¹³	8x10 ⁻¹¹	2x10 ⁻¹⁰	6x10 ⁻⁹	3x10 ⁻⁶	6x10 ⁻⁶	2x10 ⁻¹⁰	1x10 ⁻⁷	2x10 ⁻⁷

(a) No release in the instance of compacted and immobilized waste.

(b) Entries apply also to less massive variation of disposal facility.

TABLE 13-18
SUMMARY OF ACCIDENT EFFECTS: ONSITE DISPOSAL - POSTCLOSURE PHASE

Airborne Releases	Release Fract.	Event Freq. yr ⁻¹	Maximum Individual						Population					
			Dose, Rem			Risk, rem/yr			Dose, Man-rem			Risk, Man-rem/yr		
			Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung
DEEP ROCK DISPOSAL AT LEMHI LOCATIONS - SHAFT OR TUNNEL ACCESS(a)														
Explosive Volcano(b)	2x10 ⁻⁶	NC(c)	6x10 ⁻⁶	1x10 ⁻²	2x10 ⁻²	NC	NC	NC	2x10 ⁻²	4x10 ¹	8x10 ¹	NC	NC	NC
ENGINEERED SHALLOW-LAND DISPOSAL AT SITE 14(d)														
Lava Flow(b)	1x10 ⁻²	NC	1x10 ⁻⁴	1x10 ¹	9x10 ⁰	NC	NC	NC	6x10 ⁻¹	6x10 ⁴	4x10 ⁴	NC	NC	NC
Erosion	Wind Pickup	NC	4x10 ⁻⁷	7x10 ⁻³	4x10 ⁻³	NC	NC	NC	1x10 ⁻³	4x10 ¹	2x10 ¹	NC	NC	NC
Intrusion (Excavation following Erosion: 1x10 ⁻⁷ C) inhaled)(e)	N/A(f)	NC	4x10 ⁻⁶	4x10 ⁻³	8x10 ⁻³	NC	NC	NC	1x10 ⁻²	2x10 ¹	4x10 ¹	NC	NC	NC
Intrusion (Farming) Ingestion (2x10 ⁻⁶ Ci/yr)	N/A	NC	2x10 ⁻⁵	1x10 ⁰	N/A	NC	NC	NC	2x10 ⁻⁴	1x10 ¹	N/A	NC	NC	NC
Inhalation (2x10 ⁻⁸ Ci/yr) (e)	N/A	NC	5x10 ⁻⁴	1x10 ¹	9x10 ⁰	NC	NC	NC	4x10 ⁻³	8x10 ¹	7x10 ¹	NC	NC	NC
Tornado	3x10 ⁻³	NC	4x10 ⁻⁵	4x10 ⁰	3x10 ⁰	NC	NC	NC	2x10 ⁻¹	2x10 ⁴	1x10 ⁴	NC	NC	NC
Earthquake	5x10 ⁻⁹	NC	5x10 ⁻¹¹	5x10 ⁻⁶	4x10 ⁻⁶	NC	NC	NC	3x10 ⁻⁷	3x10 ⁻²	2x10 ⁻²	NC	NC	NC
LMV(g,h)														
Lava Flow(b)	1x10 ⁻²	NC	2x10 ⁻³	3x10 ¹	2x10 ¹	NC	NC	NC	9x10 ⁰	1x10 ⁵	1x10 ⁵	NC	NC	NC
Erosion	Wind Pickup	NC	2x10 ⁻⁶	2x10 ⁻²	1x10 ⁻²	NC	NC	NC	3x10 ⁻³	1x10 ²	6x10 ¹	NC	NC	NC
Intrusion (Excavation following Erosion: 3x10 ⁻⁷ C) inhaled)(e)	N/A	NC	1x10 ⁻⁵	1x10 ⁻²	2x10 ⁻²	NC	NC	NC	3x10 ⁻²	5x10 ¹	1x10 ²	NC	NC	NC
Intrusion (Farming) Ingestion (4x10 ⁻⁶ Ci/yr)	N/A	NC	5x10 ⁻⁵	2x10 ⁰	N/A	NC	NC	NC	5x10 ⁻⁴	2x10 ¹	N/A	NC	NC	NC
Inhalation (5x10 ⁻⁸ Ci/yr) (e)	N/A	NC	1x10 ⁻³	4x10 ¹	3x10 ¹	NC	NC	NC	8x10 ⁻³	3x10 ²	2x10 ²	NC	NC	NC
Tornado	3x10 ⁻³	NC	6x10 ⁻⁴	9x10 ⁰	6x10 ⁰	NC	NC	NC	3x10 ⁰	4x10 ⁴	3x10 ⁴	NC	NC	NC
Earthquake	5x10 ⁻⁹	NC	1x10 ⁻⁹	1x10 ⁻⁵	1x10 ⁻⁵	NC	NC	NC	4x10 ⁻⁶	5x10 ⁻²	4x10 ⁻²	NC	NC	NC
ENGINEERED SURFACE FACILITY NEAR THE RMC(h)														
Lava Flow(b)	1x10 ⁻²	NC	1x10 ⁻⁴	1x10 ¹	9x10 ⁰	NC	NC	NC	6x10 ⁻¹	6x10 ⁴	4x10 ⁴	NC	NC	NC
Erosion	Wind Pickup	NC	4x10 ⁻⁷	7x10 ⁻³	4x10 ⁻³	NC	NC	NC	1x10 ⁻³	4x10 ¹	2x10 ¹	NC	NC	NC
Intrusion (Excavation following Erosion: 1x10 ⁻⁷ C) inhaled)(e)	N/A	NC	4x10 ⁻⁶	4x10 ⁻³	8x10 ⁻³	NC	NC	NC	1x10 ⁻²	2x10 ¹	4x10 ¹	NC	NC	NC
Intrusion (Farming) Ingestion (2x10 ⁻⁶ Ci/yr)	N/A	NC	2x10 ⁻⁵	1x10 ⁰	N/A	NC	NC	NC	2x10 ⁻⁴	1x10 ¹	N/A	NC	NC	NC
Inhalation (2x10 ⁻⁸ Ci/yr) (e)	N/A	NC	5x10 ⁻⁴	1x10 ¹	9x10 ⁰	NC	NC	NC	4x10 ⁻³	8x10 ¹	7x10 ¹	NC	NC	NC
Tornado	3x10 ⁻³	NC	4x10 ⁻⁵	4x10 ⁰	3x10 ⁰	NC	NC	NC	2x10 ⁻¹	2x10 ⁴	1x10 ⁴	NC	NC	NC
Mackay Dam(e)	1x10 ⁻⁴	NC	3x10 ⁻⁸	8x10 ⁻⁷	1x10 ⁻⁶	NC	NC	NC	1x10 ⁻⁴	3x10 ⁻³	5x10 ⁻³	NC	NC	NC
Earthquake	5x10 ⁻⁹	NC	5x10 ⁻¹¹	5x10 ⁻⁶	4x10 ⁻⁶	NC	NC	NC	3x10 ⁻⁷	3x10 ⁻²	2x10 ⁻²	NC	NC	NC

(a) All releases evaluated for the year 2085.

(b) Dominant event.

(c) NC = Not calculated because of the difficulty of reliably predicting probabilities and geologic characteristics into the far distant future.

(d) All releases evaluated for a time 25,000 yr into the future.

(e) Intake listed is that for maximum individual.

(f) N/A = Not applicable.

(g) LMV identifies the use of the less massive variation of the engineered shallow-land disposal facility at Site 14.

(h) All releases evaluated for a time 2000 yr into the future.

(i) Resuspension by wind pickup.

Entries in the tables have generally been rounded to one significant figure. The uncertainties of the calculated doses and risks are estimated generally to be factors of one to two orders of magnitude, both upward and downward. Such uncertainties do not have a major impact on the significance of doses and risks that are already extremely small.

A summary of projected effects from short-term (up to 100-yr) release scenarios for all alternatives and concepts is given in Table 13-19. For alternatives and concepts consisting of more than one module, the risks from the various modules were summed to give total values. The maximum calculated doses are also listed. For this table, only calculations involving lung dose are presented. Whole-body doses are not as meaningful as lung doses for radionuclides that consist almost entirely of transuranics.

The short-term release scenario of greatest risk for Alternatives 1 and 2 is lava flow over the waste. For the remaining alternatives, the greatest short-term risk would be the same scenario, but involving the waste still remaining on the TSA during the retrieval campaign. Such a risk would exist even without waste retrieval operations. For clarity, this type of risk was omitted from the entries for Alternatives 3 through 6 in Table 13-19. The scenario of greatest risk for those alternatives, thus becomes a fire during retrieval operations or an explosion (with failed confinement) during slagging pyrolysis operations.

The maximum total of short-term risk appearing in Table 13-19 is 6×10^{-3} rem/yr to the maximum individual and 10 man-rem/yr to the population residing within 50 miles. These risks are based on dose commitment to the lung. By comparison, the annual lung dose received by the same people from natural background radiation would be an estimated 180×10^{-3} rem/yr (individual) and 24×10^3 man-rem/yr (population) (NCRPM 1975).

TABLE 13-19

SUMMARY OF EFFECTS FROM SHORT-TERM RELEASE SCENARIOS(a,b,c,d)

Alternative/Concept	Maximum Dose to Maximum Individual (rem)	Total Risk to Maximum Individual (rem/yr)	Maximum Population Dose (man-rem)	Total Risk to Population (man-rem/yr)
1	1×10^2	6×10^{-3}	2×10^5	1×10^1
2-a(e)	2×10^1	6×10^{-5}	4×10^4	1×10^{-1}
2-b(e)	2×10^1	6×10^{-5}	4×10^4	1×10^{-1}
2-c	1×10^0	6×10^{-5}	2×10^3	1×10^{-1}
3	1×10^{-1}	2×10^{-6}	2×10^2	3×10^{-3}
4	1×10^{-1}	2×10^{-6}	2×10^2	3×10^{-3}
5-a,5-d,5-g(f),5-j	1×10^{-1}	2×10^{-6}	2×10^2	3×10^{-3}
5-b,5-e,5-h(f),5-k	6×10^{-3}	5×10^{-7}	1×10^1	1×10^{-3}
5-c,5-f,5-i(f),5-l	6×10^{-3}	6×10^{-7}	1×10^1	1×10^{-3}
6	1×10^{-1}	2×10^{-6}	2×10^2	3×10^{-3}
Natural Background Radiation		180×10^{-3}		24×10^3

(a) Effects reported here are for lung dose only.

(b) Short-term accidents include release scenarios occurring no more than 100 yr into the future for Alternative 1 and 2. For Alternatives 3 through 6, entries include only campaign-related events. Entries do not include possible releases due to natural events or aircraft impacts that would disrupt waste still unretrieved during retrieval campaign (10-yr period). Inclusion of such events would cause entries to be similar to those for Alternative 1 for that time period. For Alternative 4, entries listed do not include release scenarios for natural events occurring while processed waste is in storage during 1985-2005. Inclusion of such events would have little effect. For Alternative 6, entries listed pertain to time after campaign starts in 2005. From 1985 through 2005, entries for Alternative 1 would apply. For Alternative 5, only releases occurring prior to or during emplacement (10-yr period) are included.

(c) Effects of possible releases occurring at the Federal Repository are not included for Alternatives 3, 4, and 6, because these effects are being evaluated in other DOE projects.

(d) See Subsections 7.4.1 and 13.2 for additional explanations of scope and assumptions.

(e) Maximum dose is associated with effects of explosive volcano, whereas total risk is dominated by risk associated with lava flow. For this reason, the entries are not simple multiples of the entries for Alternative 1 and for Concept 2-c.

(f) Entries apply to either more massive or less massive variation of the engineered shallow-land disposal facility at Site 14.

A summary of projected effects from long-term release scenarios for each alternative or concept is given in Table 13-20. All entries are calculated values of population dose to the lung for the dominant release scenario. Double entries indicate the effects before and after hypothesized times of complete deterioration of confinement. For simplicity, such deterioration was assumed to occur instantaneously rather than gradually.

The supplement following Table 13-20 presents the same data points in graphic form, with connecting curves faired through the points. The increase in dose between zero and one hundred years is due to the assumed population growth during the first hundred years. Also indicated is the level of natural background radiation, which is the population dose that is certain to accrue each year. (No estimates were made of long-term decay of the sources of natural background radiation. However, such decay is believed to be relatively small over the 25,000-yr period studied.) By contrast, the curves for the waste management alternatives represent doses from highly unlikely volcanic action events.

Subsections 13.4 through 13.10 describe the scenarios evaluated and the assumptions used to produce the entries in summary Tables 13-7 through 13-18. The dose and risk results are not repeated in the individual subsections. From the release fraction given in the text for each scenario, the release quantities can be determined by multiplying by the inventory at the time of the scenario. The inventory will be about 4.2×10^5 Ci in 1985 (Table 13-2) and 1.8×10^5 Ci in 2085 (Tables 13-2 and 13-6). Inventories at other times can be estimated by referring to Table 13-6.

13.4 LEAVE AS IS (ALTERNATIVE 1)

This subsection describes the most significant event scenarios considered in the risk analysis. Discussions of subsequent alternatives, concepts, and modules refer to these scenarios and are modified and amplified as appropriate.

TABLE 13-20
SUMMARY OF CONSEQUENCES FROM LONG-TERM RELEASE SCENARIOS(a)

Alternative/ Concept	YEARS AFTER 1985								
	0	100		400		2000		25000	
		BCF(b)	ACF(c)	BCF	ACF	BCF	ACF	BCF	ACF
1	2x10 ⁵	4x10 ⁵		3x10 ⁵		1x10 ⁵		4x10 ⁴	
2-a	4x10 ⁴ (d)	8x10 ⁴ (d)	4x10 ⁵	3x10 ⁵		1x10 ⁵		4x10 ⁴	
2-b	4x10 ⁴ (d)	8x10 ⁴ (d)	4x10 ⁵	3x10 ⁵		1x10 ⁵		4x10 ⁴	
2-c	2x10 ³	4x10 ³	3x10 ³	3x10 ⁵		1x10 ⁵		4x10 ⁴	
3	No long-term management of stored TRU waste at the INEL(e)								
4	No long-term management of stored TRU waste at the INEL(e)								
5-a through 5-f (Lemhi Range)	4x10 ¹ (d)	8x10 ¹ (d)		6x10 ¹ (d)		2x10 ¹ (d)		8x10 ⁰ (d)	
5-g through 5-i (Site 14)(f)	4x10 ² (d)	8x10 ² (d)		6x10 ² (d)		2x10 ² (d)	8x10 ¹ (d)	4x10 ⁴	
5-g through 5-i (LMV)(g,h)	1x10 ³ (d)	2x10 ³ (d)		1.5x10 ³ (d)	5x10 ² (d)	1x10 ⁵		4x10 ⁴	
5-j through 5-l (RWMC)(e)	4x10 ² (d)	8x10 ² (d)		6x10 ² (d)		2x10 ² (d)	8x10 ¹ (d)	4x10 ⁴	
6	No long-term management of stored TRU waste at the INEL(e)								

(a) All entries are the calculated values of population dose to the lung, in man-rem, for the dominant release scenario.

(b) BCF = Before Confinement Failure.

(c) ACF = After Confinement Failure.

(d) Explosive volcanic eruption is dominant release scenario. For all other entries, lava flow is dominant release scenario.

(e) Long-term effects of disposal of TRU waste at the Federal Repository are being evaluated in other DOE-sponsored studies.

(f) Resistance to explosive volcanic eruption assumed to be a factor of 100 better than that for Concepts 2-a and 2-b, as long as facility has not disintegrated.

(g) Resistance to explosive volcanic eruption assumed to be a factor of 40 better than that for Concepts 2-a and 2-b, as long as facility has not disintegrated.

(h) LMV identifies the use of the less massive variation of the engineered shallow-land disposal facility at Site 14.

Supplement to Table 13-20
(Summary of Consequences from Long-Term Release Scenarios)

13.4.1 Summary. For Alternative 1, the calculated dose and risk for events leading to accidental releases are summarized in Table 13-7. The largest short-term population risk and long-term population dose are associated with airborne release caused by lava flow over the waste. This scenario was evaluated using conservative values for the quantity of radionuclides released. Further analysis may show this release quantity to be unrealistically large.

The dominant short-term event for waterborne releases was found to be failure of the Mackay Dam, followed by flooding of the TSA. The scenario has a short-term population risk, based on bone dose, that is approximately eight orders of magnitude less than that for the scenario with lava flow. The population dose from long-term waterborne releases would be about seven orders of magnitude smaller than that for the lava flow scenario. The dominant long-term waterborne releases are associated with glaciation, climate change, and alteration of river channels.

13.4.2 Short-Term Risks.

13.4.2.1 Airborne Accidental Releases. No operational accidents were identified as causing significant releases. Only violent or unusual natural or externally caused events, capable of disrupting the waste, are significant contributors to dose and risk. Three major accident scenarios capable of causing significant releases of radionuclides were studied: (1) explosive volcanic action up through the waste, (2) lava flow over the waste, and (3) earthquakes. Tornadoes and meteorite impact were also examined but no release scenarios were identified.

13.4.2.1.1 Explosive Volcanic Action. The analyses of explosive volcanic action up through the waste and of lava flow over the waste (Subsection 13.4.2.1.2) were based primarily on the results of continuing studies (Kuntz 1978) conducted for DOE by the USGS. The geologic history and inferred past volcanic events in the area were used to assess the hazard from volcanic action. Included in the

studies were geologic field mapping, a limited number of radiometric age dates of lava flows, and a statistical assessment of volcanic recurrence intervals. Geologic and seismic aspects of the INEL environment are discussed in Subsection 3.4.

The 660-square mile Arco-Big Southern Butte area, in which the RWMC is located, includes the Arco Volcanic Rift Zone. The RWMC lies at the edge of this rift zone, which is approximately 6 miles wide and 30 miles long. The occurrence of volcanoes in this area would be concentrated in, but not limited to, the rift zone.

The general conclusions of the Kuntz study (1978) were: (1) the Arco Rift Zone and adjacent areas have been active volcanic regions for the last 400,000 yr, (2) this region has been the locus of much of the geologically recent volcanism in the eastern portion of the Snake River Plain, and (3) the region is likely to be the site of future volcanic action.

Eruption of a new volcano up through the stored waste could cause radioactive material to become airborne, the amount of which would depend on the type of eruption. Some eruptions are not accompanied by large volumes of explosively ejected material (pyroclastics) (Francis 1976), while other eruptions are.

One type of eruption is a rhyolite eruption. Such eruptions, which have not occurred in the area for several hundred thousand years, are believed to have been nonexplosive in those instances (Kuntz 1978).

Hydromagmatic eruptions are moderately violent eruptions that occur when the molten lava encounters groundwater at relatively shallow depths beneath the surface of the earth. A small but significant number of eruptions in the eastern Snake River Plain have been of this type (Kuntz 1978). The presence of zones of perched water and the aquifer underlying the area could conceivably lead to future hydromagmatic eruptions. Craters formed by such eruptions could be as large as one mile in diameter (Ollier 1974).

Fissure eruptions are relatively explosive at the vent areas and are characterized by the eruption of both large and small volumes of lava from the vents. Particulate matter in steam clouds emitted from a fissure could rise to 300 ft and be carried several miles downwind. Such events have occurred in the Arco-Big Southern Butte area (Kuntz 1978). If a fissure eruption were to occur within the RWMC, large volumes of pyroclastics containing TRU waste could be ejected (Wilcoxson 1966).

An explosive eruption scenario was assumed for this analysis. All eruptions not involving the effects of lava flow over the waste were assumed to match this scenario, although most eruptions would be less severe and a few could be more severe. The vent area was assumed to be 1 acre, or about 20% of the estimated 5-acre area of the two TSA pads in which the TRU waste would be stored. It was correspondingly assumed that 20% of the inventory of 4.2×10^5 Ci (see Table 4-2), or about 8.4×10^4 Ci, would be ejected. Further, 1% of the ejected waste (840 Ci) was assumed to remain airborne and to be carried offsite. This airborne fraction is a factor of 10 higher than that assumed for most accidents (Mishima 1974; Mishima and Schwendiman 1970, 1973a, 1973b; Selby et al. 1973; Sehmel 1977; ORNL 1970b). The increase is attributed to the severity of the scenario for volcanic action. The overall release fraction assumed was, therefore, 2×10^{-3} .

The probability of the eruption scenario described, within the stored TRU waste area, was estimated to be 4×10^{-9} /yr. This value is subject to large uncertainty. The value was based on an average recurrence frequency of 1 in 3,000 yr (3×10^{-4} /yr) for all volcanic activity (explosive or nonexplosive) in the Arco-Big Southern Butte area (Kuntz 1978). The recurrence frequency was multiplied by the ratio of the area containing the stored waste to that of the Arco-Big Southern Butte area.

The maximum individual dose and risk from this scenario were calculated, along with the dose and risk to the public. However,

there would generally be sufficient warning for individuals living nearby to evacuate the area before a major eruption. Earthquakes, ground cracking and tilting, and possible faulting and steam activity generally precede eruptions by a few days or a few hours. In some instances, warning signs occur weeks before an eruption.

13.4.2.1.2 Lava Flow Over the Waste. It has not yet been projected whether the 16-ft stack of waste, covered with 3 ft of soil and standing on an asphalt pad, is adequately protected against lava flow. The potential effects of the lava on the waste are also difficult to project. The following preliminary set of conservative assumptions was used: (1) the entire RWMC would be covered by hot lava for several days; (2) the stored waste would become mixed with the lava; and (3) all the combustible material in the waste would burn. Additional analysis may confirm or negate the validity of these assumptions.

Studies of prolonged fires (ERDA 1975) have assumed release fractions of 0.1 to 0.5. Because about 25% of the stored waste is combustible (Subsection 7.4.1.2), a release fraction of 0.025 to 0.125 might be appropriate. However, because releases would filter through a thick layer of lava, a release fraction of 0.01 was assumed.

The probability of a volcanic eruption within the Arco-Big Southern Butte area would be 3×10^{-4} /yr, as described earlier. A 20% conditional probability was estimated that a given lava flow within the area would cover the RWMC (Kuntz 1978). Therefore, the probability of radionuclide release under these conditions would be 6×10^{-5} /yr.

As in the previous scenario, the maximum individual dose and risk were calculated. Again, there would be sufficient advance warning, in most instances, for individuals living nearby to evacuate the area.

13.4.2.1.3 Earthquakes. Another postulated event leading to airborne release was an earthquake strong enough to disrupt the waste stack, causing impact and breach of one or more

waste containers. The INEL is classified as Seismic Zone 3 (UBC, revised 1973). Sixty-seven earthquakes equivalent to Modified Mercalli Intensity (MMI) V or greater were recorded in Idaho between 1884 and 1976. Of these, 29 had epicenters in Idaho, many lying in or near the mountains surrounding the eastern Snake River Plain (see Figure 13-1). Earthquake intensity at the INEL has reached MMI V or VI. No earthquake considered destructive (MMI IX or higher) has been recorded in the eastern part of the Snake River Plain. The most recent large earthquake that was accompanied by surface faulting occurred in August 1959, about 100 miles northeast of the INEL. No damage resulted to INEL facilities.

Recent studies have shown that the plain itself is rather aseismic. However, local shaking could result from intense earthquakes with epicenters in the surrounding area (ERDA 1977c). As a result, ground cracking and severe building damage at the RWMC could be caused by an earthquake of MMI IX or higher in the surrounding area.

It was assumed that, in such an earthquake, 10% of the contents of one box of waste or of 15 drums would be exposed. The fraction of the released radioactivity that would become airborne was estimated to be 1×10^{-4} (Mishima 1974, Mishima and Schwendiman 1973b, and Sehmel 1977). Thus, the fraction of the total waste inventory that would become airborne is about $(0.21 \text{ Ci/ft}^3 \times 112 \text{ ft}^3 \times 10^{-1} \times 10^{-4}) / (4.2 \times 10^5) = 5 \times 10^{-10}$.

The ground acceleration necessary to cause the damage and airborne release just described was estimated to be at least 0.5 g. Seismic resistance of the stacked waste containers is contributed by the 3-ft cover of soil, the plywood sheets between layers of containers, and the close packing. Based on the limited data in Hsieh, Okrent, and Apostolakis (1975); Otway (1969); and Agbabian Associates (1977), the frequency of such an earthquake at the RWMC was conservatively estimated to be 2×10^{-6} /yr.

Fig. 13-1 Seismic characteristics of the Intermountain Region (ERDA 1977c).

13.4.2.1.4 Tornadoes. On the average, the State of Idaho experiences two tornadoes each year (EG&G 1977). Ten funnel clouds (vortex clouds that do not reach the ground) and two tornadoes have been observed at the INEL.

An extensive survey of tornadoes in Washington, Oregon, and Idaho was performed by Fujita (1971), who found that tornadoes in this area occur primarily in "alleys." Locations of these alleys are illustrated in Figure 13-2, which includes the reported tornadoes during the period 1950 through 1969.

Tornadoes occurring in the Twin Falls alley could damage the INEL area. However, only 21 significant tornadoes were recorded in the Twin Falls alley during the 20-yr reporting period. The warm, moist air and steep density gradients required for a severe tornado were absent from the region during the 20-yr study (Fujita 1971). Assuming an additional factor of 25% for unrecorded tornadoes, the frequency of occurrence was estimated to be about 1.3 tornadoes/yr in the Twin Falls alley.

Tornadoes in the area have been small. All but one tornado resulted in a damage area of less than 0.1 square mile. Most have affected an area of less than 0.01 square mile. The area of the Twin Falls alley is approximately 25,000 square miles. Based on the Fujita data, it was estimated that the average tornado would result in a damage zone of 0.01 square mile and a velocity of 100 mph. Assuming a random process, the probability of the TSA (an area of 0.01 square mile) being the damage zone is about 5×10^{-7} /yr.

The protective cover over the waste on the TSA pads was assumed to resist tornado winds during the short term. No radioactive releases would be expected.

13.4.2.1.5 Meteorite Impact. The probability of a meteorite large enough to inflict significant damage on the TSA is several orders of magnitude smaller than the probability of other

Fig. 13-2 Distribution of characterized tornadoes in 20-yr period, 1950 through 1969 (Fugita 1971).

events studied. Because of the extremely low probability, this scenario is not included in the summary tables for any of the alternatives, concepts, or modules.

13.4.2.2 Waterborne Accidental Releases. Events that could lead to waterborne releases of radionuclides include (1) flooding from precipitation or snowmelt (either from local runoff or from Big Lost River flooding); and (2) failure of the Mackay Dam upstream on the Big Lost River. These scenarios are discussed in this subsection.

Another event that could lead to waterborne releases is perturbation of the groundwater system. Because surveillance would be conducted for the short term, levels of the water table would be monitored around the RWMC. Significant changes in irrigation, reservoir, artificial recharge, and well discharge patterns would be evaluated before implementation. Therefore, significant water table changes in the short term would be highly unlikely.

13.4.2.2.1 Flooding from Precipitation or Snowmelt. Flooding of the RWMC from precipitation or snowmelt could occur from (1) runoff from the local drainage basin or (2) Big Lost River flooding, resulting in failure or overtopping of the diversion dam and Dikes No. 1 and 2 (see Figure 13-3). These two scenarios are discussed in this subsection, after discussion of the local topography and hydrology. However, because of surveillance, it is unlikely that uncontained radionuclides from the stored waste would be present to become mobilized by flood waters during the short-term (100-yr) period.

Flooding would not release radionuclides into the Snake River via surface waters. Water entering the RWMC would either percolate as groundwater to the Snake River Plain Aquifer or travel as surface water in a northwestern direction and eventually sink into the Big Lost River playas (see Figure 3-8).

Fig. 13-3 Map of flood-control diversion system.

The RWMC lies in the bottom of a valley between basalt ridges. The area generally slopes from the southwest to the northeast (see Figure 5-3). The highest normal perimeter elevation is 5011 ft above mean sea level (MSL), and the lowest elevations are about 5000 ft above MSL. Water runs off surface irregularities (mounds covering trenches, natural high spots, etc.) and follows the normal drainage pattern eastward, concentrating surface water in the central and eastern portions of the RWMC.

The RWMC tends to be vulnerable to precipitation infiltration. The area tends to hold precipitation and to collect runoff water from surrounding slopes. Vegetation is sparse or absent over much of the area. Most of the precipitation and snowmelt comes in late winter or early spring when potential rates of evaporation and transpiration are relatively small.

As mentioned at the beginning of this subsection, mobilization of radionuclides in the stored TRU waste as a result of floodwaters is highly unlikely. However, radionuclides in the buried TRU waste have been affected by floodwaters. A discussion of these effects on the buried waste is useful here for projecting effects on the stored waste.

Subsurface migration toward the Snake River Plain Aquifer of radionuclides from buried TRU waste in the pits and trenches is discussed in Subsection 5.5. To reach the aquifer, the liquid would have to percolate vertically through about 580 ft of basalt and sedimentary layers (see Figure 3-6). It was assumed that fluid would, after entering the aquifer, travel northeast a few miles because of the head of water and recharge in the spreading areas to the southwest, as shown in Figure 13-4. Finally, the fluid would migrate southwest (Figure 13-5) about 80 miles to springs near Hagerman and Twin Falls (Figure 3-9) and enter the Snake River.

Fig. 13-4 Map of the southwestern portion of the INEL showing contours on the water table of the Snake River Plain Aquifer and inferred directions of groundwater movement, March 1972.

Fig. 13-5 INEL subsurface water flows.

Excavations at the RWMC have shown the presence of sand and gravel lenses (thin horizontal layers of water-saturated porous material). The distribution of these lenses has not been mapped in detail, because of the amount of drilling that would be required. There has been no evidence to indicate that significant quantities of water have migrated laterally into the RWMC through lenses. Schmalz (1972) indicated, however, that in the 1969 flood (see Subsection 3.5.2), some of the water that accumulated in the RWMC migrated a few feet horizontally through a sand lens. Subsurface horizontal flow would not significantly affect radionuclide migration because it would be unsaturated, i.e., less than the flow capacity of the porous media. Current data indicate that this potential outside source would contribute an insignificant quantity of water to the RWMC subsurface.

The first flooding scenario involves precipitation and surface run-off from the local drainage basin. Subsection 3.3.3 describes precipitation statistics at the INEL for the 22 yr of record. Intermittent periods of high precipitation provide an opportunity for water infiltration.

The local drainage basin flood in 1969 demonstrated the inadequacy of the dike and drainage system at that time. Since then a more extensive system has been constructed around the RWMC perimeter, as described in Subsection 3.5.2. The local drainage basin has thus been reduced from 1700 to 643 acres. For short-term considerations, erosion and radionuclide transport in the RWMC from this source of flooding would be unlikely. Thus, as long as the RWMC is maintained, local flooding should not adversely affect the RWMC or the dikes and diversion system.

The second flooding scenario involves Big Lost River flooding. The river channel, two miles north of the RWMC, has an elevation 30 to 40 ft higher than that of the RWMC. A large flood could conceivably overtop Dike No. 2 or cause it to fail. Water could overflow onto the RWMC (see Figures 13-3 and 5-3). This event has not occurred during

the INEL history. However, artifacts and fossils found during excavations indicate that floods from the Big Lost River basin have entered the RWMC since the Pleistocene Age.

The recently constructed dike and diversion system located one mile west of the RWMC provide a terminus and spreading areas for Big Lost River floods. Capacity of the spreading areas is about 38,000 acre-ft. The system was designed to provide protection against a flood with a return period as great as 55 yr (Carrigan 1972). Partial blockage of culverts from debris during a severe flood would significantly reduce the capacity of the diversion system.

One potential effect of RWMC inundation from the Big Lost River would be to initiate migration toward the aquifer of any uncontained radionuclides from the stored waste. In any given year, the probability of a flood overtopping the diversion dikes while the facilities are being maintained would be 2×10^{-2} (an average of once every 55 yr). Doubling the capacity of the diversion channel and of the connecting channels to the spreading areas would reduce the probability to 3×10^{-3} (Carrigan 1972).

The consequences of infiltrating floodwater carrying radionuclides into the soil are discussed in the following subsection related to hypothetical failure of the Mackay Dam. The Mackay Dam failure scenario is more severe than that for flooding of the Big Lost River, so the consequences would be greater. As shown below, such consequences would still be expected to be extremely small. The probabilities for the two scenarios are similar.

Another potential effect of RWMC inundation would be water erosion of the soil covering the stored waste, and subsequent atmospheric dispersion following possible breaching of the containers. (This airborne pathway is mentioned here and discussed in the following subsection, because hydrologic events would be responsible for initiating the transport of radionuclides.) This scenario would be expected to

involve a smaller airborne release than the airborne release for the Mackay Dam failure, which, in turn, is shown to lead to very small doses.

13.4.2.2.2 Mackay Dam Failure. The probability of failure of the Mackay Dam, about 42 miles upstream from the RWMC on the Big Lost River (see Figure 13-6), was estimated to be 2×10^{-3} in any given year. Possible failure due to seismic action is included in this value.

The capacity of the Mackay Reservoir is 45,900 acre-ft. A dam failure would lead to rapid draining of the reservoir. Immediately downstream from the Mackay Dam, the crest would be high, and the flood duration would be short. Below the reservoir the water would spread across the flood plain, which is 1 to 3 miles wide. The maximum depth would decrease, but the duration of flooding would be longer.

Based on preliminary studies, expected to be published in 1979, the USGS has estimated that failure of the Mackay Dam at full capacity would initiate a flood wave with the following properties:

- (1) The first flood wave would reach the RWMC in about 6 hr.
- (2) The peak flood wave stage would be about 12 ft high.
- (3) A 6-ft high stage would continue for about 40 hr.
- (4) The peak discharge would be about 30,000 to 35,000 cfs, including infiltration.

Further analytic verification is required for these preliminary results.

Fig. 13-6 Map of Big Lost River Basin downstream from Mackay Reservoir showing location of streamflow stations.

The hypothesized event could cause a radiological hazard to the public by means of two alternative pathways for radionuclides released as a result of the flood. Ingestion of contaminated drinking water and inhalation of airborne radionuclides released via resuspension are the two pathways.

The ingestion pathway would entail: (1) infiltration of flood waters into the TSA, (2) leaching of stored waste that may have been exposed via container deterioration, (3) percolation of the exposed radionuclides into the aquifer, (4) radionuclide migration through the aquifer to wells, and (5) drinking of contaminated water from wells. An estimate of the source term for this pathway is discussed below.

At the TSA, flood waters would percolate in a saturated flow (i.e., at full capacity in porous media) toward the aquifer. Radionuclides migrating with percolating water would be in a dissolved, chelated, or colloidal suspension form. Radionuclides not in a convenient form for migration, or that are sorbed or filtered, would no longer have a saturated-flow pathway to reach the aquifer. Thus, further migration would be significantly retarded.

It was assumed that less than 10% of the radionuclide inventory would be in an appropriate dissolved, chelated, or colloidal suspension form. At low solute concentrations, ion-exchange and filtering mechanisms would be extremely effective. It was therefore assumed that less than 0.1% of the migrating waste would travel the 580 ft down to the Snake River Plain Aquifer. Based on the above assumptions, the overall release fraction for migration to the aquifer would be about 1×10^{-4} . The expected radionuclide migration to the aquifer was conservatively assumed to occur rapidly relative to subsequent travel time within the aquifer. In reality, migration to the aquifer would be expected to occur very slowly.

As the radionuclides migrate through the aquifer, their concentration would be diluted by dispersion, retardation, and radioactive decay. Transport of the radionuclides in the aquifer was estimated by the groundwater transport model described in Appendix E. This analytical model was used to estimate the peak concentration of radionuclides at wells for drinking water.

The direction of groundwater travel is illustrated in Figures 3-9, 13-4, and 13-5. The well closest to the RWMC is 2 miles to the NE and is within the INEL boundaries. However, this well is not in the aquifer flowpath from the RWMC (Subsection 5.5). The water in this well could be affected if local flow patterns were to change significantly. Because of this possibility, a well closer than the nearest downgradient water supply 18 miles away, was hypothesized for purposes of calculating maximum individual doses. It was conservatively assumed that a hypothetical well was located 3 miles downgradient (south) of the RWMC, at the closest INEL boundary.

For calculating population doses, a second well was hypothesized, located about 80 miles away in the region around Hagerman. This is the nearest population center that could conceivably use contaminated water from the aquifer. (Idaho Falls and Pocatello are not located downgradient in the Snake River Plain Aquifer streamline flows shown in Figure 3-9.) In reality, the population in the Hagerman area may not take their water supply from the aquifer. However, to conservatively estimate a population dose, it was assumed that an upper limit of 10,000 people would ingest the water for 50 yr at peak concentrations of the radionuclides.

The calculated values of peak concentration and time to peak concentration of the most significant radionuclides migrating to the two wells appear in Table 13-21.

TABLE 13-21

CONCENTRATION OF PRINCIPAL ^(a) RADIONUCLIDES IN WELL WATER
DUE TO GROUNDWATER TRANSPORT FOLLOWING MACKAY DAM FAILURE SCENARIO

Radio-nuclide	Stored Waste Inventory, 1985 (Ci)	3-Mile Well		80-Mile Well	
		Peak Concentration (pCi/ml)	Time to Peak (yr)	Peak Concentration (pCi/ml)	Time to Peak (yr)
Pu-239	3.42×10^4	4×10^{-6}	4.3×10^4	$<< 10^{-18}$ ^(b)	1.2×10^6
Pu-240	8.07×10^3	4×10^{-8}	3.8×10^4	$<< 10^{-18}$	1.1×10^6
Pu-242	2.0×10^{-1}	8×10^{-11}	4.5×10^4	3×10^{-13}	1.2×10^6
U-233	1.49×10^3	5×10^{-7}	4.4×10^4	1×10^{-10}	1.2×10^6

(a) Other radionuclides which were studied, such as Pu-238, Pu-241, Am-241, and Cm-244, were found to give much lower values of peak concentration than those listed.

(b) $<<$ = Much less than.

Maximum individual doses and population doses were summed for each of the contributing radionuclides regardless of arrival time. The results are reported under "Short-Term Waterborne Releases" in summary Table 13-7. This method provides an upper bound estimate of maximum concentration for all arrival times. The maximum individual dose was estimated by assuming that a hypothetical individual would drink 2 liters of water/day from the 3-mile well for 50 yr at the peak radionuclide concentration. Population dose was estimated by assuming that 10,000 people would each drink 1 liter of water/day from the 80-mile well for 50 yr at the peak radionuclide concentration.

The other important pathway for the Mackay Dam failure scenario is inhalation of airborne radionuclides resuspended following release as a result of flooding. The evaluations for this pathway are discussed in the following paragraphs. The results are presented under "Airborne Releases" in Table 13-7, because the final phase of radionuclide transport to man is airborne transport. It was assumed that

2% of the waste would be scoured via movement of soil from its original site to a new area of 10 square miles (see Figure 13-7). The critical shear stress, i.e., the force required to move the soil, would be exceeded, so significant scouring would be expected (Vanoni 1975). The soil covering the stored waste would be completely removed in approximately 2 hr. The waste containers would be directly exposed to the remaining flood waters. An equivalent of 2% of the waste containers would be breached (drum lids removed and boxes punctured), releasing their contents.

The water level in the contaminated area would later subside by infiltration and evaporation. It was assumed that 10% of the transported waste would remain in the top one inch of sediment.

The agglomerated soil particles would form a thick mud. Until the mud dried, radionuclides trapped in the mud could not be resuspended for inhalation. After several weeks, the dried mud would break up. Particles less than about 10 microns in diameter would be available for resuspension over an extended period of time. It was assumed that, after the mud dried, the fraction of the top particles less than 10 microns would be 3×10^{-3} . The overall release fraction would be: (0.02 fraction of transported waste x 0.1 fraction of waste near soil surface x 3×10^{-3} fraction of waste particles available for lofting) = 6×10^{-6} .

13.4.3 Long-Term Effects. As described in Subsection 13.2.1, long-term risks were not calculated in this study. Long-term doses, however, were calculated for the long-term release scenarios (e.g., erosion, glaciation). The waste characteristics and the population characteristics assumed for such scenarios were those for the year 2085. If the effects of releases (doses) were significant for 2085, additional calculations were performed for a time 10^4 yr into the future. (Lava flow over the waste was the only such case for 2085.)

Fig. 13-7 Area contaminated by hypothetical Mackay Dam failure.

13.4.3.1 Airborne Accidental Releases.

13.4.3.1.1 Lava Flow Over the Waste. Sec-

tion 13.4.2.1.2 describes a volcanic event that could result in covering the entire RWMC with lava. For analysis of long-term effects, the 3-ft soil cover over the waste was assumed to have been completely removed by erosion by the year 2085. (This conservative assumption was used because the higher elevation of the soil cover would probably result in faster erosion than the surrounding area.) Additionally, earth or rock diversion barriers that might be constructed to prevent lava from entering the RWMC were assumed to be compromised by weathering or other phenomena by 2085.

It was assumed that the stored waste would be mixed with the lava, and that all combustible material would burn. The airborne release fraction was assumed to be 1×10^{-2} , leading to an airborne release of approximately 1800 Ci. This projected release quantity for 2085 is less than the 4200 Ci for the short-term analysis in Subsection 13.4.2.1.2, because radioactive decay will have reduced the inventory from about 420,000 Ci to about 180,000 Ci.

Because the calculated dose was significant for this scenario occurring in 2085, the dose was also calculated for the scenario occurring 10^4 yr in the future.

The probability of this scenario occurring in the short term was discussed in Subsection 13.4.2.1.2. In the long term, it is likely that the RWMC will experience one or more lava flows within the next 30,000 to 50,000 yr. The initial flow would probably give the most significant effect. Subsequent flows would probably have lower consequences because (1) additional radionuclide decay would have occurred, (2) the combustible material would have been consumed in the first event, and (3) a thick layer of lava would have protected the waste against subsequent flows.

13.4.3.1.2 Intrusion. It was assumed that there would be no maintenance and surveillance of the RWMC after 100 yr. See Guideline (9) in Subsection 7.4.1.1. With no institutional control on the RWMC, the public would have unlimited access to the site, possibly without knowledge of its contents. Furthermore, after 100 yr, the hazard of the waste would have decreased by only about 25% due to radioactive decay (see Table 13-5).

Two intrusion scenarios that could result in exposure to individuals and to small population groups were considered. These were (1) an individual digging into the waste, and (2) a small group of people living on and farming the 5-acre area of soil covering the TSA pads. For both scenarios the following assumptions were used: (1) the intrusion would begin in 2085; (2) the waste containers would have deteriorated and compressed, causing the waste cover to form a slumped mound approximately 10 ft high over the area; (3) approximately 0.5% of the 2085 radionuclide inventory, or 900 Ci, would have migrated into, and been homogeneously distributed in, the top 3-ft layer of the mound. The remaining inventory would be homogeneously distributed in the lower two-thirds of the mound. With a soil density of 85 lb/ft³, the total concentration of radionuclides in the upper portion of the mound would be about 1.6×10^{-5} Ci/lb.

In the excavation scenario, it was assumed that an individual would spend 100 hr digging into the waste in search of artifacts or useful materials. The digging could develop a dust cloud having a concentration of 1 mg/m³. It was assumed that, because the excavation could penetrate into the waste, 10% of the airborne dust would be waste material (Leddicotte et al. 1978). The concentration of radionuclides in the waste in 2085 would be 5.7×10^{-6} Ci/g (Table 13-6). Because the individual would be active, his breathing rate was assumed to be 1.25 m³/hr. The amount of radioactivity inhaled by the individual can be calculated by the following: (100 hr x 1.25 m³/hr x 0.1 mg waste dust/m³ x 5.7×10^{-6} Ci/g x 1g/10³ mg) = 7×10^{-8} Ci. The dust cloud would also lead to inhalation of radionuclides by people living away from the area of excavation.

The results of this scenario are not listed in Table 13-7, because it was found that a related scenario, excavation after complete erosion of the soil cover over the waste, would give larger doses. The latter scenario, discussed in Subsection 13.4.3.1.4, is the one for which the calculated doses appear in Table 13-7.

In the farming scenario, both ingestion and inhalation pathways were considered.

In evaluating ingestion, it was assumed that the people living on the 5-acre plot would obtain their entire food supply from farming the plot. It was also assumed that only the top 3-ft of soil would contribute radionuclides to the food supply.

The transfer factors used to estimate the radioactivity ingested annually were based on data for fallout plutonium in the New York diet (Bennett 1974). Through multiplication of the concentration factors by the food intake quantities, the transfer factor for plutonium was calculated to be 0.49 lb/yr. This factor includes the effects of both plant-derived and animal-derived portions of the diet. The same value was used for uranium and curium. Data (White, Dunaway, and Wireman 1977) indicate that the transfer factor for americium would be a factor of 10 lower. Multiplication of the transfer factors by the individual radionuclide concentrations in the soil gave the activity of each radionuclide ingested per year. The total activity ingested would be about 5×10^{-6} Ci/yr. The calculated doses are given in Table 13-7.

For calculations of population dose by the ingestion pathways, it was assumed that a maximum of 10 people would be involved onsite. It is unlikely that more than 10 people would live on a 5-acre farm, deriving their entire diet, including animal products, from food produced on the 5 acres.

In evaluating inhalation from farming activities, it was assumed that the farm would be plowed and cultivated in 8 hr/yr, developing an airborne dust loading of 100 mg/m^3 . The concentration is a factor of 100 higher than that used in the excavation scenario. Other farming activities, conducted for 8 hr/day, would develop a dust loading of 1 mg/m^3 (Leddicotte et al. 1978). The dust loading due to normal air movement would be 0.1 mg/m^3 for the remaining 16 hr/day. Breathing rates would be $1.25 \text{ m}^3/\text{hr}$ during the 8 hr/day of activity and $1 \text{ m}^3/\text{hr}$ for the remaining 16 hr/day. The total concentration of radionuclides in the surface soil was taken to be the same as for the ingestion pathway, $1.6 \times 10^{-5} \text{ Ci/lb}$. The total activity inhaled was calculated to be $1.1 \times 10^{-7} \text{ Ci/yr}$. The calculated doses appear in Table 13-7.

Approximately 80% of the dust inhaled annually would be during activities other than plowing and cultivating. Thus, the population dose would be $(9 \text{ people} \times 0.8 \text{ maximum individual dose}) + (1 \text{ person} \times \text{maximum individual dose}) = 8.2 \times \text{maximum individual dose}$.

13.4.3.1.3 Erosion. It was assumed that the cover over the waste would have eroded after 100 yr, exposing the waste. Wind blowing across the exposed waste would pick up and transport radionuclides to populated areas. A representative wind speed of 7 mph was assumed.

13.4.3.1.4 Intrusion Following Erosion. It was conservatively assumed that the surface cover over the waste would have eroded completely after 100 yr. In the excavation scenario, the airborne dust would consist entirely of waste material, rather than consisting of 10% waste material. The dose would be higher, by a factor of ten, than that in the excavation scenario of the previous subsection. The results for this scenario appear in Table 13-7.

It was concluded that raising crops directly in the exposed waste material, after the soil cover had eroded away, would be unrealistic.

13.4.3.1.5 Erosion with Tornado. A tornado with winds of 100 mph was assumed to strike the waste after erosion had removed the protective cover. A release fraction of 3×10^{-3} was assumed.

13.4.3.1.6 Other Events. Other events that could lead to an airborne release include earthquakes and airplane crashes. Neither poses a hazard as serious as that of a volcanic eruption with lava flow. The lava flow event could involve all the stored waste. An airplane crash would affect only part of the waste, and the likelihood of occurrence would be less than for the lava flow scenario.

For the strong earthquake scenario in the long term, additional deterioration of the waste containers was assumed, with ten times as much waste becoming airborne as in the short-term scenario. Even so, the consequences would be much less than for the lava flow scenario. The likelihood of occurrence is somewhat less than that for lava flow over the waste.

13.4.3.2 Waterborne Accidental Releases.

13.4.3.2.1 Flooding from Precipitation or Snowmelt.

The existing dikes and diversion channels must be maintained to mitigate Big Lost River flooding. Otherwise, they would probably be ineffective within 50 yr. The probability of a large local surface runoff or a Big Lost River flood would be about once every 10 yr, based on INEL historical data. However, the consequences of these events for release of waterborne radionuclides were estimated to be 1/100 of the consequences following the Mackay Dam failure, discussed below.

13.4.3.2.2 Mackay Dam Failure. In the long term, the largest waterborne releases could result from failure of the Mackay Dam or a successor dam at that location. These consequences are evaluated for the short term in Subsection 13.4.2.2.2.

The hypothesized Mackay Dam failure could lead to both ingestion and inhalation of radionuclides. For the long-term scenario, evaluation of the ingestion pathway would be the same as for the short term. Only the projected population growth would noticeably change the results.

For the long-term analysis, the inhalation scenario again considered scouring of the TSA pads, and water deposition of radionuclides, with subsequent resuspension. It was assumed that confinement would be sufficiently deteriorated such that 50% of the waste would be scoured by the flood, of which 10% would remain in the top one inch of sediment. Particles less than 10 microns in diameter would be available for resuspension over an extended period of time. The fraction of the top particles less than 10 microns was again assumed to be 3×10^{-3} . The overall release fraction would thus be about 1×10^{-4} .

13.4.3.2.3 Glaciation. In the long term, climatic changes similar to those associated with past glaciations (ice ages) must be considered. The last major glacial advance in North America attained its maximum about 18,000 yr ago. Subsequent climatic fluctuations during its retreat occurred about 10,000 yr ago. In the INEL area, this event is reflected by several glacial moraines in the Lemhi Range (Dort 1962). A more detailed record of climatic fluctuations (altered precipitation/evaporation ratios) in the region is found in the sediments from ancient Lake Bonneville in northwestern Utah and Lake Lahontan in western Nevada (Morrison 1961, 1964, and 1965). The stratigraphy of Lake Lahontan shows five climatic fluctuations within the last 5000 yr. The largest climatic change in that area occurred about 3000 yr ago (Schulman 1956).

There is no evidence of past glacial ice within the INEL area. However, a future occurrence cannot be ruled out. Over the next 250,000 yr, and possibly the next 1000 yr, climatic fluctuations resulting in a prolonged period of high precipitation could occur. The main effect of a cooler and wetter climate would be an increased probability of flooding.

The INEL is located in a shallow topographic basin that receives flow from three drainages (Big Lost River, Little Lost River, and Birch Creek). This basin is connected to a larger basin to the east (Mud Lake), which is slightly lower in elevation. A trace of the 4900-ft contour suggests that the surface outflow of both basins would be from Mud Lake south to the Snake River.

In the event of prolonged periods of high precipitation, groundwater aquifers might become saturated, leading to the emergence of a large shallow pluvial lake. Because the depth of the lake would be governed by the elevation of the outlet (less than 4900 ft), the maximum depth would probably not exceed 100 ft. The RWMC is located at an elevation slightly above 5000 ft and would lie above the hypothetical pluvial lake. However, if surface flow from the Big Lost River were to become blocked with ice or runoff debris, flood waters could enter the RWMC and cover the area to a depth of a few feet. If the flood waters ponded for an extended period, or if a stream flow were present, erosion of the soil cover could lead to the release of waste. The waste would be deposited within the basin and would be subject to later airborne resuspension or transport into the Snake River.

Alternatively, deposition rather than erosion could occur. In this instance, the waste confinement could be entirely covered with detrital material. To determine which effect (erosion vs. deposition) would most likely occur in the event of extensive flooding, detailed examination of the surrounding topography and modeling of surface flow would be necessary.

The frequency of glacial activity can be inferred from other areas in the western United States. Three major advances occurred in the last 70,000 yr in the Rocky Mountain region. The early and late stages of the Bull Lake Glaciation and the Pinedale Glaciation took place at about 20,000-yr intervals. These events lasted about 5,000 to 10,000 yr and, in terms of erosion potential, would represent the worst case for the RWMC.

A shorter return period of glaciation would be represented by the Temple Lake stage of neoglaciation which occurred about 3,000 yr ago. This event was recorded in the sediments of ancient Lake Lahontan and lasted 500 to 1000 yr. The shortest time frame for glacial advances was derived from tree ring analyses that indicated periodic glacial advances in Alaska, the Canadian Rockies, and the Cascades during the last 500 yr. The most extensive of these glacial pulses occurred around 1850 (Matthews 1951, Hausser 1956, 1957; Sigafos and Hendricks 1961).

A return frequency of 3,000 to 20,000 yr would represent a more realistic estimate of prolonged periods of wet climate that could result in severe flooding or erosion at the RWMC.

A cross-sectional view of the RWMC (see Figure 3-6) indicates that the next glacial advance might deposit sedimentary soil rather than scour material. Based on the thickness of sedimentary deposits and glacial periods: (1) the 240-ft sedimentary layer may represent deposits from the Bull Lake Glaciation period, (2) the 110-ft sedimentary layer may represent deposits from the Pinedale Glaciation period, and (3) the surficial sedimentary layer may represent deposits during the last 10,000 yr. However, this speculation should be verified by radiocarbon dating of soils and an analysis of sorting pattern, angularity, and size distribution.

Since the event frequency for climatic change was based on past events, it could be altered by large quantities of CO_2 released into the atmosphere by fossil fuel burning during the past few centuries. The overall effect of CO_2 on climatic cycles is a matter of speculation.

Based on the historical evidence, a conservative estimate of the glaciation return period would be about 30,000 yr. The quantity of radionuclides leached would be greater than that discussed for the

Mackay Dam failure because there would be a longer duration of water infiltration. It was assumed that peak concentrations at the hypothetical wells would be 100 times that for the short-term scenario for Mackay Dam failure, before adjusting for radioactive decay to reflect the time of the scenario.

13.4.3.2.4 Lake or Swamp. The RWMC could be covered by a lake or swamp in the long term. Core drillings of the site and associated radiocarbon dating could provide a basis for assessing the return period of this event, which could be on the order of 1000 yr. The quantity of radionuclides leached would be greater than that discussed for the Mackay Dam failure because there would be a longer duration of water infiltration. It was assumed that peak concentrations at the hypothetical wells would be the same as for glaciation.

13.4.3.2.5 River Channel Alterations and Erosion. Based on the current topography of the Idaho Falls area, the Snake River would have to travel over hills 300 ft higher than its present channel to reach the RWMC. The likelihood of this event would be much smaller than for a glacial advance or for a lake forming over the site.

The estimated return period of an alteration of the Big Lost River channel such that it would reach the RWMC would be 1000 yr. The quantity of radionuclides leached would be greater than that discussed for the Mackay Dam failure because there would be a longer duration of water infiltration. Peak concentrations at the hypothetical wells were assumed to be the same as for glaciation.

13.4.3.2.6 Perturbation of the Groundwater System. A significantly higher rate of aquifer flux or a significant water table rise might occur with a return period on the order of 10,000 yr. This

event was estimated to have the same long-term effects as the Mackay Dam failure, before adjusting for radioactive decay to reflect the time of the scenario.

13.4.3.2.7 Climatic Fluctuations. Extremely severe climatic fluctuations could affect processes like glaciation or lake or swamp formation over the RWMC. Less severe climatic fluctuations could result in significantly increased precipitation or higher wind erosion of the site. A return period of 100 yr could be assumed for the latter type of event. The quantity of radionuclides leached would be similar to that discussed for glaciation.

13.5 IMPROVE CONFINEMENT (ALTERNATIVE 2)

13.5.1 Add Top/Side Barrier (Concept 2-a).

13.5.1.1 Summary. For Concept 2-a, the calculated dose and risk for events leading to accidental releases are summarized in Table 13-8. Subsection 13.4, which addresses Alternative 1, discusses the basic scenarios developed and the assumptions used for the evaluations. Only differences from these are discussed in the present subsection.

The largest short-term population risk and long-term population dose are associated with airborne release caused by lava flow over the waste. The dominant short-term event for waterborne accidental releases is failure of the Mackay Dam. For this scenario, the short-term population risk, based on dose commitment to the bone, is a factor of more than 10^6 smaller than that for airborne release due to lava flow over the waste. The dominant long-term waterborne releases are associated with glaciation, climate changes, and alteration of river channels.

13.5.1.2 Short-Term Risks.

13.5.1.2.1 Airborne Accidental Releases. Emplacing an additional barrier over the top and sides of the waste would not be expected to change significantly the effects of volcanic eruption directly under the waste. (See Subsection 13.4.2.1.1.) The effect of lava flow over the waste would be similar to that described in Subsection 13.4.2.1.2, but with a lower release fraction. The 10-ft clay and 3-ft riprap cover was assumed to reduce the release fraction to 1×10^{-4} , or a factor of 100 less than for the "leave as is" alternative.

In a strong earthquake (see Subsection 13.4.2.1.3) or in a tornado (see Subsection 13.4.2.1.4), the clay cover would tend to minimize exposure of the waste. The earthquake scenario was assumed to lead to dose and risk values 25% of those for Alternative 1. As with Alternative 1, a tornado would not be expected to result in radionuclide releases.

The doses and risks associated with accidental breach of waste containers while emplacing the barrier over the waste were found to be small compared with doses and risks for disruptions caused by the forces of nature.

13.5.1.2.2 Waterborne Accidental Releases. Flooding of the RWMC could occur as described for Alternative 1 in Subsection 13.4.2.2. The cover over the waste would reduce the effects of floodwater on the waste and would further mitigate the already low risk. It was assumed that, compared with Alternative 1, the scouring effect would be reduced by a factor of 50, as would the resulting dose and risk values for the pathway involving resuspension and airborne

transport. It was assumed that infiltration would be reduced by a factor of 5, as would the resulting dose and risk values for the waterborne pathway via the Snake River Plain Aquifer.

13.5.1.3 Long-Term Effects.

13.5.1.3.1 Airborne Accidental Releases. It was assumed that, after 2085, the 10-ft clay cover would have been removed by precipitation, and the riprap cover would have eroded significantly. Therefore, the long-term airborne releases would be about the same as for Alternative 1 (see Subsection 13.4.3.1).

13.5.1.3.2 Waterborne Accidental Releases. Because the engineered improvements were assumed to have negligible benefit after 2085, the waterborne releases would be the same as described for Alternative 1 in Subsection 13.4.3.2.

13.5.2 Add Top, Side, and Bottom Barriers (Concept 2-b).

13.5.2.1 Summary. For Concept 2-b, the calculated dose and risk for events leading to accidental releases are presented in Table 13-9. Only differences from the evaluation of Alternative 1 (see Subsection 13.4) are discussed here.

The largest short-term population risk and long-term population dose are associated with airborne release caused by lava flow over the waste.

The dominant short-term event for waterborne accidental releases is failure of the Mackay Dam. For this scenario, the short-term population risk, based on dose commitment to the bone, is smaller than that for airborne release due to lava flow over the waste by a factor

of more than 10^7 . The dominant long-term waterborne releases are associated with glaciation, climate change, and alteration of river channels.

13.5.2.2 Short-Term Risks.

13.5.2.2.1 Airborne Accidental Releases. It was assumed that the effects of volcanic eruption directly under the waste would be the same as described for Alternative 1 in Subsection 13.4.2.1.1. The effect of lava flow over the waste would be similar to that described in Subsection 13.4.2.1.2, but with a lower release fraction. The improved confinement (10-ft clay and 3-ft riprap cover and grout-injected bottom barrier) was assumed to reduce the release fraction to 1×10^{-4} , or a factor of 100 less than for the "leave as is" alternative.

In a strong earthquake (see Subsection 13.4.2.1.3) or in a tornado (see Subsection 13.4.2.1.4), the clay cover would tend to minimize exposure of the waste. The earthquake scenario was assumed to lead to dose and risk values 25% of those for Alternative 1. As with Alternative 1, a tornado would not be expected to result in radionuclide releases.

Again, the dose and risk for accidental breach of waste containers during construction were found to be small compared with doses and risks, for disruptions caused by the forces of nature.

13.5.2.2.2 Waterborne Accidental Releases. The cover over the waste would reduce the effects of flooding. The grout-sealed strata would form an additional barrier to prevent water migration to the aquifer. It was assumed that, compared with Alternative 1, the scouring effect from Mackay Dam floodwaters would be reduced by a factor of 50, as would the resulting dose and risk values for the

pathway involving resuspension and airborne transport. It was also assumed that infiltration would be reduced by a factor of 20, as would the resulting dose and risk values for the waterborne pathway via the Snake River Plain Aquifer.

13.5.2.3 Long-Term Effects.

13.5.2.3.1 Airborne Accidental Releases. The long-term airborne releases would be about the same as described for Concept 2-a in Subsection 13.5.1.3.1. The grout sealing of the strata beneath the TSA pads would have little if any effect on airborne releases after 2085.

13.5.2.3.2 Waterborne Accidental Releases. It was assumed that, in the long-term, the engineered improvements would have negligible benefit in reducing waterborne releases. Therefore, the waterborne releases would be the same as for Alternative 1 (see Subsection 13.4.3.2).

13.5.3 Immobilize in Place (Concept 2-c).

13.5.3.1 Summary. For Concept 2-c, the calculated dose and risk for events leading to accidental releases are presented in Table 13-10. The largest short-term population risk and long-term population dose are associated with airborne release caused by lava flow over the waste.

The dominant short-term event for waterborne accidental releases is failure of the Mackay Dam. For this scenario, the short-term population risk, based on dose commitment to the bone is smaller than that for airborne release due to lava flow over the waste by a factor of 10^8 . The dominant long-term waterborne releases are associated with glaciation, climate change, and alteration of river channels.

13.5.3.2 Short-Term Risks.

13.5.3.2.1 Airborne Accidental Releases. It was assumed that, as a result of immobilization, the source release and resulting dose and risk values would be reduced by a factor of 100 (Leddicotte et al. 1978), compared with the "leave as is" alternative, for any scenario.

Again, the dose and risk associated with breach of waste containers during construction were found to be small compared with the doses and risks for disruptions caused by the forces of nature.

13.5.3.2.2 Waterborne Accidental Releases. Compared with Alternative 1, the immobilization would reduce the source release in flooding. It was assumed that, compared with Alternative 1, the scouring effect from Mackay Dam floodwaters would be reduced by a factor of 1000, as would the resulting dose and risk values for the pathway involving resuspension and airborne transport. It was assumed that infiltration would be reduced by a factor of 100, as would the resulting dose and risk values for the waterborne pathway via the Snake River Plain Aquifer.

13.5.3.3 Long-Term Effects

13.5.3.3.1 Airborne Accidental Releases. It was assumed that immobilization would reduce the source release by a factor of 100 for any pathway for the first 400 yr (Leddicotte et al. 1978). After that time the grout-immobilized waste would have reverted to a powder form, so no credit was taken for the improved confinement.

The results for long-term airborne releases in Table 13-10 reflect the factor of 100 reduction in source release assumed for scenarios occurring in 2085. For lava flow, results are also given

for the scenario occurring 10,000 yr in the future. Because the confinement would have deteriorated by that time, no credit was taken for reduction in source release.

13.5.3.3.2 Waterborne Accidental Releases. It was estimated that for the first 400 yr, compared with Alternative 1, the scouring effect and the resulting doses would be reduced by a factor of 1000 for the pathway involving resuspension and airborne transport. Infiltration effects would be reduced by a factor of 100, as would the resulting doses for the waterborne pathway via the Snake River Plain Aquifer. The results for long-term waterborne releases in Table 13-10 reflect scenarios occurring in 2085. After 400 yr, no benefit would be expected from the engineered improvement. The consequences would be similar to the Alternative 1 results for scenarios occurring at the same point in time.

13.6 RETRIEVE, PROCESS, AND SHIP TO THE FEDERAL REPOSITORY (ALTERNATIVE 3)

This subsection discusses the dose and risk calculated for the various modules within Alternative 3. These dose and risk results are added in Table 13-19 to give the total dose and total risk for the alternative.

Except for the topic discussed in the following introductory paragraph, only short-term doses and risks are relevant for this alternative. Within 10 yr, the waste would be located at the Federal Repository, outside the INEL boundaries. (The risk presented by the waste at the Federal Repository is being addressed in other DOE-funded studies.) The same discussion holds for Alternatives 4 and 6, except that the waste would not all be at the Federal Repository until 30 yr had passed.

The possibility of volcanic action, discussed under Alternative 1, would exist also during a campaign to retrieve and process the waste. The retrieval and processing facilities would provide some protection against the effects of lava flow, but little or no protection against an explosive eruption. Furthermore, during the campaign, much of the waste would still be on the TSA pads, exposed as in Alternative 1. On the other hand, the amount of waste remaining on the pads would decrease during the campaign, reaching zero at the campaign completion.

For convenience, the volcanic action scenarios were addressed in connection with retrieval and are discussed in Subsection 13.6.1. In the interest of conservatism, the same release fractions were assumed as for the corresponding scenarios in Alternative 1.

The above rationale applies also to other natural phenomena discussed in the short-term risk analysis for Alternative 1. One example is flooding of the RWMC. Because the volcanic scenarios are the dominant short-term natural events, they are the only events of this type discussed in connection with Alternative 3.

13.6.1 Direct-Control Retrieval

13.6.1.1 Summary. For direct-control retrieval, the calculated dose and risk for events leading to airborne accidental releases are presented in Table 13-11. Waterborne accidental releases would be negligible. The dominant event was determined to be release caused by lava flow over the waste, as in Alternative 1. The operations-related event leading to the largest short-term population risk was determined to be a major fire in the retrieval facility.

13.6.1.2 Airborne Accidental Releases.

13.6.1.2.1 Volcanic Activity. The effects of volcanic action during direct-control retrieval would be similar to those evaluated in Subsections 13.4.2.1.1 and 13.4.2.1.2.

13.6.1.2.2 Tornado. A tornado could strike the TSA during the 10-yr retrieval campaign. The tornado history of the area is discussed in Subsection 13.4.2.1.4. The projected area of the TSA retrieval facility would be approximately $150 \times 150 \text{ ft} = 8 \times 10^{-4}$ square mile. The estimated probability of tornado damage to the facility, based on the tornado damage zone area, would be $5 \times 10^{-7}/\text{yr}$.

If a tornado were to touch down at the TSA while retrieval was under way, some of the 55-gal drums could be scattered and breached. It was assumed that one row of drums would be displaced. If the 150-ft width of the pad were completely filled with 55-gal drums, approximately 300 could fall onto the pad. It was assumed that 10% of those drums would be breached and that 10^{-3} of the waste from the breached drums would be released from the pad and dispersed. The estimated volume of waste released is: $(300 \text{ drums} \times 0.10 \times 7.4 \text{ ft}^3/\text{drum} \times 10^{-3}) = 0.22 \text{ ft}^3$. This represents an inventory release fraction of about 1×10^{-7} .

13.6.1.2.3 Earthquake. An earthquake during retrieval operations was estimated to have a much smaller effect than that associated with volcanic action or a tornado.

13.6.1.2.4 Dropping of a Waste Container. Dropping of a drum or a box during retrieval operations was considered. On the average, the following number of containers would be handled daily in the retrieval facility:

Boxes:	4/day @ $112 \text{ ft}^3/\text{box}$
Drums:	60/day @ $7.4 \text{ ft}^3/\text{drum}$
Bins:	0.1/day @ $120 \text{ ft}^3/\text{bin}$

An accidental drop was estimated to occur at a frequency of 1×10^{-5} per handling operation, based on RWMC experience. The frequency of the accident would therefore be about $1 \times 10^{-1}/\text{yr}$ ($64 \text{ containers/day} \times$

220 days/yr). A conditional probability of 1×10^{-1} was assumed that the contents would become exposed upon impact, thereby adjusting the probability of a breached container to 1×10^{-2} /yr.

There would be a total of about 1000 ft^3 or 210 Ci of waste retrieved per day. The calculated average container size would be about 15 ft^3 (3 Ci). A fraction, 1×10^{-4} , of the contents would become airborne when the accidental drop occurred. The fraction of the total waste inventory entering the facility filter system would be $(3 \text{ Ci} \times 10^{-4} \text{ airborne fraction}) / (4.2 \times 10^5 \text{ Ci}) \sim 7 \times 10^{-10}$. The filter system would reduce this release by a factor of 1×10^3 .

The retrieval facility filter could be inoperable at the time of the accident. However, the likelihood of this combination of events is extremely small. Filter performance would be checked by continuously monitoring radioactivity in the stack effluent. An annunciator would be used to indicate any off-standard filter performance. Automatic switchover to a backup filter system would be effected at any indication of filter deficiency. This accident scenario was not included in the summary table because of its extremely low probability.

13.6.1.2.5 Waste Container Penetration. A drum or box of waste could be penetrated by a forklift. The estimated probability of this event is 1×10^{-5} per container handled, based on RWMC experience. The frequency of this accident would be about the same as that for dropping a container. However, since the conditional probability of a breach upon penetration would be one, the frequency of a breach would be 1×10^{-1} /yr. Because of the smaller expected size of the breach, the fraction of the waste involved that would become airborne was estimated to be 1×10^{-6} , two orders of magnitude less than that for release from a dropped and breached container.

13.6.1.2.6 Aircraft Impact. The evaluations included the possibility of impact of a large aircraft on the retrieval facility, with a resulting fire. It was assumed that the collision and ensuing fire would breach waste containers, releasing waste to the atmosphere.

The estimated frequency of an aircraft impact would be 4.6×10^{-7} /yr for an area of 0.14 square mile (Wall 1974). Fire was assumed to develop in 1/3 of such accidents (McSweeney and Hall 1975). Based on the projected area of the TSA retrieval facility of $22,500 \text{ ft}^2$, the frequency of an aircraft impact accompanied by a fire was estimated to be approximately 9×10^{-10} /yr.

Two rows of $4 \times 4 \times 7 \text{ ft}$ boxes, stacked four high and twenty-one across ($18,800 \text{ ft}^3$), were assumed to be exposed during normal retrieval operations. It was assumed that 10% of the exposed waste containers would be breached and involved in the ensuing fire, and that 1×10^{-2} of that waste would become airborne (Mishima 1974, Mishima and Schwendiman 1973b). The fraction of the total inventory released would be about $(18,800 \text{ ft}^3 \times 10^{-1} \times 10^{-2}) / (2 \times 10^6 \text{ ft}^3) \sim 9 \times 10^{-6}$. The facility was assumed not to provide any confinement.

13.6.1.2.7 Fire During Retrieval Operations. A major fire at the retrieval facility could cause a release of radionuclides. Initiation of a fire inside the facility would not be likely because no fuel would be stored inside (the retrieval equipment would be battery-operated). There would also be an insufficient percentage of combustible material within the single-walled steel structure to support combustion. However, an external fire, (e.g., a fuel spill from a truck or a range fire) could burn through the two-foot inflatable seal around the base of the facility. The probability of a fire of this severity was assumed to be 1×10^{-3} /yr.

The wooden boxes along the sides of the TSA pads were assumed to be affected by the fire. These boxes would be stacked four high about 2 to 4 ft from the wall of the retrieval structure, with the overburden removed during normal operations. It was assumed that, two adjacent columns (8 boxes) would burn as a result of the chimney effect. It was assumed that 10% of the waste would burn before the fire could be contained. This fraction would represent 40% of the combustible waste within the boxes of interest. An airborne fraction of 1×10^{-2} (Mishima 1974) was assumed to escape through the breached seal. Thus, the total inventory fraction released within the facility would be $(8 \times 112 \text{ ft}^3 \times 10^{-1} \times 10^{-2}) / (2 \times 10^6 \text{ ft}^3) \sim 4 \times 10^{-7}$. A 90% credit was assumed for retrieval facility confinement capability, in spite of the breached seal.

13.6.1.2.8 Transfer Accident. A truck accident during transfer of waste from the retrieval facility to the processing facility was considered. The Sandia Laboratories accident classification scheme (Clarke et al. 1976) was used to provide conditional probabilities of occurrence for truck shipment accidents ranging from minor to extremely severe. An accident of severity-class III would be required to cause a fractional release from a truck (for PuO_2) of about 1×10^{-3} (Clarke et al. 1976). Clarke et al. provided a conditional probability of 0.07 for such an accident. Truck accident frequencies range from 1.6 to 2.5 accidents/ 10^6 truck-miles. The lower value, reduced by a factor of 10 because of the committed roadways and use of a speed governor, was assumed for the RWMC transfer system, i.e., 1.6×10^{-7} accident/truck-mile. Thus, the probability of a release would be $(1.6 \times 10^{-7} \text{ accident/mile} \times 0.25 \text{ mile/trip} \times 0.07 \text{ conditional probability of release/accident} \times 540 \text{ trips/yr}) \sim 1 \times 10^{-6} / \text{yr}$.

An airborne release fraction of 1×10^{-4} from one breached box was assumed. (This is lower than the value of 1×10^{-3} used by Clarke et al., because a different form of material would be involved.) The total inventory release fraction would be $(112 \text{ ft}^3 \times 10^{-4}) / (2 \times 10^6 \text{ ft}^3) \sim 6 \times 10^{-9}$.

A transfer accident accompanied by a fire could increase the airborne release fraction to 1×10^{-2} . The conditional probability of such a fire would be 1.6×10^{-2} (Clarke et al. 1976), yielding a frequency for a release in a fire accident of approximately $3 \times 10^{-7} / \text{yr}$. It was assumed that one box of waste would be breached in an accident with a fire, and that 1×10^{-2} of the contents would become airborne. The total inventory release fraction would be 6×10^{-7} .

13.6.1.2.9 Loss of Electric Power. The TSA retrieval building would not depend on offsite power, but on power from a trailer-mounted diesel generator located outside the enclosure. All workers would be able to evacuate the building safely. Because there would be no exposed (loose) waste in the building during normal operations, a power failure would not be expected to result in releases to the environment.

13.6.1.3 Waterborne Accidental Releases. Migration of radionuclides to the aquifer as a result of retrieval operations would not be expected.

13.6.2 Slagging Pyrolysis and Packaging.

13.6.2.1 Summary. For slagging pyrolysis, the calculated dose and risk for events leading to airborne accidental releases are presented in Table 13-12. Waterborne accidental releases would be negligible. The event with the largest population risk was determined to be an explosion within the processing facility.

13.6.2.2 Airborne Accidental Releases.

13.6.2.2.1 Dropping of a Waste Container. A waste container could be breached due to a handling accident in the waste preparation area. The airborne radioactivity within the facility would be about the same as that calculated in Subsection 13.6.1.2.4. However, if both HEPA filters were operational, the amount released to the environment would be smaller by a factor of 1000 than that in the case of retrieval. The estimated frequency of this event (see Subsection 13.6.1.2.4) is $1 \times 10^{-2}/\text{yr}$.

Dropping of a container of waste after processing would not be expected to result in a release. Impact testing of containers of vitrified waste from drop heights of 30 ft did not result in containment breach (Smith and Ross 1975). In the shipping area, the maximum height from which a slag container could be dropped would be about 15 ft. Furthermore, in the tests referenced (Smith and Ross 1975), the breakup fraction of the waste was extremely small. On the order of 1×10^{-6} of the original contents was broken into particles less than 10 microns in diameter. Thus, even if a container were to fail, only an extremely small fraction of the slag would become airborne.

13.6.2.2.2 Fire in the Processing Facility. A fire in any of the three processing areas, with sufficient intensity to destroy one HEPA filter in a series of two, was considered a potential accident. The estimated frequency of such an event is $1 \times 10^{-2}/\text{yr}$.

About 2000 ft^3 of waste would be available for combustion in the waste preparation area, based on a surge capacity of two days supply. Recent fire experiments indicated that 5 to 10% of the simulated waste burned. It was therefore assumed that 10% of the 2000 ft^3 of waste would burn in the waste preparation area,

with an airborne fraction of 1×10^{-2} . The total inventory fraction released within the facility would be $(2000 \text{ ft}^3 \times 10^{-1} \times 10^{-2}) / (2 \times 10^6 \text{ ft}^3) = 1 \times 10^{-6}$. A DF of 10^3 was assumed for the remaining HEPA filter.

The surge capacity of the incinerator feed supply, in the pyrolysis area, would be about 20 ft^3 . An airborne fraction of 1×10^{-2} was assumed for a fire involving the waste in this area. The release quantity would be a factor of 100 less than that in the waste preparation area, because of the smaller surge capacity.

If a fire were to occur in the shipping area (which would also have a two-day surge capacity), the resulting release to the environment from the slag product would be considerably less than from the untreated waste. It was assumed that 10% of the containers would be breached by the fire, with an airborne fraction of 1×10^{-5} . The total inventory fraction released within the facility would be, based on waste volume before processing, $(2000 \text{ ft}^3 \times 10^{-1} \times 10^{-5}) / (2 \times 10^6 \text{ ft}^3) = 1 \times 10^{-9}$. A DF of 10^3 was assumed with one HEPA filter functional.

No potential was identified for a fire severe enough to burn through the reinforced concrete walls of the facility. Nor was any fire potential identified capable of destroying the second HEPA filter in series in the ventilation system. Both HEPA filters would be protected by fire dampers and sprinklers and would be remote from any location where waste would be handled in the facility.

13.6.2.2.3 Explosion. It is conceivable that an explosion could occur within the facility. The most likely area would appear to be the slagging pyrolysis area. Explosions in other areas of the facility would be expected to be much less likely or less severe.

No reference data were located for TRU waste release fractions resulting from explosions. An airborne fraction of 1×10^{-1} for an explosion involving 250 ft^3 of waste in the slagging pyrolysis unit was assumed. The total inventory fraction released within the facility would be $(250 \text{ ft}^3 \times 10^{-1}) / (2 \times 10^6 \text{ ft}^3) = 1 \times 10^{-5}$. The assumed frequency of this event was at least $1 \times 10^{-3}/\text{yr}$. It was assumed that, in most cases, at least one of the HEPA filters would remain functional, giving a DF of at least 10^3 . It was conservatively estimated that the conditional probability of a given explosion creating an open path to the atmosphere (DF of 1.0) would be 1×10^{-2} .

A less severe explosion was postulated in the waste preparation area, involving 50 ft^3 of waste. An airborne fraction of 1×10^{-1} was assumed, for a total inventory release fraction of $(50 \text{ ft}^3 \times 10^{-1}) / (2 \times 10^6 \text{ ft}^3) = 2 \times 10^{-6}$. A frequency of $1 \times 10^{-3}/\text{yr}$ was again assumed.

13.6.2.2.4 Tornado. The probability of a tornado hitting the facility would be similar to that generated in Subsection 13.4.2.1.4. The facility would be located on 1.4 acres, an area much less than the tornado damage area of 0.01 square mile (6.4 acres). Therefore, the probability of a tornado hitting this area was determined by the tornado damage zone to be $5 \times 10^{-7}/\text{yr}$.

The internal portions of the facility would be tornado-resistant because of the reinforced concrete construction. Included are the waste preparation area and the slagging pyrolysis area. (It is conceivable that a tornado of unusual severity could strike the facility and cause failure of the tornado-resistant structures. However, the probability of such an occurrence would be orders of magnitude lower than the value of $5 \times 10^{-7}/\text{yr}$ for more representative tornadoes.)

It was assumed that the incinerator off-gas ductwork leading to the HEPA filter system could be severely damaged in a tornado. Based on an assumed shutdown time for the incinerator, the release quantity (prior to shutdown) is estimated in the following paragraph.

If the off-gas ducts were damaged, the incinerator air supply would immediately switch to cold air. Incinerator shutdown was estimated to take place in about 30 min, limiting the radioactivity released with the stack gases. The residence time of waste in the incinerator would be about 6 hr. Based on a volumetric flow rate of about 42 ft^3 of waste/hr, the incinerator inventory of waste would be about 250 ft^3 . The incinerator would require preheated air at a rate of 24 tons/hr. A stack gas flow rate of $7 \times 10^5 \text{ ft}^3/\text{hr}$ was used. Mass loading was conservatively assumed to be $100 \text{ mg}/\text{m}^3$, a factor of 100 higher than that assumed by Leddicotte et al. (1978). The mass release through the stack would thus be about $(7 \times 10^5 \text{ ft}^3/\text{hr} \times 0.5 \text{ hr} \times 0.1 \text{ g}/\text{m}^3) = 1000 \text{ g}$. From Table 13-6, the activity concentration is $13.2 \times 10^{-6} \text{ Ci/g}$. Thus, the stack release would be $1000 \text{ g} \times 13.2 \times 10^{-6} \text{ Ci/g} \sim 1.3 \times 10^{-2} \text{ Ci}$.

Because of the necessity to provide for loadout of processed waste, not all boundaries of the shipping area would be tornado-resistant. It was assumed that 2000 ft^3 of waste (based on volume before processing) would be affected. The potential impact velocities of the waste containers in a tornado are not known. If the velocities were as high as 100 ft/sec, the breakup fraction (less than 10 microns) of the slag could be as high as 1×10^{-4} (Smith and Ross 1975). It was assumed that 10% of the broken slag would escape the containers (Smith and Ross 1975). Thus, the total inventory release fraction could be as high as $(2000 \text{ ft}^3 \times 10^{-4} \times 10^{-1}) / (2 \times 10^6 \text{ ft}^3) = 1 \times 10^{-8}$.

13.6.2.2.5 Other Events. Other accidents evaluated but found to have less risk to the public than those already discussed include: (1) a break in a process line, and (2) an airplane impact on the facility.

The possibility of a criticality accident during processing of transuranic materials would be minimized by maintaining a record of the flow of transuranic materials, as discussed in Subsection 9.1.2. The second administrative control would cover material retrieved, processed, and shipped. Estimates of the consequences to the public of a criticality accident in the incinerator or in supporting equipment would be highly speculative at present.

13.6.2.3 Waterborne Accidental Releases. The accidents postulated for slagging pyrolysis would not lead to any discernible release to water. In the event of an explosion sufficiently severe to damage the filter system or the facility structure, some contamination would be ejected to the ground next to the processing building. Area decontamination procedures would be undertaken, perhaps including removal of surface soil, before the radionuclides could be carried into surface or subsurface waters.

13.6.3 Shipping of Slag to the Federal Repository.

13.6.3.1 Summary. For shipment to the Federal Repository, the calculated dose and risk for events leading to airborne releases are presented in Table 13-13. The dominant population risk would result from a train accident in a rural area. The risk of waterborne releases was estimated to be small compared to that for airborne releases.

13.6.3.2 Airborne Accidental Releases. The shipment route assumed for the risk calculations is shown in Figure 9-10. The actual route has not yet been selected. A one-way, 1411-mile trip would require about 6 days. The estimated shipping rate would be 190 cars/yr.

The population densities along the postulated route have been categorized as "urban" for the Denver-Boulder area, "suburban" for the Colorado Springs and Pueblo areas, and "rural" for the remainder. Distances through "urban," "suburban," and "rural" areas were estimated to be 35, 50, and 1326 miles, respectively. The population density of the rural areas was assumed to be the same as the average density for the INEL population distribution. For the suburban and urban areas, density multiplying factors of 8 and 70, respectively, were used to approximate the population densities used by McSweeney and Hall (1975).

The accident frequency for railroad freight cars was assumed to be 1.2×10^{-8} "serious" accidents (car damaged beyond repair) per car-mile (Adcock and McCarthy 1977). Through June 1976, a total of 553 carloads of TRU waste had been shipped from Rocky Flats to the RWMC (a distance of about 800 miles) with no "serious" accidents (Adcock and McCarthy 1977). This data base covers about 440,000 car-miles. Three unusual events, including one derailment, have been recorded in rail shipments since 1970 (see Subsection 4.3.4, Table 4-4). However, in none of these events was there any breach of confinement.

An engineering evaluation has been conducted of the safety features of the ATMX rail car (Adcock and McCarthy 1977). The evaluation concluded that most of the rail car accidents normally classified as "serious" would not result in significant damage to cargo. Only under the most severe conditions would there be a significant possibility of release of radionuclides to the environment. The two following conditions were judged to be requisite for a release to the environment:

- (1) The train carrying waste collides with a second train at a net impact speed of more than 70 mph. A 30- to 60-min fire follows the crash. This accident was defined as "extra severe" (AEC 1972).
- (2) As a consequence of the collision just described, a strong, pointed object (e.g., a rail ripped from the roadbed in the collision) punctures the outer steel wall of the rail car. Only this type of railroad accident, associated with the "extra severe" accident above, was judged capable of breaching the ATMX rail car (Adcock and McCarthy 1977).

The frequency of the "extra severe" accident, based on interpretation of data presented in AEC 1972, would be 1.6×10^{-12} /car-mile. (This value is considerably lower than the rate of 1.2×10^{-8} /car-mile for "serious" accidents.) It was conservatively assumed that all "extra severe" accidents would involve penetration of a rail car by a pointed object. The frequency of breach of containment would, therefore, be 1.6×10^{-12} /car-mile.

Railroad regulations prohibit high-speed operation in urban areas. However, a low-speed head-on collision of two trains could still occur in an urban area. An accident of this type could involve a net impact velocity great enough for a classification of "severe" but probably not "extra severe" (AEC 1972). Such an accident was judged not capable of breaching the ATMX railcar. Thus, no release of radioactive material would be expected.

Based on the assumed values of shipping rates and shipping distance, fractions of the route in urban, suburban, and rural areas, and rate of "extra severe" accidents; the annual frequencies of such accidents would be 0 (urban), 2×10^{-8} (suburban), and 4×10^{-7} (rural).

The fraction of waste that would become airborne, after being subjected to container rupture forces, would depend on the waste form. Directly usable data for the airborne fractions are not available for the slag. Therefore, test data (Smith and Ross 1975) for simulated high-level waste immobilized in glass were used as a benchmark for estimating release fractions.

It was assumed that shock absorption by the railcars would reduce the effective impact velocity of the waste containers to half of the initial value. At this container velocity of 35 mph (50 ft/sec), the best-estimate curve for vitrified waste (Smith and Ross 1975) shows that 1×10^{-5} would be the fraction of glass that would break into particles of less than 10 microns equivalent diameter.

Because of the similarities between the cast slag product and vitrified waste, the fraction of particles less than 10 microns in size was taken to be the same value of 1×10^{-5} . Of this fraction, it was assumed 10% escaped from the breached container and the breached railcar (Smith and Ross 1975). The overall release fraction would therefore be 1×10^{-6} for any container breached in the postulated accident.

The number of drums likely to be penetrated has been evaluated as three (DOE 1978a). Each drum would hold 7.4 ft^3 of waste at 0.41 Ci/ft^3 . The total inventory release fraction for the postulated accident would therefore be $(3 \times 7.4 \text{ ft}^3 \times 0.41 \text{ Ci/ft}^3 \times 10^{-6}) / (4.2 \times 10^5 \text{ Ci}) = 2 \times 10^{-11}$.

13.6.3.3 Waterborne Accidental Releases. Waterborne releases of radionuclides resulting from the shipping accident described in Subsection 13.6.3.2 would result in a low level of risk. The frequency of such an event was estimated as 2 to 3 orders of magnitude less than those in Table 13-13. For radionuclides to be released to water, the accident would have to cause a train to fall into

a river or lake, or to occur during a heavy rain with local flooding. Water would have to penetrate the car through the punctured opening, dissolve the waste, and cause radionuclides to migrate out of the car.

The slag would be relatively insoluble in water. It would take some time for the water penetration and radionuclide migration to occur. During that time, mitigative measures would probably take place, such as sealing the breach or recovering the car.

Prolonged leaching was conservatively estimated to result in a waterborne release fraction on the order of 1×10^{-6} for a breached container. [This estimate was based on a slag surface area of 25 ft² before the accident, an area increase of a factor of 5 due to the accident (Smith and Ross 1975), slag weight of 1300 lb, solubility of 1×10^{-6} g/cm²/day (based on preliminary tests), and 5 days leaching.] This fraction is about the same as that estimated for an airborne release. The dose resulting from this release scenario would depend on the details of the waterborne pathway to populations, but would generally be expected to be less than the dose resulting from an airborne release of the same quantity of material.

Thus, both the probability and consequences of waterborne releases in shipping accidents would be expected to be less than for airborne releases.

13.7 RETRIEVE, PROCESS, AND DELAY SHIPMENT TO THE FEDERAL REPOSITORY 20 YEARS (ALTERNATIVE 4)

The risks associated with retrieval and processing by slagging pyrolysis for Alternative 4 would be the same as those for corresponding modules of Alternative 3 (see Subsections 13.6.1 and 13.6.2). The risks for shipping slag to the Federal Repository would be similar to those discussed in Subsection 13.6.3, except for adjustments of a few percent downward for radioactive decay and upward for population

growth. Such changes are not detectable within the accuracy of the present analysis. In addition, there would be risk associated with the 20-yr storage operation, as described below.

The surface facilities for 20-yr storage of processed waste are described in Subsection 9.2. Events affecting the waste placed into storage after incineration would have lower risk than those for the untreated waste. The slag product would be free from combustible materials, relatively immobile, and of low leachability. The pre-stressed concrete facilities for 20-yr storage would be expected to provide confinement superior to that currently provided on the TSA pads. Because of these factors, the risks associated with this module would be considerably smaller than the short-term risks for Concept 2-b (see Subsection 13.5.2), after the minor corrections required for radionuclide decay and population growth.

Dropping a container of slag during emplacement in the storage facility would not be expected to result in a significant release, for the reasons presented in Subsection 13.6.2.2.1.

The same type of accident could occur during transfer of the slag from the process facility to the storage facility as during transfer of untreated waste from the retrieval facility to the process facility (see Subsection 13.6.1.2.8). However, the risks would be several orders of magnitude less than those discussed previously. The release fractions from the slag would be much smaller than for untreated waste.

13.8 RETRIEVE, PROCESS, AND DISPOSE OF AT THE INEL (ALTERNATIVE 5)

The risks associated with retrieval and processing by slagging pyrolysis for Alternative 5 would be the same as those for corresponding modules for Alternative 3 (see Subsections 13.6.1 and 13.6.2).

13.8.1 Compaction and Immobilization.

13.8.1.1 Summary. For waste compaction and immobilization, the calculated dose and risk for events leading to airborne releases are presented in Table 13-14. Waterborne accidental releases would be negligible. The event leading to the largest risk was determined to be a fire in the compaction area.

13.8.1.2 Airborne Accidental Releases. Accidents that could occur during compaction and immobilization of the stored waste would generally be similar to those discussed for slagging pyrolysis in Subsection 13.6.2.2. One significant difference is that a surge capacity would not be maintained. The estimated inventories, based on waste processing rate and residence time, were 200 ft³ for the waste preparation area, and 800 ft³ for the compaction area.

The evaluation of handling accidents in the waste preparation area was identical to that in Subsection 13.6.2.2.

For handling accidents in the compaction area, it was assumed that the compacted waste would be processed at a rate of 36 containers/day with 16 ft³ of compacted waste/container. The frequency of dropping a container of waste was estimated to be 8×10^{-2} /yr, based on a drop probability of 1×10^{-5} /container handled and an assumption of 7920 containers/yr. A conditional probability of 1×10^{-1} was assumed for the breaching of a dropped container. A spill of all the waste in one container would result in an airborne release of $(16 \text{ ft}^3 \times 0.35 \text{ Ci/ft}^3 \times \text{an airborne release fraction of } 10^{-4}) / (4.2 \times 10^5 \text{ Ci}) = 1 \times 10^{-9}$ of the total waste inventory.

Aside from the differences in the inventories involved, the assumptions made concerning a fire or an explosion in the facility were the same as those in Subsection 13.6.2.2. However, no potential source was identified for an explosion strong enough to breach the

walls of the facility or to fail both HEPA filters and their associated blast dampers. The explosion scenario for the compaction area is the same as that for the waste preparation area.

During immobilization operations, the inventory in the aging, packaging, and shipping area would be equivalent to nearly 20,000 ft³ of precompacted waste. Concrete curing would require approximately 20 days. Because of protection provided by the concrete packaging, radionuclide releases during this phase would not be expected from the types of accidents discussed for slagging pyrolysis.

13.8.1.3 Waterborne Accidental Releases. As discussed in Subsection 13.6.2.3, no pathways were identified leading to waterborne releases.

13.8.2 Packaging Only. For packaging of the waste, the calculated dose and risk for events leading to airborne releases are given in Table 13-15. No pathways were identified leading to waterborne releases. The event leading to the greatest risk was determined to be a fire in the packaging area or shipping area.

Except for dropping a container, accidental releases during packaging operations would be the same as those described in Subsection 13.8.1. The waste would be packaged in 7.4-ft³ drums. A spill from a dropped container would result in a release of $(7.4 \text{ ft}^3 \times 0.21 \text{ Ci/ft}^3 \times \text{an airborne release fraction of } 10^{-4}) / (4.2 \times 10^5) = 4 \times 10^{-10}$ of the total waste inventory. It was assumed that 170 containers would be processed daily in a 220-day work yr. Based on RWMC experience in handling operations, the frequency of such an event would be 4×10^{-1} /yr. A conditional probability of 1×10^{-1} was assumed for the breaching of a dropped container.

The accidents considered in the shipping area included a fire, an explosion, and a dropped container. The quantity of waste involved was assumed to be the same as in the packaging area. Therefore, the dose and risk would be unchanged.

13.8.3 Shipment of Processed Waste to INEL Disposal Locations.

This subsection discusses possible accidental releases during truck shipment of processed waste to the Lemhi Range, Site 14, or an Engineered Surface Disposal Facility near the RWMC. Shipment would take place in semitrailers limited to speeds of 35 mph on committed roadways. Accidents would result only in airborne releases; no waterborne releases were postulated. The calculated dose and risk are presented in Table 13-16.

No directly applicable data were located for accidents during shipment under such conditions. U.S. Department of Transportation statistics have been compiled for highway accidents occurring on noncommitted highways at vehicle speeds of 30 to 50 mph (classified as "severe"). Accidents classified as "severe" are assumed to involve impact and puncture, followed by a 30 to 60 min fire, causing a release. The probability for a "severe" accident has been listed as about 1×10^{-10} /vehicle-mile (AEC 1972). Such an accident scenario is considerably more severe than might be expected during onsite shipment of processed waste.

Another accident classification scheme (Clarke et al. 1976) would yield a probability of 1.6×10^{-6} accident/vehicle-mile. With a conditional probability of 1.6×10^{-2} for fire, lowered by a factor of 10 as in Subsection 13.6.1.2.8, the resultant probability for an accident including fire would be 2.6×10^{-9} /vehicle-mile. The probability used for this study was the geometric mean of these two estimates, or 5×10^{-10} accident/vehicle-mile.

For transport of waste in concrete blocks, it was assumed that only one block out of the eight blocks per truckload (see Table 10-1) would be breached by the accident and that one drum in a block of four would be opened. Waste processed by the other two methods would be shipped in 55-gal drums. It was assumed that 10% of these containers would be opened as a result of the accident. This percent is half of the estimate of Clarke et al. (1976). The reduction allows for the use of committed roadways.

The airborne release fractions assumed for the waste in the breached containers were 1×10^{-5} for slag and 1×10^{-3} for packaged only and for compacted and immobilized waste. By reference to Table 10-1 for the shipping logistics, the total fractions of the waste inventory released in a shipping accident were estimated to be as follows:

Slag

$$(10^{-5} \times 0.41 \text{ Ci/ft}^3 \times 7.4 \text{ ft}^3/\text{container} \times 48 \text{ containers/load} \times 10^{-1} \text{ breached}) / (4.2 \times 10^5 \text{ Ci}) = 3 \times 10^{-10}$$

Compact and Immobilize

$$(10^{-3} \times 0.35 \text{ Ci/ft}^3 \times 16 \text{ ft}^3/\text{container} \times 1 \text{ container breach/load}) / (4.2 \times 10^5 \text{ Ci}) = 1 \times 10^{-8}$$

Package Only

$$(10^{-3} \times 0.21 \text{ Ci/ft}^3 \times 0.8 \times 7.4 \text{ ft}^3/\text{container} \times 144 \text{ containers/load} \times 10^{-1} \text{ breached}) / (4.2 \times 10^5 \text{ Ci}) = 4 \times 10^{-8}$$

13.8.4 Disposal. The analysis of dose and risk for onsite disposal was divided into three phases: the operational phase; the retrievability phase, following operations; and the postclosure phase.

13.8.4.1 Operational Phase.

13.8.4.1.1 Summary. Calculated doses and risks for the operational phase of disposal at the Lemhi Range (shaft or tunnel access), Site 14 (including the less massive variation), and the Engineered Surface Disposal Facility at the RWMC are presented in Tables 13-17. Both operations-related accidental releases and releases due to natural events were considered. For all disposal modules, the event leading to the largest population dose and risk was determined to be breaching of a dropped container.

13.8.4.1.2 Operations-Related Accidental Releases.

(1) Lemhi Range - Shaft or Tunnel. The only significant operations-related accident identified for the Lemhi Range disposal site was breaching of a dropped waste container. This event could be caused by a handling equipment malfunction or a personnel error. The resulting release would vary with the design of the access to the disposal facility.

In the shaft access design, a braking system malfunction could cause the elevator hoists to fail. The drop through the full shaft length would be approximately 800 ft. The falling containers would impact onto the underground receiving area with a velocity of about 200 ft/sec. This accident could result in breaching of the waste containers.

Hoist cage capacities would be 6 slag containers, one block of concrete containing compacted waste, or 12 drums of the packaged waste. For the compacted and immobilized waste form, it was assumed that the concrete block would provide additional protection such that only one drum out of the four involved would be breached. The fractions of the total waste activity released within the facility would be as follows:

Slag

$$(6 \text{ drums} \times 7.4 \text{ ft}^3/\text{drum} \times 0.41 \text{ Ci}/\text{ft}^3 \times 10^{-5} \text{ airborne fraction}) / (4.2 \times 10^5 \text{ Ci}) = 4 \times 10^{-10}$$

Compacted and Immobilized

$$(1 \text{ drum} \times 16 \text{ ft}^3/\text{drum} \times 0.35 \text{ Ci}/\text{ft}^3 \times 10^{-4} \text{ airborne fraction}) / (4.2 \times 10^5 \text{ Ci}) = 1 \times 10^{-9}$$

Packaged Only

$$(12 \text{ drums} \times 7.4 \text{ ft}^3/\text{drum} \times 0.8 \times 0.21 \text{ Ci}/\text{ft}^3 \times 10^{-3} \text{ airborne fraction}) / (4.2 \times 10^5 \text{ Ci}) = 4 \times 10^{-8}$$

A DF value of 10^3 was assumed for one stage of standby HEPA filters. On detection of radioactivity in the effluents, the ventilation system would automatically switch over to the filtered route.

Operating experience with Dover elevators has indicated that failure occurs every 2.5×10^7 trips. For the contemplated waste emplacement rates, the estimated probability of failure within a given year would range from 9×10^{-5} to 1×10^{-4} , depending on the processing method used.

In the tunnel access design, the underground vault would not require hoists for emplacement operations. The tunnels to the vault area would slope upward from the loading area on a 1/2% slope. A waste container could be dropped from the handling equipment, with an estimated maximum drop height of 15 ft. It was assumed that, for slagged or repackaged waste, only one drum would be breached in a given handling accident. It was assumed that a dropped container of compacted and immobilized waste would not be breached, because the concrete block would provide protection.

The airborne fraction was assumed to be 1×10^{-7} for slag (Smith and Ross 1975) and 1×10^{-4} for packaged waste. The total inventory release fractions resulting from this event would be $(10^{-7} \times 7.4 \text{ ft}^3 \times 0.41 \text{ Ci/ft}^3) / (4.2 \times 10^5 \text{ Ci}) = 7 \times 10^{-13}$ for slag and $(10^{-4} \times 7.4 \text{ ft}^3 \times 0.21 \text{ Ci/ft}^3 \times 0.8) / (4.2 \times 10^5 \text{ Ci}) = 3 \times 10^{-10}$ for waste which had been packaged only. Based on RWMC experience with handling operations accidents and on the processing output rates in Figures 10-1, 10-2, and 10-7, frequencies for this event would be 1×10^{-2} /yr for slag and 4×10^{-2} /yr for repackaged waste.

(2) Site 14 and the RWMC. Doses and risks due to operations-related accidents at the RWMC or for either the massive or less massive variations at Site 14 and would be about the same as those described for deep rock disposal with tunnel access.

13.8.4.1.3 Releases Due to Natural Events. Natural events were studied that could conceivably lead to radionuclide releases during waste emplacement operations. Included were severe earthquakes, volcanic action, and flooding. The calculated risks from these events were found to be much lower than those for accidents related to operations, which themselves would be extremely small. For example, it is conceivable that a severe earthquake could cause failure of the hoist used during waste emplacement at the Lemhi Range (shaft access). However, the risk from this scenario was found to be three to four orders of magnitude smaller than that from hoist failure by human error or operational defect.

In other scenarios, the risk from natural events in the operational phase would be much less than from the same events in the postclosure phase. In the latter phase, preventive and mitigative actions could not be ensured because no societal control over the disposal sites was assumed.

13.8.4.2 Retrievability Phase. There would be no operations-related accidental releases during the 30-yr retrievability phase (see Guideline (8) in Subsection 7.4.1.1), unless the emplaced waste were indeed retrieved. If retrieval were carried out, the probabilities and the inventory release fractions would be approximately the same at each location as those for the operational (emplacement) phase of disposal (Subsection 13.8.4.1).

Releases due to natural events during the retrievability phase would be about the same as those described in Subsection 13.8.4.1.3, with a small adjustment for radionuclide decay and population growth.

13.8.4.3 Postclosure Phase.

13.8.4.3.1 Summary. Before selecting a final disposal location for the waste, extensive geological and hydrological surveys would be carried out. Such surveys have not been made for all of the locations considered here. Therefore, detailed analyses

of postclosure (long-term) effects for the INEL disposal locations (Lemhi Range, Site 14, and RWMC) were not conducted for the present study. However, preliminary estimates were made of the effects on the waste from a number of types of natural events and from intrusion. The calculated doses for these events are presented in Table 13-18. For the Lemhi Range disposal modules, only an explosive volcanic eruption was identified as having the potential to cause a significant release. The dominant event for the Site 14 and RWMC disposal modules was determined to be lava flow over the waste.

13.8.4.3.2 Lemhi Range. Long-term effects from postclosure releases at both of the Lemhi Range sites were assessed. Possible airborne releases were considered for an explosive volcanic eruption, lava flow, erosion, intrusion, tornado, and earthquake. The waste disposal vaults would be located about 800 ft beneath the surface of the ground. The entrance would be plugged with large pieces of rock and with concrete. Therefore, no significant airborne releases were postulated to result from the effects of lava flow, a tornado, a severe earthquake, erosion, or intrusion. However, a volcanic eruption up through the waste could result in a significant airborne release of radionuclides. The likelihood of an eruption at the Lemhi Range sites would be considerably lower than at the RWMC or Site 14 (see Subsections 3.4.4 and 13.4.2.1.1). The only recorded instance of volcanic action close to a mountain along the Snake River Plain occurred in the northwest corner of Craters of the Moon National Monument (about 50 miles away). The Lemhi Range sites would be between two volcanic rift zones and within the mountain.

The distance the waste would have to travel upward during the eruption, in order to become airborne, would reduce the fraction released. The significance of this effect is difficult to estimate. For this analysis, the fraction of inventory released was assumed to be less than the corresponding (short-term) fraction for Alternative 1 by a factor of 1000. The assumed inventory release fraction

(2×10^{-6}) is also a factor of 10 lower than that for Concept 2-c. These factors of comparison are for hypothetical releases occurring at the same date, namely 2085.

Possible waterborne releases were studied for failure of a dam at the Mackay Dam site, river channel alteration, and climatic fluctuations. The Lemhi Range locations are high enough to be safe from flooding of the Little Lost River or of Birch Creek and from the effects of changes in river channel location. Any flooding from the Big Lost River (including failure of a dam at the Mackay Dam site) would sink into the playas before reaching the Lemhi Range area. Localized sheet flooding could occur. However, a dike on the upslope side of the site would be sufficient to divert this type of runoff around the site. Thus, no significant releases were estimated to occur in these events.

Thorough mapping of subsurface hydrogeology in the region has not been performed. Underground springs could conceivably develop, potentially resulting in leaching and migration of radionuclides. However, the results of the projections of subsurface migration near the RWMC (see Subsection 13.4.2.2.2) indicate that the doses expected from this scenario would be small.

13.8.4.3.3 Site 14. Effects from postclosure (long-term) releases due to natural events or intrusion at Site 14 were assessed. Two types of engineered shallow-land disposal facilities were considered: a massive concrete structure with 8-ft thick walls, and a less massive variation (LMV) with 8-in. thick walls.

Until the walls of the disposal structures had disintegrated, no significant effect on the waste would be expected from events such as a tornado, lava flow, erosion (with or without intrusion), or perturbation of the groundwater system. After disintegration of the structures, the effects of releases resulting from these events were assumed to be the same as for Alternative 1 (see Subsection 13.4.3.1). However, the effects for Alternative 1 were

evaluated for the year 2085. These effects were adjusted for radioactive decay to apply to the estimated dates of containment disintegration at Site 14, as described below.

The period of time for which the structures at Site 14 would remain intact is difficult to estimate. The cover over either type of structure (massive or less massive) would consist of 21 ft of basalt rip-rap, clay, and bentonite. It was assumed that weathering and natural phenomena would displace all of the cover material within a few hundred years, thereby exposing the concrete.

It was assumed that, after a total of about 2,000 yr, the walls of the LMV facility would have completely disintegrated. (This assumption seems conservative in that some concrete structures from the Roman era, nearly 2,000 years old, are still standing.) A uniform mixture of waste and disintegrated concrete was assumed to remain. The walls of the massive facility were assumed to have completely disintegrated after a total of 25,000 yr, resulting in a similar mixture of waste and concrete.

For all event scenarios evaluated, it was assumed that the event occurred after 2,000 yr for the LMV and after 25,000 yr for the massive disposal facility. The effects were calculated for these time periods.

The expected frequency of lava flows, the event yielding maximum dose for either containment design, would be much less than for the corresponding event at the RWMC. (The effects of the event would be similar at either location.) Site 14 is located between the Howe-East Butte and Lava Ridge-Hell's Half Acre rift zones and would be subject to flows from these rift zones. However, along the Howe-East Butte rift zone, the two major buttes are older than 100,000 yr (Kuntz 1978). The two major volcanic events in the Lava Ridge-Hell's Half Acre rift zone are indicated by Kettle Butte and Hell's Half Acre. These are young vents, about 4100 yr old (Kuntz 1978), but are located about 20 miles SE of Site 14.

Site 14 is too far from the flood route to be inundated with water from failure of a dam at the Mackay Dam location (see Subsection 13.4.2.2.2, particularly Figure 13-7, and Figures 3-1 and 3-2).

13.8.4.3.4 RWMC. Long-term effects from hypothesized accidents were assessed for the engineered surface disposal facility at the RWMC.

Until the 8-ft thick walls of the disposal structures had disintegrated, no significant effects on the waste would be expected from events such as a tornado, lava flow, erosion (with or without intrusion), or perturbation of the groundwater system. There would be little effect from river channel alteration or from failure of a dam at the Mackay Dam Site. After disintegration of the structures, the effects of releases of radionuclides were assumed to be the same as described for Alternative 1 (Subsection 13.4.3.1). However, the effects for Alternative 1 were evaluated for the year 2085. These effects were adjusted for radioactive decay to apply to the estimated date of containment disintegration for the engineered surface facility, as described below.

The period of time for which the structures would remain intact is difficult to estimate. Erosion was assumed to remove the protective cover of basalt rip-rap, clay, and bentonite from the engineered surface disposal facility within a few hundred years. Deterioration of the concrete was assumed then to occur from freeze-thaw cycles and from chemical action caused by sulfates present at the structure surface. After a total of 25,000 yr, the structure was assumed to have completely disintegrated. A uniform mixture of concrete particulate matter and radioactive waste was assumed to remain. For all event scenarios evaluated, it was assumed that the event occurred after 25,000 yr. The effects were evaluated for that time period.

13.9 DELAY RETRIEVAL 20 YEARS (ALTERNATIVE 6)

Accidental releases from delayed retrieval, slagging pyrolysis and packaging, and shipment of slag to the Federal Repository would be nearly identical to those for the same operations beginning in 1985 and described in Subsection 13.6.1. There would be a small reduction in the radionuclide composition during the 20-yr delay, but an increase of approximately 20% in the population distribution.

13.10 DECONTAMINATION AND DECOMMISSIONING (D&D)

It was assumed that D&D, as described in Subsections 9.1.5 and 10.5, would take place during a two-year period immediately following the campaign. The D&D activities considered were those involving the facilities for retrieval, slagging pyrolysis, compact-immobilize-package, and package-only. D&D for the waste-handling systems of the disposal facilities would occur later (about 2035) and would be minor in magnitude and hazard, compared with the other D&D operations.

The volume of D&D waste would be about 45,000 ft³ (Guideline (2) in Subsection 7.4.1.2 and Subsection 9.1.5), or about 2% of the total volume of TRU waste handled during the 10-yr campaign. Because the D&D campaign would last only two years, the waste volume handled annually would be approximately 10% of that during the main campaign. The D&D waste would be decontaminated before processing. If the concentration of radionuclides in the D&D waste were 10% of that in the TRU waste, the number of curies managed annually in D&D would be 1% of that for the retrieval, processing, and transfer/shipment modules. As a first approximation, one might expect the dose and the annual risk to the public from accidents during D&D activities to be about a factor of 100 lower than those associated with the main campaign.

The procedure for D&D of processing equipment would be similar to that described for processing TRU waste. However, because of the lower concentration of radionuclides, the severity of an acci-

dent involving this equipment would be much lower. In addition, only about 5% of the D&D waste would be combustible (see Guideline (3) in Subsection 7.4.1.2).

13.11 HEALTH EFFECTS

Health effects from accidental exposure to radiation are discussed briefly here in order to project the ultimate effects of the doses and risks calculated in this study. Health effects from normal operational releases are discussed in Subsection 12.4.10. Health effects from the long-term environmental dose commitment resulting from normal operational releases are also discussed there.

Health effects can be discussed in terms of short-term effects, occurring within about one year of the accident, and long-term effects, occurring several years later (NCRPM 1971, NRC 1975).

13.11.1 Short-Term Effects. Short-term health effects are usually not observed below a dose of about 25 rem, although changes in blood cells have been detected at doses as low as 5 rem (NCRPM 1971). The whole-body dose that would be lethal to 50% of the population within 60 days after exposure is approximately 500 rem, assuming medical facilities are available for prompt treatment of exposed individuals (NRC 1975). In contrast to the lethal dose of 500 rem, the largest expected whole-body dose to an individual in an uncontrolled area has been found in this study to be about 0.1 rem.

Another short-term health effect that would require prompt medical attention would be respiratory impairment. Pulmonary morbidity would be expected to occur among 5% of the subjects after a lung exposure of 3000 rem (NRC 1975). By contrast, the largest expected lung dose to an individual in an uncontrolled area was calculated in this study to be about 100 rem.

Thus, short-term public health effects from the accidental or nature-caused releases studied here would probably so small as to be undetectable. The relatively low values calculated for maximum indi-

vidual dose also suggest that use of the man-rem concept for population dose is not unrealistic here. Any health effects would be expected to be of the long-term, statistically-related type described below. If the maximum individual doses were so large that short-term health effects could be expected, use of the man-rem concept would be questionable.

13.11.2 Long-Term Effects. Long-term health effects of exposure to radiation can be discussed in terms of latent somatic effects and genetic effects.

13.11.2.1 Latent Somatic Effects. The latent somatic effect of greatest importance would be the possible development of cancer, typically 5 to 30 yr after exposure. The National Academy of Sciences has statistically related the incidence of various types of cancer to levels of radiation exposure (NAS-NRC 1972). The results of these and other studies have been correlated (NRC 1975) to give factors for projecting the incidence of cancer resulting from radiological doses.^(a) Those factors, which were used in the present projections, are as follows:

<u>Organ</u>	<u>Expected Latent Cancer Deaths</u>
	<u>Per 10⁶ Man-Rem</u>
Lung	22.2
Bone	6.9
Total (all organs except thyroid)	121.6

(a) In the referenced report, the factors of interest were subsequently multiplied by dose-effectiveness factors, reflecting dose-rate effects. (The dose-effectiveness factors were less than or equal to unity.) The present analysis bypasses that adjustment and is, therefore, more conservative.

A number of precautions have been given (NRC 1975) concerning the accuracy of predictions of health effects based on such factors. Those precautions apply doubly in the present analysis because of (1) the relative concentrations of radionuclides present, (2) the time-dependence of the radionuclide releases, and (3) the relative effects on the various organs of interest, which differ from those in the referenced study.

The factors listed above were multiplied by the calculated values of time-integrated population risk for the three organs of interest (whole body, bone, and lung). The results are the predicted numbers of cancer cases attributed to accidents or natural events affecting the TRU waste. (Note that a time-integrated risk can be considered as, and has the units of, a dose; see Subsection 13.2.2) The approximate multiplicative factors in Table 13-1 (see derivation in Appendix E, Subsection E.8.6) were used to obtain the time-integrated risks for exposure to the whole body and the lung, as well as to the bone.

The results for short-term accidental or nature-caused releases (up to 100 yr), summarized in Table 13-22, indicate that the largest impact on the public would be expected to derive from Alternative 1 (leave as is). However, as shown in the table, the projected number of cancer cases due to the waste would be negligible, compared with those normally occurring from all other causes. In fact, the most probable number of cancer cases attributed to the waste would be zero.

The annual probability of an individual contracting cancer due to the waste was estimated using the results of Table 13-22. The projected number of waste-related cancer cases for the population was divided by the number of people and by 100 yr. The average of the endpoints of the population during the 100-yr period was used. Based on the worst-case alternative, this probability of an individual contracting cancer would be only about 2×10^{-9} /yr.

TABLE 13-22

PROJECTIONS OF CANCER CASES IN 50-MILE RADIUS POPULATION DUE TO SHORT-TERM RELEASES

Alternative/ Concept	Time at Risk(a) (for Integration)		Annual Population Risk (man-rem)			Projected Number of Cancer Cases			
	No. of Yr	Multiplier(b)	Whole Body	Bone	Lung	Whole Body(c)	Bone	Lung	Total(d)
1	100	1.5×10^2	1×10^{-2}	6×10^0	1×10^1	2×10^{-4}	6×10^{-3}	3×10^{-2}	4×10^{-2}
2-a	100	1.5×10^2	1×10^{-4}	6×10^{-2}	1×10^{-1}	2×10^{-6}	6×10^{-5}	3×10^{-4}	4×10^{-4}
2-b	100	1.5×10^2	1×10^{-4}	6×10^{-2}	1×10^{-1}	2×10^{-6}	6×10^{-5}	3×10^{-4}	4×10^{-4}
2-c	100	1.5×10^2	1×10^{-4}	6×10^{-2}	1×10^{-1}	2×10^{-6}	6×10^{-5}	3×10^{-4}	4×10^{-4}
3(e)	10	1.0×10^1	1×10^{-2}	6×10^0	1×10^1	1×10^{-5}	4×10^{-4}	2×10^{-3}	2×10^{-3}
4(e)	10	1.0×10^1	1×10^{-2}	6×10^0	1×10^1	1×10^{-5}	4×10^{-4}	2×10^{-3}	2×10^{-3}
5-a, Unrough 5-1(e,f)	10(g)	1.0×10^1	1×10^{-2}	6×10^0	1×10^1	1×10^{-5}	4×10^{-4}	2×10^{-3}	2×10^{-3}
6(e)	10	1.0×10^1	1×10^{-2}	6×10^0	1×10^1	1×10^{-5}	4×10^{-4}	2×10^{-3}	2×10^{-3}
						All Other Organs	Bone	Lung	Total(d)
Normal Inci- cidence of Cancer Cases						3×10^4	2×10^2	9×10^3	4×10^4
						2×10^3	1×10^1	5×10^2	2×10^3

(a) Limited to 100 yr for this short-term analysis. See Table 13-23 for long-term analysis.

(b) Values taken from Table 13-1.

(c) Use of the numbers in this column could result in some double-counting. The effect is believed small, because lung-related cancer cases would predominate.

(d) Totals have been rounded.

(e) Dominant event (lava flow) is associated with the portion of the waste still remaining on TSA during campaign. (To be conservative, the values shown do not reflect reduction of this inventory during the campaign. For this reason, calculated values could be high by a factor of 2.) If only events related to operations for retrieving, processing, and shipping the waste were included, the annual population risk and the projected number of cancer cases would be reduced by a factor on the order of about 10,000.

(f) Analysis with LMV module, where applicable, yields identical results.

(g) Although time of exposure is 100 yr, the dominant event is as described in footnote (e). The waste would be exposed to this event, with the present minimal confinement, for a maximum of only 10 yr.

(h) Multiplication includes effects of population growth.

The projected numbers of cancer cases associated with long-term (greater than 100-yr) release scenarios are given in Table 13-23. The alternative of greatest risk, Alternative 1, was the only one so evaluated. Projections are given based on time-integrated population risk out to 10^6 yr.

(In the risk evaluations of this section, risks were not estimated beyond 100 yr, because it was felt that the probabilities were too uncertain to be reliable. However, it was desired to provide some indication of possible health effects from long-term releases. To develop the entries for Table 13-23, it was necessary to make an assumption concerning the probabilities of future releases. The probabilities for the first 100 yr were assumed to remain constant into the distant future. The long-term results appearing in the table are, therefore, subject to large uncertainties.)

For comparison, Table 13-23 includes projected numbers of cancer cases from normal incidence in the same 50-mile radius population. The calculations were based on the assumption that current incidence rates would continue unchanged into the distant future. The number of projected cancer cases from radionuclide releases for Alternative 1 is negligible compared with that from normal incidence. Furthermore, the fraction relating the two decreases from 10^{-6} for 100 yr to 10^{-8} for 10^6 yr, reflecting the impact of radioactive decay. The same type of effect, related to normal operational releases, is pictured in Figure 12-2 in Subsection 12.4.8.

13.11.2.2 Genetic Effects. In addition to somatic effects, radiation can cause mutations, or changes, in the genetic material of exposed persons. Such mutations are in excess of those occurring spontaneously. The effects of genetic changes can be visible or invisible. The changes can occur in the first generation following exposure or in later generations.

TABLE 13-23

PROJECTIONS OF CANCER CASES IN 50-MILE RADIUS POPULATION DUE TO LONG-TERM RELEASES

Time at Risk (for Integration)		Projected Number of Cancer Cases ^(a)				Normal Incidence of Cancer Cases ^(b)			
No. of Yr	Multiplier ^(c)	Whole Body	Bone	Lung	Total ^(d)	All Other Organs	Bone	Lung	Total ^(d)
10 ²	1.5x10 ²	2x10 ⁻⁴	6x10 ⁻³	3x10 ⁻²	4x10 ⁻²	3x10 ⁴	2x10 ²	9x10 ³	4x10 ⁴
10 ³	1.4x10 ³	2x10 ⁻³	6x10 ⁻²	3x10 ⁻¹	4x10 ⁻¹	4x10 ⁵	3x10 ³	1x10 ⁵	6x10 ⁵
10 ⁴	6.9x10 ³	8x10 ⁻³	3x10 ⁻¹	2x10 ⁰	2x10 ⁰	5x10 ⁶	3x10 ⁴	1x10 ⁶	6x10 ⁶
10 ⁵	2.2x10 ⁴	3x10 ⁻²	9x10 ⁻¹	5x10 ⁰	6x10 ⁰	5x10 ⁷	3x10 ⁵	1x10 ⁷	6x10 ⁷
10 ⁶	2.3x10 ⁴	3x10 ⁻²	1x10 ⁰	5x10 ⁰	6x10 ⁰	5x10 ⁸	3x10 ⁶	1x10 ⁸	6x10 ⁸

(a) Values presented are for Alternative 1 (Leave As Is), the alternative of maximum risk.

(b) Numbers include effects of population growth, assumed to continue for only 100 yr.

(c) From Table 13-1.

(d) Totals have been rounded.

The individual dose that would cause the mutation rate to become twice the spontaneous rate has been estimated to be from 20 to 200 rem (NAS-NRC 1972). A realistic value in this range has been estimated to be 100 rem (NRC 1975). A value of 100 rem would imply a fractional increase in the spontaneous mutation rate of 1×10^{-2} for 1 rem exposure (NAS-NRC 1972, NRC 1975).

For the present analysis, the whole-body dose was used as an approximation to the gonad dose. For accidents related to the alternatives and concepts studied, the largest time-integrated whole-body population risk was estimated to be 1.5 man-rem in the short-term period. This value is associated with the lava flow scenario for Alternative 1. From Table 13-7, 1×10^{-2} man-rem/yr $\times$ 150 yr (population risk multiplier for 100 yr from Table 13-1) = 1.5 man-rem.

In the 50-mile radius population, the expected number of single-gene disorders, multifactorial disorders, and effects of chromosome aberrations, associated with this accident, would be approximately 6×10^{-5} , 1×10^{-4} , and 9×10^{-6} , respectively (NRC 1975). That is, the most probable number of genetic effects would be zero. (Any effects that did occur could do so over several generations following the time of exposure.) The natural incidence rates for these effects, from all other causes, among the same population of 252,000 (average of the end-point populations over the 100-yr period), would be 4×10^3 , 1×10^4 , and 2×10^3 , respectively, over the same 100-yr period.

The maximum time-integrated whole-body risk to an individual would be associated with the same scenario. From Table 13-7, 6×10^{-6} rem/yr $\times$ 87 yr (individual risk multiplier for 100 yr from Table 13-1) = 5×10^{-4} rem. The expected fractional increase in the possibility of mutations for this individual would be about 5×10^{-6} (NRC 1975). This value compares with a fractional increase on the order of 1×10^{-8} , based on the preceding paragraph, for the 50-mile radius population as a whole.

13.12 ENVIRONMENTAL EFFECTS OF ACCIDENTS AND NATURAL EVENTS

This subsection briefly addresses the environmental contamination expected to result from the postulated accidents and natural events.

The accidents and natural events of greatest impact involve airborne release of radionuclides. The principal environmental contamination resulting from such events would be contamination of the surface soil. The following paragraphs present a method for estimating soil contamination from accidents, based on data already presented in Sections 12 and 13. The same method could be used for natural events. Contamination of surface waters, as a result of hypothetical accidents or natural events, was shown in Subsections 13.4.2.2 and 13.4.3.2 to be of negligible impact compared with other environmental pathways. Contamination of groundwater was shown to be of minor impact.

Soil contamination from accidental releases can be estimated by comparing the magnitudes of accidental releases with those of normal operational releases. Soil contamination levels presented for normal operational releases (Section 12) can then be multiplied by the ratio of accidental release to normal operational release. The procedure is likely to overestimate considerably the levels of soil contamination, because the effects of cleanup operations following accidents are not included. Such operations could greatly reduce the level of environmental contamination.

The quantity and distribution of radionuclides available for accidental release would generally be the same as for normal operational releases. The inventory release fractions during normal operations are postulated to be 1×10^{-12} for retrieval and about 1×10^{-8} for slagging pyrolysis. Inventory release fractions for accidents would range from 1×10^{-2} to about 1×10^{-15} , depending on the postulated event and the alternative.

Table 12-16 presents maximum soil contamination levels from slagging pyrolysis. These levels are based on a release fraction of about 1×10^{-8} . The contamination levels from the accidents described in Section 13 can be estimated by dividing the postulated inventory release fraction by 1×10^{-8} and multiplying by the values in Table 12-16.

The radiological impact on biota from accident conditions would be similar to the effects from normal operations (see Subsection 12.4.5), after adjustment by the estimated inventory release fraction for the accident.

14. HAZARDS TO WORKERS

This section discusses and, to the extent feasible, quantifies the hazards to workers for the alternatives studied. Quantification of the hazards is complicated by lack of a broad basis of directly applicable experience. The analysis therefore draws from the available information and experience and from data accumulated in other industrial operations of a similar nature.

14.1 CHARACTERIZATION OF HAZARDS AFFECTING WASTE MANAGEMENT WORKERS

Occupational hazards to waste management workers arise from normal operations and from potential accidents. Hazards from normal operations involve unavoidable exposures to small quantities of harmful materials during routine performance of work. For example, harmful materials in the waste might become airborne during handling. Because waste confinement systems are not 100% effective, the workers might inhale a small portion of the airborne materials. Facilities and operating procedures are designed to minimize these residual hazards.

Accidents pose threats to the workers' health and safety by increasing the exposure to hazardous materials, by causing bodily injury, or both. Measures to prevent accidents and to mitigate the consequences of those that do occur are important factors in analyzing the hazards to which workers are exposed. The severity of potential accidents, as judged by their consequences, is another important factor.

A distinction can also be made between radiological and nonradiological hazards. Radiological hazards are those that arise because of the radioactivity in the waste. Nonradiological hazards are those that could lead to accidents even if the operations did not involve radioactive materials. Examples of nonradiological accidents include crane accidents, falls, exposures to toxic substances, fires, burns, and explosions. These hazards are not fundamentally different from those that occur in similar industrial activities not involving radioactive materials.

Categories of hazards to the workers are listed in Table 14-1. In the following subsections, each category shown in the table is addressed, as appropriate, for the alternatives studied. Nonradiological hazards are discussed in Subsection 14.2; radiological hazards, in Subsection 14.3.

All waste management operations would be designed to minimize hazards to the workers. Facilities would incorporate provisions to allow safe and effective handling of all hazardous materials expected to be encountered. Health and safety implications of any alternative would be reviewed thoroughly before implementation. Appropriate preventive and mitigating measures would be incorporated.

14.2 NONRADIOLOGICAL HAZARDS

14.2.1 Nonradiological Hazards from Normal Operations. Certain materials in the waste can be harmful if contacted directly. These hazardous materials may include carcinogens and other toxic substances, explosive or highly reactive chemicals, and pyrophoric materials, such as unreacted plutonium, uranium, and zirconium. The reactive or toxic substances may have been originally stored as waste, or they may have been formed by reactions with other substances during storage. The hazards of all these materials can be discussed only in a general way, because their quantities and their physical and chemical forms in the waste are not precisely known.

Alternatives 1 and 2 would not involve any normal operational hazards from unavoidable contact with hazardous materials, because waste would not be handled.

Alternatives 3 through 6 involve handling the waste. Therefore, contact with hazardous materials could occur. Small quantities of waste materials on outside surfaces of containers might be disturbed, or waste materials might be dispersed through the air as they are processed. For instance, the waste in some of the drums contains beryllium. If a container failed during storage, beryllium could be

TABLE 14-1

CATEGORIES OF HAZARDS TO THE WORKERS

<u>Type of Accident</u>	<u>Possible Consequences</u>	
	<u>Nonradiological</u>	<u>Radiological</u>
<u>Normal Operations</u>		
Small unavoidable exposures to hazardous materials and direct radiation fields.	Exposure to possible carcinogens and other toxic substances. Resultant sickness related to degree of exposure. The expected low levels of exposure would probably have negligible effects.	Exposure to low levels of radiation. The extremely low exposures involved would probably have negligible effects.
<u>Potential Accidents</u>		
Common industrial accidents such as falls, shocks, crushing, poisoning, and burns.	Physical damage (broken bones, cuts, wounds, sickness) or death.	Moderate exposures to radiation. Inconsequential health effects expected.
More serious accidents such as explosions and fires.	Extreme injuries or fatalities.	Acute radiation exposures with health effects.

present on the outside of the container. The material could become airborne and available for inhalation. Small quantities of dust would also become airborne within the operating cells during processing operations when the containers are opened and the contents treated. Exposure of workers to extremely small amounts of such airborne contaminants would be probable. However, because the quantities would be extremely small, the exposure would be inconsequential.

The waste retrieval and processing facilities and operations would be designed to protect employees from inhaling, ingesting, and contacting hazardous substances. Dust-tight enclosures and ventilation systems would isolate personnel from toxic dusts and other hazardous agents. Controlled environment cabs would be provided for workers operating retrieval equipment. Processing operations would be conducted remotely. Maintenance would be conducted by personnel wearing protective bubble suits supplied with breathing air from a central source. These preventive measures would assure that direct exposures to hazardous materials would be extremely small. Qualitatively, this type of hazard would be greater for Alternative 6 than for Alternatives 3, 4, and 5. The 20-yr delay would allow more time for container deterioration and for decomposition of the waste into finer, more readily dispersed forms.

14.2.2 Nonradiological Hazards from Potential Accidents. The operations involved in waste management are similar to other industrial practices, with the added complication that radioactive materials are present. Because of this similarity, occupational injury and fatality rates from comparable industries (Table 14-2) were used to quantify the expected impact of nonradiological accidents during waste management operations. Projected injury and fatality rates are also included for construction of the facilities in which these operations would take place.

The data from related industries provide perspective on the expected magnitude of the hazards. However, the differences in injury and fatality rates between waste management operations and similar

industries may be substantial. For instance, several waste management operations would be performed remotely. This would greatly reduce the hazards to workers; compared with the hazards in a similar industry. Therefore, caution should be exercised in using the results of the injury and fatality projections.

TABLE 14-2
INJURY AND FATALITY RATES FOR COMPARABLE INDUSTRIES^(a)

<u>Category</u>	<u>Industry</u>	<u>Injury Rate (Injuries/10⁶ man-hr)</u>	<u>Fatality Rate (Deaths and Permanent Total Dis- abilities/10⁶ man-hr)</u>
(1)	Aerospace	2.07	0.00
(2)	Rubber and Plastics	5.31	0.02
(3)	Surface Mining	9.75	0.13
(4)	Wholesale and Retail Trade	10.15	0.00
(5)	Cement	11.83	0.06
(6)	Construction	14.66	0.17
(7)	Foundry	18.21	0.10
(8)	Underground Mining (not coal)	25.26	0.53

(a) Data from Accident Facts 1977 (National Safety Council 1977).

The following paragraphs list the various waste management operations and the industries whose injury and fatalities rates were judged most comparable for purposes of these calculations.

Surveillance and maintenance activities are relatively nonhazardous. Because the aerospace industry has the lowest injury and fatality rates tabulated, these rates were used to estimate the impacts associated with these activities. Surveillance and maintenance would continue for 100 yr following implementation of Alternatives 1, 2, and 5. For Alternatives 3, 4, and 6, such activities would, for the stored TRU waste, cease when the waste has been removed from the RWMC.

Except for activities involving grouting and underground mining, the injury and fatality rates for construction activities were taken to be comparable to those for the construction industry. For grouting activities, data from the rubber and plastics industry were used. Underground mining activities were taken to be comparable in hazard level to the noncoal underground mining industry.

Retrieval operations were taken to be comparable in hazard level to surface mining activities. Processing operations were assumed to be comparable in hazard level to the foundry industry for slagging pyrolysis, to the cement industry for compaction and immobilization, and to warehousing operations of the wholesale and retail trade industry for packaging.

Disposal operations at the Lemhi Range locations were taken to be analogous in hazard level to the noncoal underground mining industry. At Site 14, the operations would be comparable to the surface mining industry. Disposal and 20-yr storage in engineered facilities near the RWMC would involve warehousing activities similar to those in the wholesale and retail trade industry. Hazards to workers from disposal operations at the Federal Repository were not included in the calculations.

Statistical data for truck and rail shipping accident frequencies, injuries, and fatalities are summarized in Table 14-3. Onsite transfer of waste in Alternatives 3, 4, 5, and 6, and onsite shipment in Alternative 5 would be performed by trucks operating on committed roadways. The truck accident data in Table 14-3 are for shipments on public roadways and are higher than the expected rates for shipping accidents in Alternatives 3 through 6.

TABLE 14-3
TRANSPORT ACCIDENT STATISTICS(a)

<u>Mode of Transport</u>	<u>Accidents/Vehicle-Mile</u>	<u>Injuries Per Accident</u>	<u>Fatalities Per Accident</u>
Truck	1.7×10^{-6}	0.51	0.03
Rail	1.4×10^{-7} (b)	2.7	0.2

(a) Data taken from WASH-1238 (AEC 1972).

(b) Accidents/rail car-mile.

Table 14-4 presents the estimated numbers of nonradiological injuries and fatalities to workers involved in each of the waste management alternatives and concepts. The results were obtained by multiplying the man-hours of construction or operations for each module of the alternative or concept by the injury rate or fatality rate for the industry judged comparable in hazard level.

For the alternatives and concepts studied, the expected number of worker injuries ranges from 4 to 127. The expected number of fatalities ranges from 0 to 1. Alternatives 1 and 2 have the lowest number of expected injuries and fatalities. For the other alternatives, the module of greatest hazard, in terms of expected nonradiological injuries and fatalities, is slagging pyrolysis. Even for this module, the expected number of injuries and fatalities would be less than for an operation of similar magnitude in a comparable industry.

TABLE 14-4

PROJECTED NONRADIOLOGICAL INJURIES AND FATALITIES TO WASTE MANAGEMENT WORKERS

Alternative or Concept	Manpower Commitment in Various Activities(a) (10 ⁶ man-hours)					Estimated Number of Injuries(b)					Estimated Number of Fatalities(b)				
	Construction	Retrieval	Processing	Disposal/Storage	Surveillance	Construction	Retrieval	Processing	Disposal/Storage	Surveillance	Construction	Retrieval	Processing	Disposal/Storage	Surveillance
1	N/A(c)	N/A	N/A	N/A	2.1(1)	N/A	N/A	N/A	N/A	4.4	N/A	N/A	N/A	N/A	0
2-a	0.03(6)	N/A	N/A	N/A	2.1(1)	0.4	N/A	N/A	N/A	4.4	<0.1(d)	N/A	N/A	N/A	0
2-b	0.11(6,2)	N/A	N/A	N/A	2.1(1)	0.9	N/A	N/A	N/A	4.4	<0.1	N/A	N/A	N/A	0
2-c	0.04(2)	N/A	N/A	N/A	2.1(1)	0.2	N/A	N/A	N/A	4.4	<0.1	N/A	N/A	N/A	0
3	1.0(6)	0.8(3)	4.1(7)	NI(e)	N/A	15	7.8	75	NI	N/A	0.2	0.1	0.4	NI	N/A
4	1.2(6)	0.8(3)	4.1(7)	0.1(4)+NI	0.2(1)	18	7.8	75	1+NI	0.4	0.2	0.1	0.4	0+NI	0
5-a	1.3(6,8)	0.8(3)	4.1(7)	0.7(8)	2.1(1)	22	7.8	75	18	4.4	0.3	0.1	0.4	0.4	0
5-b	1.2(6,8)	0.8(3)	1.0(5)	0.7(8)	2.1(1)	20	7.8	12	18	4.4	0.3	0.1	<0.1	0.4	0
5-c	1.0(6,8)	0.8(3)	0.8(4)	0.7(8)	2.1(1)	17	7.8	8	18	4.4	0.3	0.1	0	0.4	0
5-d	1.3(6,8)	0.8(3)	4.1(7)	0.5(8)	2.1(1)	22	7.8	75	13	4.4	0.3	0.1	0.4	0.3	0
5-e	1.2(6,8)	0.8(3)	1.0(5)	0.5(8)	2.1(1)	20	7.8	12	13	4.4	0.3	0.1	<0.1	0.3	0
5-f	1.0(6,8)	0.8(3)	0.8(4)	0.5(8)	2.1(1)	17	7.8	8	13	4.4	0.3	0.1	0	0.3	0
5-g (f)	1.4(6)	0.8(3)	4.1(7)	0.1(4)	2.1(1)	21	7.8	75	1	4.4	0.2	0.1	0	0	0
LMV	1.2(6)	0.8(3)	4.1(7)	0.1(4)	2.1(1)	18	7.8	75	1	4.4	0.2	0.1	0.4	0	0
5-h	1.3(6)	0.8(3)	1.0(5)	0.1(4)	2.1(1)	19	7.8	12	1	4.4	0.2	0.1	<0.1	0	0
LMV	1.1(6)	0.8(3)	1.0(5)	0.1(4)	2.1(1)	16	7.8	12	1	4.4	0.2	0.1	<0.1	0	0
5-i	1.1(6)	0.8(3)	0.8(4)	0.3(4)	2.1(1)	16	7.8	8	3	4.4	0.2	0.1	0	0	0
LMV	0.8(6)	0.8(3)	0.8(4)	0.3(4)	2.1(1)	12	7.8	8	3	4.4	0.1	0.1	0	0	0
5-j	1.4(6)	0.8(3)	4.1(7)	0.1(4)	2.1(1)	21	7.8	75	1	4.4	0.2	0.1	0.4	0	0
5-k	1.3(6)	0.8(3)	1.0(5)	0.1(4)	2.1(1)	19	7.8	12	1	4.4	0.2	0.1	<0.1	0	0
5-l	1.1(6)	0.8(3)	0.8(4)	0.3(4)	2.1(1)	16	7.8	8	3	4.4	0.2	0.1	0	0	0
6	1.0(6)	0.8(3)	4.1(7)	NI	0.4(1)	15	7.8	75	NI	0.8	0.2	0.1	0.4	NI	0

Alternative or Concept	Hazards of Truck Shipment				Hazards of Rail Shipment				Totals (For All Activities)	
	Truck-Miles(8)	Accidents	Injuries	Fatalities	Car-Miles	Accidents	Injuries	Fatalities	Injuries	Fatalities
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4.4	0
2-a	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4.8	<0.1
2-b	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5.3	<0.1
2-c	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4.6	<0.1
3	2.7x10 ³	<0.1	<0.1	<0.1	5.3x10 ⁶	0.7	2	0.1	100+NI	0.8+NI
4	2.7x10 ³	<0.1	<0.1	<0.1	5.3x10 ⁶	0.7	2	0.1	104+NI	0.8+NI
5-a	1.8x10 ⁵	0.3	0.2	<0.1	N/A	N/A	N/A	N/A	127	1.2
5-b	1.5x10 ⁵	0.3	0.1	<0.1	N/A	N/A	N/A	N/A	62	0.8
5-c	1.6x10 ⁵	0.3	0.1	<0.1	N/A	N/A	N/A	N/A	55	0.8
5-d	1.8x10 ⁵	0.3	0.2	<0.1	N/A	N/A	N/A	N/A	122	1.1
5-e	1.5x10 ⁵	0.3	0.1	<0.1	N/A	N/A	N/A	N/A	57	0.7
5-f	1.6x10 ⁵	0.3	0.1	<0.1	N/A	N/A	N/A	N/A	50	0.7
5-g	1.2x10 ⁵	0.2	0.1	<0.1	N/A	N/A	N/A	N/A	109	0.7
LMV	1.2x10 ⁵	0.2	0.1	<0.1	N/A	N/A	N/A	N/A	106	0.7
5-h	1.0x10 ⁵	0.2	<0.1	<0.1	N/A	N/A	N/A	N/A	44	0.3
LMV	1.0x10 ⁵	0.2	<0.1	<0.1	N/A	N/A	N/A	N/A	41	0.3
5-i	1.1x10 ⁵	0.2	<0.1	<0.1	N/A	N/A	N/A	N/A	39	0.3
LMV	1.1x10 ⁵	0.2	<0.1	<0.1	N/A	N/A	N/A	N/A	35	0.2
5-j	4.2x10 ³	<0.1	<0.1	<0.1	N/A	N/A	N/A	N/A	109	0.7
5-k	3.9x10 ³	<0.1	<0.1	<0.1	N/A	N/A	N/A	N/A	44	0.3
5-l	4.0x10 ³	<0.1	<0.1	<0.1	N/A	N/A	N/A	N/A	39	0.3
6	2.7x10 ³	<0.1	<0.1	<0.1	5.3x10 ⁶	0.7	2	0.1	101+NI	0.8+NI

(a) Numbers in parentheses refer to comparable industries for which accident rates were used (see Table 14-2).

(b) Actual calculated values are reported. Fractional values have meaning only for comparison purposes. Nonzero results less than 0.1 are shown to indicate small hazard.

(c) N/A = Not Applicable.

(d) < = Less than.

(e) NI = Not Included (relates to operations at the Federal Repository).

(f) LMV = Use of the less massive variation of engineered shallow-land disposal at Site 14.

(g) Includes mileage from retrieval to processing facility and from processing to onsite disposal or storage facility.

14.3 RADIOLOGICAL HAZARDS

Radiological hazards to workers arise from the presence of radioactive material in the waste. Such hazards can be classified into those associated with normal operations and those from potential accidents. The first category involves the hazards associated with exposures of the workers to low levels of radiation and contamination during the normal course of their duties. The hazards associated with accidents involve unplanned exposures to radioactivity or releases of radionuclides during waste management operations.

14.3.1 Procedures and Design Features Used to Limit Radiation Exposures to Workers. All INEL workers are thoroughly trained in radiological safety as related to their jobs. All operations and facility designs undergo thorough review to assure that radiological hazards have been identified and that appropriate preventive and mitigating measures are incorporated. Health physics surveillance is provided during operations. Maintaining radiological exposures at levels as low as practicable is a major objective of all INEL operations.

Workers can be exposed to radiation by being near a source of ionizing radiation or by ingesting or inhaling contaminated materials. Operating procedures and facility designs are planned so as to minimize and protect against all of these exposure modes.

Exposure to direct radiation is minimized by placing shielding between workers and the radiation source, by keeping workers as far away from sources as practicable, and/or by limiting the time workers are exposed to the radiation. Waste management operations would use these methods to protect the workers.

Inhalation and ingestion of contaminated materials are avoided by (1) isolating the waste from the workers whenever possible; (2) providing airflow and filtration systems to control the movement of any

airborne contamination; and (3) following established procedures for control of contamination spread. Fresh air would be provided to areas where workers were present; the air would be routed toward areas where contamination might be present. Filtration of flows from potentially contaminated areas would be provided. Protective bubble suits supplied with breathing air would be worn by workers who would be required to enter contaminated areas.

Radiation monitors and alarms are provided in all potentially contaminated areas for additional assurance that personnel exposures are maintained at levels as low as practicable (ERDA 1977a). Special procedures are established for evacuating personnel, controlling contamination, and correcting accident conditions. Personal radiation exposure dosimeters are used to provide a record of the exposures received by individual workers. Whole-body counters and the latest medical technology are also available to determine and mitigate the consequences of any inadvertent exposures.

14.3.2 Radiation Exposures During Normal Operations. Table 14-5 presents the estimated doses to the workers during normal operations. The results are not based on detailed time-and-motion studies and detailed dose calculations. Instead, for these preliminary evaluations, simplifying assumptions were made, leading to average exposure levels for each module, as described in the following paragraphs.

Unless otherwise indicated, the workers were assumed to be exposed to radiation for 1500 hr/yr. The remaining 500 hr in a typical working year were assumed to be occupied in changing into or out of protective clothing, attending training sessions, etc.

The number of workers for each operation was taken from Table 12-9. One fourth of the personnel were generally assumed to be in supervisory or support capacities. The operational doses received by these personnel were estimated to be negligible, compared

TABLE 14-5
ESTIMATED WORKER DOSES FROM NORMAL OPERATIONS (man-rem)(a)

Alternative/ Concept	Retrieval		Processing		Transfer and Onsite Truck Shipment		Disposal/Storage		Maintenance/Surveillance		Total Dose for Concept
	Number of Workers	Total Dose (man-rem)	Number of Workers	Total Dose (man-rem)	Number of Workers	Total Dose (man-rem)	Number of Workers	Total Dose (man-rem)	Number of Workers(b)	Total Dose (man-rem)	
1	N/A(c)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	10	5	5
2-a	N/A	N/A	N/A	N/A	N/A	N/A	8(d)	<1(e)	10	5	5
2-b	N/A	N/A	N/A	N/A	N/A	N/A	27(d)	<1	10	5	5
2-c	N/A	N/A	N/A	N/A	N/A	N/A	10(d)	<1	10	5	5
3	39	88	195	205	2	<<1(f)	NI(g)	NI	N/A	N/A	293+NI
4	39	88	195	205	3	<<1	15+NI	34+NI	10	1	328+NI
5-a	39	88	195	205	4	4	39	74	10	5	376
5-b	39	88	50	52	4	4	39	74	10	5	223
5-c	39	88	40	42	4	4	39	74	10	5	213
5-d	39	88	195	205	4	4	31	56	10	5	358
5-e	39	88	50	52	4	4	31	56	10	5	205
5-f	39	88	40	42	4	4	31	56	10	5	195
5-g	39	88	195	205	2	3	19	7	10	5	308
LMV(h)	39	88	195	205	2	3	10	7	10	5	308
5-h	39	88	50	52	2	3	17	7	10	5	155
LMV	39	88	50	52	2	3	8	7	10	5	155
5-i	39	88	40	42	2	3	28	7	10	5	145
LMV	39	88	40	42	2	3	19	7	10	5	145
5-j	39	88	195	205	2	<<1	21	7	10	5	305
5-k	39	88	50	52	2	<<1	19	7	10	5	152
5-l	39	88	40	42	2	<<1	30	7	10	5	142
6	39	44	195	102	2	<<1	NI	NI	10	1	147+NI

(a) Total estimated operations-related exposure to whole body for duration of operations.

(b) Surveillance personnel for 10 yr for Alternative 4, 20 yr for Alternative 6, and 100 yr for Alternatives 1, 2, and 5.

(c) N/A = Not applicable.

(d) Covering, grouting and immobilization personnel working for 2 yr.

(e) < = Less than.

(f) << = Much less than.

(g) NI = Not included in this estimate (applies to Federal Repository workers).

(h) LMV = Use of less massive variation of engineered shallow-land disposal at Site 14.

with doses received by other personnel. For a given operation, the total exposure to the group of workers was estimated. This exposure was then reduced by 25% to obtain the total dose shown in Table 14-5.

For Alternative 1, radiation exposures during normal maintenance and surveillance operations would be expected to be very small. The waste is covered with about 3 ft of soil, which reduces doses from direct radiation to an average of about 0.02 mrem/hr (Hedahl and Janke 1978). Furthermore, perhaps only half of the personnel involved would work near the waste. Even those personnel would be near the waste during only part (perhaps one-third) of the 1500 hr/yr mentioned earlier.

For Alternative 2, radiation exposures would similarly be very small. This is true both during construction of the improved confinement (about half of the personnel were assumed to work near the waste for 1000 hr/yr) and during maintenance and surveillance (same assumptions as for Alternative 1).

The waste management activities for Alternatives 3 through 6 were categorized into retrieval, transfer, processing, onsite truck shipment, and disposal/storage. Estimated exposures during these operations are discussed in the following paragraphs. Exposures to workers at the Federal Repository are not included in this analysis. Exposures to train crews are discussed in Subsection 12.4.9. The members of the train crews would not be trained radiation workers; they would be members of the public.

During retrieval operations, workers would be in relatively close proximity to the waste containers. Preliminary calculations indicate that the maximum exposure to workers responsible for waste handling would be about 300 mrem/yr. This value was conservatively used as the average exposure for nonsupervisory, nonsupport personnel. The calculations were based on known radiation levels at the surfaces of the various types of waste containers on the TSA pads. For delayed retrieval, the dose would be reduced by about a factor of two because of radionuclide decay during the 20-yr delay period.

For normal operations in the waste processing facilities, the following assumptions were made: (1) 10% of the workers are maintenance workers and receive exposures of 400 mrem/yr; (2) 65% of the workers are operating personnel and receive 100 mrem/yr; and (3) the remaining 25% of the workers are supervisory and support personnel and receive doses that are small compared with background. For delayed processing, the dose would be reduced by about a factor of two because of radioactive decay.

Exposures during emplacement operations for disposal or storage were assumed to be identical to those for retrieval operations. There are two complicating factors, however. First, incremental construction during the campaign was projected (see Section 10) for the disposal facilities for Alternative 5. Workers associated with incremental construction operations were assumed to receive doses that are small compared with background levels. Emplacement workers other than the 25% supervisory and support personnel were assumed to receive 300 mrem/yr.

The second complication is that, in some cases, the number of emplacement workers depends on the volume of the waste emplaced. The waste volume, in turn, depends on the processing method. However, the total radioactivity of the waste does not depend on the processing method. It was assumed, therefore, that the total dose to a group of emplacement workers would be independent of the waste processing method. The numbers of emplacement workers required for the compaction and immobilization disposal method were used throughout the disposal modules of Alternative 5.

Estimated exposures to personnel operating transfer vehicles and onsite shipping vehicles were based on the waste transfer rates in Figures 10-1, 10-2, and 10-7 and on the shipping rates in Table 10-1. For shipment to the Lemhi Range disposal sites, a total of 1.6×10^5 truck-miles would typically be required (see Table 14-4). An average speed of 30 mph was assumed. Two men would be in each of the two trucks required. Calculations indicated a dose rate of 0.7 mrem/hr at

6 ft from the trailer surface. The dose rate to the workers within the cab was assumed to be half of this value. The resulting dose would be about 100 mrem/yr for each worker, or a group total of 4 man-rem for the four workers over the 10-yr campaign.

The estimated shipping distance to Site 14 is two-thirds of that to the Lemhi Range locations so the total worker dose would be about 3 man-rem in this case. The distance for shipment of processed waste to the engineered surface disposal facility or the 20-yr storage facility would be less than 1% of that for shipment to the Lemhi Range sites. Thus, the total worker dose in these cases would be much less than 1 man-rem. The same conclusion holds for waste transfer from the retrieval facility to the processing facility, because the distance involved is the same.

Normal operations during D&D of the retrieval and processing facilities would be expected to give exposures lower than those during retrieval. The potential for contamination of the D&D workers would be higher because of the necessity of working inside contaminated areas. The facilities would be designed for ease of decontamination, and the workers would be closely monitored to preclude unacceptable exposures. Standard radiological safety procedures would be followed to assure that hazards are adequately identified and appropriate preventive measures taken.

14.3.3 Radiological Hazards from Potential Accidents. The TRU waste has relatively low radiation levels. Accidental exposure to the levels of direct radiation expected to be present is not projected to be a major hazard. The type of accident posing the greatest radiological hazard to workers is that involving release of airborne contamination, leading to possible inhalation or ingestion of radionuclides. The radionuclides in the waste could become airborne as a result of mechanical impacts, fires, or spills. The accidents considered here include the dominant operational accidents analyzed in Section 13 and other hypothetical accidents.

It is conceivable that, due to failure of the waste confinement systems, the airborne radionuclides could be released directly into occupied areas of the facility and not routed to the stack. In this case, the effects on all workers within the facility could be larger than those to the member of the public receiving maximum accidental exposure, which was evaluated in Section 13. Consequences of these types of accidents are often expressed in terms of the length of time required for a worker to receive a maximum permissible body burden (MPBB) (ICRP 1959) of nuclides, under the specified accident conditions.

In the more usual case, the accident would result in an abnormal release of radionuclides routed to a facility stack. Only the workers directly involved would be exposed. The other workers, who would remain within the facility, would receive insignificant doses. Warnings of the accident would be provided by monitors and radiation alarms.

The following paragraphs discuss the probable effects on the workers from the hypothetical accidents that were considered.

For Alternative 1, no credible accidents were identified that would result in exposures to the maintenance and surveillance workers.

For Alternative 2, there is a small chance of accidentally breaching a waste container during cover emplacement or during grout injection from above. Only one or two containers would be expected to be involved. For a wind speed of 10 mph, the airborne concentration 6 ft above the ground surface, 16 ft downwind from a breached container, was estimated to be 2×10^{-5} nCi/ml. An unprotected worker downwind would receive an MPBB in about 33 hr. It is expected that, within one hour, the contents of the breached container would be repackaged. Thus, workers would not be expected to receive substantial doses from this type of accident.

The operations involved in Alternatives 3 through 6 can be categorized into retrieval, transfer, processing, shipment, and disposal or storage. These operations are discussed in the following paragraphs.

Radiological hazards during retrieval and during disposal or storage operations would be similar to one another. In all of these operations, containers of waste handled by the workers could be accidentally punctured or dropped. The consequences of such an accident were evaluated, based on the amount of activity in a container and a conservatively assumed airborne fraction of 1×10^{-4} of the container contents. If the container involved were a box, approximately 40 min would be required for an unprotected worker to receive an MPBB. The airborne concentration would be 1×10^{-3} nCi/ml. About 10 hr would be required if a drum were involved. The airborne concentration would be 7×10^{-5} nCi/ml. The retrieval workers are not unprotected, however. Failure of the environmental cab on the waste retrieval equipment simultaneously with the container breach is unlikely. The contents of the breached container could probably be repackaged within minutes.

A fire in the retrieval facility would be the accident of greatest risk to the public from retrieval operations (see Section 13). Such a fire would most likely originate outside the retrieval facility. It is expected that retrieval workers would have sufficient warning to vacate the facility before the fire caused release of radionuclides. The workers would probably retreat to the safety of the processing facility.

The processing facility would be designed for remote operations. Failures of waste confinement systems during normal operations would result in airborne radionuclide concentrations in the facility that are similar to those expected during retrieval.

From time to time, maintenance personnel would be required to enter contaminated areas in the processing facility. If their protective clothing (bubble suits) were damaged, some exposure could occur. (If the damage were caused by a pointed or jagged object, puncture of

the skin of the worker could occur. Contamination could thereby be deposited beneath the skin. Any such puncture injury would receive special medical attention.) Maximum airborne contamination levels would probably not exceed 1×10^{-3} nCi/ml. The workers would have about 40 min to leave the contaminated area before receiving an MPBB. If a worker lost his breathing air supply while in a contaminated area, the result could be inhalation of contaminated air. He would have an estimated 40 min to leave the area before receiving an MPBB. Provisions for emergency evacuation of contaminated areas would allow exit within one minute.

If an explosion were to occur within the processing facility, high levels of contamination could result. If 5 ft^3 of waste were dispersed by the explosion and if 10% of the waste remained airborne, concentrations inside the facility might reach about 3×10^{-3} nCi/ml. Unprotected workers would have about 13 min to evacuate before receiving an MPBB. The assumptions on which the foregoing scenario is based are very conservative.

Fires could also lead to significant quantities of airborne radionuclides. However, activities within the cells in which fires are most likely to occur would be performed remotely. In addition, special fire suppression systems would be installed, cells would be designed to contain fires, and the processing facility would be located only minutes away from the DOE fire department. For these reasons, only small volumes of waste would likely be involved in a fire. The consequences would probably not be greater than those calculated for an explosion.

Under accident conditions, workers operating transfer vehicles and onsite shipping vehicles could be exposed to small amounts of contamination escaping from the vehicle. These exposures would be expected to be smaller than the exposures discussed elsewhere in this subsection.

14.4 SUMMARY

The foregoing analyses and discussion indicate that implementation of any of the waste management alternatives would not result in unacceptably high levels of occupational hazard. The most prominent hazards would be those that could lead to nonradiological accidents, similar to accidents that occur in common industrial operations. The probabilities of occurrence of some of the radiological accidents are listed in Section 13. For other radiological accidents, such as tearing of protective clothing, probabilities were not estimated. In seven years of TRU waste storage experience at the RWMC, no incidents of abnormal exposure or high contamination levels have occurred. This record lends confidence to the expectation that such events would be very infrequent. Radiological doses expected during normal operations would be far below the present occupational limit of 5 rem/yr (ERDA 1977a). Proper facility design and operation, worker training, and health and safety monitoring would all contribute to performance of waste management functions with low levels of occupational hazard.

15. COSTS

15.1 BASES

The cost estimates prepared for this study include capital costs, operations and maintenance (O&M) costs, and costs for D&D of facilities. Where applicable, the costs of shipping the waste to the Federal Repository and of managing the waste at the Repository were included. All costs were based on mid-July 1978 dollar values. (See the cost guidelines in Subsection 7.4.1.4.)

The cost estimates are not considered budgetary cost estimates, because they are based on the limited amount of preconceptual design performed during the study. The cost estimates have large associated uncertainties.

Estimates for capital costs of materials and equipment were based on telephone quotes from suppliers, where possible. If telephone quotes were unavailable, the estimates were based on costs for similar equipment.

Capital costs of facilities included only construction materials, labor, and contingency. (Capital costs of the process facilities were based on remote operations in areas where uncontained waste might be encountered. Costs associated with completely remote operations and maintenance were not included.) Among items in the total construction cost that were not included in these preliminary estimates are the following: engineering and design, research and development, quality assurance and quality control, construction management, project management, environmental permits or license applications, extra utilities outside the "5 ft line," site characterization (e.g., subsurface exploration), and escalation to the projected date of construction. Inclusion of these items could cause the estimated capital costs for the facilities to increase by a factor of 2 to 4 from the preliminary estimates given here.

The slagging pyrolysis facility constitutes an example of the magnitude of the cost of items not included in the present preliminary estimates. For this facility, additional design and cost evaluations, beyond the scope of the present study, were completed in January 1979. Remote operations and maintenance were assumed for the facility. As a consequence of this assumption and of the additional design detail that was developed (e.g., support buildings and railroad spur), the estimated construction cost increased from the \$128 million given in this section to \$175 million. In addition, estimated costs for design and project management were \$59 million and \$19 million, respectively, giving a total of \$253 million (1978 dollars). Escalation, to reflect completion of construction in 1986, and 40% contingency increased the total estimated cost to \$500 million. (The estimates given in this section include a contingency of only 25%.)

To conduct such additional design and cost studies for all of the facilities evaluated in this document is beyond the scope of the study. The costs presented here, although incomplete in the sense described above, do facilitate comparisons among alternatives. However, the reader should bear in mind the increase of a factor of 2 to 4, which could occur when more detailed and more complete estimates are made of total capital costs.

The O&M costs for Alternatives 1 and 2 include the costs of performing maintenance and surveillance for the assumed 100-year period described in Subsection 7.4.1.1(9). The estimated cost of \$600,000/yr is based on the staff presently employed in these activities at or near the RWMC.

The O&M costs for Alternative 3 include salaries of operators and maintenance personnel, costs for energy consumption, and costs for replacement equipment, parts, and materials associated with retrieval, transfer, and processing of the waste. The O&M costs for Alternative 4 include the same categories as for Alternative 3. Also included are the costs for maintenance and surveillance of the storage

facility for 10 yr following the 10-yr retrieval and processing campaign. The O&M costs for Alternative 5 include: (1) the same categories as for Alternative 3; (2) the cost of the incremental construction described in Subsections 10.4.1.4, 10.4.2.4, 10.4.3.5, 10.4.3.6, and 10.4.4.2; and (3) the costs for maintenance and surveillance of the disposal facilities for the assumed 100-yr period. The O&M costs for Alternative 6 include the same categories as for Alternative 3. Also included are the costs for maintenance and surveillance of the waste during the 20-yr delay period.

Cost data for D&D operations are scarce. The difficulty of projecting D&D cost estimates for the 1996-1997 time period is compounded by the uncertainty in the D&D criteria that will be in effect at that time. D&D costs for various portions of a facility are also related to the contamination levels present and the functional complexity of the operation. The limited historical data that were reviewed for D&D costs typically range from 4% to 12% of initial capital cost, without escalation. D&D costs for administrative areas tend toward the lower limit. For highly contaminated areas housing complex processes, the higher percentage is more appropriate. The overall D&D cost for each facility studied here was estimated to be 10% of the original capital cost, without escalation. D&D costs for the disposal facilities include only those costs associated with D&D of service facilities, such as maintenance buildings. No D&D would take place for the disposal facilities themselves.

For shipment to the Federal Repository, the estimated volume and weight of the waste were used to determine the number of rail cars to be shipped. It was assumed that the present rate structure for waste shipment from the Rocky Flats Plant to the INEL would apply to shipments from the INEL to the Federal Repository. The rates were adjusted to reflect the differences in shipping distances. The cost

was evaluated for standard trains, as opposed to specially committed trains. The cost of the rail cars, assumed to be government-owned, was not included.

For shipment to disposal sites within the INEL boundaries, the number of vehicles required and the number of trips per day for each vehicle were determined. The initial cost of vehicles, the cost of replacements, and the cost of fuel and maintenance are included in the shipment costs.

The cost for long-term TRU waste management at the Federal Repository was taken to be \$60/ft³ (Cunningham 1977). This projected cost is highly uncertain and would depend on the quantity of waste shipped to the Federal Repository from the INEL and from other DOE sites. The cost was included to provide the most complete information possible on which to base cost comparisons among alternatives.

15.2 COST ESTIMATES

The cost estimates for all the alternatives and concepts that were studied are given in Table 15-1. (Table 7-3 lists the alternatives and concepts.) Also listed, where appropriate, are shipment costs, costs associated with the Federal Repository, and D&D costs. The costs of the retrieval, processing, and disposal modules are listed separately in Table 15-2. In both tables, rounding of numbers has caused some costs to appear to be equal, whereas the original values were not precisely equal.

TABLE 15-1

SUMMARY OF ESTIMATED COSTS(a)

Alter- native or Concept	Capital Cost	Total O&M Cost	Shipment Costs		Cost at Federal Reposi- tory	D&D Cost	Total Cost
			Onsite	Offsite			
1	0.1	60	N/A(b)	N/A	N/A	N/A	60
2-a	1.0	60	N/A	N/A	N/A	N/A	61
2-b	2.9	60	N/A	N/A	N/A	N/A	63
2-c	11.3	60	N/A	N/A	N/A	N/A	71
3	136	135	N/A	9	77	14	371
4	140	149	0.4	9	77	14	389
5-a	161	201	0.5	N/A	N/A	14	377
5-b	106	119	0.9	N/A	N/A	8	234
5-c	95	135	0.5	N/A	N/A	7	238
5-d	161	201	0.7	N/A	N/A	14	377
5-e	106	119	1.1	N/A	N/A	8	234
5-f	96	135	0.6	N/A	N/A	7	239
5-g	295	203	0.5	N/A	N/A	14	513
LMV(c)	155	199	0.5	N/A	N/A	14	369
5-h	211	121	0.7	N/A	N/A	8	341
LMV	102	117	0.7	N/A	N/A	8	228
5-i	420	139	0.5	N/A	N/A	7	567
LMV	107	135	0.5	N/A	N/A	7	250
5-j	227	204	0.4	N/A	N/A	14	445
5-k	176	122	0.5	N/A	N/A	8	307
5-l	329	140	0.4	N/A	N/A	7	476
6	136	147	N/A	9	77	14	383

(a) All costs are in millions of mid-July 1978 dollars.

(b) N/A = Not Applicable.

(c) LMV identifies the use of the less massive variation of the engineered shallow-land disposal facility at Site 14.

TABLE 15-2.

ESTIMATED COSTS OF RETRIEVAL,
PROCESSING AND DISPOSAL MODULES - STORED TRU WASTE(a,b)

Module	Capital Cost	Total O&M Cost	D&D Cost	Total Cost
RETRIEVAL	8	16	1	25
DELAYED RETRIEVAL	8	28(c)	1	37
PROCESS FACILITY				
SP	128	119	13	260
CPT	73	38	7	118
PKG	56	51	6	113
DISPOSAL				
<u>Deep Rock Disposal -</u>				
<u>Lemhi Site - Shaft Access</u>				
SP	25	66	0.3	91
CPT	25	65	0.3	90
PKG	31	68	0.3	99
<u>Deep Rock Disposal -</u>				
<u>Lemhi Site - Tunnel Access</u>				
SP	25	66	0.3	91
CPT	25	65	0.3	90
PKG	32	68	0.3	100
<u>Engineered Shallow-Land</u>				
<u>Disposal at Site 14</u>				
SP	159	68	0.4	227
LMV(d)	19	64	0.4	83
CPT	130	67	0.4	197
LMV	21	63	0.4	84
PKG	356	72	0.5	429
LMV	43	68	0.5	112
<u>Engineered Surface Facility</u>				
<u>near RWMC</u>				
SP	91	69	0.06	160
CPT	95	68	0.06	163
PKG	265	73	0.09	338
20-YR RETRIEVABLE STORAGE	4	14(e)	0.4	18

(a) All costs are in millions of mid-July 1978 dollars.

(b) SP: Slagging Pyrolysis and Packaging
CPT: Compact, Immobilize, and Package
PKG: Package Only

(c) Includes 20 yr maintenance and surveillance prior to start of retrieval.

(d) LMV identifies the use of the less massive variation of the engineered shallow-land disposal facility at Site 14.

(e) Includes 10 yr maintenance and surveillance after waste emplacement.

16. REQUIREMENTS FOR IMPLEMENTATION

16.1 LAND ACQUISITION AND USE

Approximately 850 square miles (95%) of the INEL has been withdrawn from the public domain, based on a series of Public Land Orders (PLOs) dating back to 1946. The PLOs, as interpreted, provide for nuclear energy research and development and related activities. The alternatives and concepts studied for retrieval, processing, storage, and disposal of the transuranic waste are related activities and, therefore, are considered consistent with the intent and purpose of the PLOs.

All of the INEL disposal sites considered fall within the areas withdrawn from the public domain. Thus, there would be no requirement to purchase land, prepare or adopt special legislation, or modify the PLOs themselves for either short- or long-term use.

The status of the PLOs is potentially affected by the Organic Act, PL94-579. Under the Act, the Secretary of the Interior is required to determine whether and for how long withdrawn lands are consistent with their dedicated uses and statutory objectives. Action to void the PLOs is unlikely in the near term. If the PLOs were voided, decontaminating and decommissioning facilities would be required before returning the facility sites to the public domain. Disposal sites would require a special exclusionary clause in any action to return the land to the public domain. For all intents and purposes, the disposal sites would have to be excluded from public domain for all time.

Further details regarding the intended uses under the Public Land Orders and the effects of the Organic Act are discussed in Subsection 12.2.6.

16.2 REGULATORY REQUIREMENTS

Several federal, state, and local agencies have cognizance over portions of the waste management activities. The detailed interfacing of these agencies in the regulation of retrieval, processing, transportation, storage, and disposal is, in some instances, unclear at this time. However, it is expected that the agencies issuing regulations applicable to waste management alternatives would include the following:

- United States Department of Energy (DOE)
- United States Environmental Protection Agency (EPA)
- United States Nuclear Regulatory Commission (NRC)
- United States Department of Transportation (DOT)
- United States Department of Labor, Occupational Safety
and Health Administration (OSHA)
- State of Idaho

It is intended that the plans for siting, design, construction, operations, and decommissioning of facilities described in this document be accomplished in accordance with all applicable regulations. An adequate level of quality assurance would be maintained to ensure that the public, the environment, and the workers would be protected from the hazards associated with transuranic waste.

16.3 TECHNICAL DEVELOPMENT STUDIES

Concepts developed during the present study were restricted to those based on state-of-the-art techniques and equipment. However, development work would be needed to adapt current technology to the envisioned application. Until an alternative is selected for long-term management of the INEL stored TRU waste, no major program commitments will be made for developing any of the alternatives. However,

existing studies will be continued and expanded to provide the necessary data on which to base the selection of an alternative. Some of these studies (either in progress or under consideration) are listed below.

For Alternatives 1 and 2, studies of the clay overburden would be helpful in projecting its long-term integrity. Examples are tests of permeability, erosion rates, and the effectiveness of soil binders. Another useful study would be of techniques for crushing basalt for the riprap. For Concept 2-c, a plot would be used to test various grout formulations and to determine the optimum spacing of pressure grout holes.

Several disposal concepts rely on a physical barrier provided by cast concrete, cement grout, clay, or basalt. While these materials are widely used, their behavior over very long periods of time (hundreds of years) is not well known. The integrity and moisture exclusion properties of these materials should be evaluated. Approaches to this problem include: (1) review of historical data, (2) accelerated testing, and (3) theoretical analysis to extrapolate the effects of known mechanisms to longer time periods. Knowledge of the effects of composition and treatment upon desired properties would be useful information.

Techniques currently do not exist to permit, on a production scale, an accurate assay of transuranics in the presence of beta-gamma emitters and in large packages of inert material. A development program is needed to determine the level of detection that can be achieved in reasonably short times, and the inaccuracies due to shielding. Active neutron interrogation is one of the more useful tools that might be adapted for waste monitoring.

A number of areas associated with the slagging pyrolysis system require additional development. There is currently no operating experience with this equipment on contaminated waste similar to that studied in this document. Areas requiring additional development include:

- (1) Mixture ratios of waste, soil, coal, and bark must be studied to determine the effects on emissions, operating efficiency, and slag characteristics of the slagging pyrolysis system.
- (2) A prototype off-gas system must be built and operated. Studies are underway in this area.
- (3) A study would be needed to determine possible methods of contamination control in the feed - processor - slag system.
- (4) Maintenance and operation of a contaminated unit must be evaluated. Design decisions permitting repair and/or replacement would be affected.
- (5) The composition and integrity of the slag casting depends on many factors. Studies are underway in this important area.

While the exact concentrations of fissionable materials in the waste are not known, the design and operating parameters for the waste treatment process must be determined so as to preclude accidental criticality. A series of calculations would be performed to determine what isotope concentrations could result in criticality. These calculations would provide information on the required level of incoming waste inspection and the margin of safety associated with the planned quantities and geometries of waste.

For concepts that involve disposal at Site 14 and the Lemhi Range, a considerable amount of additional geologic and hydrologic data would have to be gathered to determine site suitability. A drilling and sampling program would be conducted following review of all available data.

16.4 ENVIRONMENTAL AND SAFETY INVESTIGATIONS

Several environmental and safety investigations are underway or planned in support of the EIS (Subsection 7.3.2) for long-term management of INEL TRU waste. This section focuses on a few such investigations, the need for which has been highlighted during this and previous studies.

- (1) Waste Characterization: Varying estimates have been given for the quantities and chemical forms of the TRU waste. A detailed search and analysis of records is underway to better establish the waste quantities and forms, and the potential radiation levels.
- (2) Container Integrity: Sampling studies are underway to assess the integrity of the stored waste containers placed on the TSA pads as long as 8 yr ago. These studies are summarized in Subsection 4.4.3.
- (3) Radionuclide Migration Uptake: The migration of the radionuclides in the soil beneath the RWMC is the subject of continuing studies. Data are being developed to support long-term projections of migration. A mathematical model of potential migration to the aquifer, flow through the aquifer, and ingestion by populations is in a state of continuing development to help establish the risk to the public from waterborne transport.

- (4) Additional Risk Analysis Studies: Several studies are underway to better define long-term and short-term risks. Long-term predictions of geologic, hydrologic and climatologic conditions are being developed. The possibility of failure of the Mackay Dam and the potential for associated flooding of the INEL are being studied. The potential effects of sabotage and intrusion upon the RWMC are also being studied.
- (5) Ecological Studies: The Radiological and Environmental Sciences Laboratory (RESL) of the DOE has conducted limited baseline studies of soils, plants, and small mammals in the vicinity of the RWMC (Subsection 5.7). An additional study of flora and fauna within the RWMC is underway to evaluate population density, range of movement, radionuclide uptake, and food-chain pathways.

17. COMPARISONS AMONG ALTERNATIVES, CONCEPTS, AND MODULES

17.1 INTRODUCTION

This section presents comparisons among the alternatives and concepts for long-term management of the stored TRU waste. Competing modules (e.g., slagging pyrolysis versus compaction and immobilization) are also compared. The order of presenting the comparisons is as follows: (1) comparisons among alternatives and concepts for leaving the waste in place; (2) among processing modules; (3) among modules for onsite disposal; (4) among alternatives for retrieval, processing, and shipment to the Federal Repository; (5) among concepts for retrieval, processing, and disposal on the INEL; and (6) among alternatives and concepts covered in (1), (4), and (5) above. Thus, the approach is to start the comparisons on the modular level and to make successively broader comparisons. The comparisons presented in item (6) are the broadest in scope.

Some of the factors for comparison, such as radiological risk to the public, radiological effects on the environment, and cost, are basically quantitative. These comparisons are the most straightforward. The summary tables for such factors, which appear in the evaluation sections of this document, are referenced in Table 17-1.

Other factors, such as development risk, are not amenable to quantitative comparisons. The difficulty of making such comparisons does not lessen the importance of these factors, however.

The remaining factors, such as hazards to the workers and non-radiological effects on the environment, are partly quantitative. Comparisons based on these factors are intermediate between the two preceding classes of comparisons. Useful summary tables for these factors are also referenced in Table 17-1.

TABLE 17-1

SUMMARY TABLES USEFUL FOR COMPARISONS OF ALTERNATIVES
FOR LONG-TERM MANAGEMENT OF STORED TRU WASTE

<u>Factor for Comparison</u>	<u>Table(s)</u>
<u>Environmental Effects</u>	
Nonradiological	12-32, 12-33
Radiological	12-18, 12-34, 12-35
<u>Radiological Risks to the Public</u>	13-19, 13-20, 13-22
<u>Hazards to the Workers</u>	
Nonradiological	14-4
Radiological	14-5
<u>Costs</u>	15-1, 15-2

Within each subsection, environmental effects are generally compared first. Risks to the public, hazards to the workers, and costs are then compared. Finally, factors such as technical development risk and major uncertainties are discussed.

As indicated in Subsection 1.2, the comparisons presented in this section do not constitute a complete basis for selecting an alternative for implementation. The evaluations performed for this document were preliminary, and not all the relevant factors for decision making were addressed. More complete and detailed comparisons will be pre-

sented in the draft EIS for management of INEL TRU waste, discussed in Subsection 7.3.2. However, the present comparisons provide preliminary information concerning relative impacts of the alternatives that have been studied.

17.2 ALTERNATIVES AND CONCEPTS FOR LEAVING THE WASTE IN PLACE (ALTERNATIVE 1, CONCEPTS 2-a, 2-b, AND 2-c)

For the first few years after implementation, the environmental effects associated with these alternatives and concepts would be proportional to the level of construction effort. (These effects would be nonradiological.) The effects would be greatest for Concept 2-b and least for Alternative 1, with Concepts 2-a and 2-c being intermediate in effect (Table 12-32). Even for Concept 2-b, however, the overall effect on the environment would be minimal.

Hundreds of years after implementation, the ordering of concepts, based on environmental effects, would be expected to be almost the reverse of that just discussed. (These effects would be radiological.) The improved waste confinement provided in Concepts 2-b and 2-c might reduce the spread of radionuclides by erosion processes and by groundwater leaching. The least protection would be provided by Alternative 1. Thousands of years after implementation, however, none of these concepts would be expected to result in smaller environmental effects than would any other, because all confinement could have deteriorated completely. The environmental effects of releases, even without improved confinement, would be expected to be small.

Conclusions based on comparing risks to the public are similar to those for environmental effects. For all of the subject concepts, the dominant release scenario is that of volcanic action disrupting the waste, either explosively or by means of lava flow over the waste. The improved confinement in Alternative 2 would reduce this risk in the short term (Table 13-19). In the long term (Table 13-20), the benefit would diminish as the confinement deteriorated, in perhaps

100 yr for Concepts 2-a and 2-b and 400 yr for Concept 2-c. The improved confinement would similarly reduce the risk of waterborne transport for the first few hundred years.

Nonradiological hazards to the workers (Table 14-4) for the subject alternatives and concepts would be virtually identical in magnitude. Radiological doses to the workers would be expected to be small compared with background levels (Table 14-5). Radiological consequences of potential accidents affecting the workers would be very small for Alternative 2. No credible operations-related accidents were identified for Alternative 1.

The total cost over the 100-yr period studied would be \$60 million, \$61 million, \$63 million, and \$71 million, for Alternative 1 and Concepts 2-a, 2-b, and 2-c, respectively (Table 15-1). Included in each case is \$60 million for maintenance and surveillance. Thus, the cost of improving the confinement would be a small part of the total waste management cost over the 100-yr period.

Although grouting is a proven technology, R&D would be necessary for Concepts 2-b and 2-c to determine the optimum grout mix and injection spacing and to attempt to project the long-term effectiveness.

17.3 RETRIEVAL MODULES (FOR ALTERNATIVES 3, 4, 5, AND 6)

Direct-control retrieval was the only method for which environmental effects, risk, hazards to workers, and costs were evaluated.

17.4 PROCESSING MODULES (FOR ALTERNATIVES 3, 4, 5, AND 6)

Three processing modules were studied: (1) slagging pyrolysis and packaging; (2) compaction, immobilization, and packaging; and (3) packaging only. All three modules were studied in connection with onsite

disposal (Alternative 5). Only the waste form produced by slagging pyrolysis was assumed to be acceptable at the Federal Repository (Alternatives 3, 4, and 6).

Radiological effects of normal operational releases from the slagging pyrolysis facility would be slightly larger than those for the other processing modules studied (Tables 12-21, 12-22, 12-24, 12-25, 12-34, and 12-35). Most nonradiological effects would also be larger for slagging pyrolysis. (See Tables 12-32 and 12-33. Recall that Concepts 5-a through 5-c, for example, differ from one another only in the nature of the processing module.) During the operational campaign, the risks to the public from operations-related accidental releases would be slightly larger for slagging pyrolysis (Tables 13-12, 13-14, and 13-15) than for the other processes. The hazards to the workers would be somewhat higher for slagging pyrolysis than for the other processes (Tables 14-4 and 14-5). However, none of the differences mentioned is so significant as to be a controlling factor in selection of a processing module.

The principal incentive for slagging pyrolysis is the reduced long-term risk and environmental contamination due to immobilization of the waste. The slag is of low solubility and has good resistance to impact. It would be expected to maintain its integrity over long periods of time. However, depending on environmental conditions, even the slag might not maintain its integrity over geologic time periods. (By comparison, reliable containment would be provided by the steel containers for the packaging-only module for perhaps a few decades, and by the concrete blocks of the compaction and immobilization module for perhaps a few hundred years. Both time periods would depend strongly on environmental conditions.)

The effectiveness of slagging pyrolysis in reducing long-term risk depends on at least three factors. The first factor is the disposal module considered (i.e., aboveground, shallow land, or deep rock).

The second factor is the dominant release scenario contributing to risk. For scenarios involving dissolution of the waste, the low mobility of the slag would be important; for scenarios involving volcanic action, the slag product might lead to radiological doses no lower than those for concrete or even for a waste form without immobilization. The risk evaluations of Section 13 indicate that release scenarios for volcanic action are dominant for all disposal modules at the INEL (Tables 13-18, 13-19 and 13-20).

The third factor is the time at which the release event might occur, in relation to the degradation of the waste form. Further study of these factors, in the context of risk analysis, would provide useful data for selecting a waste form based on these considerations.

The capital cost for the slagging facility would be about twice those for the other processing modules (Table 15-2). Operating and maintenance (O&M) costs would be two to three times those for the other modules. For both capital and O&M costs, the other two modules would be similar to one another.

Cost effects of a processing module extend beyond the module itself, however. The effect on shipping costs and disposal costs, due to changes in material volume and weight, must also be considered. For example, the packaging-only module was studied for Alternative 5 because of its expected low cost. For this module, the saving in total processing cost, over compaction and immobilization, would be \$5 million (Table 15-2). However, compared with compaction and immobilization, onsite disposal costs would be higher by from \$9 million to \$232 million, depending on the disposal method. (Differences in onsite shipping costs would be negligible by comparison.)

Considerable R&D would be necessary before implementation of the slagging pyrolysis module. Some of the preliminary R&D is described in Subsection 4.4.2. Relatively little R&D would be anticipated for the other two processing modules.

17.5 MODULES FOR DISPOSAL AT THE INEL (FOR ALTERNATIVE 5)

Four modules were studied for waste disposal at the INEL: engineered aboveground disposal near the RWMC, engineered shallow-land disposal at Site 14, and two modules involving deep rock disposal (shaft access and tunnel access) in the Lemhi Range. Two designs were studied for the Site 14 disposal module: a more massive variation (8-ft thick walls) and a less massive variation (8-in. thick walls).

The modules in the Lemhi Range and at Site 14 would involve construction on a part of the INEL not previously used for nuclear operations. There would be some loss of grazing land.

The modules for disposal at Site 14 and at the RWMC would require sizeable quantities of clay and bentonite (Table 12-6). Except for the less massive variation at Site 14, very large quantities of concrete would be required.

Long-term effects on the public from uncontrolled releases of radionuclides would be least for the Lemhi Range modules (Tables 13-18 and 13-20), because their location is away from areas of recurrent volcanism (the dominant release scenario) and off the Snake River Plain Aquifer. (However, this part of the INEL is believed to be hydrologically coupled to the aquifer.) The great depth below the ground surface would afford protection from events such as glaciation and airplane crashes. Earthquakes could have some effect; further study of this scenario would be advisable.

The aboveground disposal module at the RWMC would lead to larger long-term waterborne releases because of the relatively thin layer of sediment available for adsorbing radionuclides. The aboveground disposal module would also be most prone to long-term erosion and to glaciation. However, the dominant release scenario at Site 14 and the RWMC is lava flow. Thus, the important parameter is the time for

which the waste confinement could resist the effects of lava flow. This time was taken to be 25,000 yr for aboveground disposal and for shallow-land disposal, except for the less massive variation at Site 14, which was assumed to provide protection for 2,000 yr.

Nonradiological hazards to the workers would be slightly higher for deep rock disposal than for the other modules for onsite disposal (Table 14-4). The difference is attributed to the need for subsurface mining operations. However, the difference is not considered significant. Deep rock disposal would also involve slightly larger radiological doses to the workers from normal operations (Table 14-5) than would the other disposal modules.

Capital costs estimated for the facilities for engineered surface disposal and engineered shallow-land disposal are about 3 to 10 times those for deep rock disposal, depending on the waste volume after processing (Table 15-2). However, the cost of the less massive variation at Site 14 would be about the same as that for deep rock disposal.

Extensive studies would be needed of the geology and hydrology in the Lemhi Range before actively pursuing plans for disposal there. There are a number of key uncertainties (e.g., the possibility of underground springs developing) concerning the safety of deep rock disposal in that location. Similar studies would also be needed of the area of Site 14.

17.6 ALTERNATIVES AND CONCEPTS FOR RETRIEVAL, PROCESSING, AND SHIPMENT TO THE FEDERAL REPOSITORY (ALTERNATIVES 3, 4, and 6)

This subsection presents comparisons made at the level of alternatives, rather than at the level of modules. The alternatives compared differ in the dates at which the waste would start to be (1) retrieved and processed, and (2) shipped to the Federal Repository. In Alternative 3, all the above operations would begin in 1985. In Alternative 4, the retrieval and processing would begin in 1985; the

processed waste would be stored until 2005, when shipping to the Federal Repository would begin. In Alternative 6, none of these operations would start until 2005.

17.6.1 Effects of Delaying Retrieval. The environmental effects, hazards to the workers, and risks to the public would be expected to be nearly identical for Alternatives 3 and 6. There would be a small effect from retrieving waste containers that had deteriorated to some extent. The inventory of radionuclides would have decreased slightly by virtue of radioactive decay. However, the assumed growth in the population during the intervening 20 yr would counteract the effect of radioactive decay. In Alternative 3, the waste would be disposed of in the Federal Repository starting in 1985, rather than remaining until 2005 in its present confinement at the RWMC. During the 20-yr delay period, the risk from processed waste at the Federal Repository would be expected to be less than that of unprocessed waste at the RWMC. However, compared with the time-integrated values of long-term effects from uncontrolled releases, the time-integrated values of the risks from this 20-yr delay would be negligible (Tables 13-18, 13-19, and 13-20).

Except for escalation, the cost of Alternative 6 would be expected to be essentially the same as that for Alternative 3. One small difference (about \$12 million, or 3%) would be the added cost of monitoring the waste for an extra 20 yr, awaiting retrieval (Tables 15-1 and 15-2).

An additional effect of the 20-yr delay concerns the waste that might be received at the RWMC between 1985 and 2005 (see Appendix C). This additional volume of waste would constitute a backlog increment of 36% above the waste in storage by 1985 (Table C-2). Thus, in Alternative 6, either the processing rate of the facility designed for Alternative 3 would have to be increased by 36%, or the operational campaign would have to be lengthened by 36% beyond the nominal 10 yr. If the campaign were lengthened, the economic effect would be found in O&M costs. If the processing rate of the facility were increased, both capital and O&M costs would be increased.

17.6.2 Effects of Delaying Shipment. Alternative 4 (delayed shipment) differs from Alternative 3 in the need for 20-yr storage and in the date of shipment to the Federal Repository. The relative contributions of the 20-yr storage module to the public risk, worker hazards, and environmental effects of the complete alternatives would be small. The same is true for the effects of delaying shipment to the Federal Repository by 20 yr.

Except for escalation, the major cost difference resulting from delayed shipment is the cost of 20-yr storage (Tables 15-1 and 15-2). Total capital and O&M costs for this operation would be about \$12 million. In addition, an extra 10 yr of monitoring the waste would be required after emplacement in 20-yr storage. The cost of this item would be about \$6 million. The net impact of \$18 million is about 5% of the total cost for the alternative.

17.7 CONCEPTS FOR RETRIEVAL, PROCESSING, AND DISPOSAL OF THE WASTE AT THE INEL (ALTERNATIVE 5)

The observations made in Subsections 17.3, 17.4, and 17.5, concerning the modules for retrieval, processing, and disposal, respectively, are not repeated here. Rather, those observations are integrated here, to assist in comparisons at the level of concepts.

The principal tradeoff in selecting a processing module appears to be the higher cost of processing by slagging pyrolysis (Tables 15-1 and 15-2) versus the improved immobilization achieved for safe disposal.

Compared with packaging only, slagging pyrolysis would lead to a saving in disposal cost because of the greater volume reduction achieved. Slagging pyrolysis and compaction and immobilization would lead to similar disposal costs. Any differences would be due principally to optimization considerations (container size and shape, storage room dimensions, etc.). Because of the relatively short distances involved, cost differences in onsite shipment would be small in all instances.

Among the onsite disposal modules, the engineered aboveground and shallow-land disposal modules are at a large disadvantage in cost (Tables 15-1 and 15-2). This disadvantage can be overcome by use of the less massive variation for engineered shallow-land disposal, although at some penalty in long-term safety (Table 13-20).

Site 14 would be less subject to flooding and volcanism than would the RWMC. The greater depth of sediments at Site 14 would restrict the subsurface migration of radionuclides more than would the sediments at the RWMC. The disposal modules at the Lemhi Range location are the only ones studied that would furnish positive protection against lava flow, glaciation, and routine weathering. Furthermore, the area is not situated above the Snake River Plain Aquifer, although it is believed to be hydrologically coupled to the aquifer. The principal drawbacks of the Lemhi Range location are (1) the relatively unknown geology and hydrology of the site, and (2) the nearness (less than 1 mile) to the present boundary of the INEL (Figure 3-4).

17.8 ALL ALTERNATIVES STUDIED FOR LONG-TERM MANAGEMENT OF THE INEL TRU WASTE

The intent of this subsection is not to advocate one particular alternative or concept over another. Rather, the intent is to integrate the preceding comparisons, highlighting the relative advantages and disadvantages of the alternatives.

To quantify some of these comparisons, six general areas were selected for comparison: (1) radiological environmental effects, (2) short-term radiological risk, (3) long-term radiological consequences, (4) nonradiological hazards to workers, (5) radiological hazards to workers, and (6) cost. To limit the complexity of the exercise, only one specific parameter was chosen to represent each general area of comparison.

The six specific parameters are, respectively, the following: (1) population (bone) dose commitment from normal operational releases, (2) total population risk (based on lung dose commitment) from short-term accidental releases, (3) maximum population lung dose from long-term accidental releases, (4) total nonradiological occupational injuries to workers during implementation, (5) total worker dose during normal operations, and (6) total estimated cost. Comparisons of the alternatives and concepts for these six parameters are presented in Table 17-2.

Considerable simplification was required to produce Table 17-2. Lack of space precludes listing all of the bases for the entries. Furthermore, one number was selected to represent the results of an entire area of study. Thus, misinterpretation of the data is possible. To minimize this possibility, the reader should consult the source tables listed at the bottom of Table 17-2.

The most straightforward comparison of the alternatives concerns the estimated costs. In round numbers, Alternative 1 would cost \$60 million; Alternative 2, about \$65 million; Alternatives 3, 4, and 6, about \$375 million; and Alternative 5, from about \$225 million to \$575 million. For the alternatives involving shipment to the Federal Repository, an apportioned cost of disposal at the Repository is included, as discussed in Section 15. The apportioned cost is highly uncertain. It depends on the volume of waste that might be shipped to the Repository, including waste from other DOE sites. Another complication is that the estimated cost of the Federal Repository (DOE 1979) includes a number of cost factors not included in the disposal cost estimates for Alternative 5. Therefore, the costs for Alternatives 3, 4, and 6 are not strictly comparable with those for Alternative 5. Also, see Subsection 15.1 for an important caveat concerning all estimates given for facilities costs.

Hazards to the waste management workers would be lowest for Alternative 1, slightly higher for Alternative 2, and considerably higher for Alternatives 3 through 6.

TABLE 17-2

SELECTED QUANTITATIVE COMPARISONS OF ALTERNATIVES AND CONCEPTS

Alternative/ Concept	Population Dose Commitment from Normal Operational Releases (man-rem/yr to bone)	Total Population Risk from Short- Term Accidental Releases(a) (man-rem/yr to lung)	Maximum Population Dose from Long- Term Accidental Releases(b) (man-rem to lung)	Total Nonradiological Occupational Injuries during Implementation	Total Worker Doses during Normal Operations (man-rem)	Total Estimated Cost (millions of mid-July 1978 dollars)
1	0	1×10^1	4×10^4	4.4	5	60
2-a	0	1×10^{-1}	4×10^4	4.8	5	61
2-b	0	1×10^{-1}	4×10^4	5.3	6	63
2-c	0	1×10^{-1}	4×10^4	4.6	5	71
3	3.3×10^{-2}	3×10^{-3}	No stored waste at INEL	100+NI(c)	293+NI	371
4	3.3×10^{-2}	3×10^{-3}	No stored waste at INEL	104+NI	328+NI	389
5-a	3.3×10^{-2}	3×10^{-3}	8×10^0	127	376	377
5-b	4.6×10^{-3}	1×10^{-3}	8×10^0	62	223	234
5-c	4.6×10^{-3}	1×10^{-3}	8×10^0	55	213	238
5-d	3.3×10^{-2}	3×10^{-3}	8×10^0	122	358	377
5-e	4.6×10^{-3}	1×10^{-3}	8×10^0	57	205	234
5-f	4.6×10^{-3}	1×10^{-3}	8×10^0	50	195	239
5-g	3.3×10^{-2}	3×10^{-3}	4×10^4	109	308	513
LMV(d)	3.3×10^{-2}	3×10^{-3}	4×10^4	106	308	369
5-h	4.6×10^{-3}	1×10^{-3}	4×10^4	44	155	341
LMV	4.6×10^{-3}	1×10^{-3}	4×10^4	41	155	228
5-i	4.6×10^{-3}	1×10^{-3}	4×10^4	39	145	567
LMV	4.6×10^{-3}	1×10^{-3}	4×10^4	35	145	250
5-j	3.3×10^{-2}	3×10^{-3}	4×10^4	109	305	445
5-k	4.6×10^{-3}	1×10^{-3}	4×10^4	44	152	307
5-l	4.6×10^{-3}	1×10^{-3}	4×10^4	39	142	476
6	3.8×10^{-2}	3×10^{-3}	No stored waste at INEL	01+NI	147+NI	383
Source Table	12-35	13-19	13-20	14-4	14-5	15-1

- (a) The risk for Alternatives 3 through 6 includes only operations-related events. Not included are possible releases due to natural events disrupting unretrieved waste during the campaign. Inclusion of such events would cause the risks for Alternative 3 through 6 to be similar to that for Alternative 1 during the campaign period.
- (b) For volcanic action scenario occurring at a time 25,000 yr into the future. Concepts 2-a through 2-c and 5-g through 5-l would provide protection against this scenario for various times, up to a maximum of 25,000 yr. Concepts 5-a through 5-f would provide protection for longer, as-yet-undetermined times.
- (c) NI = Not Included (relates to operations at the Federal Repository).
- (d) LMV identifies the use of the less massive variation of the engineered shallow-land disposal facility at Site 14.

Comparisons of the alternatives on the bases of environmental effects and of risk to the public are particularly difficult. The time periods for which these parameters were studied were 10 yr for Alternative 3, 30 yr for Alternatives 4 and 6, and many thousands of years for Alternatives 1, 2, and 5. The reason for this difference is that the long-term environmental effects and risks associated with the Federal Repository were not evaluated in this study. These topics are being addressed in other DOE-sponsored studies (DOE 1979).

Of course, the long-term radiological effects at the INEL would be less for Alternatives 3, 4, and 6 than for Alternatives 1, 2, and 5. However, these effects for Alternatives 3, 4, and 6 would not cease to exist. The effects would simply be transferred to the location of the Federal Repository, probably at a reduced level.

Because Alternatives 3, 4, and 6 would involve handling of the waste, their environmental effects and risk would be somewhat greater, in the near term, than those for leaving the waste in place, Alternatives 1 and 2. (Footnote (a) in Table 17-2 clarifies the short-term risk comparisons.) However, if the comparisons of environmental effects and of risks were to cover the long periods of time associated with disposal at the Federal Repository, this conclusion could be reversed. The environmental effects and risk associated with long-term management at the Federal Repository would probably be smaller than those for leaving the waste in place at the RWMC for the same time period. Several factors could contribute to this possible reduction in risk: (1) deeper disposal, (2) lower expected frequency of volcanic and seismic action, (3) greater isolation from an aquifer, and (4) probable lower population density. A lower risk associated with long-term management at the Federal Repository might eventually outweigh the higher near-term risk associated with operations during the campaign.

Until the analyses of long-term environmental effects at the Federal Repository are finalized and compared in detail with the results of the present study, only partial comparisons can be made of Alternative 5 with Alternatives 3, 4, and 6.

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APPENDIX A

TEXT OF COMMUNICATIONS BETWEEN THE FEDERAL GOVERNMENT AND THE GOVERNMENT OF THE STATE OF IDAHO CONCERNING LONG-TERM MANAGEMENT OF INEL TRU WASTE

Over the last several years, the DOE (and its predecessor organizations, ERDA and AEC) has corresponded with government officials of Idaho about the long-term status of TRU waste at the INEL, formerly the National Reactor Testing Station (NRTS). Although TRU waste had been routinely shipped from Rocky Flats to the INEL since 1954, it was not until 1969 that interest focused on this issue. At that time, large quantities of TRU-contaminated solid waste were being shipped to the NRTS as a result of cleanup operations from a fire at the Rocky Flats Plant. Publicity stemming from the fire caused Idaho officials to raise questions regarding the safety of burying the Rocky Flats waste in Idaho.

At the request of U.S. Senator Frank Church, four Federal agencies made a joint study of radioactive waste storage at the RWMC. The agencies were the U. S. Geological Survey, the Bureau of Radiological Health of the U. S. Public Health Service, the Federal Water Pollution Control Administration, and the Bureau of Sport Fisheries and Wildlife. Subsequent studies of the RWMC also were made by the Bureau of Radiological Health (BRH) and the Federal Water Quality Administration (FWQA). The findings of the BRH were summarized as follows in a letter transmitted in February 1970 to Senator Church from the Assistant Surgeon General:

It is our judgment that the land burial techniques currently in use meet the radiation safety criteria of the Federal Radiation Council for protection of the public. Extensive environmental radioactivity data are available for the site which show that no health and safety problems have occurred as a result of the burial of solid radioactive wastes. This

experience also indicates that it is not likely the radioactivity will migrate from the burial grounds in the future, if current procedures are continued. Because of the potential long-term effects, additional safety measures, consistent with a conservative approach regarding radioactivity, are recommended in the staff study.

The recommendations identified in the quoted report were implemented at the RWMC.

The FWQA report was completed in April of 1970. The AEC, in a subsequent meeting with Senator Church and in a letter addressed to him in June 1970, took exception to a number of the FWQA report findings. However, in a June 1970 letter to Senator Church, AEC Chairman Seaborg indicated that:

In FY [Fiscal Year] 1972 AEC will seek authority to establish a demonstration radioactive waste repository in salt which will store both high level wastes from fuel reprocessing plants and low level alpha particle emitting wastes (alpha wastes) such as the Pu-contaminated wastes from the Rocky Flats Plant. When the salt mine repository is fully operative, AEC plans to store not only currently generated alpha wastes but also to excavate, process and ship such wastes which are being temporarily stored at NRTS. A number of years will be required to complete the transfer of such wastes from NRTS which we hope to start within the decade.

The authorization request referred to by Dr. Seaborg was for a repository in salt. The repository was tentatively to be located at Lyons, Kansas, subject to satisfactory completion of certain additional tests and studies. The projected availability of the Lyons repository was 1976. Thus, the commencement of waste transfer from Idaho before the end of the decade seemed a reasonable hope. However, site-specific safety questions arose at the Lyons site. When it appeared that the questions might not be satisfactorily answered in a reasonable time, the project was abandoned in mid-1972. A search for an alternative location began.

A series of communications followed between the Governor of Idaho and DOE officials relative to the issue. In October 1973, Governor Cecil Andrus wrote a letter to Dr. Dixie Lee Ray, then Chairman of the U.S. Atomic Energy Commission, which requested, in part, that:

- (1) The AEC assure us and the people of Idaho that the National Reactor Testing Station is in no way being considered as a site for the permanent or the extended "interim" storage of long lived nuclear wastes in any form
- (2) All efforts are being exerted by the Atomic Energy Commission to assure the procurement and development of a safe and acceptable National Atomic Waste Repository, not located over a vital water resource such as the Snake Plain Aquifer, so that long lived radioactive wastes currently in interim storage at the National Reactor Testing Station can be removed for permanent storage at the earliest possible date in line with promises made by the AEC to begin preparations for the removal of such wastes from the NRTS burial ground by the end of this decade.

Chairman Ray of the AEC responded in November of 1973 with the following:

- (1) I can assure you that the NRTS is not being considered in any way as the site for permanent disposal of any long-lived nuclear waste. No decision has been made concerning the location for the Retrievable Surface Storage Facility which we plan to build for the solidified commercial high-level radioactive waste.

Wherever the facility is located, it will be designed, constructed and operated in a manner which will assure that the radioactive inventory will not be released by equipment failure, human error, overt or covert actions by man, or natural phenomena.

Further, before any decision is made in this matter, the public will be given full opportunity, through an Environmental Impact Statement, Congressional Authorization and Appropriation hearing, etc., to thoroughly review the safety considerations and to raise any and all questions it may have concerning the ability of the facility to give full protection to the health and safety of the public and to the environment.

- (2)...the Commission has a positive program to develop and implement the techniques needed to treat, package and permanently dispose of the plutonium contaminated waste now stored at NRTS, including that previously buried in the trenches at that site. The schedule of this program recognizes our commitment to be ready to start moving this waste from that site by the end of the decade.

In pursuit of this commitment, the ERDA budget submitted to Congress early in 1975 requested increased funding for core drilling to evaluate a bedded salt area in southeastern New Mexico as a potential repository for disposal of ERDA-generated wastes. This repository would be a disposal site for the backlog of Rocky Flats waste presently located at the INEL.

With this budget submittal and the possibility of a federal repository, the following action plan for the retrieval, processing, and packaging of TRU wastes was developed and given to the Governor of Idaho in 1975 by local DOE (formerly ERDA) officials.

INEL ACTION PLAN
ERDA AND COMMERCIAL TRANSURANIC WASTE

<u>CY</u>	<u>ACTIVITY</u>
1973-78	Retrieval, processing and packaging R&D
1974-76	Demonstrate retrieval at INEL
1975-77	Conceptual design of retrieval, processing, packaging facility (RPPF)
1977-	Budget request for RPPF
1977-78	Advanced conceptual design and planning
1978	Project funds become available
1978-81	Detailed facility design
1980-83/84	Facility construction
1984	Facility checkout
1985	Initial operations
1986	Full scale operations
1991 ^{1/} 1985 ^{2/}	Shipments to repository begin
1991 1985	Incoming shipments to INEL cease
1995 1994	All wastes at INEL processed (and shipped to repository)

^{1/} The dates through the remainder of this column assume 1991 is the earliest date that a federal repository can accept transuranic waste.

^{2/} The dates through the remainder of this column assume 1985 is the earliest date that a federal repository can accept transuranic waste.

The Governor indicated support of this plan in return correspondence to DOE officials in April 1975.

Several letters followed concerning emphasis and clarification of statements in previous correspondence. In October 1976, as a result of the Governors staff review of WASH-1536, "EIS Waste Management Operations - Idaho National Engineering Laboratory" (ERDA 1977c), the Governor again corresponded with DOE officials. In this letter, Governor Andrus asked the following questions concerning the practices at the RWMC:

- (1) Will burial of non-transuranic radioactive waste continue beyond the end of this decade?
- (2) Will the long-lived non-transuranic wastes which are presently being buried ever be retrieved as promised for transfer to a federal repository or are they really disposed of at their present site?
- (3) Is the present level of activity at INEL expected to change?
- (4) Is the rate of generation of waste at other areas such as Rocky Flat expected to change?

DOE responded to this letter in September 1977 with the following:

- (1) We expect that burial of INEL-generated nontransuranic waste will continue at roughly the present rate as long as current facilities are operated.
- (2) The nontransuranic wastes that are buried at INEL are considered permanently disposed of, and we know of no environmental health or safety problem that would dictate their removal.
- (3) We do not expect the present level of programs at INEL to change significantly in the foreseeable future.
- (4) The rate of generation of waste at Rocky Flats and other sites is not expected to change significantly.

In December 1977, Senator Church again corresponded with the Department of Energy, expressing concern that earlier commitments made by the AEC in 1970 had not been met; e.g., that the AEC would begin removing transuranic wastes from Idaho within the decade.

DOE responded with the following in March of 1978:

In particular, it is unfortunate that removal of the stored wastes cannot begin as early as the Atomic Energy Commission (AEC) hoped in 1970. At that time, it was expected that the Lyons, Kansas, salt repository would be in routine operation by now. As you know, that project had to be abandoned. I can assure you that we are proceeding with the priority development of a suitable repository as rapidly as is compatible with safety and with the interests of the people in its area. The schedule is contingent on the completion of the environmental impact assessment process and successful arrangements with states and localities in the area. We expect that the Waste Isolation Pilot Plant (WIPP) repository will begin to accept wastes in the 1985-1986 time period. In any event, Idaho wastes will receive priority attention.

The complete text of all the pertinent correspondence on this subject, between officials of the State of Idaho and of the DOE and its predecessor agencies, is attached.

LIST OF CORRESPONDENCE BETWEEN
STATE OF IDAHO OFFICIALS AND FEDERAL OFFICIALS

- Exhibit A - Letter of October 15, 1969, from Glen T. Seaborg, Chairman of AEC to Senator Frank Church (regarding response on joint study by Federal agencies)
- Exhibit B - Letter of April 30, 1970, from Senator Frank Church to Chairman Seaborg (regarding ultimate removal of the burial site to a more suitable location)
- Exhibit C - Letter of May 26, 1970, from John Erlewine to Senator Len. B. Jordan (regarding plans for a waste repository in salt)
- Exhibit D - Letter of June 9, 1970, from Chairman Seaborg to Senator Church (regarding commitment to remove transuranics from NRTS)
- Exhibit E - Letter of October 5, 1973, from Governor Cecil D. Andrus to R. Glenn Bradley (regarding NRTS as reprocessing facility)
- Exhibit F - Telegram of October 9, 1973, from Governor Andrus and Senator Church to Chairman Dixy Lee Ray (NRTS as reprocessing facility)
- Exhibit G - Letter of November 5, 1973, from Chairman Ray to Governor Andrus (commitment to remove plutonium waste and other very long-lived waste)
- Exhibit H - Letter of November 14, 1973, from R. Glenn Bradley to Governor Andrus (regarding monthly report)
- Exhibit I - Letter of March 13, 1974, from R. Glenn Bradley to Governor Andrus (sample monthly report)
- Exhibit J - Letter of March 20, 1974, from Governor Andrus to R. Glenn Bradley (regarding concern over NRTS being nation's major de facto burial ground)
- Exhibit K - Letter of April 22, 1974, from R. Glenn Bradley to Governor Andrus (regarding Governor's concern on interim storage)
- Exhibit L - Letter of December 18, 1974, from Governor Andrus to R. Glenn Bradley (questioning when wastes will be removed from NRTS)
- Exhibit M - INEL Action Plan (hand delivered by R. Glenn Bradley, Manager ERDA-Idaho Operations Office to Governor Andrus 3-21-75)

- Exhibit N - Letter of April 29, 1975, from Governor Andrus to R. Glenn Bradley (regarding Blue Ribbon Committee)
- Exhibit O - Letter of June 19, 1975, from R. Glenn Bradley to Governor Andrus (answer to April 29, 1975 letter)
- Exhibit P - Letter from Governor Andrus to James L. Liverman, October 8, 1976 (comments on INEL Waste Management Environmental Impact Statement)
- Exhibit Q - Letter of Sept. 30, 1977 from James L. Liverman to Governor John Evans (answer to the October 8, 1976, letter from Governor Andrus to John Liverman)
- Exhibit R - Letter from Senator Church to James Schlesinger, December 6, 1977, (regarding commitment on removal of TRU waste)
- Exhibit S - Letter of March 2, 1978 from Dale D. Myers to Senator Church (reply to December 6, 1977, letter from Church to Schlesinger)

Exhibit A

United States
ATOMIC ENERGY COMMISSION
Washington, D.C. 20545
October 15, 1969

Honorable Frank Church
United States Senate

Dear Senator Church:

This is in response to your letter of September 13, 1969, requesting comments on your proposal that four other Federal agencies make a joint study of radioactive waste storage at the AEC's National Reactor Testing Station (NRTS) in Idaho.

At the time of startup, the best geological and hydrological information was used to select a site within the NRTS suitable for burial of its solid radioactive wastes. The site has also been used for burial of solid radioactive wastes from the AEC's Rocky Flats, Colorado, plant and was used for wastes from AEC licensees until commercially operated burial sites became available.

The NRTS has always operated an environmental monitoring program to detect radioactivity which could escape into the air or water from its operations. The radiation exposure standards of comparison are basically those of organizations independent of the AEC--the Federal Radiation Council, the National Council on Radiation Protection and Measurement, and the International Commission on Radiological Protection. The environmental monitoring results, which are summarized in semiannual public reports, show radioactivity concentrations in offsite waters and in onsite underground waters have always been well below these applicable limits.

The average annual precipitation at the NRTS during the past 15 years has been 8.5 inches. Studies at the burial ground indicate that 96 percent of all precipitation is lost by evaporation from the soil or transpiration by vegetation. The remaining 4 percent is not sufficient to cause saturation. Therefore, once the wastes are buried and covered by about 3 feet of soil it seems reasonable to believe they are not leached by water but remain virtually dry.

From the foregoing, there is no reason to believe that the aquifer has been contaminated, or will become contaminated, from rainfall. We plan to intensify our efforts to detect any changes due to spring snowmelt, and to take corrective action accordingly. In addition, because of the presence of long-lived plutonium in the burial ground, we are evaluating the hazard potential of some future major flood which might exceed any flood in the known history of the site.

The four agencies named in your letter already have some familiarity with NRTS operations. The AEC has always sought the expert advice of the U. S. Geological Survey (USGS), and the USGS has always maintained a small staff of scientists at the NRTS for that reason. Additional USGS consultation has been provided at the headquarters level. The Bureau of Radiological Health, U. S. Public Health Service, routinely integrates the NRTS environmental monitoring results with those from the monitoring networks operated by itself and by State health agencies. Technical staff from the Denver Regional Office of the Public Health Service recently visited NRTS for orientation on radioactive waste disposal. The Regional Director of the Federal Water Pollution Control Administration has visited NRTS to review both radioactive and nonradioactive waste disposal practices. The Bureau of Sport Fisheries and Wildlife has direct knowledge of fish and game conditions on the NRTS through staff visits in connection with predator control programs. The AEC will continue to cooperate with these agencies on matters of common interest. The AEC, of course, is responsible for the decisions which have been made and the preceding references are not intended to imply full endorsement of such decisions by these other agencies.

As a final comment, a proposed policy on siting of private nuclear fuel reprocessing plants, published in the Federal Register on June 3, 1969, provides in part that the high-level liquid wastes from such plants would be solidified and transferred to a limited number of Federal repositories which would provide permanent isolation of the wastes from man's environment. By letter of July 23, Mr. Donald J. McKay, Chairman of the Idaho Nuclear Energy Commission, agreed with the proposed policy and requested that the NRTS be designated as one of the Federal repositories.

We hope this information is sufficiently responsive to your inquiry. If you have any further questions, or if you would like a briefing by AEC technical staff, please let us know.

Cordially,

/s/ Glenn T. Seaborg

Chairman

Exhibit B

U.S. SENATE,

Washington, D.C., April 30, 1970.

Mr. Glen Seaborg,
Chairman, Atomic Energy Commission,
Washington, D.C.

Dear Mr. Chairman: The Federal Water Quality Administration (formerly the Federal Water Pollution Control Administration) has recently completed a report concerning waste disposal practices at the National Reactor Testing Station in Idaho Falls, Idaho.

The comments and recommendations contained in this report are of vital importance to the people of my state. I request the immediate implementation of the reports in behalf of the people of the state of Idaho.

Three separate reports have now openly criticized the activities of the AEC at Idaho Falls, Idaho. Two of those reports have called for the ultimate removal of the burial site to a more suitable location. In light of these facts, I feel that the AEC should proceed with all due speed to implement these recommendations.

Please keep me fully and currently informed of the actions of the agency in this regard.

With best wishes,
Sincerely,

/s/ FRANK CHURCH

Exhibit C

United States
ATOMIC ENERGY COMMISSION
Washington, D. C. 20545

May 26, 1970

Honorable Len B. Jordan
United States Senate

Dear Senator Jordan:

We very much appreciated the opportunity to discuss with you and your staff the waste management activities at the National Reactor Testing Station. The AEC believes that these activities are being carried out safely and in accordance with applicable standards.

We described at some length the burial of low-level solid radioactive wastes at NRTS and I would like to summarize AEC's plans regarding such wastes.

AEC regards burial of solid radioactive wastes at NRTS as constituting storage, not disposal. This is not because of any near-term hazard to the aquifer, the public or employees, but in order to obtain the very long-term isolation from the biosphere required for some of these wastes, transferral to an underground repository seems to be advisable. AEC has conducted an extensive R&D program and has concluded that a salt mine would provide the most effective isolation of such wastes from fresh water aquifer and from the biosphere. AEC will seek in FY-1972 authority to establish a radioactive waste repository in salt which will store not only high-level wastes from fuel reprocessing plants but also low-level alpha contaminated wastes such as the Pu-contaminated wastes from Rocky Flats.

When the repository is operative, AEC plans to store currently generated alpha wastes there and also to excavate, process and ship such wastes presently stored at NRTS. A number of years would be required to complete the transfer of such wastes from NRTS.

Should you desire additional information regarding our waste management activities, we will be pleased to provide it.

Sincerely,

/s/ John A. Erlewine
Assistant General Manager
for Operations

Exhibit D

United States
ATOMIC ENERGY COMMISSION
Washington, D.C. 20545

June 9, 1970

Honorable Frank Church
United States Senate

Dear Frank:

Since receiving your letter of May 1, 1970, Commissioner Thompson and members of the AEC staff have had the opportunity to meet with you and your assistants to discuss waste management activities at the National Reactor Testing Station.

Among matters discussed were some of the recommendations of the recently issued report of the Federal Water Quality Administration. As you were informed, AEC is not in accord with a number of the FWQA report findings and recommendations. We have recently completed detailed comments on that report and have furnished you a copy.

As you know, the AEC has long supported an active research and development program on methods for managing and disposing of radioactive wastes. This program has resulted in the development of several effective processes for reducing the volume of high level liquid wastes and converting them into solid forms suitable for shipment and long term storage. Just about a year ago the commission announced a proposed policy that would require high level wastes from commercial fuel reprocessing plants to be solidified on site and to be shipped to a Federal repository for storage. Such a policy is possible because of the successful technological developments resulting from the AEC's R&D program. That program has also included extensive R&D on the best methods for long term storage of solid wastes. After years of study and experiment the Commission has concluded that a salt mine would provide effective long term isolation of solid radioactive wastes from fresh water aquifers and from the biosphere. In FY 1972 AEC will seek authority to establish a demonstration radioactive waste repository in salt which will store both high level solid wastes from fuel reprocessing plants and low level alpha particle emitting wastes (alpha wastes) such as the Pu-contaminated wastes from the Rocky Flats Plant.

When the salt mine repository is fully operative, AEC plans to store not only currently generated alpha wastes but also to excavate, process and ship such wastes which are being temporarily stored at NRTS. A number of years will be required to complete the transfer of such wastes from NRTS which we hope to start within the decade. The proposed transfer of such wastes is not because of any near term hazard to the aquifer which

underlies NRTS, the public or NRTS employees. Transferral to an underground repository appears to be the best method for attaining the very long-term isolation of these wastes from the biosphere.

We will keep you fully informed as our waste management plans continue to develop and will be happy to discuss them with you.

Cordially,

/s/ Glenn T. Seaborg

Chairman

Exhibit E

STATE OF IDAHO
Office of the Governor
BOISE

October 5, 1973

Cecil D. Andrus
Governor

R. Glenn Bradley, Manager
Atomic Energy Commissions
Idaho Operations
Idaho Falls, Idaho 83401

Dear Mr. Bradley:

I would like to take this opportunity to welcome you back to Idaho. I understand you were here some years ago with Phillips Petroleum Co., and so I am confident that I do not have to extoll the virtues of living in Idaho to you.

With each passing day I am sure that you are keenly aware how controversial atomic energy is becoming in the eyes of the public. I have always had a high degree of confidence in the competence of the AEC's professional personnel and their management of our facility. I also keenly recognize the importance of the AEC's presence in Idaho and the function of the reprocessing facility at the site.

However, due to such things as Atlantic Richfield's inexcusable lack of monitoring a leaking waste tank at the Hanford site, and the subsequent publicity, the subject of waste management is being scrutinized by both the public and the press as never before. Because of my responsibility to represent and to protect the best interests and the safety of all Idahoans, I feel I must clearly impress upon you my concern about what U. S. News and World Report has termed "The Rising Danger of Atomic Waste."

With your predecessor, William L. Ginkel, I had an understanding which I want to establish with you also. Basically, the understanding entails your staff keeping in direct contact with my staff concerning any unusual increases in the amount of atomic waste being transported or transferred to Idaho for purposes of "interim storage." To be quite candid with you, many Idahoans have a justifiable fear that on an interim basis the AEC may make Idaho the nation's de facto repository for atomic wastes of all varieties. This possibility concerns both myself and Senator Frank Church for while your predecessor assured us this would not happen, inquiries by Senator Church's staff in Washington resulted in an acknowledgment of the possibility.

Page 2
R. Glenn Bradley

As Governor of this state, I cannot and will not permit Idaho to become a de facto repository for a considerable portion of the nation's waste--particularly waste which in no way figures in short-term re-processing. To that end I am enclosing a copy of a telegram which Senator Church and I will jointly release on Tuesday, October 9, in which we call upon Dixy Lee Ray to assure us through both her office and your office that except for the limited purposes of fuel reprocessing and calcining waste, the storage facilities at the NRTS will not in any way be expanded or used for the storage of atomic wastes from sources which have not previously utilized the NRTS site prior to January 1, 1973.

I note for example that Mr. Ginkel's staff, in conformance with our agreement, did inform me that the first shipment of 85 barrels of waste from a plant in Pennsylvania was enroute to Idaho as of September 27. It is my understanding that this shipment is the first of a total of 3,000 some barrels to be added to the already existing 250,000 barrels stored at the NRTS site. What we are asking, then, is that although this shipment may be completed, under the assurances we seek there will be no further shipments from that plant in Pennsylvania since it was not shipping prior to January 1. Also, the assurances we seek mean that waste from non-traditional sources should not be shipped to Idaho even on a one-shot basis. The rest of the telegram is self-explanatory.

I also would like a monthly report from your office in which you identify the amount of on-site generated waste as opposed to off-site generated waste. Enclosed is a copy of the solid waste cumulation report as of December, 1972. I am specifically requesting the same report as of October, 1973, and then as of the first of each month after that. Should there be any significant increases, I want my staff to receive a detailed explanation.

I am confident you can comply with my requests, for I have always enjoyed a cooperative relationship with your predecessor. I know we are both looking forward to a candid relationship based upon a mutual understanding and appreciation with respect to the roles in which we serve.

Again, welcome to Idaho, and I will look forward to hearing from you soon and to meeting you soon.

Sincerely,

/s/ Cecil D. Andrus

CECIL D. ANDRUS
GOVERNOR

Exhibit F

October 9, 1973

TELEGRAM

Dr. Dixy Lee Ray, Chairman
U. S. Atomic Energy Commission
Washington, D. C. 20545

A recent article, which appeared in the August 28 issue of the Washington Post, is of great concern to us. We were both assured by personnel at the National Reactor Testing Station that the Atomic Energy Commission did not contemplate the use of the NRTS as a National Repository for Atomic wastes. Indeed, past reports, particularly the April 1970 report of the Federal Water Control Administration, have indicated that the long term storage of radioactive wastes above the Snake Plain Aquifer is undesirable.

In light of recent decisions to ship atomic wastes to the NRTS from Pennsylvania, and the clear implication of the newspaper account that the AEC is indeed studying the NRTS as a possible permanent waste disposal site, we specially request, in writing, the following assurances:

1. That except for the limited purposes of fuel reprocessing and calcining of wastes the storage facilities of the NRTS will not in any way be expanded or used for the storage of atomic wastes from sources which have not previously utilized the NRTS site.
2. That the AEC assure us and the people of Idaho that the National Reactor Testing Station is in no way being considered as a site for the permanent or the extended "interim" storage of long lived nuclear wastes in any form.
3. That all efforts are being exerted by the Atomic Energy Commission to assure the procurement and development of a safe and acceptable National Atomic Waste Repository, not located over a vital water resource such as the Snake Plain Aquifer, so that long lived radioactive wastes currently in interim storage at the National Reactor Testing Station can be removed for permanent storage at the earliest possible date in line with promises made by the AEC to begin preparations for the removal of such wastes from the NRTS burial ground by the end of this decade.

Sincerely,

/s/ FRANK CHURCH
U. S. SENATOR, IDAHO

/s/ CECIL D. ANDRUS
GOVERNOR OF IDAHO

Exhibit G

United States
ATOMIC ENERGY COMMISSION
Washington, D.C. 20545

November 5, 1973

Honorable Cecil D. Andrus
Governor of Idaho
Boise, Idaho 83702

Dear Governor Andrus:

Thank you for the October 5, 1973, telegram from you and Senator Church concerning the Commission's present and future use of the National Reactor Testing Station as a site for the storage of radioactive waste.

I assure you and the people of Idaho that no action will be taken by the Commission regarding the storage of radioactive waste which can possibly result in a public hazard or insult to the environment, and that steps will be taken on a timely basis to eliminate any possible source of hazard or environmental insult which might result from past Commission practices. This is a fundamental objective which we follow in all of our activities, regardless of location.

In regard to your request for written response to three specific points; namely:

- "1. That except for the limited purposes of fuel reprocessing and calcining of waste the storage facility of the NRTS will not in any way be expanded or used for the storage of atomic wastes from sources which have not previously utilized the NRTS site."

The NRTS site is uniquely suited from the standpoint of site characteristics, available facilities and equipment, and available trained personnel for safe surface or near-surface retrievable storage of certain types of waste which have been routinely generated in the past at certain AEC facilities and which will be generated in the future at other AEC facilities. I am sure you appreciate that we must make maximum efficient use of all of our sites, facilities and manpower so long as such utilization does not in any way endanger the health and safety of the public or produce an unacceptable impact on the environment.

All waste at the NRTS has been, and will continue to be, managed in a manner to assure that the health and safety of the public will not be endangered. Since 1970, all plutonium contaminated waste at the NRTS has been retrievably stored in discrete packages designed to retain their integrity for at least twenty years under the NRTS weather conditions. Prior to 1970, plutonium contaminated waste was buried at

the NRTS in packages which did not always meet this integrity criterion, but our monitoring program has shown that the radioactivity in this early waste has not migrated from its place of burial. Even so, in accord with a commitment made by Dr. Seaborg several years ago, we now have a program under way to engineer the equipment and to start exhumation and repackaging of this material within the next several years.

- "2. That the AEC assure us and the people of Idaho that the National Reactor Testing Station is in no way being considered as a site for the permanent or the extended "interim" storage of long-lived nuclear wastes in any form."

I can assure you that the NRTS is not being considered in any way as the site for permanent disposal of any long-lived nuclear waste. No decision has been made concerning the location for the Retrievable Surface Storage Facility which we plan to build for the solidified commercial high-level radioactive waste.

Wherever the facility is located, it will be designed, constructed and operated in a manner which will assure that the radioactive inventory will not be released by equipment failure, human error, overt or covert actions by man, or natural phenomena.

Further, before any decision is made in this matter, the public will be given full opportunity, through an Environmental Impact Statement, Congressional Authorization and Appropriation hearing, etc., to thoroughly review the safety considerations and to raise any and all questions it may have concerning the ability of the facility to give full protection to the health and safety of the public and to the environment.

- "3. That all efforts are being exerted by the Atomic Energy Commission to assure the procurement and development of a safe and acceptable national atomic waste repository, not located over a vital water resource such as the Snake Plain Aquifer, so that long-lived radioactive wastes currently in interim storage at the National Reactor Testing Station can be removed for permanent storage at the earliest possible date in line with promises made by the AEC to begin preparations for the removal of such wastes from the NRTS burial ground by the end of this decade."

As I noted in my response to your first point, the Commission has a positive program to develop and implement the techniques needed to treat, package and permanently dispose of the plutonium contaminated waste now stored at NRTS, including that previously buried in the trenches at that site. The schedule of this program recognizes our commitment to be ready to start moving this waste from that site by the end of the decade.

In closing, I reiterate that we have no plans to use the NRTS as a permanent disposal site for the plutonium contaminated and other very long-lived nuclear wastes with which you are concerned. All our interim storage activities at the NRTS will be guided by the principle that the Snake Plain Aquifer must be fully protected against all possibility of radioactive contamination. I further assure you that you and the people of Idaho will be kept completely informed on all of our plans for waste management at the NRTS, and we will certainly do nothing that would in any way be detrimental to the overall best interests of the State of Idaho.

I am sending this same letter to Senator Church, and if I can be of further assistance to you in this matter, please let me know.

Sincerely,

/s/ Dixy Lee Ray,
Chairman

cc: Senator James A. McClure
Representative Orval Hansen
Representative Steve D. Symms

Exhibit H

November 14, 1973

Honorable Cecil D. Andrus
Governor of Idaho
Statehouse
Boise, Idaho

Dear Governor Andrus:

I enjoyed my visit with you recently in Boise and the opportunity it provided for continuing the close, cooperative relationship which has existed between our offices. I share your interest in establishing a candid relationship, based upon a mutual understanding and appreciation with respect to the roles in which we serve.

You no doubt have received by now Chairman Ray's response to the October 5 telegram which you and Senator Church sent to Dr. Ray, posing specific questions about the radioactive waste management plans and practices at the NRTS. While the Chairman's letter responded to the policy questions raised in your parallel communication to me on this subject, there is one additional point in your October 5 letter to me about which I would like to comment.

You requested a monthly report of the type which we provided your office in December 1973, reporting both onsite and offsite-generated radioactive solid wastes accumulated at the NRTS. We will be glad to comply with this request, and in this connection we have attached a summary of the quantities of on-site and offsite solid radioactive waste disposed and stored at the NRTS for the period January through August 1973 and for the month of September. I plan to provide you with a monthly report similar to the attachment by the 25th of each month following the month being reported. This short delay each month in reporting will be due to the time required to perform the measurements, tabulate the data and process it through our data processing center.

If I can be of further assistance to you in this matter, please let me know.

Sincerely yours,

Original Signed by
R. Glenn Bradley

R. Glenn Bradley
Manager

Enclosure:

Summary of quantities of onsite and offsite radioactive solid waste.

Exhibit I

March 13, 1974

The Honorable Cecil D. Andrus
Governor of Idaho
Statehouse
Boise, ID 83707

Dear Governor Andrus:

Consistant with my promise to keep you advised of matters related to the receipt of solid radioactive wastes at the NRTS from other AEC facilities, I have had my staff update this information and provide estimates for 1974. In order to minimize any possible misunderstanding due to past discussions, I have tabulated the data and included the actual amounts received in 1973 for comparative purposes.

<u>AEC Facility</u>	<u>Volume Cubic Feet</u>	<u>Actual CY-1973 Radioactivity Curies</u>	<u>Forecast* CY-1974 Volume Cubic Feet</u>
Rocky Flats, Colo.	258,000	23,500	200,000
Bettis Laboratory, Penna.	1,190	2	5,300
Mound Laboratory, Ohio	--	--	20,000
ANL - East, Illinois	--	--	6,600
Total	259,190	23,502	231,900

*It is difficult to forecast the amount of radioactivity.

We still expect to begin receiving the wastes from Mound Laboratory in July. It is about this same time that modest quantities of wastes from the AEC facility located in Illinois will start to be shipped to the NRTS. This development, which has not been previously identified to you, is a relatively new one with definition of forecasted quantities having been received only in recent days. This waste, as with all such wastes stored at the NRTS, will be in containers designed to maintain their integrity for 20 years. The containers will be stored in the Idaho Transuranic Storage Area and destined for future shipment to an AEC facility designed for long-term storage.

I trust that if you or your staff have any questions regarding any of this information, you will contact us.

Very truly yours,

Original signed by
Carl R. Malmstrom for

R. Glen Bradley
Manager

Exhibit J

STATE OF IDAHO
Office of the Governor
BOISE
March 20, 1974

Cecil D. Andrus
Governor

Mr. R. Glenn Bradley, Manager
Idaho Operations Office
U. S. Atomic Energy Commission
P. O. Box 2108
Idaho Falls, Idaho 83401

Dear Glenn:

Just a short note in which I want to acknowledge receipt of a recent letter from you advising me of the receipt of some solid radioactive wastes at the NRTS from some other AEC facilities. I appreciate your keeping me updated in this manner, as I also appreciate receipt of the monthly reports of on-site and off-site waste at the NRTS burial grounds.

I do have one point of inquiry with regard to your recent letter. When my Administrative Assistant, William J. Murphy, and my Press Secretary, Chris Carlson, returned from their personal tour of the NRTS site, they reported to me that you had indicated that the last shipment of waste from a nontraditional source would be that from the Mound Laboratory in Ohio. I now note that in calendar year 1974 you are expecting to receive 6,600 cubic feet of waste from an AEC facility located in Illinois, and that this shipment was not previously identified to us.

As I pointed out to you previously, Glenn, my main concern has always been that the AEC might permit Idaho's NRTS site to slowly evolve into one of the nation's major de facto burial grounds. Thus, when Chris and Bill reported that you had no knowledge of any shipments after that from the Mound Laboratory, and that you were aware of no other plans for any shipment, I was most pleased because your answer rendered moot the question of an evolutionary de facto burial ground.

This previously unidentified shipment raises a new possibility that particularly in the eyes of the press, this shipment from Illinois could be construed as another step on the way towards the NRTS indeed becoming the repository of a great number of wastes from nontraditional sources. I would appreciate more detailed clarification of this shipment, and also your own personal assessment of the likelihood of the AEC almost surreptitiously permitting Idaho's NRTS burial ground to evolve into one of the nation's large de facto burial grounds on an interim basis over the next 30 years.

Page 2
R. Glenn Bradley

As always, I have appreciated our candid and fine working relationship, and I will look forward to your candid response, for I know we both have an appreciation of the somewhat different roles current circumstances have us fulfilling.

Sincerely,

/s/ Cecil D. Andrus

CECIL D. ANDRUS
GOVERNOR

cc: Lee Stokes
Mike Christie
Gary Catron

Exhibit K

April 22, 1974

Honorable Cecil D. Andrus:
Governor of Idaho
Statehouse
Boise, Idaho 83707

Dear Governor Andrus:

Your letter of March 20 reiterated earlier expressed concern about receipt at the NRTS of off-site generated low-level transuranic wastes from new sources and what the long-term implications are for the status of the NRTS as a waste storage site. Moreover, you noted that my recent communication about the receipt at the NRTS this calendar year of relatively small volumes of such wastes from the Commission's Argonne National Laboratory in Illinois is not consistent with impressions conveyed by me to Messrs. Murphy and Carlson during an earlier visit to Idaho Falls.

At the time I met with your representatives, I reviewed all known contemplated transactions involving off-site generated radioactive wastes that could come to the NRTS for storage. It was recognized at the time that, while I had no knowledge of new shipments from new sources beyond those planned from Mound Laboratory, additional explorations or initiatives could arise at any time in the future. This recognition of possible future developments, I felt, was consistent with the passage in Chairman Ray's November 5, 1973 letter to you stating that it would be necessary for the AEC to "make maximum efficient use of all our sites, facilities and manpower so long as such utilization does not in any way endanger the health and safety of the public or produce an unacceptable impact on the environment."

As soon as I became aware of a serious interest on the part of the AEC facility in Illinois to store its low-level transuranic waste at the NRTS, I advised you by letter. I regret any misunderstandings that may have resulted between me or my staff with Messrs. Murphy and Carlson. Should the AEC be favorably disposed toward storing additional off-site generated low level wastes at the NRTS, it would be undertaken, as in the case of the ANL wastes, only after a decision, based on careful deliberations, that such a course of action constitutes optimum benefit to the AEC and the nation as a whole and that it will not endanger the health and safety of the people of the State now or until such time as the waste is shipped to a permanent disposal facility.

With respect to your more general concern about the NRTS waste storage status over a period of time, you requested my assessment of the likelihood that the AEC would permit the NRTS "burial ground" to evolve into one of the nation's large de facto burial grounds on an interim basis over the next 30 years. I had interpreted your earlier statements on this subject as

April 22, 1974

reflecting concern that the NRTS would become a de facto federal repository for the bulk of the nation's long-lived radioactive wastes. To the extent that that was the intent of the general concern expressed in your March 20 letter, I can only refer you to Chariman Ray's November 5 letter for re-assurance on this point. You will recall that Dr. Ray said: "I can assure you that the NRTS is not being considered in any way as the site for permanent disposal of any long-lived nuclear waste."

On the other hand, there will undoubtedly be a continuing need for the Commission to assess and determine on a case-by-case basis the disposition of low-level transuranic wastes generated at various non-NRTS sources, perhaps even from commercial sources. Disposition in this instance means interim storage of such wastes packaged in containers meeting AEC criteria designed to provide an integrity for at least a 20-year period. This material, after an interim storage pursuant to AEC practices which you reviewed in a December 1973 visit, would be re-examined and consistent with the state of the art and economic value at that time evaluated for processing to (1) recover some of the transuranic materials; (2) reduce the volume; and (3) repackage suitably for ultimate disposal at a federal repository. (As mentioned above, the NRTS is not a candidate for the repository site.) In the event a federal repository had not yet been identified, a backup program is being considered to develop longer range engineered storage for the low level transuranic wastes just as has been done for high level commercial wastes.

One of the factors which the Commission will take into account in its deliberations about optimum interim storage of the low level transuranic wastes is the proximity of that storage site to the prime candidates sites for a waste processing and repackaging facility and the existence of a desired level of expertise in waste management. Since we have the expertise and expect to have a reprocessing and repackaging facility because of the transuranic waste already stored at the NRTS, we obviously qualify for strong consideration for interim storage. The processing plant and continued development of storage and repackaging techniques we anticipate will continue to bring R&D and design funding to Idaho. The preliminary funding for the R&D type of activity in the FY 1975 budget is about \$1,100,000.

In summary, the recent identification of additional low-level transuranic waste from non-NRTS sources (i.e., AEC's Laboratory in Illinois) which the Commission plans to ship to the NRTS for safe retrievable storage on an interim basis is consistent, we feel, with the views set forth in Dr. Ray's letter to you of November 5, 1973. I had felt that these views were reiterated in the course of my December discussions with Messrs. Murphy and Carlson during our discussion involving off-site generated transuranic wastes destined for NRTS storage. There will undoubtedly be additional instances in the future where we will be asked to receive and store such wastes on an interim basis at the NRTS.

April 22, 1974

Should these arrangements be unacceptable to the State, in spite of the possible attendant economic benefits to the region and AEC assurances about adequate provisions for the health and safety of the public and the environment, I believe this information would be helpful to the Commission in its future planning. Once again, consistent with the State's wishes, the NRTS is not being considered by the AEC as a site for permanent disposal of any long-lived nuclear waste.

We have tried to provide a complete and candid response to your letter, perhaps to the point of being unduly verbose. On the other hand, I feel it is important to have a clear understanding of views in order to fulfill our respective obligations which encompass a number of similarities, e.g., to assure a safe environment for the public from activities undertaken at the NRTS and to provide as favorable an economic climate as possible through sound management of AEC programs in Idaho.

Sincerely yours,

/s/ R. Glenn Bradley
Manager

Exhibit L

STATE OF IDAHO
Office of the Governor
BOISE

Cecil D. Andrus
Governor

December 18, 1974

R. Glenn Bradley, Manager
Idaho Operations Office
U. S. Atomic Energy Commission
550 Second Street
Idaho Falls, Idaho 83401

Dear Glenn:

As you know, my testimony with regard to Wash-1539 was recently submitted to the Atomic Energy Commission's hearing examiner in Salt Lake City. I am enclosing a copy of that testimony which you might wish to peruse.

While I think the testimony speaks clearly for itself, there are several other points I would like to make. First of all, please note that I in no way precluded receipt for interim storage of transuranic waste from the AEC's traditional source--namely, Rocky Flats, Colorado. Secondly, the testimony is consistent with the letter I wrote to you soon after you assumed your new position and in which I asked the AEC not to accept transuranic waste from non-traditional, non-AEC sources, i.e., commercial transuranic waste.

Finally, I in no way was critical of the current AEC waste management practices developed and used since 1970. I hope you will understand, however, that the main thrust of my testimony centered around the potential threat to the aquifer I believe most Idahoans view the interim storage of transuranic waste to be. Thus, I would hope that you and your superiors in Washington would recognize the efficacy and the wisdom in fulfilling the commitment to remove waste starting at the end of this decade, and that those wastes be removed as expeditiously as possible.

Page 2
R. Glenn Bradley

You can see then why I might view Mr. Bill's comments as made on the Viewpoint news conference program of December 15, with regard to the length of interim storage above the aquifer to indicate a waffling of the AEC with regard to its earlier commitments. I trust that you, Mr. Bills, and your superiors recognize the value of continuing on unabated your resolve to satisfy the request that represents the vast majority view of most Idahoans.

If the AEC does not intend to begin removing the transuranic waste from above the aquifer by the end of this decade, as it has committed itself to do, I would appreciate being notified in writing of your intention not to accept commercial transuranic waste from the nation's commercial nuclear plants until such time as such wastes could be processed without any interim storage for any appreciable length of time above the aquifer. If you cannot provide these assurances, please inform me, and I will have to consider another course of action.

In the meantime, permit me to close by wishing you the very best for the holidays, and I will look forward to hearing from you soon.

Sincerely,

/s/ CECIL D. ANDRUS
GOVERNOR

Cpl

enclosure

Exhibit M

Note: This is an action plan, hand-carried on 3-21-75 by R. G. Bradley (of the Idaho Operations Office of ERDA) to Governor Cecil D. Andrus of Idaho.

Have two sets of conditions and corresponding timetables as a result of the uncertainty about when the federal repository could start accepting TRU wastes. The timetable associated with the establishment of a waste processing at INEL is the same under either set of conditions; however, the establishment of such a processing capability at INEL (i.e., volume reduction portion) is predicated on INEL being the site selected for interim surface storage of commercial TRU wastes.

INEL ACTION PLAN ERDA and Commercial Transuranic Waste

<u>CY</u>	<u>ACTIVITY</u>
1973-78	Retrieval, processing and packaging R&D
1974-76	Demonstrate retrieval at INEL
1975-77	Conceptual design of retrieval, processing, packaging facility (RPPF)
1977-	Budget request for RPPF
1977-78	Advanced conceptual design and planning
1978	Project funds become available
1978-81	Detailed facility design
1980-83/84	Facility construction
1984	Facility checkout
1985	Initial operations
1986	Full scale operations

1991 ^{1/}	1985 ^{2/}	Shipments to repository begin
1991	1985	Incoming shipments to INEL cease
1995	1994	All wastes at INEL processed (and shipped to repository)

^{1/} The dates through the remainder of this column assume 1991 is the earliest date that a federal repository can accept transuranic waste.

^{2/} The dates through the remainder of this column assume 1985 is the earliest date that a federal repository can accept transuranic waste.

Exhibit N

STATE OF IDAHO
Office of the Governor
BOISE

Cecil D. Andrus
Governor

April 29, 1975

Mr. R. Glenn Bradley, Manager
Idaho Operations Office
U. S. Energy Research and Development Administration
550 Second Street
Idaho Falls, Idaho 83401

Dear Glenn:

I regret that it has taken such a long time for me to come up with conclusions pertaining to ERDA's proposal for interim storage at INEL, but time is now on our side in that I understand there will be a new impact statement and the decision-making process has been put off for one year. I am pleased to see, from the newspaper reports, that the new statement will speak to many of the points that Idaho's Blue Ribbon Committee posed when they studied WASH 1539.

Since our meeting in Idaho Falls and in Boise, I have not met with the entire Blue Ribbon Committee, but I have met with its chairman, Bud Davis, President of Idaho State University. I felt that because of the year's delay there was really no advantage in meeting with the entire Committee at this time.

The basic points really boil down to ones of specifics, or in the past, lack of specifics; and I respectfully suggest the ERDA speak to these points so that we, in Idaho, can make an intelligent decision about our future based on fact.

- (1) Recognizing that WASH 1539 lists as one of its criteria for the siting of the interim storage facilities high priority of public acceptance, I feel that the people of Idaho should be made aware of the positive values should we expand the storage capabilities of INEL.
- (2) I keep hearing of the economic benefits that it would accrue to Idaho if the interim storage disposal site were located here, but the figures and concepts seem vague and hazy. Exactly what would these economic benefits be?

Mr. R. Glenn Bradley, Manager
Page 2
April 29, 1975

- (3) With the exception of the Idaho Falls area, most testimony received by the Blue Ribbon Committee was in opposition to the location of a commercial interim storage site above the aquifer. Leading agricultural clubs, such as the Idaho Growers Shippers Commission, Idaho Wheat Commission, Idaho Potato Growers Association, Trout Farm and many other organizations were opposed. What has been done by ERDA or INEL in terms of meeting with these groups and getting their support and approval?
- (4) What is the current status of site selection for permanent disposal?
- (5) One recurring question keeps haunting me. With so many of the technical problems and decisions in a state of flux, there does appear to be a high-risk factor involved for the states selected as the interim disposal site; namely, what happens if no state at a later date consents to be the permanent site?

In the INEL action plan, which shows shipments to repositories begin between 1985 and 1991, I believe this is an improvement over early information and would probably find support in Idaho if the other questions were answered and we could place the commercial nontreatable wastes away from the aquifer.

As this issue continues to be illuminated by ERDA reports, please keep me advised.

Sincerely,

/s/ Cecil D. Andrus

CECIL D. ANDRUS
GOVERNOR

Exhibit 0

June 19, 1975

The Honorable Cecil D. Andrus
Governor of Idaho
Statehouse
Boise, Idaho 83720

Dear Governor Andrus:

I apologize for taking so long in responding to your April 29, 1975, letter. Considerable travel and a rash of visits by members of the management teams from the new agencies, ERDA and NRC, have occupied my time. The following is provided in response to your April 29th letter.

1. Your question related to the positive values that would occur from an expanded temporary storage program for waste at INEL. If we assume that Idaho benefits from having the old transuranic waste that is stored at INEL retrieved safely and prepared for shipment to a permanent repository at some future date, we believe the surest way of controlling the planning and thus the funding and scheduling of that operation would be to have the total ERDA responsibility for the transuranic waste storage, both ERDA-generated which INEL gets anyway and the lesser volume of commercial waste that will be involved. To become involved with another western site on a competitive basis for funding for operations, research and development, and most importantly for technical talent would not be in INEL or Idaho's best interest for influencing the schedule for the future disposition of the transuranic wastes.

Another merit we believe would be to enhance the probability that Idaho would be considered for future nuclear programs and activities, such as nuclear energy parks, with all the attendant economic advantages. INEL has relatively unique advantages for certain types of programs and projects; it would be unfortunate should these advantages to the nation, State, and INEL be offset by Idaho gaining the reputation of being an anti-nuclear state because of its position on nuclear waste management. It is, we believe, in the national interest to locate such a waste management site where these activities can be conducted in the most economical and effective manner so long as the health and safety of the public and the environment are not jeopardized. In ERDA's view, INEL ranks as a prime candidate for satisfying these criteria under present circumstances.

Waste Management is a major technology and added business for INEL insures that the talent that has been developed here over the past 20 years will stay here and not be drained away if a new staff has to be developed at another site. We have already found that the waste management technology has given spin-off to other important phases of energy technology, namely, conservation where the fluidized-bed technology is being seriously looked at as an efficient way of burning waste or for heat exchangers. Another positive value is obviously related to your second question on economic benefits.

2. The economic benefits for Idaho related to the expanded storage for commercial transuranic waste we believe have been somewhat misunderstood as they were extrapolated from the WASH-1539 concept and subsequent discussions. There were references to accrued benefits in the order of \$500 million ranging over the next 20 years. More realistically we would envision interim storage expenditures in the \$75-\$300 million range during that same period. The higher values quoted included the cost of reprocessing the millions of cubic feet of transuranic wastes now in storage at INEL. Cost estimates at this time are somewhat dependent upon the timing and mix of processing between the commercial sites of TRU waste generation and the ERDA processing capabilities. The lower estimate would be incremental to the costs associated with the ERDA-generated wastes. The lower costs are also in part due to the benefits of integrating the commercial operation with the ERDA/INEL operation, thus avoiding duplication of railroads, technical staff and associated services already at INEL. It should not be overlooked that this savings is a benefit to not only the people of Idaho but the nation since it is public funds.
3. We are not in full agreement with your conclusion that much of the testimony outside of Idaho Falls was in opposition to storage on INEL. We monitored most of the meetings and found much testimony irrelevant or confused due to the inadequate nature of WASH-1539. The nature of WASH-1539 was not to examine the specifics of the INEL site, thus the pros and cons were never fully developed for public comment as they would be in a more detailed environmental statement which would be site-specific if Idaho were to be a site contender. We found the arguments to be largely emotional and we were less than successful in getting representatives from most of the groups you mentioned to view the INEL operations and look at the facts regarding public health and safety and potential impact on the environment. Indeed your own Blue Ribbon Committee did not mention the aquifer problem specifically or allude to any health and safety problems in their report.

We recognize that a part of the problem stems from the public not being aware of our current waste management operations. We are continuing our efforts with many tours of interest groups such as the League of

June 19, 1975

Women Voters, news media, Chambers of Commerce, clergy and a successful public open house when over 600 (some from Twin Falls County) visited the facility, including the research program of retrieval and repackaging of wastes buried 5-6 years ago. The attached open letter from the League of Women Voters is indicative of the comments we have been receiving.

4. The work done on bedded salt to date indicates that it is not only acceptable, but as far as we can tell, the best method of ultimate disposal of both high level and other radioactive wastes. The work we have done with the U. S. Geological Survey in identifying an area with favorable geological formations in New Mexico has reached the point where ERDA feels it is timely to reactivate the bedded salt program with the objective of constructing a pilot plant there as soon as the results of the research and development, public acceptance, and funding permit.

This pilot plant program has been assigned to Sandia Laboratories. The FY-76 budget provides \$1 million for further work and it is hoped that some of the \$5 million that was dropped from the RSSF for FY-76 would be added to speed up the repository project. ERDA plans to request construction funds in FY-78 and expects to start placing significant quantities of waste into the bedded salt around 1983, when ERDA expects to be able to get the first commercial canisters of waste. Since it is a pilot plant, it will be operated as a retrievable facility for several years before we say that it can be used for permanent disposal.

Again we can only stress that the economics and advantages of INEL cannot be realized if the temporary storage is not in near proximity to current waste treatment operations which would still in all likelihood necessitate storage over the aquifer.

5. We believe that the program mentioned above to establish a Federal repository and the existing programs aggressively pursuing objectives to retrieve INEL buried wastes should serve as reinforcement to our previously written commitments that INEL will not become a de facto permanent site.

I trust that the foregoing material is responsive to your questions. If further clarification is required, please let me know. Should there be new developments with WASH-1539 that relate to Idaho, I will be in contact with you.

Very truly yours,

Original signed by
R. Glenn Bradley (by C. W. B.)

R. Glenn Bradley
Manager

Enclosure

Exhibit P

STATE OF IDAHO
Office of the Governor
BOISE

Cecil D. Andrus
Governor

October 8, 1976

James L. Liverman
Assistant Administrator
for Environment and Safety
U. S. Energy Research and
Development Administration
Washington, D. C. 20545

Dear Mr. Liverman:

Attached are some comments from Idaho agencies on ERDA-1536. In reviewing my agency comments and the document itself, I would specifically like to point out one glaring omission to you.

For several years, Senator Church and I have had an understanding with, first the old Atomic Energy Commission, and now ERDA, that a commitment existed on behalf of ERDA to the State of Idaho to begin to remove all radioactive wastes, both those buried underground and those stored aboveground, from above the Snake River Aquifer, starting at the end of this decade. Nowhere in ERDA-1536 is this commitment mentioned.

Considering that ERDA-1536 is to be the Draft Environmental Statement on the waste management operations at the Idaho Engineering Laboratory, I consider this omission to be inexcusable and before the statement can be considered adequate, I feel it incumbent upon me as Governor of the State of Idaho to insist that this commitment is put in writing in the environmental impact statement, ERDA-1536.

Page 2
James L. Liverman
October 8, 1976

Along with the comments from my various state agencies, I am also attaching a copy of the testimony I delivered on WASH-1539 last year in Salt Lake City. I would specifically point out that there, too, I reminded ERDA of this commitment. Personnel at the INEL are very aware of this commitment and I trust they, too, have pointed out this oversight to you with internal memorandums.

If I have one general complaint of ERDA-1536 as opposed to the above specific complaint, it is that very little attention is given to the expected environmental impact of waste management programs at the INEL. This general complaint is naturally an outgrowth of the specific complaint I have mentioned, but from reading through the statement, it is clear to me there is practically no information provided relative as to how much waste the INEL can expect to receive between now and the end of the decade when ERDA is supposed to begin removing that waste from above the aquifer. Nor is there any description of what form waste from traditional sources can be expected to take in the future.

Neither is there any clear division in ERDA-1536 between the concepts of storage and disposal. It appears that all material which is being buried is considered to be "disposed of" and that it will be left buried forever. This implication runs counter to ERDA's pledge.

On the other hand, material which is stored above ground will eventually be removed to a permanent disposal site, supposedly. The problems in using these terms appears throughout the document.

As I stated, there is no clear statement of future activities which will change the impacts described in ERDA-1536. Some questions which should be clearly answered, for me, are:

Page 3
James L. Liverman
October 8, 1976

1. Is there any plan to transfer the calcined high level waste to a federal repository when one is selected?
2. Will burial of non-transuranic radioactive waste continue beyond the end of this decade?
3. Will the long-lived non-transuranic wastes which are presently being buried ever be retrieved as promised for transfer to a federal repository or are they really disposed of at their present site?
4. Is the present level of activity at INEL expected to change?
5. Is the rate of generation of waste at other areas such as Rocky Flat expected to change?

Granted, it is important to discuss the past, but an EIS should address the future impact with the goal of improving the operation. ERDA-1536 falls far short in this respect.

Sincerely,

/s/ CECIL D. ANDRUS
GOVERNOR

Cpl

enclosures

cc: Dr. Charles Wood
Charles E. Williams
W. H. Pennington

Exhibit Q

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
WASHINGTON, D.C. 20545
September 30, 1977

Honorable John V. Evans
Governor of Idaho
Boise, Idaho 83720

Dear Governor Evans:

This is in response to Governor Andrus' letter of October 8, 1976, commenting on the Energy Research and Development Administration (ERDA) draft environmental impact statement on the waste management operations at the Idaho National Engineering laboratory (INEL). The Governor's comments, as well as those of your Division of Environment, have been considered by the ERDA staff in the preparation of the final environmental impact statement, a copy of which is enclosed for your information. Because of the importance of the issues raised by Governor Andrus, I would like to address them in this letter.

With regard to the ultimate removal of radioactive wastes from INEL, we recognize the omission in the draft statement of the correspondence between Governor Andrus and officials of the Atomic Energy Commission (AEC). This omission has been corrected and discussed in the final statement.

The AEC had indicated that it hoped to start removal of transuranic waste by the end of the decade; however, this intent was predicated on the establishment of a fully operational Federal repository. At that time, start of repository construction in Lyons, Kansas, was planned for the early 1970's, which made the beginning of transuranic waste transfer from Idaho by 1980 a reasonable hope. As you are aware, the Lyons project was cancelled, resulting in a delay in the Federal repository program. Governor Andrus was advised of this delay a couple of years ago, and a revised schedule for having a repository in place by about 1985 was given to him. At present, this schedule still seems valid.

In addition, we plan to remove the transuranic waste from INEL on a schedule consistent with the availability of funding. An operation of this magnitude will probably require specific appropriations from the Congress. This will be especially true for any proposal to remove the significant portion of the transuranic waste which was buried in pits and trenches before adoption of the present more readily retrievable storage system in 1970. In connection with this, the National Academy of Sciences has recently issued a report which pointed out risks

involved with the exhumation process and recommended a close analysis of the benefits of any such exhumation and its alternatives. Such analysis is of course consistent with and required by the National Environmental Policy Act.

ERDA is preparing reports on the technical alternatives for long-term management of both the transuranic and high-level wastes at INEL. These reports will be released for public review and comment, and will be used in the preparation of environmental impact statements on these long-term management alternatives. Drafts of these statements will also be made available for public review, and in final form will provide the environmental input into future decisions on the long-term management of the wastes.

We do wish to emphasize that we share your concern that the problem of long-term management of the wastes be resolved and to assure you that this resolution has high priority.

Governor Andrus asked several related questions which are addressed as follows:

- (1) The options for long-term management of the calcined high-level waste will be analyzed in the technical alternatives and environmental impact statement documents mentioned above.
- (2) We expect that burial of INEL-generated nontransuranic waste will continue at roughly the present rate as long as current facilities are operated.
- (3) The nontransuranic wastes that are buried at INEL are considered permanently disposed of, and we know of no environmental health or safety problem that would dictate their removal.
- (4) We do not expect the present level of programs at INEL to change significantly in the foreseeable future.
- (5) The rate of generation of waste at Rocky Flats and other sites is not expected to change significantly.

I hope this letter and the discussion in the accompanying environmental impact statement are responsive to the concerns expressed by Governor Andrus, the state agencies, and your representative at the Boise public hearing on the draft statement. A copy of the Public Hearing Record is also enclosed for your information. We appreciate your interest in INEL,

Honorable John V. Evans

- 3 -

and your constructive input into the NEPA process. If you have further questions, please feel free to call on me or Charles E. Williams, Manager of our Idaho Operations Office.

Sincerely,

/s/ James L. Liverman
Assistant Administrator
for Environment and Safety

Enclosures:

- (1) Final Environmental Impact
Statement, ERDA-1536
- (2) Public Hearing Record

cc w/enclosures:

Honorable Cecil Andrus, USDI
Idaho State Clearinghouse

Exhibit R

UNITED STATES SENATE
COMMITTEE ON
ENERGY AND NATURAL RESOURCES
WASHINGTON D.C. 20513

December 6, 1977

The Honorable James Schlesinger
Secretary of Energy
Department of Energy
Washington, D.C. 20314

Dear Mr. Secretary:

The most serious unresolved problem related to the use of nuclear energy is nuclear waste disposal. This problem has been evaded and sidestepped for years. The waste disposal problem at the Idaho National Engineering Laboratory is a case in point.

I have recently reviewed correspondence between Secretary of Interior Cecil Andrus and you, as well as earlier letters with former ERDA Administrator Robert Fri, on the matter of removing nuclear waste now stored above the Snake River aquifer in Eastern Idaho.

I fully support Secretary Andrus' position in this matter.

On June 1, 1970, a meeting was held in my office with AEC Commissioner Theos J. Thompson, Assistant AEC General Manager John B. Erlewine, and Idaho AEC Director William L. Ginkel. That meeting was the culmination of several months of correspondence and dialogue between me and the AEC about nuclear waste storage at what was then known as the National Reactor Testing Station. I was given assurances at that meeting that the AEC would begin removing transuranic wastes from Idaho within a decade.

At the meeting I pressed for much speedier action on waste removal, citing critical studies done by the National Academy of Sciences and other organizations. I accepted the 10-year commitment in good faith. Indications that ERDA, and now the Department of Energy is hedging on this commitment trouble me greatly.

I join Cecil Andrus in asking that the Department reaffirm the 1970 promises. At the minimum, the Department should commit itself to expanding the funding for current efforts to perfect techniques to retrieve and properly store wastes which were earlier buried in helter-skelter fashion. An early announcement of your

The Honorable James Schlesinger
December 6, 1977
Page Two

intent to begin this retrieval effort, coupled with a firm timetable for final removal will go a long way in restoring faith in the Department's intent to keep long-standing promises.

Sincerely,

/s/ Frank Church

cc: The Honorable Cecil Andrus
The Honorable John Evans

Exhibit S

Department of Energy
Washington D.C. 20585
March 2, 1978

Honorable Frank Church
United States Senate
Washington, D.C. 20510

Dear Senator Church:

In response to your letter of December 6, 1977, Mr. Schlesinger and I have given our personal attention to the programs for removal of radioactive wastes from above the Snake Plain aquifer. I share your concern, and those of Secretary Andrus and the Governor and people of Idaho, about the protection of public health, safety, and the environment including the Snake Plain aquifer. I have a number of comments on the work at Idaho which I will also be providing Secretary Andrus.

In particular, it is unfortunate that removal of the stored wastes cannot begin as early as the Atomic Energy Commission (AEC) hoped in 1970. At that time, it was expected that the Lyons, Kansas, salt repository would be in routine operation by now. As you know, that project had to be abandoned. I can assure you that we are proceeding with the priority development of a suitable repository as rapidly as is compatible with safety and with the interests of the people in its area. The schedule is contingent on the completion of the environmental impact assessment process and successful arrangements with states and localities in the area. We expect that the Waste Isolation Pilot Plant (WIPP) repository will begin to accept wastes in the 1985-1986 time period. In any event, Idaho wastes will receive priority attention.

Since 1970, we have stored transuranium (TRU) contaminated wastes for early retrieval when the repository would be available. We are planning to move these wastes first and are proceeding with the development of equipment for processing that may be required before some of them can meet the repository acceptance criteria.

Wastes that were buried before 1970 are not easily retrievable. We have recovered about five percent of those wastes to show that it can be done. Following recommendations by the National Academy of Sciences (NAS), we are evaluating the alternatives for the disposition of these wastes.

In response to your expressed concerns, we are providing an additional \$3M to accelerate the TRU waste programs at Idaho and to assure that we can proceed without delay when the arrangements with the Western States permit the processing, shipment, and emplacement in a suitable repository.

Honorable Frank Church

As part of the National Energy Plan, the President has requested a review of the entire nuclear waste management issue. As a first step in this review process, the Department of Energy (DOE) is preparing a report that includes the issues of interest to you. This paper will be forwarded to you when it is completed. I hope that you will find this start on a comprehensive National waste management policy to be constructive. We will welcome your comments on the paper and your active participation in the further development of the policy. I assure you that your views will weigh heavily in that process.

As citizens of this country, we continue to benefit from the National defense activities that have resulted in these wastes. We appreciate your support in the National commitment to effective nuclear waste management programs that are now required to deal with them.

Sincerely,

/s/ Dale D. Myers
Under Secretary

APPENDIX B

ALTERNATIVES, CONCEPTS, AND IDEAS IDENTIFIED BUT NOT STUDIED

B.1 INTRODUCTION

The waste management alternatives and concepts evaluated in this study are shown in Figure B-1, which is a duplicate of Figure 7-1. The alternatives and concepts depicted were developed in some detail. (See Sections 8, 9, and 10). Environmental, risk, worker hazard, and cost evaluations were conducted; these results appear in Sections 12, 13, 14, and 15, respectively.

The purpose of this appendix is to describe briefly some of the alternatives, concepts, and ideas that were identified during the study but were not studied further. This material is included in the document as a sample of the broader base from which the study evolved.

Figure B-1 shows the logical progression followed in identifying waste management concepts. With the aid of the figure, supplementary approaches can be identified in two ways. First, at many of the branch points, or decision points, shown in the figure, concepts and ideas can be added to the list of those shown. For example, four disposal methods and three INEL disposal locations are shown for Alternative 5. Additional disposal methods and disposal locations were identified but not studied. Second, for each operation shown in the figure, several ways to perform the operation can generally be identified. For example, "Add top and side barriers" for Concept 2-a could be effected using concrete, clay, asphalt, or other materials. If all the concepts and ideas generated during the study were depicted on the figure, a larger, more complex diagram would result.

Because Figure B-1 is a convenient reference point for considering concepts not studied, the organization of this appendix parallels the presentation of ideas in the figure. Concepts not studied for the

Fig. B-1 Alternatives and concepts studied for long-term management of stored INEL TRU waste.

leave-in-place alternatives are discussed, followed by modules for retrieval, processing, onsite storage, shipment, and disposal. Finally, ideas are discussed that might pertain to several alternatives.

Generally, waste management methods that were not studied further were abandoned because more attractive methods were identified. However, the screening process was applied in a cursory manner, so the results of the screening should not be considered as final evaluations. In a few instances, insufficient data were available to justify a selection on this basis. In such instances, one idea was selected for development, from among a group of similar ideas, simply to allow evaluation of a representative member of the group.

B.2 CONCEPTS AND APPROACHES NOT STUDIED FOR ALTERNATIVES 1 AND 2: LEAVE IN PLACE

The ideas in this subsection relate to ways in which in-place confinement could be improved (Alternative 2). The only variations identified in Alternative 1 involve different approaches to maintenance, surveillance, and security. These variations are addressed in Subsection B.8.6.

Table B-1 lists all combinations of barrier types (top, sides, and bottom) that could be used to isolate the waste, along with the possibility of fixing the waste in place by immobilization. Each entry represents either an alternative or concept that was developed or an idea that is discussed briefly in the following subsections. In general, combinations of barriers, with or without immobilization, can be realized simply by combining the methods for erecting each barrier.

Even for concepts studied, different techniques or materials than those selected could be used. Only a few representative approaches are listed; a complete list of all possible approaches is not attempted.

TABLE B-1

WASTE BARRIER/IMMOBILIZATION COMBINATIONS FOR WASTE LEFT IN PLACE

Barrier/ Immobilization Combinations ^(a)	Alternatives Or Concepts Studied (See Figure B-1)	Alternatives Or Concepts Identified But Not Studied ^(c) (Subsection of Appendix B)
None	1	
T ^(b)	2-a	B.2.1 ^(d) , B.2.2 ^(d)
S ^(b)	2-a	
B		
T+S ^(b)	2-a	
T+B		
S+B		
T+S+B	2-b	B.2.3 ^(d)
I	2-c	
T+I		
S+I		
B+I		
T+S+I		
T+B+I		
S+B+I		
T+S+B+I		

- (a) T = Top Cover or Barrier
S = Side Barrier
B = Bottom Barrier
I = In-Place Immobilization Of Waste

(b) T, S, and T + S are identical because of the configuration of the stored waste.

(c) Barrier/immobilization combinations without a reference to the specific subsection can be derived by combining the appropriate ideas found in the referenced subsections. However, there is no guarantee that a reasonable combination will result.

(d) The method indicated here for emplacing the barrier(s) is different from that studied in the concepts which were developed.

B.2.1 Top Cover: Concrete Cover. A layer of concrete or asphalt would be placed over the waste storage areas. The impermeable surface would be subject to cracking as the ground surface subsides due to the waste settling. The degree of additional protection provided by this approach did not warrant further exploration.

B.2.2 Top Cover: Lapped Surface Cover. Overlapping slabs of concrete or basalt would be placed over the existing compacted clay on top of the waste storage areas. As the waste subsided, these slabs would settle and would tend to separate from one another. Weather protection would no longer be provided. Therefore, this concept was not explored further.

B.2.3 Top, Side^(a), and Bottom Barriers: Vaults Constructed Under Present Stored Waste. Without disturbing the waste, large caverns would be excavated beneath the stored waste. The caverns would be lined with clay of low permeability. By standard mining techniques, concrete floors and walls would then be formed inside the clay, resulting in a concrete vault. The waste would then be caved into the vault. Permanent covers of concrete would be constructed over the entire area.

Because of the excavation and construction costs for the vault and vault linings, and also because of the possible escape of contamination during the caving-in operation, this approach was not developed further.

B.3 RETRIEVAL METHODS NOT STUDIED

Various methods of retrieving the stored waste have been studied (DOE 1978a, FMC 1978). Retrieval alternatives identified in those

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- (a) The stored waste is in a dome-like configuration. Side and top covers are considered synonymous.

reports, but not studied in this document, are briefly described below. More complete descriptions are given in the original reports.

Off-the-shelf equipment could be used for the retrieval of the stored waste from the TSA pads. The waste has been placed on the TSA pads with retrieval in mind. Front end loaders were judged inferior when compared with forklifts for retrieval.

The practice of direct retrieval of the stored waste, with workers lifting the containers by hand or by means of hand trucks, was rejected. Many of the containers are too large or heavy to be readily handled in this manner. The radiation dose to the retrieval workers would be increased, as would the possibility of workers becoming contaminated.

Remote control of retrieval equipment for retrieving the stored waste was judged unnecessarily costly and complex.

Retrieval with no enclosure or within an air-supported building was excluded by the study guidelines (Subsection 7.4.1) because of poor control of contamination.

B.4 PROCESSING METHODS NOT STUDIED

B.4.1 Combinations of Processes. Four types of waste processing operations were identified for the purposes of this study:

- (1) Incineration - a high-temperature treatment of waste to achieve oxidation. The primary reason for incineration, as applied to TRU waste management, is to achieve chemical stabilization of the waste, in the sense of resistance to later combustion. Depending on the waste form and the incineration process, a measure of volume reduction is also achieved. A slagging pyrolysis incinerator is the reference unit considered, for reasons given in Subsection 4.4.2 and at the beginning of Section 9.

- (2) Immobilization - a fixation process that results in a waste form more resistant to leaching and/or dispersion. Casting in concrete and vitrification are two examples of immobilization.
- (3) Compaction - a mechanical compression of the waste to reduce the volume and to eliminate trapped air or other gases.
- (4) Packaging - the placing of waste in a container that results in a sealed, contamination-free object for further handling and disposal activities. The package remains in place and is disposed of with the waste.

The four processes cover a wide range of cost, with incineration being the most expensive. The processes also differ greatly in the degree of long-term isolation that is provided for the waste.

These four processes are not all mutually exclusive; in fact, some combinations of processes are attractive. Table B-2 lists all 16 possible combinations of the four processes. Of the 16 combinations, some were not considered further because of redundancy in the processing. For example, since slagging pyrolysis results in a dense solid waste form of low leachability, neither additional compaction nor immobilization is useful. On this basis, options 6, 7, 13, 14, 15, and 16 in Table B-2 were not studied. Without suitable packaging or immobilization, the output product from most processes is unsuitable for handling and shipping operations. On this basis, combinations 1, 2, 3, 4, and 9 were not studied.

Combinations 5, 8, and 12 were selected for further consideration. (Combination 12 was studied, rather than combination 10 or 11, because it encompasses those combinations.) They represent feasible (although not necessarily the most desirable) combinations of processes. Among them, they contain all the four processes considered. Combination 5 represents minimal processing. Combination 8 is the

TABLE B-2
WASTE PROCESSING COMBINATIONS(a)

<u>Option No.</u>	<u>Incinerate</u>	<u>Compact</u>	<u>Immobilize</u>	<u>Package</u>
(1)	---	---	---	---
(2)	X	---	---	---
(3)	---	X	---	---
(4)	---	---	X	---
(5)	---	---	---	X
(6)	X	X	---	---
(7)	X	---	X	---
(8)	X	---	---	X
(9)	---	X	X	---
(10)	---	X	---	X
(11)	---	---	X	X
(12)	---	X	X	X
(13)	X	---	X	X
(14)	X	X	---	X
(15)	X	X	X	---
(16)	X	X	X	X

(a) Includes size reduction as necessary.

only combination of these three that will satisfy the current acceptance criteria for the Federal Repository (see Appendix D). Combination 12 represents an intermediate case, in terms of the cost and the long-term isolation provided.

In summary, the three processing combinations studied are:

- (1) incinerate waste and package residue;
- (2) compact, immobilize, and package waste; and
- (3) package waste.

B.4.2 Incineration Processes. Incineration processes other than slagging pyrolysis were not addressed in the present study. A recent study (FMC 1977), conducted for EG&G Idaho, Inc., involved in-depth comparisons of eight candidate incineration processes (plus acid digestion) for the buried TRU waste at the INEL. The eight incineration processes were agitated hearth, controlled air, cyclone drum, fluidized bed, molten salt, pyrolysis, rotary kiln, and slagging. The study recommended that development of slagging pyrolysis be studied for processing the buried waste. Most of the results of the FMC study apply also to incineration of the stored TRU waste. See the introduction to Section 9 for additional details.

Based on the FMC study (1977) and on the positive results (Dodson, Hopper, and McCormack 1978; Kaiser Engineers 1977) of formulating a conceptual design for a slagging pyrolysis unit, this process was selected by the DOE for development for treating INEL TRU waste. As discussed in Subsection 4.4.2 and at the beginning of Section 9, R&D studies are underway of slagging pyrolysis, as applied to TRU waste at the INEL. An initial R&D study entailed a review and critique, by an independent multicompany task force, of the decision to develop slagging pyrolysis. The task force concurred with the general conclusions favoring slagging pyrolysis for this application. The interested reader should consult the referenced studies for further information on incinerator comparisons.

B.4.3 Immobilization Processes. The purpose of immobilization is to produce a waste form of lower leachability, lower mobility, and/or greater ease of handling. Immobilization processes may be viewed as being of two basic types. The first type involves formation of a continuous matrix, with the waste distributed fairly uniformly throughout. The second type entails encasement of the waste in a surrounding layer. The selection of a process entails choosing an immobilization technique (both the general principles and the operational details) and an immobilization material.

The immobilization technique selected for the study is to cast the immobilizing agent (concrete, in this instance) around cylindrical containers of compacted waste. This technique was selected for two principal reasons. First, the mechanical properties of most immobilizing agents are seriously affected by the inclusion of large metal objects, such as the hand tools and pieces of process equipment found in the waste. Second, definite hazards would be associated with shredding the waste (FMC 1977) to produce a more homogeneous product. Some of the waste is not readily shredded and would have to be presorted. The presorting step, in turn, would add to the hazard and cost of the process. Thus, the possibility of shredding the waste and mixing it with a binder, such as concrete, was not studied.

Concrete was the immobilization material selected for use with the chosen method of immobilization. Although glass is less soluble than concrete, glass would probably be prohibitively expensive for encapsulating waste quantities in the millions of cubic feet. Also, a number of technical questions exist for the vitrification process. Examples are the outgassing of the waste at the elevated temperatures required in the glassmaking process, and the long cooldown periods required.

Rubber, fiberglass, and concrete can all be cast at ambient temperatures. Bitumen encapsulation requires elevated temperatures (approximately 400°F). All these materials, except concrete, would result in a waste form that is combustible.

Thus, concrete was selected because of its structural strength, noncombustibility, chemical inertness, low cost, and general availability.

B.5 METHODS NOT STUDIED FOR MANAGING THE EFFECTS OF A 20-YR DELAY IN THE AVAILABILITY OF THE FEDERAL REPOSITORY

Three points in time were identified at which the 20-yr delay could be imposed on the alternatives for retrieval, processing, and shipment of waste to the Federal Repository: (1) after processing but before shipment, (2) after retrieval but before processing, and (3) before retrieval. The ramifications of these three approaches are discussed in Subsections B.5.1, B.5.2, and B.5.3, respectively.

B.5.1 Delay Shipment to the Federal Repository. In this approach, waste retrieval and processing would proceed as scheduled, but the processed waste would be stored for 20 yr before shipment to the Federal Repository. This approach is embodied in Alternative 4.

Only one method for the 20-yr storage module was addressed in the study: that involving an aboveground engineered structure (see Subsection 9.2). Other approaches for 20-yr storage are discussed briefly below.

The storage methods identified are classified, for the purposes of this subsection, into "outdoor" and "indoor" methods. "Outdoor" methods are those requiring no self-supporting structure for storing containers. "Indoor" methods are those that take place inside buildings. The ability of the waste containers to withstand 20-yr storage at a particular site, with or without additional protection, would affect the choice of the storage method. For both of these storage classifications, several methods were considered.

B.5.1.1 Outdoor Storage Methods: Aboveground.

B.5.1.1.1 Totally Exposed Surface Storage. In this method, the waste containers would be stored in the open and exposed to the elements similar to the method commonly used in salvage yards. A barrier would be provided to deny access to unauthorized personnel. The ground surface could be left as is, or a hard surface (such as asphalt or concrete) could be provided. In general, a suitably prepared hard surface is advantageous for operation of handling equipment and for promoting drainage. This method was eliminated for lack of confinement of the waste.

B.5.1.1.2 Surface Storage With Weather Cover. This method is identical to the previous one, except that the stored waste containers would be covered with a removable covering. The covering, made from plastic or other similar materials, would be weighted or otherwise secured to prevent it from being blown away. Depending on the material selected and the method for securing the edges, the covering might have to be replaced one or more times during the 20-yr storage life. This method was eliminated because of inadequate waste confinement.

B.5.1.1.3 Mounded Earth Cover Over Storage Containers. This type of storage has been used since November 1970 at the TSA for retrievable storage of low-level, solid transuranic waste. Containers are stacked on a hard-surfaced pad. The array of containers is then covered with a protective layer of earth. This method was evaluated in the leave-in-place alternatives. It was not considered for the processed waste because it would not offer an improvement in risk and environmental effects compared to the leave-in-place alternatives.

B.5.1.1.4 Shielded and Protected Outdoor Storage. In these concepts, closed pipes, constructed from concrete, steel, or some other material, would be located above the ground surface, either vertically or horizontally. Waste containers would be loaded into

these pipes for storage. When the capacity of a pipe is reached, the open end would be covered and sealed. A large number of pipes would be required because of the inefficiency of this storage method, so the method was eliminated.

B.5.1.2 Outdoor Storage Methods: Underground.

B.5.1.2.1 Hole-in-Ground Storage. Holes would be provided in the ground to contain a number of stacked waste containers. Concrete or steel pipes would be used as liners for the holes. The holes could be constructed vertical or placed horizontally in an earth wall. As each hole is filled with waste containers, the opening would be closed with a lid and covered with earth. The lid would serve primarily to inhibit entry of water resulting from rain or melting snow. Depending on the storage location, provisions might be required for draining the holes to prevent accumulation of water. This method was eliminated because of the large number of pipes required.

B.5.1.2.2 Trench Storage. The trench or pit configuration is a variation of the hole-in-ground concept, wherein the waste containers would be stored in a long trench. The size and shape of the trench would be selected to accommodate waste handling equipment, as well as the waste containers. An inclined ramp could be provided for equipment access. As in the previous concept, the walls and bottoms of the trenches would be lined with concrete to prevent wall cave-ins and to facilitate storage and retrieval operations. A variation of this method was studied for Alternative 5 at Site 14.

B.5.1.2.3 Cave or Mine Storage. Storing transuranic waste in caves or abandoned mines is attractive because this type of storage site, which offers excellent protection from the elements, may already exist. Suitably selected caves or mines would provide nearly constant temperatures and humidity, zero precipitation, and freedom

from wind and flood hazards. No suitable caves or abandoned mines were identified on the INEL. However, tunnel and shaft disposal methods were studied for the Lemhi Range in Alternative 5.

B.5.1.3 Indoor Storage Methods: Aboveground. Characteristics upon which an indoor storage method might be selected include:

- (1) ease of monitoring the storage environment and detection of radiation leakage,
- (2) siting flexibility,
- (3) ease of accommodating waste containers of essentially all sizes and shapes,
- (4) ease of accessibility for in-storage inspection,
- (5) capability for year-round operations, and
- (6) control of storage environment for protection of the containers.

The basic disadvantage of indoor storage methods compared with protected outdoor concepts is higher construction cost. However, surplus buildings may be identified that would be suitable for storing waste containers.

B.5.1.3.1 Precast Concrete Structure. The use of precast, prestressed concrete panels in constructing low-cost permanent buildings is well established. Individual panels, approximately 8-ft wide and any reasonable length, containing prestressed, high-tensile steel wire, are cast near the cement mixing plant. After curing, the panels are transported to the construction site. Steel plates are imbedded in the concrete on each side. The panels are joined as they are erected into position by welding these steel plates together. The roof and walls are formed from the same type of panels.

Storage of waste would take place as in routine warehousing operations. The waste would be delivered to the warehouse in appropriate containers and stacked using conventional equipment for materials handling. Depending on the local environment and the structural integrity of the waste containers, the atmosphere inside the building would be controlled to within temperature and humidity limits. This is the selected method of short-term storage in Alternative 4 (20-yr delay in shipment of processed waste to the Federal Repository).

B.5.1.3.2 Cast-in-Place Concrete Structure. This type of construction is similar to the previous type, except that the walls are cast in place. The roof for this type of building might be constructed of corrugated steel or precast panels, as described in the preceding subsection. This type of structure is generally used for nuclear reactors or processing buildings for which massive concrete biological shielding is needed. However, for low-level waste, such shielding is not needed. This type of construction would be more expensive than the other types of concrete buildings considered. Therefore, it was eliminated from further consideration.

B.5.1.3.3 Concrete Block Structure. The third basic type of concrete structure is similar to the preceding two, except that the walls are laid with concrete blocks. The roof on this type of structure is usually supported by exposed steel structural members, which constitute a weakness in case of fire within the building. Although the building itself is fire-resistant, a fire within the building frequently causes the steel to overheat and collapse. Without added fire protection, this type of building would probably be unsatisfactory.

B.5.1.3.4 Metal Frame Building. Several types of metal frame buildings are commercially available. Building styles, prices, and quality vary widely. This class of building is fire-resistant and can be built to meet minimum criteria for wind resistance, snow loading, and earthquake resistance. However, this building is also subject to collapse during a fire.

B.5.1.3.5 Air Support Building. A plastic-coated fabric structure supported by internal air pressure is currently used in experimental retrieval projects. However, the sun's ultraviolet rays degrade the fabric. A service life of 5 yr is generally expected, with 10 yr being the upper limit. Thus, for 20-yr storage, this type of building would have to be replaced periodically. This method is also unsatisfactory because of the use of a positive (rather than the desired negative) air pressure differential.

B.5.1.3.6 Structural Support Buildings. The structural support fabric building is similar to the air support building. The cover material is the same type of fabric, but it is supported internally by steel arches rather than by air pressure. This structure has the same limitations on fabric life as the air support building. The initial cost is higher than that for an air support building, but less than that for the rigid structures discussed previously. This facility has the same basic disadvantages of the air support building and was eliminated.

B.5.1.4 Indoor Storage Methods: Underground. The same general selection criteria, advantages, and disadvantages apply for these methods as for aboveground methods for indoor storage. The structures discussed in Subsection B.5.1.3 were considered for construction aboveground. Most of the same structures could be considered for use underground or partially buried. For example, underground storage would provide greater resistance to storms, earthquakes, vandalism, or sabotage. However, underground construction is more expensive than construction of a similar structure at ground level. Except for the concrete structures, other building materials are more susceptible to degradation or corrosion if used underground. Since the same type of concrete building constructed aboveground would meet minimum criteria for earthquakes and other requirements for radioactive waste storage, the only substantial advantages of underground storage would be additional protection against adverse events and extra shielding against radiation.

Multistoried structures are generally attractive economically only if the cost of land is relatively high. Since land is readily available at the INEL, multistoried structures were not studied.

B.5.2 Delay Processing. In this approach, retrieval would proceed on schedule, but processing would be delayed for 20 yr. The retrieved waste would require storage for the 20-yr period. This approach is essentially the same as that in Subsection B.5.1, except that unprocessed, rather than processed, waste would be placed into storage. Because processing would provide volume reduction and improved chemical stability and leach resistance, this approach was considered inferior to the previous approach and was not studied.

B.5.3 Delay Retrieval. In this approach, waste retrieval would be delayed for 20 yr. This situation involves a number of possible scenarios and management options.

The key technical decision, about which other decisions would revolve, is whether the existing containment/confinement of the waste would be satisfactory until the year 2005. (Because of the assumed 10-yr length of the retrieval campaign, some waste might not be retrieved until 2015.) This decision might be made by the nominal date of implementation in 1985. However, a decision to continue to delay retrieval might have to be reversed later if the results of continuing surveillance indicated a significant hazard resulting from degradation of the containment/confinement.

Monitoring studies of the TSA have been underway for several years and have indicated no significant hazard from the stored TRU waste. Steel drums removed from TSA during the reentry study (see Subsection 4.4.3) showed some rust and corrosion on the containers. However, the data are insufficient to substantiate a projection of container integrity to the year 2005.

For this brief discussion, it was assumed that the decision concerning whether to continue present containment/confinement methods would be made in 1985. At that time the accumulated data could indicate that projections of containment/confinement adequacy in the 2005 to 2015 time frame are (1) favorable, (2) unfavorable, or (3) uncertain.

If the projections were favorable, then a 20-yr delay in retrieval could take place with confidence that environmental effects during the intervening 20 yr would be minimal. This scenario forms the background assumptions for Alternative 6. (See Subsection 9.3.)

If the projections were unfavorable, a number of options would be available. If a near-term hazard to the environment existed, action would be taken as soon as feasible. However, if, for example, the stored waste containers were found to be breached, a near-term threat to the environment would not necessarily exist. The containers for the buried TRU waste have been breached for several years, without such a near-term hazard ensuing. It might be feasible to continue, for 20 extra years, to manage the stored waste as at present, even though a substantial number of containers might be breached.

If it were judged that a hazard to the environment would ensue from continuing present management for 20 yr before retrieval, a number of approaches could be followed. Improved confinement, such as described in Alternative 2, could be constructed. (However, the required retrievability of the waste could be a constraint placed on any work to improve confinement.) Another approach would be to overpack those containers judged to have failed. The magnitude of this effort would determine its feasibility. If the overpack operation could be conducted in existing facilities, in an Air Support Weather Shield (ASWS), or (possibly) in the open air, such an effort could be feasible.

If the projections of containment/confinement adequacy were uncertain, the retrieval decision could be delayed or the conservative approach of initiating retrieval without further delay could be followed.

B.6 SHIPMENT AND TRANSFER METHODS NOT STUDIED

The basic means of shipment considered in this document are (1) ATMX 600 railcars for shipment to the Federal Repository, (2) conventional semitrailers for shipment between the RWMC and disposal sites on the INEL, and (3) specially designed transfer vehicles between the retrieval facility and the process facility within the RWMC. The semitrailers would travel over committed roadways within the INEL.

The use of trucks for shipment to the Federal Repository was considered but not studied. The principal reason was the expected higher cost of shipping by truck. However, a potential lack of available railcars suitable for such shipments could force the use of trucks.

The use of a conveyor was also considered for transfer within the RWMC. This approach was rejected for three reasons. First, the use of a conveyor up to 1 mile long to move hazardous radioactive materials is an application for which there is little or no experience. Second, the possibility of conveyor breakdowns after contamination by radionuclides poses a serious maintenance problem. Third, enclosed conveyors (such as this would have to be) are subject to fire when handling combustibles.

B.7 LOCATIONS AND TECHNIQUES NOT STUDIED FOR WASTE DISPOSAL AT THE INEL

Disposal locations off the INEL were excluded from this study by the guidelines (Subsection 7.4.1).

Onsite disposal would involve selection of a disposal location and a waste emplacement technique. Three potential locations for onsite disposal were studied: the RWMC, Site 14, and the Lemhi Range at the northwest corner of the INEL. Two other locations, that were considered but not studied, are discussed below. A broad range of emplacement techniques was selected for study: deep rock disposal, engineered shallow-land disposal, and engineered aboveground disposal. Two other disposal techniques are discussed in this subsection.

B.7.1 INEL Disposal Locations Not Studied.

B.7.1.1 Middle Butte. Middle Butte is a silicic volcanic formation with a basaltic cap, located just inside the southern INEL boundary. For waste disposal, vertical mining and deep excavation (quarrying) from the top would be possible but were not considered favorable because of the inaccessibility of the top of the butte. Horizontal mining with the excavation of internal vaults would be more feasible. In either case, special containment structures could be built if needed. Once the waste is in place, the containment would be sealed and the mine or excavation backfilled to prevent intrusion.

Favorable aspects of Middle Butte include its location within INEL boundaries, proximity to the RWMC, elevation above the floodplain, and relative geologic stability. Considerable information about the butte is available from the United States Geological Survey (USGS). A committed roadway for transportation of the waste could be constructed completely within INEL boundaries and would be relatively short in length. Long-term monitoring of the waste would be performed to detect radionuclide movement.

Unfavorable aspects (and reasons for lack of further study) of Middle Butte include its location over the Snake River Plain Aquifer, inaccessibility of the top of the butte, and the possibility of recurring silicic volcanism.

B.7.1.2 Circular Butte and EBR-II Ridge. The INEL locations of Circular Butte and the ridge east of EBR-II were considered as potential sites for engineered shallow-land disposal.

Advantages of these sites include close proximity to the RWMC, location within the INEL boundaries, location off the current floodplain, and lack of surface water. The ridge near EBR-II is at a higher elevation than most of the INEL. Information about these sites is available from the USGS.

Disadvantages of these sites include their location above the Snake River Plain Aquifer, the possibility of renewed volcanism in the area, and possible climatic changes causing flooding of these areas.

These locations were not studied because they do not offer as many advantages for deep rock disposal as the Lemhi Range sites and because the geologic and hydrologic characteristics are less favorable than those of Site 14.

B.7.2 Waste Disposal Techniques Not Studied.

B.7.2.1 Waste Disposal in Deep Drilled Holes. Waste would be placed in deep holes drilled into a thick, hydrologically tight, stable formation. If holes were used that were 3 ft in diameter and 2000 ft deep, each hole would hold approximately 14,000 ft³ of waste. Depending on the method of waste treatment, hundreds of such holes could be required to contain the TRU waste. After the waste is lowered, the hole would be plugged, filled, and sealed.

While this method would require a minimum of aboveground facilities, the waste would not be retrievable after the holes were sealed. More important, the presence of the Snake River Plain Aquifer below nearly all of the INEL would create the possibility of groundwater transport of the radionuclides to distant populations. Disposal of the waste beneath the aquifer would risk the same transport of

radionuclides. Also, drilling through the aquifer (estimated to be 1000 to 5000 ft thick) for the purpose of emplacing waste, would be difficult.

B.7.2.2 Deep Well Injection of Liquified Wastes. This concept requires that the waste be finely divided and mixed into a grout slurry. The slurry is then injected into a geologic formation through a deep injection well. This disposal method is currently being used by another DOE laboratory (ERDA 1977b). However, the loss of retrievability, the waste processing requirements, and the possibility of contaminating the Snake River Plain Aquifer are major disadvantages.

B.7.2.3 Shallow-Land Disposal at the RWMC. Shallow-land disposal at the RWMC following retrieval and processing was not studied. Over long periods of time, the effects of such a method would be similar to those from the current disposal methods for the buried TRU waste. The principal difference might be attributed to immobilization of the waste in concrete or as slag. It was concluded however, that to retrieve, process, and rebury the waste without confinement would not be worth the cost.

B.8 OTHER ALTERNATIVES, CONCEPTS, AND IDEAS IDENTIFIED BUT NOT STUDIED FURTHER

A number of approaches related to management of the INEL TRU waste were suggested during the study. The approaches ranged from major changes in waste management philosophy to minor variations in the technique by which a concept might be implemented. Time constraints prevented further study of these ideas, but several of the ideas are mentioned in this subsection.

B.8.1 Postdecision Changes in Alternatives or Concepts. For most of the alternatives and concepts studied, the disposal method is reversible, at least for a period of up to 40 yr. Selection of an alternative that involves reversible disposal would leave the way open

to change to a different alternative, should the need arise. For example, the "Leave-As-Is" Alternative could later be abandoned in favor of almost any other alternative. However, Concept 2-c is not readily reversible, because of the difficulty of retrieving the immobilized waste from a huge body of grout.

The potential number of these postdecision changes in alternatives is very large, and the implications vary greatly. The possible range of timing for such changes could be a subject in itself. This entire subject is not considered further in the present study.

B.8.2 Return the Waste to Points of Origin. One alternative mentioned during the study was to return the waste to its various points of origin. Under this approach, most of the waste would be returned to Rocky Flats. This idea was not studied because implementation of the idea would contribute little, if anything, to resolving the national need for safe, permanent disposal of defense TRU waste. This approach would not even result in removal of all TRU waste from the INEL, because some of the waste has been generated at the INEL.

B.8.3 Terminate the Receipt of Waste from Off-INEL Locations. The idea of reducing the waste disposal problem at the INEL by prohibiting the receipt of any new waste from off-INEL sources was not studied. This would not help to eliminate the national waste disposal problem because the production of defense TRU waste is continuing. Additionally, the problem of waste currently stored at the RWMC would not be resolved.

B.8.4 Separation of the Waste. It has been proposed that the waste material be separated into two or three portions, based on the level of transuranic contamination. Contamination levels that might serve as logical division points are (1) 10 nCi/g, and (2) the lowest detectable level of transuranic contamination. The advantage of this approach is that waste portions of successively lower levels of contamination might be managed with less processing or with less expensive disposal methods. An approach of this type was evaluated in a

recent study (DOE 1978a). As noted therein and in other studies (e.g., Kaiser Engineers 1977), the approach suffers from a number of weaknesses. Separation of millions of cubic feet of waste and/or soil into two or three portions, based on contamination level, would be difficult within a 10-yr operating campaign. The separation process would be hazardous, and it would be costly, possibly leading to no net overall cost reduction. For these reasons, the approach was not considered further in the present study.

B.8.5 Dilute and Disperse. In this alternative, the waste would be reduced to particulate material and dispersed, or diluted with additional material and then dispersed. In either case, this process is essentially irreversible, should later retrieval be desired. Another major weakness of this alternative is the resulting low-level contamination of the biosphere.

B.8.6 Selection of a Period for Maintenance, Surveillance, and Security. The guidelines of Subsection 7.4.1 specify an assumed 100-yr period for surveillance of the disposal area and for conducting maintenance and security activities. The alternative was proposed of open-ended pursuit of maintenance, surveillance, and security. That is, these activities would continue from one human generation to another, until the hazards associated with the waste were judged to be acceptably small. This philosophy was not studied because of the inherent difference in the half-lives of the radio-nuclides in the waste and the demonstrated periods of stability of human institutions related to managing hazards to man. The opposite extreme approach, that of abandonment in less than 100 yr, was also not studied.

B.8.7 Nongeologic Disposal Methods. Nongeologic disposal methods have been considered in earlier studies and are summarized in the EIS (DOE 1979) that this document is intended to support. These methods

include disposal in sea beds, ice sheets, and tectonic plate boundaries; rocketing into the sun or into deep space; and artificial transmutation of the radionuclides. Study of these disposal methods falls outside the scope of the present study.

B.8.8 Separating the Melt Product During the Slagging Process.

If the waste material were separated while molten, perhaps by making use of density gradients, the heavy metal portion could be specially handled to enhance radiological safeguards, criticality protection, and economic recovery. Because this process variation would violate the guidelines of Subsection 7.4.1 (no reclamation of fissile material), it was not studied.

APPENDIX C

THE EFFECTS OF TRU WASTE RECEIVED AFTER 1985 ON THE WASTE MANAGEMENT ALTERNATIVES STUDIED

C.1 INTRODUCTION

Generation rates for defense TRU waste beyond 1985 are subject to great uncertainty. Although projections can be formulated on a strictly technological basis, such projections become increasingly unreliable with the length of time projected into the future.

Most of the TRU waste projected to be shipped to the INEL is related to nuclear weapons programs. Thus, significant changes in international relations or in disarmament efforts could affect the quantity of waste to be received at the INEL. Such consequences of international politics are not amenable to quantitative prediction.

In addition, it is difficult to predict the national policies and programs for the management of defense nuclear waste in the time period beyond 1985. For example, the availability, number, location, type, and capacity of Federal Repositories would need to be known to make projections for waste management at the INEL. Also needed would be knowledge of the type of waste processing, if any, that would take place at each facility that generates TRU waste.

These large uncertainties have led to the decision to address the topic of post-1985 waste in this appendix, rather than in the body of the report. The reason was to separate the baseline studies (facility layout, cost, risk, and environmental effects) from the uncertainties associated with the post-1985 waste. The impacts of the post-1985 waste on the alternatives are, therefore, addressed separately here. These impacts on the design of the processing, storage, and disposal facilities range from very small to very large, depending on the alternative studied.

C.2 WASTE PROJECTIONS TO 1985

TRU waste is currently being received at the RWMC from the facilities listed in Table C-1. The table lists the estimated volumes shipped in 1978, as well as the projected volumes to be shipped in 1985. Projections of the waste generation rates are available through 1987. However, the 1987 values are generally straight-line extrapolations of the estimates through 1985. Thus, little reliable information is added by the 1985-1987 estimates.

Most of the waste comes from Rocky Flats. Changing the rate of waste generation by a factor of two or three at any other facility listed, would not have a large effect on the rate of receiving TRU waste at the RWMC. But fluctuations in the amount of waste generated at Rocky Flats, or unforeseen changes in the method of waste treatment there, could have significant effects upon the required capacity of the facilities in the alternatives for TRU waste management at the INEL. Furthermore, facilities not currently shipping low-level TRU waste to the INEL could conceivably begin to ship waste to the INEL.

C.3 ASSUMPTIONS

In spite of the uncertainties involved, an effort was made to assess the effects on the INEL waste management alternatives of the waste that might be received after 1985. To facilitate this assessment, the following assumptions were made:

- (1) The generation rate of TRU waste at Rocky Flats will continue at approximately $67,000 \text{ ft}^3/\text{yr}$ after 1985.
- (2) The Rocky Flats waste generated after January 1, 1985, will be incinerated and immobilized at Rocky Flats.

NOTE: Any delay in the startup of this facility would cause a greater volume of waste to be shipped to the INEL than that predicted here.

TABLE C-1

FACILITIES CURRENTLY SHIPPING TRU WASTE TO THE RWMC

Abbreviation	Identification	Location	Estimated	Projected
			Volume Shipped in 1978 (ft ³)	Volume Shipped in 1985 (ft ³)
ANL-W	Argonne West	INEL	530	7,410
CPP	Idaho Chemical Processing Plant	INEL	2,120	6,350
BETTIS	Westinghouse	PA	1,230	0
MOUND	Mound Laboratory	OH	14,120	14,120
RFP	Rocky Flats Plant	CO	127,080	67,070(a)
ANL-E	Argonne Nat. Lab.	IL	4,940	4,940
APPROXIMATE TOTAL			150,000	100,000

- (a) Before incineration, compaction, or immobilization of the combustible portion of the waste. Of the listed facilities, only Rocky Flats is known to have firm plans to begin processing waste in the next several years. The projected yearly volume of 67,070 ft³ would be reduced to about 51,000 ft³ after the combustible portion of the waste is processed.

- (3) Seventy-five percent (by volume) of the Rocky Flats waste will be noncombustible. The 25% that is combustible will be reduced in volume by a ratio of 40:1 in the incineration process at Rocky Flats. No volume reduction is assumed for the noncombustible waste. The ash from the incinerator will be immobilized by adding glass-forming materials. Thus, the approximate yearly volume of 67,000 ft³ would be reduced to about 51,000 ft³/yr after the combustible portion of the waste is processed.

NOTE: This conclusion is relatively insensitive to the proportion of glass-forming materials added, because a high percentage of the waste is noncombustible and is assumed not to be immobilized.

- (4) The processed Rocky Flats waste and its packaging will be acceptable, without further processing, for shipment to and receipt at a federal repository (if such a repository exists), or for shipment to and disposal at the INEL.

NOTE: If the criteria for disposal change after the Rocky Flats waste processing facility has been built, or if this facility does not operate as planned, then the Rocky Flats waste could require further processing, or packaging, or both. (In this study, no plans have been made to process, reprocess, or package any post-1985 Rocky Flats waste at the INEL.)

- (5) The volume of TRU waste generated at the INEL is assumed to remain at approximately 14,000 ft³/yr after 1985. No onsite processing of this waste is assumed, other than that which might be performed at the RWMC.

NOTE: A major program change at the INEL could have a major effect on this quantity.

- (6) The TRU waste generated by Mound Laboratory and at ANL-E is assumed to continue at approximately 19,000 ft³/yr after 1985. No waste treatment by these waste generators is assumed. It is assumed that Bettis ships no TRU waste to the RWMC after 1985.

NOTE: A major program change or the addition of an incineration program at either lab could effect a major change in this value.

- (7) The Federal Repository will include no waste processing facilities such as incinerators. The waste acceptance criteria will require a waste form acceptable for disposal upon arrival at the Repository.

C.4 EFFECTS

This section addresses the effects of the TRU waste generated after 1985 on the INEL waste management alternatives. The effects are calculated, based on the previous assumptions and the scenarios that are described. Because burial of TRU waste at the RWMC ceased in 1970, TRU waste that might be received after 1985 is addressed as a potential addition to the stored TRU waste. The effects on the alternatives for managing the stored waste are summarized in Table C-2 and discussed in the following subsections.

The number of scenarios that can be envisioned is extremely large, so this brief study should not be expected to be all-encompassing. Furthermore, the scenarios discussed here are studied only by way of example and are not necessarily the most likely to occur. The results are highly dependent on the specific assumptions made in each scenario.

C.4.1 Alternative 1 - Leave the Stored Waste As Is. In this alternative, it is assumed that the INEL waste is left as is and that there is no Federal Repository. All TRU waste newly generated by the

TABLE C-2

EFFECTS OF TRU WASTE GENERATED AFTER 1985 ON ALTERNATIVES FOR WASTE MANAGEMENT AT THE INEL

Units are ft^3/yr , except for subtotal entries in parentheses, which are in units of ft^3 of waste accumulated during the time period indicated in the heading.

Alternative	Description(a)	1985-1995 Operations			1995-2005 Operations			2005-2015 Operations			Operations after 2015		
		Processing	Storage	Disposal	Processing	Storage	Disposal	Processing	Storage	Disposal	Processing	Storage	Disposal
1	Leave As Is	0(c)	N/A	84,000 (840,000)	0(c)	N/A	84,000 (840,000)	0(c)	N/A	84,000 (840,000)	0(c)	N/A	84,000 (time- integrated sum is in- determinate)
2	Leave In Place: Improve Confinement	0(c)	N/A	84,000 (840,000)	0(c)	N/A	84,000 (840,000)	0(c)	N/A	84,000 (840,000)	0(c)	N/A	84,000 (time- integrated sum is in- determinate)
3	Retrieve and Process, Starting in 1985; Ship to Federal Repository as Processed	14,000 (6% incre- ment)(d)	N/A	N/A	14,000	N/A	N/A	14,000	N/A	N/A	14,000	N/A	N/A
4	Retrieve and Process, Starting in 1985, Store 20 yr, then Ship to Federal Repository	33,000 (15% incre- ment)(e)	67,500 (675,000) (65% incre- ment)	N/A	33,000	67,500 (675,000) (addition- al 65% in- crement)	N/A	14,000	0	N/A	14,000	0	N/A
5	Retrieve and Process, Starting in 1985; Dispose at INEL	33,000 (15% incre- ment)(e)	N/A	67,500 (675,000) (65% incre- ment)	33,000	N/A	67,500 (675,000) (additional 65% incre- ment)	33,000	N/A	67,500 (675,000) (additional 65% incre- ment)	33,000	N/A	67,500 (time- integrated sum is in- determinate)
6	Retrieve and Process, Starting in 2005; Ship to Federal Repository as Processed	0	84,000(f) (840,000)	N/A	0	84,000(f) (840,000)	N/A	80,000 (36% incre- ment)(g)	0	N/A	14,000	0	N/A

(a) See text for more detailed description of scenarios pursued, because many scenarios are possible for each alternative.

(b) Slagging pyrolysis is the assumed process for this study.

(c) It is assumed here that no waste is processed at the RWMC after 1985 unless a facility were built at the INEL for (1) processing buried waste or (2) processing incoming waste, or both.

(d) The 14,000 ft^3/yr would be from newly generated INEL TRU waste. (Waste from Rocky Flats, Mound Laboratory, and ANL-E would not be received at the INEL after 1985.) The 14,000 ft^3/yr is equivalent to 6% of the processing rate for the pre-1985 waste in a 10-yr campaign during 1985-1995.

(e) The 33,000 ft^3/yr would be from newly generated INEL, Mound, and ANL-E waste received after 1985. Waste from Rocky Flats would be processed at Rocky Flats. The 33,000 ft^3/yr is equivalent to 15% of the processing rate for the pre-1985 waste in a 10-yr campaign during 1985-1995.

(f) Storage would be on TSA pads, rather than in an engineered aboveground facility, as for Alternative 4.

(g) The increased processing load of 80,000 ft^3/yr is larger than that for Alternatives 4 and 5, because a 20-yr accumulation (1985-2005) of post-1985 waste would be worked off in 10 yr (2005-2015), along with 14,000 ft^3/yr of new waste generated in 2005-2015 at the INEL.

N/A Not Applicable

facilities listed in Table C-1 would continue to be shipped to the RWMC. Approximately 84,000 ft³ of waste (51,000 ft³ from Rocky Flats after processing, 19,000 ft³ from ANL-E and Mound Laboratory, and 14,000 ft³ from INEL operations) would be placed on the TSA pads in the year 1985 and every year thereafter. Thus, by about the year 2009, the volume of stored TRU waste on the TSA would have doubled, from about 2,000,000 ft³ in 1985, to about 4,000,000 ft³. Of this quantity, only the Rocky Flats portion would have been processed. When each TSA pad is filled, it would be covered in accordance with present practices (see Subsection 4.2). Thus, the current storage method would become a continuing de facto disposal method for the defense TRU waste to be received from the current waste generators.

C.4.2 Alternative 2 - Leave the Stored Waste in Place and Improve Confinement. Alternative 2 is identical to Alternative 1 with respect to the waste received after 1985, until a TSA pad is filled. After the plywood, polyvinyl, and clay are placed over the waste, additional confinement would be provided by one of the methods described in Subsection 8.2.

C.4.3 Alternative 3 - Retrieve the Stored Waste, Process, and Ship to the Federal Repository. Because this alternative presupposes the operation of a Federal Repository accepting waste in 1985, the Rocky Flats waste is assumed to go directly to the Federal Repository starting in 1985. Waste newly generated at Mound Laboratory or at ANL-E could be incinerated at the RWMC or at Rocky Flats, or shipped to the Repository without incineration. Although the guidelines chosen for this exercise preclude the possibility of incineration at Mound and ANL-E, such a possibility exists. In this alternative, waste generated after 1985 at Mound and ANL-E is assumed not to be processed at the RWMC.

During the retrieval and processing of the stored waste, the waste newly generated at the INEL would also be processed. This increment would amount to approximately 14,000 ft³/yr, or about 6% of the 220,000 ft³/yr rate associated with processing the pre-1985 waste in a 10-yr campaign.

The estimated 6% increment in processing demand would be such a small addition as to have minimal impact on the waste processing facility at the INEL during the 1985-1995 campaign. By 1995 the retrieval and processing of the waste stored at the TSA would be complete. It is assumed in this study that the processing facility (and any replacement facilities) would remain operational indefinitely, although on a much smaller scale, to process newly generated INEL TRU waste before shipment to the Federal Repository.

C.4.4 Alternative 4 - Retrieve and Process the Stored Waste Between 1985 and 1995; Store Onsite; Ship to the Federal Repository in 2005. In the scenario studied for this alternative, the TRU waste from ANL-E, Mound, and the INEL would be processed at the RWMC, along with the TRU waste previously stored on the TSA. (Rocky Flats waste would be processed before receipt at the INEL.) A 15% increase in processing capacity (an additional 33,000 ft³/yr) would be required over the processing rate for the TSA-stored waste alone. All of this TRU waste would then be placed into storage, stored until 2005, and then shipped to the Federal Repository. The extra waste put into storage would consist of the 51,000 ft³/yr of processed waste from Rocky Flats, plus 16,500 ft³/yr from processing the 33,000 ft³/yr of waste generated at the INEL, Mound, and ANL-E. An overall volume reduction ratio of approximately 2:1 was used for the waste processed at the INEL (see Figure 9-9, Subsection 9.1.2.2). This ratio allows for the possible addition of clean soil to produce an acceptable output from the slagging pyrolysis incinerator. Thus, the total additional storage volume would be 67,500 ft³/yr, or about 65% of the 103,000 ft³/yr of processed waste resulting from processing the waste in a 10-yr campaign.

The post-1985 TRU waste would have a major effect (65% increase) on the facility requirements for 20-yr storage in the 1985-1995 time period. In the 1995-2005 time period, another 65% increase in storage volume would be required, for a total increase of 130% to the required capacity of the 20-yr storage facility.

C.4.5 Alternative 5 - Retrieve and Process the Stored Waste, Dispose of at the INEL. In this alternative, it is presupposed that there would be no Federal Repository. The waste stored at the TSA would be retrieved, processed, and disposed of at the INEL by one of the four methods described in Subsection 10.4. New waste from Rocky Flats, Mound, ANL-E, and the INEL would continue to be shipped to the RWMC and disposed of at the INEL. The Rocky Flats waste would be processed at Rocky Flats, so no processing capability at the INEL would be required for this waste. Waste from Mound, ANL-E, and the INEL would be processed at the INEL.

The effect on waste processing requirements during the 10-yr campaign of retrieving and processing the TSA-stored waste would be the same as in Alternative 4. However, the projected amount of waste to be disposed of at the INEL between 1985 and 1995 would be increased by approximately 675,000 ft³ due to the post-1985 waste. This is a 65% addition to the volume requirement for disposal of the pre-1985 waste. Furthermore, the effect on disposal requirements would accumulate to larger and larger values (65% increase for every 10 yr), as long as TRU waste continued to be generated.

C.4.6 Alternative 6 - Delay Retrieval, Processing, and Shipment of the Stored Waste to the Federal Repository Until 2005. In the scenario studied for this alternative, new TRU waste from Rocky Flats, ANL-E, Mound, and the INEL would continue to be received and stored on the TSA pads until the Federal Repository became available in 2005. The Rocky Flats waste would be processed at Rocky Flats. All the other TRU waste would be processed at the RWMC, beginning with the campaign startup in 2005.

It might be appropriate to store the new Rocky Flats waste at Rocky Flats, after processing, or at the site of the Federal Repository. However, it was assumed here that the storage would be located at the RWMC.

The impact on processing would come in the 2005-2015 time period. The 20-yr accumulation of post-1985 waste, plus the new waste from the INEL would have to be worked off in the 10-yr time period from 2005 to 2015. The required increment of processing capacity is computed as follows:

Waste accumulated between 1985 and 1995:	33,000 ft ³ /yr
Waste accumulated between 1995 and 2005:	33,000 ft ³ /yr
Waste generated at the INEL between 2005 and 2015:	<u>14,000 ft³/yr</u>
TOTAL	80,000 ft ³ /yr

The effects on the storage requirements would be greater than those for Alternative 4 because the 1985-2005 waste placed on the TSA pads would not have been processed, except for that from Rocky Flats. However, as mentioned above, the waste is assumed to be stored on the TSA pads during 1985 to 2005, rather than in an engineered storage facility.

C.5 CONCLUSIONS

For the scenarios investigated, the effects of the post-1985 TRU waste on the required capacity of processing facilities contemplated at the INEL would range from 6% to 36%. A 10-yr campaign is assumed for waste processing. Another approach would be to retain the same capacity for the processing facility as that required for processing the pre-1985 waste only, but to lengthen the campaign by the percentage indicated.

The more important effect of the post-1985 TRU waste would be to extend the required period of operation for the processing facilities. For several scenarios, the period of extension would have no foreseeable endpoint, because processing would be required as long as TRU waste continued to be generated. Replacement of all processing equipment and facilities would eventually be required.

The effects on requirements for 20-yr engineered storage at the INEL would be significant (130% increase). For all alternatives, no requirements for interim storage would exist after 2005. (Note: To simplify the presentation, instantaneous emptying of storage facilities was assumed to occur as soon as processing began. In reality, the emptying could take 10 yr, thus prolonging accordingly the length of time for which storage facilities would be required.)

For Alternatives 1, 2, and 5, in which no Federal Repository is projected, the effects on disposal requirements at the INEL would extend in time with no foreseeable endpoint.

APPENDIX D

The following is the verbatim text of the "WIPP Acceptance Criteria for Defense Low-Level TRU Waste, July 1, 1977." These are the draft criteria for waste acceptance at the Waste Isolation Pilot Plant, a proposed Federal Repository. Although the criteria are subject to change, they are presented here as background material to amplify the processing discussions in the present report.

WIPP ACCEPTANCE CRITERIA FOR DEFENSE LOW-LEVEL TRU WASTE July 1, 1977

This document delineates the acceptance criteria proposed for defense low-level TRU waste received for storage at the Waste Isolation Pilot Plant (WIPP). By intent--and by ERDA directive--these criteria are conservative; it is likely that future changes in the criteria will be in the direction of less restrictive specifications. Changes will be made only when they can be justified on the basis of more complete knowledge of the behavior of the salt storage medium and of the waste material itself. "Final" pre-operational criteria will probably not be available before July, 1979.

In this document, "TRU waste" refers specifically to the solid radioactive waste described in ERDA Manual Appendix 0511, Part I, paragraphs B-18, 22, and 23 (interpreted here to include Pu-238, but not Pu-241, among the transuranic isotopes). "Low-level" refers to waste packages which exhibit surface dose rates no greater than 500 mrem/hour, as defined in Chapter 20 of ERDA-76-43 (TAD).

The present criteria have evolved from earlier drafts through numerous reviews by most of the agencies involved in the management of ERDA-generated radioactive wastes; the contribution of these agencies is gratefully acknowledged.

I. DEFINITIONS

Low-Level TRU Waste: Any solid waste material, other than high-level waste, which is contaminated with long-lived alpha emitters to the extent that, under the provisions of ERDA Manual Chapter 0511, it is not suitable for surface burial, but which exhibits sufficiently low radiation levels (surface dose rate levels ≤ 500 mrem/hr) that it is amenable to handling by "contact" (as opposed to "remote") methods.

Waste Container: The box or drum, including any associated liner and/or shielding material, which immediately surrounds (and is considered to be an integral, disposable part of) the waste material.

Waste Package: The final configuration of the waste in its container, ready for emplacement in a suitably prepared storage site.

Overpack: A second layer of containment which may be required (and applied) by the WIPP operator because of the mechanical condition or level of surface contamination of the waste container.

Combustible Materials: Materials which will sustain combustion when exposed to a temperature of 1300°F (700°C) for a period of 15 minutes or less, in atmosphere air. (Examples of combustible materials are paper, most plastics, cloth, and wood.)

Gas-Producing Materials: Materials which produce gas during their decomposition by radiolysis, pyrolysis, chemical reaction, or bacterial decay. (Gas-producing materials include virtually all combustibles and such non-combustibles as concrete, steel, and certain process sludges.)

II. ACCEPTANCE CRITERIA

It is axiomatic that no acceptance criteria document can adequately address all the special cases which may arise in the management of defense low-level TRU waste. The WIPP operator will cooperate with waste generating agencies in formulating waste treatment and packaging procedures which bring special waste forms into compliance with the spirit, if not the letter, of these criteria.

A. WASTE FORM

1. Combustible Materials: The shipment of low level TRU waste to the WIPP will be coordinated on an ERDA-wide basis so that the total amount of combustible material in a single storage room does not exceed 20 percent by volume (but Section II.A.2 also applies). In the content of this criterion, the materials used in the fabrication of DOT-7A and similar non-metal containers is considered to be combustible.

When necessary to meet this specification, combustible waste will be incinerated or digested, using technology current at the time of processing, to convert the combustibles to a chemically stable form.

In order to control the radiolytic production of flammable gases, the TRU nuclide content of unprocessed combustible waste is limited to 2 Ci/ft^3 (70 Ci/m^3) of alpha emitters.

2. Gas-Producing Material: The shipment of low-level TRU waste to the WIPP will be coordinated on an ERDA-wide basis so that the total amount of combustible and gas-producing materials in a single storage room does not exceed 10 percent by weight. In the context of this criterion, the materials used in the fabrication of all present containers and liners are considered to be gas-producing.

3. Explosive and Pyrophoric Materials: Waste containing explosive or pyrophoric materials will not be accepted for storage at the WIPP.

4. Toxic Materials: Packages containing waste whose constituents are known to produce toxic fumes (e.g., by thermal decomposition or chemical reaction with other materials in the same container) when exposed to fire temperatures up to 1300°F (700°C) will be prominently labeled in a manner prescribed by the WIPP operator. The term "toxic fumes" refers to gases and vapors of moderate and severe toxicity, as defined in Section 9 of "Dangerous Properties of Industrial Materials," Library of Congress Catalog Card Number 74-17275.

5. Liquids: Waste containing free liquids will not be accepted for storage at the WIPP. Process sludges must either be dried by heating or mixed homogeneously with an appropriate drying agent; in either case, the liquid content of the product should be controlled to minimize dispersal of the waste in a handling accident.

6. Stabilization: Finely divided waste forms such as incinerator residues will be stabilized in concrete or glass (or such other matrices as may be approved by the WIPP operator), or pelletized, in such a manner as to minimize the production of respirable fines in a handling accident.

7. Thermal Power Density: Individual low-level TRU waste packages in which the average thermal power density exceeds 0.1 watt/ft³ (3.5 watts/m³) will be prominently labeled in a manner prescribed by the WIPP operator.

8. Nuclear Criticality: The fissile isotope content of low-level TRU waste is limited to the values specified in DOT Exemption No. 5948: 200 g of fissile isotope per 55-gallon (210-liter) or larger drum, 100 g per 30-gallon (115-liter) drum,

and 6 g/ft^3 (200 g/m^3) in boxes. (Note that Section II.A.7 limits the concentration of heat source plutonium to about 1 g per 55-gallon drum, 0.5 g per 30-gallon drum, and 0.2 g/ft^3 (6 g/m^3) in boxes.)

B. WASTE CONTAINER

1. Dimensions: The largest waste container which can be accommodated inside the WIPP low-level hoist cage is 8 feet x 12 feet x 9 feet high (2.4m x 3.7m x 2.7m high), including handling appurtenances. The use of waste containers smaller than the DOT 17C 55-gallon (210-liter) drum is discouraged but not prohibited.

2. Handling Appurtenances: All low-level TRU waste containers must be provided with cleats, offsets or chins which permit handling by means of fork trucks. Lifting rings and similar handling devices are permissible provided they are recessed or hinged in a manner which permits stacking in a close array.

3. Materials of Construction: Metal containers are preferred; wooden and plastic containers are permitted. In all cases, the materials used in the fabrication of waste containers are subject to the limitations for combustible and gas-producing materials defined in Sections II.A.1 and II.A.2.

4. Structural Design: The structural design of all low-level TRU waste containers must meet the requirements for Type A packages as outlined in 49CFR 173.398b and, in addition, must permit the stacking of fully loaded containers on an empty container of the same type, to an overall height of 12 ft (3.7m).

5. Liners: The use of drum or box liners is permitted when required because of the physical or chemical properties of the contained waste material. When used, the liners should be made

of materials which minimize the rate and total quantity of gas produced as a result of radiolytic, pyrolytic and bacterial decomposition; Sections II.A.1 and II.A.2, limiting the use of combustible and gas-producing materials, apply to liner materials. The use of halogenated plastics such as PVC is discouraged but not prohibited.

C. WASTE PACKAGE.

1. Weight: The weight of a single low-level TRU waste package is limited to 25,000 pounds (11400 kg), the capacity of the WIPP low-level hoist.

2. Surface Contamination: The maximum permissible levels of loose plus fixed surface contamination (above which the waste package will be decontaminated or overpacked at the expense of the shipper) are as specified in 49CFR 173.397:

<u>Contaminant</u>	<u>Maximum Permissible Loose Plus Fixed Contamination Level</u>	
	<u>$\mu\text{Ci}/\text{cm}^2$</u>	<u>$\text{dis}/\text{min}\text{-cm}^2$</u>
Natural or depleted uranium and natural thorium:		
β - γ	10^{-3}	2200
α	10^{-4}	220
All other β - γ emitting radionuclides	10^{-4}	220
All other α emitting radionuclides	10^{-5}	22

3. Penetrating Radiation: The dose rate from penetrating radiation at the surface of an individual waste package may not exceed 500 mrem/hour. Averaged over the waste packages in a given transport vehicle, the surface dose rate may not exceed 200 mrem/hour.

An additional limit applies to agencies which generate more than 5000 ft³ (140 m³) of low-level TRU waste per year: averaged over the waste packages shipped in a given quarter, the surface dose rate may not exceed 10 mrem/hour.

4. Labeling: Each waste package will be uniquely identified by means of a label which is permanently attached to the container in a conspicuous location. Information obtainable from the label itself and from the records pertinent to the waste package will include the following:

Label

- Package identification number (to be standardized)
- Waste generating agency
- Date of packaging
- Radiation levels: mrem/hour of neutrons and gammas, at the surface and at a point 1 m from the surface
- Weight (in pounds and kg)

III. APPENDIX: RATIONALE FOR ACCEPTANCE CRITERIA

A. WASTE FORM

1. Combustible Materials: The permissible volume percent of combustible is derived as follows:

Assumptions

- a. A 4 ft x 4 ft x 7 ft plywood box contains 350 g (148 Ci) of plutonium.

- b. The fractional airborne release due to burning contaminated waste is 0.05% (PNWL-B-27L).
- c. The airflow through a repository room is $17 \text{ m}^3/\text{sec}$.
- d. A fire is initiated by the detonator of explosive gases, with rupture of the associated boxes.
- e. The burning time of a single box is 30 minutes. This corresponds to a fire propagation rate of 0.07 cm/sec , a value which is consistent with experimentally determined rates.
- f. The maximum permissible body burden for plutonium is between 0.04×10^{-6} and $0.1 \times 10^{-6} \text{ Ci}$, depending on the date of publication.
- g. The human breathing rate is $3.47 \times 10^{-4} \text{ m}^3/\text{sec}$.

(a) and (b) imply that a box releases 0.074 Ci (at a rate of $4 \times 10^{-5} \text{ Ci/sec}$ in a 30-minute fire).

From (c), the air activity is $2.4 \times 10^{-6} \text{ Ci/m}^3$.

From (g), the exposure rate is $8.3 \times 10^{-10} \approx 10^{-9} \text{ Ci/sec}$.

From (f), the time to reach maximum permissible body burden is from 40 to 100 seconds (about 1 to 2 minutes, a reasonable time for an individual downstream from the fire to isolate himself from the hazardous environment).

In order to contain the fire and reduce its impact on associated boxes, the combustible boxes are stacked among non-combustible boxes in an array which isolates the combustibles (storage rooms are designed for a 3-high stacking):

Edge contact allowed, no combustibles in top layer

x denotes combustible boxes

Top Layer

In this array, $9/27 = 33\%$ of the boxes can be combustible

Middle Layer

Bottom Layer

Corner contact allowed, no combustibles in top layer

x denotes combustible boxes

Top Layer

In this array, $5/27 = 19\%$
of the boxes can be combustible

Middle Layer

Bottom Layer

For conservatism, the corner-contact array is chosen; the permissible percent of combustibles is $\sim 20\%$.

The allowable fraction of combustibles is expressed as a volume percent, rather than as a weight percent, to emphasize the importance of trash compaction; this reduces the fire hazard and at the same time saves storage volume.

LASL experiments have shown that during the 20-50 years of active WIPP operation, hydrogen generation from the radiolysis of combustibles can be held to a non-hazardous level by limiting the alpha activity of combustible TRU waste to 2 Ci/ft^3 .

2. Gas-Producing Materials: This criterion is predicated on the desire to control pressurization of the (decommissioned) repository due to long-term gas build-up. The underground openings are expected to close by salt creep in a period from 200-2000 years, a time which is short compared with the time during which gas will be produced in radiolytic, pyrolytic, chemical, and bacterial processes. The gas permeability of the salt formation is presently unknown, but is estimated to be small

enough to allow significant accumulation of gas. Gas pressure may cause some re-inflation of the underground workings. The amount of re-inflation which can occur before gas fracture of the geologic formation results is an open question. It is not clear that this essentially hydrostatic environment would not allow sufficient plastic flow to accommodate whatever gas is produced. Current thinking, however, is that less than 10 percent re-inflation may cause gas fracture of the waste storage horizon.

If total gas generation can be shown experimentally to be low enough and/or if the gas permeability of the salt medium is found to be high enough, then the permissible amount of gas-generating materials can be revised upward from the present conservative value.

Estimation of gas leakage, using the calculations of Cheverton, Claiborne and Evans (ORNL-TM-4569), suggest that the salt has a permeability coefficient which is sufficiently low that a substantial amount of gas will be retained. Laboratory and in situ measurement of salt permeability is a first-priority requirement; this has been initiated at Sandia Laboratories.

Assumptions

- a. Volume of storage room plus associated tunnel = $2 \times (356,400) \text{ ft}^3$.
- b. Volume of drums in storage room = $92,400 \text{ ft}^3$.
- c. Volume of void space to be backfilled with crushed salt = $264,000 \text{ ft}^3$.
- d. Volume of tunnel to be backfilled with crushed salt = $356,400 \text{ ft}^3$.

- e. Total initial void volume - void space in backfilled salt in storage room and tunnel + one-half volume of drums.
- f. Nitrogen in mine contributes 2×10^5 moles of N_2 .
- g. Gas production (other than H_2 produced by corrosion of steel)--i.e., the capacity of the trash to produce gas--is 450 m^3 (STP)/1000 kg ($\sim 2 \times 10^4$ moles/1000 kg).
- h. $PV = \sum n_i RT$
- i. Gas temperature = 40°C .

The number of metric tons of gas-producing waste required to fill the available void space with gas at hydrostatic pressure (82 bars) and lithostatic pressure (152 bars) are tabulated below for backfill densities of 50% and 80%.

Gas Volume (Percent of Original Void Space)	Required for P=82 Bars		Required for P=152 Bars	
	Moles of Gas	Metric Tons of Gas-Pro- ducing Waste	Moles of Gas	Metric Tons of Gas-Pro- ducing Waste
50% Backfill Density				
100	1.6×10^7	800	3×10^7	1500
50	8×10^6	400	1.5×10^7	750
25	4×10^6	200	7.4×10^6	375
10	1.6×10^6	80	3×10^6	150
80% Backfill Density				
100	1.53×10^7	765	2.8×10^7	1420
50	7.6×10^6	382	1.4×10^7	710
25	3.8×10^6	191	7×10^6	355
10	1.5×10^6	76.5	2.8×10^6	142

For re-inflation of the mine to 10 percent of the original void volume, the amount of gas-producing waste required to produce a gas pressure of 152 bars (with a backfill density of 50 percent) is 150 metric tons. This is equivalent to about 1000 55-gallon drums (@150 kg per drum)--or 8 ($\approx$ 10) percent by weight of the total room capacity.

3. Explosive and Pyrophoric Materials: A recent survey by Mound Laboratory indicates that no ERDA agency contemplates shipping explosive or pyrophoric wastes for storage at the WIPP. Therefore, the categorical exclusion of such materials causes no immediate inconvenience for the waste generators, and it assures proper planning to avoid possible future conflicts with this criterion.

4. Toxic Materials: This criterion does not bar material having a potential for producing toxic fumes in a fire environment; it merely assures that the WIPP operator will be aware of the presence of such materials, so that he can take extra precautions against exposure of that waste to high temperature.

5. Liquids: The intention here is to allow a waste generator to exercise his judgement as to how much liquid to leave in the final waste form. From the standpoint of the long-term safety of the WIPP, it is clearly desirable to leave as little liquid as possible in the waste: the liquid can serve as both a leaching agent and a transport medium. On the other hand, a completely dewatered and otherwise unstabilized sludge would release an unacceptably and unnecessarily large amount of fines in a handling accident. As a guideline, it is observed that the new Waste Treatment Facility at Rocky Flats will reduce sludges to a pelletized form containing 5 to 10 percent sorbed water.

6. Stabilization: This specification has both short-and long-term safety implications. The short-term concern is, again, the release of fines in a handling accident. The long-term concern is the leachability of the waste form; this is taking on a greater and greater importance in Sandia's risk assessment activities. Unfortunately, present technology will not support a meaningful specification for leachability, but it should not be dismissed as an objective. By way of providing reassurance to waste generators, it is pointed out that, from the standpoint of leachability, ordinary concrete is probably adequate as a stabilizing matrix; glass is better, and recent work at Rocky Flats indicates that "glassification" of incinerator residues is feasible both technologically and economically.

7. Thermal Power Density: This criterion is based on the power density corresponding to 200 grams of weapons-grade plutonium (or 1 gram of heat source plutonium) in a 55-gal drum containing 6 ft³ of waste. The interest is in identifying especially "hot" waste packages so that they can be stored among packages which contain relatively little combustible and gas-producing material. Thermal considerations in the WIPP do not impose a readily identifiable limit on power density; in a practical sense, the upper limit is determined by shipping regulations and the economics of plutonium recovery.

8. Nuclear Criticality: Shipping regulations (specifically, DOT Exemption No. 5948) alone are sufficient to prevent criticality incidents in the WIPP--unless there is dissolution and reconcentration of the fissile species. This is a highly improbable scenario, but one whose importance cannot be evaluated until more sophisticated nuclide transport codes are available.

B. WASTE CONTAINER

1. Dimensions: Except for a few very large items of decommissioning waste, container sizes will never approach the 8 ft x 12 ft x 9 ft limit imposed by the size of the WIPP low-level TRU waste hoist cage. As a rare perturbation of normal operating procedures, it may be possible to rig very large items below the hoist cage.

2. Handling Appurtenances: The justification for this specification is self-evident.

3. Materials of Construction: All container materials of practical interest are potential gas producers; metal is the least objectionable from this standpoint. Rocky Flats is not considering the use of an all-Fiberglass box; LASL suggests that the Fiberglass (actually, Fiberglass-reinforced polyester) should be treated with antimony oxide as a fire retardant. Any container material is acceptable, as long as the conditions of Sections II.A.1 and II.A.2 are satisfied.

4. Structural Design: At a June 2, 1977, meeting at Mound Laboratory, representatives of Mound, LASL ARHCO (for OWI) and Sandia concluded that there is no need for the structural design of TRU waste containers to exceed the requirements of 49CFR.

5. Liners: The position taken in these criteria is that the decision to use or not to use a liner should rest with the waste generator. There is no requirement for container integrity beyond the time of emplacement in the storage rooms, but survival of packages containing unneutralized acids or bases for even that long might well depend on the use of a liner. Alternatively, the waste generator might choose to neutralize the acid or base before drying or sorbing it, and omit the liner.

C. WASTE PACKAGE

1. Weight: The capacity of the WIPP low-level TRU waste hoist is 25,000 pounds--a value determined on the basis of Sandia's best engineering judgement. Surface and underground handling equipment is designed to handle a single 25,000-pound waste package.

2. Surface Contamination: The WIPP plan to inspect incoming waste packages by automated direct alpha counting makes it impossible to distinguish between fixed and removable surface contamination. Admittedly, if all waste packages arrived with maximum permissible contamination levels, and if all the surface contamination were removable, there could be a serious airborne contamination problem throughout the WIPP low-level TRU waste facility. Historically, this has not happened, and the fact that the WIPP is prepared to accommodate occasional (relatively) highly contaminated waste packages will not provide an incentive for waste generators to alter their present practices.

3. Penetrating Radiation: The major producers of defense TRU waste have indicated that there is a very real advantage, in terms of processing and packaging requirements, in treating packages with surface dose rates up to 500 mrem/hr as "low-level" waste. Records shows that there will be relatively few such packages, and that a great majority of the packages will exhibit surface dose rates less than the 10 mrem/hr value used as the basis for the WIPP design. Automated inspection equipment will divert "hot" packages for special handling, so that no serious perturbation of routing operation is anticipated.

4. Labeling: Labeling requirements will be more fully developed in consultation with the waste generators. There is no intention to place an unnecessary burden on shippers, but it is

considered important to be able to distinguish power reactor fuel reprocessing waste, for example, from weapons program waste. It is likely that a coding system similar (or identical) to that in use at INEL will be adopted.

5. Color Coding: Again, further development work is necessary. As noted in the criterion itself, the color-coding system will be compatible with systems already in use, and should not pose a serious problem for waste shippers.

APPENDIX E

METHODOLOGY FOR CALCULATING DOSE COMMITMENT

E.1 INTRODUCTION

This appendix discusses the methodology used to calculate the dose commitments (often called "doses", for brevity, in Sections 12 and 13) expected from normal operations (Section 12) and from postulated accidents (Section 13). The discussion includes airborne transport, groundwater transport, individual dose commitment, population dose commitment, and time-integrated effects.

Calculation of the consequences of radionuclide releases requires consideration of transport from the point of release to the various locations at which members of the public could receive a dose commitment. Such transport could be either through the air or through groundwater systems. (Except where indicated otherwise, pathways involving surface water transport and animal and plant transport were found to be insignificant contributions by comparison.)

External doses to the public would result from external exposure to the airborne radionuclides and to radionuclides deposited on the ground. Internal dose commitments would result from inhalation of the initial airborne radionuclides, inhalation of resuspended radionuclides, ingestion of plant or animal matter containing radionuclides formerly deposited on the ground, and/or ingestion of water contaminated with radionuclides.

E.2 ATMOSPHERIC TRANSPORT AND DISPERSION

The most important transport mechanism for radionuclides would be the wind that could carry radionuclides to population centers, agricultural areas, or grazing lands on or around the INEL. As noted in Subsection 3.3, meteorological monitoring and research programs have been conducted at the INEL for more than 20 yr. In recent years,

simultaneous measurements of wind speed and direction have been made at numerous locations on the Upper Snake River Plain. These data have been used as input to an improved model of atmospheric dispersion for the INEL and surrounding areas.

The model and associated computer code (MESODIF) (Start and Wendell 1974) use a boundary layer field of wind vectors. Measured temporal and spatial variations in the wind speed and direction were used to calculate plume transport and dispersion. The influences of local topography are indirectly incorporated through simultaneous wind measurements at many locations across the plain. The present model has achieved two major improvements over the conventional single-station wind rose technique. First, the greater concentrations resulting from stagnation or recirculation of airborne effluents are included in the model, since the hour-by-hour transport of the effluent was modeled using wind field data. Second, dispersion parameters are adjusted hourly to reflect changes in atmospheric stability.

The six-year average (1972-1977) relative time-integrated concentration (ψ/Q , hr^2/m^3) was calculated using MESODIF. Consistent with Section 12, average meteorological conditions were used to calculate the consequences of accidental airborne releases in Section 13. Figure E-1 shows the calculated values of ψ/Q for the INEL and surrounding areas. The results are for a stack release from an INEL location discharging gaseous effluents at an effective height of 76 m (250 ft). Though not shown in Figure E-1, the maximum ψ/Q was found to be $180 \times 10^{-9} \text{ hr}^2/\text{m}^3$.

The atmospheric dilution factors, X/Q (sec/m^3), required for dose commitment calculations were derived from the relative time-integrated concentrations by taking the appropriate ψ/Q and dividing by the number of hours (8760) in a year. The resulting number is the annual average atmospheric dilution factor in hr/m^3 . By converting hours to seconds, the atmospheric dilution factor, X/Q , becomes:

Fig. E-1 Average annual time-integrated concentrations 1972-1977.
(Multiply isopleth values by 10^{-9} for correct magnitude
in hr^2/m^3 .)

$$\frac{X}{Q} \left(\frac{\text{sec}}{\text{m}^3} \right) = 0.41 \frac{\psi}{Q} \left(\frac{\text{hr}^2}{\text{m}^3} \right) \quad (\text{E-1})$$

Annual average air concentrations, $X(\text{Ci}/\text{m}^3)$, for each radionuclide released were calculated by multiplying X/Q by the annual average release rate, $Q (\text{Ci}/\text{hr})$. The values calculated were maximum values, since no credit was taken for removal processes such as dry and wet deposition and radioactive decay. The mean annual X/Q values are given in Table E-1. The sectors are numbered in a clockwise direction with the first sector bordering on the north. The X/Q 's were determined for the midpoint of each 10-mile radial interval.

E.3 DEPOSITION AND SCAVENGING

Transport of airborne material to ground surfaces was calculated using Equation (E-2) below. The equation was developed to describe the transport of particulate radioactive fallout from air to ground surfaces (Pelletier and Voilleque 1971). Both wet and dry transport processes are considered. The average daily deposition rate is related to the mean air concentration by

$$D = (V_d + gr)X \quad (\text{E-2})$$

where

- D = deposition rate ($\text{Ci}/\text{m}^2\text{-sec}$) of particulates
- V_d = empirical constant for dry deposition of airborne particulates (m/sec)
- g = empirical constant for precipitation scavenging of airborne particulates (m/cm of rain)
- r = average rainfall rate (cm of rain/ sec)
- X = average air concentration (Ci/m^3) of particulate material.

TABLE E-1

MEAN ANNUAL X/Q (sec/m^3) BY SECTOR AND DISTANCE(a)

Sector	Distance (miles)				
	0-10	10-20	20-30	30-40	40-50
1	2×10^{-8}	8×10^{-9}	3×10^{-9}	3×10^{-9}	2×10^{-9}
2	2×10^{-8}	2×10^{-8}	1×10^{-8}	4×10^{-9}	4×10^{-9}
3	3×10^{-8}	2×10^{-8}	2×10^{-8}	1×10^{-8}	1×10^{-8}
4	3×10^{-8}	3×10^{-8}	2×10^{-8}	2×10^{-8}	4×10^{-8}
5	4×10^{-8}	2×10^{-8}	8×10^{-9}	4×10^{-9}	2×10^{-9}
6	8×10^{-8}	2×10^{-8}	8×10^{-9}	2×10^{-9}	2×10^{-9}
7	8×10^{-8}	2×10^{-8}	1×10^{-8}	4×10^{-9}	4×10^{-9}
8	4×10^{-8}	2×10^{-8}	8×10^{-9}	4×10^{-9}	2×10^{-9}
9	4×10^{-8}	2×10^{-8}	8×10^{-9}	4×10^{-9}	2×10^{-9}
10	3×10^{-8}	2×10^{-9}	2×10^{-8}	4×10^{-9}	2×10^{-9}
11	2×10^{-8}	8×10^{-9}	2×10^{-9}	8×10^{-10}	4×10^{-10}
12	1×10^{-8}	2×10^{-9}	8×10^{-10}	3×10^{-10}	2×10^{-10}
13	1×10^{-8}	2×10^{-9}	8×10^{-10}	4×10^{-10}	2×10^{-10}
14	1×10^{-8}	2×10^{-9}	1×10^{-9}	8×10^{-10}	4×10^{-10}
15	2×10^{-8}	4×10^{-9}	2×10^{-9}	4×10^{-10}	2×10^{-10}
16	2×10^{-8}	8×10^{-9}	4×10^{-9}	2×10^{-9}	4×10^{-10}

(a) Sectors are numbered in a clockwise direction with the first sector bordering on the north. X/Q is determined for the midpoint of each 10-mile radial interval.

The daily buildup of particulate radionuclides on the surface was computed using Equation (E-3):

$$dS/dt = D - \lambda_r S \quad (E-3)$$

in which

S = surface concentration (Ci/m^2) of deposited material
 λ_r = radiological decay rate constant for the radionuclide (sec^{-1}).

The values used for the parameters in Equations (E-2) and (E-3) are listed below. To reflect differences in the assumed size of particulates in the effluent from normal and accidental releases, different values for V_d were used for the calculations.

V_d = 0.01 m/sec (accident conditions: particles $1.0 \mu\text{m}$ AMAD)
 0.005 m/sec (normal operation: particles $0.3 \mu\text{m}$ AMAD)

g = 4530 m/cm of rain (Voilleque and Pelletier 1974)

r = 6.8×10^{-7} cm rain/sec (based on 8.5 in. rain/yr, as given in Subsection 3.3.3).

E.4. DISTRIBUTION OF RADIONUCLIDES IN THE SOIL

The distribution of a radionuclide in the superficial soil layer has frequently been found to decrease exponentially with increasing depth. The distribution can be approximated by Equation (E-4)

$$S(z) = S(0)\exp(-\alpha z) \quad (E-4)$$

in which

z = distance below the soil surface (cm, positive downward)
 $S(z)$ = areal concentration (Ci/m^2) at depth z

$S(0)$ = areal concentration (Ci/m^2) at the surface
 α = a parameter which characterizes the distribution (cm^{-1}).

The quantity $1/\alpha$ (cm) is termed the relaxation length of the distribution.

In estimating the long-term activity distributions of transuranics in INEL soils, it was assumed that future downward migration could be adequately approximated by the local observations of fallout. Measurements have been made of the concentrations of plutonium from atmospheric fallout at various depths below the surface of the INEL. The data from 1-cm layers of soil indicate that the distribution of Pu-239 is characterized by a relaxation length of about 2 cm. The deposition and downward migration have been underway for about 30 yr. The chemical and transport processes that yield the presently observed distributions are not well understood. However, the distributions of plutonium in undisturbed soil at other locations (Essington and Fowler 1977) can also be described using Equation (E-3).

Approximately 40% of the fallout plutonium in the INEL soil lies in the top cm. About 60% of the total deposition occurred in the 1962-64 period. Much of the remainder was deposited before that time. An approximate description of the rate of movement downward from the top 1-cm layer is: 20% of the total plutonium has moved from the top layer to lower layers in about 15 yr. Thus, the decrease of plutonium concentration has been somewhat more than 1%/yr. Thus, a rate of 1%/yr was used in the present study. This rate is substantially smaller than the exponential migration rate constant of 0.13/yr for fallout plutonium, estimated by Jakubick (1976) for 5-cm thick, partially saturated layers of natural soil. However, the soil moisture content used was larger than that for the relatively arid INEL environment.

E.5 RESUSPENSION OF DEPOSITED MATERIAL

Over long periods of time, the resuspension of deposited material becomes an important mechanism by which radionuclides are available for intake via inhalation. Two different approaches were used to determine resuspension, one for that due to normal releases and one for that due to accidental releases. The method used by Healy (1974) was used for normal releases. WASH-1400 (NRC 1975) methodology was used for accidental releases. (The two approaches were used because of familiarity with and availability of the computational tools by different evaluator groups conducting different portions of the study. The use of slightly different approaches applies also to other aspects of the dose commitment methodology. For this report, the two approaches would be expected to yield similar results for the same physical situations.)

Healy (1974) has examined several ways in which inhabitants in and near areas contaminated with plutonium could receive radiation doses as a consequence of contact with contaminated soil. Resuspension of surface material was found to be the most important exposure pathway. Another detailed review of the surface contamination problem by the Environmental Protection Agency (EPA 1977) confirmed resuspension as the critical pathway.

Two models were used to estimate radiation doses to persons as the result of resuspension of deposited material. For the local area (within 50 miles of the representative site), the modified mass loading approach (EPA 1977), with airborne particulate concentrations measured in the INEL vicinity (ERDA 1977c), was used to predict local concentrations of resuspended nuclides. The following equation was used to compute the air concentration of resuspended activity

$$x = (1.5)(6.67 \times 10^{-2}) x_d S_1 \quad (E-5)$$

where

x	=	concentration of resuspended radioactivity in air (fCi/m ³)
x_d	=	concentration of dust in air (μg/m ³)

S_1 = areal concentration of radioactivity in the top 1 cm of soil ($\mu\text{Ci}/\text{m}^2$)
 1.5 = enrichment factor (EPA 1977)
 6.67×10^{-2} = product of several constants:

$$(10^9 \text{ fCi}/\mu\text{Ci}) (1 \text{ g}/10^6 \mu\text{g}) (1 \text{ m}^2/1.5 \times 10^4 \text{ g})$$

For INEL and boundary locations, the average airborne mass loading, X_d , averages $28 \mu\text{g}/\text{m}^3$ (ERDA 1977c), so the relationship (E-5) becomes

$$X = 2.8 S_1 \quad (\text{E-6})$$

The observed average mass loading reflects local variations in snow cover, soil moisture, and wind speed, even though such variations cannot be considered explicitly.

For populations at greater distances, the resuspension rate model (Healy 1974) was used with the average areal concentration of activity in the top cm of soil (S_1) to obtain a resuspension source term for long-distance diffusion calculations. The area was considered to be large enough that no correction for a finite source was necessary. Healy (1974) examined a variety of data and found that the resuspension rate constant K (sec^{-1}) varied from 10^{-9} to 10^{-8} for freshly deposited activity and 10^{-12} to 10^{-11} for older deposits. In these calculations, an intermediate value of $K = 10^{-10} \text{ sec}^{-1}$ was used, which probably overestimates the long-term impact of resuspension.

The surface contamination S_1 is not constant with time. Three processes reduce the amount available for resuspension at time t : (1) radioactive decay, (2) downward migration out of the top 1-cm layer, and (3) resuspension itself. These effects are described by Equation (E-7) for an existing surface deposit:

$$dS_1/dt = -(\lambda_r + \lambda_m + \lambda_R) S_1 \quad (\text{E-7})$$

in which

- S_1 = average areal concentration in the top 1-cm layer (Ci/m^2),
 λ_r = radioactive decay rate constant (yr^{-1}),
 λ_m = downward migration rate constant (yr^{-1}), and
 λ_R = resuspension rate constant (yr^{-1}).

Integration yields

$$S_1 = S_{1_0} \exp(-\lambda_e t) \quad (\text{E-8})$$

where

S_{1_0} = average initial areal concentration (Ci/m^2).

$$\lambda_e = (\lambda_r + \lambda_m + \lambda_R) (\text{yr}^{-1}).$$

Equation (E-7) was used to describe the time dependence of the resuspension source term in calculations of the local and distant impacts of resuspended soil contamination.

For accidental releases, the resuspension of deposited particles was modeled based on WASH-1400 (NRC 1975) methodology. The time-dependent resuspension factor, $K(t)$, was multiplied by the surface concentration (Ci/m^2) to determine the local air concentration (Ci/m^3). The factor, $K(t)$, is:

$$K(t) = K_0 \exp(-\lambda_k t) + K_e \quad (\text{E-9})$$

where

K_0 = resuspension factor initially after deposition (10^{-5} m^{-1})

K_e = equilibrium resuspension factor (10^{-9} m^{-1})

t = time after deposition (yr)

λ_k = resuspension equivalent half-life constant (0.677 yr^{-1})

E.6 TRANSFER TO THE HUMAN FOOD CHAIN

Transuranic nuclides released in gaseous effluents can be directly transferred to food crops by wet and dry deposition mechanisms previously discussed. Radioactive material deposited in the soil can also be taken up into the plants via the roots. Root uptake factors are small, ranging from approximately 10^{-4} ($\mu\text{Ci/g}$ of plant)/($\mu\text{Ci/g}$ of soil) for plutonium to 3 to 4×10^{-3} ($\mu\text{Ci/g}$ of plant)/($\mu\text{Ci/g}$ of soil) for americium and curium (Cline 1968, Price 1972, Buchholz et al. 1971). Transuranic nuclides in or on plant materials generally pass through the animal gut with only minor fractions transferred to the blood (ICRP 1972). This fact is also reflected in the small measured transfer of plutonium from feed to milk of $10^{-4}\%$ per liter (Sansom 1964) and the measured low concentrations of plutonium in milk (Magno, Kauffman, and Shleien 1967; Bennett 1974). Transfer of plutonium in foods to human internal organs is similarly limited by the small transfer from the gastrointestinal (GI) tract to blood (ICRP 1959, ICRP 1964).

E.7 GROUNDWATER TRANSPORT MODEL

An analytical model was developed by Codell and Schreiber (1977) to estimate radionuclide transport in an aquifer. The governing equation was based on solution of the three-dimensional partial differential equation for conservation of mass in a uniform saturated medium. The model included advection, dispersion, sorption (retardation), and radioactive decay. For this analysis, the assumed geometry and initial conditions were uniform aquifer thickness, infinite lateral extent, a vertical line source, instantaneous release, and homogeneous properties.

For an instantaneous input of one curie, the applicable solution would be:

$$X = (n_e a)^{-1} XYZ \quad (E-10)$$

where

- X = concentration of the nuclide at a point (X,Y) for an instantaneous one curie release (Ci/cm^3) at the origin
 n_e = effective porosity of the medium
 a = retardation factor, $1 + K_d \rho_b/n$
 ρ_b = bulk density of medium (g/cm^3)
 n = total porosity
 K_d = distribution coefficient (cm^3/g)
 X = $(4\pi D_x t/a)^{-1/2} \exp \left[-(x-ut/a)^2/(4D_x t/a) - \lambda t \right]$ (cm^{-1})
 Y = $(4\pi D_y t/a)^{-1/2} \exp \left[-y^2/(4D_y t/a) \right]$ (cm^{-1})
 Z = $1/h$ (cm^{-1})
 D_x = dispersion coefficient in the x direction (cm^2/sec)
 D_y = dispersion coefficient in the y direction (cm^2/sec)
 t = time after release (sec)
 u = x-component groundwater velocity (cm/sec)
 λ = radioactive decay constant (sec^{-1})
 h = thickness of aquifer (cm)

The transverse distance, y , was considered to be zero for estimating the maximum concentration at a location at time t . Equation (E-10) simplifies to:

$$X = \frac{1}{4\pi n_e a h (D_x D_y)^{1/2}} \exp \left[-\frac{(x - ut/a)^2}{4D_x t/a} - \lambda t \right] \quad (\text{E-11})$$

The retardation factor, a , or alternately the distribution coefficient, K_d , has been estimated for each radionuclide in several papers (Burkholder 1976, Staley et al. 1977, Leddicotte et al. 1978). The work by Staley et al. included a comparison of coefficients for sand, silt, and clay. Retardation factors for sand were about 1/8 the values for silt and clay and were the smallest values estimated in the above papers. Since there are many fissures in the basalt,

beneath the RWMC, this study conservatively used the sand retardation factors from Staley et al. (1977), effecting the quickest migration and least dilution.

Dispersivities have been estimated and verified for the ICPP site 6 miles NE of the RWMC (Robertson 1974). Using the equations

$$D_x = \alpha(x)u \quad (E-12)$$

$$D_y = \alpha(y)u$$

and $u = 4.3$ ft/day (Codell and Schreiber 1977), the dispersion coefficients were calculated to be $D_x = 1290$ ft²/day and $D_y = 1935$ ft²/day.

The thickness of the aquifer, h , was assumed to be 250 ft, the same as below the ICPP site (Robertson 1974). The effective porosity, n_e , was estimated as 0.10, from the same reference.

E.8 DOSE CALCULATIONS

E.8.1 Dose Calculations - General. Both maximum individual and population doses were calculated as defined in Section 13. The individual receiving the maximum airborne dose was assumed to reside in Sector 7 (Table E-1) where the X/Q was a maximum. The population distribution around the site is illustrated in Figure 3-13.

The pathways considered for calculating doses were for both external and internal exposure mechanisms. The following pathways contributed to the overall total doses:

- (1) external exposure to the initial cloud of radioactivity;
- (2) external exposure to the deposited radioactivity;
- (3) inhalation of initial cloud of radionuclides;
- (4) inhalation of resuspended radionuclides; and
- (5) ingestion of contaminated plants, animals, and water.

The potential consequences calculated were dose commitments to the whole body, lung, and bone. The individual dose commitment was expressed in rem, and the population dose commitment was expressed in man-rem.

The calculations extended to a distance of 50 miles. No credit was taken for evacuation of the population near the site. A shielding factor of 1/3 (NRC 1975) was used for all external doses. This factor accounts for protection provided by structures such as buildings, cars, etc.

For normal operation, the effects of the released radionuclides over a 70-yr period (70-yr dose commitment) were calculated. For accident situations, a period of 50 yr following the accident was assumed. A population growth of 1%/yr from 1985 to 2085 was assumed in computing the risk to the public. After 2085, the population was assumed to remain constant. The chronic pathways considered were external exposure to contaminated surfaces and inhalation of resuspended particles for both accidental and normal operational releases. For normal operations, external exposure to and inhalation of the initial cloud were also considered.

E.8.2 Models for Calculating Internal Radiation Doses. The basic expression used for calculating internal radiation doses received as the result of inhalation or ingestion of a radionuclide is

$$D_k = 51.2 \epsilon_k / m_k \int_0^T q_k(t) dt \quad (E-13)$$

where

- D_k = the dose equivalent (rem) delivered to the k^{th} tissue
- ϵ_k = effective absorbed energy deposited by nuclide in the k^{th} tissue (MeV/dls) (rem/rad)
- m_k = mass of the k^{th} tissue (g)

$$q(t) = \text{activity } (\mu\text{Ci}) \text{ of the nuclide present in the } k^{\text{th}} \text{ tissue as a function of time}$$

$$51.2 = \left(3.7 \times 10^4 \frac{\text{dis/sec}}{\text{Ci}}\right) \left(1.6 \times 10^{-6} \frac{\text{erg}}{\text{MeV}}\right) \left(10^{-2} \frac{\text{rad}}{\text{erg/g}}\right) \left(8.64 \times 10^4 \frac{\text{sec}}{\text{day}}\right)$$

Values of the parameters ϵ_k and m_k were obtained from ICRP publications (1959, 1964 and 1975). The functions $q(t)$ were determined using models of human metabolism of each nuclide considered. Brief descriptions of these models and associated computer codes follow.

All calculations of the doses resulting from inhalation used the ICRP Task Group model of the human respiratory tract (ICRP 1966), as revised (ICRP 1972). The Task Group model was coupled to metabolic models for other organs previously developed for internal dosimetry (ICRP 1959, ICRP 1964). Acute and chronic inhalation exposure calculations were made using the DACRIN code (Houston, Streng, and Watson 1974). DACRIN was used to obtain lifetime dose commitments to the various organs as functions of exposure time and the quantity of activity inhaled. For acute accidental exposure, 50-yr dose commitments were calculated for each organ. For chronic exposure, 70-yr dose commitments were calculated for each organ. The activity median aerodynamic diameter was assumed to be 1 micron for accidental releases and 0.3 micron for normal releases. This distinction was intended to reflect the fact that normal operational releases would be filtered, whereas some of the accidental releases would not be. The dose commitment factors (DCFs) (rem/ μCi inhaled) were then used with the transport and resuspension models to obtain the dose commitment for each nuclide and pathway.

For ingestion pathways, the dose conversion factors were calculated with the INREM (Killough and McKay 1976) code using dosimetry described in Publication 2 of the ICRP (ICRP 1959). Again, for accidental releases, 50-yr dose commitment conversion factors were used; for normal operational releases, 70-yr factors.

E.8.3 External Radiation. The radioactive material released to the environment and subsequently deposited on the land surface provides a small source of gamma radiation for a long time after the cloud passage. The initial radiation exposure to individuals by the cloud passage is much smaller than the long-term effects of the resulting surface contamination.

All external dose conversion factors were calculated from the EXREM III computer program developed at Oak Ridge National Laboratory (Killough and McKay 1976).

Only photon doses resulting from immersion in contaminated air and exposure to a contaminated land surface were considered. The doses resulting from standing on contaminated land present some long-term exposure that must be addressed to assess the level of external irradiation.

E.8.4 Normal Release Dose Calculations. As stated earlier, the local population was assumed to grow exponentially at the rate of 1%/yr until 2085, after which it was assumed to remain constant. See Guideline (7) in Subsection 7.4.1.5. Figure 3-13 illustrates the 80 sectors into which the population is divided. Maximum x/Q values were taken from Table E-1 for each sector. The average annual population dose commitment for inhalation of dispersed airborne activity in a given sector was computed using

$$\sum = Q (x/Q)(BR)(DCF) P \quad (E-14)$$

where

- $\sum$ = the annual population dose commitment (man-rem/yr)
- Q = the release rate of the nuclide ($\mu\text{Ci/sec}$)
- x/Q = the dispersion factor (sec/m^3)
- BR = the breathing rate (m^3/yr)

DCF = the organ or tissue dose commitment factor
(rem/ μ Ci inhaled) for the nuclide
P = the population of the sector (persons).

The contributions to the total population dose were then summed over all nuclides and sectors to obtain the total population dose commitment for each organ for one year of operation.

Long-term environmental dose commitments were calculated for the local population exposed to direct radiation and resuspended surface contamination. During the period of 1985-2085, it was assumed that both the population P and surface concentration S_1 would be changing, and this was considered in the dose calculations. For periods beyond 2085, only S_1 was assumed to be time-dependent. For a time t between the end of operations in 1995 and 2085, the annual population dose to an organ from resuspension of a particular isotope is

$$\sum(t) = 2.8 \times 10^{-9} S_1 \left[\exp(-\lambda_e t) \right] (BR)(DCF)(1.3)P(t) \text{ (man-rem/yr)} \quad (E-15)$$

The factor of 10^{-9} converts fCi to μ Ci, and the factor of 1.3 accounts for the average changes in body organ size and breathing rates prior to age 20. The other factors and variables have already been discussed. The cumulative population dose commitment (man-rem) for a single nuclide at time t is $\sum(t)$ (man-rem):

$$\sum(t) = \frac{3.64 \times 10^{-9} S_{10} (BR) (DCF) P(1995)}{(\lambda_e - \gamma)} \left\{ 1 - \exp[-(\lambda_e - \gamma) t] \right\} \quad (E-16)$$

where

γ = the population growth rate constant
P(1995) = the population in 1995.

For periods beyond 2085, the expression for the cumulative population dose commitment to an organ is

$$\Sigma(t) = \Sigma(2085) + \frac{3.64 \times 10^{-9} S_{10} (BR) (DCF) P(2085)}{\lambda_e} [1 - \exp(-\lambda_e t)] \quad (E-17)$$

$\Sigma(2085)$ is the cumulative population dose commitment to an organ up to 2085. In both time periods, the contributions of all the nuclides were summed to obtain the total population dose commitment for each organ or tissue.

Populations of U.S. locations distant from the INEL were also assumed to grow exponentially at the rate of 1%/yr until 2085. The resuspension rate approach was used to obtain the source term for long-distance diffusion calculations:

$$Q_r = KAS_{10} \exp(-\lambda_e t) \quad (E-18)$$

where

- Q_r = resuspension source term ($\mu\text{Ci/sec}$)
- K = resuspension rate (sec^{-1})
- A = the area of the 50-mile circle (m^2)
- S_{10} = the initial concentration ($\mu\text{Ci/m}^2$)
- λ_e = the effective source reduction constant (yr^{-1})

Between 1995 and 2085 the cumulative contribution of each nuclide to the dose commitment for an organ or tissue is given by

$$\Sigma(t) = \frac{S_{10} AK (X/Q)' (BR) (DCF) (1.3) P'(1995)}{(\lambda_e - \gamma)} \left\{ 1 - \exp[-(\lambda_e - \gamma)t] \right\} \quad (E-19)$$

where $(X/Q)'$ and $P'(1995)$ refer to dispersion factors and populations for the distant locations. For the period after 2085,

$$\Sigma(t) = \Sigma(2085) + \frac{S_{10}^{AK} (X/Q)' (BR) (DCF) (1.3) P'(2085)}{\lambda_e} [1 - \exp(-\lambda t)] \quad (E-20)$$

In both cases, the cumulative population dose commitment for a particular organ is the sum of the contributions of the individual nuclides.

The dispersion factors and the estimated 1985 populations for the areas presumed to be affected by the transport of resuspended contamination are given in Table E-2. The dispersion factors are based on a single set of tracer measurements (Cowan et al. 1976) and the extrapolations from them. The referenced measurements were made with a non-depositing tracer, so the dispersion factors do not include plume depletion by wet or dry deposition. Plume depletion would reduce the air concentrations at the distant locations. Therefore, the dispersion factors are conservative. The population data are based on 1970 census information (U.S. Bureau of the Census 1973).

TABLE E-2

ESTIMATED POPULATIONS AND DISPERSION FACTORS FOR DISTANT LOCATIONS

Regions of United States	States Included	Estimated Population P' (1985)	Estimated Dispersion $(X/Q)'$ (sec/m ³)
New England	ME, NH, VT, MA, RI, CT	13,754,215	2.4×10^{-12}
Middle Atlantic	NY, NJ, PA	43,133,262	2.4×10^{-12}
East North Central	OH, IN, IL, MI, WI	46,732,110	5.4×10^{-12}
West North Central	MN, IA, MO, ND, SD, NB, KS	18,952,109	9.5×10^{-12}
Mountain	M, WY, CO	3,754,671	5.7×10^{-11}

E.8.5 Accident Dose Calculations. All dose commitments were calculated for 50 yr following the release of activity from an accident. The assumed population growth was the same as described earlier. For all airborne release accidents, the most significant contributor to the 50-yr total dose was the inhalation of radionuclides. Calculation of the chronic pathways considered the inhalation pathway due to resuspension, as well as external exposure due to contaminated ground. The following equation was used for the inhalation pathway:

$$P_k = \int_0^{50} \exp(-\lambda t) S_0 K(t) \cdot B \cdot C \cdot P_0 \exp(\gamma t) dt \quad (E-21)$$

where

P_k	=	population dose commitment within the sector interval (man-rem)
$\exp(-\lambda t)$	=	correction for decay
P_0	=	population at time zero
$K(t)$	=	resuspension function
S_0	=	surface contamination at time zero
B	=	breathing rate
C	=	dose conversion factor
$\exp(\gamma t)$	=	correction for population growth

For external exposure due to contaminated ground, the equation used was:

$$P_k = \int_0^{50} \exp(-\lambda t) S_0 W(t) F P_0 \exp(\gamma t) dt \quad (E-22)$$

where

$W(t)$	=	weathering function
F	=	shielding factor (1/3)

and the other terms have been defined above.

For the waterborne accident releases, the maximum dose commitment to an individual and the population dose commitment were calculated for the pathway of drinking water. The individual receiving the maximum dose commitment was assumed to drink 2 liters per day of contaminated water, while the general population was assumed to drink 1 liter per day. The sources of drinking water are described in Subsection 13.4.2.2.2. The dose conversion factors were generated from the INREM code (Killough and McKay, 1976), as indicated in Section E.8.2.

E.8.6 Time-Integrated Risk. Time-integrated risks depend on population growth, radionuclide decay and buildup, and change in resuspension factors. The major effects are due to the population growth and radionuclide decay. Each release in 1985 would consist of a mix of the radionuclides given in Table 13-2. The resulting doses on a nuclide-by-nuclide basis were determined to vary exponentially with time. An increase in population would increase the doses, while radioactive decay would decrease the doses. Because each radionuclide has a different radioactive decay rate and different dose conversion factors for each organ, it was necessary to derive the multiplicative factors in Table 13-1, based on a mix of nuclides. The effective dose due to each nuclide would be the quantity of the nuclide released multiplied by its dose conversion factor. For these calculations, only dose to the bone due to inhalation was considered. Separate calculations for dose to the lung indicated that the multiplicative factors would differ from the values shown in Table 13-1 by less than a factor of two for all times given.

The multiplicative factors represent the integration of the time-varying effective doses of each released nuclide. These doses have been normalized such that the summation over all the nuclides is equal to one at release time:

$$\sum_i D_i = 1 \quad (E-23)$$

$$D_i = R_i \text{ DCF}_i \quad (E-24)$$

where

- D_i = relative effective dose of the i^{th} nuclide (rem)
 R_i = release of i^{th} nuclide in 1985 (Ci)
 DCF_i = dose conversion factor (50-yr commitment to bone) due to inhalation (rem/Ci)

The time-varying relative effective doses are

$$RD_i(t) = D_i \exp (\gamma - \lambda_i) \quad (\text{E-25})$$

where

- $RD_i(t)$ = relative time-varying effective dose of the i^{th} nuclide (rem)
 γ = population growth factor for 1%/yr increase ($9.95 \times 10^{-3} \text{ yr}^{-1}$)
 λ_i = radioactive decay factor for i^{th} nuclide (yr^{-1})
 t = time from release (yr)

To calculate the desired time-integration interval risk multipliers, Equation (E-25) must be integrated from time 0 to time T (yr), which results in

$$DT_i = (D_i/\lambda_i - \gamma) \left\{ 1 - \exp [(\gamma - \lambda_i) T] \right\} \text{ for } T < 100 \text{ yr} \quad (\text{E-26})$$

and for $T > 100$ yr:

$$DT_i = (D_i/\lambda_i - \gamma) \left\{ 1 - \exp [100(\gamma - \lambda_i)] \right\} + (D_i/\lambda_i) \left\{ \exp (100\gamma) \left[\exp (-100\lambda_i) - \exp (-\lambda_i T) \right] \right\} \quad (\text{E-27})$$

where

- T = time since release (yr)
 DT_i = integrated relative effective dose from time 0 to T (rem-yr)

The multiplicative factors are then determined by summing over all the nuclides and dividing by the effective dose at release.

$$M_T = \sum_i DT_i / \sum_i D_i \quad (E-28)$$

where

M_T = multiplicative factor for time-integration from 0 to T (yr)

For the case of the maximum individual dose, the procedure is the same except there is no population effect ($\gamma=0$).

The preceding method is not exact, but it does indicate the effect of population growth and radionuclide decay on time-integrated risk. Table 13-1 indicates this effect. During the first 100 yr, the population growth would be the controlling factor. At much later times, there would be a decrease in risk due to decay. Therefore, the risk multiplicative factors approach a constant.

APPENDIX F

SCIENTIFIC NOTATION

When dealing with very large or very small numbers, the conventional notation is awkward and cumbersome. Writing 0.000000000000001, for example, is undesirable, as is calling this number "a millionth of a billionth." To overcome this problem, a notation system in general use throughout the scientific community has been employed in this report. This system would indicate the above number as 1×10^{-15} . This notation can then be converted back to the original number by moving the decimal point according to the power of ten that is indicated. If the power of ten is positive, for example, the decimal is moved to the right the number of places indicated by the power. If the power of ten is negative, the decimal is moved to the left the number of places indicated by the power. Examples of positive and negative powers of ten follow:

$$\begin{aligned} 1.25 \times 10^5 &= 125,000 \\ 1.25 \times 10^{-4} &= 0.000125 \end{aligned}$$

Prefixes are often added to units (such as curies or grams) to indicate the magnitude of the value. Common prefixes, their values, and their abbreviations are as follows:

<u>Prefix</u>	<u>Power</u>	<u>Value</u>	<u>Symbol</u>
mega	10^6	1,000,000	M
kilo	10^3	1,000	k
centi	10^{-2}	0.01	c
milli	10^{-3}	0.001	m
micro	10^{-6}	0.000001	μ
nano	10^{-9}	0.000000001	n
pico	10^{-12}	0.000000000001	p
femto	10^{-15}	0.000000000000001	f

Thus, 1 kilogram (kg) = 10^3 grams = 1,000 grams
and 1 microcurie (μCi) = 10^{-6} curie = 0.000001 curie.

APPENDIX G

ABBREVIATIONS

AEC	Atomic Energy Commission (now DOE)
ALAP	As Low As Practicable
AMAD	Activity Median Aerodynamic Diameter
ANL	Argonne National Laboratory
ANL-E	Argonne National Laboratory East
ANL-W	Argonne National Laboratory West
ASWS	Air Support Weather Shield
Bettis	Bettis Laboratory, (Pittsburgh, Pa)
BLM	Bureau of Land Management
BRH	Bureau of Radiological Health
c	centi (see Appendix F)
CEQ	President's Council on Environmental Quality
CFA	Central Facilities Area
CFR	Code of Federal Regulations
X/Q (Chi/Q)	atmospheric dilution factor
Ci	Curie
cfs	cubic feet per second
CPT	Compaction, Immobilization, and Packaging
CY	Calendar Year
D&D	Decontamination & Decommissioning
DCF	Dose Commitment Factor
DF	Decontamination Factor
DFS	Decontamination Facility South
DOD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
DOT Spec	Department of Transportation Specification
dpm	disintegrations per minute
EBR-I, -II	Experimental Breeder Reactor I, II

ABBREVIATIONS (Cont'd)

ECIPDA	East-Central Idaho Planning and Development Association
EDR	Experimental Data Report
EG&G	EG&G Idaho, Inc. (Edgerton, Germeshausen & Grier)
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ERDA	Energy Research & Development Administration (Now DOE)
ERDAM	ERDA Manual
eV	electron volt
EWR	Early Waste Retrieval
f	femto (see Appendix F)
FAA	Federal Aviation Administration
ft	foot
FMC	Corporate identification - formerly Food Machinery Corporation
FWQA	Federal Water Quality Administration
FY	Fiscal Year
g	gram
GI	Gastro-Intestinal
HEPA	High Efficiency Particulate Air (filter)
hr	hour
ICPP	Idaho Chemical Processing Plant
ICRP	International Commission on Radiation Protection
IDI	In-Drum Incineration
IDO	Department of Energy, Idaho Operations Office
IDR	Initial Drum Retrieval
in.	inch
INEL	Idaho National Engineering Laboratory
k	kilo (see Appendix F)
KE	Kaiser Engineers
LASL	Los Alamos Scientific Laboratory (Los Alamos, New Mexico)

ABBREVIATIONS (Cont'd)

LATA	Los Alamos Technical Associates
lb	pound
LMV	Less Massive Variation
m	milli (see Appendix F)
M	Mega (see Appendix F)
μ (mu)	micro (see Appendix F)
m/m	man/materials
MMI	Modified Mercalli Intensity
Mound	Mound Laboratory (Miamisburg, Ohio)
MPBB	Maximum Permissible Body Burden
MPC	Maximum Permissible Concentration
mR	milliroentgen
mrem	milliroentgen equivalent man
MSI	Molten Salt Incineration
MSL	Mean Sea Level
n	nano (see Appendix F)
NAS	National Academy of Sciences
NBS	National Bureau of Standards
NDE	Nondestructive Examination
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
NOAA	National Oceanic & Atmospheric Administration
NCRP	National Council on Radiation Protection
NPS	National Park Service
NRC	National Research Council
NRC	Nuclear Regulatory Commission
NRTS	National Reactor Testing Station (Now INEL)
NSC	National Safety Council
NSC	Nuclear Services Corporation
O&M	Operating & Maintenance
ORNL	Oak Ridge National Laboratories (Oak Ridge, Tennessee)
OSHA	Occupational Safety and Health Administration

ABBREVIATIONS (Cont'd)

p	pico (see Appendix F)
PKG	Packaging Only
PLO	Public Land Order
Ψ/Q (Psi/Q)	relative time integrated concentration
PVC	Polyvinyl chloride
R	Roentgen
R&D	Research and Development
RAL	Radiation Analysis Laboratory
rem	roentgen equivalent man
RESL	Radiological and Environmental Sciences Laboratory
RF	Release Fraction
RFP	Rocky Flats Plant (Golden, Colorado)
RPPF	Retrieval, Processing and Packaging Facility
RWMC	Radioactive Waste Management Complex (INEL)
SCC	Secondary Combustion Chamber
SDA	Subsurface Disposal Area (part of RWMC)
SP	Slagging Pyrolysis and Packaging
TDA	Transuranic Disposal Area (part of RWMC)
TLD	Thermoluminescent Dosimeter
TRA	Test Reactor Area
TRU	Transuranic
TSA	Transuranic Storage Area (part of RWMC)
UBC	Uniform Building Code
USGS	United States Geological Survey
WIPP	Waste Isolation Pilot Plant
WVRF	Waste Volume Reduction Facility
yd	yard
yr	year

APPENDIX H

GLOSSARY

ATMX series 600 railroad cars: Railroad freight cars that have been specially designed for high structural integrity.

activity: A measure of the rate at which a material is emitting nuclear radiations; usually given in terms of the number of nuclear disintegrations occurring in a given quantity of material over a unit of time. The standard unit of activity is the curie (Ci).

adiabatic lapse rate: The rate of decrease of temperature with height of dry air lifted with no external heat losses or gains through an atmosphere in hydrostatic equilibrium.

aeolian: Borne, deposited, eroded or produced by the wind.

alluvial fan: Rock deposit laid down by streams flowing from mountains to lower regions.

alluvium: Clay, silt, gravel or similar material deposited by running water.

alpha emitters: Radioactive elements that emit alpha particles, (i.e. transuranics).

alpha particle: Used with respect to radiation; a positively charged particle consisting of two protons and two neutrons; a helium atom that has lost two electrons.

alpha radiation: An emission of alpha particles from a material undergoing nuclear transformation; the particles have a nuclear mass number of four and a charge of plus two. It is the least penetrating of the three common types of radiation (alpha, beta, and gamma), being stopped by a sheet of paper. It is not dangerous to plants, animals or man unless the alpha-emitting substance has entered the body.

alpha waste: Waste material that is contaminated by radionuclides which emit alpha particles, particularly transuranic elements.

alternative: As used in this report, a general method of managing the TRU waste. For example, Alternative 5 is "Retrieve as Scheduled, Process, and Dispose of on the INEL."

alumino-silicate: A combined aluminate (aluminum oxide) and silicate (silicon oxide).

aquifer: A stratum or zone below the surface of the earth that is capable of producing water, as from a well.

asphaltic cement: A paving material that uses asphalt bitumen as a binder.

background radiation: The level of radioactivity in an area, which is produced by sources other than the one of specific interest. Background radiation is produced by naturally occurring radioactive materials in the crust of the earth, cosmic radiation, and the fallout from nuclear weapons tests. It is also called natural radiation.

basalt: A dark, fine-grained, basic, igneous rock. Basalt is the world's most abundant type of lava. The ferromagnesian minerals predominate in basalt, but feldspar is abundant; quartz is absent.

bentonite: A colloidal clay formed by decomposition of volcanic ash, having the ability to absorb large quantities of water and to expand to several times its normal volume.

beta particle: An elementary particle emitted from a nucleus during radioactive decay, with a single electrical charge and a mass equal to $1/1837$ that of a proton. A negatively charged beta particle is equivalent to an electron and a positively charged beta particle is equivalent to a positron. Beta radiation may cause skin burns, and are harmful if they enter the body. However, beta particles are easily stopped by a thin sheet of metal.

bioassay: A procedure to determine the active power or potency of a substance by measuring a given effect on plants or experimental animals as test objects. Bioassay is also used to study the biological effect of various radioactive materials on humans or to measure the intake of radioactive materials into the body. For example, measurement of radioactive isotopes in the urine of individuals working with radioactive materials is a measure of ingestion or inhalation of radioactive material.

block faults: High angle normal or reverse faults bordering a mass of rock on at least two opposite sides. The mass may be elevated or depressed relative to the adjoining region, or it may be elevated relative to the region on one side and depressed relative to that on the other.

body burden: The amount of a specified radioactive material or the summation of the various radioactive materials present in an animal or human body at the time of interest.

brattice: A partition or wall, often temporary, of wood or cloth used in a mine to control ventilation.

breccia: Rock consisting of sharp fragments cemented together or embedded in a fine-grained matrix.

butte: An isolated hill or mountain, usually having a flat top, rising abruptly above the surrounding land.

calcareous: Consisting of or containing calcium carbonate, CaCO_3 .

Carboniferous: See Table H-1 (Geological Time Periods) at the end of the glossary.

carcinogen: A substance that tends to produce a cancer.

chelate: To form a ring structure containing a metal ion (such as plutonium) held by coordination bonds.

chert: A rock resembling flint and consisting essentially of microcrystalline quartz.

colloidal suspension: A suspension of particles ranging in size from 1 to 500 millimicrons in diameter.

concept: As used in this report, a specific method for implementing an alternative (through the use of a series of modules). For example in Alternative 5, Concept 5-a would entail direct-control retrieval, incineration by slagging pyrolysis, packaging, and deep rock disposal (shaft access) in the Lemhi Range.

contamination (contaminated material): The deposition, solvation, or infiltration of radionuclides on or into an object, material, or area whereupon the area, material, or object is considered "contaminated."

critical: The condition in which a material is undergoing nuclear fission at a self-sustaining rate. The critical mass of a material is that amount that will self-sustain nuclear fission when placed in optimum arrangement in its present form. The minimum critical mass is the amount of a fissile isotope that will self-sustain nuclear fission when placed in optimum conditions.

criticality safety: Those procedures necessary to the handling of fissile materials in a manner that will prevent them from reaching a critical condition.

curie (Ci): A unit of radioactivity defined as the amount of a radioactive material that has an activity of 3.7×10^{10} disintegrations per second (d/s).

daughter products: The nuclides formed by the radioactive disintegration of a first nuclide (parent).

decay product: A nuclide resulting from the radioactive disintegration of a radionuclide, formed either directly or as the result of successive transformations. A decay product may be either radioactive or stable.

decommissioning: The process of removing a facility or area from operation and decontaminating and/or disposing of it or placing it in a condition of standby with appropriate controls and safeguards.

decontamination: The selective removal of radioactive material from a surface or from within another material.

direct control retrieval: Retrieval of buried or stored waste in which the retrieval equipment is directly controlled by operators riding on the equipment in environmentally controlled cabs.

disposal: Operations designed to isolate waste permanently from mankind and his environs with no expectation of retrieval after emplacement.

diurnal: Having a daily cycle.

dolomite: Calcium magnesium carbonate, $\text{CaMg}(\text{CO}_3)_2$, or a rock composed chiefly of this mineral.

dome: A roughly symmetrical upfold with beds dipping radially outward with roughly equal amounts from a given point; with the development of an axis, a dome becomes an anticline.

dose: A general term indicating the amount of energy absorbed from incident radiation per unit of mass, by a body or by any portion of a body.

dose commitment: The integrated dose that results from an intake of radioactive material when the dose is evaluated from the beginning of intake to a later time (usually 50 yr); also used for the long-term integrated dose from radioactive material released to the environment.

dosimeter: A device carried on the person for measuring the quantity of radiation to which one has been exposed.

dust palliative: A substance used to reduce or lessen the severity of airborne dust.

ecology: That branch of biological science that deals with the relationships between organisms and their environment.

ecosystem: An assemblage of biota (community) and their environment.

effluent: Something that flows out such as waste material discharged to the environment.

evapotranspiration: The combined loss of water from soil by evaporation from the soil and from plant surfaces.

exposure: The condition of being made subject to the action of radiation.

fallout: Particulate material, which may be radioactive, deposited on the ground from the air.

Federal Repository: A planned, federally-owned facility for the long-term management of nuclear waste.

feldspar: Any of a group of crystalline minerals that consist of aluminum silicates with either potassium, sodium, calcium, or barium and that are an essential constituent of nearly all crystalline rocks.

film badge: A small pack of sensitive photographic film worn as a badge for indicating exposure to radiation.

finer: Finely crushed or powdered material; very small particles in a mixture of various sizes.

fission (nuclear): The division of a nucleus into two nuclides of lower mass, usually accompanied by the expulsion of gamma rays and neutrons.

fission products: The nuclides formed by the division of a heavier nucleus; usually in a nuclear reactor.

flap valve: A valve with a hinged closure that allows flow in only one direction.

gamma rays: High-energy, short-wavelength, electromagnetic radiation deriving from nuclear transformations; similar to, but generally more penetrating than, X-rays. Gamma radiation frequently accompanies alpha and beta emissions and always accompanies fission. Gamma rays are very penetrating and are best stopped or shielded against by dense materials, such as lead or depleted uranium.

graben: A geological structure that is a generally linear block bounded by faults on each side, along which the block has dropped, relative to the sides.

groundwater: Water that exists or flows below the surface (within the zone of saturation).

grout: A mortar or cement mixture that does not contain gravel or other reinforcing aggregate.

half-life: The time during which one-half of the original amount of a radioactive isotope decays or disintegrates into another nuclear form.

halogenate: To treat or cause to combine with a halogen (fluorine, chlorine, bromine, iodine, or astatine).

high efficiency particulate air filter (HEPA): An air filter capable of removing at least 99.97% of the particulate material as small as 0.3 micron from an air stream. (0.3 micron is approximately the size of the particulate material in tobacco smoke.)

hydrostatic: Of or relating to liquids at rest or to the pressures they exert or transmit.

inversion: A condition where temperature increases with height in the atmosphere.

ion-exchange: Process for selectively removing a constituent from a waste stream by reversibly transferring ions between an insoluble solid and the waste stream; the exchange medium (usually a column of resin or soil) can then be washed to collect the waste or taken directly to disposal; for example, a hot water softener.

isopleth: A line drawn on a map through all points having the same numerical value such as population, geographic measurements, or concentration.

isotope: Nuclides with the same atomic number, (i.e., the same chemical element) but with different atomic masses; although chemical properties are the same, radioactive and nuclear properties may be quite different for each isotope of an element.

lacustrine: Of or relating to lakes.

lava: Fluid rock such as that which issues from a volcano; also this rock solidified by cooling.

leach: The process of removal or separation of soluble components from a solid by percolating water or other liquids through the solid.

limestone: A rock composed mainly of calcium carbonate, usually formed by accumulation of organic material such as shells or coral.

lithic: Of or relating to rock.

loess: An unstratified loamy sediment, deposited chiefly by the wind.

man-rem: The radiation dose received by a typical individual, multiplied by the number of individuals in a given population group.

Maximum Permissible Body Burden (MPBB): The maximum permissible amount of a specific radioactive material or the summation of the amounts of various radioactive materials, present in an animal or human body at the time of interest.

Maximum Permissible Concentration (MPC): The average concentration of a radionuclide in air or water to which a worker or member of the general population may be continuously exposed without exceeding an established standard.

Mesozoic: See Table H-1 (Geologic Time Periods) at the end of the glossary.

Miocene: See Table H-1 (Geologic Time Periods) at the end of the glossary.

Modified Mercalli Intensity (MMI): A subjective scale used to estimate the intensity of an earthquake. The scale varies from I to XII. A reading of I indicates an earthquake so slight it was not felt; IV indicates that chandeliers shake; and XII indicates very extensive damage.

module: As used in this report, a specific operation, such as direct-control retrieval, or slagging pyrolysis.

moraine: An accumulation of earth and stones carried and finally deposited by a glacier.

neutron: A particle existing in or emitted from the atomic nucleus. It is electrically neutral and has a mass approximately equal to that of a stable hydrogen atom.

nucleus: The positively charged center of an atom.

nuclide: A species of atom having a specific mass, atomic number, and nuclear energy state.

off-gas: Gas produced by a reaction or by a process.

overburden: Rock or soil of little value overlying a layer with desirable features, and which must be removed before mining can proceed.

overpack: A container into which a smaller container is placed.

oxide: A compound of oxygen and another element or elements.

pahoehoe: A basaltic lava flow characterized by a smooth surface showing ropy folds.

Paleozoic: See Table H-1 (Geologic Time Periods) at the end of the glossary.

particulate: Referring to finely divided particles suspended in a gaseous media.

perched water: Subsurface water located above the aquifer over an impermeable layer that is small relative to the extent of the aquifer.

percolate: To pass through fine interstices; to filter, as water percolates through sand.

permissible dose: That dose of ionizing radiation which, in the light of present knowledge, carries negligible probability of causing severe somatic injury or genetic effect.

physiographic: Pertaining to physical geography.

playa: A flat area that forms the bottom of an undrained basin. Playas are usually found in arid regions, and at times become shallow lakes.

Pleistocene: See Table H-1 (Geologic Time Periods) at the end of the glossary.

Pliocene: See Table H-1 (Geologic Time Periods) at the end of the glossary.

pluvial: Occurring through the action of rain.

poise: A unit of viscosity.

population dose (population exposure): The summation of individual radiation doses received by all those exposed to the source or event being considered.

pressure grout: The process of forcing a cementitious grout mixture into fissures or cracks in rock.

pyroclastic: A general term applied to detrital volcanic materials that have been explosively or aerially ejected from a volcanic vent. Also a general term for the class of rocks made up of these materials.

pyrolysis: Chemical change brought about by heat.

pyrophoric: Igniting spontaneously.

Quaternary: See Table H-1 (Geologic Time Periods) at the end of the glossary.

rad: Abbreviation for Radiation Absorbed Dose, the basic unit of absorbed dose of ionizing radiation. A dose of 1 rad corresponds to the absorption of 100 ergs of radiation energy per gram of tissue.

radiation (ionizing): Particles and electromagnetic energy emitted by nuclear transformations which are capable of producing ions when interacting with matter; gamma rays and alpha and beta particles are primary examples.

radioactive: Unstable in a manner indicated by nuclear disintegration.

radiolysis: Chemical decomposition by the action of radiation.

radionuclide: A radioactive nuclide.

Recent: See Table H-1 (Geologic Time Periods) at the end of the glossary.

rem (abbreviation for Roentgen Equivalent Man.): A unit of measure for the dose of ionizing radiation which gives the same biological effect as one roentgen of X-rays; one rem approximately equals one rad for X, gamma, or beta radiation.

rhyolite: A light colored fine-grained, acidic, volcanic rock, in which feldspar and quartz predominate.

rift zone: A narrow belt of structures and volcanic land forms in which most, if not all, of the eruptions of an area are localized.

riprap: A foundation or retaining wall of stones thrown together without order; also, the stone used for riprap.

roentgen: A unit of exposure of ionizing radiation. It is that amount of gamma or X-rays required to produce ions carrying 1 electrostatic unit of electrical charge in 1 cubic centimeter of dry air under standard conditions.

roughing filter: A relatively coarse filter installed in front of HEPA filters to avoid overloading the HEPA filters.

seismicity: The tendency for the occurrence of an earthquake.

shale: A finely stratified rock formed by the consolidation of clay, mud, or silt.

silicic: Of or relating to silica or silicon.

slag: The glass-like product of a slagging pyrolysis incinerator.

slurry: A watery mixture of insoluble matter.

somatic effects: Effects on the body.

sorb: To take up and hold by either adsorption or adsorption.

steppe: Arid land (usually an extensive plain) with vegetation requiring little moisture, usually found in regions of extreme temperature range and loess soil.

storage: Retention of waste in a manner for which (a) surveillance and human control are provided, and (b) subsequent retrieval is possible.

tectonic: Related to the deformation of the earth's crust and the forces involved in producing such deformations.

thermal neutron: A neutron slowed down by collisions with light atoms (e.g., hydrogen) to the speed of gas molecules at room temperature (about 0.025 eV at 15°C).

thermal neutron flux: The number of thermal neutrons passing through a unit area in unit time. It is a term expressing the intensity of thermal neutron radiation, measured in neutrons/cm²/sec.

thermoluminescent dosimeter: A solid-state dosimeter typically made of lithium fluoride or calcium fluoride. The energy (or radiation) absorbed by the dosimeter is directly proportional to the light of a particular color emitted when the crystal is heated.

transuranic: Generally refers to the elements beyond uranium in the periodic table, i.e., with an atomic number greater than 92. A more detailed definition is given in ERDAM-0511 (ERDA 1973a), indicating which nuclides are included and which are not.

transuranic (TRU) waste: Waste contaminated with transuranic radionuclide. In this document, the term is applied without regard to the level of transuranic contamination. See Footnote (b) in Subsection 1.1 for further detail.

travertine: A type of limestone formed by the deposition of calcium carbonate from spring waters, especially from hot spring waters.

tuff: A fine-grained, pyroclastic rock composed of fragments less than 4 mm in diameter. The fragments are often fused or welded together by heat. Tuff is often quite porous.

water table: The upper boundary of the portion of the ground that is saturated with water.

wind rose: A diagram designed to show the distribution of prevailing wind directions at a given location; some variations include wind speed groupings by direction.

TABLE H-1
GEOLOGIC TIME PERIODS(a)

Eon	Era	System-Period	System-Period Subdivisions	Series-Epoch	Approx. Age (10 ⁶ yr)	
Phanerozoic	Cenozoic	Quaternary		Recent (Holocene)		
				Pleistocene	0.01	
		Tertiary	Neogene	Pliocene	2	
				Miocene	22	
			Paleogene	Oligocene		
				Eocene		
				Paleocene		
					62	
		Mesozoic	Cretaceous			130
			Jurassic			180
	Triassic			230		
	Paleozoic	Permian			280	
		Carboniferous	Pennsylvanian			
			Mississippian		340	
		Devonian			400	
		Silurian			450	
		Ordovician			500	
		Cambrian			570	
Precambrian		Proterozoic			2600	
	Archean			3600		
	No record					

(a) Source: Webster's New Collegiate Dictionary (Woolf et al. 1977).