

ENVIRONMENTAL AND OTHER EVALUATIONS OF ALTERNATIVES FOR LONG-TERM MANAGEMENT OF BURIED INEL TRANSURANIC WASTE

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DEPARTMENT OF ENERGY

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1.0 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) buried 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.

There is also a large quantity of transuranic waste stored in the Transuranic Storage Area (TSA) at the RWMC. For perspective and completeness, the stored waste is described, along with the buried waste, in this document. However, alternatives for managing the stored TRU waste are not listed or evaluated in this document. Management of the stored TRU waste is addressed in detail in a document (DOE 1979b) intended to provide supporting evaluations for the Draft Environmental Impact Statement, Waste Isolation Pilot Plant (DOE 1979a).

Because of similarities with DOE 1979b, several sections of the present document simply refer the reader to corresponding sections of DOE 1979b for

-
- (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) Some of the buried waste is contaminated to levels of less than 10 nanocuries per gram (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.

NOTE: Use of the value of 10 nCi/g to define transuranic waste (ERDA 1973a) is being reviewed and may be revised. The potential effects of such a revision are not addressed in this document.

details. These essentially blank sections are retained to allow use of the same section numbers in the two documents. For sections that differ even slightly from corresponding sections of DOE 1979b, the entire section is included in the present document.

Hereafter, in this document, the term TRU waste refers to the buried waste only, unless the context indicates otherwise.

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 buried 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 U.S. 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 Plant (RFP)], (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 buried TRU waste, an environmental impact statement (EIS) 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.

1.2 BACKGROUND

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

The 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 Plant (RFP) near Golden, Colorado, and from other operations of the AEC and its successor agencies. In addition, a limited amount of waste (predominantly nontransuranic) generated by universities, hospitals, and private research organizations was accepted from 1960 through 1964.

From 1954 until 1970, the TRU-contaminated waste was buried in pits and trenches at the RWMC and was covered with soil. In 1978, an additional cover of highly compacted clay was emplaced 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 some of the pits and trenches with the TRU waste and is estimated to total 500,000 ft³.

The TRU waste received since 1970 has been placed in retrievable above-ground 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. The stored waste is discussed only for background. This document does not develop alternatives for the management of stored waste.

1.3 SCOPE OF THE STUDY

This study identifies and evaluates long-term management alternatives for TRU waste presently buried at the INEL, but does not evaluate alternatives for stored TRU waste.

The study addresses three possibilities with respect to the availability of an offsite geologic repository for the waste: (1) an offsite geologic repository will be available in 1985; (2) an offsite geologic repository will be available, 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) an offsite geologic repository will not be available.

The third possibility, no offsite geologic repository, would require permanent waste disposal at the INEL. However, no waste stored or disposed of at other DOE locations would be shipped to the INEL 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 Section 4, in Subsections 7.2 and 7.3, and in DOE 1979b.) 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 projects most closely linked with this study are the Initial Drum Retrieval and the Early Waste Retrieval projects, described in Subsection 4.4.4.

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 buried INEL TRU waste are described in Sections 8, 9, and 10. Section 12 outlines the environmental effects. Section 13 evaluates the short- and long-term risks for the alternatives. Hazards to waste management workers are addressed briefly in Section 14, and Section 15 examines 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.

2.0 SUMMARY

2.1 BACKGROUND

This study identifies, develops, and evaluates, in a preliminary manner, alternatives for long-term management of the TRU waste that has been buried at the RWMC at the INEL. The technology required for managing the waste, the environmental effects, the risks to the public, the radiological and non-radiological 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 a 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. In 1970, the population living within a 50-mile radius of the RWMC was approximately 117,000. Land uses in the surrounding area (50-mile radius) include urban, industrial, irrigated farming, and dry land farming. In addition, a large 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 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, solid waste contaminated with transuranic radionuclides has been received from defense-related activities at the RFP and from other operations of the AEC 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 ^{238}Pu , ^{239}Pu , ^{240}Pu , ^{241}Pu , ^{242}Pu , and ^{241}Am .

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 buried TRU waste has been retrieved from the pits and trenches, repackaged, 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. Three 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 less than the maximum concentrations allowed by DOE standards for specific radionuclides in water released to an uncontrolled area. These floodwaters, 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 8,200 ft from the RWMC, which is still well within the INEL boundary. The maximum contamination levels found in surface soils (0 to 5 cm) were 2,048 nCi $^{241}\text{Am}/\text{m}^2$, 1,377 nCi $^{239}\text{Pu}/\text{m}^2$, and 32 nCi $^{238}\text{Pu}/\text{m}^2$. These levels were found at the northeastern perimeter of the RWMC.

Subsurface migration of radionuclides from the buried TRU waste is being monitored periodically. Soil samples collected immediately below the waste show migration to a maximum of 5 to 10 ft below the waste-sediment interface.

However, the levels of contamination found had been attenuated to near the detection limit by the time the radionuclides had moved about 2 ft below the waste. Because of the adsorptive properties of the sediments and basalts underlying the RWMC, there is almost no danger of radionuclides migrating downward to the aquifer in significant concentrations if the surface of the RWMC is maintained so as to minimize infiltration of water.

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 ^{238}Pu , ^{239}Pu , and ^{241}Am 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 I through VI, were studied for long-term management of the buried TRU waste. Alternatives for long-term management of the stored TRU waste were addressed in DOE 1979b. 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.

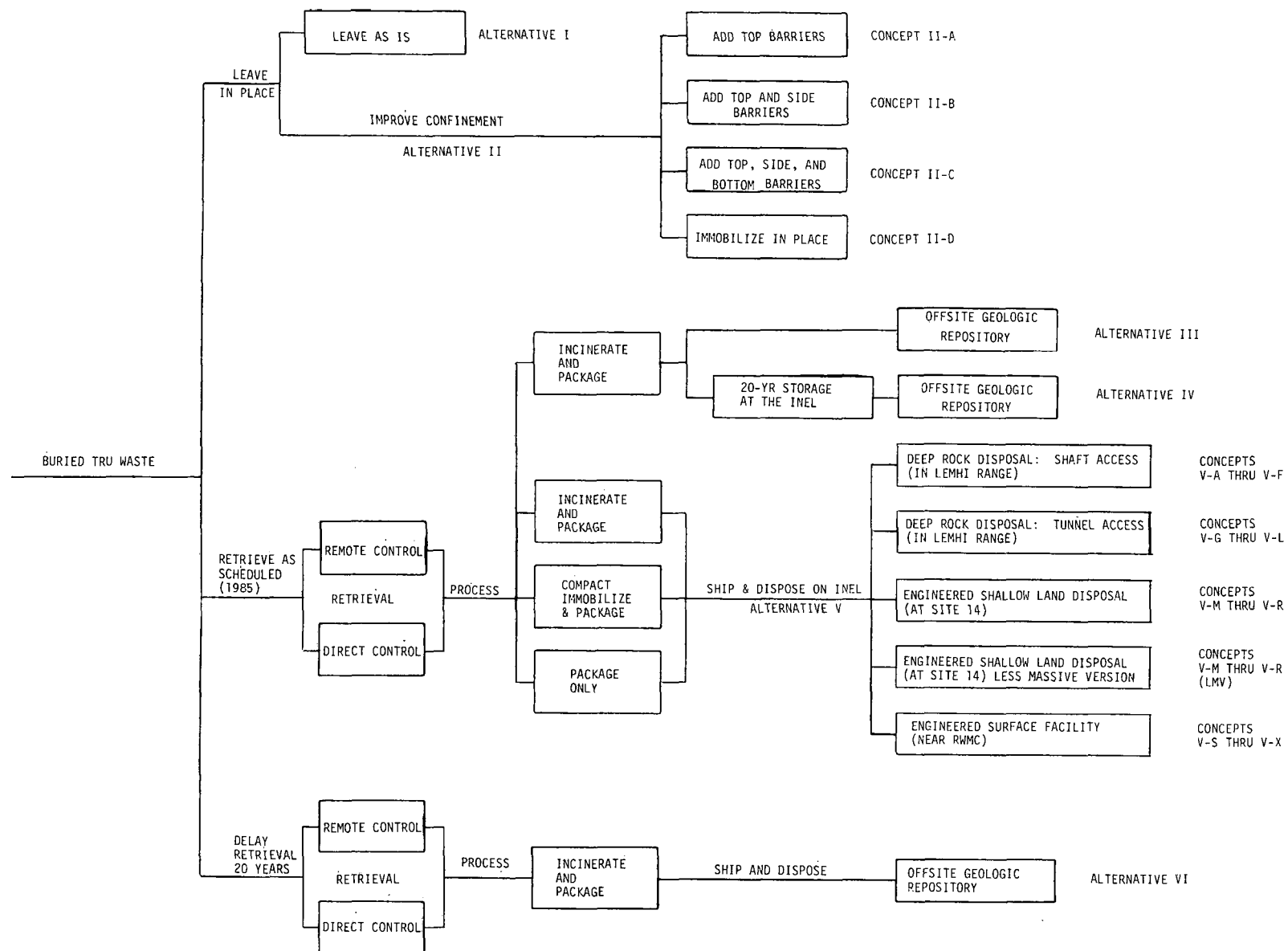


Fig. 2-1. Alternatives and concepts studied for long-term management of buried INEL TRU waste.

TABLE 2-1

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

<u>Alternatives</u>	<u>Concepts</u>	<u>Description</u>
I		<u>Leave As Is</u>
II		<u>Leave In Place With Improved Confinement</u>
	II-A	Improve Confinement--Above
	II-B	Improve Confinement--Above and Around
	II-C	Improve Confinement--Above, Around, and Below
	II-D	Improve Confinement--Immobilization
III		<u>Retrieve As Scheduled, Process, Ship To Offsite Geologic Repository</u>
	III-A	Direct-Control Retrieval, SP ^(a)
	III-B	Remote-Control Retrieval, SP
IV		<u>Retrieve As Scheduled, Process, Store 20 Yr, Ship To Offsite Geologic Repository</u>
	IV-A	Direct-Control Retrieval, SP
	IV-B	Remote-Control Retrieval, SP
V		<u>Retrieve As Scheduled, Process, Deep Rock Disposal - Shaft Access (In Lemhi Range)</u>
	V-A	Direct-Control Retrieval, SP
	V-B	Direct-Control Retrieval, CPT ^(b)
	V-C	Direct-Control Retrieval, PKG ^(c)
	V-D	Remote-Control Retrieval, SP
	V-E	Remote-Control Retrieval, CPT
	V-F	Remote-Control Retrieval, PKG
		<u>Retrieve As Scheduled, Process, Deep Rock Disposal - Tunnel Access (In Lemhi Range)</u>
	V-G	Direct-Control Retrieval, SP
	V-H	Direct-Control Retrieval, CPT
	V-I	Direct-Control Retrieval, PKG
	V-J	Remote-Control Retrieval, SP
	V-K	Remote-Control Retrieval, CPT
	V-L	Remote-Control Retrieval, PKG

TABLE 2-1 (Cont'd)

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

<u>Alternatives</u>	<u>Concepts</u>	<u>Description</u>
		<u>Retrieve As Scheduled, Process, Engineered Shallow Land Disposal (At Site 14)</u>
	V-M (& LMV) ^(d)	Direct-Control Retrieval, SP
	V-N (& LMV)	Direct-Control Retrieval, CPT
	V-O (& LMV)	Direct-Control Retrieval, PKG
	V-P (& LMV)	Remote-Control Retrieval, SP
	V-Q (& LMV)	Remote-Control Retrieval, CPT
	V-R (& LMV)	Remote-Control Retrieval, PKG
		<u>Retrieve As Scheduled, Process, Disposal In Engineered Surface Facility (Near RWMC)</u>
	V-S	Direct-Control Retrieval, SP
	V-T	Direct-Control Retrieval, CPT
	V-U	Direct-Control Retrieval, PKG
	V-V	Remote-Control Retrieval, SP
	V-W	Remote-Control Retrieval, CPT
	V-X	Remote-Control Retrieval, PKG
VI		<u>Delay Retrieval 20 Years, Process, Ship to Offsite Geologic Repository</u>
	VI-A	Direct-Control Retrieval, SP
	VI-B	Remote-Control Retrieval, SP

(a) SP - slagging pyrolysis and packaging.

(b) CPT - compaction, immobilization, and packaging.

(c) PKG - packaging only.

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

The six major alternatives derive from three different premises: (1) an offsite geologic repository will be available as scheduled, assumed for this study to be in 1985; (2) an offsite geologic repository will be available in the year 2005, and (3) an offsite geologic 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 III falls into the first category; Alternatives IV and VI, the second. The third possibility would necessitate alternatives such as I, II, and V.

In Alternative I, the TRU waste would be left in place as is. The present cover of soil and compacted clay 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.

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

In Alternative III, 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 an offsite geologic repository. Each of these operations (retrieval, processing, and shipment) was evaluated as a separate module. The combination of the three modules constitutes Alternative III.

In Alternative IV, 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 a (delayed) offsite geologic repository in 2005.

In Alternative V, 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 V differ in the type of retrieval, the type of processing, and in the method and location of disposal. Retrieval modules studied were (1) direct control, and (2) remote control. Processing operations, or modules, studied were the following: (1) slagging pyrolysis and packaging; (2) compaction, immobilization, and packaging; and (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); and (4) disposal in an engineered surface facility near the RWMC.

In Alternative VI, retrieval would be delayed for 20 yr (to the year 2005). Processing would involve slagging pyrolysis and packaging in a 10-yr period. The TRU waste would then be shipped to an offsite geologic repository. Except for the 20-yr delay in retrieval, this alternative is identical to Alternative III.

2.6 ENVIRONMENTAL EFFECTS OF ALTERNATIVES

For each alternative and concept, the potential radiological and non-radiological 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 or expected to be near the allowable limits.

TABLE 2-2
SUMMARY OF QUANTITATIVE NONRADIOLOGICAL IMPACTS
(CONSTRUCTION PHASE)

Concept ^(a)	Usage (10 ³ yd ³)		Particulate Emissions ^(c) (10 ³ lbs)	Labor ^(d) (man- years)	Diesel Fuel Usage (10 ³ gal)
	Clay ^(b)	Concrete			
I	0	0	0	0	0
II-A	680	0	79	140	720
II-B	700	0	87	140	790
II-C	700	58 ^(e)	100	440	940
II-D	0	160 ^(e)	32	180	290
III-A, III-B	0	3.6 ^(f)	97	1000	880
IV-A, IV-B	0	14	110	1050	970
V-A, V-D	0	6.0	140	1100	1300
V-B, V-E	0	4.4	130	750	1200
V-C, V-F	0	4.4	150	690	1400

V-G, V-J	0	9.0	140	1100	1200
V-H, V-K	0	7.4	130	730	1200
V-I, V-L	0	7.4	140	670	1300

V-M, V-P	1200	1500	110	1000	990
LMV ^(g)	360	30	100	1000	960
V-N, V-Q	1600	1600	72	640	650
LMV	760	63	67	620	610
V-O, V-R	3800	3300	72	570	650
LMV	1200	100	60	510	550

V-S, V-V	270	860	110	1000	980
V-T, V-W	410	1300	74	630	680
V-U, V-X	890	2800	84	560	770
VI-A, VI-B	0	3.6 ^(f)	97	1000	880
See Tables	12-6	12-6	12-2	12-1	12-1

(a) Concept descriptions appear in Table 7-3.

(b) Includes bentonite.

(c) From diesel-powered construction equipment.

(d) Certain concepts were grouped together for simplification. To accomplish this, the average number of construction workers for direct-control retrieval was assumed to be the same as for remote-control retrieval; i.e., 220.

(e) Includes grout.

(f) Includes concrete required for SP facility construction.

(g) LMV refers to less massive variation of the engineered shallow land disposal facility at Site 14.

TABLE 2-3
SUMMARY OF QUANTITATIVE NONRADIOLOGICAL IMPACTS
(OPERATIONS PHASE)

Concept ^(a)	Particulate Emissions ^(b) (10 ³ lb/yr)	Land Usage ^(d) (acres)	Employment ^(c)		Energy Used	
			Jobs	(10 ⁶ \$/yr) ^(c)	Diesel (10 ³ gal/yr)	Electric (10 ⁶ kWh/yr)
I	0	0 ^(d)	10 ^(e)	0.17	0	0
II-A, II-B						
II-C, II-D	0	44 ^(d)	10 ^(e)	0.17	0	0
III-A, III-B	31	2.5	550	9.9	280	50 ^(f)
IV-A, IV-B	41	10.0	590	10.7	380	51 ^(f)
V-A, V-D	64	210	660	11.9	580	57 ^(f)
V-B, V-E	64	220	430	7.5	580	32 ^(f)
V-C, V-F	88	230	400	6.9	800	29 ^(f)
V-G, V-J	60	220	630	11.4	550	55 ^(f)
V-H, V-K	60	220	400	7.0	550	29 ^(f)
V-I, V-L	81	230	370	6.3	740	23 ^(f)
V-M, V-P	40	540	600	10.8	360	51 ^(f)
LMV ^(g)	35	240	570	10.3	320	51 ^(f)
V-N, V-Q	40	720	380	6.7	370	22 ^(f)
LMV	36	360	360	6.2	320	22 ^(f)
V-O, V-R	46	1500	360	6.3	420	13 ^(f)
LMV	40	480	340	5.8	370	13 ^(f)
V-S, V-V	52	110	610	11.0	480	51 ^(f)
V-T, V-W	53	150	370	6.4	480	22 ^(f)
V-U, V-X	56	320	370	6.4	500	12 ^(f)
VI-A, VI-B	31	2.5	550	9.9	280	50 ^(f)
See Tables	12-7	12-3	12-9	12-9	12-9	12-9

(a) Concept descriptions appear in Table 7-3.

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

(c) 1979 rates, weighted according to estimated skills used: \$18,400/yr for SP processing; \$17,800/yr for CPT processing; \$17,300/yr for all others.

(d) Alternative I and Concept II-D would involve no incremental land usage beyond area in the RWMC currently in use.

(e) Employment is for monitoring personnel only and continues for 100 yr.

(f) For remote control of retrieval facility: add 1 x 10⁶ kWh/yr.

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

For all alternatives and concepts except Alternative I, 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 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. Construction activities would utilize the best available management practices to minimize these potential adverse impacts.

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 an estimated 1,452 acres, or about 0.25% 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 processing 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 9,400 people. By comparison, for the worst-case alternative, the peak direct employment during construction of waste management facilities would be 1,070 people. During the operational phase, direct employment for the worst case alternative would be an estimated 664 people. Idaho Falls would be the major city impacted by the 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 before 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

(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.

fraction of the natural background dose. The whole-body dose from natural background radiation in southeastern Idaho is about 150 mrem/yr (ERDA 1977c). For any of the alternatives or concepts, the maximum whole-body dose commitment to an individual, resulting from 1 yr of normal operation, was conservatively calculated to be 3 mrem (see Table 2-4). The projected dose commitments to the population living within 50 miles are summarized in Table 2-5.

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), future intrusion by individuals or small populations, 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, generally the organ of maximum dose, are presented. In all instances, the scenario of greatest importance, in terms of population risk, is lava flow over the waste, leading to possible airborne release of a fraction of the radionuclides present. (Even for Alternatives III through VI, involving retrieval of the waste, the lava flow scenario is predominant because of the possibility of lava flow disrupting

TABLE 2-4

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
I	None	None	None	None	None
II	None	None	None	None	None
III, IV, V-A, -D, -G, -J, -M ^(a) , -P ^(a) , -S, -V	$3.0 \times 10^{0(b)}$	4.6×10^{-3}	4.6×10^{-3}	3.4×10^{-3}	1.7×10^{-3}
V-B, -C, -E, -F, -H, -I, -K, -L, -N ^(a) , -O ^(a) , -Q ^(a) , R ^(a) , -T, -U, -W, -X	3.0×10^{-4}	2.6×10^{-4}	2.7×10^{-4}	2.0×10^{-4}	9.9×10^{-5}
VI	7.3×10^{-1}	4.4×10^{-3}	4.4×10^{-3}	3.3×10^{-3}	1.7×10^{-3}

(a) Values would be unchanged for the less massive variation of the engineered shallow land disposal facility at Site 14.

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

TABLE 2-5

LIFETIME LOCAL 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
I	None	None	None	None	None
II	None	None	None	None	None
III, IV; V-A, -D, -G, -J, -M ^(a) , -p ^(a) , -S, -V	2.4×10^1	3.7×10^{-2}	3.7×10^{-2}	2.6×10^{-2}	1.4×10^{-2}
V-B, -C, -E, -F, -H, -I, -K, -L, -N ^(a) , -O ^(a) , -Q ^(a) , -R ^(a) , -T, -U, -W, -X	2.4×10^{-3}	2.0×10^{-3}	2.2×10^{-3}	1.6×10^{-3}	8.0×10^{-4}
VI	7.1×10^0	4.3×10^{-2}	4.3×10^{-2}	3.1×10^{-2}	1.7×10^{-2}

(a) Values would be unchanged for the less massive variation of the engineered shallow land disposal facility at Site 14.

TABLE 2-6
SUMMARY OF EFFECTS FROM SHORT-TERM RELEASE SCENARIOS (a-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)
I	3×10^1	2×10^{-3}	5×10^4	3×10^0
II-A(e)	6×10^{-1}	2×10^{-5}	1×10^3	3×10^{-2}
II-B(e)	6×10^{-1}	2×10^{-5}	1×10^3	3×10^{-2}
II-C(e)	6×10^{-1}	2×10^{-5}	1×10^3	3×10^{-2}
II-D	3×10^{-1}	2×10^{-5}	5×10^2	3×10^{-2}
III-A, III-B	2×10^{-3}	3×10^{-9}	3×10^0	4×10^{-6}
IV-A, IV-B	2×10^{-3}	3×10^{-9}	3×10^0	4×10^{-6}
V-A, V-D, V-G, V-J	2×10^{-3}	3×10^{-9}	3×10^0	4×10^{-6}
V-B, V-E, V-H, V-K	2×10^{-3}	2×10^{-9}	3×10^0	3×10^{-6}
V-C, V-F, V-I, V-L	2×10^{-3}	2×10^{-9}	3×10^0	4×10^{-6}
V-M(f), V-P(f)	2×10^{-3}	3×10^{-9}	3×10^0	4×10^{-6}
V-N(f), V-Q(f)	2×10^{-3}	2×10^{-9}	3×10^0	3×10^{-6}
V-O(f), V-R(f)	2×10^{-3}	2×10^{-9}	3×10^0	4×10^{-6}
V-S, V-V	2×10^{-3}	3×10^{-9}	3×10^0	4×10^{-6}
V-T, V-W	2×10^{-3}	2×10^{-9}	3×10^0	3×10^{-6}
V-U, V-X	2×10^{-3}	2×10^{-9}	3×10^0	4×10^{-6}
VI-A, VI-B	2×10^{-3}	3×10^{-9}	3×10^0	4×10^{-6}
Natural background radiation(a)		180×10^{-3}		24×10^3

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

(b) Short-term accidents include release scenarios occurring less than 100 yr into the future for Alternatives I and II. For Alternatives III through VI, entries include only campaign-related events. Entries do not include possible releases due to volcanic activity that would disrupt waste still unretrieved during the retrieval campaign (10-yr period), the 20-yr storage, or the retrieval delay period of Alternative VI. Inclusion of such events would cause entries to be similar to those for Alternative I for that time period. For Alternative V, only releases occurring before or during emplacement (10-yr period) are included. Maximum dose and total risk for Alternative III through VI are dominated by possible releases due to a destructive tornado during the retrieval campaign.

(c) Effects of possible releases occurring at an offsite geologic repository are not included for Alternatives III, IV, and VI, because these effects are being evaluated in other DOE projects.

(d) See Subsections 7.4.1 and 13.2 for 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 I and Concept II-D.

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

waste that would not yet have been retrieved. For simplicity, however, the short-term lava flow scenario for Alternatives III through VI has been deleted from the table.) The operational scenarios (Alternatives III through VI) of greatest importance, in terms of population risk, are (1) a criticality in the slagging pyrolysis facility, (2) a waste transfer accident involving fire, and (3) a tornado during waste retrieval. The population risk from even the dominant scenario (3 man-rem/yr) would be small compared with the risk based on lung dose from natural background radiation to the same population (24,000 man-rem/yr).

A summary of projected effects from long-term (100 yr or greater) 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 1×10^5 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 0 and 100 yr is due to the assumed population growth during the first 100 yr. Also indicated is the level of natural background radiation, the population dose that is certain to accrue each year. 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 small.

TABLE 2-7

SUMMARY OF CONSEQUENCES FROM LONG-TERM RELEASE SCENARIOS^(a)

Alternative/ Concept	Population Dose (man-rem) for Specified Time after 1985 (yr)								
	100		400		2,000		25,000		
	0	BCF ^(b)	ACF ^(c)	BCF	ACF	BCF	ACF	BCF	ACF
I	5 x 10 ^{4(d)}	1 x 10 ^{5(d)}		1 x 10 ^{5(d)}		5 x 10 ^{4(d)}		4 x 10 ²	
II-A	1 x 10 ³	2 x 10 ³	1 x 10 ^{5(d)}	1 x 10 ^{5(d)}		5 x 10 ^{4(d)}		4 x 10 ²	
II-B	1 x 10 ³	2 x 10 ³	1 x 10 ^{5(d)}	1 x 10 ^{5(d)}		5 x 10 ^{4(d)}		4 x 10 ²	
II-C	1 x 10 ³	2 x 10 ³	1 x 10 ^{5(d)}	1 x 10 ^{5(d)}		5 x 10 ^{4(d)}		4 x 10 ²	
II-D	5 x 10 ^{2(d)}	1 x 10 ^{3(d)}		1 x 10 ^{3(d)}	1 x 10 ^{5(d)}	5 x 10 ^{4(d)}		4 x 10 ²	
III-A, III-B	No long-term management of buried TRU waste at the INEL. ^(e)								
IV-A, IV-B	No long-term management of buried TRU waste at the INEL. ^(e)								
V-A through V-L (Lemhi Range)	1 x 10 ¹	2 x 10 ¹		2 x 10 ¹		1 x 10 ¹		4 x 10 ⁰	
V-M through V-R (Site 14) ^(f)	4 x 10 ⁰	7 x 10 ⁰		7 x 10 ⁰		4 x 10 ⁰		1 x 10 ⁰	1 x 10 ²
V-M through V-R (LMV) ^(f,g)	1 x 10 ¹	2 x 10 ¹		2 x 10 ¹		1 x 10 ¹	1 x 10 ³	4 x 10 ²	
V-S through V-X (RWMC) ^(f)	1 x 10 ¹	2 x 10 ¹		2 x 10 ¹		1 x 10 ¹		4 x 10 ⁰	4 x 10 ²
VI-A, VI-B	No long-term management of buried TRU waste at the INEL. ^(e)								

(a) All entries are the calculated values of population dose to the lung for the dominant release scenario.

(b) BCF = before confinement failure.

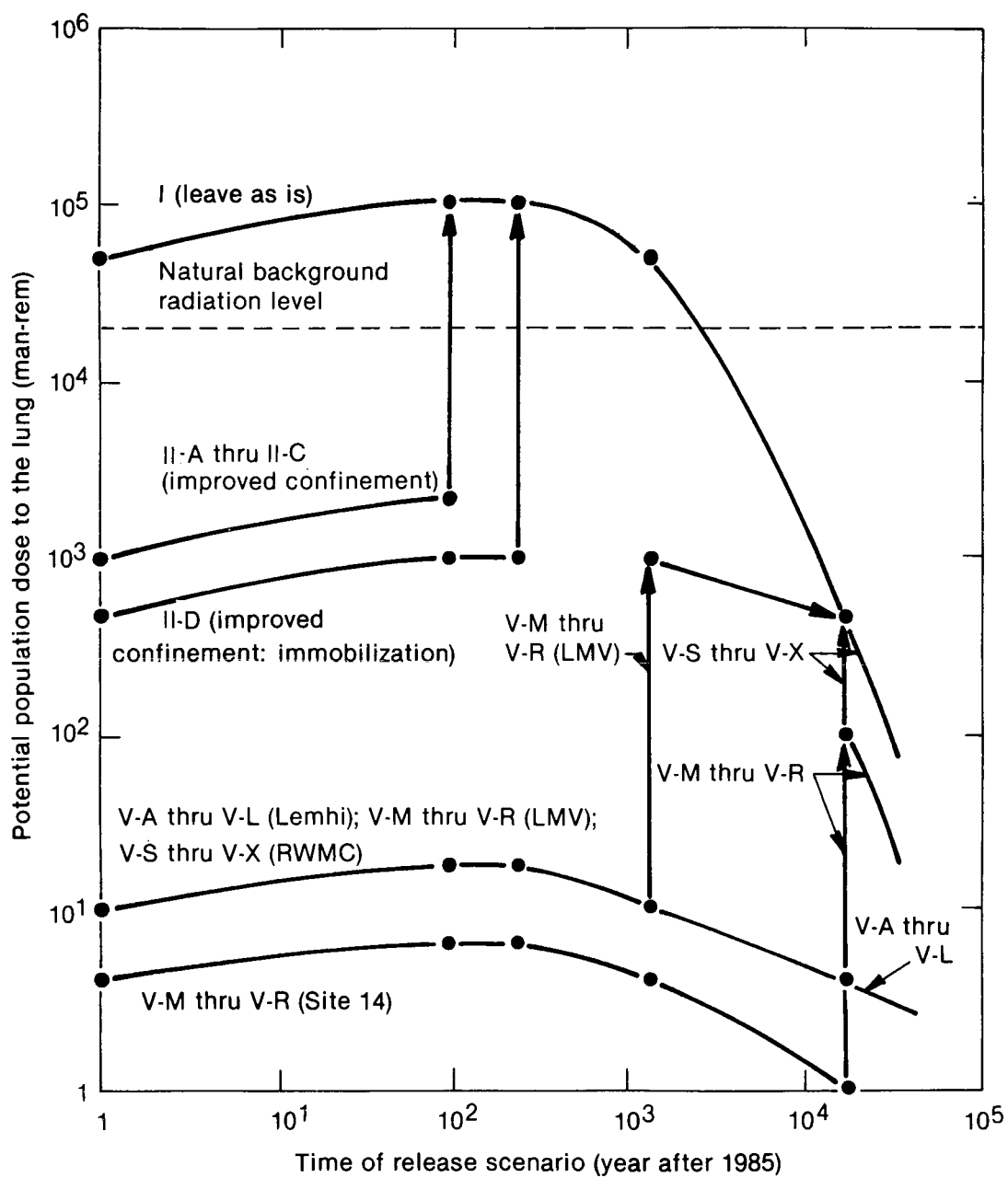
(c) ACF = after confinement failure.

(d) Lava flow is the dominant release scenario. For all other entries, explosive volcanic eruption is the dominant release scenario.

(e) Long-term effects of disposal of TRU waste at an offsite geologic repository are being evaluated in other DOE-sponsored studies.

(f) Resistance to explosive volcanic eruption assumed to be a factor of 100 better before containment failure than after containment failure.

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



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

Based on the maximum dose to an individual, the dominant long-term events are various scenarios of future intrusion of individuals and small groups on the waste site. The maximum individual doses were projected to be 100 rem to the bone and 100 rem to the lung. These doses would be received over a 50-yr period.

The train crews involved in shipping the waste to an offsite geologic repository would comprise approximately 90 people. These people would receive a population dose of about 6.7 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 1.6 man-rem/yr.

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 1 yr of the exposure) would be expected. Long-term effects (typically occurring several years after exposure) could occur. Over a period of one million years, about four such effects might occur due to radiation exposures from nature-caused releases of radionuclides. However, such effects, both somatic and genetic, would be expected to occur at a frequency about 10^8 times smaller, in the worst case, than the normal rate of occurrence of such effects.

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 III through VI). 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.

TABLE 2-8

PROJECTED NONRADIOLOGICAL INJURIES AND FATALITIES TO WASTE MANAGEMENT WORKERS (BURIED WASTE)

Alternative or Concept	Manpower Commitment in Various ^(a) Activities (10 ⁶ man-hours)					Estimated Number of Injuries					Estimated Number of Fatalities ^(b)				
	Construction	Retrieval	Processing	Disposal/Storage	Surveillance	Construction	Retrieval	Processing	Disposal/Storage	Surveillance	Construction	Retrieval	Processing	Disposal/Storage	Surveillance
	NA ^(c)	NA	NA	NA	2.08(1)	NA	NA	NA	NA	4.31	NA	NA	NA	NA	0.0
I	NA ^(c)	NA	NA	NA	2.08(1)	NA	NA	NA	NA	4.31	NA	NA	NA	NA	0.0
II-A	0.29(6)	NA	NA	NA	2.08(1)	4.25	NA	NA	NA	4.31	0.05	NA	NA	NA	0.0
II-B	0.29(6)	NA	NA	NA	2.08(1)	4.25	NA	NA	NA	4.31	0.05	NA	NA	NA	0.0
II-C	0.91(6)	NA	NA	NA	2.08(1)	13.34	NA	NA	NA	4.31	0.15	NA	NA	NA	0.0
II-D	0.37(6)	NA	NA	NA	2.08(1)	5.42	NA	NA	NA	4.31	0.06	NA	NA	NA	0.0
III-A	2.04(6)	3.24(3)	8.11(7)	NI ^(d)	NA	29.91	31.59	147.68	NI	NA	0.35	0.42	0.81	NI	NA
III-B	2.07(6)	3.24(1)	8.11(7)	NI	NA	30.35	6.71	147.68	NI	NA	0.35	0.0	0.81	NI	NA
IV-A	2.15(6)	3.24(3)	8.11(7)	1.00(4)+NI	0.21(1)	31.52	31.59	147.68	10.15+NI	0.43	0.37	0.42	0.81	0.0+NI	0.0
IV-B	2.18(6)	3.24(1)	8.11(7)	1.00(4)+NI	0.21(1)	31.96	6.71	147.68	10.15+NI	0.43	0.37	0.0	0.81	0.0+NI	0.0
V-A	2.23(6)	3.24(3)	8.11(7)	2.45(8)	2.08(1)	32.69	31.59	147.68	61.89	4.31	0.38	0.42	0.81	1.30	0.0
V-B	1.52(6)	3.24(3)	3.33(5)	2.37(8)	2.08(1)	22.28	31.59	39.30	59.87	4.31	0.26	0.42	0.20	1.26	0.0
V-C	1.41(6)	3.24(3)	2.66(4)	2.37(8)	2.08(1)	20.67	31.59	27.00	59.87	4.31	0.24	0.42	0.0	1.26	0.0
V-D	2.26(6)	3.24(1)	8.11(7)	2.45(8)	2.08(1)	33.13	6.71	147.68	61.89	4.31	0.38	0.0	0.81	1.30	0.0
V-E	1.55(6)	3.24(1)	3.33(5)	2.37(8)	2.08(1)	22.72	6.71	39.30	59.87	4.31	0.26	0.0	0.20	1.26	0.0
V-F	1.44(6)	3.24(1)	2.66(4)	2.37(8)	2.08(1)	21.11	6.71	27.00	59.87	4.31	0.24	0.0	0.0	1.26	0.0
V-G	2.22(6)	3.24(3)	8.11(7)	1.79(8)	2.08(1)	32.55	31.59	147.68	45.22	4.31	0.38	0.42	0.81	0.95	0.0
V-H	1.49(6)	3.24(3)	3.33(5)	1.71(8)	2.08(1)	21.84	31.59	39.30	43.19	4.31	0.25	0.42	0.20	0.91	0.0
V-I	1.36(6)	3.24(3)	2.66(4)	1.71(8)	2.08(1)	19.94	31.59	27.00	43.19	4.31	0.23	0.42	0.0	0.91	0.0
V-J	2.25(6)	3.24(1)	8.11(7)	1.79(8)	2.08(1)	32.99	6.71	147.68	45.22	4.31	0.38	0.0	0.81	0.95	0.0
V-K	1.52(6)	3.24(1)	3.33(5)	1.71(8)	2.08(1)	22.28	6.71	39.30	43.19	4.31	0.26	0.0	0.20	0.91	0.0
V-L	1.39(6)	3.24(1)	2.66(4)	1.71(8)	2.08(1)	20.38	6.71	27.00	43.19	4.31	0.24	0.0	0.0	0.91	0.0
V-M	2.13(6)	3.24(3)	8.11(7)	1.12(3)	2.08(1)	31.23	31.59	147.68	10.92	4.31	0.36	0.42	0.81	0.15	0.0
LMV ^(e)	2.09(6)	3.24(3)	8.11(7)	0.52(3)	2.08(1)	30.64	31.59	147.68	5.07	4.31	0.36	0.42	0.81	0.07	0.0
V-N	1.29(6)	3.24(3)	3.33(5)	1.37(3)	2.08(1)	18.91	31.59	39.30	13.36	4.31	0.22	0.42	0.20	0.18	0.0
LMV	1.25(6)	3.24(3)	3.33(5)	0.83(3)	2.08(1)	18.33	31.59	39.30	8.09	4.31	0.21	0.42	0.20	0.11	0.0
V-O	1.15(6)	3.24(3)	2.66(4)	1.64(3)	2.08(1)	16.86	31.59	27.00	15.99	4.31	0.20	0.42	0.0	0.21	0.0
LMV	1.04(6)	3.24(3)	2.66(4)	1.12(3)	2.08(1)	15.25	31.59	27.00	10.92	4.31	0.18	0.42	0.0	0.15	0.0
V-P	2.16(6)	3.24(1)	8.11(7)	1.12(3)	2.08(1)	31.67	6.71	147.68	10.92	4.31	0.37	0.0	0.81	0.15	0.0
LMV	2.12(6)	3.24(1)	8.11(7)	0.52(3)	2.08(1)	31.08	6.71	147.68	5.07	4.31	0.36	0.0	0.81	0.07	0.0
V-Q	1.32(6)	3.24(1)	3.33(5)	1.37(3)	2.08(1)	19.35	6.71	39.30	13.36	4.31	0.22	0.0	0.20	0.18	0.0
LMV	1.28(6)	3.24(1)	3.33(5)	0.83(3)	2.08(1)	18.76	6.71	39.30	8.09	4.31	0.22	0.0	0.20	0.11	0.0
V-R	1.18(6)	3.24(1)	2.66(4)	1.64(3)	2.08(1)	17.30	6.71	27.00	15.99	4.31	0.20	0.0	0.0	0.21	0.0
LMV	1.07(6)	3.24(1)	2.66(4)	1.12(3)	2.08(1)	15.69	6.71	27.00	10.92	4.31	0.18	0.0	0.0	0.15	0.0
V-S	2.10(6)	3.24(3)	8.11(7)	1.37(4)	2.08(1)	30.79	31.59	147.68	13.91	4.31	0.36	0.42	0.81	0.0	0.0
V-T	1.27(6)	3.24(3)	3.33(5)	1.04(4)	2.08(1)	18.62	31.59	39.30	10.56	4.31	0.22	0.42	0.20	0.0	0.0
V-U	1.13(6)	3.24(3)	2.66(4)	1.77(4)	2.08(1)	16.57	31.59	27.00	17.97	4.31	0.19	0.42	0.0	0.0	0.0
V-V	2.13(6)	3.24(1)	8.11(7)	1.37(4)	2.08(1)	31.23	6.71	147.68	13.91	4.31	0.36	0.0	0.81	0.0	0.0
V-W	1.30(6)	3.24(1)	3.33(5)	1.04(4)	2.08(1)	19.06	6.71	39.30	10.56	4.31	0.22	0.0	0.20	0.0	0.0
V-X	1.16(6)	3.24(1)	2.66(4)	1.77(4)	2.08(1)	17.01	6.71	27.00	17.97	4.31	0.20	0.0	0.0	0.0	0.0
VI-A	2.04(6)	3.24(3)	8.11(7)	NI	0.42(1)	29.91	31.59	147.68	NI	0.87	0.35	0.42	0.81	NI	0.0
VI-B	2.07(6)	3.24(1)	8.11(7)	NI	0.42(1)	30.35	6.71	147.68	NI	0.87	0.35	0.0	0.81	NI	0.0

TABLE 2-8 (Cont'd)
PROJECTED NONRADIOLOGICAL INJURIES AND FATALITIES TO WASTE MANAGEMENT WORKERS (BURIED WASTE)

Alternative or Concept	Hazards of Truck Shipment				Hazards of Rail Shipment				Totals for All Accidents	
	Truck Miles ^(f)	Accidents	Injuries	Fatalities	Car Miles	Accidents	Injuries	Fatalities	Injuries	Fatalities
I	NA	NA	NA	NA	NA	NA	NA	NA	4	0.0
II-A	NA	NA	NA	NA	NA	NA	NA	NA	9	0.1
II-B	NA	NA	NA	NA	NA	NA	NA	NA	9	0.1
II-C	NA	NA	NA	NA	NA	NA	NA	NA	18	0.2
II-D	NA	NA	NA	NA	NA	NA	NA	NA	10	0.1
III-A	2.8x10 ⁴	0.048	0.024	0.001	12.15x10 ⁶	1.7	4.59	0.34	214+NI	1.9+NI
III-B	2.8x10 ⁴	0.048	0.024	0.001	12.15x10 ⁶	1.7	4.59	0.34	189+NI	1.5+NI
IV-A	3.1x10 ⁴	0.053	0.027	0.002	12.15x10 ⁶	1.7	4.59	0.34	226+NI	1.9+NI
IV-B	3.1x10 ⁴	0.053	0.027	0.002	12.15x10 ⁶	1.7	4.59	0.34	202+NI	1.5+NI
V-A	4.13x10 ⁵	0.70	0.36	0.02	NA	NA	NA	NA	279	2.9
V-B	5.72x10 ⁵	0.97	0.49	0.03	NA	NA	NA	NA	158	2.2
V-C	4.67x10 ⁵	0.79	0.40	0.02	NA	NA	NA	NA	144	1.9
V-D	4.13x10 ⁵	0.70	0.36	0.02	NA	NA	NA	NA	254	2.5
V-E	5.72x10 ⁵	0.97	0.49	0.03	NA	NA	NA	NA	133	1.8
V-F	4.67x10 ⁵	0.79	0.40	0.02	NA	NA	NA	NA	119	1.5
V-G	4.13x10 ⁵	0.70	0.36	0.02	NA	NA	NA	NA	262	2.6
V-H	5.72x10 ⁵	0.97	0.49	0.03	NA	NA	NA	NA	141	1.8
V-I	4.67x10 ⁵	0.79	0.40	0.02	NA	NA	NA	NA	126	1.6
V-J	4.13x10 ⁵	0.70	0.36	0.02	NA	NA	NA	NA	237	2.2
V-K	5.72x10 ⁵	0.97	0.49	0.03	NA	NA	NA	NA	116	1.4
V-L	4.67x10 ⁵	0.79	0.40	0.02	NA	NA	NA	NA	102	1.2
V-M	2.84x10 ⁵	0.48	0.24	0.01	NA	NA	NA	NA	226	1.8
LMV ^(e)	2.84x10 ⁵	0.48	0.24	0.01	NA	NA	NA	NA	220	1.7
V-N	3.91x10 ⁵	0.66	0.34	0.02	NA	NA	NA	NA	108	1.0
LMV	3.91x10 ⁵	0.66	0.34	0.02	NA	NA	NA	NA	102	1.0
V-O	3.21x10 ⁵	0.55	0.28	0.02	NA	NA	NA	NA	96	0.9
LMV	3.21x10 ⁵	0.55	0.28	0.02	NA	NA	NA	NA	89	0.8
V-P	2.84x10 ⁵	0.48	0.24	0.01	NA	NA	NA	NA	202	1.3
LMV	2.84x10 ⁵	0.48	0.24	0.01	NA	NA	NA	NA	195	1.3
V-Q	3.91x10 ⁵	0.66	0.34	0.02	NA	NA	NA	NA	83	0.6
LMV	3.91x10 ⁵	0.66	0.34	0.02	NA	NA	NA	NA	78	0.6
V-R	3.21x10 ⁵	0.55	0.28	0.02	NA	NA	NA	NA	72	0.4
LMV	3.21x10 ⁵	0.55	0.28	0.02	NA	NA	NA	NA	65	0.4
V-S	3.1x10 ⁴	0.053	0.027	0.002	NA	NA	NA	NA	228	1.6
V-T	3.3x10 ⁴	0.056	0.029	0.002	NA	NA	NA	NA	104	0.8
V-U	3.2x10 ⁴	0.054	0.027	0.002	NA	NA	NA	NA	97	0.6
V-V	3.1x10 ⁴	0.053	0.027	0.002	NA	NA	NA	NA	204	1.2
V-W	3.3x10 ⁴	0.056	0.028	0.002	NA	NA	NA	NA	80	0.4
V-X	3.2x10 ⁴	0.054	0.027	0.002	NA	NA	NA	NA	73	0.2
VI-A	2.8x10 ⁴	0.048	0.024	0.001	12.15x10 ⁶	1.7	4.59	0.34	215+NI	1.9+NI
VI-B	2.8x10 ⁴	0.048	0.024	0.001	12.15x10 ⁶	1.7	4.59	0.34	190+NI	1.5+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. Injuries include fatalities.

(c) NA = not applicable.

(d) NI = not Included (relates to operations at an offsite geologic repository).

(e) LMV = use of the less massive variation of engineered shallow land disposal at Site 14.

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

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 workers in operations for direct-control retrieval of the waste. 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 are summarized in Table 2-10. All estimates are based on July 1979 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 research and development, site characterization, new utilities outside the "5-ft line," and escalation to the projected date of construction, are not included. Where applicable, the costs of shipping the waste to an offsite geologic repository (or to any other disposal site studied) and of long-term management of the waste at an offsite geologic repository are included. The latter cost was assumed to be applied as a one-time acceptance cost on receipt of the waste at an offsite geologic 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

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 ^(c)
	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)	
I	N/A ^(d)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	10	12	12
II-A	N/A	N/A	N/A	N/A	N/A	N/A	70 ^(e)	7	10	12	20
II-B	N/A	N/A	N/A	N/A	N/A	N/A	70 ^(e)	7	10	12	20
II-C	N/A	N/A	N/A	N/A	N/A	N/A	220 ^(e)	22	10	12	34
II-D	N/A	N/A	N/A	N/A	N/A	N/A	90 ^(e)	9	10	12	22
III-A	156	585	390	449	2	<1 ^(f)	NI ^(g)	NI	N/A	N/A	1035+NI
III-B	156	87	390	449	2	<1	NI	NI	N/A	N/A	537+NI
IV-A	156	585	390	449	2	<1	48+NI	180+NI	10	1.2	1216+NI
IV-B	156	87	390	449	2	<1	48+NI	180+NI	10	1.2	718+NI
V-A	156	585	390	449	6	65	118	443	10	12	1555
V-B	156	585	160	184	4	91	114	428	10	12	1301
V-C	156	585	128	147	4	74	114	428	10	12	1247
V-D	156	87	390	449	6	65	118	443	10	12	1057
V-E	156	87	160	184	4	91	114	428	10	12	803
V-F	156	87	128	147	4	74	114	428	10	12	749
V-G	156	585	390	449	6	65	86	323	10	12	1435
V-H	156	585	160	184	4	91	82	308	10	12	1181
V-I	156	585	128	147	4	74	82	308	10	12	1127
V-J	156	87	390	449	6	65	86	323	10	12	937
V-K	156	87	160	184	4	91	82	308	10	12	683
V-L	156	87	128	147	4	74	82	308	10	12	629
V-M	156	585	390	449	4	44	54	203	10	12	1294
LMV ^(h)	156	585	390	449	4	44	25	94	10	12	1185
V-N	156	585	160	184	4	61	66	248	10	12	1091
LMV	156	585	160	184	4	61	40	150	10	12	993
V-O	156	585	128	147	4	50	79	296	10	12	1091
LMV	156	585	128	147	4	50	54	203	10	12	998
V-P	156	87	390	449	4	44	54	203	10	12	796
LMV	156	87	390	449	4	44	25	94	10	12	687
V-Q	156	87	160	184	4	61	66	248	10	12	593
LMV	156	87	160	184	4	61	40	150	10	12	495
V-R	156	87	128	147	4	50	79	296	10	12	593
LMV	156	87	128	147	4	50	54	203	10	12	500
V-S	156	585	390	449	2	<1	66	248	10	12	1296
V-T	156	585	160	184	2	1	50	188	10	12	971
V-U	156	585	128	147	2	1	85	319	10	12	1065
V-V	156	87	390	449	2	<1	66	248	10	12	798
V-W	156	87	160	184	2	1	50	188	10	12	473
V-X	156	87	128	147	2	1	85	319	10	12	567
VI-A	156	195	390	148	2	<1	NI	NI	10	2.5	347+NI
VI-B	156	30	390	148	2	<1	NI	NI	10	2.5	182+NI

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

(b) Surveillance personnel for 10 yr for Alternative IV, 20 yr for Alternative VI, and 100 yr for Alternatives I, II, and V.

(c) Because of rounding, the totals may not exactly equal the sums of the listed entries.

(d) N/A = not applicable.

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

(f) < = less than.

(g) NI = not included in this estimate (applies to an offsite geologic repository).

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

TABLE 2-10

SUMMARY OF ESTIMATED COSTS - BURIED TRU WASTE^(a)

Alternative or Concept	Capital Cost	Total O&M Cost	Shipment Costs		Cost at Reposi- tory	D&D Cost	Total Costs
			Onsite	Offsite			
I	0	60	N/A ^(b)	N/A	N/A	N/A	60
II-A	32	60	N/A	N/A	N/A	N/A	92
II-B	35	60	N/A	N/A	N/A	N/A	95
II-C	85	60	N/A	N/A	N/A	N/A	145
II-D	100	60	N/A	N/A	N/A	N/A	160
III-A	726	526	N/A	31	174	73	1,530
III-B	767	545	N/A	31	174	77	1,594
IV-A	742	555	N/A	31	174	73	1,575
IV-B	783	574	N/A	31	174	77	1,639
V-A	764	646	4.4	N/A	N/A	73	1,489
V-B	242	458	7.9	N/A	N/A	21	729
V-C	208	482	2.7	N/A	N/A	17	710
V-D	805	665	4.4	N/A	N/A	77	1,551
V-E	283	477	7.9	N/A	N/A	25	793
V-F	249	501	2.7	N/A	N/A	21	774
V-G	765	633	4.4	N/A	N/A	73	1,475
V-H	243	444	7.9	N/A	N/A	21	716
V-I	209	471	2.7	N/A	N/A	17	700
V-J	806	652	4.4	N/A	N/A	77	1,539
V-K	284	463	7.9	N/A	N/A	25	780
V-L	250	490	2.7	N/A	N/A	21	764
V-M	1,276	611	4.1	N/A	N/A	73	1,964
LMV ^(c)	799	598	4.1	N/A	N/A	73	1,474
V-N	1,040	414	5.6	N/A	N/A	21	1,481
LMV	325	402	5.6	N/A	N/A	21	754
V-O	1,906	434	1.5	N/A	N/A	18	2,359
LMV	337	423	1.5	N/A	N/A	18	779
V-P	1,317	630	4.1	N/A	N/A	77	2,028
LMV	840	617	4.1	N/A	N/A	77	1,538
V-Q	1,081	433	5.6	N/A	N/A	25	1,545
LMV	366	421	5.6	N/A	N/A	25	818
V-R	1,947	453	1.5	N/A	N/A	22	2,423
LMV	378	442	1.5	N/A	N/A	22	843
V-S	1,122	618	N/A	N/A	N/A	73	1,813
V-T	813	408	N/A	N/A	N/A	21	1,242
V-U	1,472	438	N/A	N/A	N/A	18	1,928
V-V	1,163	637	N/A	N/A	N/A	77	1,877
V-W	854	427	N/A	N/A	N/A	25	1,306
V-X	1,513	457	N/A	N/A	N/A	22	1,992
VI-A	726	538	N/A	31	174	73	1,542
VI-B	767	557	N/A	31	174	77	1,606

(a) All costs are millions of mid-July 1979 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.

that uncertainties of as much as 50% 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 indicates that the lowest costs would be associated with Alternatives I and II, ranging from \$60 million to \$160 million. The cost to retrieve and process the waste and to ship it to an offsite geologic repository and dispose of it there would range from \$1,530 million to \$1,639 million (Alternatives III, IV, and VI). 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 \$700 million to \$2,423 million, depending on the methods of retrieval, processing, and disposal.

2.10 COMPARISONS

The alternatives and concepts studied for long-term management of the buried 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.

3.0 PRESENT ENVIRONMENT OF THE INEL (INCLUDING RWMC, SITE 14, AND LEMHI RANGE SITES)

The INEL occupies 894 square miles 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. (See Figure 3-1.) The Lemhi Range sites are located in the northern portion of the INEL, Site 14 is in the central area of the INEL, and the RWMC is in the southwestern part.

Section 3 of DOE 1979b describes the geography, topography, climate and meteorology, geology and seismology, hydrology, and ecology of the INEL in general, and of the particular INEL locations mentioned above. Also described are the archaeology, land use, population characteristics, and economic setting.

Data from DOE 1979b are repeated as needed in Sections 8 through 10 and 12 through 14 of this report.

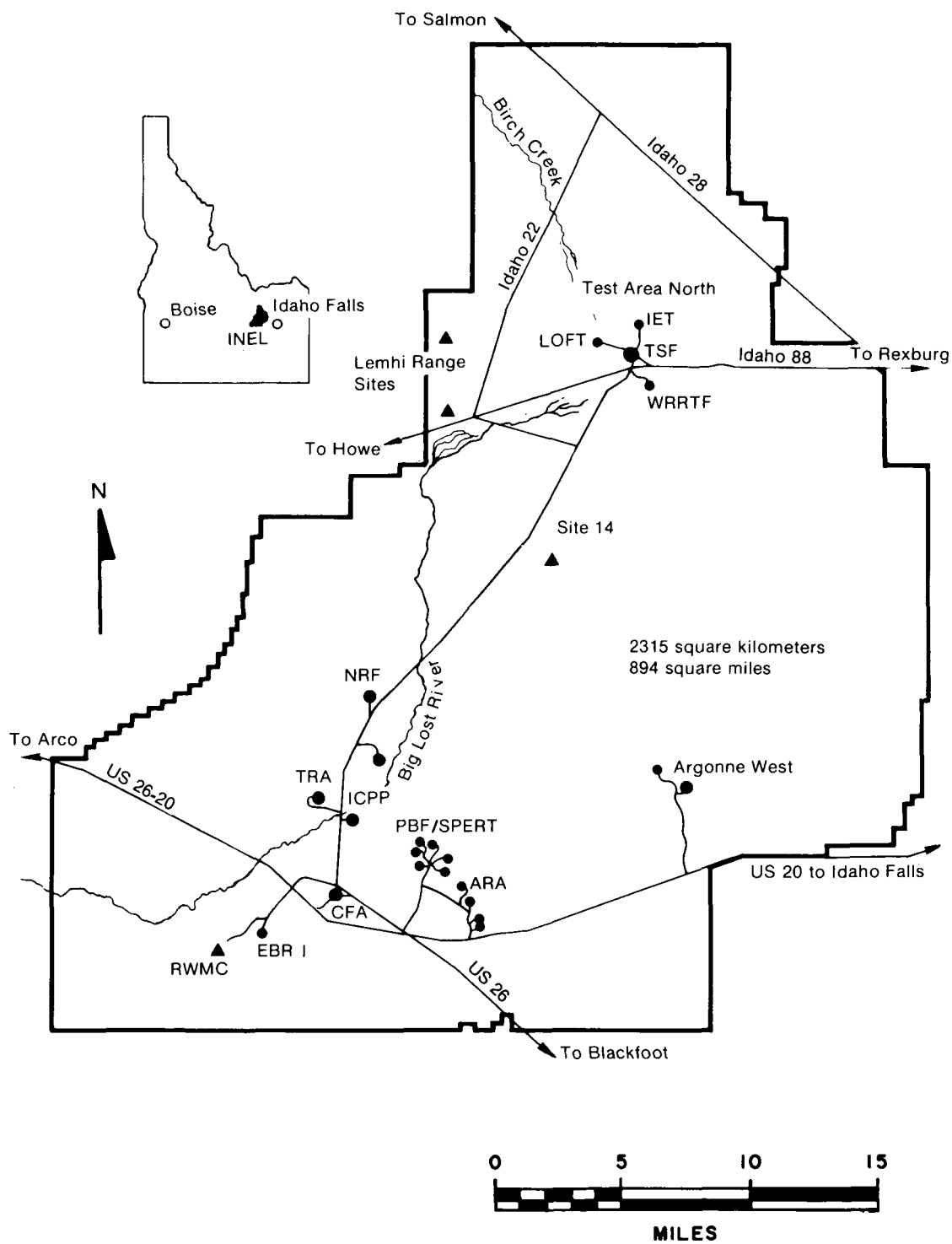


Fig. 3-1. Location and principal features of the INEL.

4.0 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 (AEC) 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. The RWMC 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) were buried here in pits and trenches. The pits and trenches have an average depth of 12 ft (ERDA 1977c). 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 has been 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. The TRU waste buried within the SDA is the subject of the present study.

The TSA is a 56-acre area, established in 1970 for 20-yr retrievable storage of waste contaminated with more than 10 nCi of transuranic radionuclides per gram of waste.^(a) The TSA is surrounded by a security fence and has an intrusion alarm system. Asphalt pads, approximately 150 by 700 ft,

(a) The stored waste is described here for perspective and to provide some background in current TRU waste management. Management alternatives for the stored TRU waste are discussed in DOE 1979b.

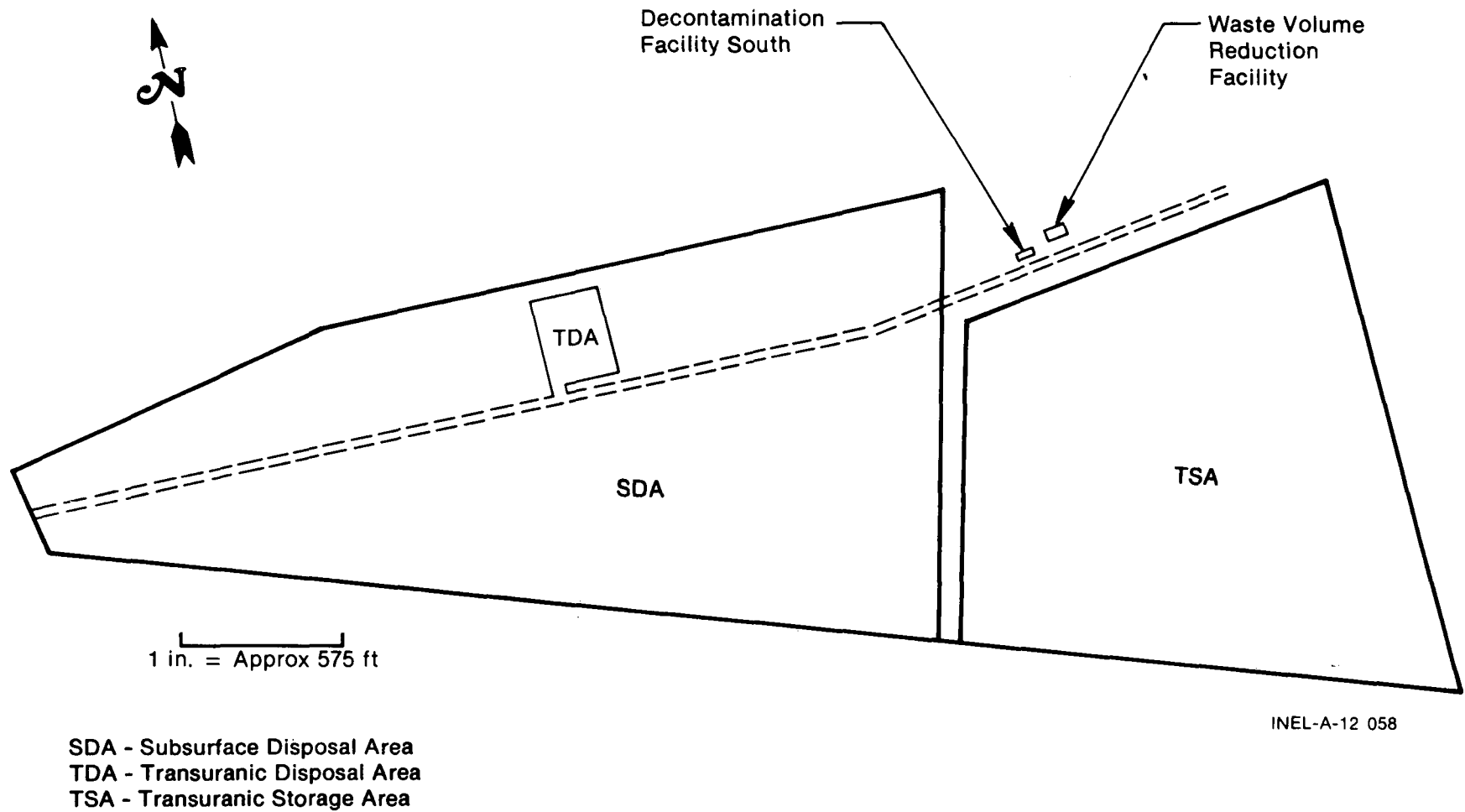


Fig. 4-1. Layout of the Radioactive Waste Management Complex (RWMC).

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 of transuranic activity per gram of waste. (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. This low-activity waste is considered to be disposed. Management of this waste is not within the scope of the current study, because the waste is not considered to be TRU waste (ERDA 1973a).

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 (1977) 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 Plant (RFP) near Golden, Colorado. TRU waste has also been received from INEL facilities and other DOE-sponsored facilities, such as Mound Facility (formerly Mound Laboratory), Bettis Atomic Power Laboratory, and Argonne National Laboratory. A limited amount of waste (predominantly nontransuranic) was received from 1960 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 the RFP 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 begun, TRU waste requiring storage has been emplaced on the TSA, rather than buried.

TRU waste to be stored on the TSA is received in commercial truck trailers or in government-owned ATMX railcars. 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 on the TSA prior to 1974 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.

Until 1972, the plywood boxes placed on the TSA were not covered with fiberglass. Such boxes constituted 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 polyethylene liners provide additional containment for the TRU waste and additional assurance of container integrity for the 20-yr intended life.) Such drums constituted 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. In particular, the waste is suspected of containing toxic chemicals, pyrophoric materials, and other materials that present nonradiological hazards.

4.3.2 Volumes

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 container volume, not necessarily on 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 buried TRU waste)	500,000	500,000
Contaminated soil	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, 6,000 boxes, and 13,000 cartons. Through 1978, approximately 165,000 ft³ of the total buried waste had been retrieved in experimental projects. (The experimental retrieval projects are the Initial 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. Another 26% is nitrate salts of low TRU content. Nitrate salts have a higher leachability and have a greater potential than the TRU waste to migrate from the immediate burial location.

Through 1964, 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 volume of soil that would become contaminated.

Between 1970 and 1977 approximately 1,100,000 ft³ of waste was received and stored aboveground on the TSA. Through the end of 1977, an additional 100,000 ft³ of repackaged TRU waste had been stored on the TSA as a result of the experimental projects for retrieving the buried TRU waste. It is estimated that, by the beginning of 1985, about 2,000,000 ft³ of TRU waste will be in aboveground storage.

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

Beta-gamma waste, as such, is not mixed with the stored TRU waste, but there are small quantities of beta-gamma-emitting radionuclides in the stored waste. The radiation levels produced at the surface of the steel bins on the TSA 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 radioactivity) in 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 are given for waste placed on the TSA through 1977 (based on activity at the time of receipt) and for the total inventory projected to 1985. The estimates and calculations for the latter quantity take into account both radioactive decay and an assumption of increased waste compaction in the future by the waste generators.

Beta-gamma waste was intermixed with the TRU waste from 1954 through 1964. About one-half of the radioactivity was buried in the years 1962 and 1963. No detailed, complete, year-by-year listing is available for the quantity of radionuclides in this beta-gamma waste. Table 4-3 gives an estimated inventory at the time of disposal, based on the distribution of beta-gamma radionuclides currently being disposed in the SDA (see the last paragraph of Subsection 4.1). In order to simplify the estimate of the beta-gamma curies in 1985, all of the beta-gamma waste was assumed to have been buried on January 1, 1961.

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 TRU waste shipment are listed in Table 4-4, and 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.

TABLE 4-2

RADIONUCLIDE CONTENT OF BURIED AND STORED TRU WASTE

Uranium and Transuranic Radionuclides	Half-Life ^(a) (Yr)	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
Pu-238	86.4	571.4	0.23	462	0.37	16,120	9.48	44,223	10.59
Pu-239	24,390	21,043	8.32	19,789	15.75	11,720	6.89	34,230	8.19
Pu-240	6,580	4,860	1.92	4,564	3.63	2,856	1.68	8,071	1.93
Pu-241	13.2	178,425	70.53	54,234	43.16	91,940	54.08	194,092	46.46
Pu-242	379,000	0.2	<0.01	0.2	<0.01	0.2	<0.01	0.2	<0.01
Am-241	458	48,007	18.98	46,548 ^(c)	37.04	45,740	26.90	133,284 ^(c)	31.91
Cm-244	17.6	0	0	0	0	1,113	0.65	2,343	0.56
U-233	162,000	0.5	<0.01	0.5	<0.01	527	0.31	1,486	0.36
U-235	710,000,000	0.3	<0.01	0.3	<0.01	0.001	<0.01	0.002	<0.01
U-238	4,510,000,000	68	0.03	68	0.05	0.002	<0.01	0.003	<0.01
Total radioactivity		252,975	100	125,666	100	170,016	100	417,729	100
Total weight of TRU, (including U-233), g ^(d)		381,000		356,900		280,116		787,140	
Total weight of U-235 + U-238, kg		203,322		203,322		6.5		9.9	
Total waste volume, ft ³		2,200,000		2,000,000		1,200,000		2,000,000	
Transuranic 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. See Table 4-3 for beta-gamma content.

(c) Includes americium-241 produced by decay of plutonium-241 after emplacement.

(d) Because of rounding errors, values shown may differ slightly from values obtained by converting curies of individual radionuclides to grams and adding.

TABLE 4-3

ESTIMATED ACTIVITY IN BETA-GAMMA WASTE MIXED WITH BURIED TRU WASTE

Beta-Gamma Radionuclide	Half-Life ^(a) (Yr)	Emplaced		As of January 1, 1985 ^(b)	
		Curies	Percent	Curies	Percent
Co-60	5.27	99,000	17.0	4214.3	56.8
Ni-59	80,000	1,500	0.3	1500.0	20.2
Sr-90	29.0	1,000	0.2	563.5	7.6
Cs-137	30.17	1,000	0.2	576.2	7.8
Mixed activation products (Co-60) ^(c)	5.27	6,000	1.0	255.4	3.4
Mixed fission products (Cs-137) ^(c)	30.17	500	0.1	288.1	3.9
Unidentified beta-gamma ^(d)	3.0	5,500	0.9	21.5	0.3
Short-lived beta-gamma	<<1 ^(e)	<u>468,500</u>	<u>80.3</u>	<u>Negligible</u>	<u>0.0</u>
Totals		583,000	100.0	7419	100.0

(a) Values are taken from the Chart of the Nuclides, Naval Reactors - U.S. Department of Energy, April 1977.

(b) Although beta-gamma waste was buried with the TRU waste from 1954 through 1964, about half of the activity was buried in 1962 and 1963. Therefore, these simplified calculations of radioactive decay were based on an assumed burial date of January 1, 1961 (24 yr of decay by the year 1985) for all of the beta-gamma waste.

(c) Decay calculations are based on the half-life of the dominant radionuclide.

(d) Decay calculations are based on an estimated value of the effective half-life.

(e) << = much less than.

TABLE 4-4

ACCIDENTS OR INCIDENTS - OFFSITE SHIPMENT TO RWMC

<u>Item</u>	<u>Date</u>	<u>Location</u>	<u>Incident Description</u>	<u>Effects</u>
(1)	3/25/70	Blackfoot, Idaho	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 containers themselves.	No breach, no contamination or radiation release.
(3)	8/7/73	Blackfoot, Idaho	Derailment during switch- ing of ATMX car.	No release, no apparent damage.
(4,5)	3/31/76 9/21/76	Unknown	Opened ATMX car, found evidence of hard bump; some wooden blocking was broken and four to five waste containers were dented.	No breach, no breakage.

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)	7/9/75	Solid sewage sludge drum generated internal pressure causing bulging of the lid. Drums were repacked in overpack containers.	No contamination release.
(2)	1976	Partial drum penetration by forklift. No breach of inner liner.	No contamination release.
(3)	1/9/78	Drum penetration by forklift; a small portion of contents was spilled onto the cargo container floor.	Small amount of local contamination. The contamination was immediately contained and the drum placed in an overpack container. There was no airborne activity. After recontainment, the area was thoroughly surveyed. No contamination was found.

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, and improved personnel radiation monitors.

4.4.2 Waste Processing Research and Development 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 identify the incinerator that appeared most promising for further study for processing the buried TRU waste. Additional details of the study are given in Appendix B of this document.

The FMC study determined that slagging pyrolysis was the most desirable method to process the buried waste. This conclusion was confirmed by an independent task force (Cox et al. 1978). Based on these studies and the positive 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 DOE for further development for treating INEL TRU waste. The major advantages of this particular incineration process are that it would 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 would be required. 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 supporting research and development studies are under way. 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 supporting 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 offgas control systems, are being investigated. Studies are under way concerning slag characteristics (e.g., leach rates), incineration 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

To determine the degree of deterioration of stored TRU waste containers (intended life of 20 yr), two storage cells at TSA were opened (Bishoff 1979). Steel drums and plywood boxes, stored in the cells between 1970 and 1973, were removed. Air monitors indicated no release of airborne contaminants during cell opening. The retrieved waste containers were inspected visually and by an ultrasonic device to determine the degree of container deterioration.

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, 2 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 RFP. 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.

4.4.4 Experimental Retrieval Projects

Two projects at the RWMC have been concerned with demonstrating, on an experimental basis, techniques for retrieving buried TRU waste: the Initial Drum Retrieval (IDR) Project and the Early Waste Retrieval (EWR) Project. The projects have led to a number of findings that have been used in this evaluation.

The IDR Project (completed in June 1978) involved retrieval of drums containing TRU waste buried at the RWMC from 1968 to 1970. An air support weather shield (ASWS), a plastic-coated, fabric structure supported by internal air pressure, was erected over the worksite. Direct control retrieval was conducted by personnel wearing anticontamination clothing. Respirators were not worn during routine operations but were available as a precautionary measure. About 155,000 ft³ of TRU waste was retrieved, repackaged, and placed into storage at TSA as a result of the IDR Project.

The drums retrieved in the IDR Project showed visible rusting. Some of the paper identification labels could not be read. About 2% of the drums were found to be breached or without lids. Contamination was found on the surfaces of about 5% of the drums but was tightly adhered to the drums. Very little contaminated soil was found near the drums. The contamination encountered was relatively easy to control and showed no tendency to spread to other areas.

The EWR Project entails experimental retrieval of some of the oldest buried TRU waste. The objective is development of the technological base for full-scale production retrieval. The operations are conducted in a small, portable metal building that is moved from place to place within an ASWS. The metal building provides confinement for the excavation area. By means of excavation equipment, retrieval is conducted directly by personnel wearing plastic bubble suits that totally encase the wearer. The suits are supplied with breathing air from an external source. Recent retrieval rates have been about 3,000 ft³ per year. This relatively low retrieval rate reflects the

complexities of handling waste that is in severely deteriorated containers. After retrieval and repackaging, this waste is placed into storage at the TSA.

The waste retrieved in the EWR Project consists of breached drums, loose waste, and contaminated soil. About 9% of the drums have leaked free liquids. Most of the loose waste and the soil surrounding it has been found highly contaminated. The contamination has been confined without release to the environment and without the workers receiving a significantly increased body burden of radioisotopes.

4.4.5 Retrieval Research and Development Studies

In June 1978, a research and development study was completed for full-scale retrieval of buried TRU waste at the RWMC (FMC 1978). The study evaluated and made recommendations concerning (1) requirements for retrieving and separating contaminated soil and waste, and (2) handling requirements for the retrieved TRU waste and contaminated soil at the INEL. Preliminary designs were included in the study (Burton et al. 1978). The study recommendations were reviewed by an independent EG&G task force. These recommendations and the comments of the reviewers form the basis for the buried waste retrieval methods used in this study.

The basic design recommended for waste retrieval operations consisted of a portable containment structure. The structure would be moved by extending jackable wheels and towing the building over pre-laid tracks. Equipment for waste retrieval and handling would include shielded and environmentally controlled operator cabs to protect the equipment operators from radiation and other hazards. Alternatively, retrieval would be performed by remote operation of equipment by operators in a control room. The retrieval and handling equipment design would incorporate existing equipment with appropriate modifications when necessary. Separating the waste into combustible and noncombustible portions in the retrieval facility was deemed undesirable from the standpoint of exposure of the workers and possibility of release of contaminated material to the environment.

The conclusions of the R&D study and of the reviewing task force may not be implemented exactly as given. However, they were used in the present study of long-term management alternatives that require retrieval of the buried waste.

5.0 ENVIRONMENTAL EFFECTS FROM CURRENT OPERATIONS OF TRU WASTE MANAGEMENT

No significant environmental effects from current operations have been observed at the RWMC. Ongoing programs monitor radioactive emissions, air and water quality, and soil contamination on a continuing basis. Monitoring of flora and fauna has begun. For details of these activities, see Section 5, DOE 1979b.

6.0 EFFECTS OF CURRENT TRU WASTE MANAGEMENT ON THE WORKERS AND ON THE PUBLIC

No adverse effects due to current TRU waste management at the RWMC have been observed on workers or the public. For further details, see Section 6, DOE 1979b.

7.0 IDENTIFICATION OF ALTERNATIVES FOR INEL TRU WASTE MANAGEMENT

This section reviews communications between state and federal officials concerning the INEL TRU waste and discusses past and current studies of the management of this waste. Guidelines and terminology used for the present study are given. The waste management alternatives studied are briefly described. Detailed descriptions of the alternatives are found in Sections 8 through 10.

7.1 COMMUNICATIONS BETWEEN THE FEDERAL GOVERNMENT AND THE GOVERNMENT OF THE STATE OF IDAHO

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 fire at the RFP in 1969, when TRU-contaminated solid waste resulting from the cleanup operations was shipped to the INEL. Although the INEL had been receiving RFP waste since 1954, the publicity from the fire caused Idaho officials to raise questions concerning the safety of the RFP waste at the INEL. The AEC made a commitment in 1970 to place top priority on removing the waste from the INEL and shipping it to a federal repository for radioactive waste. A summary of the communications and copies of official correspondence are included in Appendix A of DOE 1979b.

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 Research Council Committee on Radioactive Waste Management evaluated current and future low-level radioactive waste management practices at ERDA-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 the following:

- (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 waste 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) ERDA 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

The NRC Committee on Radioactive Waste Management also evaluated future and current radioactive waste management practices at Hanford, Washington. The interested reader is referred to the resulting document (NAS-NRC 1978). 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. The principal conclusion concerning TRU waste is that most soils and sediments containing

dispersed radionuclides should be left in place, rather than exhumed, unless and until a major hazard to the environment can be demonstrated.

7.3 THE DOE ALTERNATIVES STUDY AND ENVIRONMENTAL IMPACT STATEMENT 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. These alternatives are summarized in Table 7-1.

The alternatives and concepts evaluated are within the scope of current technology. In the case of slagging pyrolysis, development studies were under way 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 basic information for the environmental impact statement (EIS) described in Subsection 7.3.2, for DOE 1979b, and for the present study of alternatives. However, these follow-up documents update the alternatives of the referenced study.

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.

7.3.2 EIS for INEL TRU Waste Management

An EIS is being prepared for alternatives for TRU waste management at the RWMC. The study is analyzing the environmental impact, risks, costs, and implications of selected major alternatives. The results of experimental environmental studies, currently in progress, will be incorporated. More detail will be provided on fewer management concepts than for the environmental analyses in the present document.

7.4 THE CURRENT STUDY

Basic information used for the current study is presented below, including important assumptions and terminology. Brief descriptions are given of the waste management alternatives and concepts that were analyzed.

7.4.1 Guidelines for Study of Buried Waste

The guidelines discussed below were formulated to provide a common baseline for evaluating and comparing alternatives. It is recognized that revisions in regulations and in national policies for waste management could depart from these guidelines. Thus, reevaluation of results obtained under the present guidelines could be required before implementation of alternatives.

7.4.1.1 General

- (1) The study shall present and evaluate alternatives, and concepts within these alternatives, for long-term management of TRU waste buried at the RWMC.
- (2) The study shall address three scenarios concerning an offsite geologic repository: (a) such a repository will be available; (b) such a repository will be available, but will be delayed by 20 yr; and (c) such a repository will not be available.

- (3) Implementation of any long-term waste management alternative shall be assumed to commence in 1985 or as soon thereafter as practicable. (Evaluations based on this assumption have already been performed in DOE 1978a and DOE 1979b.)

NOTE: All references to operations occurring in the year 1985 are to be 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. Current projections are that waste retrieval could begin in late 1986 or early 1987. However, these projections are subject to change.

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

NOTE: The requirement to complete the campaign for buried waste within 10 yr is an arbitrary constraint imposed for the present study. This time period represents a worst case, in that it is the shortest reasonable campaign and would result in the maximum rates of emissions to the environment. The actual length of the campaign is not known at present. A campaign lasting from 10 to 20 yr is considered the most likely.

Table 7-2 presents comparisons of processing rates for buried waste for 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.

TABLE 7-2
WASTE PROCESSING RATES^(a,b,c) FOR
SEVERAL CAMPAIGN LENGTHS

<u>Length of Campaign (yr)</u>	<u>Processing Feed Rate for Buried Waste^(d) (ft³/yr)</u>
10	709,200
20	354,600
30	236,400

- (a) Processing rates do not include coal, bark, or concrete.
- (b) 220 operating days/yr.
- (c) Rates are identical for all methods of waste 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.)

For many parameters, the effect of a change in campaign period can be estimated simply by multiplying the parameter by the ratio of periods. However, in some cases, the effects are not linear. Radioactive decay is one contributor to this nonlinearity. The transport of radionuclides along certain pathways to man is also nonlinear in time. For these and other reasons, forming simple ratios of campaign periods may lead to inaccurate estimates.

- (5) For shipment analyses in this study, an offsite geologic repository shall be assumed to be located near Carlsbad, New Mexico.
- (6) Except for possible shipment to an offsite geologic repository, no disposal locations outside the INEL shall be contemplated.

- (7) Facilities for disposal of retrieved waste at the INEL shall be designed so as to allow the removal of waste for a period of 40 yr following initial emplacement, after which disposal may be irretrievable.
- (8) For any concept that proposes not shipping the waste to an offsite geologic 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 upper limit for assumed reliance on institutional control for protection of radioactive waste. All confinement would be designed to provide passive isolation for radionuclides for time periods in excess of the 100-yr period.

- (9) 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, no new technology development is assumed in this study. There is no guarantee that significant new technology for TRU waste management will develop within 20 yr. 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.

- (10) All facilities shall be designed so that all effluents will be limited to levels consistent with the requirements of existing regulations.
- (11) All facilities shall be designed so as to limit radiation exposures to operating personnel to levels consistent with the requirements of existing regulations.

- (12) The waste shall be monitored so as to provide an assessment of plutonium content after retrieval, during processing, and after packaging.
- (13) Contaminated soil intermixed with the buried TRU waste shall be treated in the same manner as the waste.
- (14) Any facility for retrieval of the buried TRU waste must provide double containment, supplying progressively lower pressures in the direction of increasing contamination.
- (15) Any processing of retrieved waste shall be performed at or near the RWMC.
- (16) No concept shall be studied that proposes reclamation of fissile material.
- (17) Any facility for processing (including packaging only) TRU waste must provide double containment, supplying progressively lower pressures in the direction of increasing contamination. An additional level of containment shall be provided around the waste processing equipment.
- (18) 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.
- (19) All waste shipped to an offsite geologic repository shall be processed so as to satisfy the waste acceptance criteria of the repository. (The Draft Waste Acceptance Criteria of the Waste Isolation Pilot Plant (WIPP) are given in Appendix D of DOE 1979b. These criteria were under consideration for the WIPP at the time this study was begun. The draft waste acceptance criteria are subject to change.)

- (20) All waste shipped to an offsite geologic repository shall be contained so as to meet federal regulations. The use of ATMX 600 railcars shall be assumed.

NOTE: This study shall not address the availability of the ATMX 600 railcars for shipment of INEL TRU waste at the time of interest. Furthermore, it is recognized that these cars may not satisfy 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 volumes and radionuclide contents of waste and contaminated soil (Tables 4-1, 4-2, and 4-3) 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 buried waste shall be assumed to generate an additional 800,000 ft³ of waste, such as contaminated hand tools and protective clothing. An estimated additional 85,000 ft³ of waste requiring disposal would result from D&D of the retrieval and treatment facilities for buried waste. Only half of the D&D waste shall be assumed to be processed. (The remaining D&D waste, consisting primarily of portions of the processing facility itself, could be packaged and disposed of in the same manner as the TRU waste.) For simplicity, the D&D waste shall be assumed to be processed along with the TRU waste and the waste resulting from operations. In reality, the D&D waste would not be generated until a time period assumed to be 1996 and 1997.

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 is included in the evaluations in this study.

- (3) The following combustible/noncombustible volume ratios shall be assumed: buried TRU waste and intermixed beta-gamma waste, 20/80; self-generated waste, 95/5; and D&D waste, 5/95.
- (4) The following values for density (in lb/ft³) shall be assumed: buried TRU waste and intermixed beta-gamma waste, 40 overall (15 for combustible and 46.25 for noncombustible); contaminated soil, 80; 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 calculation of density for each noncombustible portion listed was based on the overall density, the density of combustibles, and the percentage of combustibles. (For self-generated waste only, the overall density was calculated.) The number of significant digits shown above for each derived value does not reflect the accuracy of the value, but is 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 conservatively assumed to be 1 micron activity median aerodynamic diameter (AMAD) for accidental releases and 0.3 micron AMAD for normal operational releases.

- (7) For simplifying the calculations of releases of radionuclides, the contaminated soil and the buried beta-gamma waste shall be assumed to be completely and uniformly mixed throughout the buried TRU waste.

7.4.1.3 Risk Analysis

- (1) The risk analysis shall address radiological risks to the public from accidental releases. The long-term effects of near-term accidental releases shall also be addressed. (Normal operational releases shall be considered in the analysis of environmental effects.)
- (2) The analysis shall summarize both radiological and nonradiological hazards to the workers.
- (3) For concepts that propose shipping the waste to an offsite geologic repository, the risk analysis shall extend from retrieval through receipt at the repository.

NOTE: The radiological effects associated with long-term management at an offsite geologic repository are being evaluated in other studies. The repository risks and long-term effects, when evaluated, should be added to the risks and long-term radiological effects analyzed in this study, to obtain the total risk and radiological effects for Alternatives III, IV, and VI.

- (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 or that propose retrieving, processing, and storing waste before shipment to an offsite geologic repository, the risk analysis shall cover (a) the delay period, and (b) the operations from retrieval through receipt at an offsite geologic repository.
- (7) Risks associated with the decontamination and decommissioning (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) Time periods evaluated in cost studies shall be the same as those for risk evaluations, Subsection 7.4.1.3., with the following exceptions: (a) no costs shall be assessed for site maintenance for time periods beyond 100 yr after implementation, and (b) allocated costs assumed to be assessed for long-term management at an offsite geologic repository shall be included.
- (2) Estimates of capital costs shall be based on projected July 1979 prices.
- (3) 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 July 1979.

- (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 estimates.
- (6) Shipment costs shall be based on shipping waste from the RWMC to the location of concern.
- (7) Costs of Department of Transportation (DOT)-approved shipping containers shall be included where applicable.
- (8) Costs of ATMX railcars (assumed to be government owned) shall not be included.

7.4.1.5 Environmental Analyses

- (1) Environmental aspects of the project shall be described using available data.
- (2) Time periods evaluated for the environmental study shall be the same as those evaluated for the risk study (see Subsection 7.4.1.3).
- (3) Normal operational releases shall be considered in the environmental analysis. The long-term effects of near-term releases from normal operations shall also be addressed. (Doses, risks, and environmental effects associated with accidental releases shall be analyzed in the risk analysis.)
- (4) Shipments shall meet DOT requirements that would preclude normal operational releases. Accidents associated with shipments shall be discussed in the risk analysis.
- (5) Dose estimates shall be based on the 1978 data bank of meteorological characteristics and transfer coefficients.

- (6) 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) 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 terms "alternative," "concept," and "module" are used. For the present document, these terms are defined as follows:

- (1) Alternative: a general method of managing the TRU waste. For example, Alternative V 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 V, Concept V-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 Table 7-3 and in the simplified decision tree presented in Figure 7-1.

TABLE 7-3

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

<u>Alternatives</u>	<u>Concepts</u>	<u>Description</u>
I		<u>Leave As Is</u>
II		<u>Leave In Place With Improved Confinement</u>
	II-A	Improve Confinement--Above
	II-B	Improve Confinement--Above and Around
	II-C	Improve Confinement--Above, Around, and Below
	II-D	Improve Confinement--Immobilization
III		<u>Retrieve As Scheduled, Process, Ship To Offsite Geologic Repository</u>
	III-A	Direct-Control Retrieval, SP ^(a)
	III-B	Remote-Control Retrieval, SP
IV		<u>Retrieve As Scheduled, Process, Store 20 Yr, Ship To Offsite Geologic Repository</u>
	IV-A	Direct-Control Retrieval, SP
	IV-B	Remote-Control Retrieval, SP
V		<u>Retrieve As Scheduled, Process, Deep Rock Disposal - Shaft Access (In Lemhi Range)</u>
	V-A	Direct-Control Retrieval, SP
	V-B	Direct-Control Retrieval, CPT ^(b)
	V-C	Direct-Control Retrieval, PKG ^(c)
	V-D	Remote-Control Retrieval, SP
	V-E	Remote-Control Retrieval, CPT
	V-F	Remote-Control Retrieval, PKG
		<u>Retrieve As Scheduled, Process, Deep Rock Disposal - Tunnel Access (In Lemhi Range)</u>
	V-G	Direct-Control Retrieval, SP
	V-H	Direct-Control Retrieval, CPT
	V-I	Direct-Control Retrieval, PKG
	V-J	Remote-Control Retrieval, SP
	V-K	Remote-Control Retrieval, CPT
	V-L	Remote-Control Retrieval, PKG

TABLE 7-3 (Cont'd)

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

<u>Alternatives</u>	<u>Concepts</u>	<u>Description</u>
		<u>Retrieve As Scheduled, Process, Engineered Shallow Land Disposal (At Site 14)</u>
	V-M (& LMV) ^(d)	Direct-Control Retrieval, SP
	V-N (& LMV)	Direct-Control Retrieval, CPT
	V-O (& LMV)	Direct-Control Retrieval, PKG
	V-P (& LVM)	Remote-Control Retrieval, SP
	V-Q (& LMV)	Remote-Control Retrieval, CPT
	V-R (& LMV)	Remote-Control Retrieval, PKG
		<u>Retrieve As Scheduled, Process, Disposal In Engineered Surface Facility (Near RWMC)</u>
	V-S	Direct-Control Retrieval, SP
	V-T	Direct-Control Retrieval, CPT
	V-U	Direct-Control Retrieval, PKG
	V-V	Remote-Control Retrieval, SP
	V-W	Remote-Control Retrieval, CPT
	V-X	Remote-Control Retrieval, PKG
VI		<u>Delay Retrieval 20 Years, Process, Ship to Offsite Geologic Respository</u>
	VI-A	Direct-Control Retrieval, SP
	VI-B	Remote Control Retrieval, SP

(a) SP - slagging pyrolysis and packaging.

(b) CPT - compaction, immobilization, and packaging.

(c) PKG - packaging only.

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

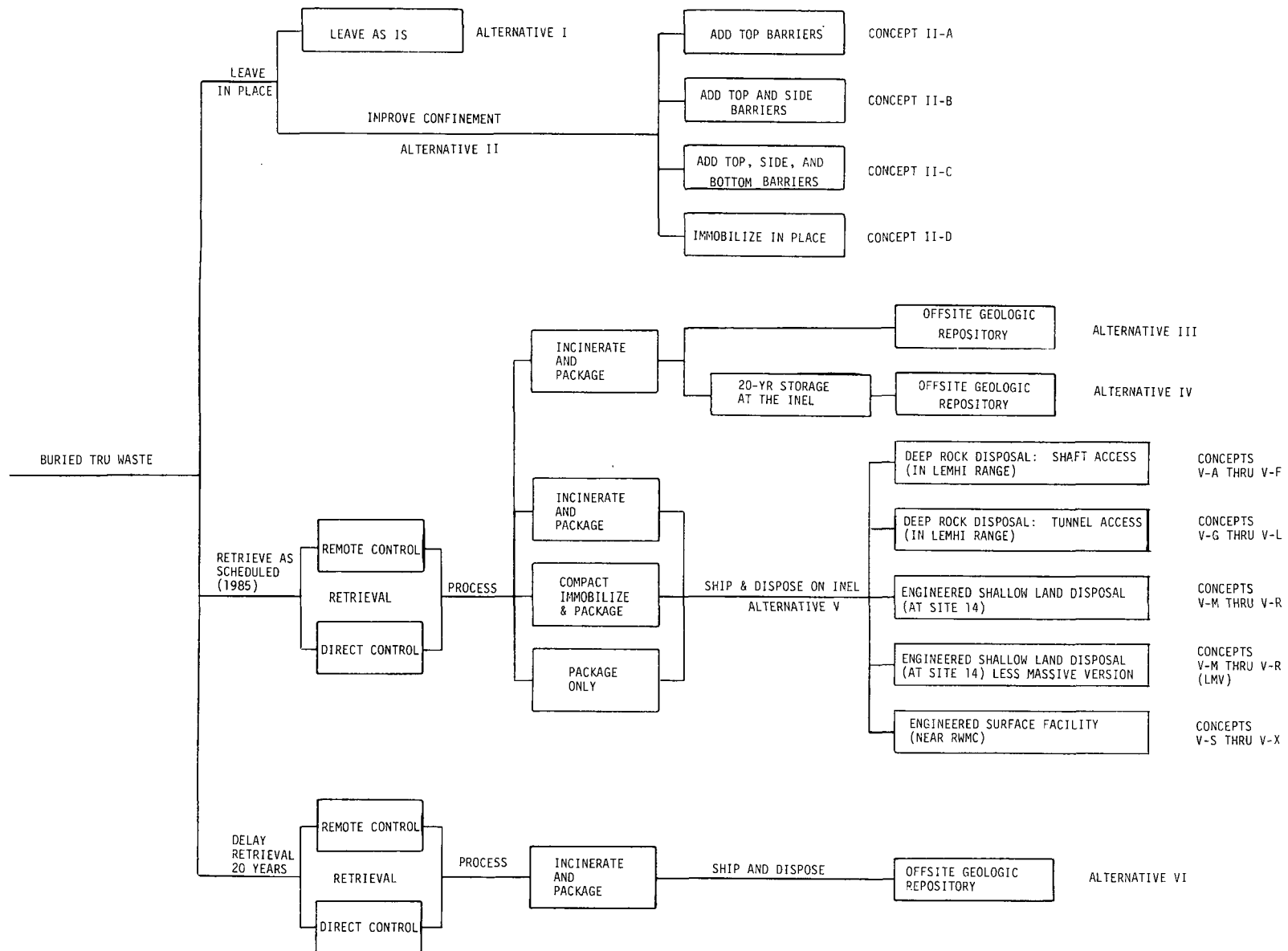


Fig. 7-1. Alternatives and concepts studied for long-term management of buried INEL TRU waste.

The six major alternatives studied for managing buried TRU waste stem from three possibilities: (1) an offsite geologic repository will be available as scheduled, in 1985, (2) an offsite geologic repository will be available, but will be delayed until the year 2005, and (3) an offsite geologic repository will not be available. Alternative III falls under the first possibility; Alternatives IV and VI, under the second possibility. The third possibility would necessitate alternatives such as I, II, and V.

In Alternative I, 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 I is found in Subsection 8.1.

In Alternative II, 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. As in Alternative I, monitoring, maintenance, and security would be provided for 100 yr. Alternative II is described in detail in Subsection 8.2.

In Alternative III, the TRU waste would be retrieved as scheduled (beginning in 1985 or as soon thereafter as practicable), processed, and shipped to an offsite geologic repository. Only two concepts for Alternative III were studied: direct-control or remote-control retrieval; followed by slagging pyrolysis and packaging; and shipment by rail to an offsite geologic repository. Reasons are given at the beginning of Section 9 for studying only these retrieval, processing, and shipment methods for alternatives involving waste disposal at an offsite geologic repository (III, IV, and VI). Alternative III is described in Subsection 9.1.

In Alternative IV, the TRU waste would be retrieved as scheduled, processed by slagging pyrolysis and packaging, stored at the INEL for 20 yr, and shipped to the (delayed) geologic repository in the year 2005. See Guideline (2) in Subsection 7.4.1.1. Alternative IV is discussed in Subsection 9.2.

In Alternative V, the waste would be retrieved as scheduled, processed, and disposed of on the INEL. The concepts studied differ in the method of retrieval, type of processing, or the method and location of disposal. Retrieval modules may be either direct control or remote control. 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) similar disposal with access by a tunnel, (3) engineered shallow land disposal in a massive or less massive facility at Site 14, or (4) disposal in an engineered surface facility near the RWMC. All combinations of retrieval, processing, and disposal modules were studied. Alternative V 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. Each method was then 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 VI, retrieval would be delayed for 20 yr (to the year 2005). Processing would involve slagging pyrolysis and packaging, and the processed TRU waste would be shipped to an offsite geologic repository. Alternative VI is described in Subsection 9.3. Except for the 20-yr delay in retrieval, this alternative is identical to Alternative III.

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 buried 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.

8.0 ALTERNATIVES INVOLVING LEAVE-IN-PLACE MANAGEMENT

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

For these alternatives, existing waste management procedures, such as maintenance, surveillance, monitoring, and security, would be retained or improved as necessary. These procedures would be modified to suit the containment improvements of Alternative II. Guideline (8) in Subsection 7.4.1.1 specifies that the waste management procedures would be continued for 100 yr after implementation.

8.1 ALTERNATIVE I: LEAVE BURIED TRU WASTE IN PLACE AS IS

8.1.1 General Procedures

In Alternative I, the 3 ft of backfill soil and the 2-ft clay cover over the buried TRU waste, described in Subsection 4.4.1, would be maintained. The current practice of periodic visual inspection would be continued to detect subsidence in the soil and clay cover, to detect damaged fences and signs, and to survey general conditions. Monitoring, maintenance, and security 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) for 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 improved techniques become available.

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 continuing on the potential for horizontal migration near the surface and for downward migration 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 airborne radionuclides are ^{60}Co and ^{137}Cs . 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 DOE 1979b, 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 samples of 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 DOE 1979b.

Recently initiated monitoring by the RESL can detect the accumulation of radionuclides in plants or animals. (See DOE 1979b.) 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, soil moisture is monitored by lowering a combination neutron source and thermal neutron detector into perforated pipes driven through the soil to the basalt and 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.

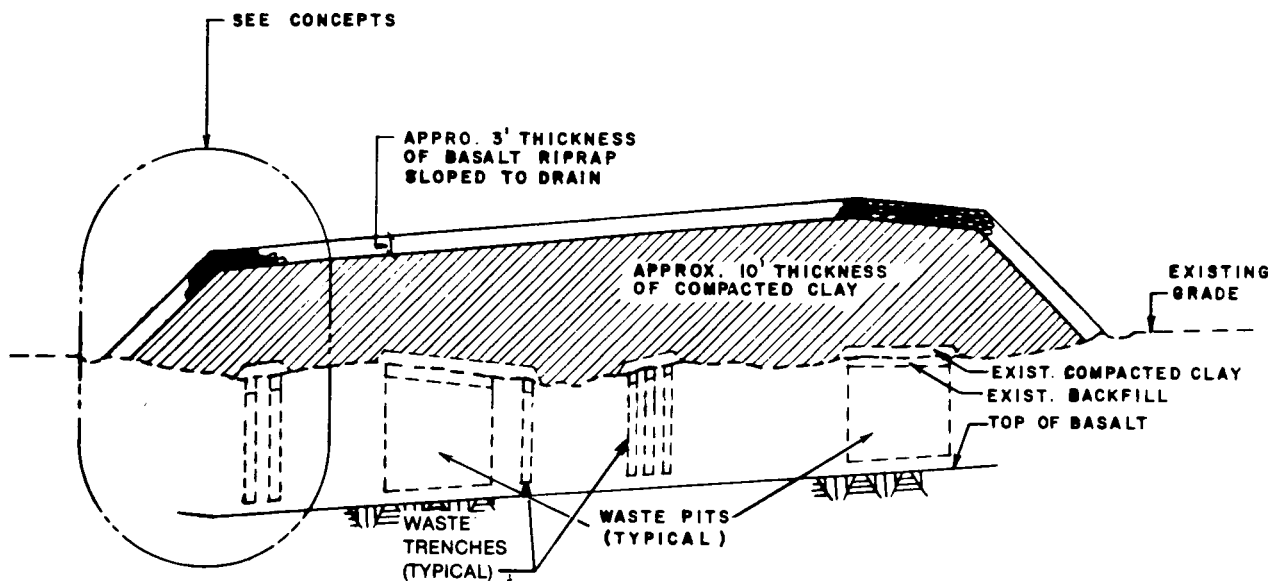
Wells No. 87 through 89, located around the periphery of the RWMC, (see DOE 1979b) are used to sample the aquifer at depths of approximately 600 ft below the ground surface. Aquifer samples have also been drawn from the RWMC production well. Perched water samples have been drawn from Well No. 92 (about 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 DOE 1979b).

The waste containers in the pits and trenches would continue to deteriorate, allowing the soil cover to subside. The average density of the buried waste and containers is estimated to be approximately 40 lb/ft³. As the waste and the soil cover compact and subside, it is assumed that the average density of the waste and containers could eventually reach the natural soil density of about 80 lb/ft³. Therefore, the waste would settle to approximately one-half of the present height. Waste was buried to a depth of as much as 12 ft. Thus, after subsidence of the waste, the top of the 2-ft mound of clay could be as much as 4 ft below grade. In addition, differential subsidence could occur.

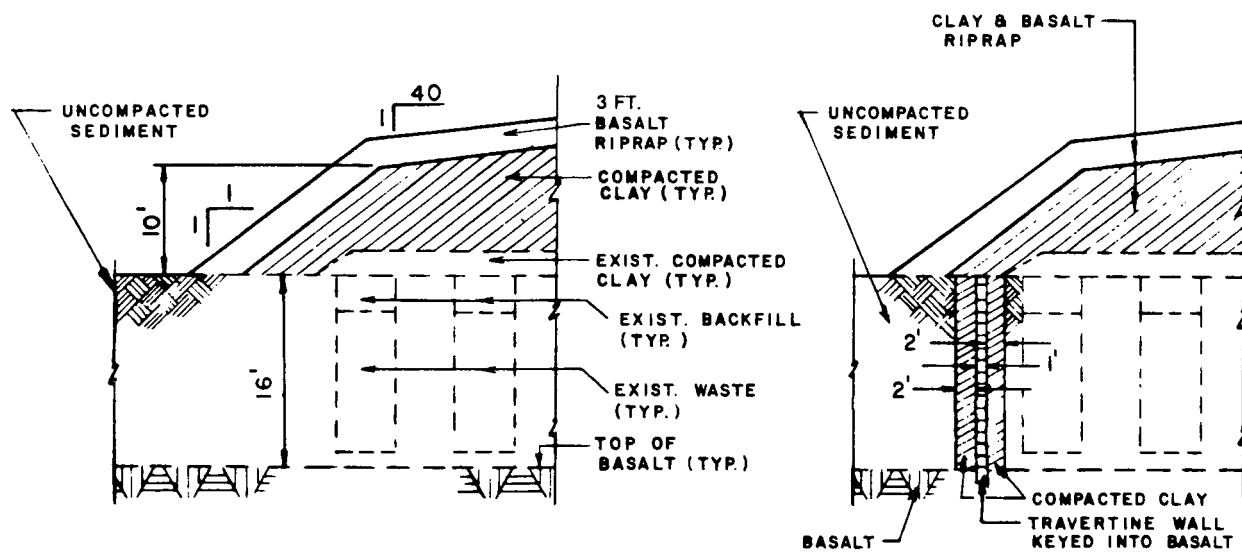
During the 100-yr maintenance period [Guideline (8) in Subsection 7.4.1.1], replacement cover material would be added to reduce the final depth of subsidence and minimize effects of differential subsidence. After 100 yr, maintenance is assumed to be discontinued; however, only slight additional subsidence would be expected.

8.2 ALTERNATIVE II: LEAVE BURIED 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. Three concepts for constructing confinement barriers for the waste, designated II-A (above), II-B (above and around), and II-C (above, around, and below), are discussed within this alternative. One immobilization concept (II-D) is also discussed. These concepts are illustrated in Figure 8-1. The block flow diagrams are shown in Figure 8-2. As shown in Figure 8-1, the pits



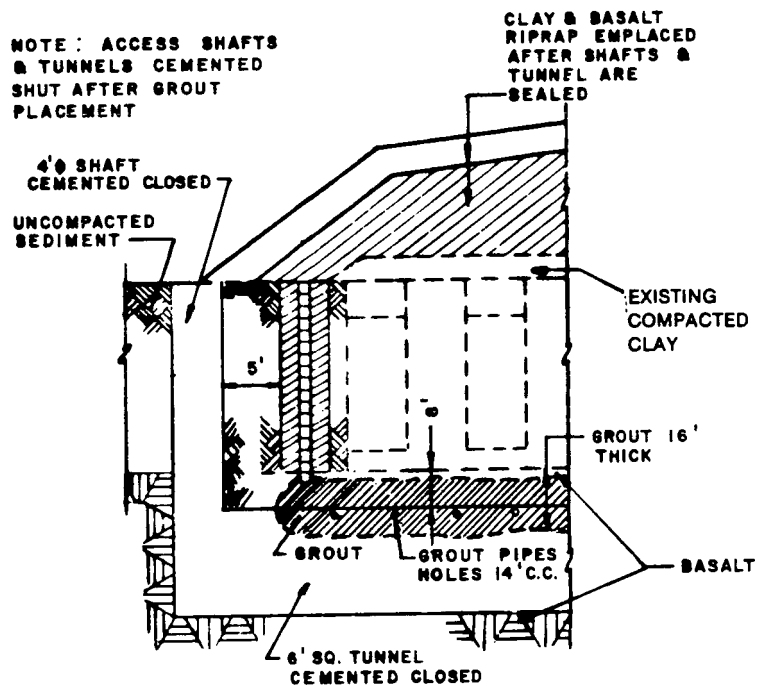
**TYPICAL SECTION THROUGH THE RWMC
SHOWING MOUND & RIPRAP COVER**



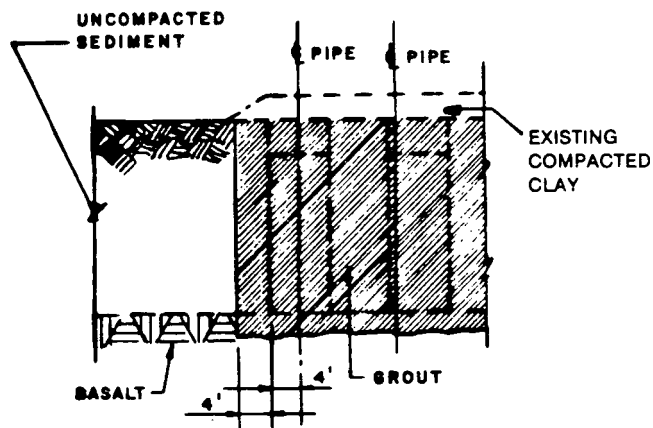
CONCEPT II-A: EMPLACEMENT
CLAY COVER & BASALT RIPRAP

CONCEPT II-B: EMPLACEMENT
CONCEPT II-A + CLAY & TRAVERTINE WALL

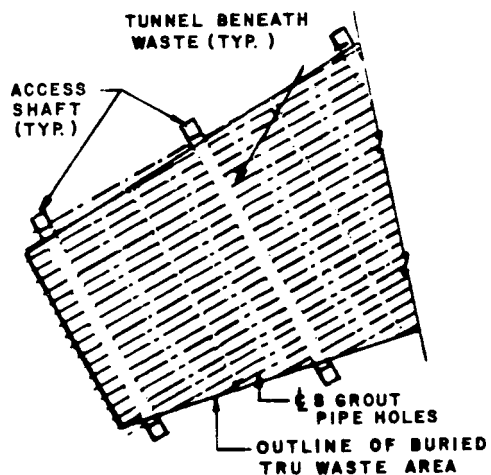
Fig. 8-1. Improved engineered confinement (sheet 1 of 2).



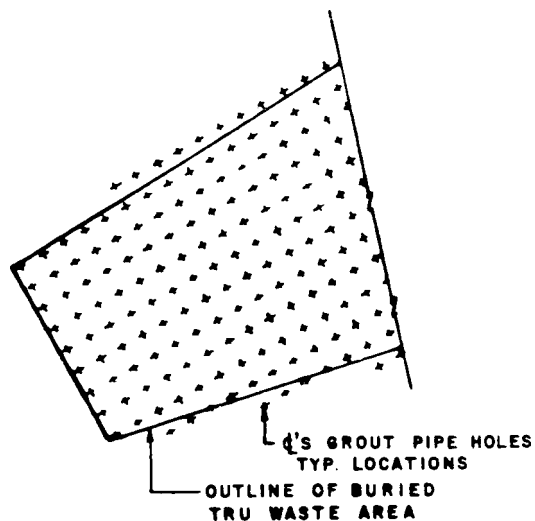
CONCEPT II-C EMBLEMENT
CONCEPT II-B + GROUT SEAL OF BASALT



CONCEPT II-D ENCAPSULATION
GROUT INJECTION



PARTIAL PLAN VIEW
CONCEPT II-C



PARTIAL PLAN VIEW
CONCEPT II-D

Fig. 8-1. Improved engineered confinement (sheet 2 of 2).

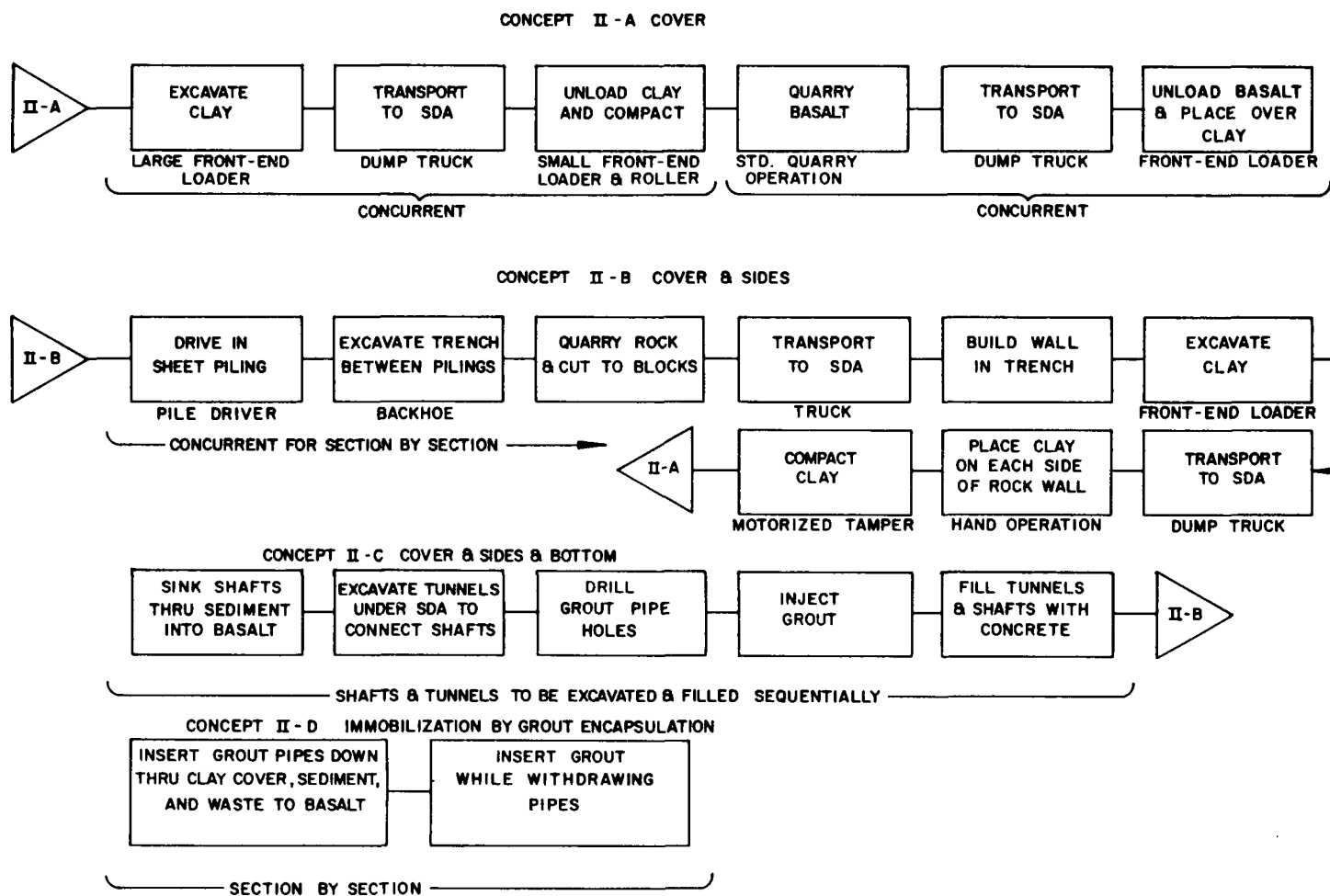


Fig. 8-2. Block flow diagram, improved engineered confinement.

and trenches would be treated as one large area including the areas between pits or trenches when implementing the confinement and immobilization concepts.

8.2.1 Concept II-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 above the buried waste (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 during wetting and drying cycles, thereby retaining its flexibility and resistance to penetration by water. If observations indicate that the clay material (lake bottom clay available on the INEL) used for the present 2-ft cover 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.

As discussed in Subsection 8.1.2, the containers of buried waste would continue to deteriorate, allowing the soil cover to subside. The settled height of the waste, including the current 2-ft clay cover and the 13-ft clay and basalt cover just described, is estimated to be a minimum of 9 ft. Thus, even after subsidence of the waste, the top of the clay and basalt mound would be well above the surrounding area, thereby providing drainage.

8.2.2 Concept II-B

This concept would include the clay and riprap cover described for Concept II-A. Increased protection from horizontal intrusion of water and burrowing animals would be afforded by a continuous subsurface wall around the area of the TRU waste pits and trenches. The wall would extend downward from the ground surface to the underlying basalt (Figure 8-1). The markers defining the limits of the pits and the ends of the trench centerlines would be used as guides in locating the wall outside the TRU waste area.

Two parallel rows of sheet piling, 5 ft apart, would be driven down to the basalt layer for a predetermined distance along the surveyed wall line. The soil would then be removed from between the rows of sheet piling, and bridging would be used to prevent the collapse of the piling. Starting at the basalt layer, several courses of travertine blocks would be laid, without mortar, upward from the basalt to form a 1-ft-thick wall.

A 2-ft-thick wall of clay would be placed in thin layers on each side of the travertine blocks in the space between the piling and the blocks. The clay would be of the same type as that used for the 10-ft clay mound over the TRU waste. Each layer of clay would be compacted to approximately 95% of the theoretical density before addition of the next layer. When the clay reached the top of the travertine blocks, more courses of blocks would be laid, and additional clay emplaced. When the wall reached grade level, the sheet piling would be removed and advanced to the next position around the periphery of the waste area. This process would continue until the entire area had been surrounded by the wall.

The travertine block wall would prevent animals from burrowing laterally into the waste area. Travertine was selected as a suitable material because it is a naturally occurring rock near the RWMC and has proved highly resistant to deterioration. No other locally available rock is amenable to being sawed into blocks. The compacted clay would minimize horizontal intrusion of water. Additionally, should earth movement occur, the clay would retain its flexibility, help support the travertine, and seal any cracks that might develop.

8.2.3 Concept II-C

This concept would include the clay mound and riprap cover, and the subsurface wall described for Concept II-B (Figure 8-1). Increased isolation would be provided by pressure-grout sealing of the basalt beneath the buried waste. 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.

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 and 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 has been accomplished by forcing pipes into the soil, often to depths of several hundred feet, and pumping grout through the pipes into the soil. 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 this operation, a continuous wall, or curtain, of grout is formed in the soil or rock. Application of pressure-grouting to seal the basalt beneath the waste in Concept II-C would be accomplished as described in the following paragraphs.

Using nonexplosive mining techniques, access shafts would be sunk into the basalt at predetermined locations outside the travertine and clay walls. The shafts would be about 4 ft in diameter and would be sunk along two opposite sides of the TRU waste area and would be connected by about 6-ft square tunnels through the basalt beneath the waste (see Figure 8-1). From the tunnels, horizontal grout holes would be drilled at a predetermined spacing outward into the basalt. Near the boundaries of the waste area, the holes would be drilled at an angle upward to the base of the travertine and clay walls. Grout pipes would be inserted into the drilled holes, and pressure grouting would commence. 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 capillary penetration.

Initially, the grout injected would follow the easiest flow paths, such as cracks and fissures in the basalt. Continued injection would force the grout into progressively smaller channels and into the porous basalt. As the grout pipes are withdrawn, pressure-grouting would continue until the ends of the pipes reach the tunnel wall. The grout pipes would be reinserted into adjacent holes and pressure grouting would recommence. The procedure would be repeated until all grout holes had been used. When the pressure-grouting was completed, the tunnels and access shafts would be filled with concrete to preclude the intrusion of animals or surface water.

The grout would harden and form a solid floor in the basalt beneath the waste. The optimum grout mix and spacing of the tunnels and grout holes would be determined in a test area.

8.2.4 Concept II-D

In this concept, the waste would be immobilized in place by injecting grout into the waste pits and trenches. 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 2-ft clay cover, the buried waste, and down to the basalt. Figure 8-1 illustrates typical pipe locations. The spacing of the grout pipe locations in this concept would be greater than would be used for the grout holes in Concept II-C. The soil and waste are less dense than the basalt; therefore, the grout would encounter less resistance than in basalt and would spread over a larger area.

Pressure-grouting would be performed as described in Concept II-C until the ends of the pipes had been withdrawn to the ground surface. The grout pipes would then be relocated to an adjacent area and again forced downward to the basalt. The procedure would be repeated until the entire TRU waste area had been treated.

The grout would form a solid mass around the waste containers, inside breached containers, and around loose waste and soil. 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 and contaminated soil 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 as described in Subsection 8.2.3 would be used. 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 would be performed. Changes in these characteristics with time would also be measured.

9.0 ALTERNATIVES INVOLVING RETRIEVAL, PROCESSING, AND SHIPMENT TO AN OFFSITE GEOLOGIC REPOSITORY

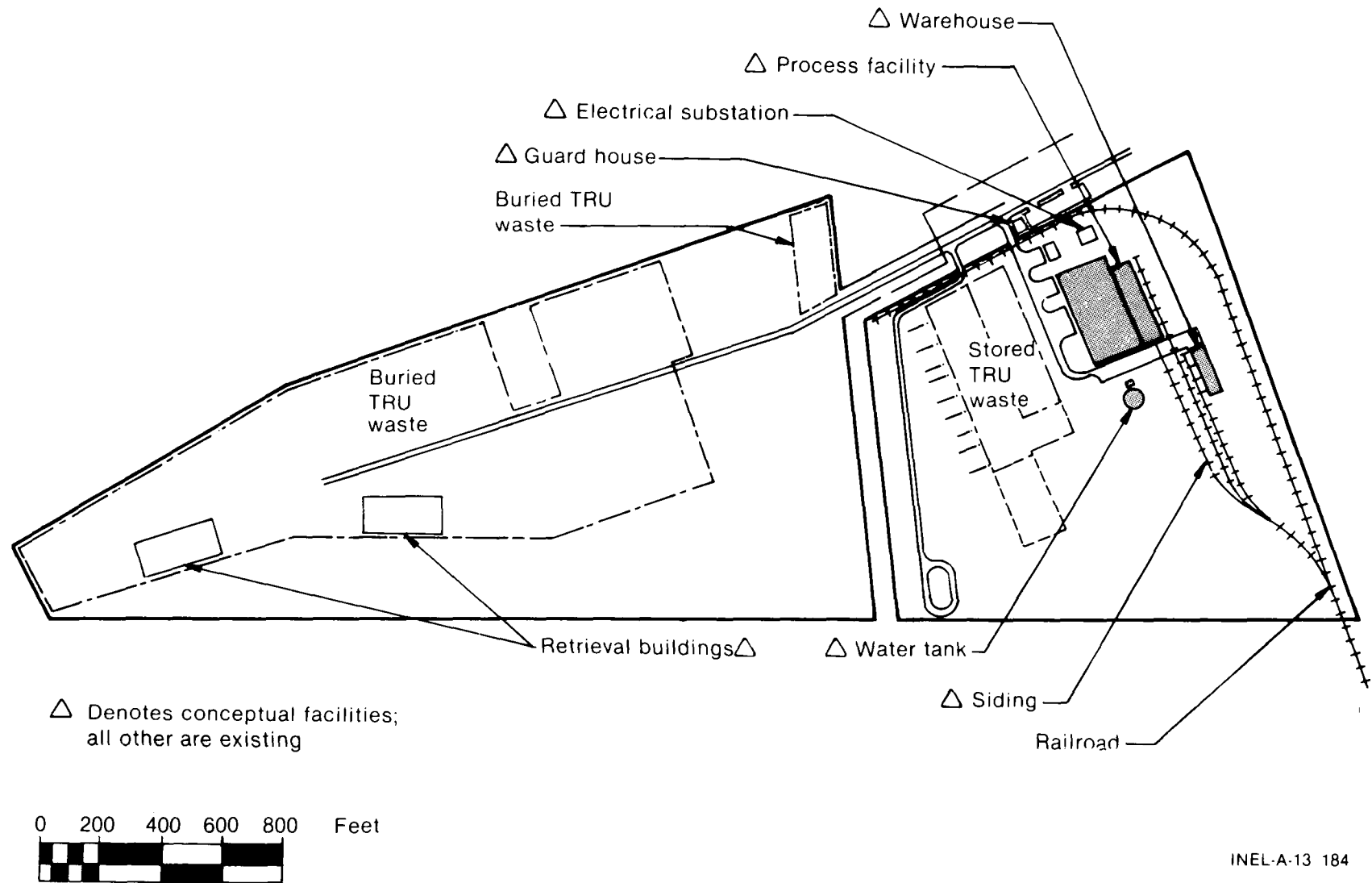
This section discusses the methods studied for (1) retrieval of the buried TRU waste and contaminated soil at the RWMC, (2) onsite processing and packaging, and (3) shipment to an offsite geologic repository. A general layout of the facilities and storage areas developed for the waste management alternatives 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 (4) in Subsection 7.4.1.1.

Two handling methods were evaluated for retrieving the buried waste and contaminated soil: (1) handling by operator-controlled equipment (direct control); and (2) handling by remote-controlled equipment. Confinement during retrieval operations would be provided by a movable, double-walled structure, operating at subatmospheric pressure. See Guideline (14) in Subsection 7.4.1.1.

Three processing options were considered: (1) package only; (2) compact, immobilize, and package; and (3) incinerate and package.

Evaluations of incineration methods (FMC 1977, Kaiser Engineers 1977), discussed in Subsection B.4.2 in Appendix B, have concluded that slagging pyrolysis is the most promising method for processing the buried INEL TRU waste (see also Subsection 4.4.2). An independent task force reached essentially the same conclusion (Cox et al. 1978). Slagging pyrolysis would achieve both physical and chemical stabilization of the waste, as well as volume reduction, in one operation. Immobilization of the contaminated soil would also be achieved. Therefore, the slagging pyrolysis process was selected for study here.

The slag product containers were assumed to be 55-gal steel drums because of past handling experience and the availability of this type of container.



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Fig. 9-1. Site plan of existing and conceptual facilities for retrieval, onsite processing, and shipment to an offsite geologic repository.

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

Thus, the sequence of operations selected for study was (1) retrieval with either direct-controlled or remote-controlled equipment inside a movable, double-walled structure at subatmospheric pressure; (2) processing by slagging pyrolysis with the slag packaged in 55-gal drums; and (3) rail shipment to an offsite geologic repository. These operations and their effects are discussed briefly in the following subsections.

9.1 SHIPMENT AS SCHEDULED

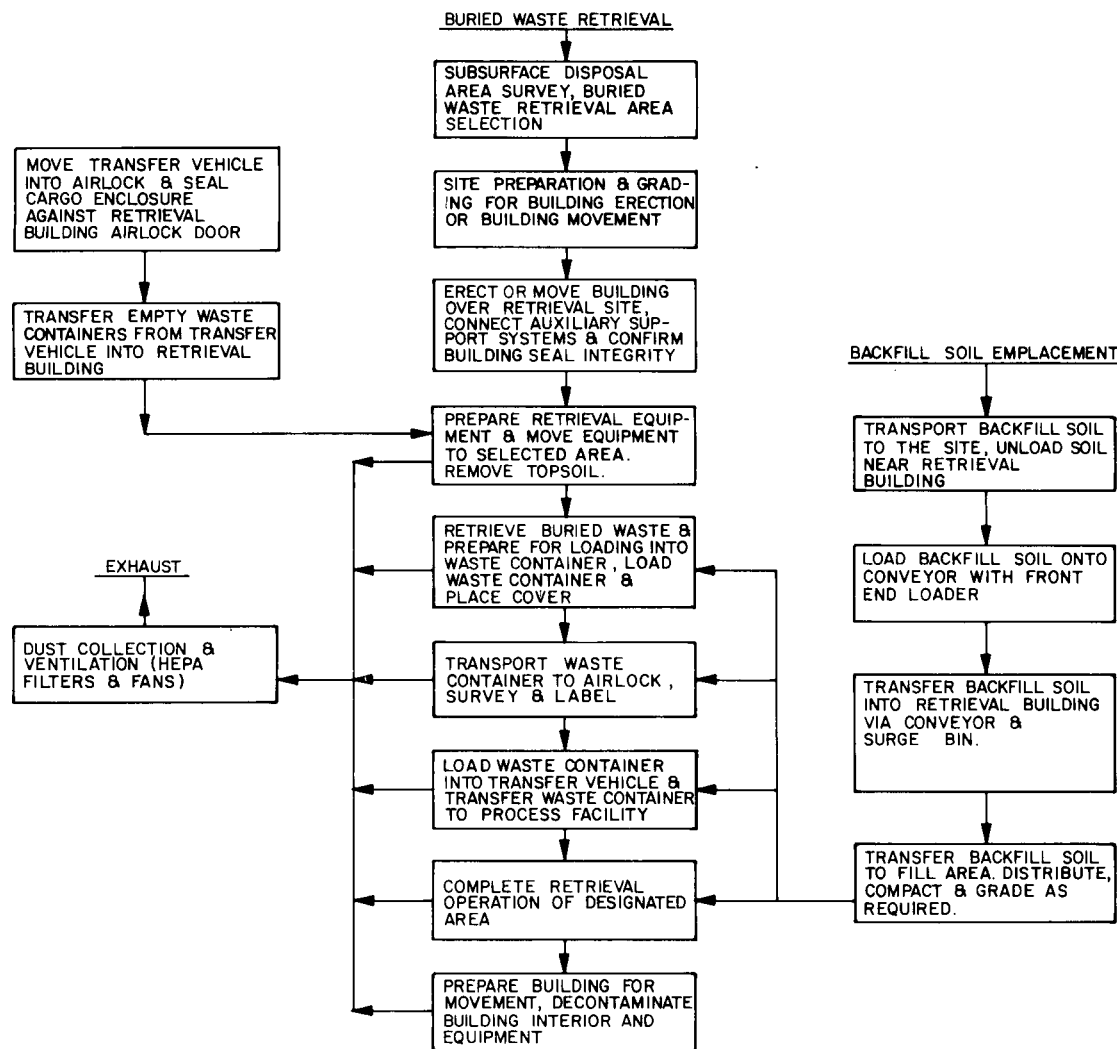
This subsection discusses Alternative III, in which the TRU waste buried at the RWMC would be retrieved, processed, and shipped to an offsite geologic repository, as scheduled.

9.1.1 Retrieval

The sequence of retrieval activities required for both direct and remote control methods is illustrated in Figure 9-2. With either retrieval method, two retrieval buildings would be required to meet the 10-yr retrieval guideline. A single large building would be unwieldy to move, and would necessitate an interruption of all retrieval and transfer operations while repositioning the retrieval building.

9.1.1.1 Direct-Control Retrieval

The direct-control retrieval building (see Figure 9-3) would be a mobile, double-walled structure. It would provide double containment of the waste during retrieval operations. Air pressure below ambient would be maintained between the outer and inner walls, and a still lower pressure would be maintained within the building. See Guideline (14) in Subsection 7.4.1.1. Thus, air leakage would be directed inward, precluding the escape of contaminants to the environment. The successively negative pressure differentials would be maintained by two separate ventilation systems. All air removed by the ventilation systems would pass through a series of roughing



NOTES

1. DIRECT CONTROL METHOD

OPERATOR CONTROLS MACHINE BY USE OF DIRECT CONTROLS FROM ENVIROMENTALLY PROTECTED CAB LOCATED ON THE MACHINE.

2. REMOTE CONTROL METHOD

OPERATOR CONTROLS MACHINE(S) FROM REMOTE LOCATED CONTROL ROOM BY USE OF RADIO EQUIPMENT, TV CAMERAS & MONITORS.

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

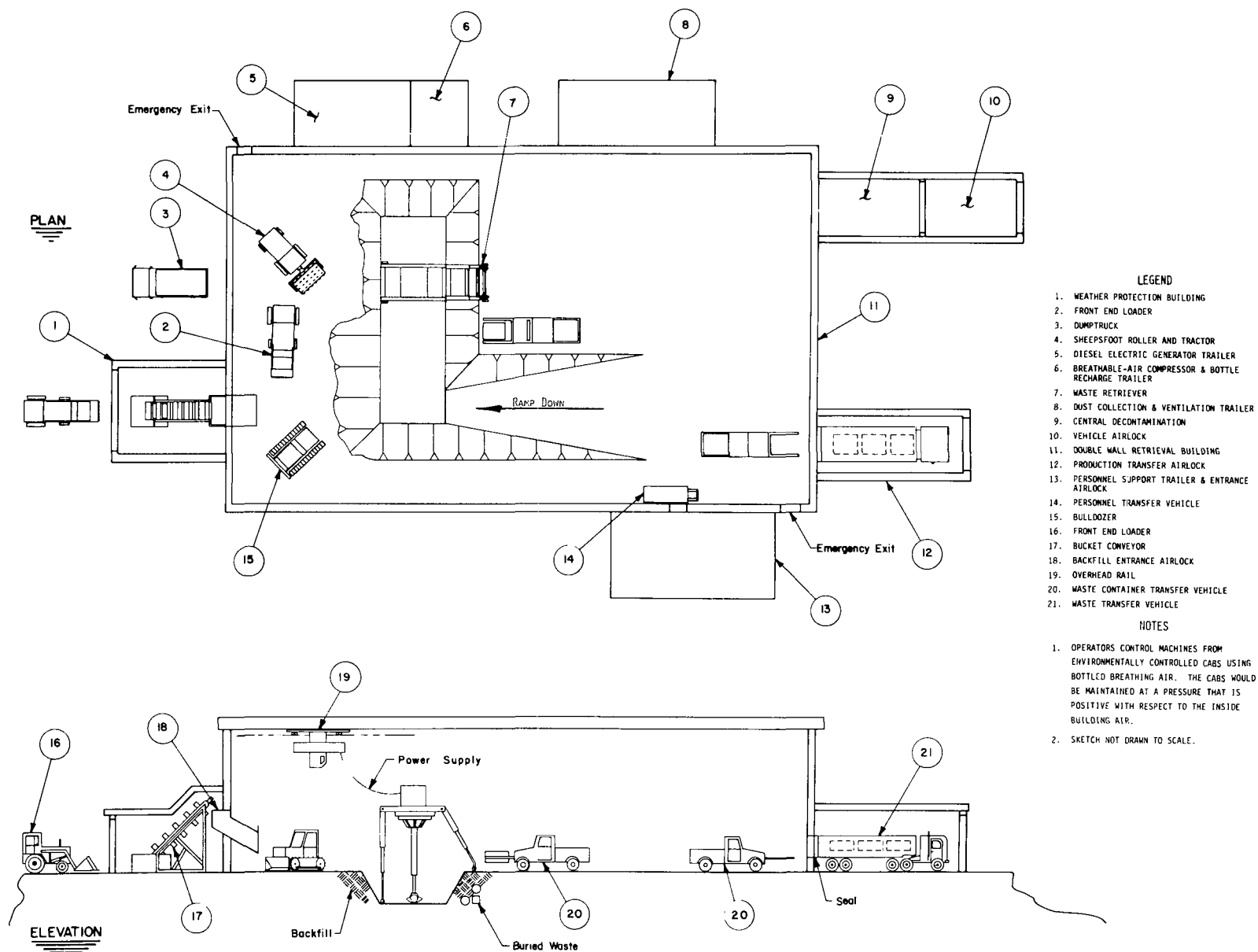


Fig. 9-3. Direct-control retrieval building.

filters and then through one or two banks of High Efficiency Particulate Air (HEPA) filters. Air from the inner zone would pass through two HEPA filter banks; air from the outer zone, through only one HEPA filter bank. A seal mechanism would seal the building with the ground 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. Movable, channel-shaped steel tracks would be provided to permit the building to be moved on a year-round basis. One production transfer airlock, a vehicle airlock, a personnel airlock, two emergency personnel exits, and a backfill port would be provided through the building walls.

Electrical power, heating, ventilating, and other auxiliary support systems would be provided from movable trailer-mounted facilities.

One corner of a pit or group of trenches would be selected for initial retrieval operations. To provide a working surface for erecting a retrieval building, the adjacent ground surface would be stabilized by techniques such as intermixing cement with the soil and spraying the mixture with water, or spraying the soil with an asphaltic compound. The clay cover and a portion of the soil cover over the retrieval area would be removed. The remaining soil cover over the waste would be stabilized. (Stabilization is required for the building seal mechanism to seal the building effectively to the ground during retrieval operations.) The area would then be covered with an impervious membrane to protect it from weather and to prevent erosion. After erection of the building, the membrane would be removed from the retrieval area and the building moved into the first retrieval position. The retrieval equipment would then be moved into the building through the vehicle airlock.

All operations within the retrieval building would be performed by personnel directly controlling the retrieval equipment from environmentally protected cabs located on the equipment. If shielding of operators is necessary, removable shields would be mounted on the retrieval equipment. Bubble suits would be required for personnel performing special operations or maintenance. (A bubble suit completely encloses the wearer and is supplied with breathing air from an external source.)

Specific retrieval procedures would vary with the dimensions of the waste trenches and pits and with the type or condition of the waste. For retrieval from pits, a hole would be excavated and a ramp constructed to facilitate excavation and removal of the waste and contaminated soil from the pit. For retrieval from trenches, the waste and associated soil would be removed from within the boundaries of the trench, but generally the soil between trenches would not be disturbed.

All material to be transferred to the processing facility would be placed in transfer containers. The containers would be rectangular boxes approximately 4 x 4 x 7 ft with a filled capacity of about 90 ft³. When full, each container would be closed and moved to a transfer vehicle. The waste transfer containers would be monitored for gamma radioactivity. If high gamma activity were detected, the container would be placed in a shield for transfer.

In addition to the soil intermixed with loose waste, the soil located immediately below and around the waste would be retrieved to ensure adequate removal of all contaminants. Any sound drums encountered would be removed intact and placed in transfer containers. Damaged drums and other loose or partially contained waste would also be placed directly in these containers. Large items would be reduced in size as necessary in the retrieval building so that the resulting pieces would fit in the transfer containers. Backfilling of the excavated area, as indicated in the block flow diagram of Figure 9-2, would be performed continually during retrieval. Care would be taken to avoid contaminating the backfilled areas by the retrieval operations.

There are a few items of buried waste that exhibit extremely high radiation levels, upwards of 1,000 roentgens per hour at the surface. When radiation measurements during retrieval indicate the presence of such items, the items would be left in place with sufficient soil to shield retrieval personnel to acceptable levels. Retrieval of these few items would take place as a special effort, the schedule of which would depend on a number of materials flow considerations.

When as much of the waste had been retrieved as could be excavated without moving the retrieval building, the interior of the building would be surveyed for contamination. Any contamination would be removed or fixed in place with an impermeable coating. All retrieval equipment inside the building would be positioned near the forward wall of the building and covered to prevent the spread of contamination. The face being excavated would be covered with plastic sheeting.

Before moving the building to the next retrieval position, the impervious membrane over the next retrieval area would be removed. The mobile auxiliary support systems would be disconnected from the retrieval building and moved separately to the new location. Towing tractors would be positioned to move the building, the retractable wheels would be lowered to lift the building off the ground, and the tractors would tow the building to the next retrieval position. As the wheels were raised, the building would settle and would be sealed to the ground. The support systems would be reconnected, and retrieval operations would recommence. Retrieval operations would be coordinated so that one of the two retrieval buildings would continue retrieval operations while the other building was being repositioned. Thus, there would be a continuous flow of retrieved waste from the retrieval area to the processing facility.

9.1.1.2 Remote-Control Retrieval

Remotely controlled equipment would be used to perform essentially the same operations in the remote-control retrieval buildings as would be performed by direct control in the direct-control retrieval buildings. The remote-control retrieval buildings and equipment would be nearly identical to those used for direct-control retrieval. See Figure 9-4. The procedures for erecting and relocating the buildings would also be similar to those for direct-control retrieval.

Retrieval would be performed by retrieval equipment operated remotely from a control room. The equipment would be controlled by operators using direct vision from the control room, or television cameras mounted on the equipment, or a combination of the two.

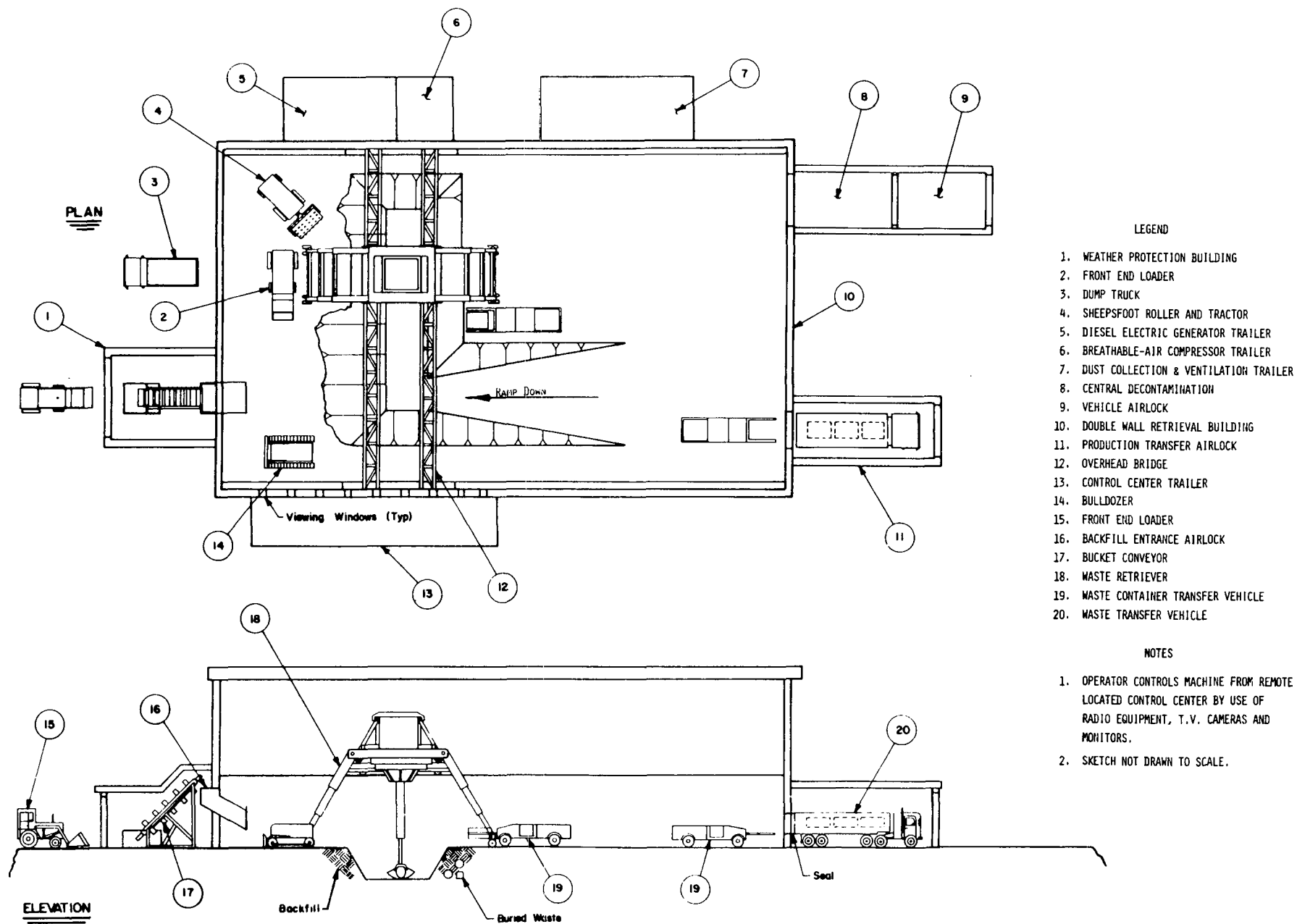


Fig. 9-4. Remote-control retrieval building.

9.1.1.3 Transfer of Waste

The waste and contaminated soil, in closed containers, would be transferred from the retrieval facilities to the processing facility in low-speed transfer vehicles consisting 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. The stainless steel liner and the van body would each be sealed during transfer of the waste.

When loading or unloading at a facility airlock, the van body and liner would be sealed to the airlock entrance. An airtight extension of the airlock would thereby be formed. The stainless steel liner would be periodically surveyed for contamination and decontaminated as necessary. Contamination of the exterior of the vehicle would not be expected.

9.1.2 Processing

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

9.1.2.1 Reasons for the Choice of Slagging Pyrolysis Processing

Some of the buried TRU waste at the RWMC has already been in the ground for as long as 25 yr. The original containers have, for the most part, deteriorated. Experimental retrieval projects have shown that the buried waste currently consists of breached drums, loose waste, and contaminated soil. The amount of contaminated soil, or soil that would become contaminated during retrieval, is estimated to be 3,750,000 ft³. Separating the waste from

the soil and sorting the combustible waste from the noncombustible waste would be difficult and costly. Some of the waste contains reactive chemicals, toxic substances, and possibly even biological materials. Definite hazards would be associated with manually sorting the intermixed TRU waste, beta-gamma waste, and soil. If the buried waste were to be retrieved, the preferred approach would be to remove the waste and contaminated soil from the ground and process the material through a treatment facility with a minimum of sorting and preparation. The use of slagging pyrolysis as an incineration method would minimize the preprocessing costs as well as the hazards to operating personnel. Furthermore, the slagging pyrolysis process can accommodate non-combustibles (including soil) in substantial quantities. The product of the process is an inert slag of low leachability.

9.1.2.2 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 United States in 1971. Three plants, each capable of incinerating about 190 to 220 tons^(a) 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 is being modified 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.

(a) Short ton (2,000 lb).

9.1.2.3 Conceptual Processing of INEL TRU Waste by Slagging Pyrolysis

A conceptual flow diagram for the processing of buried TRU waste by slagging pyrolysis is presented in Figure 9-5. The preliminary layout for a facility incorporating the necessary functions is shown in Figures 9-6, 9-7, and 9-8. To process the estimated 6,250,000 ft³ of buried waste and soil in 10 yr, two slagging units would be incorporated into the facility. (Additional self-generated waste and D&D waste would also have to be processed.) These units would be designed to process unsegregated waste and each would have a capacity of about 47 tons/day of waste and contaminated soil.

9.1.2.3.1 Preprocessing

Retrieved buried waste, in closed containers, would be transferred from the SDA to the receiving airlock of the processing facility. All operations in the facility, from waste entry into the airlock through packaging of the output product, would be remotely controlled. After passing through the airlock, each container would 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 incinerators during minor interruptions in the receipt of waste at the processing facility. Under normal operating conditions, incoming containers would be dumped onto a conveyor. The containers would then be returned to the waste retrieval area for reuse.

Intact drums and other sound 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 large or potentially 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.

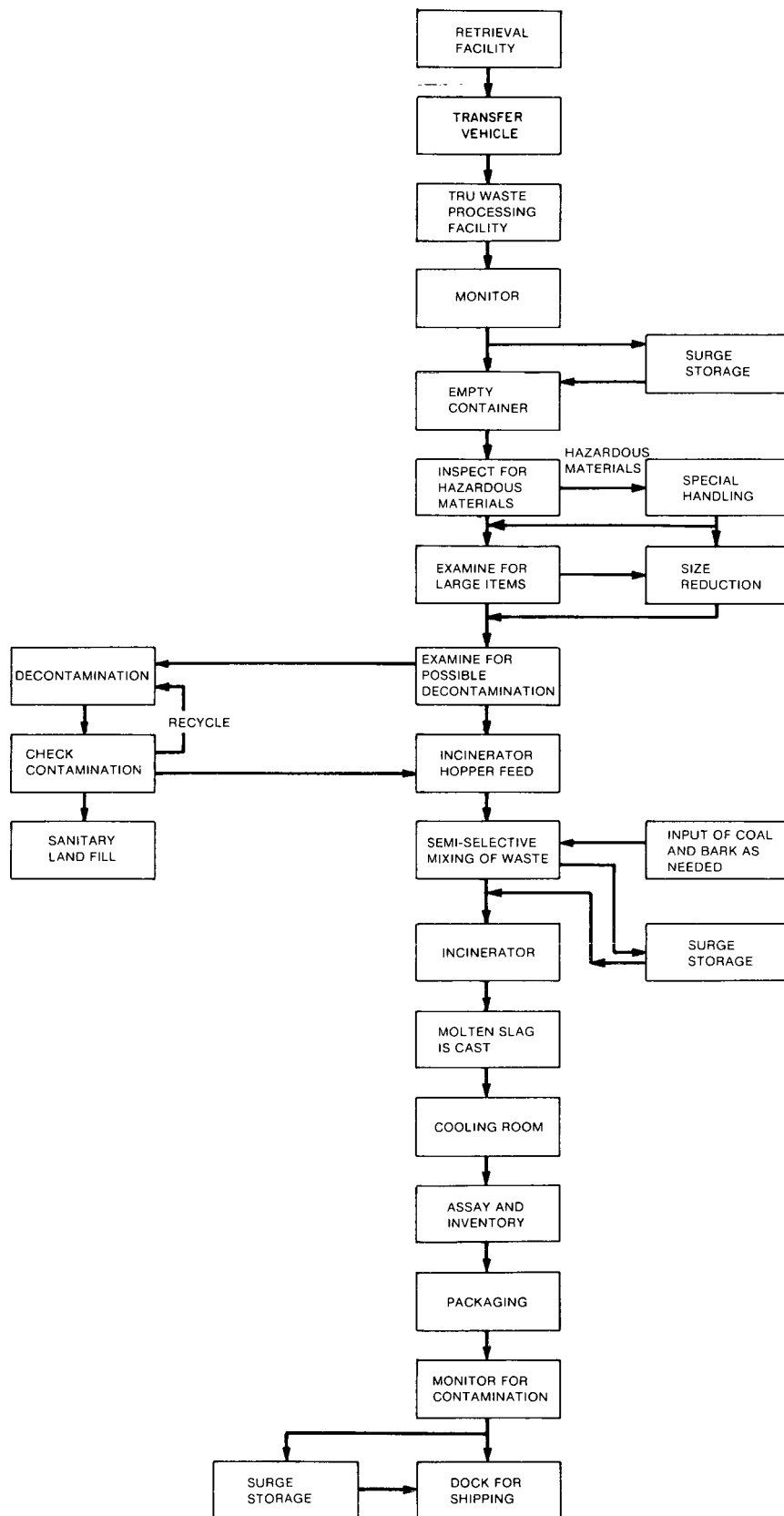


Fig. 9-5. Block flow diagram for processing TRU waste by slagging pyrolysis.

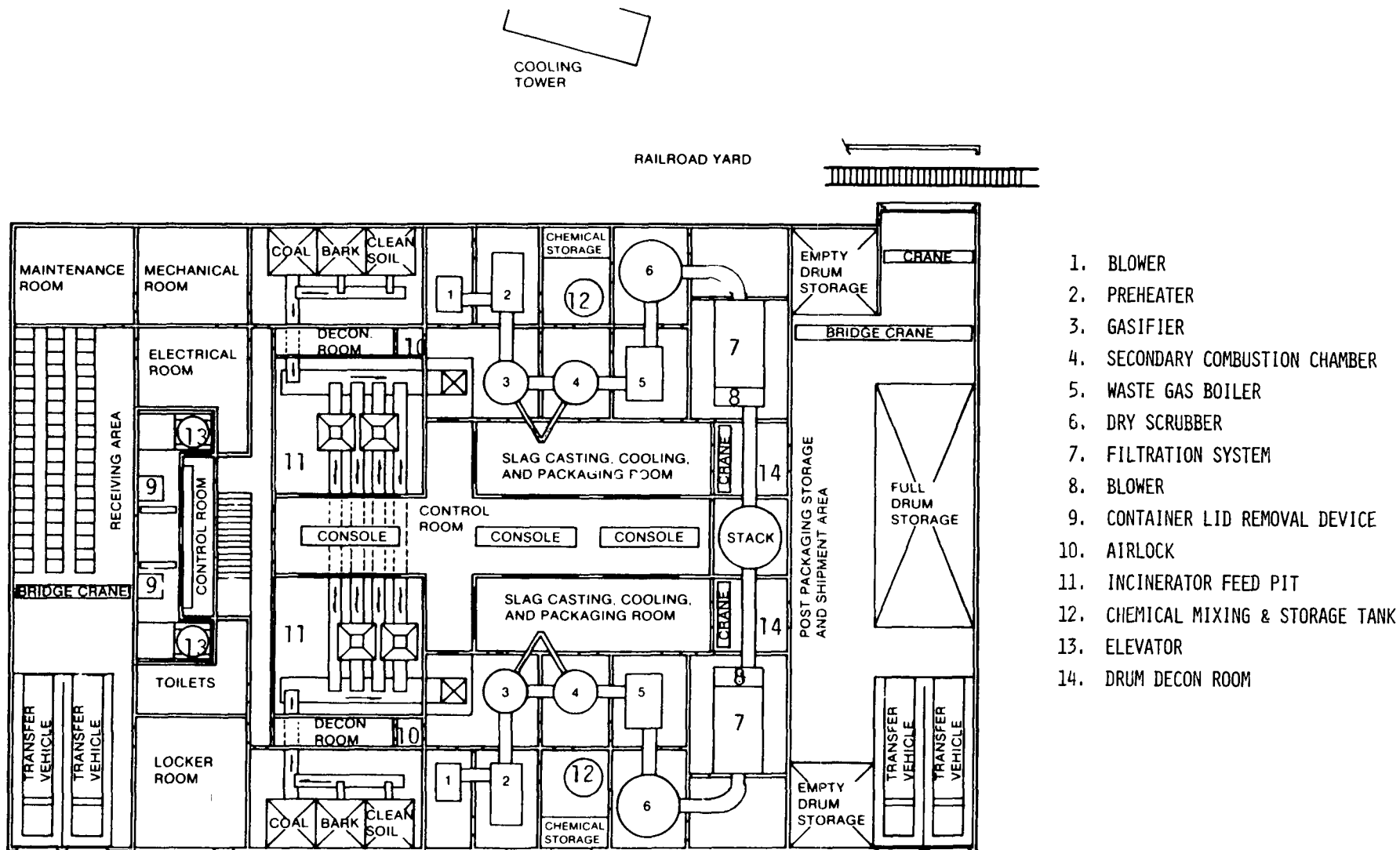


Fig. 9-6. Plan of ground level for slagging pyrolysis facility for buried TRU waste.

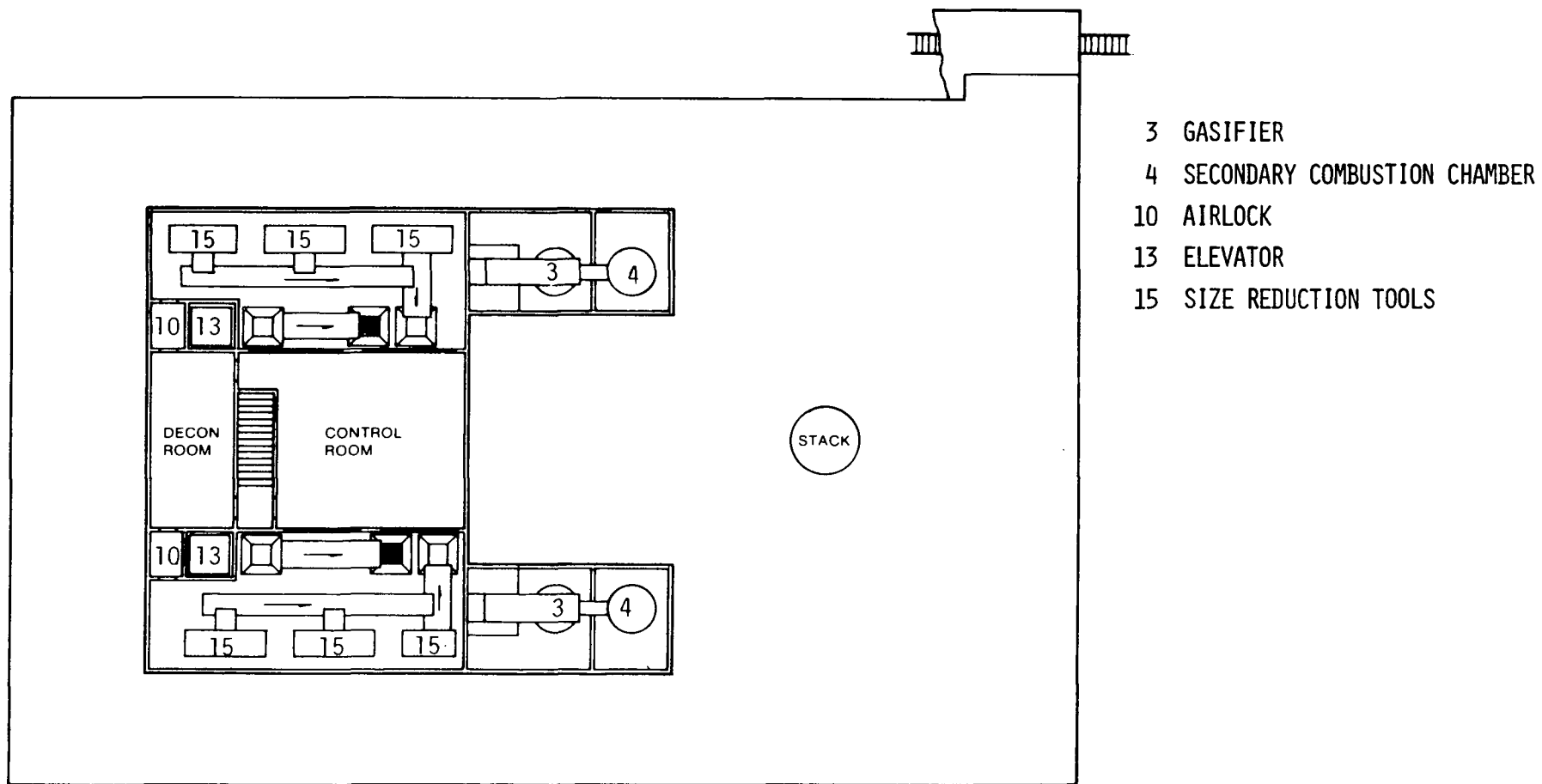


Fig. 9-7. Plan of second level for slagging pyrolysis facility for buried TRU waste.

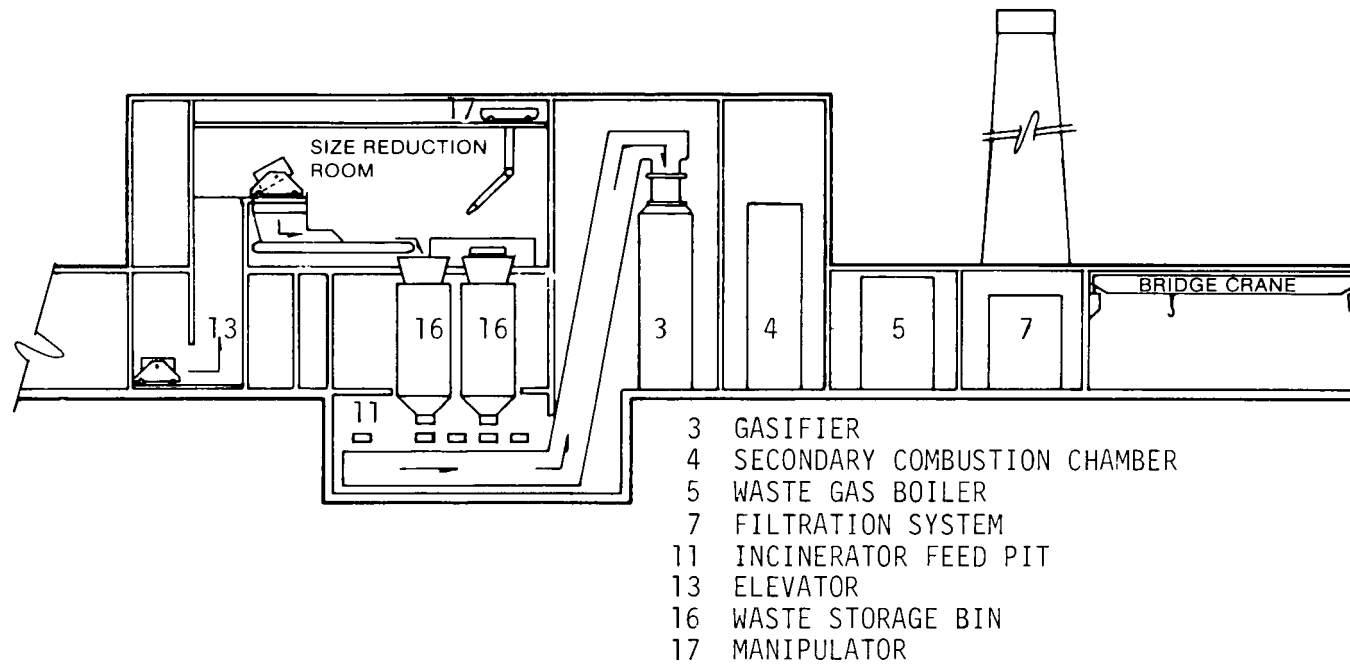


Fig. 9-8. Cross section of slagging pyrolysis facility for buried TRU waste.

The waste would be blended to achieve some uniformity of the feed material. Incinerator operations would be impaired if large quantities of noncombustible materials were fed into it without blending with combustible materials. Additionally, a certain minimum proportion of 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 anticipated volume of contaminated soil (3,750,000 ft³) that would be retrieved with the TRU waste would be expected to preclude the need for any makeup soil.

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

9.1.2.3.2 Incineration

Figure 9-9 is a process flow diagram of the slagging pyrolysis and offgas treatment processes. Each 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 airlock. Solids from the offgas treatment system would also be introduced in this manner. The airlock 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

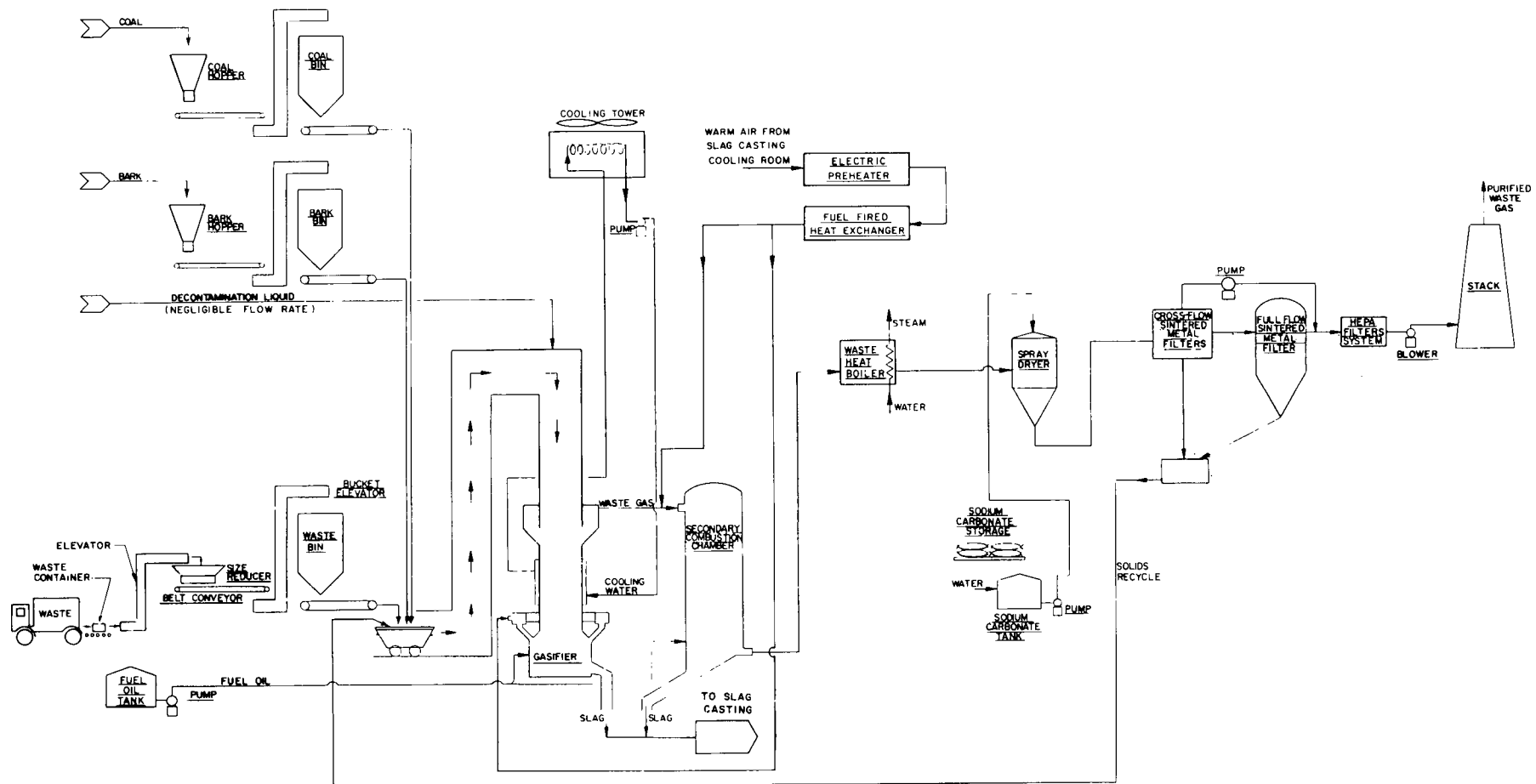


Fig. 9-9. Process flow diagram for slagging pyrolysis and offgas treatment system.

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 vessel 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.

Molten slag would be conveyed through a heated conduit from the gasifier (primary combustor) to the slag-casting chambers, where it would be cast into molds. Gases and particulate matter would leave the top of the gasifier at approximately 1100°F, pass through an outlet plenum, and then flow into the secondary combustion chamber. Here the oxygen-deficient exit gases would be mixed with secondary combustion air, which 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 chambers in the same manner as the slag from the gasifier.

9.1.2.3.3 Slag Packaging

The slag would be poured into molds and moved to cooling chambers. 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 an offsite geologic 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 railcars, 74 containers per carload.

9.1.2.3.4 Offgas Treatment

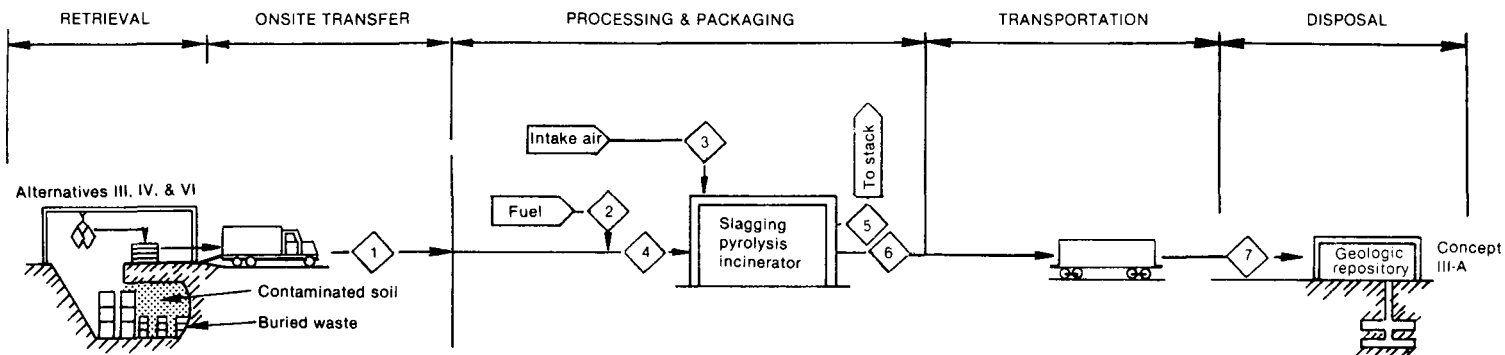
An effective offgas treatment system for each slagging incinerator would be used to minimize environmental releases of particulates, aerosols, and volatile compounds. Airborne solid and aerosol material would contain the greatest quantity of radioactive substances in the effluent gas stream; therefore, 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 offgas 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 offgas stream. The temperature of the entering offgas 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 with subsequent filtration, 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 three types of particle-collection devices arranged in series: 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.

9.1.2.3.5 Flow Rates and Volumes

Figure 9-10 presents the estimated quantities and flow rates for buried waste and soil. 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.



ESTIMATED QUANTITIES AND FLOW RATES FOR SLAGGING PYROLYSIS PROCESSING OF BURIED TRU WASTE TO BE SENT TO THE OFFSITE GEOLOGIC REPOSITORY^(a,b)

	Combus- tibles	Noncom- bustibles	Con- taminated soil	Coal	Bark	Fuel Oil	Ash	Air	Waste Gases	Total
1 WASTE FEED										
ft ³ /day	574	946	1705	N/A	N/A	N/A	N/A	N/A	N/A	3225
tons/day	3.09	21.6	68.2	N/A	N/A	N/A	N/A	N/A	N/A	92.9
10 ³ ft ³ /10 yr	1262	2080	3750	N/A	N/A	N/A	N/A	N/A	N/A	7092
10 ³ tons/10 yr	6.8	47.6	150	N/A	N/A	N/A	N/A	N/A	N/A	204.4
2 FUEL										
ft ³ /day	N/A	N/A	N/A	1600	3250	113	N/A	N/A	N/A	4963
tons/day	N/A	N/A	N/A	40	65	3	N/A	N/A	N/A	108
3 AIR										
10 ⁶ ft ³ /day	N/A	N/A	N/A	N/A	N/A	N/A	N/A	34.1	N/A	34.1
tons/day	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1303	N/A	1303
4 PROCESS FEED										
ft ³ /day	574	946	1705	1600	3250	113	N/A	N/A	N/A	8188
tons/day	3.09	21.6	68.2	40	65	3	N/A	N/A	N/A	201
5 STACK EFFLUENT										
10 ⁶ ft ³ /day	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	36.9	36.9
tons/day	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1410	1410
6 SLAG OUTPUT										
ft ³ /day	N/A	247	779	N/A	N/A	N/A	51	N/A	N/A	1077
tons/day	N/A	21.6	68.2	N/A	N/A	N/A	4.45	N/A	N/A	94.2
7 TRANSPORTATION										
Containers/day	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	146
Railcars/day	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2

N/A Not Applicable

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

(b) Includes all the self-generated waste and 1/2 the D&D waste. Other D&D waste was assumed not processed.

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Fig. 9-10. Flow rates for retrieval, onsite processing, and shipment of buried TRU waste to an offsite geologic repository.

The amounts of coal and bark fed to the incinerator were determined by a 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 pound of combined waste and soil, 0.43 lb of coal and 0.70 lb of bark would be required.

The slag would consist of (1) all the soil and the noncombustible 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 offgas 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. Mass and energy balances were used for the various portions of the process.

Part of the heat from the offgas leaving the secondary combustion chamber of each incinerator would be captured in waste heat boilers. The steam from these boilers 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 cast slag would be 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 1,360 lb including the weight of the drum.

9.1.2.4 Facility

The slagging pyrolysis facility, shown in Figures 9-6, 9-7, and 9-8, would be a reinforced concrete structure designed with three separate controlled ventilation zones. See Guideline (17) of Subsection 7.4.1.1. 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 one or two banks of 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 offgas 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. To the greatest extent practicable, maintenance would be performed by remote control. Airlocks would be provided between the middle zone and the innermost zone to permit personnel access for special purposes. Passage between the middle and outer zones would be through monitoring portals.

9.1.3 Offsite Shipment

ATMX 600 railcars would be used to ship the processed waste to an offsite geologic repository [Guideline (20) of Subsection 7.4.1.1]. To calculate the cost and risks of waste shipment, it was necessary to assume a specific route. The assumed route, shown in Figure 9-11, is one of several possible routes. The actual route that would be followed has not yet been selected. Denver,

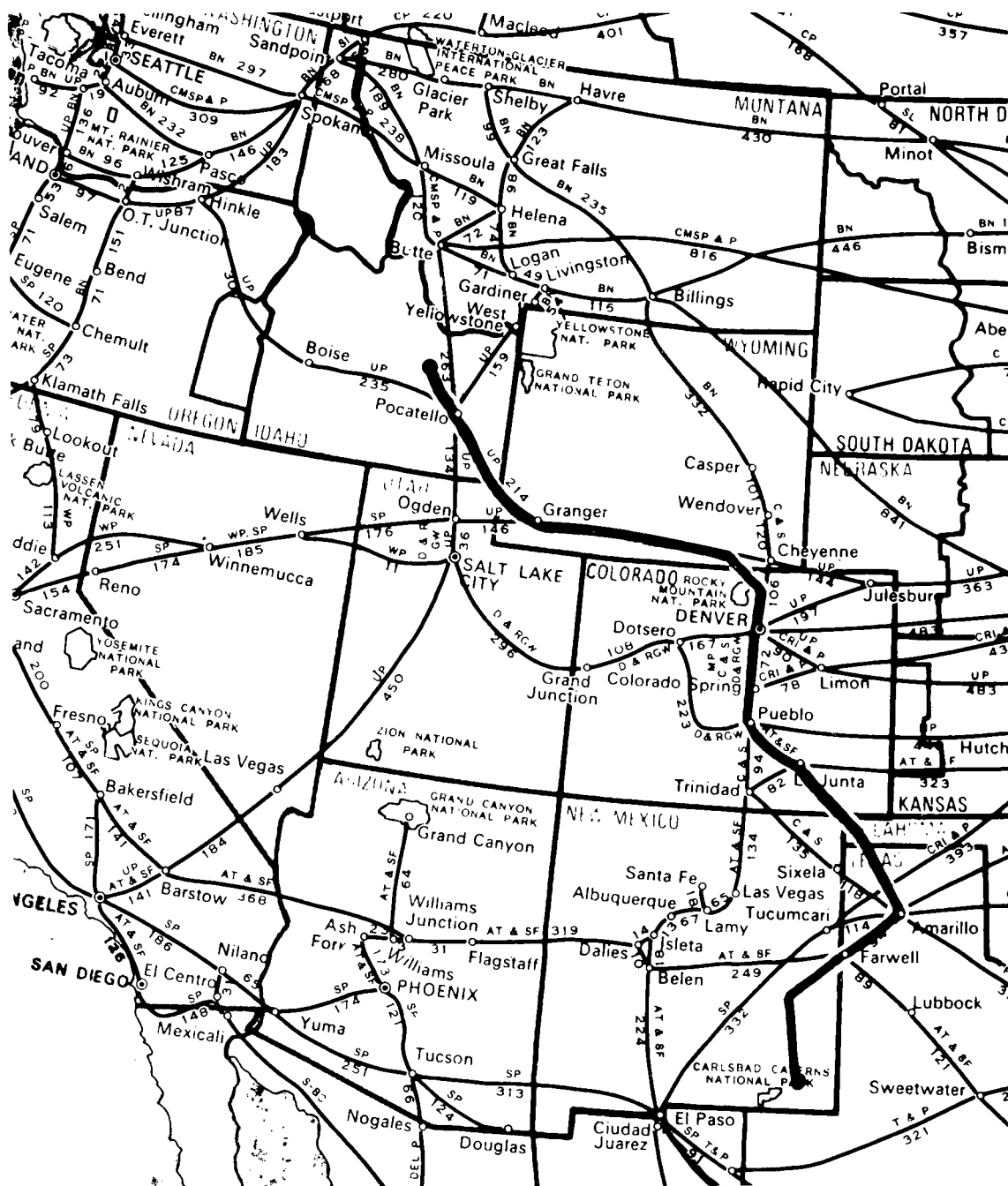


Fig. 9-11. Assumed rail route from the INEL to the Federal Repository.

Colorado is the major population center along the assumed route with Pueblo and Colorado Springs, Colorado, Amarillo, Texas, and Pocatello, Idaho next in size. The remainder of the route is primarily through rural areas of low population density. A one-way trip of approximately 1,400 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 of slag could be placed in each car. The estimated shipment rate would be 434 cars/yr.

9.1.4 Disposal at an Offsite Geologic Repository

A description of an offsite geologic repository and the waste management methods to be used there lies outside the scope of this document. Design studies for the repository are under way 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 surfaces of the retrieval buildings, all equipment located inside the buildings, and the transfer containers would probably become contaminated during operations. It is assumed that dismantling and shipment to an offsite geologic repository would be required. All retrieval facility materials destined for an offsite geologic repository would be processed through the processing facility.

Decommissioning of the processing facility would be conducted so that one of the slagging pyrolysis units 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 an offsite geologic repository. The remaining equipment in the processing facility would probably be decontaminated, and then either disposed of or salvaged. It would probably be possible to decontaminate such equipment as cell doors and the heating and ventilating equipment. Construction materials would also be decontaminated. 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 85,000 ft³. See Guideline (2) in Subsection 7.4.1.2.

9.2 SHIPMENT DELAYED 20 YR

In Alternative IV, retrieval and processing of the buried waste would proceed as scheduled. However, for the purposes of this study, a delay was assumed in the availability of an offsite geologic 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 III (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 9-12. 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 9-13. This type of building is exceptionally strong and relatively low in cost. Each building would be approximately 190 x 600 x 20 ft high.

The use of precast, prestressed concrete panels in constructing low-cost permanent buildings is well established. In general, the panels are about 8 ft wide, of the desired length, and contain prestressed, high-tensile steel wire. They are cast and then transported to the construction site after being

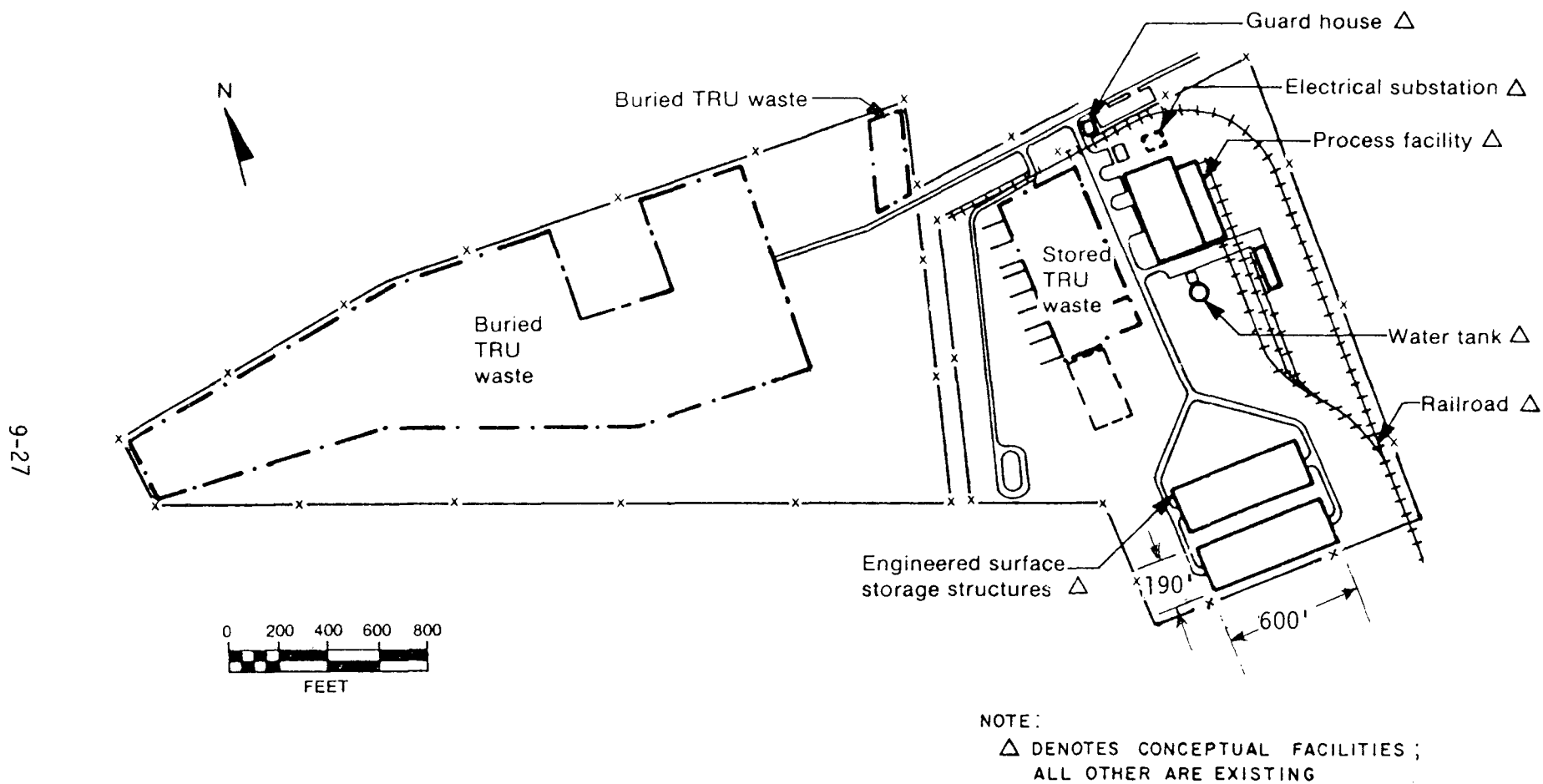


Fig. 9-12. Location and arrangement of 20-yr storage structures for processed waste.

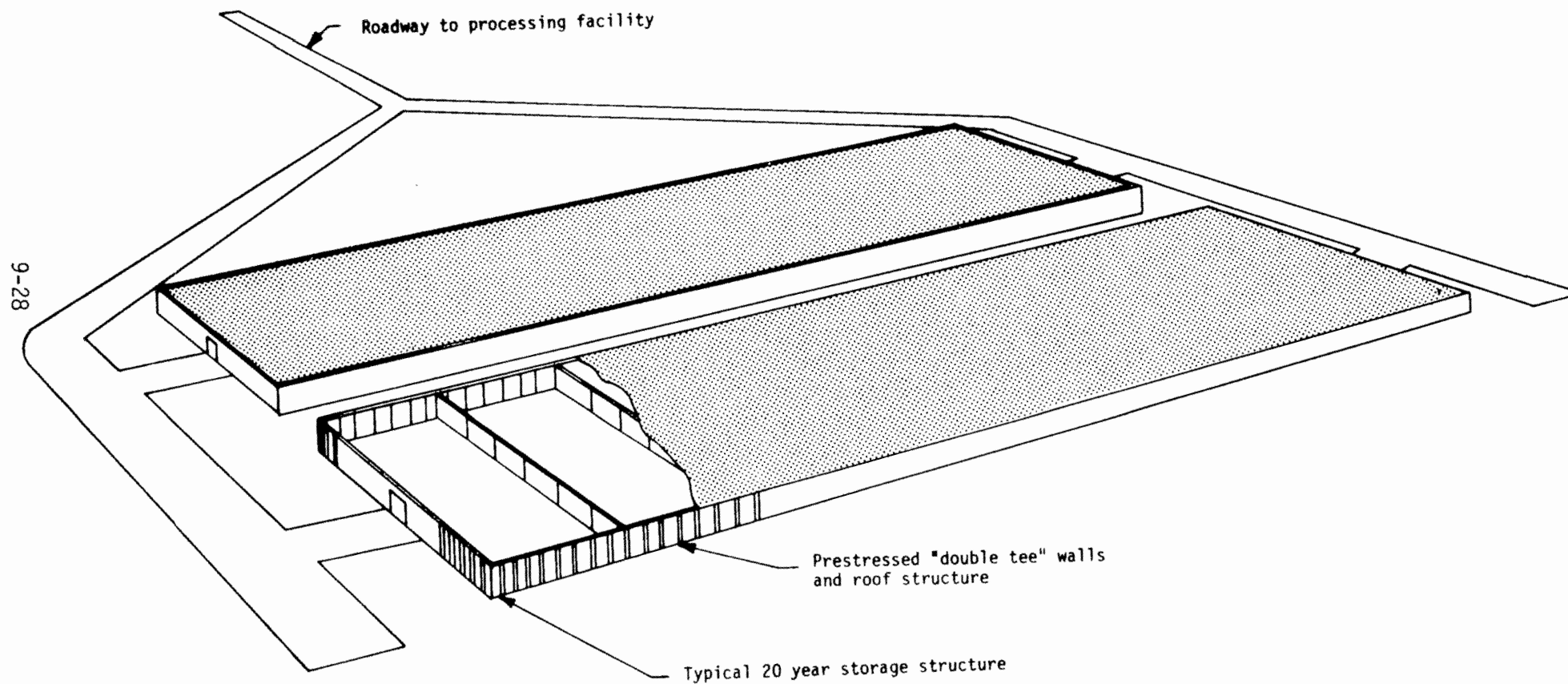


Fig. 9-13. Perspective of 20-yr storage structures for processed waste.

properly aged. Steel plates are imbedded in each edge of each panel, and the plates are welded together during erection of the building. 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 each 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 bank of HEPA filters. Both systems would be provided with fire protection. After the building had 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 six 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 had 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 YR

In Alternative VI, retrieval and processing of the buried waste would be delayed 20 yr and begin in the year 2005. An offsite geologic repository was assumed available at that time so that the waste could be shipped to the repository after treatment at the processing facility.

This alternative is identical to Alternative III except for the 20-yr delay of all facilities and operations. The only change would result from the additional 20-yr decay of the radionuclides and the further decomposition of the already-degraded waste packaging. The amount of contaminated soil that would be processed could conceivably be increased very slightly as a result of the delay.

10.0 ALTERNATIVES INVOLVING RETRIEVAL, PROCESSING, AND DISPOSAL ON THE INEL

In Alternative V, the buried TRU waste would be retrieved, processed, and shipped to a disposal facility on the INEL. Because there are two retrieval modules (methods), three processing modules, and four disposal modules, there are 24 possible combinations within this alternative. (Additionally, one of the disposal modules, Site 14, has two variations: massive and less massive.) The 24 concepts for Alternative V are listed in Table 7-3. Retrieval would begin in 1985 or as soon thereafter as practicable.

10.1 RETRIEVAL OF BURIED WASTE

The retrieval modules would be identical to those for Alternative III, described in Subsection 9.1.1.

10.2 PROCESSING THE BURIED WASTE

Three methods were analyzed for processing the buried waste and contaminated soil under Alternative V. 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 V-A, V-D, V-G, V-J, V-M, V-P, V-S, and V-V in Table 7-3. However, these concepts have different retrieval methods or different disposal methods and locations.

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

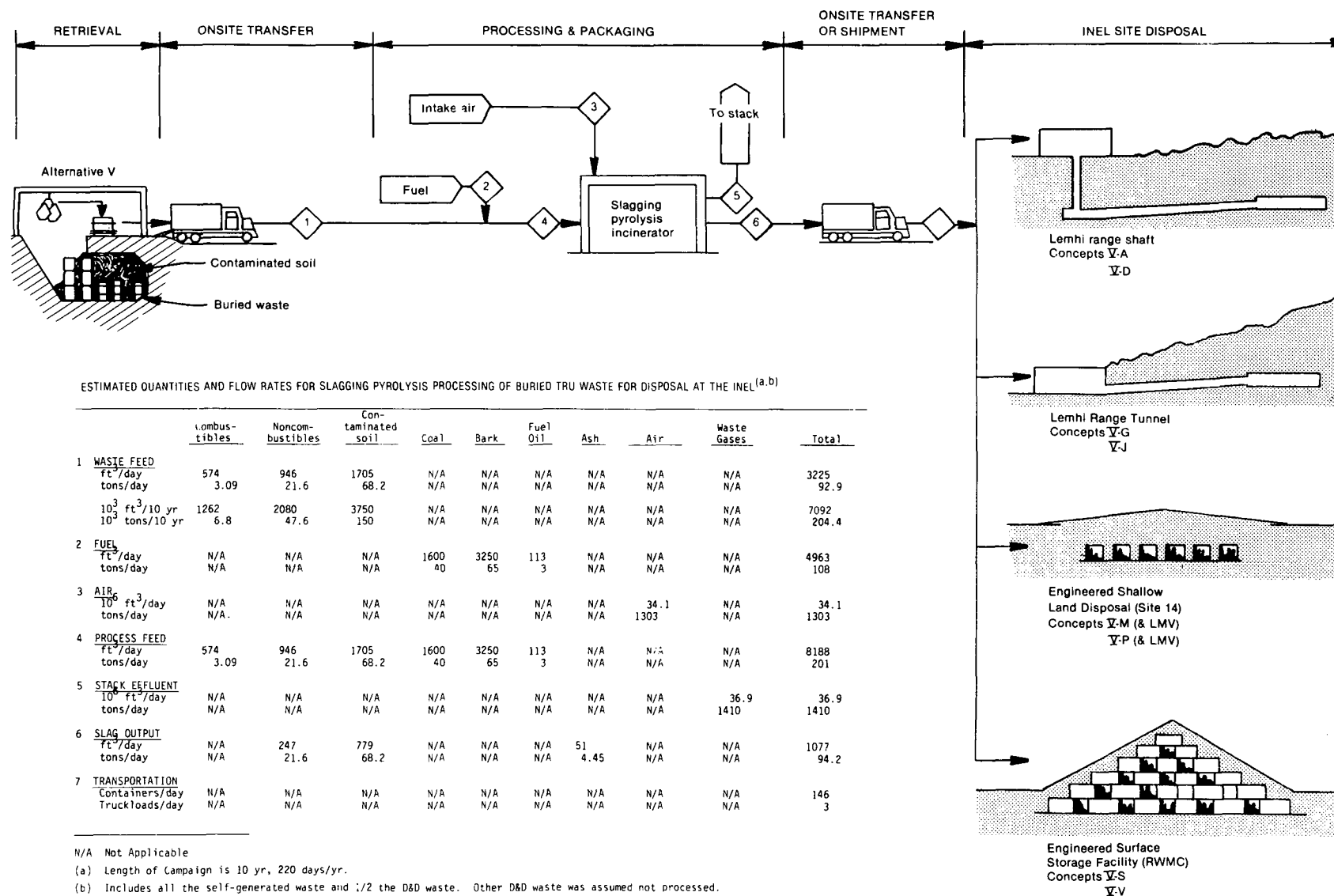


Fig. 10-1. Flow rates for retrieval, onsite processing (slagging pyrolysis), and shipment of buried TRU waste to an onsite disposal facility.

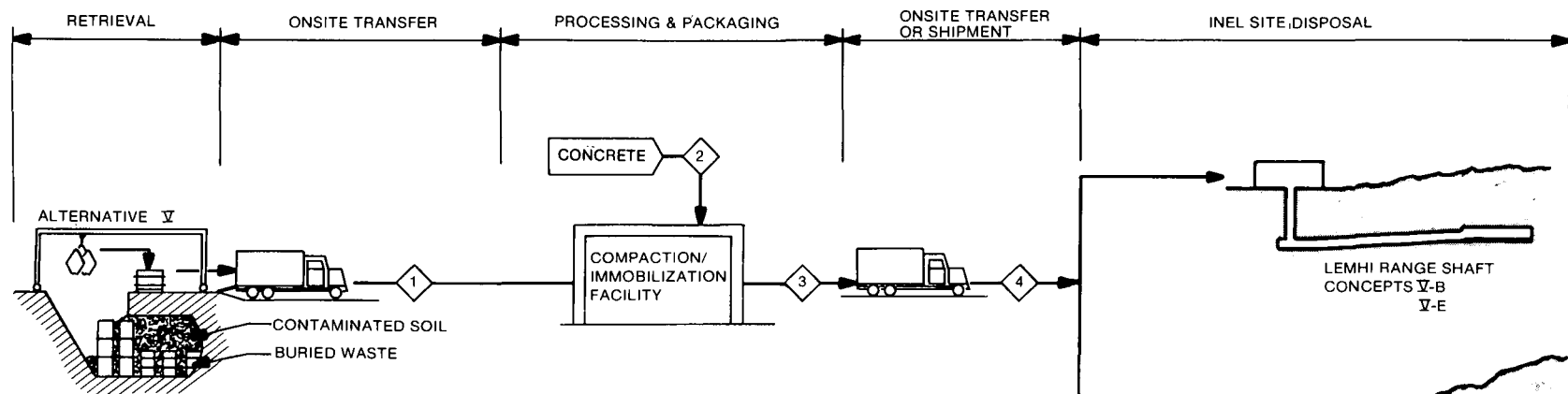
10.2.2 Compaction, Immobilization, and Packaging

This subsection describes the processing operation for Concepts V-B, V-E, V-H, V-K, V-N, V-Q, V-T, and V-W (see Table 7-3). These concepts have different retrieval methods or 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 facility size is the same as that for the stored waste (DOE 1979b). However, the facility would operate three shifts/day instead of one shift/day in order to process the larger amount of buried waste plus contaminated soil. The transfer vehicle from the retrieval area would bring the waste in closed 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 into a temporary storage area or onto 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. The empty containers would be returned to the retrieval area for reuse. 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.

All operations in the facility, from waste entry into the airlock through packaging of the output product, would be remotely controlled. To the greatest extent practical, maintenance would also be performed by remote means.

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



FLOWRATES FOR COMPACTION AND IMMOBILIZATION OF BURIED TRU WASTE^(a,b)

	Materials				
	Combustible	Noncombustible	Contaminated Soil	Concrete	Total
1 WASTE FEED					
ft ³ /day	574	946	1705	N/A	3225
tons/day	3.09	21.6	68.2	N/A	92.9
10 ³ ft ³ /10 yr	1262	2080	3750	N/A	7092
10 ³ tons/10 yr	6.8	47.6	150	N/A	204.4
2 CONCRETE					
ft ³ /day	N/A	N/A	N/A	1110	1110
10 ³ tons/day	N/A	N/A	N/A	83.3	83.3
3 PRODUCT ^(c)					
ft ³ /day	57.4	757	1364	1110	3288
tons/day	3.09	21.6	68.2	83.3	176
4 TRANSPORTATION ^(d)					
Containers/day	N/A	N/A	N/A	N/A	33
Truckloads/day	N/A	N/A	N/A	N/A	4

N/A Not Applicable.

(a) Includes all self-generated waste and half 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.

(d) Concrete blocks.

Fig. 10-2. Flow rates for retrieval, onsite processing (compaction and immobilization), and shipment of buried TRU waste to an onsite disposal facility.

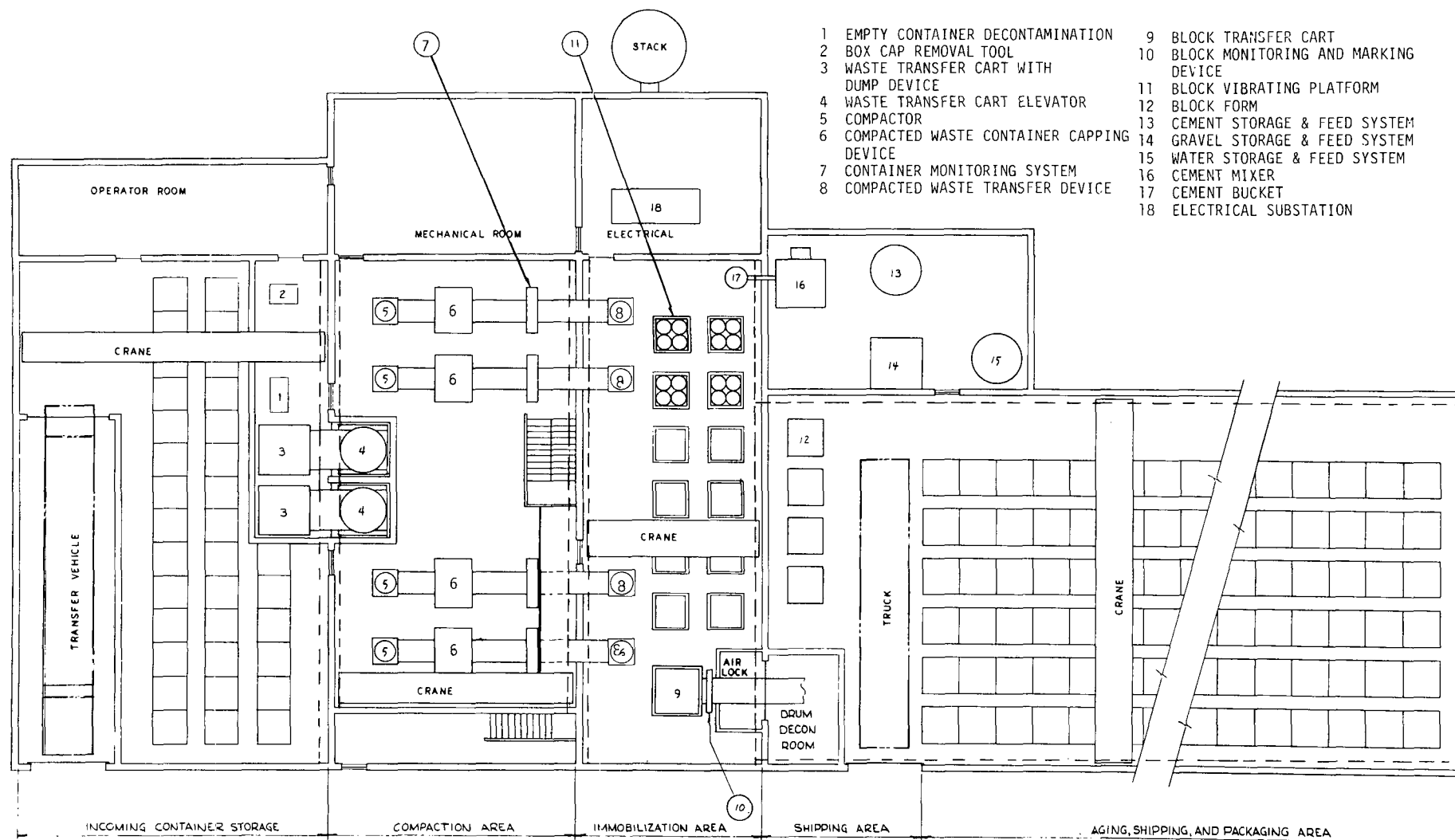


Fig. 10-3. Plan of ground level for compaction, immobilization, and packaging facility for buried TRU waste.

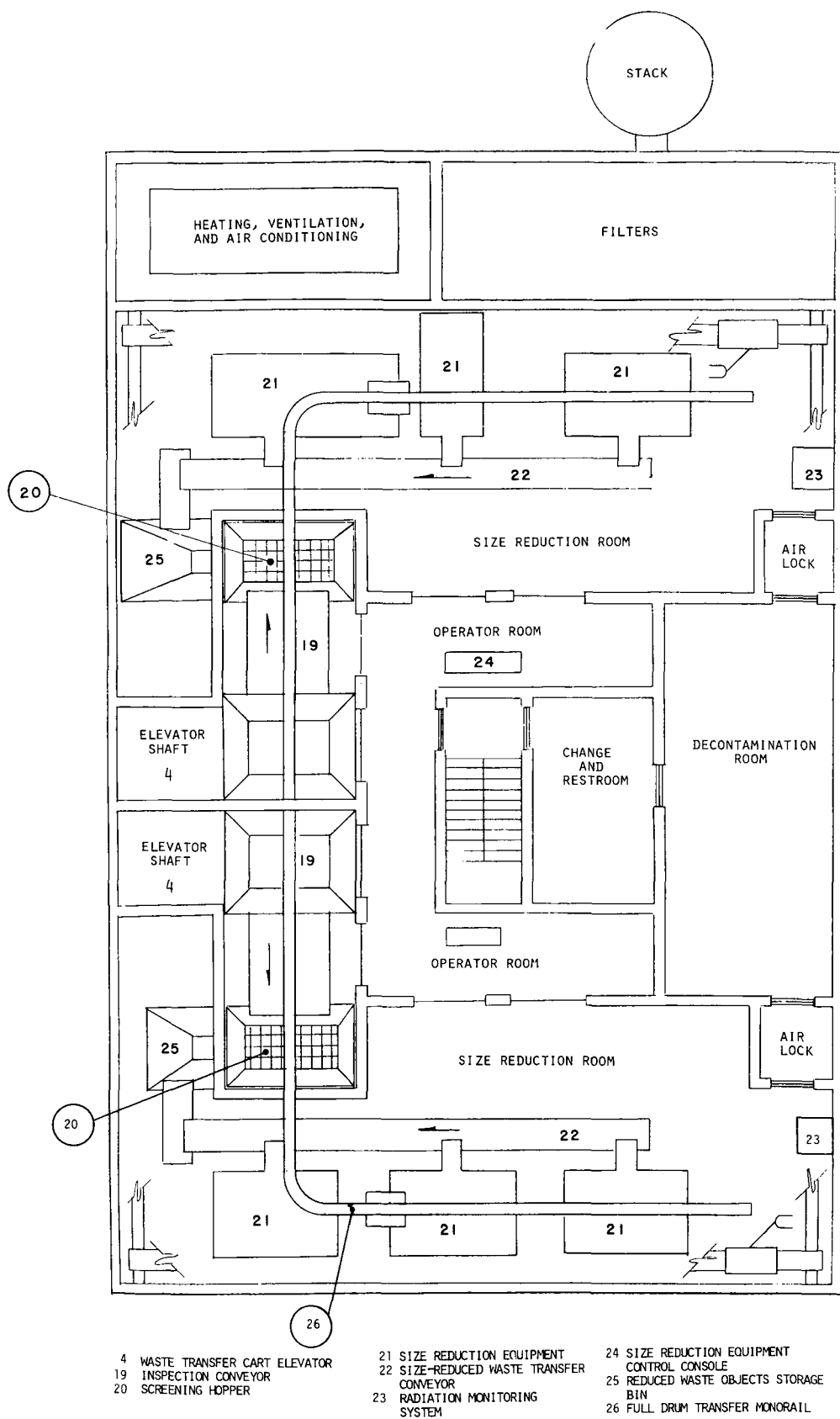


Fig. 10-4. Plan of second level for compaction, immobilization, and packaging facility for buried TRU waste.

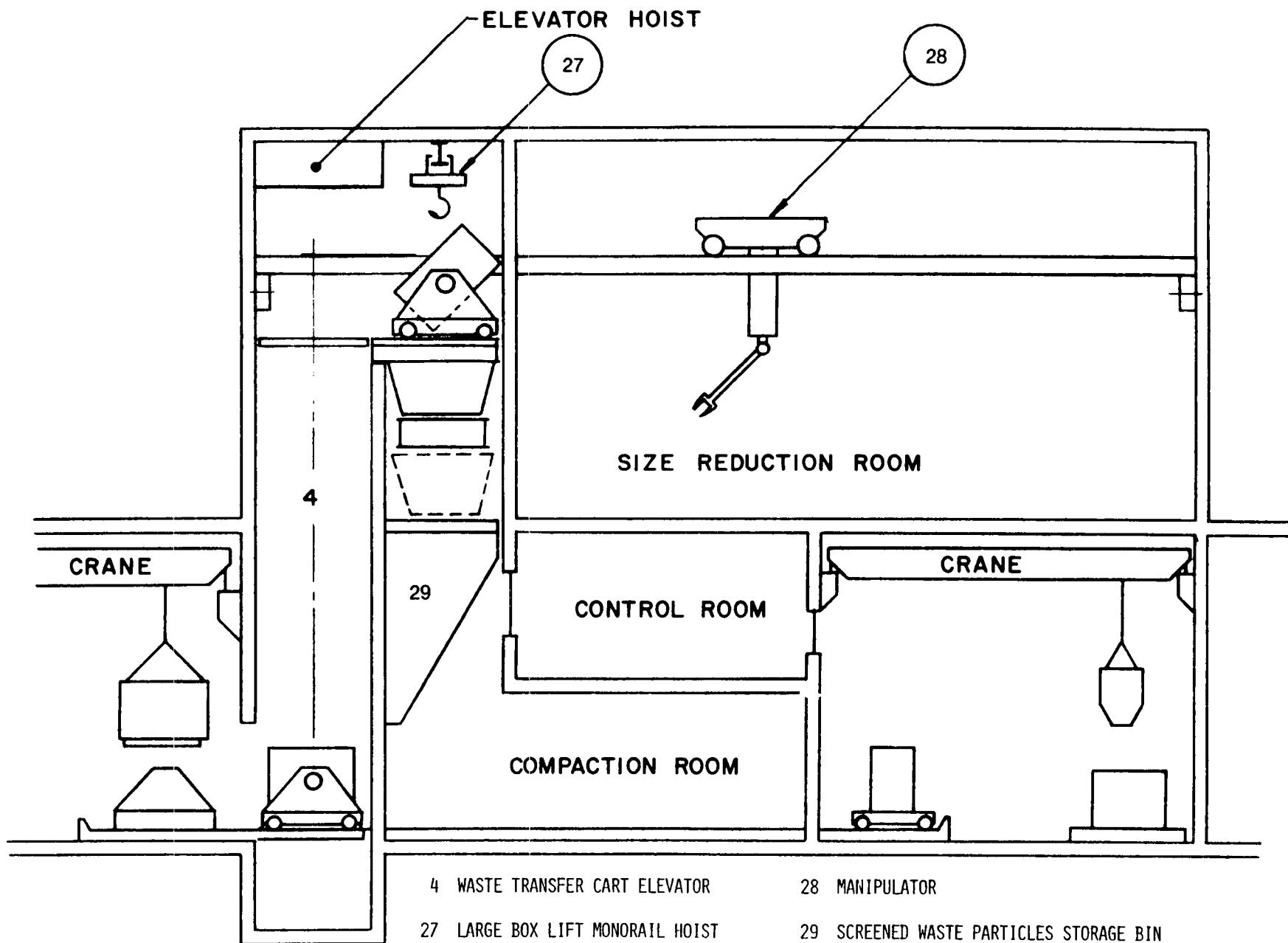


Fig. 10-5. Cross section of compaction, immobilization, and packaging facility for buried TRU waste.

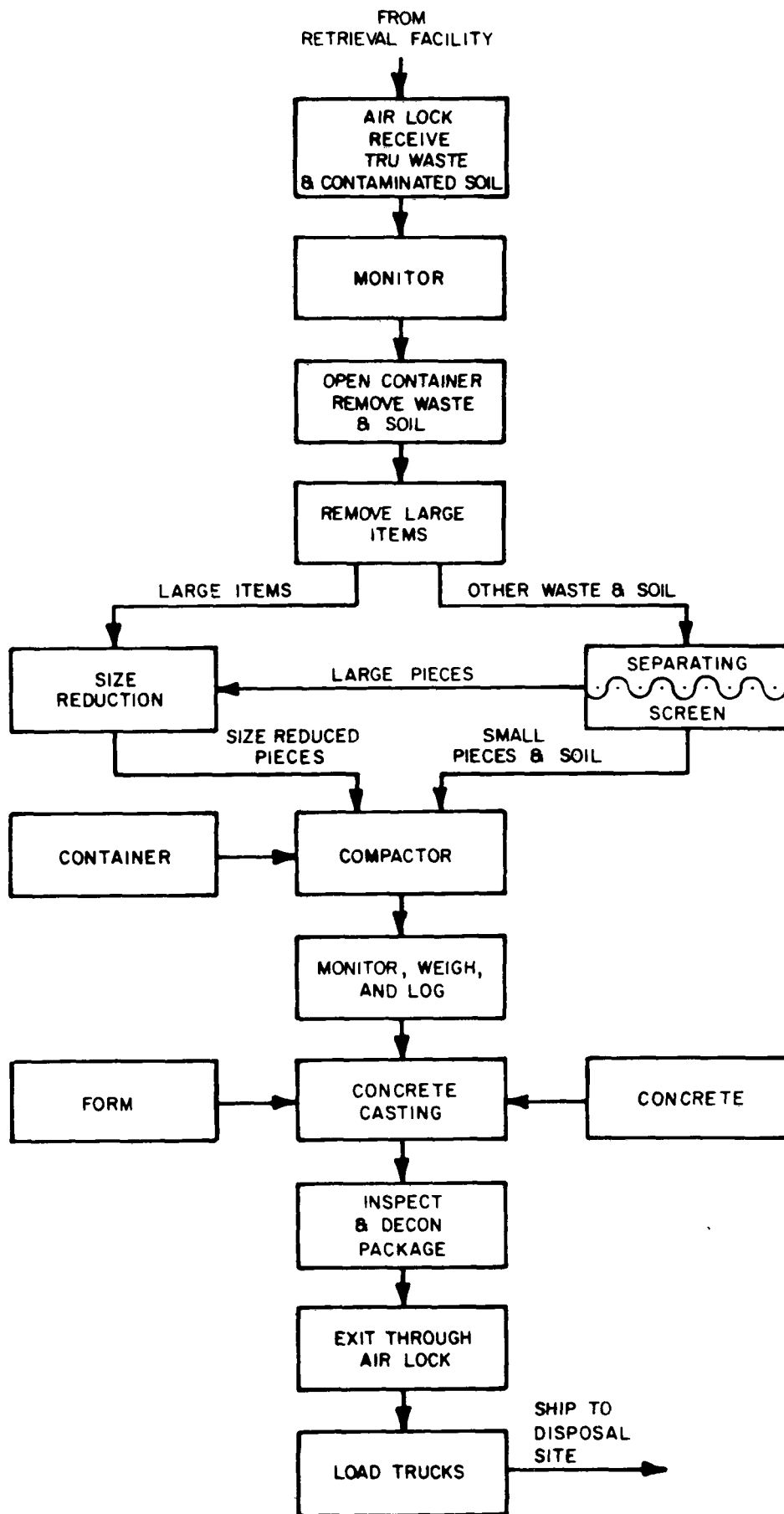


Fig. 10-6. Block flow diagram for processing TRU waste by compaction, immobilization, and packaging.

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 soil and small pieces.

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. Soil and 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 hydraulic piston. Successive filling and compacting would compress the waste and soil into a solid cylinder within the fiberboard container. The compaction operation would reduce the waste and soil input of 7,092,000 ft³ to about 4,790,000 ft³ (an overall volume reduction of 32%). The flow rate from the compaction operation would be about 920 filled fiberboard containers per week.

When full, the fiberboard container would be moved to a capping station and capped. It would then leave the compaction area and enter the immobilization area, where it would be placed into 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 in the concrete. The casting operation would generate about 230 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 10,700 lb. When curing is complete, the blocks would be monitored for contamination. Any contamination would be removed before loading. The blocks would then be moved by the bridge crane to a truck for shipment to the disposal location.

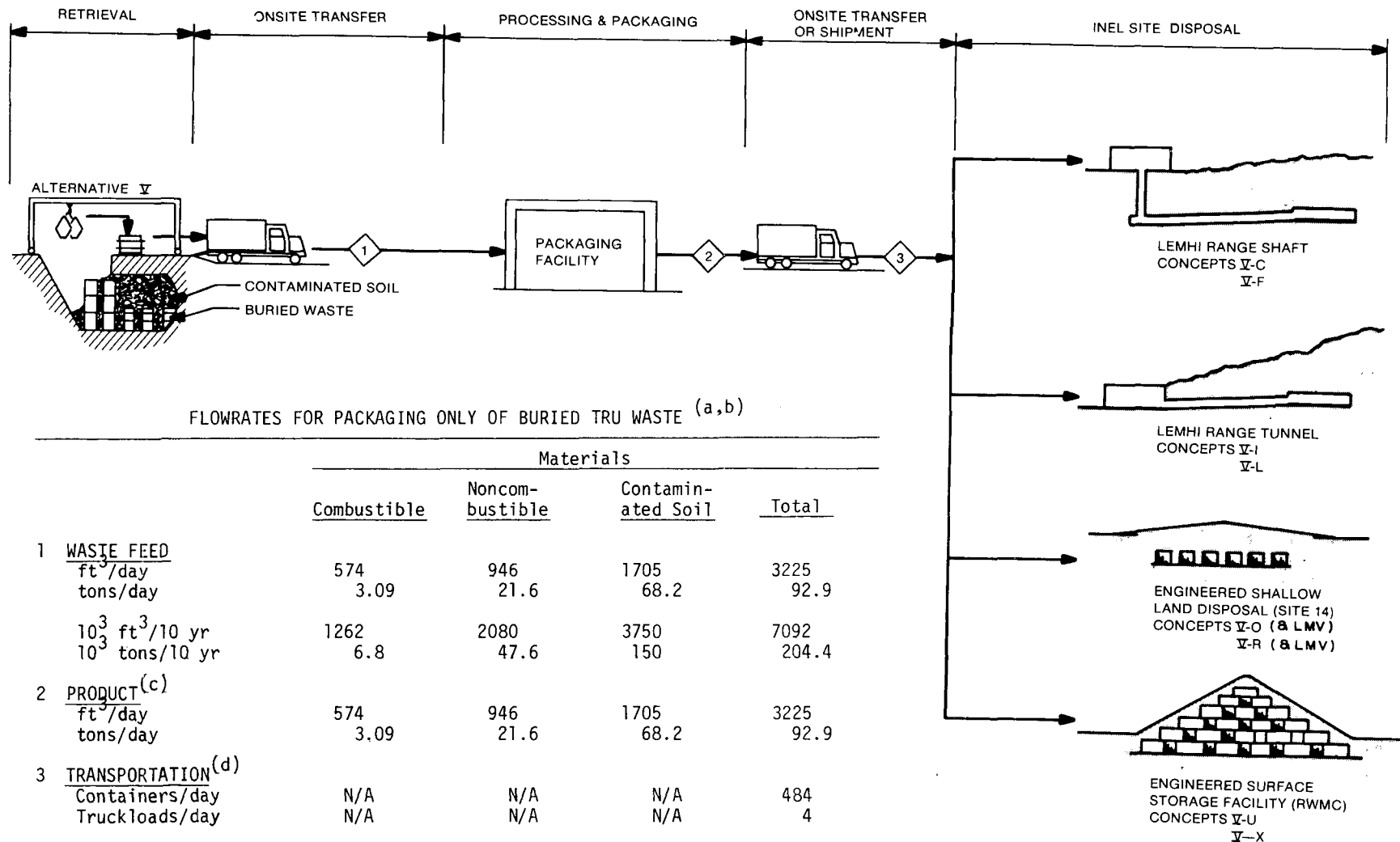
As with the slagging pyrolysis facility (Subsection 9.1.2.3), the compaction facility would be a reinforced concrete structure with three separate air zones, each based on the potential level of contamination. All inlet air would pass through a single bank of HEPA filters. All air removed by the ventilation systems would pass through roughing filters having 30% and 90% efficiencies, and then through one or two banks of HEPA filters. Air from the innermost and middle zones would pass through two HEPA filter banks in series; air from the outer zone, through one HEPA filter bank.

10.2.3 Packaging Only

This section describes the processing operation for Concepts V-C, V-F, V-I, V-L, V-O, V-R, V-U, and V-X. (Refer to Table 7-3.) These concepts have different retrieval methods or 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 with 90-mil polyethylene liners. 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 facility size is the same as that for the stored waste. However, the facility would operate three shifts/day instead of one shift/day in order to process the larger amount of buried waste plus contaminated soil. 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 lined steel drums and 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 flow rate from the packaging operation would be about 3,390 drums per week. The packing fraction was assumed to be 90% of that for the buried waste containers and soil.



N/A Not Applicable.

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

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

(c) Actual volume of waste.

(d) Reflects the volume increase caused by a packaging efficiency of only 90% within the waste containers.

Fig. 10-7. Flow rates for retrieval, onsite processing (packaging only), and shipment of buried TRU waste to an onsite disposal facility.

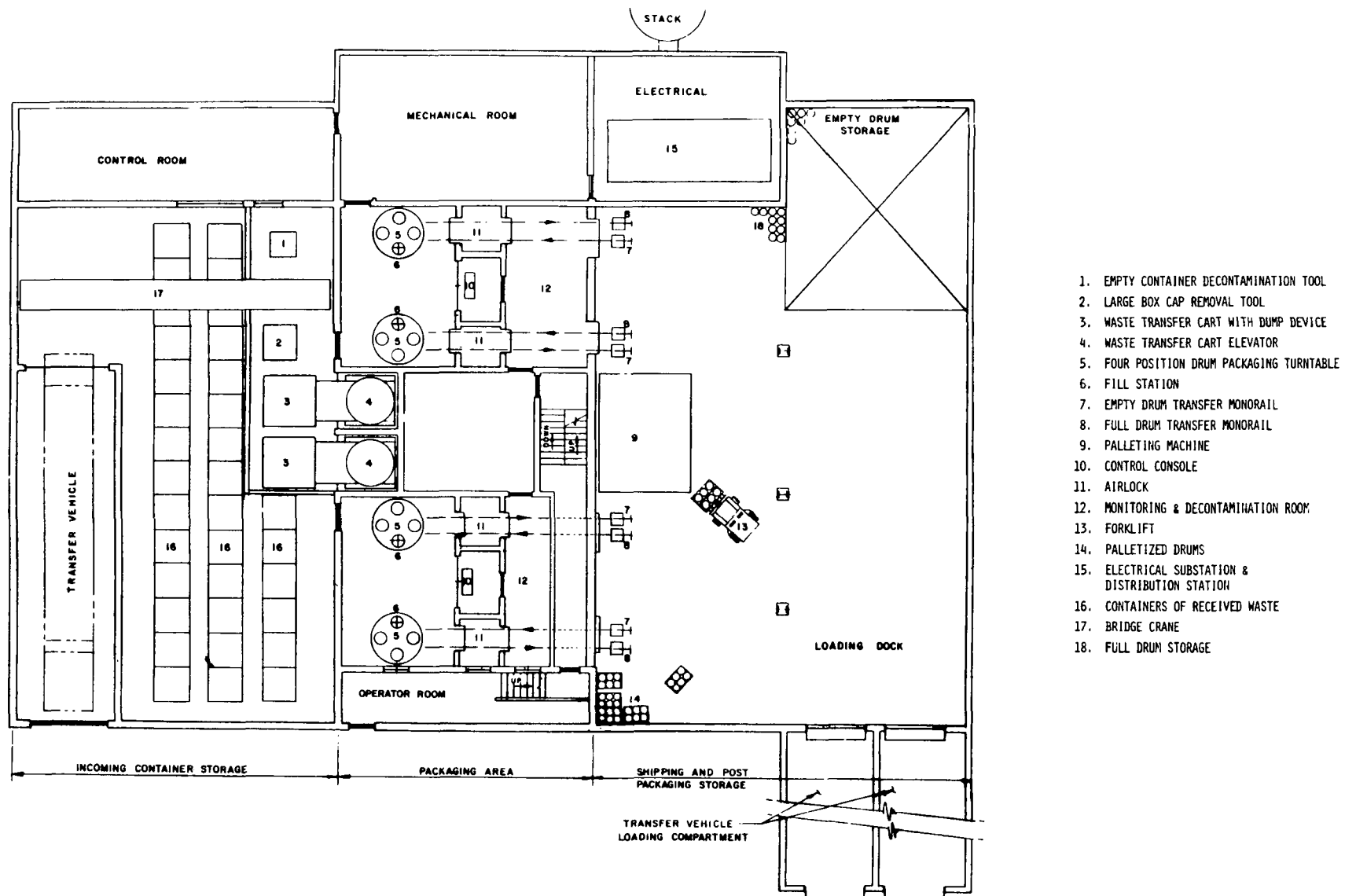


Fig. 10-8. Plan of ground level of packaging-only facility for buried TRU waste.

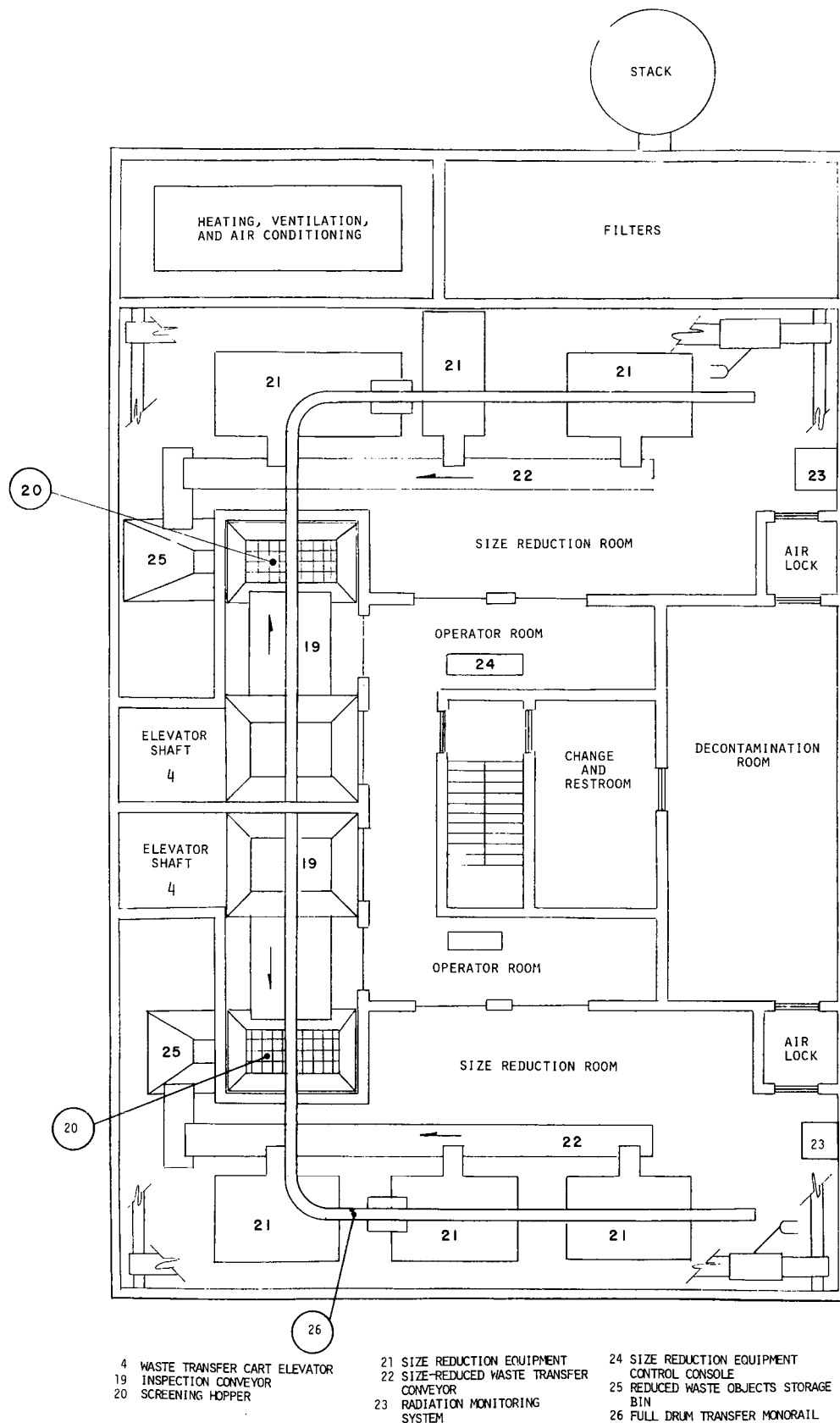


Fig. 10-9. Plan of second level of packaging-only facility for buried TRU waste.

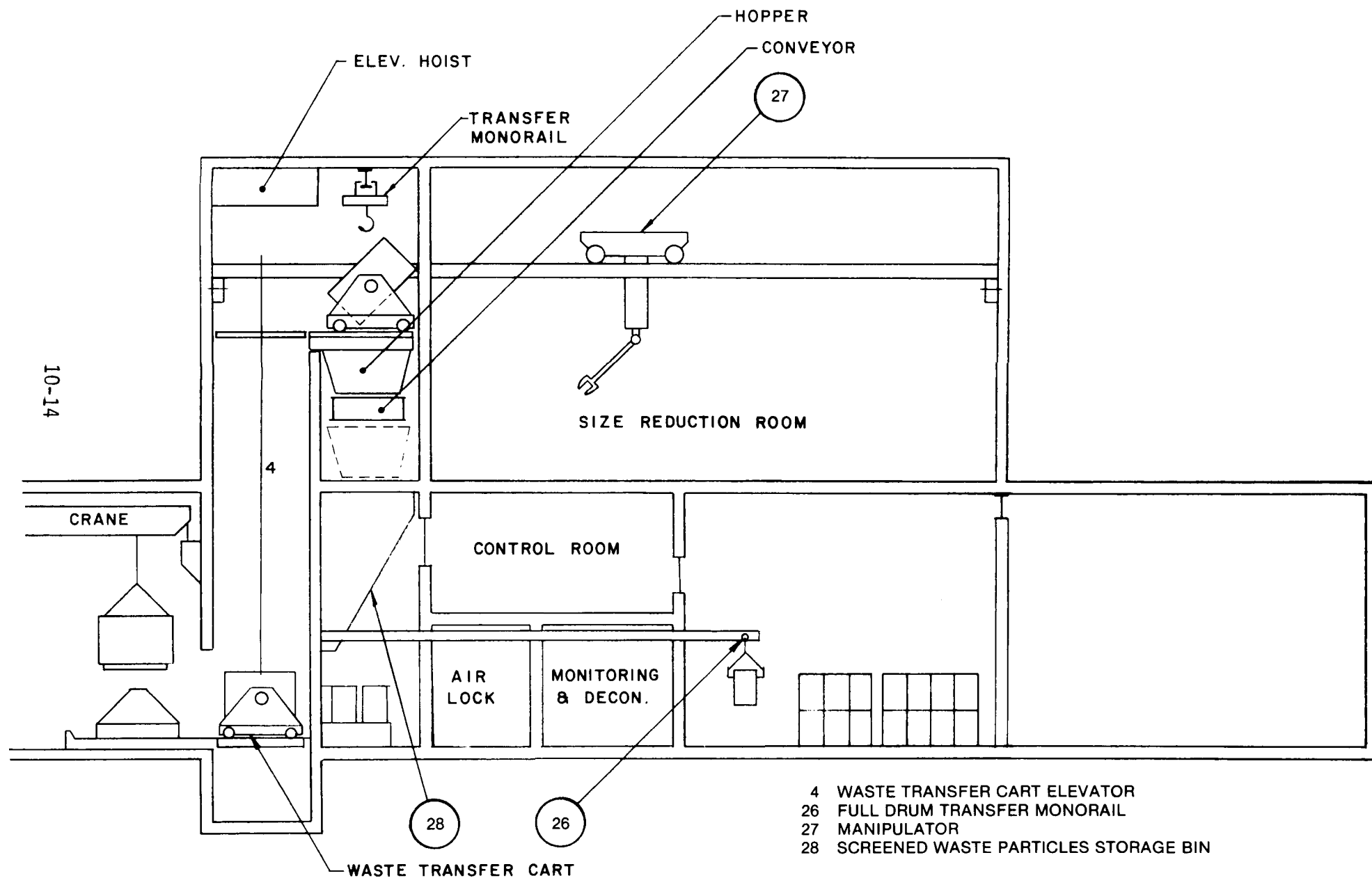


Fig. 10-10. Cross section of packaging-only facility for buried TRU waste.

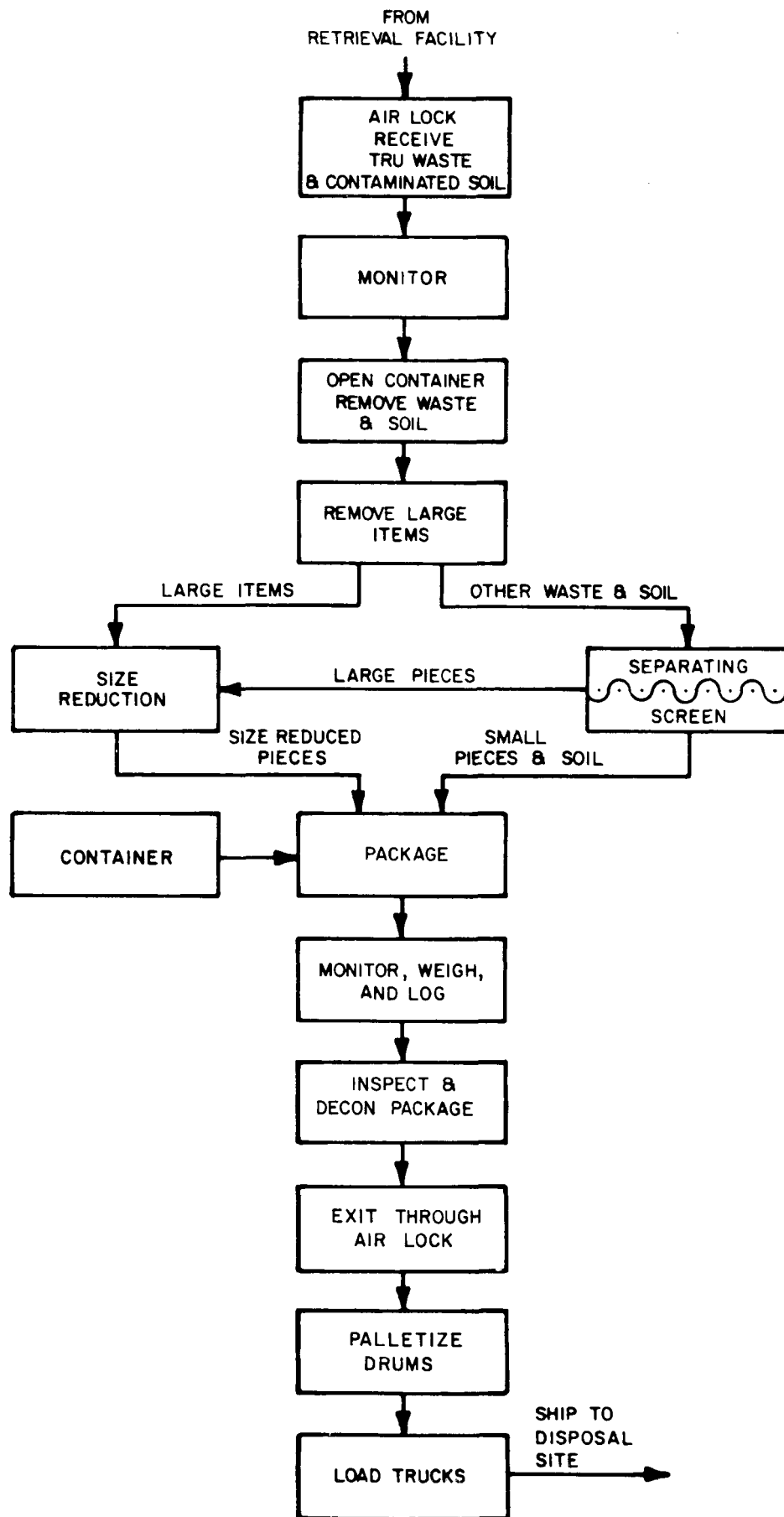


Fig. 10-11. Block flow diagram for processing TRU waste by packaging only.

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 six drums each per pallet. The flow rate would be about 280 pallets per week. The pallets would be loaded onto trucks using forklifts, or stored for later shipment.

All operations in the facility, from waste entry into the airlock through packaging of the output product, would be remotely controlled. To the greatest extent practical, maintenance would also be performed by remote means.

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 roadway 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 1,360 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 and soil 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 10,700 lb. Four blocks would be loaded onto a semitrailer. Again, travel over a committed roadway would waive weight limits.

The packaged waste and soil would be shipped in DOT Spec 17C, 55-gal capacity drums with plastic liners. Each drum would weigh about 450 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 per semitrailer, multiplication of the shipment rates by the container volumes will not exactly equal the total waste volume to be shipped.

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. The 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 access. 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 of the disposal modules, surveillance of the area would be continued for a period of 100 yr.

For all disposal methods and locations studied, the volumes, including containers, to be disposed of would be (1) 2,900,000 ft³ from the incineration process, (2) 7,200,000 ft³ from the compaction and immobilization process, and (3) 9,800,000 ft³ from the packaging-only process.

10.4.1 Deep Rock Disposal - Shaft Access

Concepts V-A through V-F 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 placed. The repository would be similar in design to, but smaller and less complex than, the Waste Isolation Pilot Plant (WIPP), proposed by DOE as a geologic repository (DOE 1979a).

TABLE 10-1

SUMMARY OF DAILY ONSITE SHIPMENT OF PROCESSED BURIED WASTE

Waste From:	Destination								
	Deep Rock Disposal, Shaft Access 60 miles/round trip			Deep Rock Disposal, Tunnel Access 60 miles/round trip			Site 14 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 pack- aging	50 ^(a)	3	1	50 ^(a)	3	1	50 ^(a)	2	2
Compact, immobi- lize, and package	8 ^(b)	1	4	8 ^(b)	1	4	8 ^(b)	1	4
Package only	144 ^(c)	1	4	144 ^(c)	1	4	144 ^(c)	1	4

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

(b) Each container holds 65.4 ft³ of compacted waste.

(c) Each container holds 6.7 ft³ of packaged waste. (7.4 ft³ capacity drum at 90% fill factor.)

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 of DOE 1979b. (See also Figure 3-1 of the present document.) 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 isolation, 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 of DOE 1979b. 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 retrievability period [see Guideline 7.4.1.1 (7)], 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 and exhaust fans located at the surface. Air flow will be 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 or contamination level in the exhaust increases significantly, a detector in the exhaust stream will activate a motor to rapidly close a damper 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. The workings will be maintained for a retrievability period after final emplacement for possible reentry and waste removal. See Guideline (7) 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. 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 as follows:

- (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, to repackage damaged containers, and to place drums of slag onto pallets for ease of handling. 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 would also be 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 security facilities.

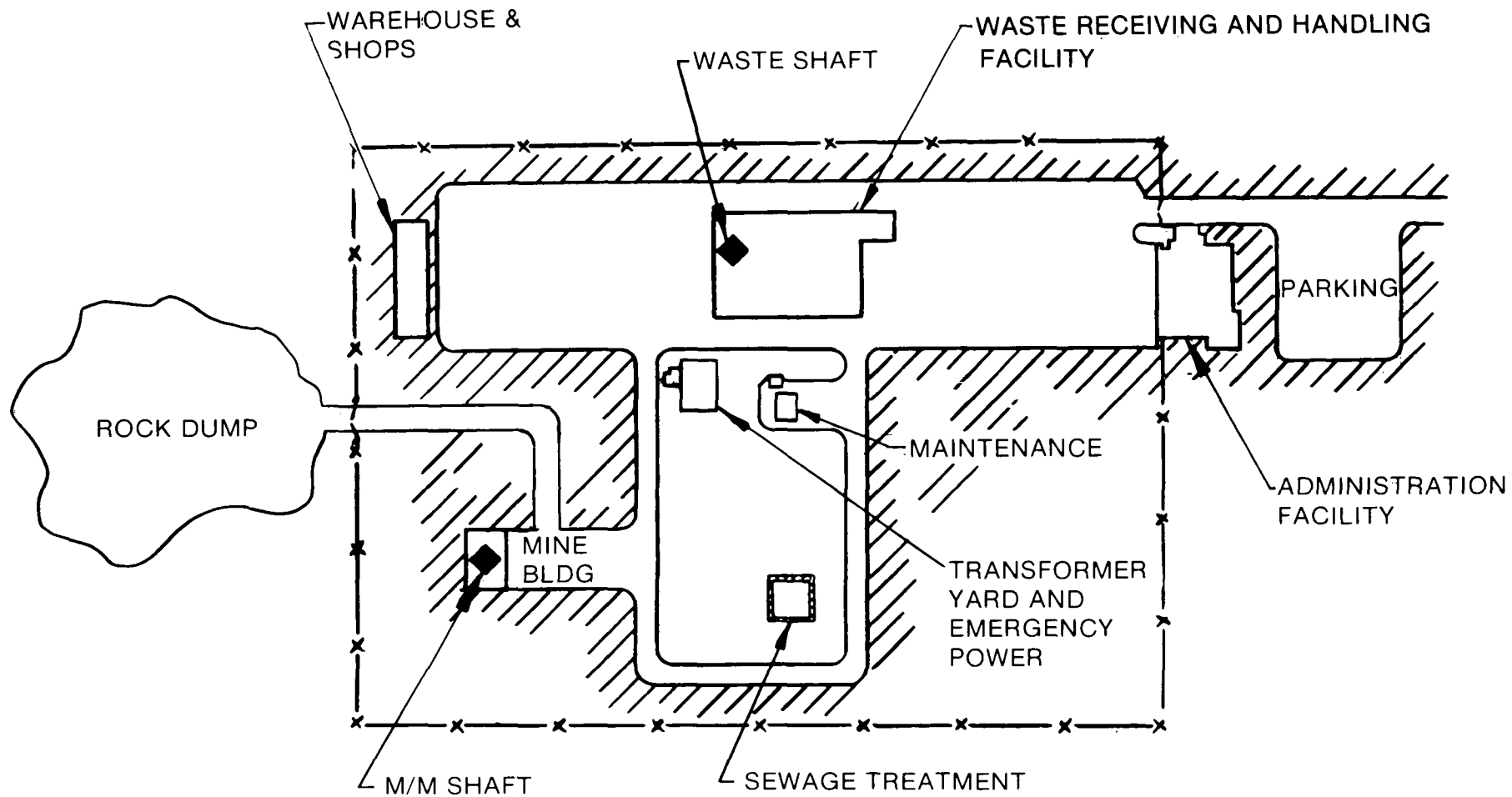


Fig. 10-12. Site plan for surface facilities for deep rock disposal - shaft access.

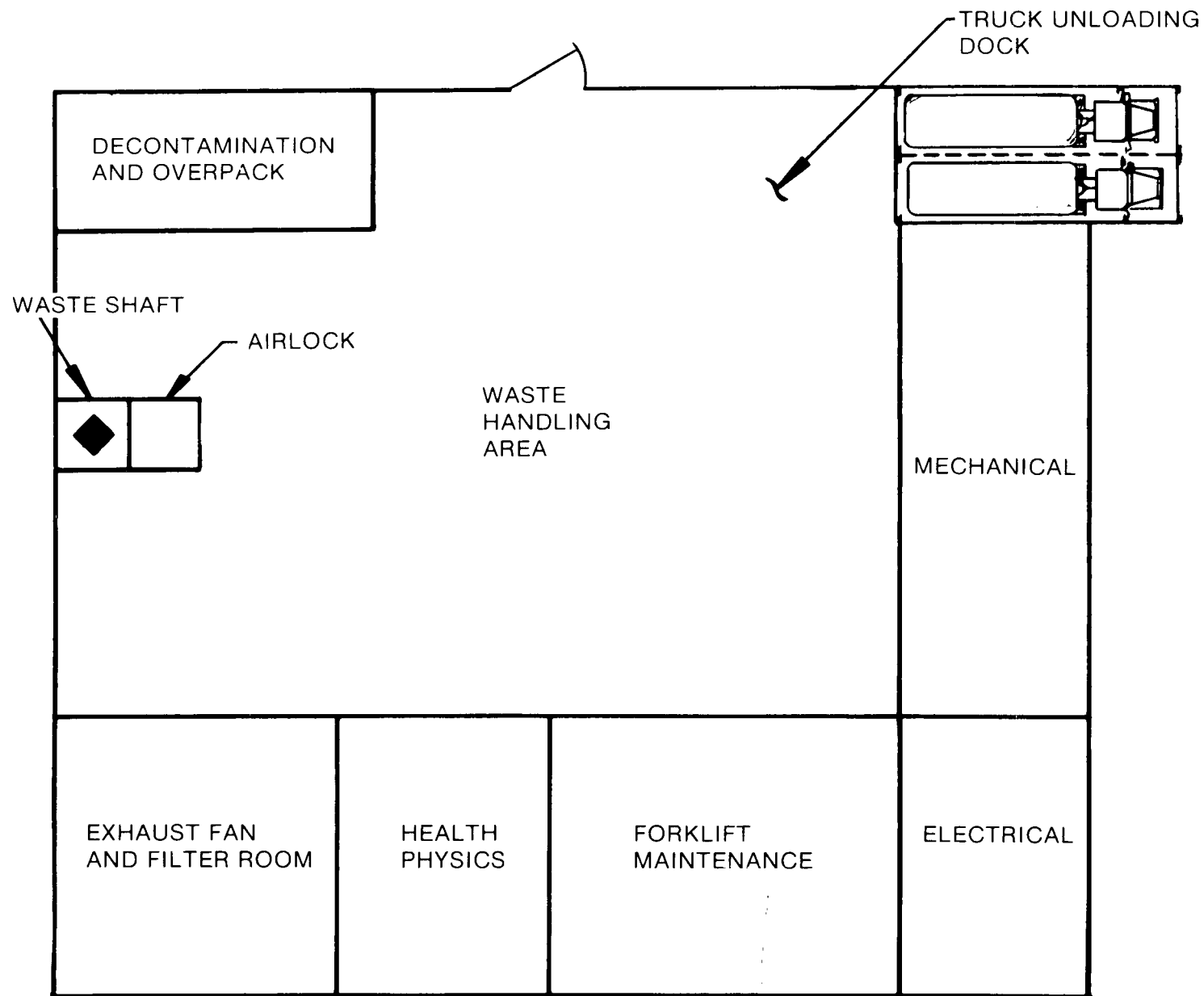


Fig. 10-13. Plan of waste facility for deep rock disposal - shaft access.

The mine 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 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 1 yr 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 cannot be related directly to the containers/day output from the process facilities as shown in 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 hoists and head frames of suitable capacity. The m/m shaft would also be equipped with a skip pocket for rock removal at the underground station and a rock bin at the

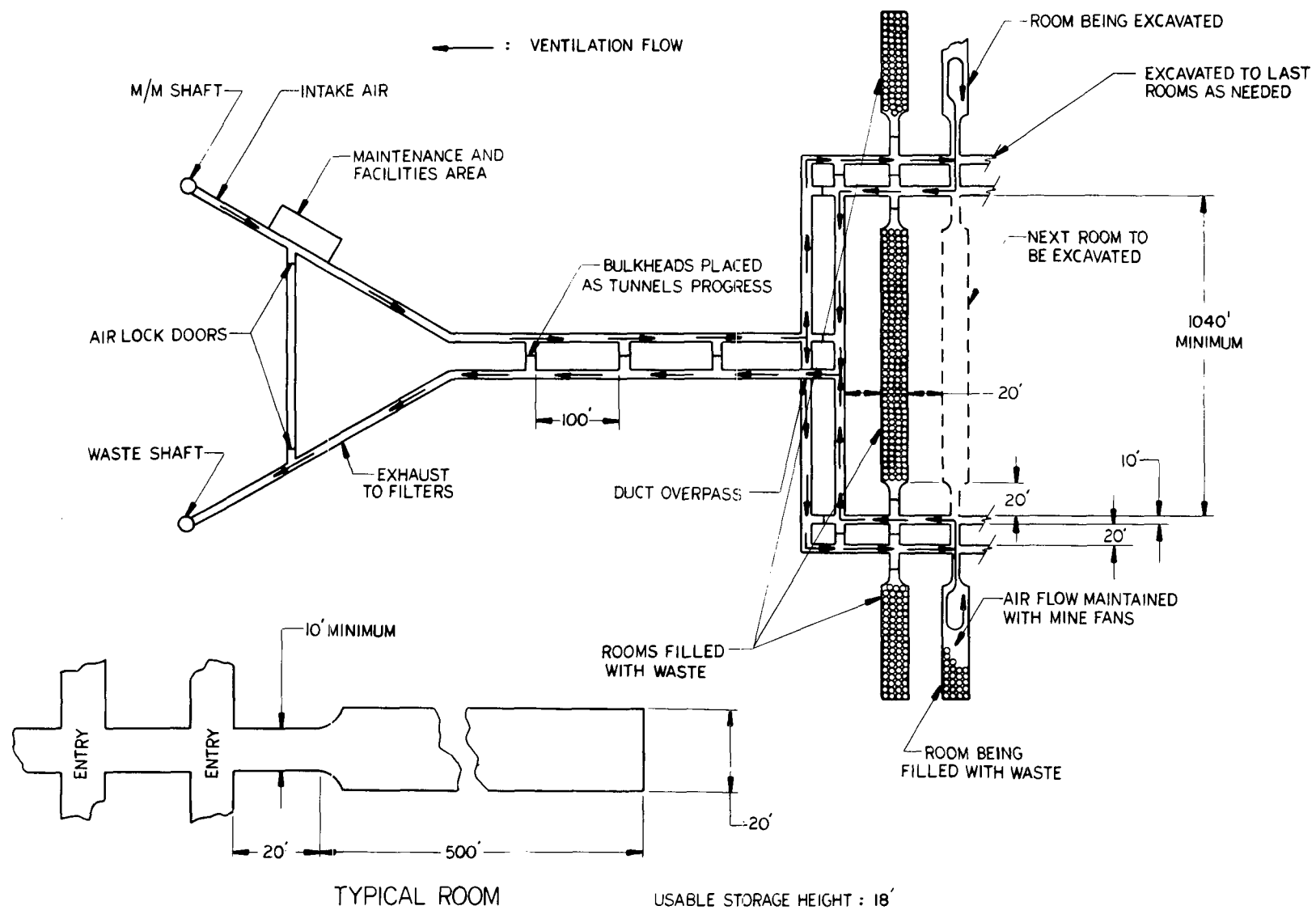


Fig. 10-14. Plan and ventilation flow of underground facility for deep rock disposal - shaft access.

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	4.8	10.2	14.5
Disposal volume, rooms ^(b)	22	51	74
Excavation rate ^(a)			
Rooms/yr ^(b)	2.2	5.1	7.4
Ft of tunnel/yr	143	332	481
Container	55-gal drum	Concrete block 63 x 63 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	10,700	5,400
Waste emplacement rate ^(c)			
Containers/week	618	140	2,048
Handling units/week	103	140	171

(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.

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.

The waste would be removed from the waste hoist cage at the underground station and placed on a rubber-tired vehicle for transfer to the vault area. This vehicle would be of standard mine design. In the vault where waste is being emplaced, a forklift equipped with appropriate handling attachments would unload the truck and place 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 repairs 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 V-G through V-L 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 of DOE 1979b; 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 retrievability period [see Guideline 7.4.1.1 (7)], 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 module.

Two parallel tunnels would be required, each about 5,000 ft long. Their entrances would be located about 5,275 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 5,300 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 entrances and approximately the outer half of the tunnels 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 tunnels 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 and no concrete liner would be required.

10.4.2.2 General Description

The Lemhi Range disposal facility would consist of a surface facility, two tunnels approximately 5,000 ft long each, and an underground vault area. Figure 10-15 shows a cross section of the 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 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 to permit any moisture to drain out of the mine. Thus, there would 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.

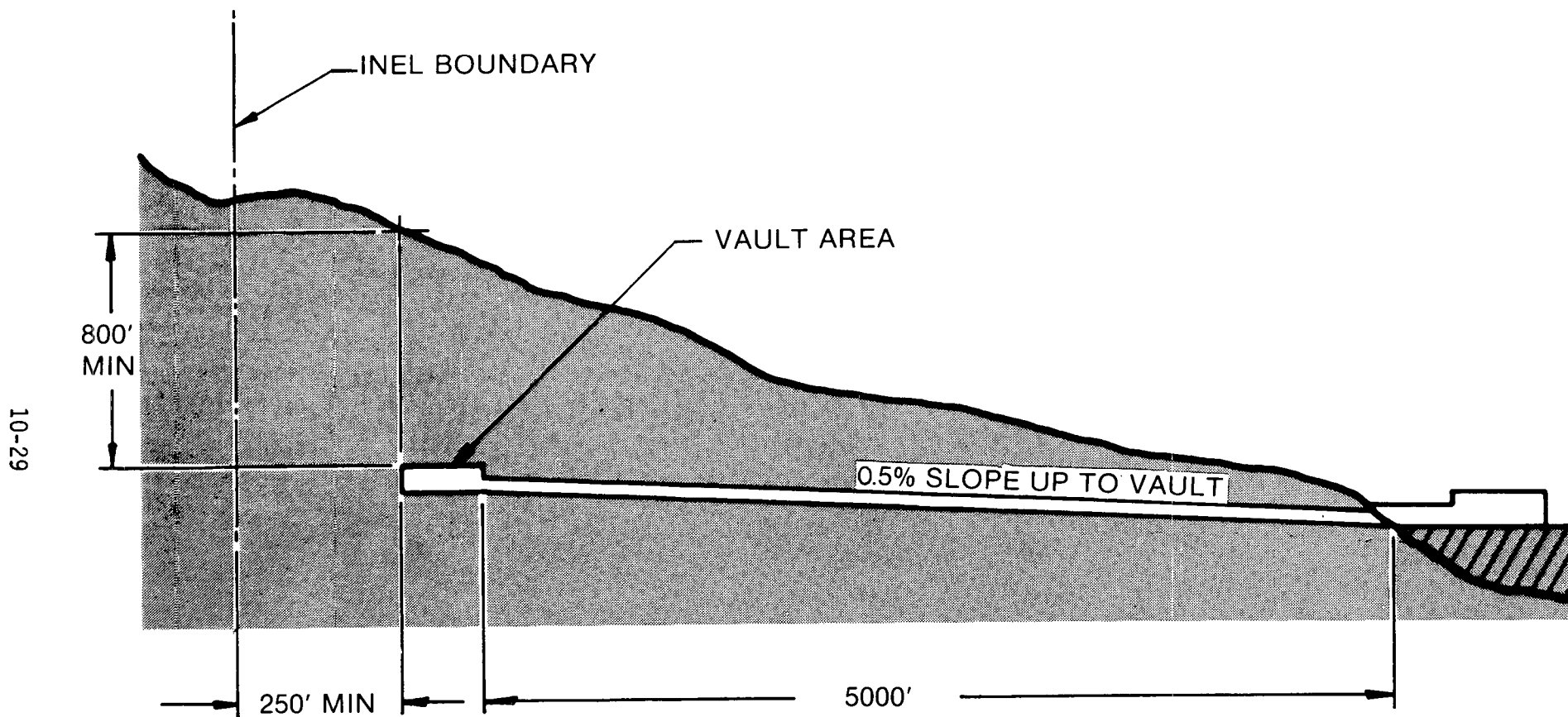


Fig. 10-15. Cross section of facility for deep rock disposal - tunnel access.

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. Containers of waste would be removed from the transfer vehicle and placed on mine trucks to be hauled to the vault area. Drums of slag would be palletized in this 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 1 yr 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.

Both tunnels would be lined with concrete for approximately the outer half of their length and would have finished inside dimensions of about 10 ft square. Their roofs would be rock bolted with wire mesh for their remaining

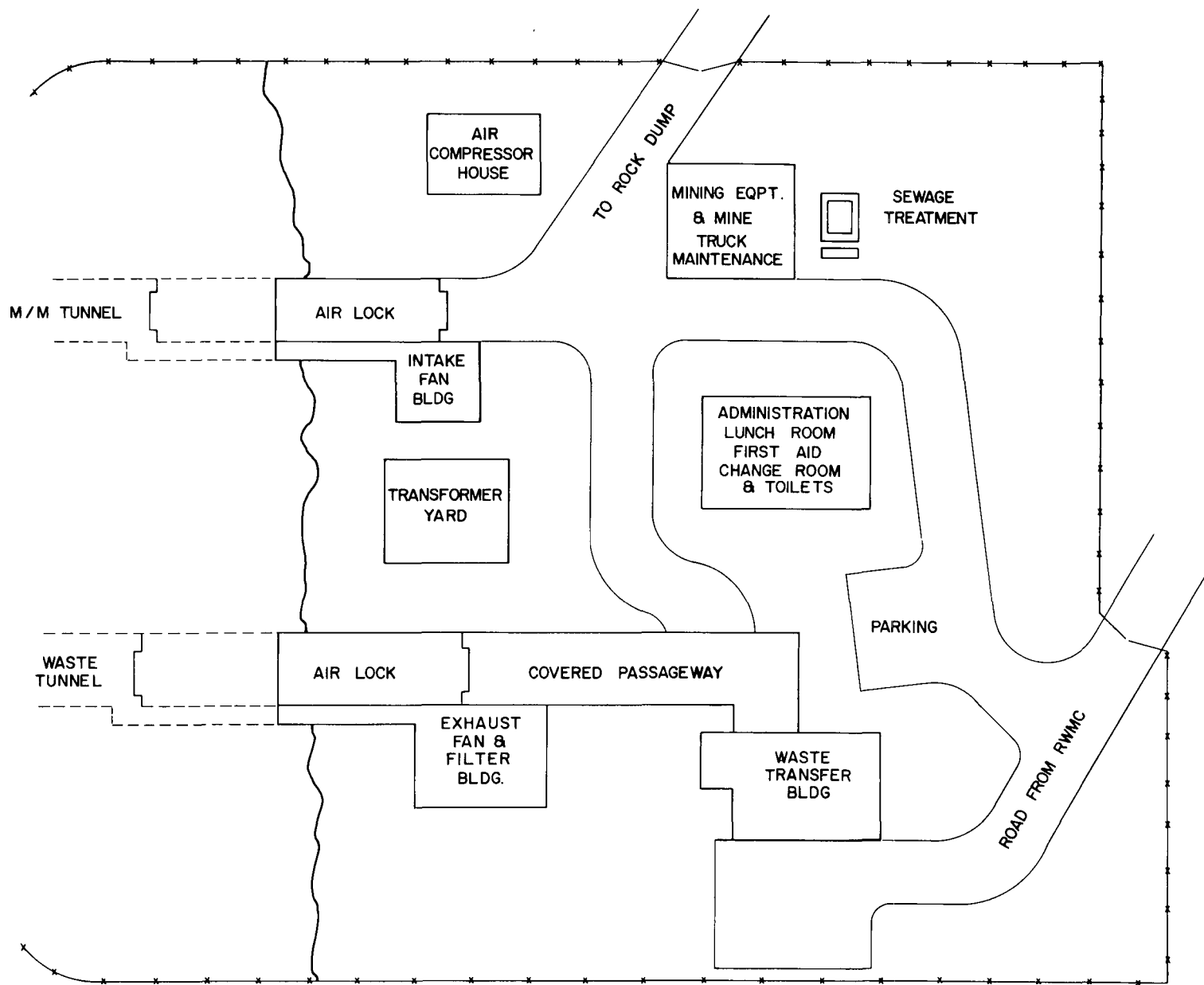


Fig. 10-16. Site plan of surface facilities for deep rock disposal - tunnel access.

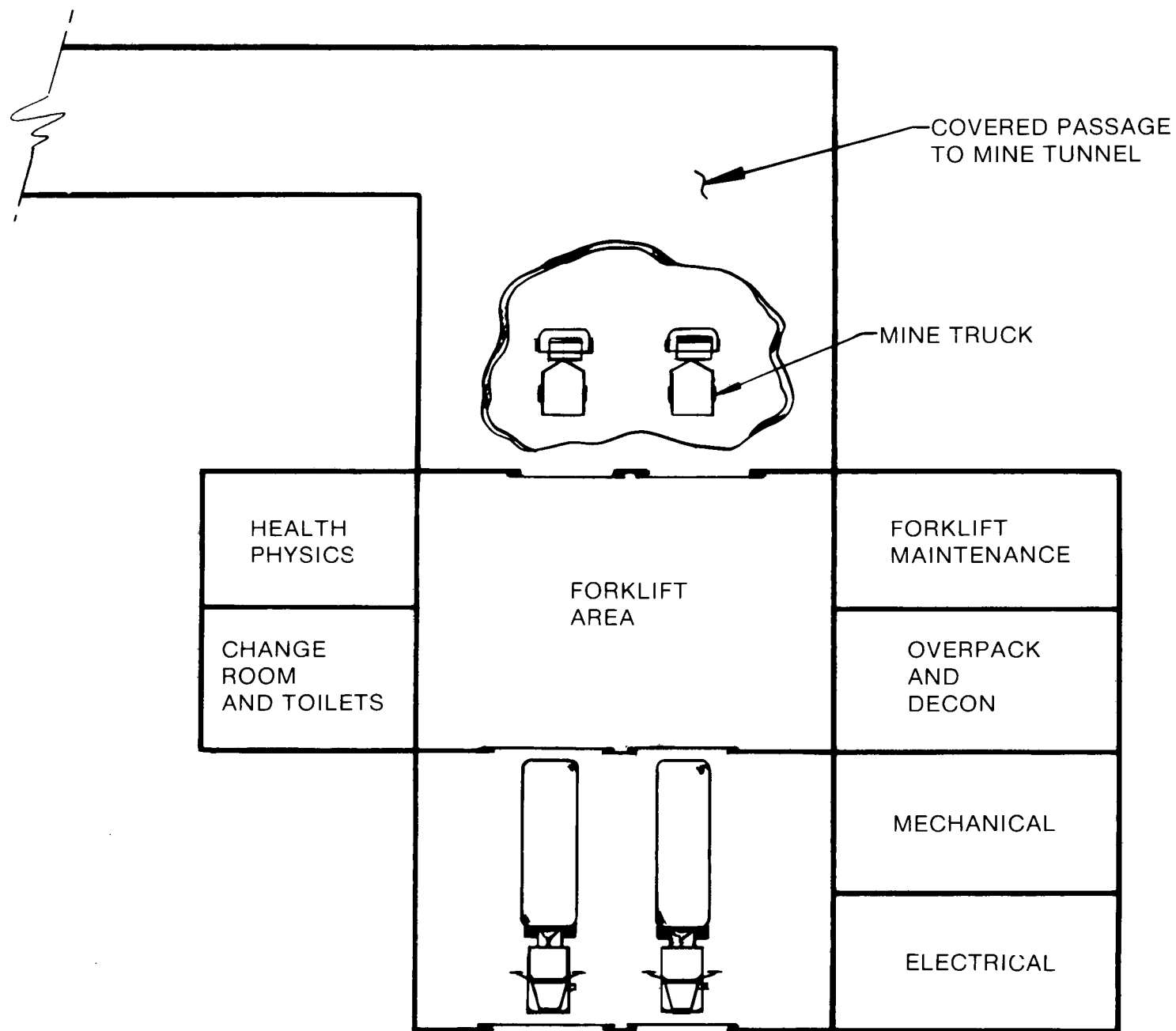


Fig. 10-17. Plan of waste transfer building for deep rock disposal - tunnel access.

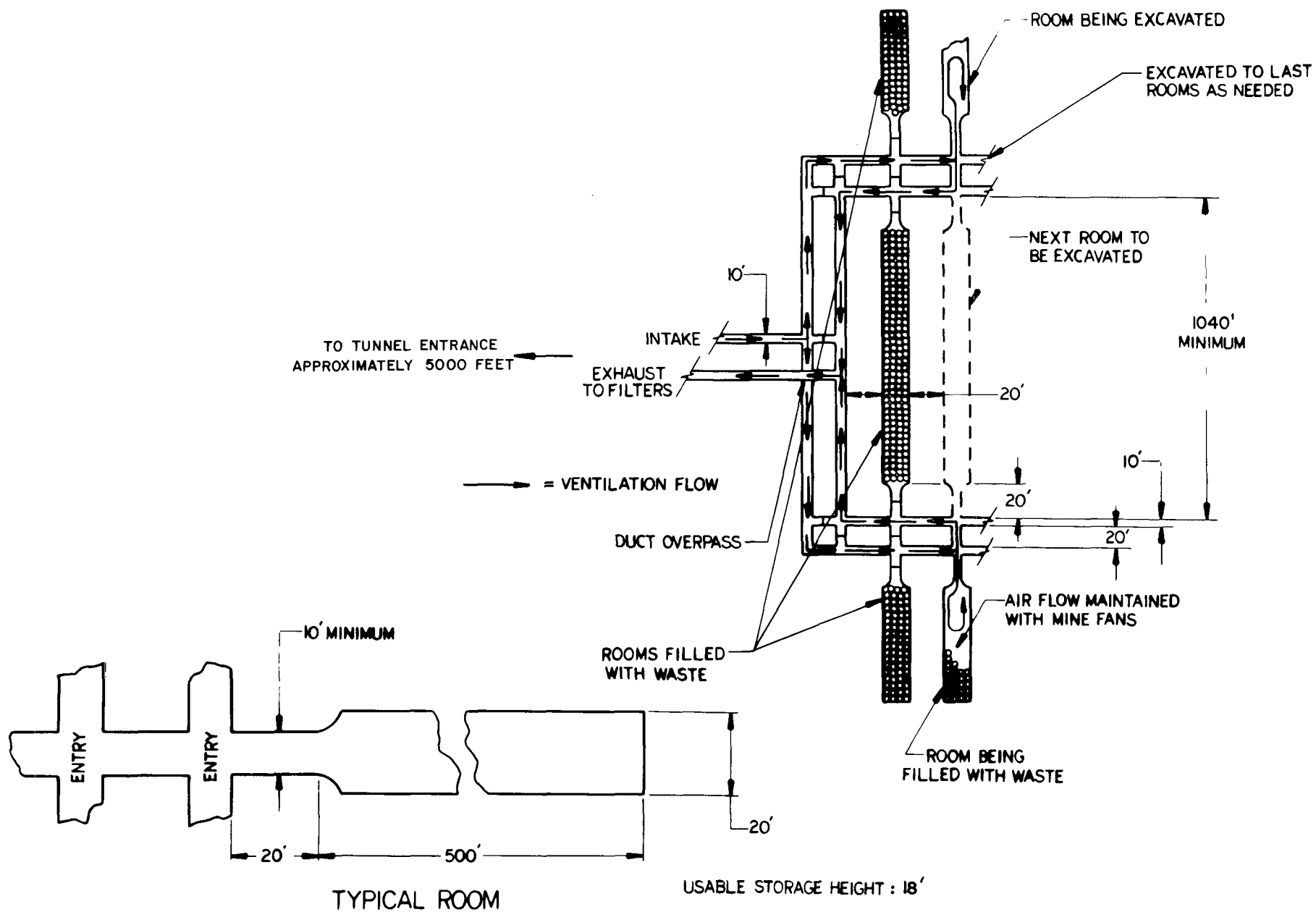


Fig. 10-18. Plan and ventilation flow for underground facility for deep rock disposal - tunnel access.

TABLE 10-3

SIZE REQUIREMENTS FOR DEEP ROCK DISPOSAL FACILITY - TUNNEL ACCESS

Item	Process		
	Slagging Pyrolysis and Packaging	Compaction, Immobilization, and Packaging	Packaging Only
Volumes to be mined ^(a) , 10 ⁶ ft ³	5.0	10.4	14.7
Disposal volume, room	22	51	74
Excavation rate ^(b)			
Rooms/yr	2.2	5.1	7.4
Ft of tunnel/yr	143	332	481
Container	55-gal drum	Concrete block 63 x 63 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	10,700	5,400
Waste emplacement rate ^(c)			
Containers/week	618	140	2,048
Handling units/week	103	140	171

(a) Includes two 5,000-ft long access tunnels.

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

(c) Based on 52 weeks/yr operation.

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. Vehicles 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 V-M through V-R 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 10.4.3.5.

10.4.3.1 Site Description

Site 14 is described in Section 3 of DOE 1979b; Figure 3-1 of the present document 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 at an elevation of about 4,800 ft above sea level.

TABLE 10-4
 SIZE REQUIREMENTS FOR ENGINEERED SHALLOW LAND
 DISPOSAL FACILITY AT SITE 14

	<u>Process</u>		
	<u>Slagging Pyrolysis and Package</u>	<u>Compaction, Immobilization, and Packaging</u>	<u>Packaging Only</u>
Container	55-gal drum	concrete block 63 x 63 x 43 in. high	55-gal drum
Approximate number of containers	321,200	72,600	1,064,800
Disposal room cross section	10 ft wide 10 ft high	10 ft wide 12 ft high	10 ft wide 10 ft high
Total length of disposal rooms, ft	42,800	63,600	142,000
Number of structures required	12 ^(a)	18 ^(b)	39 ^(a)

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

(b) Includes 17 structures about 186 ft wide and 600 ft long, and one structure about 186 ft wide and 400 ft long. Each structure 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. For the slagging pyrolysis and package only processing modules, each structure would be about 600 ft long, 186 ft wide, and 24 ft thick. To accommodate the output from the compact, immobilize, and package processing module, the structures would be about 600 ft long, 186 ft wide, and 26 ft thick, and one additional structure about 400 ft long would also be required. The facility would be constructed so that the tops of the structures would be 13 or 15 ft below the original surface of the ground, depending on the waste containers. Each structure would contain six rooms running the full length of the structure. A room would have a cross section 10 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 five across and stacked three high, or placement of the concrete blocks two across and stacked three 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:

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

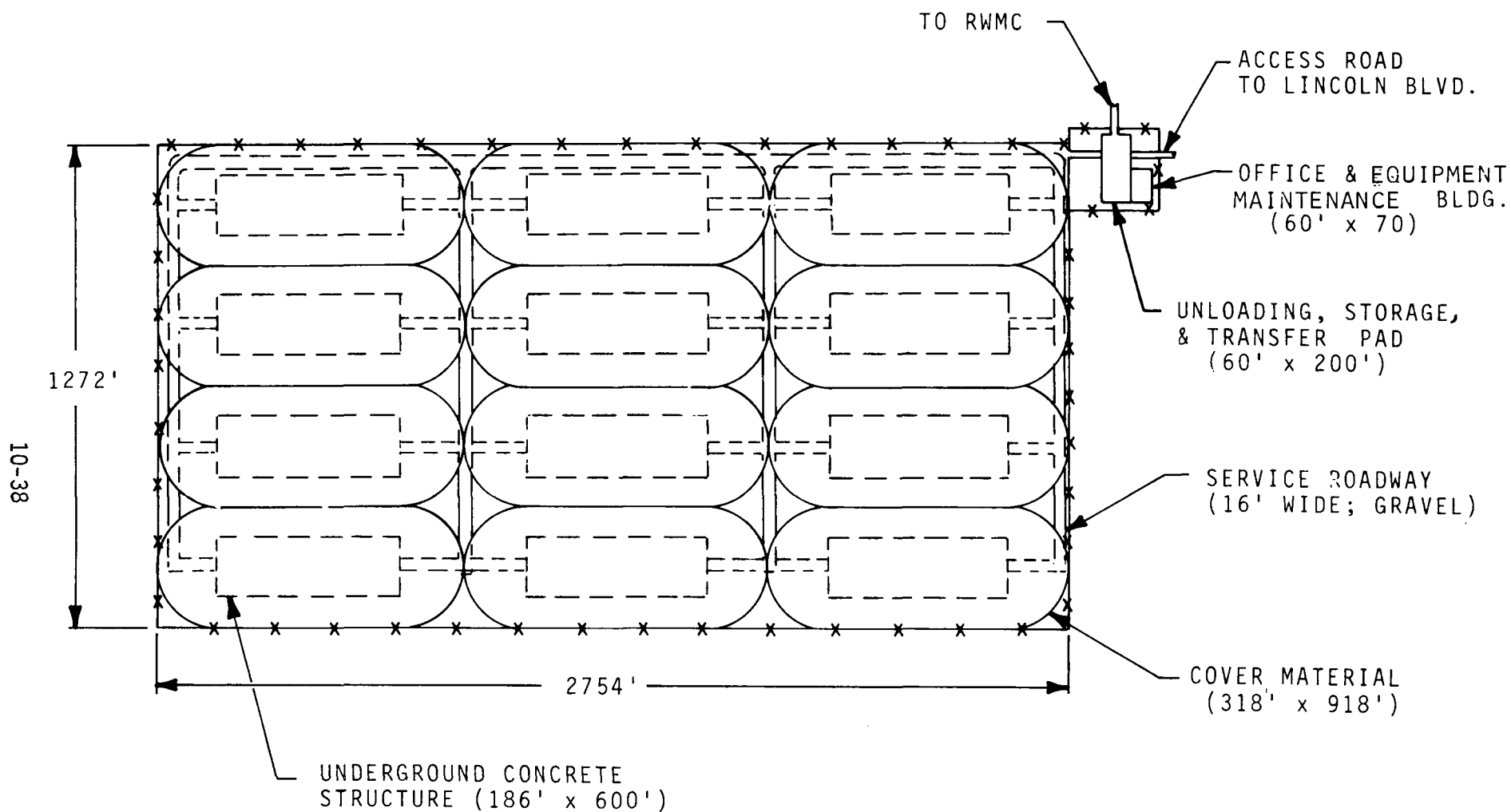
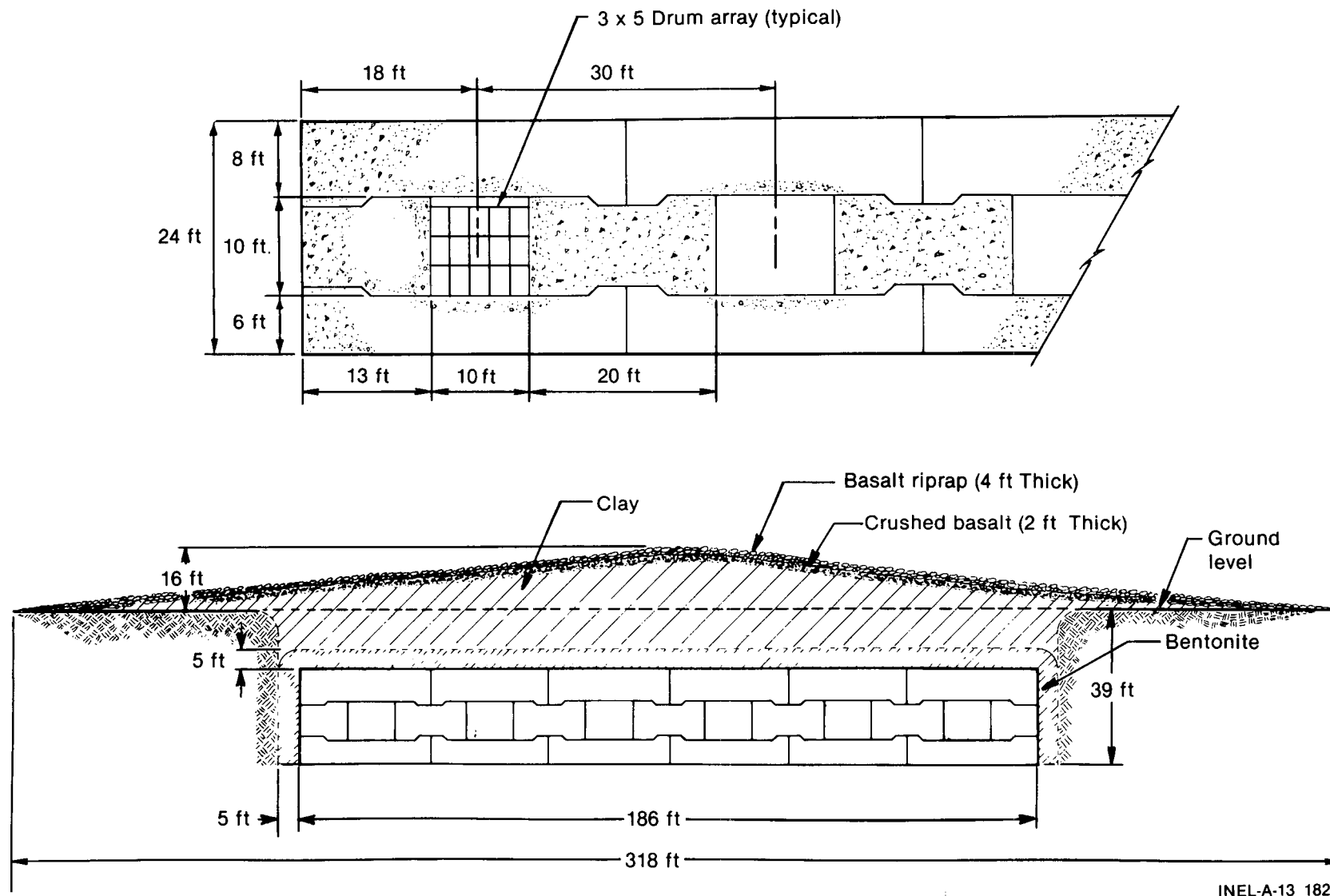


Fig. 10-19. Plan of shallow land disposal facility for buried TRU waste at Site 14 (typical).



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

The 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.

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 disposal rooms. 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 19 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 ground level.

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 16-ft wide gravel roadway would be constructed at the disposal facility to permit access for waste emplacement. The entire area would be surrounded by a 12-ft chain link fence.

10.4.3.3 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 operational and observational period [during which retrieval capability would be provided in accordance with Guideline 7.4.1.1 (7)], the barrier would be replaced with a solid concrete plug and the ramp area completely filled.

10.4.3.4 Construction Techniques

The concrete blocks used for construction would be 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 movable 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 1 yr 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. Further evaluation of constructability could indicate more economical means of construction. The above described technique was used for cost and risk evaluations.

10.4.3.5 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 600 ft long, 118 ft wide, and 13 or 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 structures would be subdivided by cross walls about every 50 ft, forming individual cells approximately 50 ft long, 16.8 ft wide, and 12.5 or 11.5 ft high. The stacked waste container arrays would be surrounded by a layer of tar approximately 5 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 20-ft layer of clay, bentonite, and basalt 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 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 1 yr of operation of the

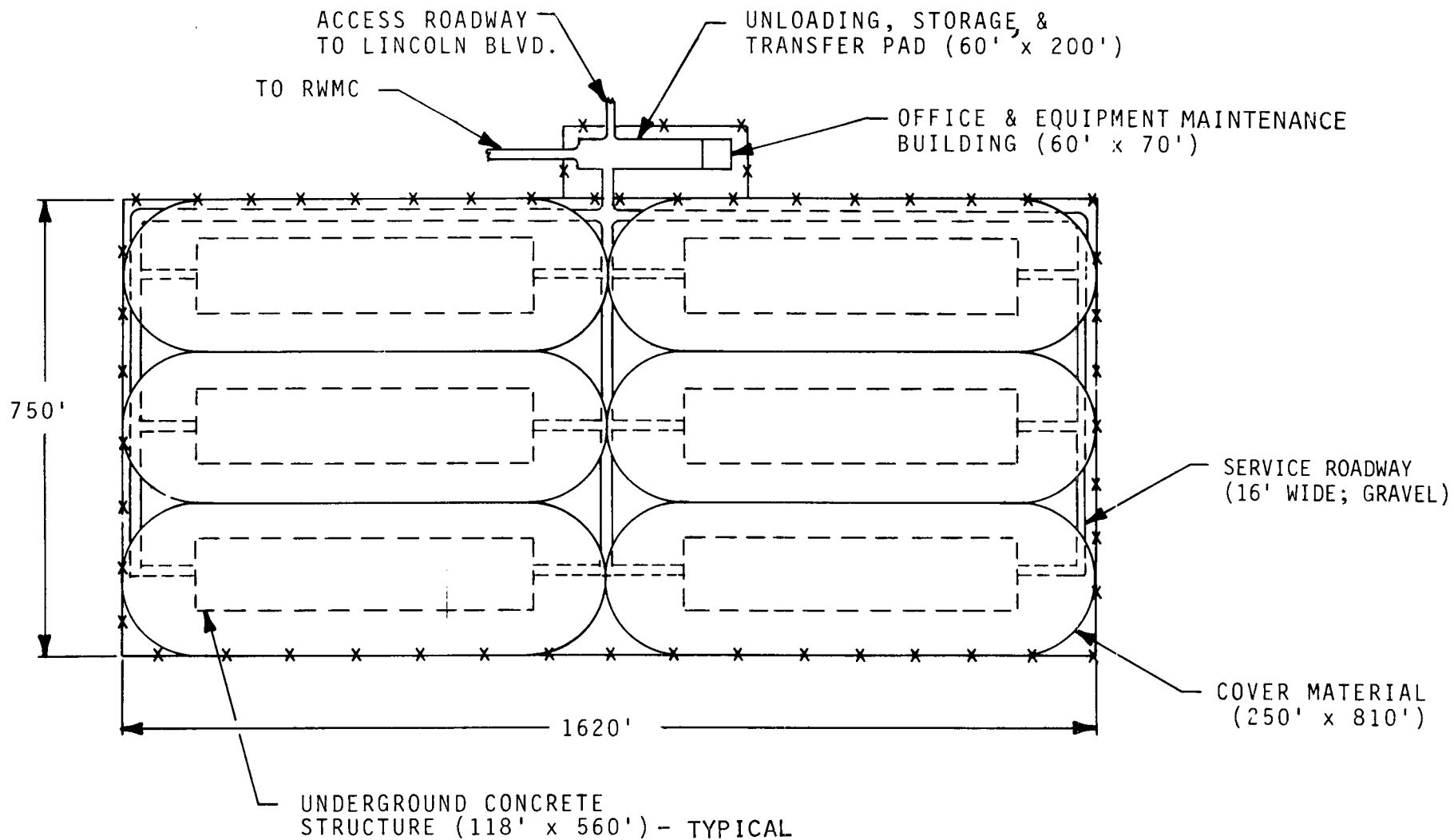
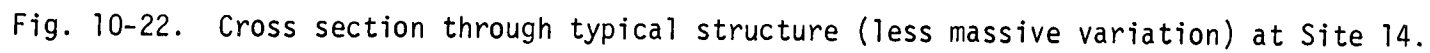


Fig. 10-21. Plan of shallow land disposal facility (less massive variation) for buried TRU waste at Site 14.

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 x 63 x 43 in. high	55-gal drum
Approximate number of containers	321,200	72,600	1,064,800
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 structures required (a)	6	12	18
Approximate length per structure, ft	560	600	610
(a) Each structure would be 118 ft wide and would contain six disposal rooms.			



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 V-S through V-X involve disposal of processed waste in an engineered surface facility near the RWMC. The size of the facility would be based on disposal of buried 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 of DOE 1979b. 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 5,010 to 5,020 ft above sea level. The surface soil is typically about 15 ft thick, with an underlying layer of basalt approximately 100 ft thick (see Figure 3-6, DOE 1979b).

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 about 1,000 ft long, 360 ft wide and 73 ft high (aboveground 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 cross section would

TABLE 10-6

SIZE REQUIREMENTS FOR ENGINEERED SURFACE DISPOSAL
FACILITY NEAR THE RWMC

	Process		
	<u>Slagging Pyrolysis and Packaging</u>	<u>Compaction, Immobilization, and Packaging</u>	<u>Packaging Only</u>
Container	55-gal drum	concrete block 63 x 63 x 43 in. high	55-gal drum
Approximate number of containers	321,200	72,600	1,064,800
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, ft	42,800	63,500	142,000
Number of structures required	4	6	10
Length of structure, ft	994	994	1,218
Height of structure, ft	73	73	73

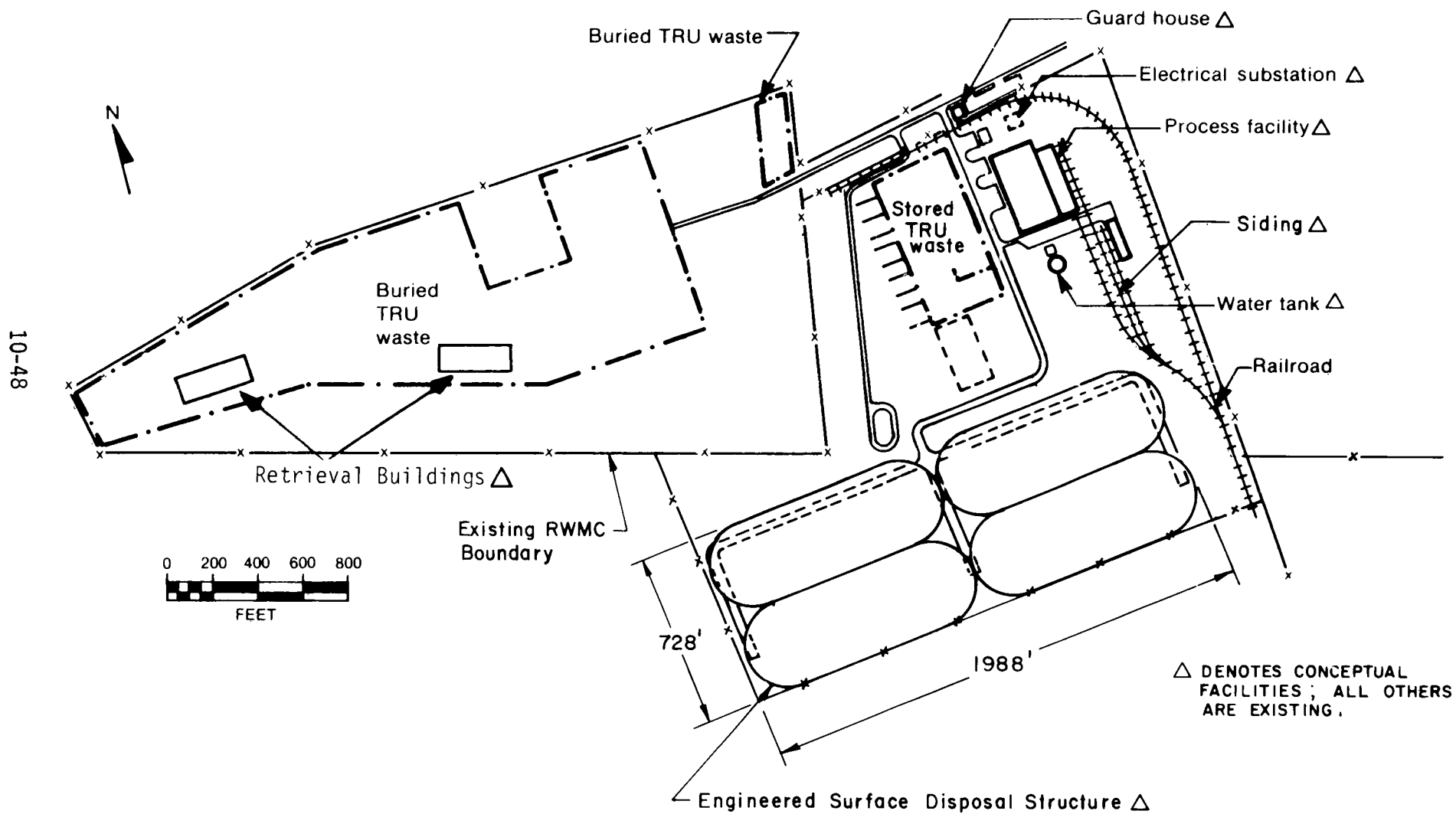


Fig. 10-23. Plan for disposal in engineered structures for buried TRU waste near the RWMC.

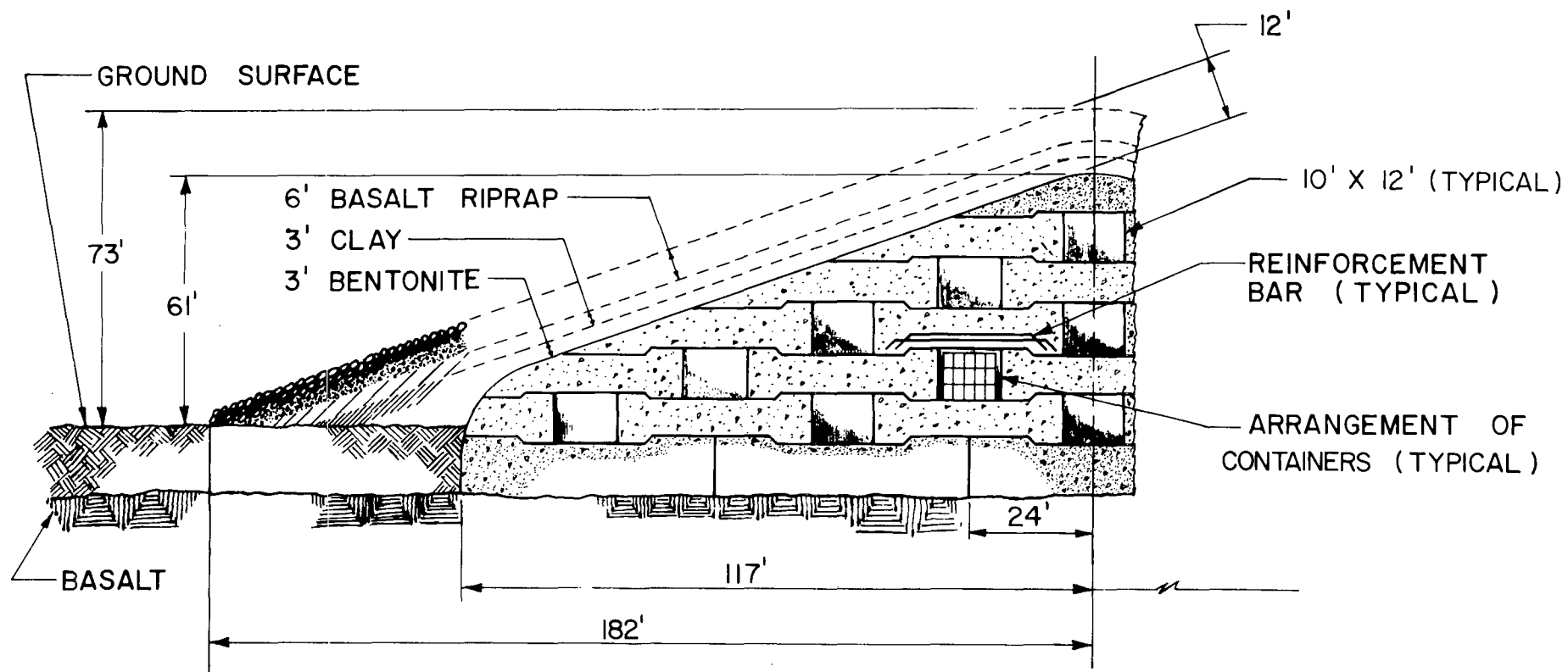


Fig. 10-24. Cross section through typical engineered disposal structure near the RWMC.

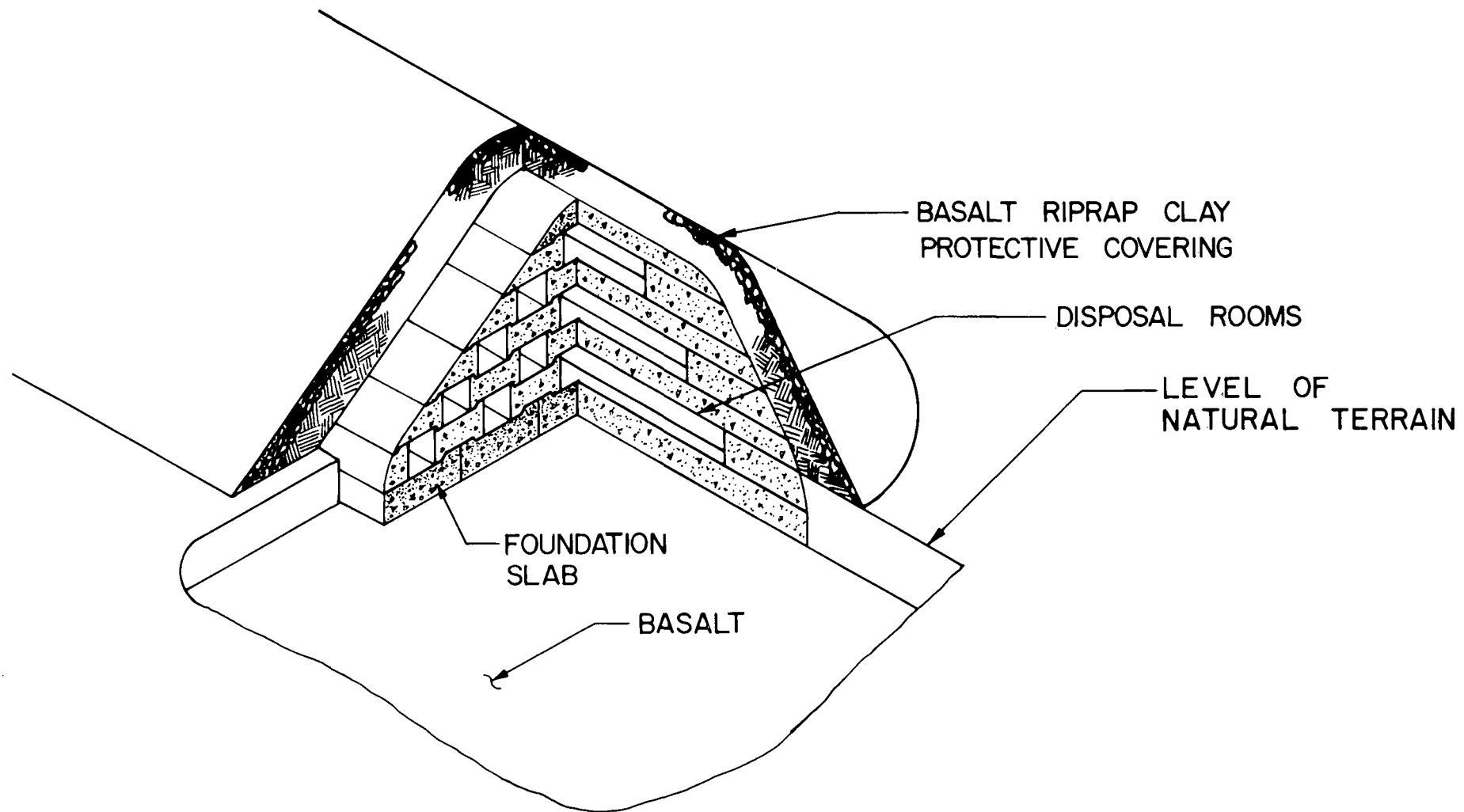


Fig. 10-25. Isometric cutaway of typical engineered disposal structure near the RWMC.

permit placement of 55-gal drums five across and three high, or concrete blocks two across and three 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 less than 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 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 disposal rooms. The containers would be transferred from the processing facility to the disposal facility using semitrailers pulled by conventional highway truck tractors. Forklifts would be used to position the containers in the disposal rooms. As each room is filled, it would be temporarily closed

with a concrete barrier. At the end of the operational and observational period during which retrieval capability would be provided [see Guideline 7.4.1.1 (7)], 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.

10.4.4.4 Construction Techniques

The concrete blocks used for construction would be 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 movable forms and by placing impermeable barriers on adjacent blocks to provide controlled separation between blocks. Further evaluation of constructability might indicate more economical means of construction. However, the above described technique was used for the cost and risk evaluations.

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 highly contaminated. Therefore, D&D would be relatively simple compared with D&D of retrieval or process facilities.

11.0 COMBINED MANAGEMENT OF BURIED TRU WASTE AND STORED TRU WASTE

As mentioned in Subsection 7.3, the alternatives study for INEL TRU waste (DOE 1978a) addresses both buried and stored TRU waste. Selection of a particular alternative or concept for managing one of these types of TRU waste could affect the choice of an alternative or concept for the other type (see Section 6 of DOE 1978a). Because the present study covers only buried 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.

12.0 ENVIRONMENTAL EFFECTS OF ALTERNATIVES FOR MANAGING TRU WASTE

12.1 INTRODUCTION AND APPROACH

This discussion of environmental effects is presented in three major subsections that parallel the corresponding subsections for stored waste (DOE 1979b). In some cases, brief background material is repeated verbatim from that report to maintain continuity in this section and to avoid excessive cross referencing. Subsection 12.2 discusses the potential impacts, basically all nonradiological, of site preparation and construction. Subsection 12.3 discusses the nonradiological effects of operating the facilities and subsequently decontaminating and decommissioning (D&D) them. Subsection 12.4 discusses the radiological effects of operations and D&D.

Whenever possible, the environmental effects are discussed in general terms, equally applicable to all alternatives and concepts. When this would be inadequate, an effect (or impact) is discussed by module, first in terms of the leave-in-place alternatives. Then four waste management modules are discussed in turn: retrieval, processing, storage (Alternative IV 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), 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. The existing environment is described in Section 3 of DOE 1979b. Construction effects would arise from improved confinement (Alternative II), retrieval and processing facilities (Alternatives III, IV, V, and VI), a 20-yr storage facility (Alternative IV), waste disposal facilities (Alternative V), and ancillary facilities associated with all of the above. Alternative I (leave as is) would not require any new 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 at site boundaries. Mitigative measures 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 impacts 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 due to construction activities would affect construction workers at the site. These effects would cease upon completion of the construction, but wind-generated dust could 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	24	50	720	70	70
Above and around	24	55	790	70	70
Above, around, and below	24	65	940	220	220
Immobilization	24	20	290	90	90
RETRIEVAL FACILITY					
Direct control	9	40	220	200	300
Remote control	9	40	220	220	330
PROCESS FACILITY ^(a)					
SP	20	55	660	500	600
CPT	20	25	300	250	300
PKG	18	20	220	200	250
DISPOSAL FACILITIES ^(b)					
<u>Deep rock disposal</u>					
<u>Lemhi site-</u>					
<u>shaft access</u>					
SP	30	15	270	27	27
CPT	30	33	590	57	57
PKG	30	47	850	81	81
<u>Tunnel access</u>					
SP	30	14	250	24	24
CPT	30	29	520	51	51
PKG	30	41	740	72	72
<u>Lemhi roadway^(c)</u>	14	13	110	21	21
<u>Engineered shallow</u>					
<u>land disposal at</u>					
<u>Site 14</u>					
SP	9	9	49	36	50
LMV ^(d)	6	4	14	22	33
CPT	9	13	70	53	74
LMV ^(d)	6	9	32	46	69
PKG	9	28	150	118	165
LMV ^(d)	6	14	50	71	107
<u>Site 14 roadway^(e)</u>	8	13	62	21	21
<u>Engineered surface</u>					
<u>facility near RWMC</u>					
SP	9	18	97	37	52
CPT	9	27	150	57	80
PKG	9	59	320	123	172
Service roads	1	13	8	21	21
20-YR RETRIEVABLE STORAGE	6	25	90	100	140

(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) A two-lane committed roadway about 30 miles long would be built to either Lemhi facility. 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)						Particu- lates
	Alde- hydes ^(a)	CO	Hydro- carbons	NO _x	SO ₂	Acetic Acid ^(a)	
LEAVE AS IS	0	0	0	0	0	0	0
IMPROVED CONFINEMENT							
Above	7.2	43	98	160	29	22	79
Above and around	7.9	48	110	180	32	25	87
Above, around, and below	9.4	56	130	210	37	29	100
Immobilization	2.9	17	39	64	12	8.9	32
RETRIEVAL FACILITY ^(b)	2.2	13	29	48	8.6	6.7	24
PROCESS FACILITY ^(c)							
SP	6.6	40	90	150	26	20	73
CPT	3.0	18	41	67	12	9.3	33
PKG	2.2	13	29	48	8.6	6.7	24
DISPOSAL FACILITIES							
<u>Deep rock disposal</u>							
<u>Lemhi site -</u>							
<u>shaft access</u>							
SP	2.7	16	37	60	11	8.4	30
CPT	5.9	36	81	130	24	18	65
PKG	8.5	51	120	190	34	26	93
<u>Tunnel access</u>							
SP	2.5	15	34	56	10	7.8	28
CPT	5.2	31	71	120	21	16	57
PKG	7.4	44	100	160	30	23	81
<u>Lemhi roadway</u>	1.1	6.6	15	24	4.4	3.4	12
<u>Engineered shallow</u>							
<u>land disposal at</u>							
<u>Site 14</u>							
SP	0.49	2.9	6.7	11	2.0	1.5	5.4
LMV ^(d)	0.14	0.84	1.9	3.1	0.56	0.43	1.5
CPT	0.70	4.2	9.5	16	2.8	2.2	7.7
LMV ^(d)	0.32	1.9	4.4	7.1	1.3	0.99	3.5
PKG	1.5	9.1	21	34	6.0	4.7	17
LMV ^(d)	0.50	3.0	6.8	11	2.0	1.6	5.5
<u>Site 14 roadway</u>	0.62	3.7	8.4	14	2.5	1.9	6.8
<u>Engineered surface</u>							
<u>facility near RWMC</u>							
SP	0.97	5.8	13	22	3.9	3.0	11
CPT	1.50	8.8	20	32	5.8	4.5	16
PKG	3.20	19	43	71	13	9.9	35
<u>Service roads</u>	0.08	0.47	1.1	1.7	0.31	0.24	0.86
20-YR RETRIEVABLE STORAGE	0.90	5.4	12	20	3.6	2.8	9.9

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

(b) Releases are the same for construction of direct control or remote control retrieval facility.

(c) SP: slagging pyrolysis and packaging.
CPT: compaction, immobilization, and packaging.
PKG: packaging only.

(d) 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 proportional to the number of machines operating and the length of the construction period shown in Table 12-1.

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 Occupational Safety and Health Administration (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. A 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 after the D&D phase of the program.

As shown in Table 12-3, additional vegetation would be disturbed as a result of extraction of construction materials such as clay and basalt on the INEL. (Acreage for bentonite is not included because it would be purchased from offsite.) Potential material sites have not yet been identified, but some material extraction might occur in the Big Lost River area near the RWMC and Site 14 and at the playas to the north. After material needs have been met, these sites could be rehabilitated and would eventually return to their previous state.

TABLE 12-3

VEGETATION TYPES AND ESTIMATED ACREAGE NEEDED FOR AFFECTED FACILITIES

Facility	Vegetation Community	Spoil (10 ³ yd ³)	Spoil	Land Requirements (Acres)				Total
				Facility	Roads	Borrow Area for Clay	Borrow Area for Riprap	
LEAVE AS IS AND IMPROVED CONFINEMENT (a)	Big Sagebrush	0	0	0	0	36	8.3	44
RETRIEVAL FACILITY	Big Sagebrush	0	0	0	0	0	0	0
PROCESS FACILITY(b)								
SP	Big Sagebrush	0	0	2.5	0	0	0	2.5
CPT		0	0	1.8	0	0	0	1.8
PKG		0	0	1.0	0	0	0	1.0
DISPOSAL FACILITIES(c)								
Deep rock disposal Lemhi site - shaft access	Juniper (Roadway: Sagebrush & playas)	176	7.3	1	204	0	0	212
SP		376	15	1	204	0	0	220
CPT		535	22	1	204	0	0	227
PKG								
Deep rock disposal Lemhi site tunnel access	Juniper (Roadway: Sagebrush & playas)	185	7.6	1	204	0	0	213
SP		385	16	1	204	0	0	221
CPT		544	23	1	204	0	0	228
PKG								
Engineered shallow land disposal at Site 14								
SP	Sagebrush	2040	252	80	136	43	29	540
LMV(d)	and	460	57	28	136	12	9.3	242
CPT	grasses	3000	372	114	136	57	43	722
LMV(d)		953	118	58	136	27	20	359
PKG		6620	821	261	136	140	93	1451
LMV(d)		1500	187	88	136	41	30	482
Engineered surface facility near RWMC								
SP	Big Sagebrush	395	49	33	2	5.7	13	103
CPT		593	74	49	2	8.8	19	153
PKG		1230	152	100	2	19	42	315
20-YR RETRIEVABLE STORAGE	Big Sagebrush	0.63	<0.01	6	2	0	0	8

(a) Leave As Is and Improved Confinement (immobilization) require no additional acreage.

(b) SP: slagging pyrolysis and packaging.
CPT: compaction, immobilization, and packaging.
PKG: packaging only.

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

(d) 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 an estimated 1,451 acres, or about 0.25% of the total acreage of the INEL. This is the acreage required for Concepts V-0 or V-R: retrieval, packaging only, and disposal in an 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 results mainly from the need to dispose of spoils. 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 of DOE 1979b (also McBride et al. 1978). New facilities there could result in the loss of up to 316 acres of big sagebrush habitat, but this is not considered a major impact because of the availability of similar habitat elsewhere 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 - Artemisia 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 minimize 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 minimize adverse impact.

12.2.4 Water Resources

12.2.4.1 Surface Water

Surface water on the INEL is discussed in Subsection 3.5 of DOE 1979b.

Several aspects of construction activity could cause small adverse effects on surface waters during the short term: (1) withdrawal of water for use in construction, (2) discharge of wastewater, such as sewage effluent 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 with resultant siltation of streams.

Because surface waters are subject to seasonal variations, most water would be obtained from the more reliable groundwater source. 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 by adequate planning or by using well water only.

Wastewater generated during construction would be managed in conformance with applicable federal and state water quality standards and effluent guidelines. Sewage effluent would be treated before discharge to the environment.

Other water quality impacts could result from the 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. However, the removal of gravel, soil, or clay from the Big Lost River or playa vicinity would likely result in increased silt loads during construction. 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 could also cause an increase in silt loads to occur. This impact can be mitigated by scheduling work for periods when surface runoff is absent, then restoring the disturbed area and using erosion control techniques.

The only potential long-term impact to surface water resources would be caused by inadequate drainage structures at roadway river crossings. Inadequate drainage could 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 degradation of water quality caused by the discharge of wastewater. 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 other users.

Except for the small volumes of sewage 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 waste, 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 long-term commitment of land for disposal activities and the short-term aesthetic impacts caused by development of the disposal site. 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. Several Public Land Orders (PLOs), dating back to 1946, have established the present research park boundary and uses and are fully cited in DOE 1979b (Subsection 12.2.6). Each of the alternatives and concepts studied is located in the area that has been withdrawn from the public domain. The PLOs, as interpreted, provide for nuclear energy research and development and related activities. Waste processing, storage, and disposal are considered related activities, consistent with the purpose of the orders, and land would be available for implementing the alternatives. No special legislation or 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 available land. Examination of the existing facility locations, plans for new facilities and the TRU waste processing, storage, and disposal alternatives, 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, DOE 1979b) 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 Bureau of Land Management (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 could 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. As discussed in DOE 1979b (Subsection 12.2.6), only one potential conflict (with BLM plans) was found, because none of the other agencies has developed any plans or policies related to 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 plan.

All waste retrieval, processing, and storage concepts would have small requirements for land, with disposal concepts being 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, but 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 about 0.25% of the total INEL land area. None of the alternatives or concepts creates any known 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 number of man-years of construction labor needed for INEL construction programs already completed or committed through FY 1982. Construction employment is expected to peak in FY 1980,

TABLE 12-4

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

	<u>FY 1977</u>	<u>FY 1978</u>	<u>FY 1979</u>	<u>FY 1980</u>	<u>FY 1981</u>	<u>FY 1982</u>
Construction craft labor	282	474	1,024	1,353	1,282	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	1,205	1,592	1,474	572

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

decreasing gradually in 1981 and dropping significantly in 1982. The indicated decline of 1,020 jobs in the last 2 yr suggests that more than enough workers would thereby be available for construction of waste management facilities. For operations to begin in 1985, construction of facilities would start in 1982 or 1983. The concept using the most construction workers, IV-B, would employ about 820 workers (numbers from "average" column in Table 12-1) or a maximum of 1,070 in the unlikely event that all the peaks occurred simultaneously. This concept would involve facility construction for remote control retrieval, slagging pyrolysis, and a 20-yr retrievable storage facility--about 1,050 man-years of effort on projects lasting 6 to 20 months.

If measured by the total man-years of construction effort, Concept V-D would be more labor-intensive, requiring an estimated 1,090 man-years on tasks lasting 9 to 30 months. Because this work would be spread out over a longer time, the totals of the average numbers of workers and of the maximum numbers are both lower: 768 and 978 workers, respectively. (Concept V-D would involve remote control retrieval, slagging pyrolysis, and deep rock disposal at a Lemhi site with shaft access.)

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 II-A or II-B would lead to an additional 35 jobs in the area, or up to 410 for Concept IV-B. These estimates should be regarded as upper limits, because of the projected drop in 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 \$26 million for construction of waste management facilities, based on weighted 1979 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 \$32 million.

12.2.7.2 Housing

Table 12-5 shows the housing characteristics of INEL employees in March 1978, as reflected in nearly 7,000 responses to a DOE questionnaire (DOE 1978b). If half of the construction workers were immigrants, the most labor-intensive concepts could be expected to create a demand for about 400 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.

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).

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 490 school children due to construction employment (assuming 50% immigration), or an increase of up to 740 if indirect employment is also considered. Nearly all schools are currently at capacity because of recent growth in the area and 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.

Demands on local health facilities would be expected to increase about 2%, at most (see Tables 3-2 and 3-3, DOE 1979b). Population growth in smaller outlying communities and counties was 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 costs.

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 major quantities of 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.] Additional 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 linear ft of fencing.

12.2.9 Archaeological and Historical Sites

Formal archaeological surveys of the INEL have found fossils dating back 40,000 yr and artifacts that indicate man's presence in the area approximately 12,500 yr ago. These surveys are discussed more fully in DOE 1979b (Subsection 12.2.9). Some sites were identified near the locations of the conceptual facilities. However, because the exact locations of these facilities have not been established, construction impacts 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, and was

(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.

TABLE 12-6

ESTIMATED MAJOR REQUIREMENTS FOR CONSTRUCTION MATERIALS

Facility	Material (10 ³ yd ³) ^(a)				
	Concrete	Grout	Riprap	Bentonite	Other Clay
IMPROVED CONFINEMENT					
Above	0	0	160	0	680
Above and around	0	0	160	0	700
Above and around and below	44	14	160	0	700
Immobilization	0	160	0	0	0
DISPOSAL FACILITIES^(b,c)					
<u>Deep rock disposal</u>					
<u>Lemhi site - shaft access</u>					
SP	2.4	0	0	0	0
CPT	2.4	0	0	0	0
PKG	2.4	0	0	0	0
<u>Tunnel access</u>					
SP	5.4	0	0	0	0
CPT	5.4	0	0	0	0
PKG	5.4	0	0	0	0
<u>Engineered shallow land disposal at Site 14</u>					
SP	1,500	0	560	330	830
LMV ^(d)	30	0	180	120	240
CPT	1,600	0	830	490	1,100
LMV	63	0	390	240	520
PKG	3,300	0	1,800	1,100	2,700
LMV	100	0	590	380	800
<u>Engineered surface facility near RWMC</u>					
SP	860	0	250	160	110
CPT	1,300	0	370	240	170
PKG	2,800	0	810	520	370
20-YR RETRIEVABLE STORAGE					
	10	0	0	0	0

- (a) All data rounded to two significant digits. The only material requirements for retrieval or processing facilities that are comparable in scale would be about 3.6×10^3 yd³ of concrete for an SP facility and about 2.0×10^3 yd³ of concrete for a CPT or PKG facility.
- (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, CPT, and PKG 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.
- (d) LMV: less massive variation of the disposal facility at Site 14 (note the large reduction in quantities of materials used--especially concrete).

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

The INEL is relatively undeveloped over most of its area, lying 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 highway (U.S. 20). This impact would persist only until the facilities were dismantled. The stack for a processing facility would be particularly prominent, since there has been little development of the INEL south of U.S. 20 compared with the area north of this highway (see 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 and is a source of recharge for the Snake River Plain aquifer. 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 materials, 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 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, DOE 1979b); 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, DOE 1979b), but only the Lemhi sites overlap grazing areas. Initial effects, during construction, would affect only a very limited area, but could be more extensive later (see Subsection 12.3.6).

The peregrine falcon (Falco peregrinus) 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 blacktail jackrabbit (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 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 reduces 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 effects from facility construction and to recommend procedures to mitigate impacts to important sites.
- (3) Design would include consideration of aesthetic effects.
- (4) Effects on 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 the 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 effects on the environment.

12.3 NONRADIOLOGICAL EFFECTS OF OPERATIONS AND OF DECONTAMINATION AND DECOMMISSIONING

This subsection describes the nonradiological environmental effects expected from operations 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 effect 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, 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 I), or improving confinement (Alternative II), would have little or no effect on air quality. The greatest increase in airborne releases would come from retrieval, slagging pyrolysis, and shipment 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 (c) of the table. The calculation of air concentrations from emission rates is based on the methodology described in Appendix E.

The largest emissions in Table 12-7 are nitrogen oxides. The estimated total of these oxides would be a maximum of 339,000 lb/yr for retrieval, slagging pyrolysis, and disposal at the Lemhi site with shaft access (Concept V-A or V-D). This total would amount to 1,540 lb/day (based on the assumed operating period of 220 days/yr). Current NO_x discharges from other facilities and vehicles operating at the INEL range from 2,800 to 4,800 lb/day. The highest observed concentration onsite was $4.3 \times 10^{-6} \text{ g/m}^3$ (ERDA 1977c). This estimated increase in NO_x emissions would neither contravene the EPA standard ($100 \times 10^{-6} \text{ g/m}^3$, 40 CFR 50) nor cause any significant environmental impact. The maximum offsite concentration, at the nearest INEL boundary, would be increased by $3.6 \times 10^{-7} \text{ g/m}^3$ if Concept V-A or V-D 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 limit of $7.5 \times 10^{-6} \text{ g/m}^3$ (ERDA 1977c). The maximum offsite concentration of SO_2 that would be added by any waste management concept (again, Concept V-A or V-D) would be about $6.3 \times 10^{-8} \text{ g/m}^3$. When compared to the EPA standard ($80 \times 10^{-6} \text{ g/m}^3$), 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/m^3 and the EPA air quality standard is 10 mg/m^3 . The maximum increases in CO emissions from operating activities result from Concepts V-C and V-F. However, based on comparisons with existing operations, the projected increase of $5.1 \times 10^{-8} \text{ g/m}^3$ would cause no detectable change in concentrations at site boundaries.

TABLE 12-7

ESTIMATED AIR EMISSION RATES FROM VEHICULAR EXHAUST DURING OPERATIONS

Facility/Operation	Contaminant (10 ³ lb/yr)						
	Alde- hydes	CO	Hydro- carbons	NO _x	SO ₂	Acetic Acid	Parti- culates
RETRIEVAL FACILITY ^(a)	2.8	17	38	62	11	8.7	31
PROCESS FACILITY ^(b)							
SP ^(c)	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 ^(d)							
<u>Deep rock disposal</u>							
<u>Lemhi site -</u>							
<u>shaft access</u>							
SP	3.0	18	41	67	12	9.4	33
CPT	3.0	18	41	67	12	9.4	33
PKG	5.2	31	70	120	21	16	57
<u>Deep rock disposal</u>							
<u>Lemhi site -</u>							
<u>tunnel access</u>							
SP	2.7	16	36	59	11	8.3	29
CPT	2.7	16	36	59	11	8.3	29
PKG	4.5	27	62	100	18	14	50
<u>Engineered shallow</u>							
<u>land disposal at</u>							
<u>Site 14</u>							
SP	0.79	4.8	11	18	3.2	2.5	8.7
LMV ^(e)	0.36	2.2	4.9	8.0	1.4	1.1	4.0
CPT	0.86	5.2	12	19	3.5	2.7	9.5
LMV	0.43	2.6	5.9	9.6	1.7	1.3	4.8
PKG	1.4	8.2	19	30	5.5	4.2	15
LMV	0.86	5.2	12	19	3.5	2.7	9.5
<u>Engineered surface</u>							
<u>facility near RWMC</u>							
SP	1.9	12	26	43	7.8	6.0	21
CPT	2.0	12	27	45	8.1	6.2	22
PKG	2.2	13	30	50	8.9	6.9	25
20-YR RETRIEVABLE STORAGE	0.94	5.6	13	21	3.7	2.9	10

(a) Release rates would be the same for direct control or remote control retrieval because they are from vehicles used for transfer to a processing facility.

(b) SP: slagging pyrolysis and packaging.
 CPT: compaction, immobilization, and packaging.
 PKG: packaging only.
 (No diesel equipment is operating for any of these modules.)

(c) Although there are no emissions from diesel exhaust, SP stack emissions would contribute 210,000 lb/yr of NO_x; 36,000 lb/yr SO₂; 12,000 lb/yr of HCl; and 0.06 lb/yr of particulates. (Christian, Girton, Kirstein, and Pence, 1978, with DF for HCl taken as 20, for conservatism.)

(d) 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.

(e) LMV refers to less massive variation of the engineered shallow land disposal facility at Site 14.

Maximum particulate emissions would arise from Concept V-C or V-F, totaling 88,000 lb/yr, or about 400 lb/day on a 220 day/yr operating schedule. This would contribute 9.4×10^{-8} g/m³ to the annual average particulate levels at the RWMC, which have recently been above the EPA secondary ambient air standard (see DOE 1979b). However, these levels should not affect air quality at the site boundaries nor cause the primary ambient air standard to be exceeded at the RWMC. Particulate levels at distant monitoring stations have historically exceeded those on the INEL and the EPA standards, presumably because of urban and agricultural activity (ERDA 1977c). Nevertheless, careful monitoring would be continued to assure that waste management operations did not affect 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 shipment. Other modules involving trucking or vehicle movements would have similar effects. However, increased noise levels would affect 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 0.25% 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 Sagebrush 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 of 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 Subsection 12.2.4.1 (and Subsection 3.5 in DOE 1979b). 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 to 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 sewage effluent, 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 other 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, water contaminants would have to migrate nearly 600 ft through basalt and sedimentary layers with substantial retention capacity before reaching the aquifer. Substances such as nitrates not removed by sorption or filtration, would be very dilute upon mixing with the aquifer. A calculation of potential nitrate concentration in the Snake River Plain aquifer (Subsection 7.2.2.3, DOE 1978a) indicates a nitrate level well below the EPA Drinking Water Standard of 0.045 g/l (40 CFR 141). 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 V (disposal on the INEL) would continue to generate excavation spoils. The construction phase includes only enough site preparation to handle the first year's 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 acreage required for spoils from construction of an engineered disposal facility at the RWMC could be reduced by using some of the spoils for backfill at the retrieval facility (see Subsection 9.1.1.1). Backfill to replace the retrieved waste and contaminated soil would total about 230,000 yd³, equivalent to an estimated 28 acres of spoils area (spread 5 ft deep). If the backfill for the waste pits and trenches were taken from a 10-ft deep borrow pit near the RWMC, this would require a 14-acre area. Thus, the area of land disturbed could be reduced by as much as 42 acres if it were found practical to use the spoils this way.

Part of the 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 shipment 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 would be those given in Table 12-3 under construction impacts (Subsection 12.2.3). For alternatives involving waste retrieval, those areas would be increased by 14 acres or reduced by 28 acres, depending on whether spoils could be used for backfill in the waste pits and trenches (Subsection 12.3.5). 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 compete 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 2-mile buffer zone 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 operations for 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 grew substantially (43%) from 1975 to June 1978, when total employment was about 9,400. The recent rapid growth rate is expected to level off in the near future.

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 for existing waste management operations. 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 338 new employees for the less massive variation of Concept V-0 or V-R (156 for retrieval, 128 for packaging, and 54 for disposal at

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	5,526	6,044	----
1968	5,403	6,027	-0.3
1969	5,669	5,996	-0.5
1970	5,574	6,016	0.3
1971	5,324	6,023	0.1
1972	5,228	6,237	3.6
1973	5,665	6,175	-1.0
1974	5,872	6,241	1.0
1975	6,343	6,561	5.1
1976	6,298	7,499	14.3
1977	7,454	8,632	15.1
1978 ^(b)	8,515	9,406	9.0

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

(b) Through June 1978.

Site 14) to 664 for Concept V-A or V-D, (156 for retrieval, 390 for slagging pyrolysis, and 118 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 actually a continuation of earlier construction work.) At a maximum, the estimated new direct employment would be a 7% 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 500 to 1,000 jobs in the supporting economy. The recent INEL personnel questionnaire (DOE 1978b) showed that about half of the current employees had

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	173	0	0
RETRIEVAL FACILITY				
Direct control	156	2,700	281	2,400
Remote control	156	2,700	281	3,200
PROCESS FACILITY ^(c,d)				
SP	390	7,180	0	48,000
CPT	160	2,850	0	19,000
PKG	128	2,210	0	9,600
DISPOSAL FACILITIES				
<u>Deep rock disposal</u>				
<u>Lemhi site - shaft access</u>				
SP	118	2,040	302	6,800
CPT	114	1,970	302	11,000
PKG	114	1,970	518	17,000
<u>Tunnel access</u>				
SP	86	1,490	266	4,600
CPT	82	1,420	266	7,300
PKG	82	1,420	454	11,000
<u>Engineered shallow land disposal at Site 14</u>				
SP	54	934	79	300
LMV	25	432	36	300
CPT	66	1,140	86	370
LMV	40	692	43	370
PKG	79	1,370	137	730
LMV	54	934	86	730
<u>Engineered surface facility near RWMC</u>				
SP	66	1,140	194	230
CPT	50	865	202	370
PKG	85	1,470	223	480
20-YR RETRIEVABLE STORAGE ^(e)	48	830	94	370

(a) 1979 rates, weighted according to estimated skills used: \$18,400/yr for SP processing; \$17,800/yr for CPT processing; \$17,300/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 8,800 tons/yr of coal, 14,300 tons/yr of bark, and 180,000 gal/yr of fuel oil.

(e) Employment and energy use would continue for 20 yr; however, the work force, with its associated energy use, would be reduced after 10 yr to include only maintenance and surveillance personnel. All others would continue for 10 yr (except for monitoring disposal sites, which would continue for 100 yr).

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 338 to 664 new operating employees would total about \$5.8 to \$11.9 million/yr, as seen by summing the corresponding modules in Table 12-9. This would be 4% to 8% of the 1978 INEL payroll. Using the earnings multiplier of 2.2, the total economic impact on the area could be \$13 to \$26 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 1,030 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.

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 280 single-family units. Secondary employment would require additional housing, presumably proportionately. At most, an estimated 1,625 units would be required for direct and indirect workers. This maximum demand for additional housing can be compared to the approximately 700 houses on the market in Idaho Falls, alone, in 1978. Thus, there would be a definite housing impact, but it should be within the capacity of local communities.

TABLE 12-10

ESTIMATED RESIDENCE DISTRIBUTION OF NEW EMPLOYEES

<u>City</u>	<u>Percent</u> ^(a)	<u>Direct Employment</u>	<u>Total New Employment</u>
Idaho Falls	66.5	225-441	562-1104
Blackfoot	6.9	23-46	58-115
Pocatello	4.6	16-30	39-76
Shelley	3.4	11-23	29-56
Arco	2.6	9-17	22-43
Rigby	1.8	6-12	15-30
Ucon	1.6	5-11	14-27
Others	12.6	43-84	106-209
TOTALS	100%	338-664 ^(b)	845-1660

(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 I and II, which involve only 10 direct employees).

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 would 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 nearly 2,000 pupils to local schools, if all 1,660 new jobs (664 direct plus 996 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 could 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, which applies to changes in direct employment).

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 buried 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 deep-rock disposal. The slagging pyrolysis facility would use some wood bark, a locally available waste by-product of lumber processing. 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 effects 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 effects for the life of the project. Additionally, a visible plume from the processing facility stack could cause an adverse aesthetic effect on 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 a long-term impact on aesthetics. Given the existing development on the INEL, this effect 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, shipment 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. Shipping activities would cause localized disturbance to wildlife along roadways and potential increases in road kills. Solid waste disposal from operations and D&D could affect 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 I were selected. This potential would be reduced by the confinement concepts under Alternative II.

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, 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 buried 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 and other constituents present in soil, water, and air at the INEL. Also present is radioactivity from world-wide testing of nuclear weapons. 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 effects 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 uranium and the transuranic nuclides is inhalation of dispersed airborne effluents and resuspended material previously deposited on the ground. Direct radiation from the airborne effluent 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

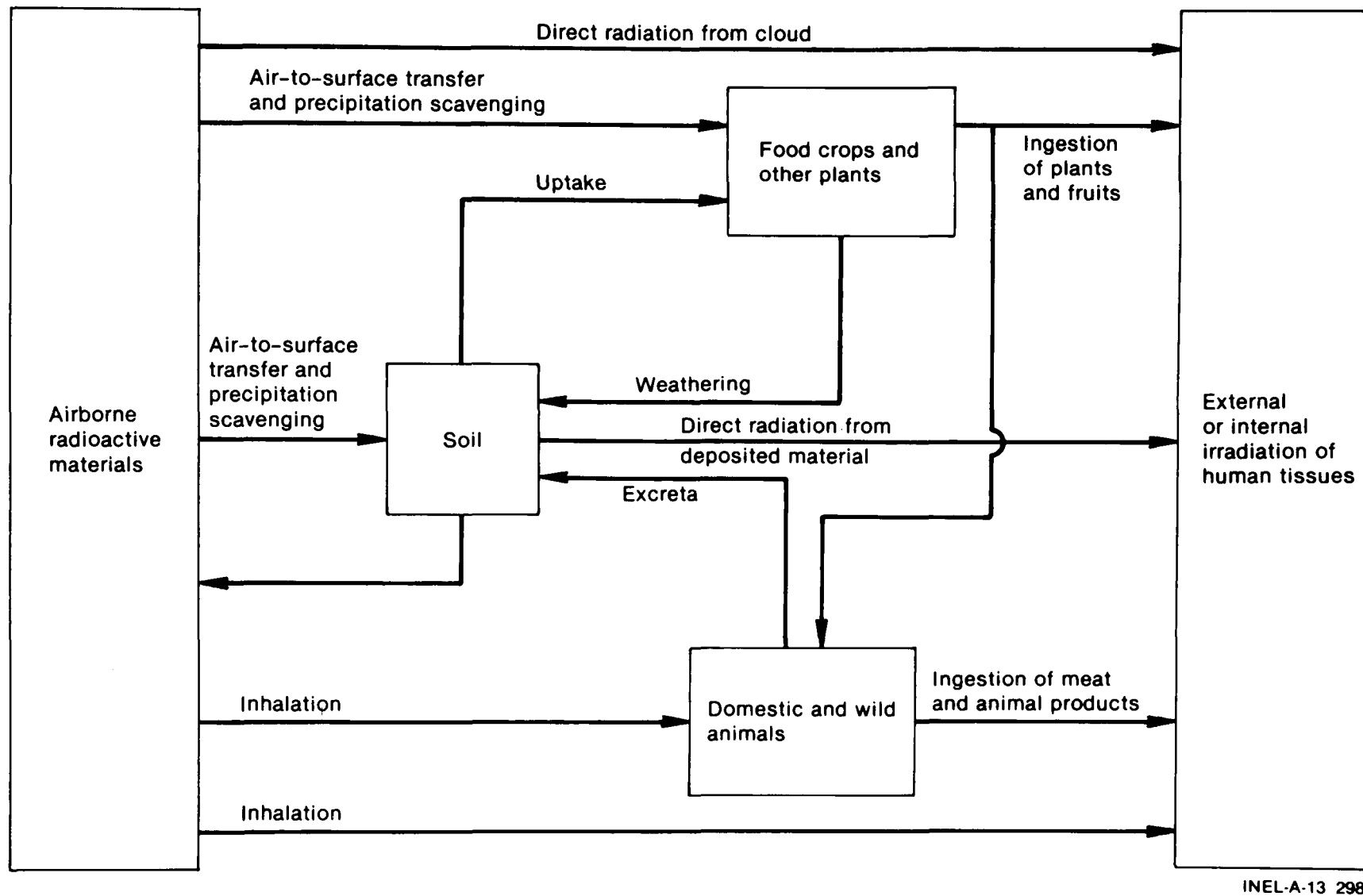


Fig. 12-1. Potential exposure pathways for radionuclides released to the atmosphere.

tissue are also minor pathways because of small soil-to-plant and intestine-to-blood transfer factors for the transuranic elements. However, external irradiation from material deposited on the ground and internal doses resulting from consumption of meat produced by grazing animals are important pathways for fission products contained in the buried waste.

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 this analysis.

12.4.3 Releases of Radionuclides During Normal Operations and During Decontamination and Decommissioning

This subsection discusses the normal operational releases of radionuclides from facilities operated for each waste management alternative or concept. Alternatives I and II would involve no facilities and would have no normal releases.

12.4.3.1 Releases from Retrieval Facilities

The retrieval process would result in the generation of airborne dust within each facility. The mixture of soil and waste to be excavated contains fission products, uranium, and transuranic nuclides. The dust produced during retrieval would result in the release of a fraction of the material through the ventilation systems of the two retrieval buildings. Ventilation air for each facility would pass through two HEPA filters in series, yielding an estimated total decontamination factor (DF) (effluent concentration before filter banks divided by effluent concentration after filtration) of 1×10^6 . In estimating the release rate, it was assumed that the upper limit for stable aerosol concentration within each building would be 100 mg/m^3 (Mishima and Schwendiman 1973b; Mishima 1974) and be maintained at all times. The concentrations of waste nuclides in the waste, given in Table 12-11, are based on the inventory data in Subsection 4.3.3. For radionuclide release and dose calculations, it was assumed that the 255.4 Ci of mixed activation products were all ^{60}Co and that the mixed fission product and unidentified beta-gamma

TABLE 12-11

AVERAGE NUCLIDE CONCENTRATIONS IN BURIED WASTE
AND AVERAGE RELEASE RATES DURING RETRIEVAL

Nuclide	Average Concentration in 1985 ^(a) ($\mu\text{Ci/g waste}$)	Average Release Rates during Retrieval (pCi/sec)	
		Scheduled (1985-1995)	Delayed (2005-2015)
U-233	2.9×10^{-6}	2.5×10^{-6}	2.5×10^{-6}
U-235	1.8×10^{-6}	1.5×10^{-6}	1.5×10^{-6}
U-238	4.0×10^{-4}	3.4×10^{-4}	3.4×10^{-4}
Pu-238	2.7×10^{-3}	2.3×10^{-3}	1.9×10^{-3}
Pu-239	1.2×10^{-1}	9.9×10^{-2}	9.9×10^{-2}
Pu-240	2.7×10^{-2}	2.3×10^{-2}	2.3×10^{-2}
Pu-241	3.2×10^{-1}	2.7×10^{-1}	7.4×10^{-2}
Pu-242	1.2×10^{-6}	1.0×10^{-6}	1.0×10^{-6}
Am-241	2.7×10^{-1}	2.3×10^{-1}	2.3×10^{-1}
Ni-59	8.8×10^{-3}	7.5×10^{-3}	7.5×10^{-3}
Co-60	2.6×10^{-2}	2.2×10^{-2}	1.0×10^{-3}
Sr-90	4.2×10^{-3}	3.6×10^{-3}	2.0×10^{-3}
Cs-137	4.3×10^{-3}	3.7×10^{-3}	2.1×10^{-3}

(a) Based on inventory data in Subsection 4.3.3.

waste (309.6 Ci) were half ^{90}Sr and half ^{137}Cs . (These assumptions are conservative since they will lead to overestimation of the radiological effects of facility operation.) Table 12-11 contains the average rates of release to the environment during retrieval between 1985 and 1995 and during delayed retrieval between 2005 and 2015.

Radionuclide releases to the atmosphere during decommissioning of the retrieval facilities 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 each building during operations. That requirement would limit the amount of internal contamination of the facilities and thereby limit the decommissioning releases.

12.4.3.2 Releases From Slagging Pyrolysis Facility

There are two sources of airborne 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 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 for the preparation cell are given in Tables 12-12 and 12-13.

The second source of airborne effluents is the process offgas, which contains particulate and (possibly) volatilized radionuclides. Release rates for these effluents also are given in Tables 12-12 and 12-13. It was conservatively assumed that the offgas treatment system would provide a decontamination factor of 10^5 for volatile species. (However, recent studies suggest that volatile radionuclides in the offgas stream would be removed prior to release from the stack. The volatiles would be expected to condense and nucleate on offgas particulate material or on equipment surfaces as the

TABLE 12-12

AVERAGE RELEASE RATES FROM SLAGGING PYROLYSIS
FACILITY (PROCESSING BETWEEN 1985 AND 1995)

Average Release Rates to the Environment during Processing (pCi/sec)				
Nuclide ^(a)	Preparation Cell Particulate	Processing Offgas Stream		Total
		Particulate	Volatile	
U-233	3.2×10^{-7}	7.9×10^{-6}	6.0×10^{-9}	8.2×10^{-6}
U-235	1.9×10^{-7}	1.1×10^{-5}	7.2×10^{-9}	1.2×10^{-5}
U-238	4.4×10^{-5}	7.9×10^{-4}	2.0×10^{-6}	8.3×10^{-4}
Pu-238	2.9×10^{-4}	1.8×10^{-2}	1.6×10^{-2}	3.4×10^{-2}
Pu-239	1.3×10^{-2}	7.8×10^{-1}	7.5×10^{-1}	1.5×10^0
Pu-240	3.0×10^{-3}	1.8×10^{-1}	1.7×10^{-1}	3.5×10^{-1}
Pu-241	2.8×10^{-2}	1.7×10^0	1.6×10^0	3.4×10^0
Pu-242	1.3×10^{-7}	7.9×10^{-6}	4.0×10^{-6}	1.2×10^{-5}
Am-241	3.0×10^{-2}	1.9×10^0	2.7×10^0	4.6×10^0
Ni-59	9.7×10^{-4}	1.7×10^{-2}	1.7×10^0	1.7×10^0
Co-60	1.8×10^{-3}	6.1×10^{-2}	1.3×10^2	1.3×10^2
Sr-90	4.2×10^{-4}	1.4×10^{-2}	3.6×10^1	3.6×10^1
Cs-137	4.3×10^{-4}	4.7×10^{-3}	7.8×10^1	7.8×10^1

(a) All radionuclides are assumed to be in oxide form.

TABLE 12-13

AVERAGE RELEASE RATES FROM SLAGGING PYROLYSIS
FACILITY (PROCESSING BETWEEN 2005 AND 2015)

Average Release Rates to the Environment during Processing (pCi/sec)				
Nuclide	Preparation Cell Particulate	Processing Offgas Stream		Total
		Particulate	Volatile	
U-233	3.2×10^{-7}	7.9×10^{-6}	6.0×10^{-9}	8.2×10^{-6}
U-235	1.9×10^{-7}	1.1×10^{-5}	7.2×10^{-9}	1.2×10^{-5}
U-238	4.4×10^{-5}	7.9×10^{-4}	2.0×10^{-6}	8.3×10^{-4}
Pu-238	2.5×10^{-4}	1.6×10^{-2}	1.4×10^{-2}	3.0×10^{-2}
Pu-239	1.3×10^{-2}	7.8×10^{-1}	7.5×10^{-1}	1.5×10^0
Pu-240	3.0×10^{-3}	1.8×10^{-1}	1.7×10^{-1}	3.5×10^{-1}
Pu-241	9.6×10^{-3}	5.9×10^{-1}	5.7×10^{-1}	1.2×10^0
Pu-242	1.3×10^{-7}	7.9×10^{-6}	4.0×10^{-6}	1.2×10^{-5}
Am-241	3.0×10^{-2}	1.8×10^0	2.6×10^0	4.5×10^0
Ni-59	9.7×10^{-4}	1.7×10^{-2}	1.7×10^0	1.7×10^0
Co-60	1.3×10^{-4}	4.4×10^{-3}	9.6×10^0	9.6×10^0
Sr-90	2.6×10^{-4}	8.8×10^{-3}	2.2×10^1	2.2×10^1
Cs-137	2.7×10^{-4}	2.9×10^{-3}	4.9×10^1	4.9×10^1

temperature of the offgas stream is reduced. In Tables 12-12 and 12-13 the contribution from the volatiles is conservatively added directly into the average release rate total). The offgas stream would pass through the volatile offgas 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 offgas concentrations (Christian, Girton, Kirstein, and Pence 1978; Christian, Kirstein, and Pence 1978), scaled for the size of the facility under consideration and the expected 1985 waste concentrations. The design flow rate through the secondary combustion chamber is based on the referenced calculations. It reflects the daily mass of waste processed and is $10.4 \text{ m}^3/\text{sec}$ for a facility processing the buried 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 offgas. Any volatile radioactive component would consist of oxides or chlorides of the elements listed. Because oxides would be expected to be predominant, the calculations were based on all radionuclides being in the oxide form. Radionuclide releases to the atmosphere during decommissioning of the slagging pyrolysis facility would be expected to be less than 1% of those during operations.

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

TABLE 12-14

AVERAGE RELEASE RATES FROM COMPACTION FACILITY

Nuclide	Average Release Rates to the Environment during Processing (pCi/sec)
	Following Scheduled Retrieval (1985-1995)
U-233	3.2×10^{-7}
U-235	1.9×10^{-7}
U-238	4.4×10^{-5}
Pu-238	2.9×10^{-4}
Pu-239	1.3×10^{-2}
Pu-240	3.0×10^{-3}
Pu-241	2.8×10^{-2}
Pu-242	1.3×10^{-7}
Am-241	3.0×10^{-2}
Ni-59	9.7×10^{-4}
Co-60	1.8×10^{-3}
Sr-90	4.2×10^{-4}
Cs-137	4.3×10^{-4}

as for the compaction facility given in Table 12-14. Radionuclide releases to the atmosphere during decommissioning would be expected to be less than 1% of those during operations.

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 Subsection E.3 of 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 ratio holds for all tables in this subsection.

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 a 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 an offsite geologic repository or at

TABLE 12-15

MAXIMUM SOIL CONTAMINATION RESULTING FROM AIRBORNE EFFLUENTS
FROM RETRIEVAL FACILITY

Nuclide	Maximum Soil Concentrations ^(a) (nCi/m ²)	
	Retrieval as Scheduled, 1985-1995	Delayed Retrieval, 2005-2015
U-233	9.3×10^{-7}	9.3×10^{-7}
U-235	5.6×10^{-7}	5.6×10^{-7}
U-238	1.3×10^{-4}	1.3×10^{-4}
Pu-238	8.0×10^{-4}	6.8×10^{-4}
Pu-239	3.7×10^{-2}	3.7×10^{-2}
Pu-240	8.5×10^{-3}	8.5×10^{-3}
Pu-241	6.2×10^{-2}	2.1×10^{-2}
Pu-242	3.7×10^{-7}	3.7×10^{-7}
Am-241	8.7×10^{-2}	8.6×10^{-2}
Ni-59	1.9×10^{-3}	1.9×10^{-3}
Co-60	2.0×10^{-3}	1.4×10^{-4}
Sr-90	7.2×10^{-4}	4.4×10^{-4}
Cs-137	7.4×10^{-4}	4.6×10^{-4}

(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

MAXIMUM SOIL CONTAMINATION RESULTING FROM AIRBORNE EFFLUENTS
FROM SLAGGING PYROLYSIS FACILITY

Nuclide	Maximum Soil Concentrations ^(a) (nCi/m ²)	
	1985-1995	2005-2015
U-233	3.1×10^{-6}	3.1×10^{-6}
U-235	4.4×10^{-6}	4.4×10^{-6}
U-238	3.1×10^{-4}	3.1×10^{-4}
Pu-238	1.2×10^{-2}	1.1×10^{-2}
Pu-239	5.7×10^{-1}	5.7×10^{-1}
Pu-240	1.3×10^{-1}	1.3×10^{-1}
Pu-241	9.7×10^{-1}	3.4×10^{-1}
Pu-242	4.5×10^{-6}	4.5×10^{-6}
Am-241	1.7×10^0	1.7×10^0
Ni-59	4.2×10^{-1}	4.2×10^{-1}
Co-60	1.8×10^1	1.3×10^0
Sr-90	7.9×10^0	4.9×10^0
Cs-137	1.7×10^1	1.1×10^1

(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>
U-233	1.2×10^{-7}
U-235	7.2×10^{-8}
U-238	1.6×10^{-5}
Pu-238	1.0×10^{-4}
Pu-239	4.8×10^{-3}
Pu-240	1.1×10^{-3}
Pu-241	8.1×10^{-3}
Pu-242	4.8×10^{-8}
Am-241	1.1×10^{-2}
Ni-59	2.4×10^{-4}
Co-60	2.6×10^{-4}
Sr-90	9.2×10^{-5}
Cs-137	9.5×10^{-5}

(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.

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 measured in soil at the INEL are given in Table 12-19. The projected maximum total concentration of alpha-emitters resulting from any alternative is about 2.6 nCi/m^2 ; the corresponding average concentration would be about 0.2 nCi/m^2 . This average is about 13% 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 projected maximum fission and activation product soil concentrations that could result from processing of the buried waste are 17, 7.9, 18, and 0.42 nCi/m^2 for ^{137}Cs , ^{90}Sr , ^{60}Co , and ^{59}Ni , respectively. Projected average concentrations are, respectively, 1.3, 0.61, 1.4, and 0.032 nCi/m^2 for the same isotopes. Projected average ^{137}Cs and ^{90}Sr concentrations are 1.2% and 0.9% of the average INEL fallout concentrations of those nuclides. The maximum concentrations of both ^{60}Co and ^{59}Ni are much smaller than the concentration of the long-lived naturally occurring ^{40}K .

The radiological doses resulting from the projected concentrations of fission product, uranic, and 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 in the context of anticipated future land use patterns. The expected continuation of the RWMC as a disposal area for fission product (beta-gamma) waste (see Section 4) represents a long-term commitment of that land. This commitment is independent of the selection of a TRU waste management alternative.

As a point of reference, a comparison of the soil radioactivity levels with the EPA screening level for transuranic nuclides (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 centimeter of soil (EPA 1977).

TABLE 12-18
 MAXIMUM SOIL CONTAMINATION RESULTING FROM NORMAL OPERATION
 OF FACILITIES REQUIRED TO IMPLEMENT MANAGEMENT ALTERNATIVES FOR BURIED WASTE

Management Alternative or Concept	Radionuclide Concentration in Surface Soil (nCi/m ²) ^(a)												
	U-233	U-235	U-238	Pu-238	Pu-239	Pu-240	Pu-241	Pu-242	Am-241	Ni-59	Co-60	Sr-90	Cs-137
I	None	None	None	None	None	None	None	None	None	None	None	None	None
II-A, -B, -C, -D	None	None	None	None	None	None	None	None	None	None	None	None	None
III-A, -B IV-A, -B V-A, -D, -G, -J, -M ^(b) , -P ^(b) , -S, -V	4.0x10 ⁻⁶	5.0x10 ⁻⁶	4.4x10 ⁻⁴	1.3x10 ⁻²	6.1x10 ⁻¹	1.4x10 ⁻¹	1.0x10 ⁰	4.9x10 ⁻⁶	1.8x10 ⁰	4.2x10 ⁻¹	1.8x10 ¹	7.9x10 ⁰	1.7x10 ¹
V-B, -C, -E, -F, -H, -I, -K, -L, -N ^(b) , -O ^(b) , -Q ^(b) , -R ^(b) , -T ^(b) , -U, -W, -X	1.1x10 ⁻⁶	6.4x10 ⁻⁷	1.5x10 ⁻⁴	9.0x10 ⁻⁴	4.2x10 ⁻²	9.6x10 ⁻³	7.0x10 ⁻²	4.2x10 ⁻⁷	9.8x10 ⁻²	2.1x10 ⁻³	2.3x10 ⁻³	8.1x10 ⁻⁴	8.4x10 ⁻⁴
VI-A, -B	4.0x10 ⁻⁶	5.0x10 ⁻⁶	4.4x10 ⁻⁴	1.2x10 ⁻²	6.1x10 ⁻¹	1.4x10 ⁻¹	3.6x10 ⁻¹	4.9x10 ⁻⁶	1.8x10 ⁰	4.2x10 ⁻¹	1.3x10 ⁰	4.9x10 ⁰	1.1x10 ¹

(a) These concentrations would be found only at the point of maximum air concentration (see Figure E-1). The average concentrations within the 50-mile circle around the reference site would be 1/13 of the tabulated values.

(b) Values would be unchanged for the less massive variation of the engineered shallow land disposal facility at Site 14.

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 and alpha- beta emitting daughters	Natural	190
Th-232	Natural	30
Th-232 and 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

Note: The concentration shown for naturally occurring nuclides is only that in the top centimeter of the soil. The values for fallout nuclides are the total deposition, which is mainly distributed in the top 10 cm.

There are areas within and immediately adjacent to the Subsurface Disposal Area (SDA) 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 level (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 animals 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. Both ^{238}Pu and ^{239}Pu 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.

Projected releases of ^{137}Cs and other fission and activation products would result in higher concentrations of these isotopes in tissues of grazing animals. However, the tissue concentrations cannot be predicted precisely because of the variability of animal grazing patterns. Antelope previously collected onsite have contained the highest concentrations, presumably reflecting grazing in areas where vegetation concentrations are higher. However, concentrations of ^{137}Cs in edible tissues from sheep that had grazed

the peripheral areas of the site were not significantly higher than those grazing offsite (ERDA 1977c).

The highest concentrations of ^{137}Cs found in antelope were 1.5 pCi/gram in muscle and 2.7 pCi/gram of liver. These concentrations resulted from ^{137}Cs releases about 100 times greater than anticipated from any TRU waste management alternative. If the observed tissue concentrations were maintained throughout the year, the doses would be about 20 mrad/yr to the whole animal. The maximum doses to antelope from fission and activation products released during buried waste processing would be less than 3 mrad/yr. Doses received by domestic animals grazing on the site would be comparable to those received by antelope. No significant effects on either individual antelope or the resident population would be expected as the result of these doses. Similarly, neither individual domestic animals nor grazing herds would suffer adverse effects. The addition of at most 3 mrad/yr to a dose of at most 20 mrad/yr from other INEL sources would not change the outlook for continued healthy animal populations in the INEL vicinity.

Small mammals will also ingest contaminated soil, a pathway not shown in Figure 12-1. Traces of ^{238}Pu , ^{239}Pu , and ^{241}Am have been found in small mammals residing in and near the SDA of the RWMC (ERDA 1977c; 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 $2,000 \text{ nCi/m}^2$, or about 580 times larger than the maximum total transuranic soil concentration 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 an 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 ground-level air concentration (and surface deposition) throughout the year. (This hypothetical location of residence is actually on the INEL. See Figure E-1 in Appendix E.) 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 ground-level 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 probable annual radiation dose commitment for members of either group 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 1 yr of waste retrieval operations are shown in Table 12-20.

The lifetime dose commitments resulting from 1 yr of operation of a slagging pyrolysis facility are shown in Table 12-21. 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 a compaction facility.

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.

(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	2.7×10^{-4}	4.9×10^{-5}
Lung	2.3×10^{-4}	2.2×10^{-4}
Bone	2.4×10^{-4}	2.4×10^{-4}
Liver	1.8×10^{-4}	1.8×10^{-4}
Kidney	8.8×10^{-5}	8.7×10^{-5}

(a) Dose commitments for "Delayed" retrieval are lower than those for "As Scheduled" retrieval because of radioactive decay during the 20-yr delay period.

TABLE 12-21

MAXIMUM INDIVIDUAL LIFETIME DOSE COMMITMENT RESULTING FROM
AIRBORNE EFFLUENTS FROM ONE YEAR OF OPERATION OF
SLAGGING PYROLYSIS FACILITY

Organ or Tissue	Maximum Lifetime Dose Commitment (mrem) Per Year of Slagging Pyrolysis Operation	
	As Scheduled (1985-1995)	Delayed ^(a) (2005-2015)
Whole body	3.0×10^0	7.3×10^{-1}
Lung	4.4×10^{-3}	4.2×10^{-3}
Bone	4.4×10^{-3}	4.2×10^{-3}
Liver	3.2×10^{-3}	3.1×10^{-3}
Kidney	1.6×10^{-3}	1.6×10^{-3}

(a) Dose commitments for "Delayed" are less than those for "As Scheduled" because of radioactive decay 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	3.5×10^{-5}
Lung	2.9×10^{-5}
Bone	3.1×10^{-5}
Liver	2.3×10^{-5}
Kidney	1.1×10^{-5}

The population doses to employees who work at the various INEL facilities are included in this discussion. The dose commitment for the INEL employees was computed using the conservative assumption that they reside at their work locations. The calculations of 50-mile population dose commitments are based on 1970 census data (see Subsection 3.9 of DOE 1979b), modified by an assumed growth rate guideline [see Guideline (6) 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. 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.

The lifetime population dose commitment to the local population resulting from the release of airborne effluents during 1 yr of operation of the retrieval facility is shown in Table 12-23.

Tables 12-24 and 12-25 contain the lifetime local population dose commitments from 1 yr of operation of the slagging pyrolysis facility and compaction facility, respectively. The lifetime local population dose commitments for the packaging facility would be about the same as those given in Table 12-25 for the compaction facility.

TABLE 12-23

LIFETIME DOSE COMMITMENT TO LOCAL POPULATION 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	2.1×10^{-3}	3.3×10^{-4}
Lung	1.8×10^{-3}	1.8×10^{-3}
Bone	1.9×10^{-3}	1.9×10^{-3}
Liver	1.4×10^{-3}	1.4×10^{-3}
Kidney	7.1×10^{-4}	6.9×10^{-4}

TABLE 12-24

LIFETIME DOSE COMMITMENT TO LOCAL POPULATION 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	2.4×10^1	7.1×10^0
Lung	3.5×10^{-2}	4.1×10^{-2}
Bone	3.5×10^{-2}	4.1×10^{-2}
Liver	2.5×10^{-2}	3.0×10^{-2}
Kidney	1.3×10^{-2}	1.6×10^{-2}

TABLE 12-25

LIFETIME DOSE COMMITMENT TO LOCAL POPULATION 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	2.8×10^{-4}
Lung	2.4×10^{-4}
Bone	2.5×10^{-4}
Liver	1.8×10^{-4}
Kidney	9.1×10^{-5}

The total local population dose commitments from 10 yr of facility operation are approximately 10 times the values tabulated above. The largest projected whole body dose commitment from normal releases is then 240 man-rem for the slagging pyrolysis facility.

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 to 1995. The lifetime dose commitments to the local population from inhalation of airborne materials, external irradiation by deposited gamma-emitters, and ingestion of locally produced meat during the 10-yr operating period were summarized in the previous subsection. The following discussion is confined to the long-term consequences of the soil contamination. The principal pathways of concern are inhalation of resuspended radionuclides and direct radiation from deposits of ^{137}Cs and ^{60}Co .

In estimating doses from resuspension of surface deposits, it was assumed that all radioactivity deposited was contained in the top centimeter 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 centimeter of soil, radioactive decay, and the resuspension process itself. Thus, the resuspension source term decreases exponentially with time (see Subsection E.5 of Appendix E). The mass loading approach was used with the calculated source term to compute the airborne 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 1995. 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 geometrically at the rate of 1%/yr from 1985 to 2085 and to remain constant thereafter.

The maximum long-term whole-body dose commitment is comparable to that projected for the 10-yr operating period. During the period from 1995 to 2005, the average annual whole-body dose commitment would be 9.5 man-rem. This dose commitment would be distributed over a mean population of about 158,000 persons; hence, the average individual's annual whole-body dose commitment would be 0.06 mrem during that period. The largest long-term dose commitment to a specific organ would be to the lung. It is about 250 times that projected for the 10-yr operating period. The annual lung dose commitment during the 1995 to 2005 period would be about 0.0044 mrem for the average individual.

For comparison, the local cumulative whole-body and lung doses to the local population from natural sources are shown in Table 12-27. Average annual dose rates are 150 and 180 mrem to the whole body and lung respectively (ERDA 1977c, NCRP 1975b). Radioactive decay during the 1,000,000-yr period studied will not significantly reduce the so-called terrestrial component of the background dose.

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	9.5×10^1	6.9×10^0	3.7×10^0	3.0×10^0	1.4×10^0
20	1.4×10^2	1.3×10^1	7.2×10^0	5.8×10^0	2.7×10^0
50	1.9×10^2	3.1×10^1	1.7×10^1	1.4×10^1	6.4×10^0
100	2.3×10^2	5.6×10^1	3.0×10^1	2.5×10^1	1.2×10^1
200	2.6×10^2	8.0×10^1	4.3×10^1	3.5×10^1	1.6×10^1
500	2.7×10^2	8.8×10^1	4.8×10^1	3.8×10^1	1.8×10^1
10^3	2.7×10^2	8.8×10^1	4.8×10^1	3.8×10^1	1.8×10^1
10^4	2.7×10^2	8.8×10^1	4.8×10^1	3.8×10^1	1.8×10^1
10^5	2.7×10^2	8.8×10^1	4.8×10^1	3.8×10^1	1.8×10^1
10^6	2.7×10^2	8.8×10^1	4.8×10^1	3.8×10^1	1.8×10^1

TABLE 12-27

CUMULATIVE LIFETIME DOSE COMMITMENTS TO LOCAL POPULATION
FROM NATURAL SOURCES FOR VARIOUS TIMES AFTER 1995

Time (Yr)	Cumulative Whole-Body and Lung Population Doses (man-rem) To Specified Year ^(a)	
	Whole Body	Lung
After 1995		
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}

(a) Based on 150 mrem/yr whole-body dose and 180 mrem/yr lung dose from natural sources (ERDA 1977c, NCRP 1975b).

(This component is due principally to ^{238}U and ^{232}Th and their daughter nuclides, and to ^{40}K .) It was assumed that the cosmic ray component would remain constant during the period. Figure 12-2 compares the cumulative whole-body dose commitments from normal operation of the highest-dose alternative and natural background radiation.

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 Subsection E.8.4 of Appendix E. Populations were again assumed to grow geometrically 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.

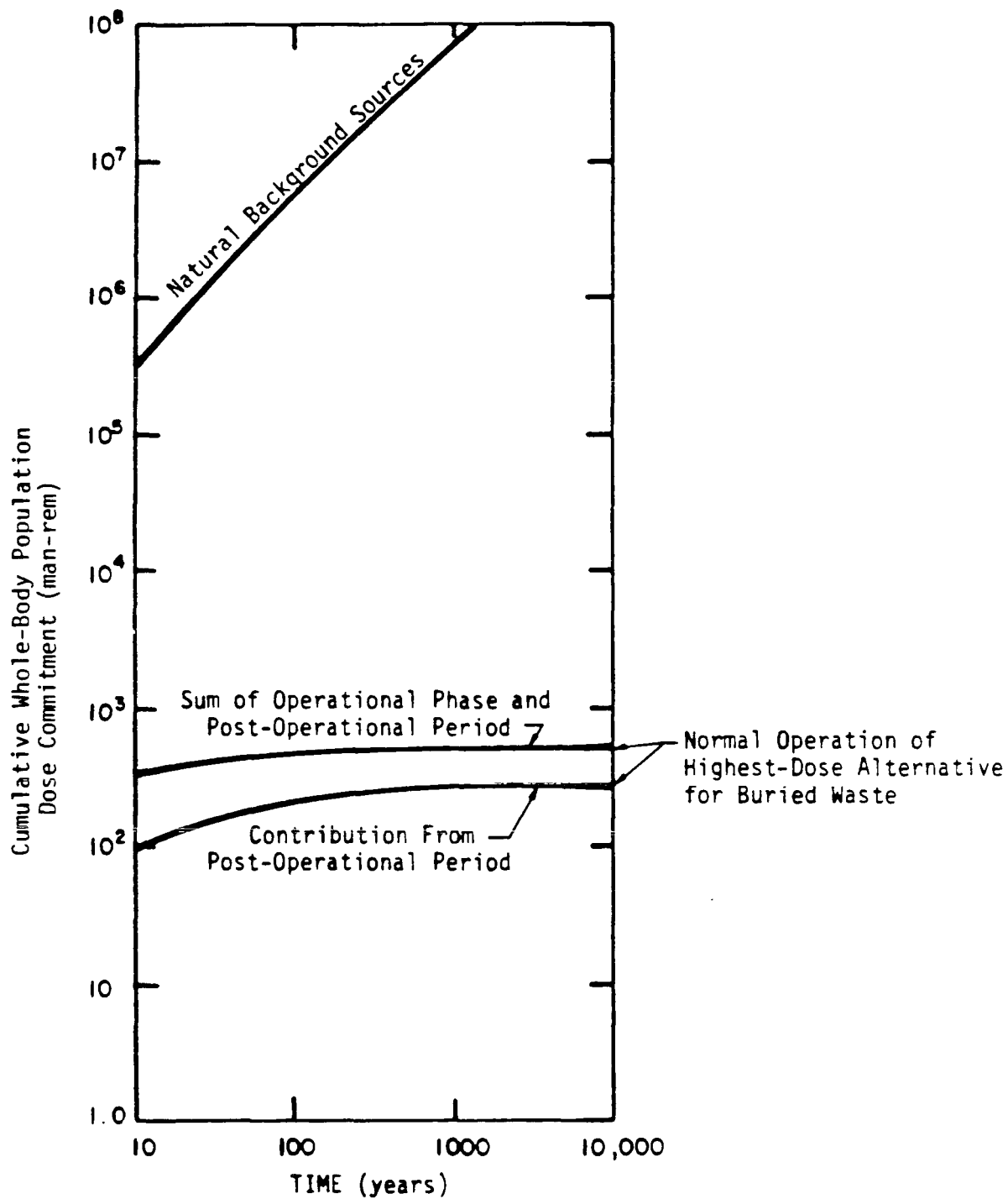


Fig. 12-2. Comparison of the cumulative whole-body dose commitment to the local population for buried waste.

TABLE 12-28

CUMULATIVE LIFETIME DOSE COMMITMENTS FOR DISTANT POPULATIONS AT VARIOUS TIMES AFTER 1995, FOR THE 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	6.9×10^{-3}	3.2×10^1	1.7×10^1	1.4×10^1	6.5×10^0
20	1.2×10^{-2}	6.3×10^1	3.3×10^1	2.7×10^1	1.3×10^1
50	2.2×10^{-2}	1.5×10^2	7.8×10^1	6.3×10^1	3.0×10^1
100	3.1×10^{-2}	2.6×10^2	1.4×10^2	1.1×10^2	5.4×10^1
200	3.5×10^{-2}	3.7×10^2	2.0×10^2	1.6×10^2	7.6×10^1
500	8.2×10^{-1}	4.1×10^2	2.2×10^2	1.8×10^2	8.3×10^1
10^3	8.2×10^{-1}	4.1×10^2	2.2×10^2	1.8×10^2	8.3×10^1
10^4	8.2×10^{-1}	4.1×10^2	2.2×10^2	1.8×10^2	8.3×10^1
10^5	8.2×10^{-1}	4.1×10^2	2.2×10^2	1.8×10^2	8.3×10^1
10^6	8.2×10^{-1}	4.1×10^2	2.2×10^2	1.8×10^2	8.3×10^1

12.4.9 Radiation Doses From Rail Shipment of the Processed TRU Waste

The transport of 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 an offsite geologic 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 buried TRU waste are alpha-emitters. However, beta-gamma emitting radionuclides in the waste would be a source of external radiation exposure to the train crews and to the public near the

shipment route. Use of shielded shipping containers would reduce the radiation dose rate below that required by transportation regulations. At 6 ft from the external surface of the railcars, the radiation level permitted by federal regulations is 10 mR/hr (49 CFR 173.393).

Figure 9-11 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 five 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 434 railcars/yr. The population densities along the postulated railroad route were categorized as urban for the Denver-Boulder area, suburban for the Colorado Springs, Pueblo, and Amarillo, Pocatello areas, and rural for the remainder of the route. Distances through urban, suburban, and rural areas were estimated to be 35, 50, and 1,326 miles, respectively (DOE 1978a).

External whole-body exposure from normal operational shipment of the waste could be received by the general public, passing rail traffic, station personnel, and train crews. The maximum annual dose to an individual crew member was calculated to be approximately 110 mrem. This is about 22% of the allowable limit of 500 mrem/yr for individuals in unrestricted areas (10 CFR 20.105). The dose to a railroad station employee was estimated to be 24 mrem/yr. The maximum dose to a member of the general public was estimated at 0.02 mrem/yr. Table 12-29 illustrates the expected population dose from external whole body exposure from shipment of 434 carloads of waste per yr. The shipments would take place at this rate for 10 yr in Alternatives III, IV, and VI. The effect of the 20-yr delay in Alternatives IV and VI would be to reduce the calculated doses from external exposure by approximately a factor of 2. (The assumptions used for calculating the doses listed in Table 12-29 differed somewhat from those used for similar calculations in DOE 1978a.) Calculations in DOE 1979b were based on the assumptions used in DOE 1978a. The principal difference was in the assumed distribution within the train of the railcars containing the beta-gamma waste.

TABLE 12-29

EXPECTED DOSE FROM EXTERNAL WHOLE-BODY EXPOSURE
DUE TO RAIL TRANSPORT OF BURIED TRU WASTE

<u>Group</u>	<u>Annual Population Dose (man-rem/yr)</u>
General public	1.6
Passing rail traffic	<0.2
Station personnel	0.3
Train crews	6.7

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 were calculated to be 3, 10, and 110 mrem/yr, respectively. These doses are approximately 2%, 7%, and 73%, respectively, of the annual individual whole-body doses received from natural sources (150 mrem/yr).

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; NCRP 1975a).

TABLE 12-30

MAXIMUM POTENTIAL NUMBER OF HEALTH EFFECTS
PER UNIT POPULATION DOSE^(a)

<u>Organ or Tissue at Risk</u>	<u>Total Incidence</u>	<u>Maximum Potential Health Effects (Number/man-rem population dose)</u>	
		<u>Fatal</u>	<u>Nonfatal</u>
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.

For operation of retrieval and slagging pyrolysis facilities (the highest-dose alternative), 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 for both local and distant populations. The values in Table 12-31 include the effects of operation of the facilities, shipment to an offsite geologic repository, and the re-suspension of radionuclides that were deposited in soils from releases to the environment during the original 10-yr retrieval and processing campaign.

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.

TABLE 12-31

MAXIMUM CUMULATIVE POTENTIAL HEALTH EFFECTS
FROM IMPLEMENTATION OF ANY ALTERNATIVE

Time (yr) After 1985	Maximum Cumulative Potential Health Effects		
	Cancers		
	Fatal	Nonfatal	Genetic
10	7.3×10^{-2}	7.0×10^{-2}	1.0×10^{-1}
20	8.4×10^{-2}	7.8×10^{-2}	1.2×10^{-1}
50	1.0×10^{-1}	9.1×10^{-2}	1.3×10^{-1}
100	1.3×10^{-1}	1.0×10^{-1}	1.5×10^{-1}
200	1.4×10^{-1}	1.1×10^{-1}	1.5×10^{-1}
500	1.5×10^{-1}	1.1×10^{-1}	1.6×10^{-1}
10^3	1.5×10^{-1}	1.1×10^{-1}	1.6×10^{-1}
10^4	1.5×10^{-1}	1.1×10^{-1}	1.6×10^{-1}
10^5	1.5×10^{-1}	1.1×10^{-1}	1.6×10^{-1}
10^6	1.5×10^{-1}	1.1×10^{-1}	1.6×10^{-1}

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.

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 3 mrem/yr, or about 2% of the annual background dose of 150 mrem/yr (ERDA 1977c). 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. The maximum individual whole-body doses from the shipment of waste to an offsite geologic repository are comparatively much

higher than doses received from retrieval and processing. This maximum dose, about 110 mrem/yr to a few individuals, is about 73% of the individual dose received from natural sources and 22% of the dose allowed by federal standards (10 CFR 20.105). The cost effectiveness of measures that could lower these doses would be evaluated to assure that shipping operations would be consistent with the philosophy of maintaining doses as low as practicable.

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 buried TRU waste. On the other hand, concern has been expressed about the environment (particularly the Snake River Plain aquifer) 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 12.2.1 and 12.3.1. 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

TABLE 12-32
SUMMARY OF QUANTITATIVE NONRADIOLOGICAL IMPACTS
(CONSTRUCTION PHASE)

Concept ^(a)	Usage (10 ³ yd ³)		Particulate Emissions ^(c) (10 ³ lbs)	Labor ^(d) (man- years)	Diesel Fuel Usage (10 ³ gal)
	Clay ^(b)	Concrete			
I	0	0	0	0	0
II-A	680	0	79	140	720
II-B	700	0	87	140	790
II-C	700	58 ^(e)	100	440	940
II-D	0	160 ^(e)	32	180	290
III-A, III-B	0	3.6 ^(f)	97	1000	880
IV-A, IV-B	0	14	110	1050	970
V-A, V-D	0	6.0	140	1100	1300
V-B, V-E	0	4.4	130	750	1200
V-C, V-F	0	4.4	150	690	1400

V-G, V-J	0	9.0	140	1100	1200
V-H, V-K	0	7.4	130	730	1200
V-I, V-L	0	7.4	140	670	1300

V-M, V-P	1200	1500	110	1000	990
LMV ^(g)	360	30	100	1000	960
V-N, V-Q	1600	1600	72	640	650
LMV	760	63	67	620	610
V-O, V-R	3800	3300	72	570	650
LMV	1200	100	60	510	550

V-S, V-V	270	860	110	1000	980
V-T, V-W	410	1300	74	630	680
V-U, V-X	890	2800	84	560	770
VI-A, VI-B	0	3.6 ^(f)	97	1000	880
See Tables	12-6	12-6	12-2	12-1	12-1

(a) Concept descriptions appear in Table 7-3.

(b) Includes bentonite.

(c) From diesel-powered construction equipment.

(d) Certain concepts were grouped together for simplification. To accomplish this, the average number of construction workers for direct-control retrieval was assumed to be the same as for remote-control retrieval; i.e., 220.

(e) Includes grout.

(f) Includes concrete required for SP facility construction.

(g) LMV refers to less massive variation of the engineered shallow land disposal facility at Site 14.

TABLE 12-33

SUMMARY OF QUANTITATIVE NONRADIOLOGICAL IMPACTS
(OPERATIONS PHASE)

Concept ^(a)	Particulate Emissions (10 ³ lb/yr) ^(b)	Land Usage (acres)	Employment (10 ⁶)		Energy Used	
			Jobs	\$/yr ^(c)	Diesel (10 ³ gal/yr)	Electric (10 ⁶ kWh/yr)
I	0	0 ^(d)	10 ^(e)	0.17	0	0
II-A, II-B						
II-C, II-D	0	44 ^(d)	10 ^(e)	0.17	0	0
III-A, III-B	31	2.5	550	9.9	280	50 ^(f)
IV-A, IV-B	41	10.0	590	10.7	380	51 ^(f)
V-A, V-D	64	210	660	11.9	580	57 ^(f)
V-B, V-E	64	220	430	7.5	580	32 ^(f)
V-C, V-F	88	230	400	6.9	800	29 ^(f)
V-G, V-J	60	220	630	11.4	550	55 ^(f)
V-H, V-K	60	220	400	7.0	550	29 ^(f)
V-I, V-L	81	230	370	6.3	740	23 ^(f)
V-M, V-P	40	540	600	10.8	360	51 ^(f)
LMV ^(g)	35	240	570	10.3	320	51 ^(f)
V-N, V-Q	40	720	380	6.7	370	22 ^(f)
LMV	36	360	360	6.2	320	22 ^(f)
V-O, V-R	46	1500	360	6.3	420	13 ^(f)
LMV	40	480	340	5.8	370	13 ^(f)
V-S, V-V	52	110	610	11.0	480	51 ^(f)
V-T, V-W	53	150	370	6.4	480	22 ^(f)
V-U, V-X	56	320	370	6.4	500	12 ^(f)
VI-A, VI-B	31	2.5	550	9.9	280	50 ^(f)
See Tables	12-7	12-3	12-9	12-9	12-9	12-9

(a) Concept descriptions appear in Table 7-3.

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

(c) 1979 rates, weighted according to estimated skills used: \$18,400/yr for SP processing; \$17,800/yr for CPT processing; \$17,300/yr for all others.

(d) Alternative I and Concept II-D would involve no incremental land usage beyond area in the RWMC currently in use.

(e) Employment is for monitoring personnel only and continues for 100 yr.

(f) For remote control of retrieval facility: add 1 x 10⁶ kWh/yr.

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

near or expected to be 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., $3800 \times 10^3 \text{ yd}^3$ of clay and $3300 \times 10^3 \text{ yd}^3$ of concrete for Concepts V-0 or V-R (shallow land 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 and 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.

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 for spoils, or 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 applicable standards. The environmental impact of each alternative must be evaluated in terms of the gain to be achieved. These tradeoffs are a matter of judgment and public perception.

12.5.2 Radiological Environmental Impacts

The maximum individual doses resulting from normal operations of the waste management facilities 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

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
I	None	None	None	None	None
II	None	None	None	None	None
III, IV, V-A, -D, -G, -J, -M ^(a) , -P ^(a) , -S, -V	3.0×10^0	4.6×10^{-3}	4.6×10^{-3}	3.4×10^{-3}	1.7×10^{-3}
V-B, -C, -E, -F, -H, -I, -K, -L, -N ^(a) , -O ^(a) , -Q ^(a) , -R ^(a) , -T, -U, -W, -X	3.0×10^{-4}	2.6×10^{-4}	2.7×10^{-4}	2.0×10^{-4}	9.9×10^{-5}
VI	7.3×10^{-1}	4.4×10^{-3}	4.4×10^{-3}	3.3×10^{-3}	1.7×10^{-3}

(a) Values would be unchanged for the less massive variation of the engineered shallow land disposal facility at Site 14.

the small increment of about 3 mrem associated with slagging pyrolysis is not significant. It would not be cost-effective to pursue mitigating actions beyond those already incorporated in the designs being evaluated. In none of the concepts is there any cause for concern about significant radiological environmental impacts from normal facility operations. (The impacts from abnormal operations and long-term release scenarios are discussed in Sections 13 and 14.)

The maximum individual dose during shipment of the processed waste to an offsite repository would be much larger. It is projected that a few railroad workers could receive doses of about 110 mrem/yr. The cost effectiveness of measures that could lower these doses would be evaluated to assure that shipping operations would be consistent with the philosophy of maintaining doses as low as practicable.

The annual local population dose commitments associated with normal waste management facility operations are summarized by alternative or concept in Table 12-35. These doses can be compared with the annual population doses from external and internal radiation from natural sources. In 1985, each individual in the population of about 136,000 within 50 miles would receive a whole-body dose of approximately 150 mrem/yr from natural sources. The estimated population dose would be about 2×10^4 man-rem in that year.

The largest total whole-body population dose commitment from pursuit of any waste management alternative or concept would be about 600 man-rem; 240 man-rem from 10 yr of facility operation, 270 man-rem (virtually all received in the next 500 yr) resulting from land contamination during operation, and 88 man-rem from 10 yr of offsite shipment of processed waste. This total population dose is about 0.3% of the local population dose from natural sources during the 10 yr of facility operation. Less than one health effect would be expected as a consequence of normal operational releases for the highest-dose waste management alternative.

TABLE 12-35

LIFETIME LOCAL 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
I	None	None	None	None	None
II	None	None	None	None	None
III, IV, V-A, -D, -G, -J, -M ^(a) , -P ^(a) , -S, -V	2.4×10^1	3.7×10^{-2}	3.7×10^{-2}	2.6×10^{-2}	1.4×10^{-2}
V-B, -C, -E, -F, -H, -I, -K, -L, -N ^(a) , -O ^(a) , -Q ^(a) , -R ^(a) , -T, -U, -W, -X	2.4×10^{-3}	2.0×10^{-3}	2.2×10^{-3}	1.6×10^{-3}	8.0×10^{-4}
VI	7.1×10^0	4.3×10^{-2}	4.3×10^{-2}	3.1×10^{-2}	1.7×10^{-2}

(a) Values would be unchanged for the less massive variation of the engineered shallow land disposal facility at Site 14.

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. The alternatives resulting 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 1200 acres, depending on the alternative, for construction of facilities. This results in loss of habitat and commitment of this land until D&D occurs. 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 Tables 12-33 and 15-1). 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 after processing. 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 or operation activity 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.

13.0 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 (less than 100 yr), the results presented include maximum individual and population dose commitment, as well as maximum individual and population risk. For the long term (100 yr and beyond), 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 I (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 as for Alternative I.

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.

(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.9.

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 up 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 after completion of waste disposal [see Guideline 7.4.1.1 (7)] was studied.

Long-term effects (dose commitments), involving times equal to, or 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 an offsite geologic 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 rem/event	x 4 events/yr	= 4 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} event/yr, the risk would be

<u>Dose</u>	<u>Frequency</u>	<u>Risk</u>
4 rem/event	x 0.01 event/yr	= 0.04 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.

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:

(a) The discussion in Subsection 13.11 enables the interested reader to translate the stated definition of risk into one based on health effects.

- (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 (man-rem/event) 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 multipliers in Table 13-1 are only approximate.

TABLE 13-1

MULTIPLIERS FOR TIME-INTEGRATED RISK TO THE BONE

Time- Integration Interval (yr)	Population Risk Multiplier (yr)	Individual Risk Multiplier (yr)	Dominant Radionuclides, Including Decay ^(a) Daughter Products
1×10^1	1.1×10^1	1.0×10^1	Am-241, Pu-239, Pu-240
1×10^2	1.7×10^2	8.8×10^1	Am-241, Pu-239, Pu-240
4×10^2	9.2×10^2	3.4×10^2	Pu-239, Am-241, Pu-240
1×10^3	2.0×10^3	7.3×10^2	Pu-239, Am-241, Pu-240
2×10^3	3.4×10^3	1.2×10^3	Pu-239, Pu-240, Am-241
1×10^4	1.2×10^4	4.3×10^3	Pu-239, Pu-240, Np-237
2.5×10^4	2.3×10^4	8.1×10^3	Pu-239, Pu-240, Np-237
1×10^5	4.0×10^4	1.5×10^4	Pu-239, Th-229, Np-237
1×10^6	4.6×10^4	1.7×10^4	Th-230, Th-229, Ra-226

(a) Listed in order of importance.

Calculations of short-term dose commitments and risks assumed that releases would 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 would occur in 2085. For the most significant release scenarios, the long-term dose commitments were also calculated for times as much as 1,000,000 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.

13.2.3 Assumptions

A number of approximations and simplifying assumptions were 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; NCRP 1971, 1975a; 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 (such as equipment failures, operating errors, and utility outages); natural events (such as earthquakes, tornadoes, volcanic action, and floods); aircraft crashes; and future intrusion of individuals or small groups of people onto the waste management site.

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 at the assumed time of release 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 the airborne pathway 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 of DOE 1979b. 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 of DOE 1979b). 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 member of the public receiving the maximum dose was conservatively assumed to be located at the point of maximum expected airborne concentration, which is actually on the INEL (see Figure E-1).

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. This is the year generally assumed for implementation. It is also the year after implementation when the radioactivity in the waste would be at a maximum. In calculating the doses for Alternative VI (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 doses calculated for 1985 and the later year of implementation.

Estimation of long-term risks (100 yr and greater) 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 2085. This is the year when the radioactivity would be a maximum for the long-term period starting in 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 SDA within the next 50,000 yr. However, impact of a giant meteorite on the SDA 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 1,000,000 yr into the future.

13.2.5 Long-Term Hazard Characteristics of the INEL TRU Waste

The INEL buried waste is described in Subsection 4.3. The long-term hazard characteristics of the buried waste, including decay daughter products, are described in the following paragraphs.

Total radioactivity is not an accurate measure of the relative hazard of the radionuclides in the waste. Radionuclides vary widely in radiotoxicity, with ^{239}Pu having a high specific toxicity. ^{239}Pu is present in the waste in sufficient quantity and has a half-life long enough to be considered the principal radionuclide of concern over the time period from 0 yr up to about 2.5×10^5 yr after 1985.

Table 13-2 gives the expected radionuclide composition of the buried INEL waste in 1985. The total radioactivity in the waste in 1985 will be approximately 6.5 times the ^{239}Pu activity.

The hazards of the other nuclides in the buried waste can be related to the hazard of ^{239}Pu , as follows:

$$\text{Relative Hazard of Nuclide X} = \frac{\text{Concentration of Nuclide X}}{\text{Concentration of } ^{239}\text{Pu}} \times \frac{[(\text{MPC})_a] ^{239}\text{Pu}}{[(\text{MPC})_a] \text{ X}} \quad (13-1)$$

The quantity $[(\text{MPC})_a] \text{ X}$ 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 radioactivity concentrations of Table 13-2, will be only about two times the ^{239}Pu hazard. (See Table 13-3 for results and calculational details.)

TABLE 13-2

AVERAGE RADIONUCLIDE COMPOSITION OF INEL BURIED WASTE IN 1985

Radionuclide	Half-Life ^(a) (yr)	Nuclide Activity (Ci)	Activity Concentration ^(b) (μ Ci/g of Waste)
U-233	1.59×10^5	5.0×10^{-1}	2.9×10^{-6}
U-235	7.10×10^8	3.0×10^{-1}	1.8×10^{-6}
U-238	4.51×10^9	6.8×10^1	4.0×10^{-4}
Pu-238	8.77×10^1	4.6×10^2	2.7×10^{-3}
Pu-239	2.41×10^4	2.0×10^4	1.2×10^{-1}
Pu-240	6.54×10^3	4.6×10^3	2.7×10^{-2}
Pu-241	1.47×10^1	5.4×10^4	3.2×10^{-1}
Pu-242	3.76×10^5	2.0×10^{-1}	1.2×10^{-6}
Am-241	4.32×10^2	4.7×10^4	2.7×10^{-1}
Ni-59	8.0×10^4	1.5×10^3	8.8×10^{-3}
Co-60	5.26×10^0	$4.5 \times 10^{3(c)}$	2.6×10^{-2}
Sr-90	2.88×10^1	$7.2 \times 10^{2(c)}$	4.2×10^{-3}
Cs-137	3.02×10^1	$7.3 \times 10^{2(c)}$	4.3×10^{-3}
	TOTAL	1.3×10^5	7.8×10^{-1}

(a) Values taken from Chart of Nuclides, 12th Edition, General Electric (1977).

(b) Includes weight of contaminated soil and assumes an overall density of 60 lb/ft³ for the waste-soil mixture.

(c) Based on the inventory data in Subsection 4.3.3, it was assumed that the 255 Ci of mixed activation products were all Co-60 and that the mixed fission products and unidentified beta-gamma waste (310 Ci) were half Sr-90 and half Cs-137.

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	$\frac{[(\text{MPC})_a] \text{ Pu-239}}{[(\text{MPC})_a] \text{ X}}$	Relative Hazard, ^(b) 1985
U-233	4×10^{-11}	2.5×10^{-5}	1.5×10^{-2}	3.8×10^{-7}
U-235	4×10^{-11}	1.5×10^{-5}	1.5×10^{-2}	2.3×10^{-7}
U-238	3×10^{-11}	3.4×10^{-3}	2.0×10^{-2}	6.8×10^{-5}
Pu-238	7×10^{-13}	2.3×10^{-2}	8.6×10^{-1}	2.0×10^{-2}
Pu-239	6×10^{-13}	1.0×10^0	1.0×10^0	1.0×10^0
Pu-240	6×10^{-13}	2.3×10^{-1}	1.0×10^0	2.3×10^{-1}
Pu-241	3×10^{-11}	2.7×10^0	2.0×10^{-2}	5.4×10^{-2}
Pu-242	6×10^{-13}	1.0×10^{-5}	1.0×10^0	1.0×10^{-5}
Am-241	2×10^{-12}	2.4×10^0	3.0×10^{-1}	7.2×10^{-1}
Ni-59	2×10^{-7}	7.6×10^{-2}	3.0×10^{-6}	2.3×10^{-7}
Co-60	3×10^{-9}	2.3×10^{-1}	2.0×10^{-4}	4.6×10^{-5}
Sr-90	1×10^{-10}	3.6×10^{-2}	6.0×10^{-3}	2.2×10^{-4}
Cs-137	5×10^{-9}	3.7×10^{-2}	1.2×10^{-4}	4.4×10^{-6}
			TOTAL	2.0×10^0

(a) $(\text{MPC})_a$ - 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 resulting from 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 waste.

The relative hazard of buried waste nuclides, including daughter products, as a function of time, is given in Table 13-5. The predominant hazards at 0 to 100 yr after 1985 result from ^{239}Pu , and ^{241}Am and their daughter products. At 10^3 , 10^4 , and 10^5 yr, the predominant hazard is from ^{239}Pu . At 10^6 yr, ^{238}U and its daughter products predominate. The total relative hazard is reduced by about a factor of about 1.5 after 10^3 yr, 2.5 after 10^4 yr, 25 after 10^5 yr, and 45 after 10^6 yr.

It is also of interest to examine the radioactivity of the waste as a function of time. The total radioactivity is listed in Table 13-6 and includes all uranium, TRU, beta-gamma, and daughter radionuclides.

Table 13-7 shows the time dependence of the total concentration of transuranic nuclides in the buried waste. The predominant nuclides (including daughter products) are given in order of their concentration at each time. The total concentration of transuranic nuclides in 1985 will be about 740 nCi/g (0.74 $\mu\text{Ci/g}$). This assumes that the activity of the most important transuranic daughter product (^{241}Am) would be at its peak value at that time. Between 10^4 and 10^5 yr after 1985, the concentration of transuranics will drop below 10 nCi/g, the current lower concentration limit for waste to be classified as transuranic-contaminated.

13.3 SUMMARY OF RESULTS

For the waste management alternatives, concepts, and modules studied, summary Tables 13-8 through 13-21 present the results of the dose and risk analyses. For alternatives and concepts that consist of more than one module,

TABLE 13-4

CHANGE IN RELATIVE HAZARD OF RADIONUCLIDES
AS A FUNCTION OF TIME

Nuclide ^(a)	Relative Hazard at Specified Time After 1985 (yr)					
	0 ^(b)	10 ²	10 ³	10 ⁴	10 ⁵	10 ⁶
U-233	1.0x10 ⁰	1.0x10 ⁰	1.0x10 ⁰	9.6x10 ⁻¹	6.6x10 ⁻¹	1.3x10 ⁻²
U-235	1.0x10 ⁰	1.6x10 ⁰	1.6x10 ¹	1.5x10 ²	6.6x10 ²	7.5x10 ²
U-238	1.0x10 ⁰	1.0x10 ⁰	1.0x10 ⁰	1.7x10 ⁰	5.8x10 ¹	5.5x10 ²
Pu-238	1.0x10 ⁰	4.5x10 ⁻¹	7.7x10 ⁻⁴	2.7x10 ⁻⁴	1.5x10 ⁻³	3.9x10 ⁻⁴
Pu-239	1.0x10 ⁰	1.0x10 ⁰	9.7x10 ⁻¹	7.5x10 ⁻¹	7.2x10 ⁻²	2.9x10 ⁻⁴
Pu-240	1.0x10 ⁰	1.0x10 ⁰	9.0x10 ⁻¹	3.5x10 ⁻¹	1.5x10 ⁻⁴	5.0x10 ⁻⁶
Pu-241	1.0x10 ⁰	5.2x10 ⁻¹	1.4x10 ⁻¹	2.2x10 ⁻⁴	2.4x10 ⁻³	5.9x10 ⁻³
Pu-242	1.0x10 ⁰	1.0x10 ⁰	1.0x10 ⁰	9.8x10 ⁻¹	8.4x10 ⁻¹	1.7x10 ⁻¹
Am-241	1.0x10 ⁰	8.5x10 ⁻¹	2.0x10 ⁻¹	4.6x10 ⁻⁴	4.6x10 ⁻³	6.9x10 ⁻³
Ni-59	1.0x10 ⁰	1.0x10 ⁰	9.9x10 ⁻¹	9.2x10 ⁻¹	4.2x10 ⁻¹	1.7x10 ⁻⁴
Co-60	1.0x10 ⁰	1.9x10 ⁻⁶	<10 ⁻²⁰	<10 ⁻²⁰	<10 ⁻²⁰	<10 ⁻²⁰
Sr-90	1.0x10 ⁰	9.0x10 ⁻²	3.5x10 ⁻¹¹	<10 ⁻²⁰	<10 ⁻²⁰	<10 ⁻²⁰
Cs-137	1.0x10 ⁰	1.0x10 ⁻¹	1.1x10 ⁻¹⁰	<10 ⁻²⁰	<10 ⁻²⁰	<10 ⁻²⁰

(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
U-233	3.8x10 ⁻⁷	3.8x10 ⁻⁷	3.8x10 ⁻⁷	3.6x10 ⁻⁷	2.5x10 ⁻⁷	4.9x10 ⁻⁹
U-235	2.3x10 ⁻⁷	3.6x10 ⁻⁷	3.6x10 ⁻⁶	3.4x10 ⁻⁵	1.5x10 ⁻⁴	1.7x10 ⁻⁴
U-238	6.9x10 ⁻⁵	6.9x10 ⁻⁵	6.9x10 ⁻⁵	1.2x10 ⁻⁴	4.0x10 ⁻³	3.8x10 ⁻²
Pu-238	2.0x10 ⁻²	9.0x10 ⁻³	1.5x10 ⁻⁵	5.4x10 ⁻⁶	3.0x10 ⁻⁵	7.8x10 ⁻⁶
Pu-239	1.0x10 ⁰	1.0x10 ⁰	9.7x10 ⁻¹	7.5x10 ⁻¹	7.2x10 ⁻²	2.9x10 ⁻⁴
Pu-240	2.3x10 ⁻¹	2.3x10 ⁻¹	2.1x10 ⁻¹	8.1x10 ⁻²	3.5x10 ⁻⁵	1.2x10 ⁻⁶
Pu-241	5.5x10 ⁻²	2.9x10 ⁻²	7.7x10 ⁻³	1.2x10 ⁻⁵	1.3x10 ⁻⁴	3.2x10 ⁻⁴
Pu-242	1.0x10 ⁻⁵	1.0x10 ⁻⁵	1.0x10 ⁻⁵	9.8x10 ⁻⁶	8.4x10 ⁻⁶	1.7x10 ⁻⁶
Am-241	7.1x10 ⁻¹	6.0x10 ⁻¹	1.4x10 ⁻¹	3.2x10 ⁻⁴	3.2x10 ⁻³	4.9x10 ⁻³
Ni-59	2.3x10 ⁻⁷	2.3x10 ⁻⁷	2.2x10 ⁻⁷	2.1x10 ⁻⁷	9.5x10 ⁻⁸	3.9x10 ⁻¹¹
Co-60	4.5x10 ⁻⁵	8.6x10 ⁻¹¹	<10 ⁻²⁴	<10 ⁻²⁴	<10 ⁻²⁴	<10 ⁻²⁴
Sr-90	2.2x10 ⁻⁴	2.0x10 ⁻⁵	7.6x10 ⁻¹⁵	<10 ⁻²⁴	<10 ⁻²⁴	<10 ⁻²⁴
Cs-137	4.4x10 ⁻⁶	4.4x10 ⁻⁷	4.9x10 ⁻¹⁶	<10 ⁻²⁴	<10 ⁻²⁴	<10 ⁻²⁴
TOTAL	2.0x10 ⁰	1.9x10 ⁰	1.3x10 ⁰	8.3x10 ⁻¹	8.0x10 ⁻²	4.4x10 ⁻²

(a) Pu-239 hazard set at 1.0x10⁰ in 1985 (0 yr after 1985).

TABLE 13-6
TOTAL RADIOACTIVITY IN INEL BURIED WASTE
AS A FUNCTION OF TIME^(a)

<u>Time After 1985 (yr)</u>	<u>Total Radio- activity (Ci)</u>
0	133,000
100	68,000
400	53,000
2,000	26,000
25,000	11,000
100,000	1,900
1,000,000	25

(a) Includes all TRU, uranium, beta-gamma, and daughter nuclides.

TABLE 13-7
TOTAL CONCENTRATIONS OF TRANSURANIC NUCLIDES IN THE
SUBSURFACE DISPOSAL AREA

<u>Time After 1985 (yr)</u>	<u>Predominant Nuclides^(a)</u>	<u>Concentration of Transuranics (nCi/g)</u>
0	Pu-241, Am-241, Pu-239	740
10	Am-241, Pu-241, Pu-239	620
100	Am-241, Pu-239, Pu-240	390
1,000	Pu-239, Am-241, Pu-240	190
10,000	Pu-239, Pu-240, Np-237	97
100,000	Pu-239, Np-237, Pu-240	6.8
1,000,000	Np-237, Pu-242	0.042

(a) Listed in order of importance.

TABLE 13-8

SUMMARY OF ACCIDENT EFFECTS FOR ALTERNATIVE I: LEAVE AS IS

Releases ^(a)	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(0)	2x10 ⁻⁴	3x10 ⁻⁸	4x10 ⁻⁴	6x10 ⁻¹	6x10 ⁻¹	1x10 ⁻¹¹	2x10 ⁻⁸	2x10 ⁻⁸	8x10 ⁻¹	1x10 ³	1x10 ³	2x10 ⁻⁸	3x10 ⁻⁵	3x10 ⁻⁵
Earthquake(0)	8x10 ⁻⁹	2x10 ⁻⁶	2x10 ⁻⁸	2x10 ⁻⁵	2x10 ⁻⁵	4x10 ⁻¹⁴	4x10 ⁻¹¹	4x10 ⁻¹¹	3x10 ⁻⁵	5x10 ⁻²	4x10 ⁻²	6x10 ⁻¹¹	1x10 ⁻⁷	6x10 ⁻⁸
Mackay Dam(0) ^(b)	3x10 ⁻⁷	2x10 ⁻³	9x10 ⁻¹⁴	1x10 ⁻⁹	2x10 ⁻⁹	2x10 ⁻¹⁶	2x10 ⁻¹²	4x10 ⁻¹²	1x10 ⁻¹⁰	2x10 ⁻⁶	3x10 ⁻⁶	2x10 ⁻¹³	4x10 ⁻⁹	6x10 ⁻⁹
Lava flow(0) ^(c)	1x10 ⁻²	6x10 ⁻⁵	2x10 ⁻²	3x10 ¹	3x10 ¹	1x10 ⁻⁶	2x10 ⁻³	2x10 ⁻³	4x10 ¹	6x10 ⁴	5x10 ⁴	2x10 ⁻³	4x10 ⁰	3x10 ⁰
Long term														
Lava flow (100) ^(c)	1x10 ⁻²	NC ^(e)	1x10 ⁻²	3x10 ¹	2x10 ¹	NC	NC	NC	5x10 ¹	2x10 ⁵	1x10 ⁵	NC	NC	NC
Lava flow (2 x 10 ³)(c)	1x10 ⁻²	NC	1x10 ⁻³	1x10 ¹	9x10 ⁰	NC	NC	NC	6x10 ⁰	7x10 ⁴	5x10 ⁴	NC	NC	NC
Explosive volc. (100)	2x10 ⁻⁴	NC	2x10 ⁻⁴	6x10 ⁻¹	4x10 ⁻¹	NC	NC	NC	1x10 ⁰	4x10 ³	2x10 ³	NC	NC	NC
Erosion (100)	Wind Pickup	NC	1x10 ⁻⁷	1x10 ⁻⁵	9x10 ⁻⁶	NC	NC	NC	3x10 ⁻⁴	4x10 ⁻²	3x10 ⁻²	NC	NC	NC
Intrusion (100) (excavation following erosion: 2 x 10 ⁻⁷ Ci inhaled) ^(f)	NA ^(g)	NC	2x10 ⁰	1x10 ²	1x10 ²	NC	NC	NC	1x10 ⁻²	1x10 ¹	1x10 ¹	NC	NC	NC
Intrusion (farming)(100) ingestion (3 x 10 ⁻⁶ Ci/yr)	NA	NC	1x10 ⁰	5x10 ⁰	NA	NC	NC	NC	1x10 ¹	5x10 ¹	NA	NC	NC	NC
inhalation (7 x 10 ⁻¹⁰ Ci/yr) ^(f)	NA	NC	2x10 ⁻¹	1x10 ¹	2x10 ¹	NC	NC	NC	2x10 ⁰	1x10 ²	2x10 ²	NC	NC	NC
Tornado (100)	3x10 ⁻⁴	NC	3x10 ⁻⁴	9x10 ⁻¹	6x10 ⁻¹	NC	NC	NC	2x10 ⁰	6x10 ³	3x10 ³	NC	NC	NC
Mackay Dam (100) ^(b)	3x10 ⁻⁶	NC	9x10 ⁻¹³	1x10 ⁻⁸	2x10 ⁻⁸	NC	NC	NC	1x10 ⁻⁹	2x10 ⁻⁵	3x10 ⁻⁵	NC	NC	NC
Earthquake (100)	8x10 ⁻⁸	NC	8x10 ⁻⁸	2x10 ⁻⁴	2x10 ⁻⁴	NC	NC	NC	4x10 ⁻⁴	2x10 ⁰	8x10 ⁻¹	NC	NC	NC
WATERBORNE ^(h)														
Short term														
Mackay Dam (0) ^(c)	1x10 ⁻⁴	2x10 ⁻³	5x10 ⁻⁷	9x10 ⁻⁵	NA	1x10 ⁻⁹	2x10 ⁻⁷	NA	2x10 ⁻⁷	1x10 ⁻³	NA	4x10 ⁻¹⁰	2x10 ⁻⁶	NA
Long term ^(d)														
Mackay Dam (100)	1x10 ⁻⁴	NC	1x10 ⁻⁷	6x10 ⁻⁵	NA	NC	NC	NC	2x10 ⁻⁷	1x10 ⁻³	NA	NC	NC	NC
River channel alteration (100) ^(c)	1x10 ⁻²	NC	1x10 ⁻⁵	6x10 ⁻³	NA	NC	NC	NC	2x10 ⁻⁵	1x10 ⁻¹	NA	NC	NC	NC
Groundwater variation (100)	1x10 ⁻⁴	NC	1x10 ⁻⁷	6x10 ⁻⁵	NA	NC	NC	NC	2x10 ⁻⁷	1x10 ⁻³	NA	NC	NC	NC
Glaciation, climate change, etc. (100) ^(c)	1x10 ⁻²	NC	1x10 ⁻⁵	6x10 ⁻³	NA	NC	NC	NC	2x10 ⁻⁵	1x10 ⁻¹	NA	NC	NC	NC
Glaciation, etc. (1x10 ⁶)(c)	1x10 ⁻²	NC	2x10 ⁻⁵	2x10 ⁻¹	NA	NC	NC	NC	6x10 ⁻⁶	1x10 ⁻¹	NA	NC	NC	NC

(a) Numbers in parentheses after accident refer to the time of release, in number of years after 1985.

(b) Resuspension by wind pickup.

(c) Dominant event for population doses.

(d) Includes 1% per year geometric population growth to 2085 and assumes 100 yr decay of radionuclides unless otherwise specified.

(e) NC = not calculated because of the difficulty of reliably predicting probabilities and geologic characteristics into the distant future.

(f) Intake listed is that for maximum individual.

(g) NA = not applicable.

(h) 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 II-A: IMPROVE CONFINEMENT - ABOVE

Releases (a)	Release	Event	Maximum Individual						Population						
			Freq., yr ⁻¹	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(0)	2x10 ⁻⁴	3x10 ⁻⁸	4x10 ⁻⁴	6x10 ⁻¹	6x10 ⁻¹	1x10 ⁻¹¹	2x10 ⁻⁸	2x10 ⁻⁸	8x10 ⁻¹	1x10 ³	1x10 ³	2x10 ⁻⁸	3x10 ⁻⁵	3x10 ⁻⁵	
Earthquake	2x10 ⁻⁹	2x10 ⁻⁶	4x10 ⁻⁹	6x10 ⁻⁶	6x10 ⁻⁶	8x10 ⁻¹⁵	1x10 ⁻¹¹	1x10 ⁻¹¹	8x10 ⁻⁶	1x10 ⁻²	1x10 ⁻²	2x10 ⁻¹¹	2x10 ⁻⁸	2x10 ⁻⁸	
Mackay Dam(0)(b)	6x10 ⁻⁹	2x10 ⁻³	2x10 ⁻¹⁵	2x10 ⁻¹¹	4x10 ⁻¹¹	4x10 ⁻¹⁸	4x10 ⁻¹⁴	8x10 ⁻¹⁴	2x10 ⁻¹²	4x10 ⁻⁸	6x10 ⁻⁸	4x10 ⁻¹⁵	8x10 ⁻¹¹	1x10 ⁻¹⁰	
Lava flow(0)(c)	1x10 ⁻⁴	6x10 ⁻⁵	2x10 ⁻⁴	3x10 ⁻¹	3x10 ⁻¹	1x10 ⁻⁸	2x10 ⁻⁵	2x10 ⁻⁵	4x10 ⁻¹	6x10 ²	5x10 ²	2x10 ⁻⁵	4x10 ⁻²	3x10 ⁻²	
Long term (d)															
Lava flow (100)(c)	1x10 ⁻²	NC(e)	1x10 ⁻²	3x10 ¹	2x10 ¹	NC	NC	NC	5x10 ¹	2x10 ⁵	1x10 ⁵	NC	NC	NC	
Lava flow (2 x 10 ³)(c)	1x10 ⁻²	NC	1x10 ⁻³	1x10 ¹	9x10 ⁰	NC	NC	NC	6x10 ⁰	7x10 ⁴	5x10 ⁴	NC	NC	NC	
Explosive volc. (100)	2x10 ⁻⁴	NC	2x10 ⁻⁴	6x10 ⁻¹	4x10 ⁻¹	NC	NC	NC	1x10 ⁰	4x10 ³	2x10 ³	NC	NC	NC	
Erosion (100)	Wind Pickup	NC	1x10 ⁻⁷	1x10 ⁻⁵	9x10 ⁻⁶	NC	NC	NC	3x10 ⁻⁴	4x10 ⁻²	3x10 ⁻²	NC	NC	NC	
Intrusion (100)															
(excavation fol-															
lowing erosion:															
2' x 10 ⁻⁷ Ci in-															
haled)(f)															
NA(g)															
NC															
2x10 ⁰															
1x10 ²															
1x10 ²															
NC															
NC															
NC															
1x10 ⁻²															
1x10 ¹															
1x10 ¹															
NC															
NC															
NC															
Intrusion (farming)(100)															
ingestion (3 x 10 ⁻⁶ Ci/yr)															
NA															
NC															
1x10 ⁰															
5x10 ⁰															
NA															
NC															
NC															
inhalation															
(7 x 10 ⁻¹⁰ Ci/yr)(f)															
NA															
NC															
2x10 ⁻¹															
1x10 ¹															
2x10 ¹															
NC															
NC															
NC															
2x10 ⁰															
1x10 ²															
2x10 ²															
NC															
NC															
NC															
Tornado (100)															
3x10 ⁻⁴															
NC															
3x10 ⁻⁴															
9x10 ⁻¹															
6x10 ⁻¹															
NC															
NC															
NC															
2x10 ⁰															
6x10 ³															
3x10 ³															
NC															
NC															
NC															
Mackay Dam (100)(b)															
3x10 ⁻⁶															
NC															
9x10 ⁻¹³															
1x10 ⁻⁸															
2x10 ⁻⁸															
NC															
NC															
NC															
1x10 ⁻⁹															
2x10 ⁻⁵															
3x10 ⁻⁵															
NC															
NC															
NC															
Earthquake (100)															
8x10 ⁻⁸															
NC															
8x10 ⁻⁸															
2x10 ⁻⁴															
2x10 ⁻⁴															
NC															
NC															
NC															
4x10 ⁻⁴															
2x10 ⁰															
8x10 ⁻¹															
NC															
NC															
NC															
WATERBORNE (h)															
Short term															
Mackay Dam (0)(c)															
2x10 ⁻⁵															
2x10 ⁻³															
1x10 ⁻⁷															
2x10 ⁻⁵															
NA															
2x10 ⁻¹⁰															
4x10 ⁻⁸															
NA															
4x10 ⁻⁸															
2x10 ⁻⁴															
NA															
8x10 ⁻¹¹															
4x10 ⁻⁷															
NA															
Long term (d)															
Mackay Dam (100)															
1x10 ⁻⁴															
NC															
1x10 ⁻⁷															
6x10 ⁻⁵															
NA															
NC															
NC															
NC															
2x10 ⁻⁷															
1x10 ⁻³															
NA															
NC															
NC															
NC															
River channel															
alteration (100)(c)															
1x10 ⁻²															
NC															
1x10 ⁻⁵															
6x10 ⁻³															
NA															
NC															
NC															
NC															
2x10 ⁻⁵															
1x10 ⁻¹															
NA															
NC															
NC															
NC															
Groundwater															
variation (100)															
1x10 ⁻⁴															
NC															
1x10 ⁻⁷															
6x10 ⁻⁵															
NA															
NC															
NC															
NC															
2x10 ⁻⁷															
1x10 ⁻³															
NA															
NC															
NC															
NC															
Glaciation, climate															
change, etc. (100)(c)															
1x10 ⁻²															
NC															
1x10 ⁻⁵															
6x10 ⁻³															
NA															
NC															
NC															
NC															
2x10 ⁻⁵															
1x10 ⁻¹															
NA															
NC															
NC															
NC															
Glaciation, etc.															
(1x10 ⁶)(c)															
1x10 ⁻²															
NC															
2x10 ⁻⁵															
2x10 ⁻¹															
NA															
NC															
NC															
NC															
6x10 ⁻⁶															
1x10 ⁻¹															
NA															
NA															
NC															
NC															

(a) Numbers in parentheses after accident refer to the time of release, in terms number of years after 1985.

(b) Resuspension by wind pickup.

(c) Dominant event for population doses.

(d) Includes 1% per year geometric population growth to 2085 and assumes 100 yr decay of radionuclides unless otherwise specified.

(e) NC = not calculated because of the difficulty of reliably predicting probabilities and geologic characteristics into the distant future.

(f) Intake listed is that for maximum individual.

(g) NA = not applicable.

(h) 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 II-B: IMPROVE CONFINEMENT - ABOVE AND AROUND

Releases ^(a)	Release	Event	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(0)	2x10 ⁻⁴	3x10 ⁻⁸	4x10 ⁻⁴	6x10 ⁻¹	6x10 ⁻¹	1x10 ⁻¹¹	2x10 ⁻⁸	2x10 ⁻⁸	8x10 ⁻¹	1x10 ³	1x10 ³	2x10 ⁻⁸	3x10 ⁻⁵	3x10 ⁻⁵
Earthquake	2x10 ⁻⁹	2x10 ⁻⁶	4x10 ⁻⁹	6x10 ⁻⁶	6x10 ⁻⁶	8x10 ⁻¹⁵	1x10 ⁻¹¹	1x10 ⁻¹¹	8x10 ⁻⁶	1x10 ⁻²	1x10 ⁻²	2x10 ⁻¹¹	2x10 ⁻⁸	2x10 ⁻⁸
Mackay Dam(0)(b)	6x10 ⁻⁹	2x10 ⁻³	2x10 ⁻¹⁵	2x10 ⁻¹¹	4x10 ⁻¹¹	4x10 ⁻¹⁸	4x10 ⁻¹⁴	8x10 ⁻¹⁴	2x10 ⁻¹²	4x10 ⁻⁸	6x10 ⁻⁸	4x10 ⁻¹⁵	8x10 ⁻¹¹	1x10 ⁻¹⁰
Lava flow(0)(c)	1x10 ⁻⁴	6x10 ⁻⁵	2x10 ⁻⁴	3x10 ⁻¹	3x10 ⁻¹	1x10 ⁻⁸	2x10 ⁻⁵	2x10 ⁻⁵	4x10 ⁻¹	6x10 ²	5x10 ²	2x10 ⁻⁵	4x10 ⁻²	3x10 ⁻²
Long term ^(d)														
Lava flow (100)(c)	1x10 ⁻²	NC ^(e)	1x10 ⁻²	3x10 ¹	2x10 ¹	NC	NC	NC	5x10 ¹	2x10 ⁵	1x10 ⁵	NC	NC	NC
Lava flow (2 x 10 ³)(c)	1x10 ⁻²	NC	1x10 ⁻³	1x10 ¹	9x10 ⁰	NC	NC	NC	6x10 ⁰	7x10 ⁴	5x10 ⁴	NC	NC	NC
Explosive volc. (100)	2x10 ⁻⁴	NC	2x10 ⁻⁴	6x10 ⁻¹	4x10 ⁻¹	NC	NC	NC	1x10 ⁰	4x10 ³	2x10 ³	NC	NC	NC
Erosion (100)	Wind Pickup	NC	1x10 ⁻⁷	1x10 ⁻⁵	9x10 ⁻⁶	NC	NC	NC	3x10 ⁻⁴	4x10 ⁻²	3x10 ⁻²	NC	NC	NC
Intrusion (100) (excavation fol- lowing erosion: 2 x 10 ⁻⁷ Ci in- haled)(f)	NA ^(g)	NC	2x10 ⁰	1x10 ²	1x10 ²	NC	NC	NC	1x10 ⁻²	1x10 ¹	1x10 ¹	NC	NC	NC
Intrusion (farming)(100) ingestion (3 x 10 ⁻⁶ Ci/yr) inhalation (7 x 10 ⁻¹⁰ Ci/yr)(f)	NA	NC	2x10 ⁻¹	1x10 ¹	2x10 ¹	NC	NC	NC	2x10 ⁰	1x10 ²	2x10 ²	NC	NC	NC
Tornado (100)	3x10 ⁻⁴	NC	3x10 ⁻⁴	9x10 ⁻¹	6x10 ⁻¹	NC	NC	NC	2x10 ⁰	6x10 ³	3x10 ³	NC	NC	NC
Mackay Dam (100)(b)	3x10 ⁻⁶	NC	9x10 ⁻¹³	1x10 ⁻⁸	2x10 ⁻⁸	NC	NC	NC	1x10 ⁻⁹	2x10 ⁻⁵	3x10 ⁻⁵	NC	NC	NC
Earthquake (100)	8x10 ⁻⁸	NC	8x10 ⁻⁸	2x10 ⁻⁴	2x10 ⁻⁴	NC	NC	NC	4x10 ⁻⁴	2x10 ⁰	8x10 ⁻¹	NC	NC	NC
WATERBORNE ^(h)														
Short term														
Mackay Dam (0)(c)	1x10 ⁻⁵	2x10 ⁻³	5x10 ⁻⁸	9x10 ⁻⁶	NA	1x10 ⁻¹⁰	2x10 ⁻⁸	NA	2x10 ⁻⁸	1x10 ⁻⁴	NA	4x10 ⁻¹¹	2x10 ⁻⁷	NA
Long term ^(d)														
Mackay Dam (100)	1x10 ⁻⁴	NC	1x10 ⁻⁷	6x10 ⁻⁵	NA	NC	NC	NC	2x10 ⁻⁷	1x10 ⁻³	NA	NC	NC	NC
River channel alteration (100)(c)	1x10 ⁻²	NC	1x10 ⁻⁵	6x10 ⁻³	NA	NC	NC	NC	2x10 ⁻⁵	1x10 ⁻¹	NA	NC	NC	NC
Groundwater variation (100)	1x10 ⁻⁴	NC	1x10 ⁻⁷	6x10 ⁻⁵	NA	NC	NC	NC	2x10 ⁻⁷	1x10 ⁻³	NA	NC	NC	NC
Glaciation, climate change, etc. (100)(c)	1x10 ⁻²	NC	1x10 ⁻⁵	6x10 ⁻³	NA	NC	NC	NC	2x10 ⁻⁵	1x10 ⁻¹	NA	NC	NC	NC
Glaciation, etc. (1x10 ⁶)(c)	1x10 ⁻²	NC	2x10 ⁻⁵	2x10 ⁻¹	NA	NC	NC	NC	6x10 ⁻⁶	1x10 ⁻¹	NA	NC	NC	NC

(a) Numbers in parentheses after accident refer to the time of release, in number of years after 1985.

(b) Resuspension by wind pickup.

(c) Dominant event for population doses.

(d) Includes 1% per year geometric population growth to 2085 and assumes 100 yr decay of radionuclides unless otherwise specified.

(e) NC = not calculated because of the difficulty of reliably predicting probabilities and geologic characteristics into the distant future.

(f) Intake listed is that for maximum individual.

(g) NA = not applicable.

(h) 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 FOR CONCEPT 11-C: IMPROVE CONFINEMENT - ABOVE, AROUND, AND BELOW

Releases ^(a)	Release	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(0)	2x10 ⁻⁴	3x10 ⁻⁸	4x10 ⁻⁴	6x10 ⁻¹	6x10 ⁻¹	1x10 ⁻¹¹	2x10 ⁻⁸	2x10 ⁻⁸	8x10 ⁻¹	1x10 ³	1x10 ³	2x10 ⁻⁸	3x10 ⁻⁵	3x10 ⁻⁵
Earthquake	2x10 ⁻⁹	2x10 ⁻⁶	4x10 ⁻⁹	6x10 ⁻⁶	6x10 ⁻⁶	8x10 ⁻¹⁵	1x10 ⁻¹¹	1x10 ⁻¹¹	8x10 ⁻⁶	1x10 ⁻²	1x10 ⁻²	2x10 ⁻¹¹	2x10 ⁻⁸	2x10 ⁻⁸
Mackay Dam(0) ^(b)	6x10 ⁻⁹	2x10 ⁻³	2x10 ⁻¹⁵	2x10 ⁻¹¹	4x10 ⁻¹¹	4x10 ⁻¹⁸	4x10 ⁻¹⁴	8x10 ⁻¹⁴	2x10 ⁻¹²	4x10 ⁻⁸	6x10 ⁻⁸	4x10 ⁻¹⁵	8x10 ⁻¹¹	1x10 ⁻¹⁰
Lava flow(0) ^(c)	1x10 ⁻⁴	6x10 ⁻⁵	2x10 ⁻⁴	3x10 ⁻¹	3x10 ⁻¹	1x10 ⁻⁸	2x10 ⁻⁵	2x10 ⁻⁵	4x10 ⁻¹	6x10 ²	5x10 ²	2x10 ⁻⁵	4x10 ⁻²	3x10 ⁻²
Long term ^(d)														
Lava flow (100) ^(c)	1x10 ⁻²	NC ^(e)	1x10 ⁻²	3x10 ¹	2x10 ¹	NC	NC	NC	5x10 ¹	2x10 ⁵	1x10 ⁵	NC	NC	NC
Lava flow (2 x 10 ³) ^(c)	1x10 ⁻²	NC	1x10 ⁻³	1x10 ¹	9x10 ⁰	NC	NC	NC	6x10 ⁰	7x10 ⁴	5x10 ⁴	NC	NC	NC
Explosive volc. (100)	2x10 ⁻⁴	NC	2x10 ⁻⁴	6x10 ⁻¹	4x10 ⁻¹	NC	NC	NC	1x10 ⁰	4x10 ³	2x10 ³	NC	NC	NC
Erosion (100)	Wind Pickup	NC	1x10 ⁻⁷	1x10 ⁻⁵	9x10 ⁻⁶	NC	NC	NC	3x10 ⁻⁴	4x10 ⁻²	3x10 ⁻²	NC	NC	NC
Intrusion (100) (excavation fol- lowing erosion: 2 x 10 ⁻⁷ Ci in- haled) ^(f)	NA ^(g)	NC	2x10 ⁰	1x10 ²	1x10 ²	NC	NC	NC	1x10 ⁻²	1x10 ¹	1x10 ¹	NC	NC	NC
Intrusion (farming)(100) ingestion (3 x 10 ⁻⁶ Ci/yr)	NA	NC	1x10 ⁰	5x10 ⁰	NA	NC	NC	NC	1x10 ¹	5x10 ¹	NA	NC	NC	NC
inhalation (7 x 10 ⁻¹⁰ Ci/yr) ^(f)	NA	NC	2x10 ⁻¹	1x10 ¹	2x10 ¹	NC	NC	NC	2x10 ⁰	1x10 ²	2x10 ²	NC	NC	NC
Tornado (100)	3x10 ⁻⁴	NC	3x10 ⁻⁴	9x10 ⁻¹	6x10 ⁻¹	NC	NC	NC	2x10 ⁰	6x10 ³	3x10 ³	NC	NC	NC
Mackay Dam (100) ^(b)	3x10 ⁻⁶	NC	9x10 ⁻¹³	1x10 ⁻⁸	2x10 ⁻⁸	NC	NC	NC	1x10 ⁻⁹	2x10 ⁻⁵	3x10 ⁻⁵	NC	NC	NC
Earthquake (100)	8x10 ⁻⁸	NC	8x10 ⁻⁸	2x10 ⁻⁴	2x10 ⁻⁴	NC	NC	NC	4x10 ⁻⁴	2x10 ⁰	8x10 ⁻¹	NC	NC	NC
WATERBORNE ^(h)														
Short term														
Mackay Dam (0) ^(c)	5x10 ⁻⁶	2x10 ⁻³	3x10 ⁻⁸	5x10 ⁻⁶	NA	6x10 ⁻¹¹	1x10 ⁻⁸	NA	1x10 ⁻⁸	5x10 ⁻⁵	NA	2x10 ⁻¹¹	1x10 ⁻⁷	NA
Long term ^(d)														
Mackay Dam (100)	1x10 ⁻⁴	NC	1x10 ⁻⁷	6x10 ⁻⁵	NA	NC	NC	NC	2x10 ⁻⁷	1x10 ⁻³	NA	NC	NC	NC
River channel alteration (100) ^(c)	1x10 ⁻²	NC	1x10 ⁻⁵	6x10 ⁻³	NA	NC	NC	NC	2x10 ⁻⁵	1x10 ⁻¹	NA	NC	NC	NC
Groundwater variation (100)	1x10 ⁻⁴	NC	1x10 ⁻⁷	6x10 ⁻⁵	NA	NC	NC	NC	2x10 ⁻⁷	1x10 ⁻³	NA	NC	NC	NC
Glaciation, climate change, etc. (100) ^(c)	1x10 ⁻²	NC	1x10 ⁻⁵	6x10 ⁻³	NA	NC	NC	NC	2x10 ⁻⁵	1x10 ⁻¹	NA	NC	NC	NC
Glaciation, etc. (1x10 ⁶) ^(c)	1x10 ⁻²	NC	2x10 ⁻⁵	2x10 ⁻¹	NA	NC	NC	NC	6x10 ⁻⁶	1x10 ⁻¹	NA	NC	NC	NC

(a) Numbers in parentheses after accident refer to the time of release, in number of years after 1985.

(b) Resuspension by wind pickup.

(c) Dominant event for population doses.

(d) Includes 1% per year geometric population growth to 2085 and assumes 100 yr decay of radionuclides unless otherwise specified.

(e) NC = not calculated because of the difficulty of reliably predicting probabilities and geologic characteristics into the distant future.

(f) Intake listed is that for maximum individual.

(g) NA = not applicable.

(h) 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 13-12
SUMMARY OF ACCIDENT EFFECTS FOR CONCEPT 11-D: IMPROVE CONFINEMENT - IMMOBILIZATION

Releases (a)	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(0)	2x10 ⁻⁶	3x10 ⁻⁸	4x10 ⁻⁶	6x10 ⁻³	6x10 ⁻³	1x10 ⁻¹³	2x10 ⁻¹⁰	2x10 ⁻¹⁰	8x10 ⁻³	1x10 ¹	1x10 ¹	2x10 ⁻¹⁰	3x10 ⁻⁷	3x10 ⁻⁷
Earthquake(0)	8x10 ⁻¹¹	2x10 ⁻⁶	2x10 ⁻¹⁰	2x10 ⁻⁷	2x10 ⁻⁷	4x10 ⁻¹⁶	4x10 ⁻¹³	4x10 ⁻¹³	3x10 ⁻⁷	5x10 ⁻⁴	4x10 ⁻⁴	6x10 ⁻¹³	1x10 ⁻⁹	8x10 ⁻¹⁰
Mackay Dam(0)(b)	3x10 ⁻¹⁰	2x10 ⁻³	9x10 ⁻¹⁷	1x10 ⁻¹²	2x10 ⁻¹²	2x10 ⁻¹⁹	2x10 ⁻¹⁵	4x10 ⁻¹⁵	1x10 ⁻¹³	2x10 ⁻⁹	3x10 ⁻⁹	2x10 ⁻¹⁶	4x10 ⁻¹²	6x10 ⁻¹²
Lava flow(0)(c)	1x10 ⁻⁴	6x10 ⁻⁵	2x10 ⁻⁴	3x10 ⁻¹	3x10 ⁻¹	1x10 ⁻⁸	2x10 ⁻⁵	2x10 ⁻⁵	4x10 ⁻¹	6x10 ²	5x10 ²	2x10 ⁻⁵	4x10 ⁻²	3x10 ⁻²
Long term (d)														
Lava flow (100)(c)	1x10 ⁻⁴	NC(e)	1x10 ⁻⁴	3x10 ⁻¹	2x10 ⁻¹	NC	NC	NC	5x10 ⁻¹	2x10 ³	1x10 ³	NC	NC	NC
Lava flow (2 x 10 ³)(c)	1x10 ⁻²	NC	1x10 ⁻³	1x10 ¹	9x10 ⁰	NC	NC	NC	6x10 ⁰	7x10 ⁴	5x10 ⁴	NC	NC	NC
Explosive volc. (100)	2x10 ⁻⁶	NC	2x10 ⁻⁶	6x10 ⁻³	4x10 ⁻³	NC	NC	NC	1x10 ⁻²	4x10 ¹	2x10 ¹	NC	NC	NC
Erosion (100)	Wind Pickup	NC	1x10 ⁻⁹	1x10 ⁻⁷	9x10 ⁻⁸	NC	NC	NC	3x10 ⁻⁶	4x10 ⁻⁴	3x10 ⁻⁴	NC	NC	NC
Intrusion (100)														
(excavation following erosion: 2 x 10 ⁻⁹ Ci inhaled)(f)														
Intrusion (2 x 10 ³)	NA(g)	NC	2x10 ⁻²	1x10 ⁰	1x10 ⁰	NC	NC	NC	1x10 ⁻⁴	1x10 ⁻¹	1x10 ⁻¹	NC	NC	NC
(excavation following erosion: 9 x 10 ⁻⁸ Ci inhaled)(f)														
Intrusion (farming) (100)	NA	NC	4x10 ⁻¹	7x10 ¹	7x10 ¹	NC	NC	NC	2x10 ⁻⁴	3x10 ⁻¹	7x10 ⁻¹	NC	NC	NC
Intrusion (farming) (100)														
ingestion (3 x 10 ⁻⁸ Ci/yr)														
Intrusion (farming) (100)	NA	NC	1x10 ⁻²	5x10 ⁻²	NA	NC	NC	NC	1x10 ⁻¹	5x10 ⁻¹	NA	NC	NC	NC
inhalation														
(7 x 10 ⁻¹² Ci/yr)(f)	NA	NC	2x10 ⁻²	1x10 ⁻¹	2x10 ⁻¹	NC	NC	NC	2x10 ⁻²	1x10 ⁰	2x10 ⁰	NC	NC	NC
Intrusion (farming) (2x10 ³)														
ingestion (6x10 ⁻⁶ Ci/yr)														
Intrusion (farming) (2x10 ³)	NA	NC	2x10 ⁰	1x10 ²	NA	NC	NC	NC	2x10 ¹	1x10 ³	NA	NC	NC	NC
inhalation														
(7x10 ⁻⁹ Ci/yr)(f)	NA	NC	4x10 ⁻¹	2x10 ²	2x10 ²	NC	NC	NC	4x10 ⁰	2x10 ³	2x10 ³	NC	NC	NC
Tornado (100)	3x10 ⁻⁶	NC	3x10 ⁻⁶	9x10 ⁻³	6x10 ⁻³	NC	NC	NC	2x10 ⁻²	6x10 ¹	3x10 ¹	NC	NC	NC
Mackay Dam (100)(b)	3x10 ⁻⁹	NC	9x10 ⁻¹⁶	1x10 ⁻¹¹	2x10 ⁻¹¹	NC	NC	NC	1x10 ⁻¹²	2x10 ⁻⁸	3x10 ⁻⁸	NC	NC	NC
Earthquake (100)	8x10 ⁻¹¹	NC	8x10 ⁻¹¹	2x10 ⁻⁷	2x10 ⁻⁷	NC	NC	NC	4x10 ⁻⁷	2x10 ⁻³	8x10 ⁻⁴	NC	NC	NC
WATERBORNE(h)														
Short term														
Mackay Dam (0)(c)	1x10 ⁻⁶	2x10 ⁻³	5x10 ⁻⁹	9x10 ⁻⁷	NA	1x10 ⁻¹¹	2x10 ⁻⁹	NA	2x10 ⁻⁹	1x10 ⁻⁵	NA	4x10 ⁻¹²	2x10 ⁻⁸	NA
Long term (d)														
Mackay Dam (100)	1x10 ⁻⁶	NC	1x10 ⁻⁹	6x10 ⁻⁷	NA	NC	NC	NC	2x10 ⁻⁹	1x10 ⁻⁵	NA	NC	NC	NC
River channel														
alteration (100)(c)														
River channel alteration (100)(c)	1x10 ⁻⁴	NC	1x10 ⁻⁷	6x10 ⁻⁵	NA	NC	NC	NC	2x10 ⁻⁷	1x10 ⁻³	NA	NC	NC	NC
Groundwater														
variation (100)														
Groundwater variation (100)	1x10 ⁻⁶	NC	1x10 ⁻⁹	6x10 ⁻⁷	NA	NC	NC	NC	2x10 ⁻⁹	1x10 ⁻⁵	NA	NC	NC	NC
Glaciation, climate change, etc. (100)(c)														
Glaciation, climate change, etc. (100)(c)	1x10 ⁻⁴	NC	1x10 ⁻⁷	6x10 ⁻⁵	NA	NC	NC	NC	2x10 ⁻⁷	1x10 ⁻³	NA	NC	NC	NC
Glaciation, etc. (1x10 ⁶)(c)														
Glaciation, etc. (1x10 ⁶)(c)	1x10 ⁻²	NC	2x10 ⁻⁵	2x10 ⁻¹	NA	NC	NC	NC	6x10 ⁻⁶	1x10 ⁻¹	NA	NC	NC	NC

(a) Numbers in parentheses after accident refer to the time of release, in number of years after 1985.

(b) Resuspension by wind pickup.

(c) Dominant event for population doses.

(d) Includes 1% per year geometric population growth to 2085 and assumes 100 yr decay of radionuclides unless otherwise specified.

(e) NC = not calculated because of the difficulty of reliably predicting probabilities and geologic characteristics into the distant future.

(f) Intake listed is that for maximum individual.

(g) NA = not applicable.

(h) 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 13-13
SUMMARY OF ACCIDENT EFFECTS: DIRECT-CONTROL RETRIEVAL

Airborne Releases	Release	Event Freq. , Fract.	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 ⁻⁴	3x10 ⁻⁸	4x10 ⁻⁴	6x10 ⁻¹	6x10 ⁻¹	1x10 ⁻¹¹	2x10 ⁻⁸	2x10 ⁻⁸	8x10 ⁻¹	1x10 ³	1x10 ³	2x10 ⁻⁸	3x10 ⁻⁵	3x10 ⁻⁵
Lava flow(a,b)	1x10 ⁻²	6x10 ⁻⁵	2x10 ⁻²	3x10 ¹	3x10 ¹	1x10 ⁻⁶	2x10 ⁻³	2x10 ⁻³	4x10 ¹	6x10 ⁴	5x10 ⁴	2x10 ⁻³	4x10 ⁰	3x10 ⁰
Tornado	6x10 ⁻⁷	5x10 ⁻⁷	1x10 ⁻⁶	2x10 ⁻³	2x10 ⁻³	5x10 ⁻¹³	1x10 ⁻⁹	1x10 ⁻⁹	2x10 ⁻³	4x10 ⁰	3x10 ⁰	1x10 ⁻⁹	2x10 ⁻⁶	2x10 ⁻⁶
Earthquake	8x10 ⁻⁹	2x10 ⁻⁶	2x10 ⁻⁸	2x10 ⁻⁵	2x10 ⁻⁵	4x10 ⁻¹⁴	4x10 ⁻¹¹	4x10 ⁻¹¹	3x10 ⁻⁵	5x10 ⁻²	4x10 ⁻²	6x10 ⁻¹¹	1x10 ⁻⁷	8x10 ⁻⁸
Aircraft impact with fire	6x10 ⁻⁷	4x10 ⁻⁹	1x10 ⁻⁶	2x10 ⁻³	2x10 ⁻³	4x10 ⁻¹⁵	8x10 ⁻¹²	8x10 ⁻¹²	2x10 ⁻³	4x10 ⁰	3x10 ⁰	8x10 ⁻¹²	2x10 ⁻⁸	1x10 ⁻⁸
Transfer accident	1x10 ⁻⁸	7x10 ⁻⁶	2x10 ⁻⁸	3x10 ⁻⁵	3x10 ⁻⁵	1x10 ⁻¹³	2x10 ⁻¹⁰	2x10 ⁻¹⁰	4x10 ⁻⁵	6x10 ⁻²	5x10 ⁻²	3x10 ⁻¹⁰	4x10 ⁻⁷	4x10 ⁻⁷
Transfer accident with fire	1x10 ⁻⁷	2x10 ⁻⁶	2x10 ⁻⁷	3x10 ⁻⁴	3x10 ⁻⁴	4x10 ⁻¹³	6x10 ⁻¹⁰	6x10 ⁻¹⁰	4x10 ⁻⁴	6x10 ⁻¹	5x10 ⁻¹	8x10 ⁻¹⁰	1x10 ⁻⁶	1x10 ⁻⁶
Dropped container(c)	1x10 ⁻¹⁵	7x10 ⁻²	2x10 ⁻¹⁵	3x10 ⁻¹²	3x10 ⁻¹²	1x10 ⁻¹⁶	2x10 ⁻¹³	2x10 ⁻¹³	4x10 ⁻¹²	6x10 ⁻⁹	5x10 ⁻⁹	3x10 ⁻¹³	4x10 ⁻¹⁰	4x10 ⁻¹⁰
Fire	3x10 ⁻¹⁴	1x10 ⁻²	6x10 ⁻¹⁴	9x10 ⁻¹¹	9x10 ⁻¹¹	6x10 ⁻¹⁶	9x10 ⁻¹³	9x10 ⁻¹³	1x10 ⁻¹⁰	2x10 ⁻⁷	2x10 ⁻⁷	1x10 ⁻¹²	2x10 ⁻⁹	2x10 ⁻⁹

(a) These scenarios apply principally to waste remaining buried during the campaign and do not apply to the actual retrieval operations.

(b) Dominant event.

(c) Dominant event related to retrieval operations.

TABLE 13-14
SUMMARY OF ACCIDENT EFFECTS: REMOTE-CONTROL RETRIEVAL

	Release	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>Airborne Releases</u>														
<u>Short term</u>														
Explosive														
volcano(a)	2x10 ⁻⁴	3x10 ⁻⁸	4x10 ⁻⁴	6x10 ⁻¹	6x10 ⁻¹	1x10 ⁻¹¹	2x10 ⁻⁸	2x10 ⁻⁸	8x10 ⁻¹	1x10 ³	1x10 ³	2x10 ⁻⁸	3x10 ⁻⁵	3x10 ⁻⁵
Lava flow(a,b)	1x10 ⁻²	6x10 ⁻⁵	2x10 ⁻²	3x10 ¹	3x10 ¹	1x10 ⁻⁶	2x10 ⁻³	2x10 ⁻³	4x10 ¹	6x10 ⁴	5x10 ⁴	2x10 ⁻³	4x10 ⁰	3x10 ⁰
Tornado	6x10 ⁻⁷	5x10 ⁻⁷	1x10 ⁻⁶	2x10 ⁻³	2x10 ⁻³	5x10 ⁻¹³	1x10 ⁻⁹	1x10 ⁻⁹	2x10 ⁻³	4x10 ⁰	3x10 ⁰	1x10 ⁻⁹	2x10 ⁻⁶	2x10 ⁻⁶
Earthquake	8x10 ⁻⁹	2x10 ⁻⁶	2x10 ⁻⁸	2x10 ⁻⁵	2x10 ⁻⁵	4x10 ⁻¹⁴	4x10 ⁻¹¹	4x10 ⁻¹¹	3x10 ⁻⁵	5x10 ⁻²	4x10 ⁻²	6x10 ⁻¹¹	1x10 ⁻⁷	8x10 ⁻⁸
Aircraft impact														
with fire	6x10 ⁻⁷	4x10 ⁻⁹	1x10 ⁻⁶	2x10 ⁻³	2x10 ⁻³	4x10 ⁻¹⁵	8x10 ⁻¹²	8x10 ⁻¹²	2x10 ⁻³	4x10 ⁰	3x10 ⁰	8x10 ⁻¹²	2x10 ⁻⁸	1x10 ⁻⁸
Transfer														
accident	1x10 ⁻⁸	7x10 ⁻⁶	2x10 ⁻⁸	3x10 ⁻⁵	3x10 ⁻⁵	1x10 ⁻¹³	2x10 ⁻¹⁰	2x10 ⁻¹⁰	4x10 ⁻⁵	6x10 ⁻²	5x10 ⁻²	3x10 ⁻¹⁰	4x10 ⁻⁷	4x10 ⁻⁷
Transfer														
accident														
with fire	1x10 ⁻⁷	2x10 ⁻⁶	2x10 ⁻⁷	3x10 ⁻⁴	3x10 ⁻⁴	4x10 ⁻¹³	6x10 ⁻¹⁰	6x10 ⁻¹⁰	4x10 ⁻⁴	6x10 ⁻¹	5x10 ⁻¹	8x10 ⁻¹⁰	1x10 ⁻⁶	1x10 ⁻⁶
Dropped														
container(c)	1x10 ⁻¹⁵	7x10 ⁻¹	2x10 ⁻¹⁵	3x10 ⁻¹²	3x10 ⁻¹²	1x10 ⁻¹⁵	2x10 ⁻¹²	2x10 ⁻¹²	4x10 ⁻¹²	6x10 ⁻⁹	5x10 ⁻⁹	3x10 ⁻¹²	4x10 ⁻⁹	4x10 ⁻⁹
Fire	3x10 ⁻¹⁴	1x10 ⁻²	6x10 ⁻¹⁴	9x10 ⁻¹¹	9x10 ⁻¹¹	6x10 ⁻¹⁶	9x10 ⁻¹³	9x10 ⁻¹³	1x10 ⁻¹⁰	2x10 ⁻⁷	2x10 ⁻⁷	1x10 ⁻¹²	2x10 ⁻⁹	2x10 ⁻⁹

(a) These scenarios apply principally to waste remaining buried during the campaign and do not apply to the actual retrieval operations.

(b) Dominant event.

(c) Dominant event related to retrieval operations.

TABLE 13-15

SUMMARY OF ACCIDENT EFFECTS: SLAGGING PYROLYSIS AND PACKAGING

	Release	Event Freq., yr ⁻¹	Maximum Individual						Population					
			Dose (rem)			Risk (rem/yr)			Dose (man-rem)			Risk (man-rem/yr)		
	Fract.		Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung
<u>Airborne Releases</u>														
<u>Waste Preparation Area</u>														
Earthquake ^(a)	4x10 ⁻⁸	4x10 ⁻⁸	8x10 ⁻⁸	1x10 ⁻⁴	1x10 ⁻⁴	3x10 ⁻¹⁵	4x10 ⁻¹²	4x10 ⁻¹²	2x10 ⁻⁴	2x10 ⁻¹	2x10 ⁻¹	8x10 ⁻¹²	8x10 ⁻⁹	8x10 ⁻⁹
Dropped container	1x10 ⁻¹⁵	7x10 ⁻²	2x10 ⁻¹⁵	3x10 ⁻¹²	3x10 ⁻¹²	1x10 ⁻¹⁶	2x10 ⁻¹³	2x10 ⁻¹³	4x10 ⁻¹²	6x10 ⁻⁹	5x10 ⁻⁹	3x10 ⁻¹³	4x10 ⁻¹⁰	4x10 ⁻¹⁰
Earthquake ^(b)	4x10 ⁻¹⁴	2x10 ⁻⁶	8x10 ⁻¹⁴	1x10 ⁻¹⁰	1x10 ⁻¹⁰	2x10 ⁻¹⁹	2x10 ⁻¹⁶	2x10 ⁻¹⁶	2x10 ⁻¹⁰	2x10 ⁻⁷	2x10 ⁻⁷	4x10 ⁻¹⁶	4x10 ⁻¹³	4x10 ⁻¹³
Fire	3x10 ⁻¹⁴	1x10 ⁻²	6x10 ⁻¹⁴	9x10 ⁻¹¹	9x10 ⁻¹¹	6x10 ⁻¹⁶	9x10 ⁻¹³	9x10 ⁻¹³	1x10 ⁻¹⁰	2x10 ⁻⁷	2x10 ⁻⁷	1x10 ⁻¹²	2x10 ⁻⁹	2x10 ⁻⁹
<u>Pyrolysis Area</u>														
Criticality ^(c)	NA ^(d)	5x10 ⁻⁶	1x10 ⁻⁴	1x10 ⁻⁴	2x10 ⁻⁴	5x10 ⁻¹⁰	5x10 ⁻¹⁰	1x10 ⁻⁹	7x10 ⁻²	7x10 ⁻²	1x10 ⁻¹	4x10 ⁻⁷	4x10 ⁻⁷	5x10 ⁻⁷
Tornado	1x10 ⁻¹⁰	5x10 ⁻⁷	2x10 ⁻¹⁰	3x10 ⁻⁷	3x10 ⁻⁷	1x10 ⁻¹⁶	2x10 ⁻¹³	2x10 ⁻¹³	4x10 ⁻⁷	6x10 ⁻⁴	5x10 ⁻⁴	2x10 ⁻¹³	3x10 ⁻¹⁰	3x10 ⁻¹⁰
Gasifier rupture	1x10 ⁻¹³	1x10 ⁻⁴	2x10 ⁻¹³	3x10 ⁻¹⁰	3x10 ⁻¹⁰	2x10 ⁻¹⁷	3x10 ⁻¹⁴	3x10 ⁻¹⁴	4x10 ⁻¹⁰	6x10 ⁻⁷	5x10 ⁻⁷	4x10 ⁻¹⁴	6x10 ⁻¹¹	5x10 ⁻¹¹
Waste heat boiler rupture	6x10 ⁻¹²	1x10 ⁻⁶	1x10 ⁻¹¹	2x10 ⁻⁸	2x10 ⁻⁸	1x10 ⁻¹⁷	2x10 ⁻¹⁴	2x10 ⁻¹⁴	2x10 ⁻⁸	4x10 ⁻⁵	3x10 ⁻⁵	2x10 ⁻¹⁴	4x10 ⁻¹¹	3x10 ⁻¹¹
<u>Shipping Area</u>														
Tornado	3x10 ⁻⁹	5x10 ⁻⁷	6x10 ⁻⁹	9x10 ⁻⁶	9x10 ⁻⁶	3x10 ⁻¹⁵	5x10 ⁻¹²	5x10 ⁻¹²	1x10 ⁻⁵	2x10 ⁻²	2x10 ⁻²	5x10 ⁻¹²	1x10 ⁻⁸	1x10 ⁻⁸

(a) Dominant event for bone and lung population doses, earthquake with breach of building.

(b) Earthquake without breach of building.

(c) Thyroid dose from criticality estimated to be 6x10⁻³ rem for maximum individual dose, and 3 man-rem for population dose.

(d) NA = not applicable.

TABLE 13-16

SUMMARY OF ACCIDENT EFFECTS: SHIPMENT OF PROCESSED WASTE TO OFFSITE GEOLOGIC REPOSITORY

Airborne Releases	Release	Event Freq., yr ⁻¹	Maximum Individual						Population					
			Dose (rem)			Risk (rem/yr)			Dose (man-rem)			Risk (man-rem/yr)		
	Fract.		Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung	Body	Bone	Lung
Rural ^(a,b)	9x10 ⁻¹²	9x10 ⁻⁷	2x10 ⁻¹¹	3x10 ⁻⁸	3x10 ⁻⁸	2x10 ⁻¹⁷	3x10 ⁻¹⁴	3x10 ⁻¹⁴	4x10 ⁻⁸	5x10 ⁻⁵	5x10 ⁻⁵	4x10 ⁻¹⁴	5x10 ⁻¹¹	5x10 ⁻¹¹
Suburban ^(c)	9x10 ⁻¹²	4x10 ⁻⁸	2x10 ⁻¹¹	3x10 ⁻⁸	3x10 ⁻⁸	8x10 ⁻¹⁹	1x10 ⁻¹⁵	1x10 ⁻¹⁵	3x10 ⁻⁷	4x10 ⁻⁴	4x10 ⁻⁴	1x10 ⁻¹⁴	2x10 ⁻¹¹	2x10 ⁻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 13-17

SUMMARY OF ACCIDENT EFFECTS: COMPACTION AND IMMOBILIZATION

	Release	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>Airborne Releases</u>														
<u>Short term</u>														
Earthquake (a)	4x10 ⁻⁸	4x10 ⁻⁸	8x10 ⁻⁸	1x10 ⁻⁴	1x10 ⁻⁴	3x10 ⁻¹⁵	4x10 ⁻¹²	4x10 ⁻¹²	2x10 ⁻⁴	2x10 ⁻¹	2x10 ⁻¹	8x10 ⁻¹²	8x10 ⁻⁹	8x10 ⁻⁹
Dropped container	1x10 ⁻¹⁵	7x10 ⁻²	2x10 ⁻¹⁵	3x10 ⁻¹²	3x10 ⁻¹²	1x10 ⁻¹⁶	2x10 ⁻¹³	2x10 ⁻¹³	4x10 ⁻¹²	6x10 ⁻⁹	5x10 ⁻⁹	3x10 ⁻¹³	4x10 ⁻¹⁰	4x10 ⁻¹⁰
Fire	3x10 ⁻¹⁴	1x10 ⁻²	6x10 ⁻¹⁴	9x10 ⁻¹¹	9x10 ⁻¹¹	6x10 ⁻¹⁶	9x10 ⁻¹³	9x10 ⁻¹³	1x10 ⁻¹⁰	2x10 ⁻⁷	2x10 ⁻⁷	1x10 ⁻¹²	2x10 ⁻⁹	2x10 ⁻⁹
Earthquake (b)	4x10 ⁻¹⁴	2x10 ⁻⁶	8x10 ⁻¹⁴	1x10 ⁻¹⁰	1x10 ⁻¹⁰	2x10 ⁻¹⁹	2x10 ⁻¹⁶	2x10 ⁻¹⁶	2x10 ⁻¹⁰	2x10 ⁻⁷	2x10 ⁻⁷	4x10 ⁻¹⁶	4x10 ⁻¹³	4x10 ⁻¹³
(a) Dominant event, earthquake with breach of building.														
(b) Earthquake without breach of building.														

TABLE 13-18
SUMMARY OF ACCIDENT EFFECTS: PACKAGING ONLY

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														
Earthquake ^(a)	4x10 ⁻⁸	4x10 ⁻⁸	8x10 ⁻⁸	1x10 ⁻⁴	1x10 ⁻⁴	3x10 ⁻¹⁵	4x10 ⁻¹²	4x10 ⁻¹²	2x10 ⁻⁴	2x10 ⁻¹	2x10 ⁻¹	8x10 ⁻¹²	8x10 ⁻⁹	8x10 ⁻⁹
Dropped container	1x10 ⁻¹⁵	7x10 ⁻²	2x10 ⁻¹⁵	3x10 ⁻¹²	3x10 ⁻¹²	1x10 ⁻¹⁶	2x10 ⁻¹³	2x10 ⁻¹³	4x10 ⁻¹²	6x10 ⁻⁹	5x10 ⁻⁹	3x10 ⁻¹³	4x10 ⁻¹⁰	4x10 ⁻¹⁰
Fire	3x10 ⁻¹⁴	1x10 ⁻²	6x10 ⁻¹⁴	9x10 ⁻¹¹	9x10 ⁻¹¹	6x10 ⁻¹⁶	9x10 ⁻¹³	9x10 ⁻¹³	1x10 ⁻¹⁰	2x10 ⁻⁷	2x10 ⁻⁷	1x10 ⁻¹²	2x10 ⁻⁹	2x10 ⁻⁹
Earthquake ^(b)	4x10 ⁻¹⁴	2x10 ⁻⁶	8x10 ⁻¹⁴	1x10 ⁻¹⁰	1x10 ⁻¹⁰	2x10 ⁻¹⁹	2x10 ⁻¹⁶	2x10 ⁻¹⁶	2x10 ⁻¹⁰	2x10 ⁻⁷	2x10 ⁻⁷	4x10 ⁻¹⁶	4x10 ⁻¹³	4x10 ⁻¹³

(a) Dominant event, earthquake with breach of building.

(b) Earthquake without breach of building.

TABLE 13-19

SUMMARY OF ACCIDENT EFFECTS: ONSITE SHIPMENT FOR ALL PROCESS MODULES

	Release	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>Airborne Releases</u>														
<u>Short term</u>														
<u>Slagging pyrolysis and packaging</u>														
Lemhi	2x10 ⁻¹⁰	1x10 ⁻⁵	4x10 ⁻¹⁰	6x10 ⁻⁷	6x10 ⁻⁷	4x10 ⁻¹⁵	6x10 ⁻¹²	6x10 ⁻¹²	8x10 ⁻⁷	1x10 ⁻³	1x10 ⁻³	8x10 ⁻¹²	1x10 ⁻⁸	1x10 ⁻⁸
Site 14	2x10 ⁻¹⁰	6x10 ⁻⁶	4x10 ⁻¹⁰	6x10 ⁻⁷	6x10 ⁻⁷	2x10 ⁻¹⁵	4x10 ⁻¹²	4x10 ⁻¹²	8x10 ⁻⁷	1x10 ⁻³	1x10 ⁻³	5x10 ⁻¹²	6x10 ⁻⁹	6x10 ⁻⁹
RWMC	2x10 ⁻¹⁰	8x10 ⁻⁸	4x10 ⁻¹⁰	6x10 ⁻⁷	6x10 ⁻⁷	3x10 ⁻¹⁷	5x10 ⁻¹⁴	5x10 ⁻¹⁴	8x10 ⁻⁷	1x10 ⁻³	1x10 ⁻³	6x10 ⁻¹⁴	8x10 ⁻¹¹	8x10 ⁻¹¹
<u>Compact, immobilization, packaging</u>														
Lemhi	3x10 ⁻¹⁰	1x10 ⁻⁵	6x10 ⁻¹⁰	9x10 ⁻⁷	9x10 ⁻⁷	6x10 ⁻¹⁵	9x10 ⁻¹²	9x10 ⁻¹²	1x10 ⁻⁶	2x10 ⁻³	2x10 ⁻³	1x10 ⁻¹¹	2x10 ⁻⁸	2x10 ⁻⁸
Site 14	3x10 ⁻¹⁰	9x10 ⁻⁶	6x10 ⁻¹⁰	9x10 ⁻⁷	9x10 ⁻⁷	5x10 ⁻¹⁵	8x10 ⁻¹²	8x10 ⁻¹²	1x10 ⁻⁶	2x10 ⁻³	2x10 ⁻³	9x10 ⁻¹²	2x10 ⁻⁸	2x10 ⁻⁸
RWMC	3x10 ⁻¹⁰	1x10 ⁻⁷	6x10 ⁻¹⁰	9x10 ⁻⁷	9x10 ⁻⁷	6x10 ⁻¹⁷	9x10 ⁻¹⁴	9x10 ⁻¹⁴	1x10 ⁻⁶	2x10 ⁻³	2x10 ⁻³	1x10 ⁻¹³	2x10 ⁻¹⁰	2x10 ⁻¹⁰
<u>Packaging only</u>														
Lemhi	1x10 ⁻⁸	1x10 ⁻⁵	2x10 ⁻⁸	3x10 ⁻⁵	3x10 ⁻⁵	2x10 ⁻¹³	3x10 ⁻¹⁰	3x10 ⁻¹⁰	4x10 ⁻⁵	6x10 ⁻²	5x10 ⁻²	4x10 ⁻¹⁰	6x10 ⁻⁷	5x10 ⁻⁷
Site 14	1x10 ⁻⁸	7x10 ⁻⁶	2x10 ⁻⁸	3x10 ⁻⁵	3x10 ⁻⁵	1x10 ⁻¹³	2x10 ⁻¹⁰	2x10 ⁻¹⁰	4x10 ⁻⁵	6x10 ⁻²	5x10 ⁻²	3x10 ⁻¹⁰	4x10 ⁻⁷	4x10 ⁻⁷
RWMC	1x10 ⁻⁸	9x10 ⁻⁸	2x10 ⁻⁸	3x10 ⁻⁵	3x10 ⁻⁵	2x10 ⁻¹⁵	3x10 ⁻¹²	3x10 ⁻¹²	4x10 ⁻⁵	6x10 ⁻²	5x10 ⁻²	4x10 ⁻¹²	5x10 ⁻⁹	5x10 ⁻⁹

TABLE 13-20

SUMMARY OF ACCIDENT EFFECTS: ONSITE DISPOSAL - OPERATIONAL PHASE

	Release	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>Airborne Releases</u>														
<u>Deep rock disposal</u>														
<u>Lemhi Site - shaft access</u> (hoist failure)														
Slag	2x10 ⁻¹³	2x10 ⁻⁴	4x10 ⁻¹³	6x10 ⁻¹⁰	6x10 ⁻¹⁰	8x10 ⁻¹⁷	1x10 ⁻¹³	1x10 ⁻¹³	8x10 ⁻¹⁰	1x10 ⁻⁶	1x10 ⁻⁶	2x10 ⁻¹³	2x10 ⁻¹⁰	2x10 ⁻¹⁰
Compacted	1x10 ⁻¹²	3x10 ⁻⁴	2x10 ⁻¹²	3x10 ⁻⁹	3x10 ⁻⁹	6x10 ⁻¹⁶	9x10 ⁻¹³	9x10 ⁻¹³	4x10 ⁻⁹	6x10 ⁻⁶	5x10 ⁻⁶	1x10 ⁻¹²	2x10 ⁻⁹	2x10 ⁻⁹
Packaged	1x10 ⁻¹¹	4x10 ⁻⁴	2x10 ⁻¹¹	3x10 ⁻⁸	3x10 ⁻⁸	8x10 ⁻¹⁵	1x10 ⁻¹¹	1x10 ⁻¹¹	4x10 ⁻⁸	6x10 ⁻⁵	5x10 ⁻⁵	2x10 ⁻¹¹	2x10 ⁻⁸	2x10 ⁻⁸
<u>Deep rock disposal</u>														
<u>Lemhi Site - shaft or tunnel access^(a)</u> (dropped and breached container)														
Slag	3x10 ⁻¹⁶	5x10 ⁻³	6x10 ⁻¹⁶	9x10 ⁻¹³	9x10 ⁻¹³	3x10 ⁻¹⁸	5x10 ⁻¹⁵	5x10 ⁻¹⁵	1x10 ⁻¹²	2x10 ⁻⁹	2x10 ⁻⁹	5x10 ⁻¹⁵	1x10 ⁻¹¹	1x10 ⁻¹¹
Packaged	1x10 ⁻¹³	2x10 ⁻²	2x10 ⁻¹³	3x10 ⁻¹⁰	3x10 ⁻¹⁰	4x10 ⁻¹⁵	6x10 ⁻¹²	6x10 ⁻¹²	4x10 ⁻¹⁰	6x10 ⁻⁷	5x10 ⁻⁷	8x10 ⁻¹²	1x10 ⁻⁸	1x10 ⁻⁸
<u>Deep rock disposal</u>														
<u>Lemhi Site - shaft or tunnel access^(a)</u> (container penetration by handling equipment)														
Slag	3x10 ⁻¹⁸	3x10 ⁻²	6x10 ⁻¹⁸	9x10 ⁻¹⁵	9x10 ⁻¹⁵	2x10 ⁻¹⁹	3x10 ⁻¹⁶	3x10 ⁻¹⁶	1x10 ⁻¹⁴	2x10 ⁻¹¹	2x10 ⁻¹¹	3x10 ⁻¹⁶	6x10 ⁻¹³	6x10 ⁻¹³
Packaged	1x10 ⁻¹⁵	1x10 ⁻¹	2x10 ⁻¹⁵	3x10 ⁻¹²	3x10 ⁻¹²	2x10 ⁻¹⁶	3x10 ⁻¹³	3x10 ⁻¹³	4x10 ⁻¹²	6x10 ⁻⁹	5x10 ⁻⁹	4x10 ⁻¹³	6x10 ⁻¹⁰	5x10 ⁻¹⁰
<u>Engineered shallow land Disposal at Site 14^(a,b)</u> (Container penetration by handling equipment)														
Slag	3x10 ⁻¹⁵	3x10 ⁻²	6x10 ⁻¹⁵	9x10 ⁻¹²	9x10 ⁻¹²	2x10 ⁻¹⁶	3x10 ⁻¹³	3x10 ⁻¹³	1x10 ⁻¹¹	2x10 ⁻⁸	2x10 ⁻⁸	3x10 ⁻¹³	6x10 ⁻¹⁰	6x10 ⁻¹⁰
Packaged	1x10 ⁻¹²	1x10 ⁻¹	2x10 ⁻¹²	3x10 ⁻⁹	3x10 ⁻⁹	2x10 ⁻¹³	3x10 ⁻¹⁰	3x10 ⁻¹⁰	4x10 ⁻⁹	6x10 ⁻⁶	5x10 ⁻⁶	4x10 ⁻¹⁰	6x10 ⁻⁷	5x10 ⁻⁷
<u>Engineered surface Disposal near RMMC^(a)</u> (container penetration by handling equipment)														
Slag	3x10 ⁻¹⁵	3x10 ⁻²	6x10 ⁻¹⁵	9x10 ⁻¹²	9x10 ⁻¹²	2x10 ⁻¹⁶	3x10 ⁻¹³	3x10 ⁻¹³	1x10 ⁻¹¹	2x10 ⁻⁸	2x10 ⁻⁸	3x10 ⁻¹³	6x10 ⁻¹⁰	6x10 ⁻¹⁰
Packaged	1x10 ⁻¹²	1x10 ⁻¹	2x10 ⁻¹²	3x10 ⁻⁹	3x10 ⁻⁹	2x10 ⁻¹³	3x10 ⁻¹⁰	3x10 ⁻¹⁰	4x10 ⁻⁹	6x10 ⁻⁶	5x10 ⁻⁶	4x10 ⁻¹⁰	6x10 ⁻⁷	5x10 ⁻⁷
(a) No release in the instance of compacted and immobilized waste.														
(b) Entries apply also to less massive variation of disposal facility.														

TABLE 13-21

SUMMARY OF ACCIDENT EFFECTS: ONSITE DISPOSAL - POSTCLOSURE PHASE

	Release	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 Releases	Fract.	yr ⁻¹												
Deep rock disposal at														
Lemhi locations - shaft														
or tunnel access ^(a)														
Explosive volcano ^(b)	2x10 ⁻⁶	NC ^(c)	2x10 ⁻⁶	6x10 ⁻³	4x10 ⁻³	NC	NC	NC	1x10 ⁻²	4x10 ¹	2x10 ¹	NC	NC	NC
Engineered shallow land														
disposal at Site 14														
Explosive volcano ^(b)	7x10 ⁻⁵	NC	3x10 ⁻⁶	4x10 ⁻²	3x10 ⁻²	NC	NC	NC	7x10 ⁻³	2x10 ²	1x10 ²	NC	NC	NC
Erosion	Wind pickup	NC	2x10 ⁻⁹	2x10 ⁻⁶	2x10 ⁻⁶	NC	NC	NC	8x10 ⁻⁶	8x10 ⁻³	6x10 ⁻³	NC	NC	NC
Intrusion														
excavation (7 x 10 ⁻⁹														
Ci inhaled) ^(e)	NA ^(f)	NC	1x10 ⁻²	6x10 ⁰	5x10 ⁰	NC	NC	NC	6x10 ⁻⁶	1x10 ⁻²	2x10 ⁻²	NC	NC	NC
Intrusion (farming)														
ingestion														
(3 x 10 ⁻⁷ Ci/yr) ^(e)	NA	NC	1x10 ⁻¹	5x10 ⁰	NA	NC	NC	NC	1x10 ⁰	5x10 ¹	NA	NC	NC	NC
inhalation														
(6 x 10 ⁻¹⁰ Ci/yr) ^(b,e)	NA	NC	2x10 ⁻²	1x10 ¹	1x10 ¹	NC	NC	NC	2x10 ⁻¹	1x10 ²	1x10 ²	NC	NC	NC
Tornado	2x10 ⁻⁶	NC	8x10 ⁻⁸	1x10 ⁻³	8x10 ⁻⁴	NC	NC	NC	2x10 ⁻⁴	6x10 ⁰	4x10 ⁰	NC	NC	NC
Earthquake	1x10 ⁻¹⁰	NC	4x10 ⁻¹²	6x10 ⁻⁸	4x10 ⁻⁸	NC	NC	NC	1x10 ⁻⁸	3x10 ⁻⁴	2x10 ⁻⁴	NC	NC	NC
LMV	(g,h)													
Explosive volcano ^(b)	2x10 ⁻⁴	NC	2x10 ⁻⁵	2x10 ⁻¹	2x10 ⁻¹	NC	NC	NC	1x10 ⁻¹	1x10 ³	1x10 ³	NC	NC	NC
Erosion	Wind pickup	NC	1x10 ⁻⁸	4x10 ⁻⁶	4x10 ⁻⁶	NC	NC	NC	4x10 ⁻⁵	2x10 ⁻²	1x10 ⁻²	NC	NC	NC
Intrusion														
excavation (3 x 10 ⁻⁸														
Ci inhaled) ^(e)	NA	NC	1x10 ⁻¹	2x10 ¹	2x10 ¹	NC	NC	NC	6x10 ⁻⁵	9x10 ⁻²	2x10 ⁻¹	NC	NC	NC
Intrusion (farming)														
ingestion														
(4 x 10 ⁻⁶ Ci/yr) ^(e)	NA	NC	9x10 ⁻¹	6x10 ¹	NA	NC	NC	NC	9x10 ⁰	6x10 ²	NA	NC	NC	NC
inhalation														
(4 x 10 ⁻⁹ Ci/yr) ^(e)	NA	NC	2x10 ⁻¹	9x10 ¹	9x10 ¹	NC	NC	NC	2x10 ⁰	9x10 ²	9x10 ²	NC	NC	NC
Tornado	7x10 ⁻⁶	NC	7x10 ⁻⁷	7x10 ⁻³	6x10 ⁻³	NC	NC	NC	4x10 ⁻³	5x10 ¹	4x10 ¹	NC	NC	NC
Earthquake	3x10 ⁻¹⁰	NC	3x10 ⁻¹¹	3x10 ⁻⁷	3x10 ⁻⁷	NC	NC	NC	2x10 ⁻⁷	2x10 ⁻³	2x10 ⁻³	NC	NC	NC
Engineered surface														
facility														
near the RMMC ^(d)														
Explosive volcano ^(b)	2x10 ⁻⁴	NC	8x10 ⁻⁶	1x10 ⁻¹	8x10 ⁻²	NC	NC	NC	2x10 ⁻²	6x10 ²	4x10 ²	NC	NC	NC
Erosion	Wind pickup		2x10 ⁻⁹	2x10 ⁻⁶	2x10 ⁻⁶	NC	NC	NC	8x10 ⁻⁶	8x10 ⁻³	6x10 ⁻³	NC	NC	NC
Intrusion														
excavation (7 x 10 ⁻⁹														
Ci inhaled) ^(e)	NA	NC	1x10 ⁻²	6x10 ⁰	5x10 ⁰	NC	NC	NC	1x10 ⁻⁵	2x10 ⁻²	4x10 ⁻²	NC	NC	NC
Intrusion (farming)														
ingestion														
(3 x 10 ⁻⁷ Ci/yr) ^(e)	NA	NC	1x10 ⁻¹	5x10 ⁰	NA	NC	NC	NC	1x10 ⁰	5x10 ¹	NA	NC	NC	NC
inhalation														
(6 x 10 ⁻¹⁰ Ci/yr) ^(e)	NA	NC	2x10 ⁻²	1x10 ¹	1x10 ¹	NC	NC	NC	2x10 ⁻¹	1x10 ²	1x10 ²	NC	NC	NC
Tornado	3x10 ⁻⁶	NC	1x10 ⁻⁷	2x10 ⁻³	1x10 ⁻³	NC	NC	NC	3x10 ⁻⁴	9x10 ⁰	6x10 ⁰	NC	NC	NC
Flood ^(i,j)	6x10 ⁻⁶	NC	1x10 ⁻¹⁴	4x10 ⁻¹¹	3x10 ⁻¹⁰	NC	NC	NC	4x10 ⁻¹¹	8x10 ⁻⁷	1x10 ⁻⁶	NC	NC	NC
Earthquake	1x10 ⁻¹⁰	NC	4x10 ⁻¹²	6x10 ⁻⁸	4x10 ⁻⁸	NC	NC	NC	1x10 ⁻⁸	3x10 ⁻⁴	2x10 ⁻⁴	NC	NC	NC
Waterborne release														
Engineered shallow land														
Disposal at Site 14 or														
Engineered surface														
Facility near the RMMC ^(d)														
Flood (near RMMC only) ^(j)	1x10 ⁻⁴	NC	5x10 ⁻⁸	4x10 ⁻⁵	NA	NC	NC	NC	2x10 ⁻⁷	1x10 ⁻³	NA	NC	NC	NC
River channel alteration ^(b)	1x10 ⁻²	NC	5x10 ⁻⁶	4x10 ⁻³	NA	NC	NC	NC	2x10 ⁻⁵	1x10 ⁻¹	NA	NC	NC	NC
Groundwater variation	1x10 ⁻⁴	NC	5x10 ⁻⁸	4x10 ⁻⁵	NA	NC	NC	NC	2x10 ⁻⁷	1x10 ⁻³	NA	NC	NC	NC
Climate change,														
glaciation, etc. (b)	1x10 ⁻²	NC	5x10 ⁻⁶	4x10 ⁻³	NA	NC	NC	NC	2x10 ⁻⁵	1x10 ⁻¹	NA	NC	NC	NC
glaciation, etc. (k)	1x10 ⁻²	NC	2x10 ⁻⁵	2x10 ⁻¹	NA	NC	NC	NC	6x10 ⁻⁶	1x10 ⁻¹	NA	NC	NC	NC
Waterborne release														
LMV	(g,h)													
River channel alteration ^(b)	1x10 ⁻²	NC	6x10 ⁻⁶	5x10 ⁻³	NA	NC	NC	NC	2x10 ⁻⁵	1x10 ⁻¹	NA	NC	NC	NC
Groundwater variation	1x10 ⁻⁴	NC	6x10 ⁻⁸	5x10 ⁻⁵	NA	NC	NC	NC	2x10 ⁻⁷	1x10 ⁻³	NA	NC	NC	NC
Climate change,														
glaciation, etc. (b)	1x10 ⁻²	NC	6x10 ⁻⁶	5x10 ⁻³	NA	NC	NC	NC	2x10 ⁻⁵	1x10 ⁻¹	NA	NC	NC	NC
glaciation, etc. (k)	1x10 ⁻²	NC	2x10 ⁻⁵	2x10 ⁻¹	NA	NC	NC	NC	6x10 ⁻⁶	1x10 ⁻¹	NA	NC	NC	NC

(a) All releases for Lemhi location evaluated for the year 2085.

(b) Dominant event for population doses.

(c) NC = not calculated because of the difficulty of reliably predicting probabilities and geological characteristics into the distant future.

(d) All releases for Site 14 and RMMC evaluated for a time 25,000 yr into the future.

(e) Intake listed is that for maximum individual.

(f) NA = not applicable.

(g) LMV identifies use of less massive variation for engineered shallow land disposal at Site 14.

(h) All releases for LMV evaluated for a time 2,000 yr into the future.

(i) Resuspension by wind pickup.

(j) Flooding assumed to be comparable to failure of Mackay Dam, occurring 25,000 yr in the future.

(k) Evaluated for a time 1,000,000 yr into the future.

the results are given for each module (if the results have not been given previously). Evaluations of hypothetical short-term releases of radionuclides were based on events occurring in the year 1985. This is the postimplementation year in which the radioactivity in the waste would be a maximum. Unless indicated otherwise, long-term releases were based on hypothetical events occurring in the year 2085. This is the year in the long-term period starting in 2085 when the radioactivity in the waste would be a maximum. For some concepts, the waste confinement was assumed to deteriorate at a given time in the future (e.g., 25,000 yr). In such cases (as indicated in the footnotes of the tables), the long-term releases were assumed to occur at the time of deterioration of the confinement.

Included in the tables are release fractions (RF), which include decontamination factors (DF) where applicable, and event frequencies. The RF is the fraction of the total inventory of waste (at the time of the accident) that would be released to the environment, i.e., the fraction of all TRU waste buried at the SDA. The total radioactivity in the waste, as a function of time, is given in Table 13-6. The DF is discussed in Subsection 13.2.3.

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 small.

A summary of projected effects from short-term (less than 100-yr) release scenarios for all alternatives and concepts is given in Table 13-22. 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 I and II 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

TABLE 13-22

SUMMARY OF EFFECTS FROM SHORT-TERM RELEASE SCENARIOS^(a-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)
I	3×10^{-1}	2×10^{-3}	5×10^4	3×10^0
II-A(e)	6×10^{-1}	2×10^{-5}	1×10^3	3×10^{-2}
II-B(e)	6×10^{-1}	2×10^{-5}	1×10^3	3×10^{-2}
II-C(e)	6×10^{-1}	2×10^{-5}	1×10^3	3×10^{-2}
II-D	3×10^{-1}	2×10^{-5}	5×10^2	3×10^{-2}
III-A, III-B	2×10^{-3}	3×10^{-9}	3×10^0	4×10^{-6}
IV-A, IV-B	2×10^{-3}	3×10^{-9}	3×10^0	4×10^{-6}
V-A, V-D, V-G, V-J	2×10^{-3}	3×10^{-9}	3×10^0	4×10^{-6}
V-B, V-E, V-H, V-K	2×10^{-3}	2×10^{-9}	3×10^0	3×10^{-6}
V-C, V-F, V-I, V-L	2×10^{-3}	2×10^{-9}	3×10^0	4×10^{-6}
V-M ^(f) , V-P ^(f)	2×10^{-3}	3×10^{-9}	3×10^0	4×10^{-6}
V-N ^(f) , V-Q ^(f)	2×10^{-3}	2×10^{-9}	3×10^0	3×10^{-6}
V-O ^(f) , V-R ^(f)	2×10^{-3}	2×10^{-9}	3×10^0	4×10^{-6}
V-S, V-V	2×10^{-3}	3×10^{-9}	3×10^0	4×10^{-6}
V-T, V-W	2×10^{-3}	2×10^{-9}	3×10^0	3×10^{-6}
V-U, V-X	2×10^{-3}	2×10^{-9}	3×10^0	4×10^{-6}
VI-A, VI-B	2×10^{-3}	3×10^{-9}	3×10^0	4×10^{-6}
Natural background radiation ^(a)		180×10^{-3}		24×10^3

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

(b) Short-term accidents include release scenarios occurring less than 100 yr into the future for Alternatives I and II. For Alternatives III through VI, entries include only campaign-related events. Entries do not include possible releases due to volcanic activity that would disrupt waste still unretrieved during the retrieval campaign (10-yr period), the 20-yr storage, or the retrieval delay period of Alternative VI. Inclusion of such events would cause entries to be similar to those for Alternative I for that time period. For Alternative V, only releases occurring prior to or during emplacement (10-yr period) are included. Maximum dose and total risk for Alternative III through VI are dominated by possible releases due to a destructive tornado during the retrieval campaign.

(c) Effects of possible releases occurring at an offsite geologic repository are not included for Alternatives III, IV, and VI, because these effects are being evaluated in other DOE projects.

(d) See Subsections 7.4.1 and 13.2 for 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 I and Concept II-D.

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

buried at the SDA during the retrieval campaign. Such a risk would exist even without waste retrieval operations. For clarity, this type of nonoperational risk was omitted from the entries for Alternatives III through VI in Table 13-22. Only campaign-related accidents involving waste being retrieved, processed, or shipped were included. The scenario of greatest risk for those alternatives thereby becomes a destructive tornado during retrieval operations.

The maximum total of short-term risk appearing in Table 13-22 is 2×10^{-3} rem/yr to the maximum individual and 3 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) (NCRP 1975b) and 24×10^3 man-rem/yr (population).

A summary of projected effects from long-term release scenarios for each alternative or concept is given in Table 13-23. 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 13-23 presents the same data points in graphic form, with smooth curves drawn through the points. The increase in dose between 0 and 100 yr is due to the assumed population growth during the first 100 yr. Also indicated is the level of natural background radiation, which is the population dose that is certain to accrue each year, based on zero-population growth. (Long-term decay of the sources of natural background radiation would be very small over the 25,000-yr period studied. See Subsection 12.4.8.) 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 13-8 through 13-21. 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

TABLE 13-23

SUMMARY OF CONSEQUENCES FROM LONG-TERM RELEASE SCENARIOS^(a)

Alternative/ Concept	Population Dose (man-rem) for Specified Time after 1985 (yr)								
	0	100		400		2,000		25,000	
		BCF ^(b)	ACF ^(c)	BCF	ACF	BCF	ACF	BCF	ACF
I	5 x 10 ^{4(d)}		1 x 10 ^{5(d)}		1 x 10 ^{5(d)}		5 x 10 ^{4(d)}		4 x 10 ²
II-A	1 x 10 ³	2 x 10 ³	1 x 10 ^{5(d)}		1 x 10 ^{5(d)}		5 x 10 ^{4(d)}		4 x 10 ²
II-B	1 x 10 ³	2 x 10 ³	1 x 10 ^{5(d)}		1 x 10 ^{5(d)}		5 x 10 ^{4(d)}		4 x 10 ²
II-C	1 x 10 ³	2 x 10 ³	1 x 10 ^{5(d)}		1 x 10 ^{5(d)}		5 x 10 ^{4(d)}		4 x 10 ²
II-D	5 x 10 ^{2(d)}		1 x 10 ^{3(d)}		1 x 10 ^{3(d)}	1 x 10 ^{5(d)}	5 x 10 ^{4(d)}		4 x 10 ²
III-A, III-B	No long-term management of buried TRU waste at the INEL. ^(e)								
IV-A, IV-B	No long-term management of buried TRU waste at the INEL. ^(e)								
V-A through V-L (Lemhi Range)	1 x 10 ¹		2 x 10 ¹		2 x 10 ¹		1 x 10 ¹		4 x 10 ⁰
V-M through V-R (Site 14) ^(f)	4 x 10 ⁰		7 x 10 ⁰		7 x 10 ⁰		4 x 10 ⁰	1 x 10 ⁰	1 x 10 ²
V-M through V-R (LMV) ^(f,g)	1 x 10 ¹		2 x 10 ¹		2 x 10 ¹		1 x 10 ¹	1 x 10 ³	4 x 10 ²
V-S through V-X (RWMC) ^(f)	1 x 10 ¹		2 x 10 ¹		2 x 10 ¹		1 x 10 ¹	4 x 10 ⁰	4 x 10 ²
VI-A, VI-B	No long-term management of buried TRU waste at the INEL. ^(e)								

(a) All entries are the calculated values of population dose to the lung for the dominant release scenario.

(b) BCF = before confinement failure.

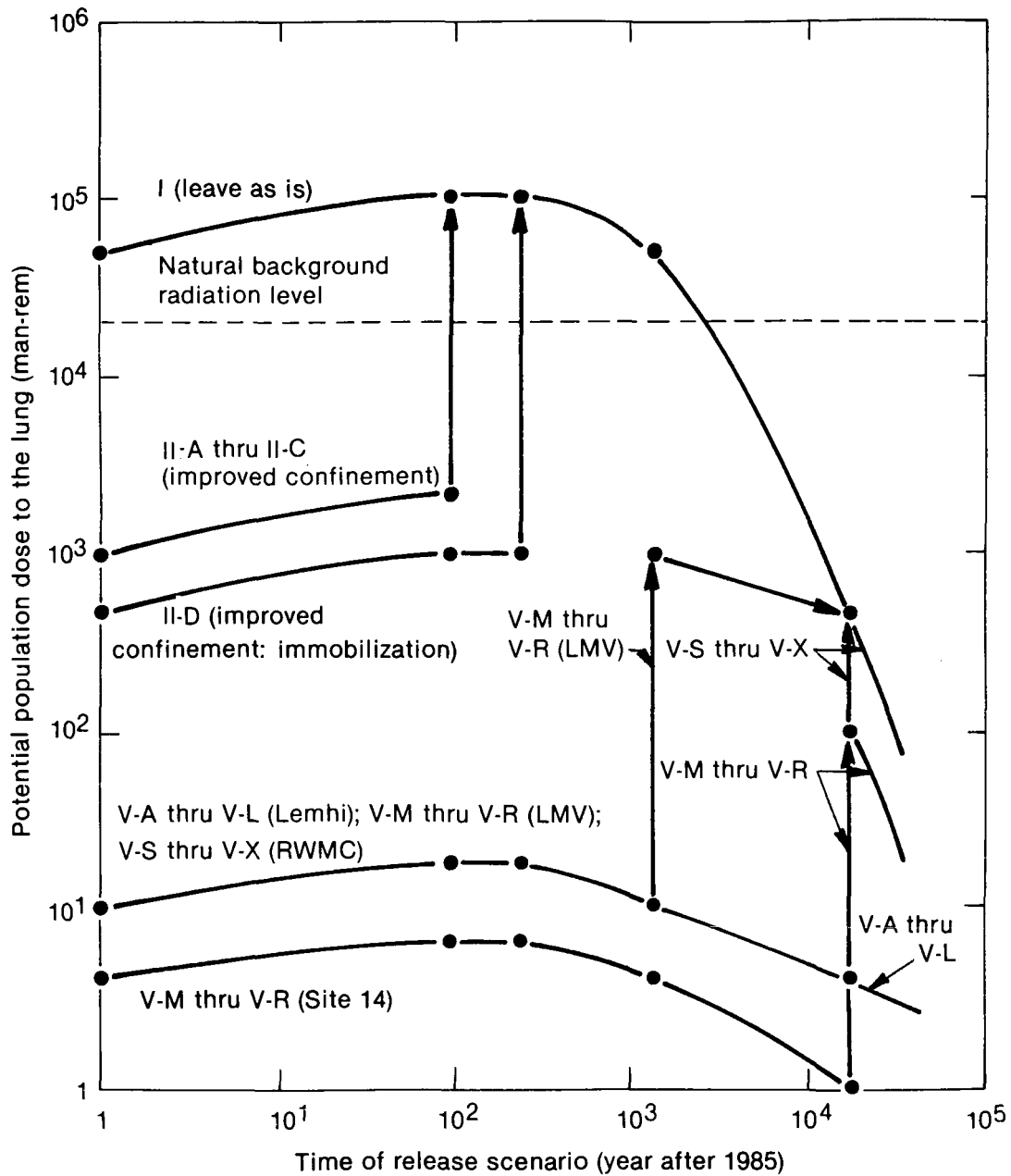
(c) ACF = after confinement failure.

(d) Lava flow is the dominant release scenario. For all other entries, explosive volcanic eruption is the dominant release scenario.

(e) Long-term effects of disposal of TRU waste at an offsite geologic repository are being evaluated in other DOE-sponsored studies.

(f) Resistance to explosive volcanic eruption assumed to be a factor of 100 better before containment failure than after containment failure.

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



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Supplement to Table 13-23
Summary of Consequences from Long-Term Release Scenarios

quantities can be determined by multiplying by the inventory at the time of the scenario (Table 13-6). The inventory will be about 1.3×10^5 Ci in 1985 and 6.8×10^4 Ci in 2085.

13.4 LEAVE AS IS (ALTERNATIVE I)

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.

13.4.1 Summary

For Alternative I, the calculated dose and risk for events leading to accidental releases are summarized in Table 13-8. 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 RWMC. The scenario has a short-term population risk, based on bone dose, that is many orders of magnitude less than that for the scenario with lava flow. The dose from long-term waterborne releases is associated with alteration of river channels, groundwater radiation, glaciation, climate change, and formation of lakes and swamps.

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 of DOE 1979b.

The 660-square mile Arco-Big Southern Butte area, in which the RWMC is located, includes the Arco Volcanic Rift Zone. The RWMC lies near 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 buried 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 1 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 a height of 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 2% of the estimated 41-acre area of the buried waste. It was correspondingly assumed that 2% of the inventory of 133,085 Ci (see Tables 4-2 and 4-3), or about 2.7×10^3 Ci, would be ejected. Further, 1% of the ejected waste (27 Ci) was assumed to remain airborne and to be carried offsite. The 1% 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 total inventory release fraction assumed was, therefore, 2×10^{-4} .

The probability of the eruption scenario described, within the buried TRU waste area, was estimated to be 3×10^{-8} /yr. This value is subject to large uncertainty. The value was based on an average recurrence frequency of one 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 buried waste to that of the Arco-Big Southern Butte area (41/420,000).

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 buried waste, covered with 3 ft of soil and 2 ft of compacted clay, is adequately protected against lava flow. The potential effects of the lava on the waste are also difficult to project. In all probability, the burial ground would not be penetrated (DOE 1978a). Nevertheless, in the worst case, the lava might interact with the waste, causing a release.

Studies of prolonged fires (ERDA 1975) have assumed release fractions of 0.1 to 0.5. Because about 20% of the buried waste is combustible (Subsection 7.4.1.2), a release fraction of 0.020 to 0.10 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, however, there would be sufficient advance warning, in most instances, for individuals living nearby to evacuate the area.

13.4.2.1.3 Earthquake

Another postulated event leading to airborne release was an earthquake strong enough to crack open the ground and expose some of the waste. 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, a crack would occur that would expose 200 ft^3 of waste. The fraction of the exposed 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 $\{(0.053 \text{ Ci/ft}^3 \times 200 \text{ ft}^3 \times 10^{-4}) / (1.33 \times 10^5 \text{ Ci})\} = 8 \times 10^{-9}$. (The concentration of 0.053 Ci/ft^3 is based upon the total Ci from Tables 4-2 and 4-3 divided by the $2.5 \times 10^6 \text{ ft}^3$ of TRU and intermixed beta-gamma waste.)

The ground acceleration necessary to cause the damage and airborne release just described was estimated to be at least 0.5 g. 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 $2 \times 10^{-6}/\text{yr}$.

13.4.2.1.4 Tornado

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) have been observed at the INEL.

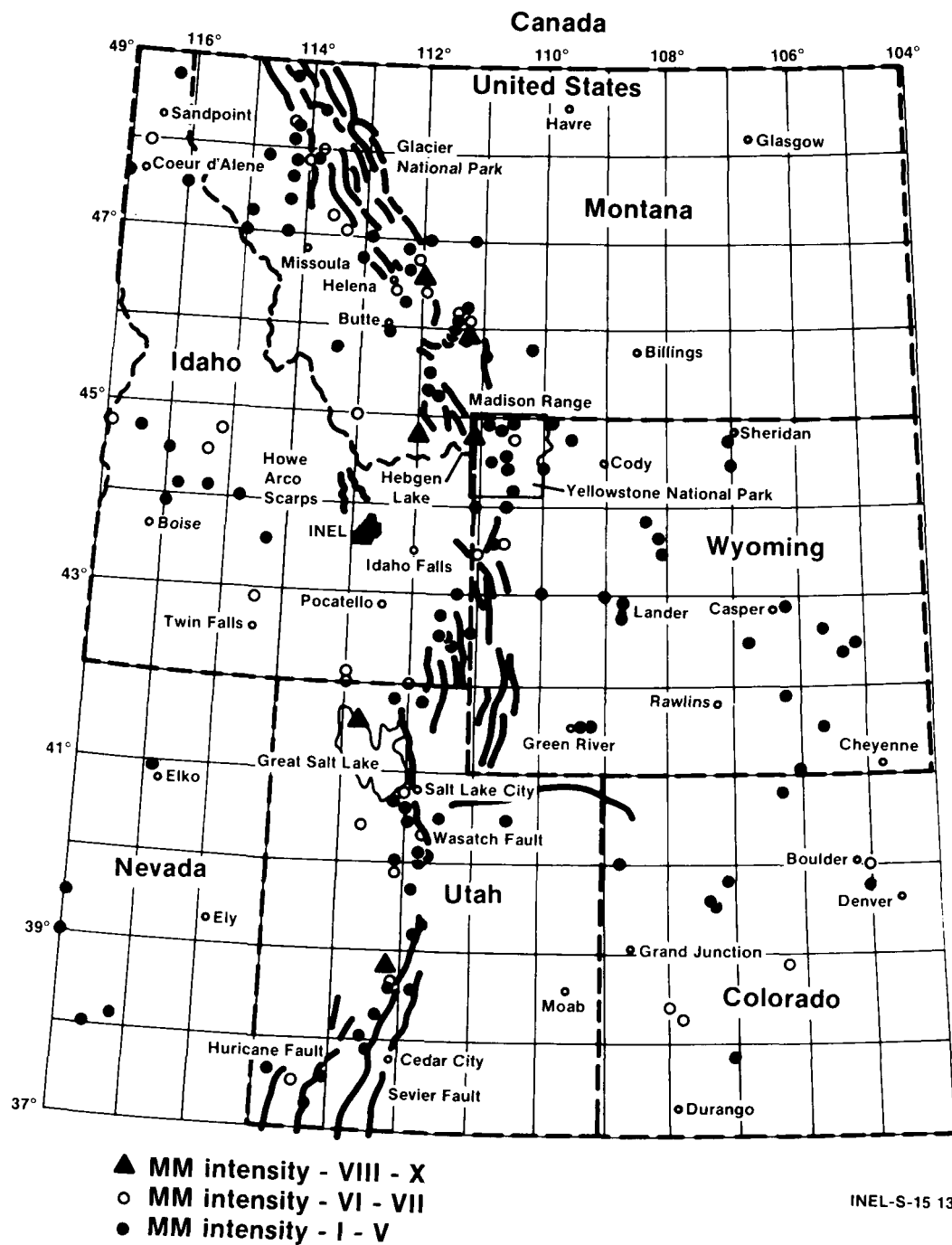


Fig. 13-1. Seismic characteristics of the Intermountain Region (ERDA 1977c).

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 would have a velocity of 100 mph. Assuming a random process, the probability of the buried waste (an area of 0.06 square mile) being the damage zone is about 3×10^{-6} /yr.

The clay protective cover over the waste 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 buried waste is several orders of magnitude smaller than the probability of other 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.

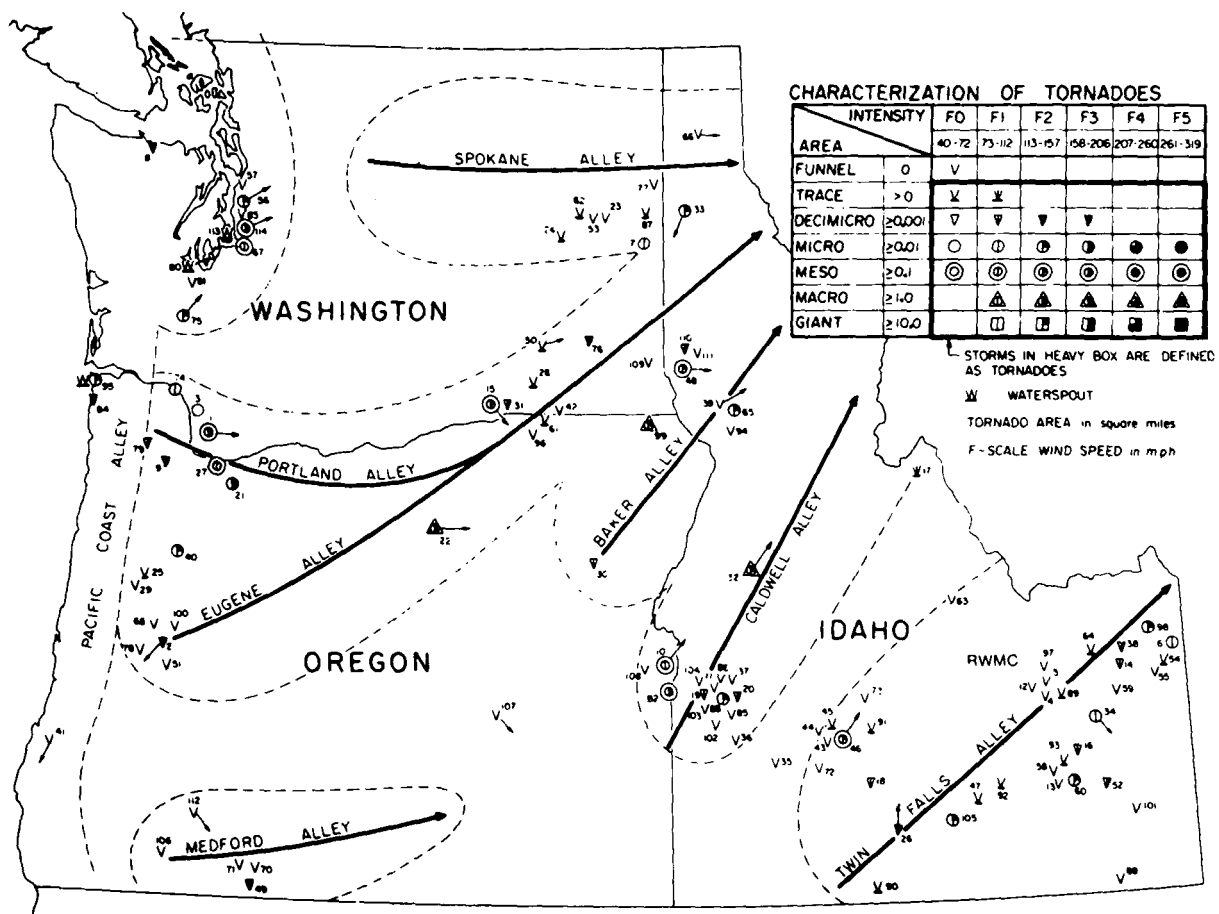


Fig. 13-2. Distribution of characterized tornadoes in 20-yr period, 1950 through 1969 (Fugita 1971).

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. Significant water table changes in the short term appear to be highly unlikely (ERDA 1977c).

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.

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.

The RWMC lies in the bottom of a valley between basalt ridges. The area generally slopes from the southwest to the northeast. The highest normal perimeter elevation is 5,011 ft above mean sea level (MSL), and the lowest elevations are about 5,000 ft above MSL. Water runs off the 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.

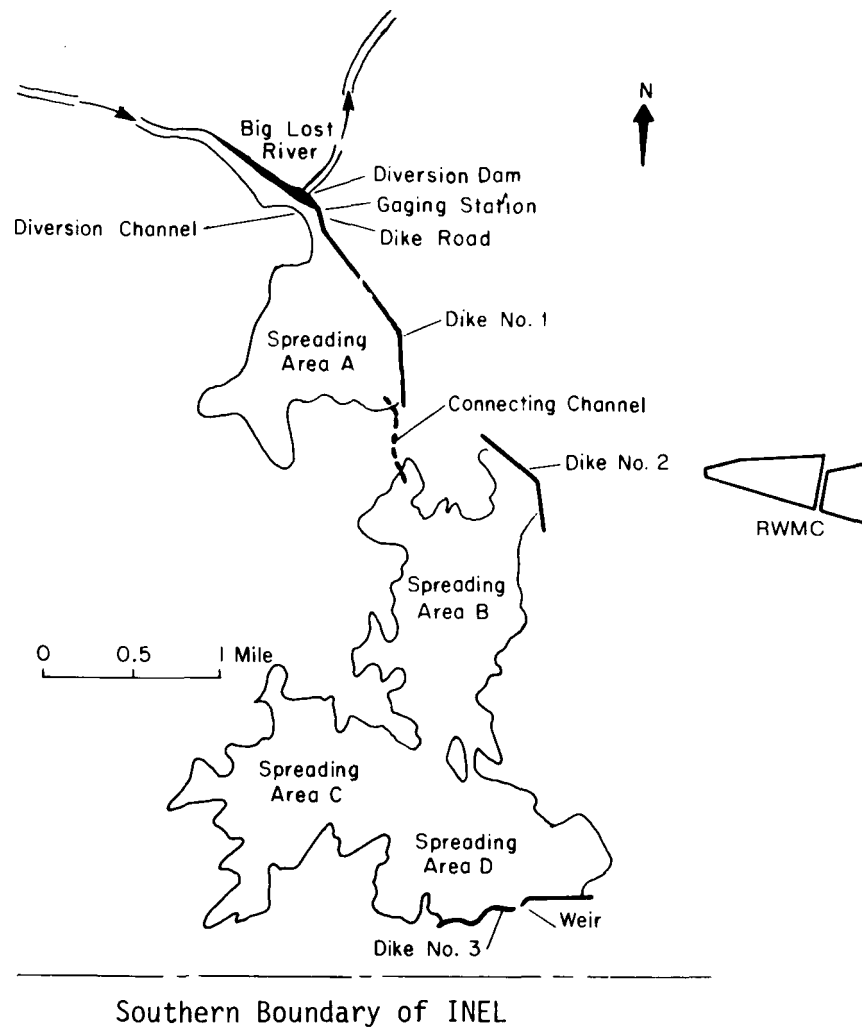


Fig. 13-3. Map of flood-control diversion system.

The RWMC tends to be subject 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.

Subsurface migration of radionuclides toward the Snake River Plain aquifer from buried TRU waste in the pits and trenches is discussed in Subsection 5.5 of DOE 1979b. To reach the aquifer, the contaminated water would have to percolate through about 580 ft of basalt and sedimentary layers (see Figure 3-6 of DOE 1979b). It was assumed that, after entering the aquifer, this water would travel northeast a few miles because of the head of water and the recharge from the spreading areas to the southwest, as shown in Figure 13-4. The water would then migrate southwest (Figure 13-5) about 80 miles to springs near Hagerman and Twin Falls (Figure 3-9 of DOE 1979b) and enter the Snake River.

Excavations at the RWMC have shown the presence of sand and gravel lenses (thin horizontal layers of material with greater porosity than the surrounding media). 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 of DOE 1979b), 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 the flow would be unsaturated, i.e., less than the flow capacity of the porous media. Current data indicate that this potential outside source would not contribute a significant quantity of water to the RWMC subsurface.

The first flooding scenario involves precipitation and surface runoff from the local drainage basin. Subsection 3.3.3 of DOE 1979b describes precipitation statistics at the INEL for the 22 yr of record. Intermittent periods of high precipitation provide an opportunity for soil saturation and resultant local flooding.

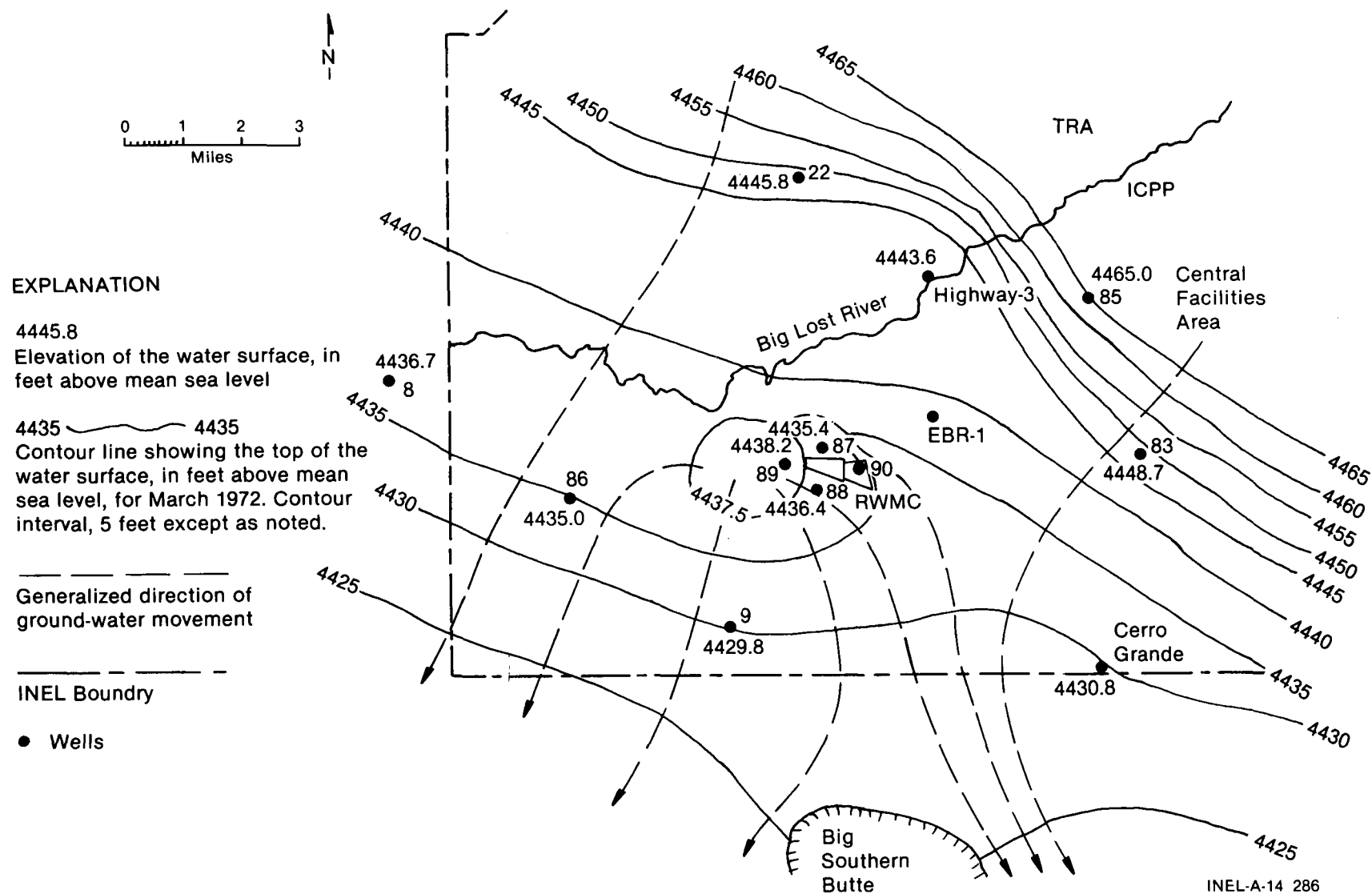


Fig. 13-4. Map of the southwestern portion of the INEL showing contours on the water table of the Snake River Plain aquifer and inferred directions of groundwater movement, March 1972.

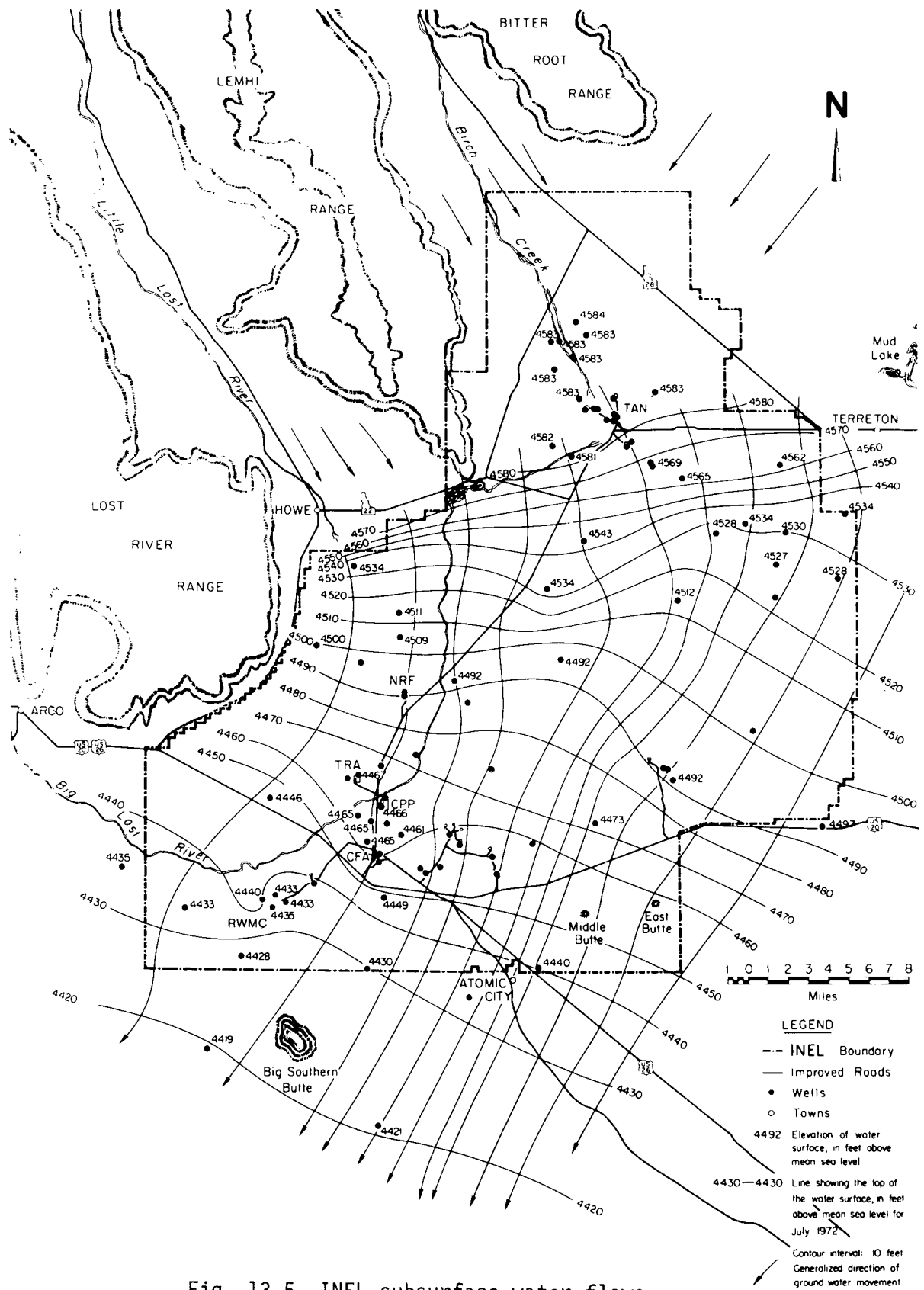


Fig. 13-5. INEL subsurface water flows.

The local drainage basin flood in 1969 demonstrated the inadequacy of the dike and drainage system in place at that time. Since then a more extensive system has been constructed around the RWMC perimeter, as described in Subsection 3.5.2 of DOE 1979b. The local drainage basin has thereby been reduced from 1,700 to 643 acres. For short-term considerations, erosion and radionuclide transport in the RWMC from local flooding would be unlikely. Thus, as long as the RWMC is maintained, local flooding would not adversely affect the RWMC or the dikes and diversion system.

The second flooding scenario involves Big Lost River flooding. The river channel, 2 miles north of the RWMC, has an elevation 30 to 40 ft higher than that of the RWMC. A large flood could conceivably overtop or breach Dike No. 2. Water could overflow onto the RWMC (see Figure 13-3, and Figure 5-3 of DOE 1979b). 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 1 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 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 the flooding scenario for 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 waste, and subsequent atmospheric dispersion. (This airborne pathway is mentioned here and discussed in the following subsection, because hydrologic events would be responsible for initiating the transport of radionuclides.) The 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 soon, 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.

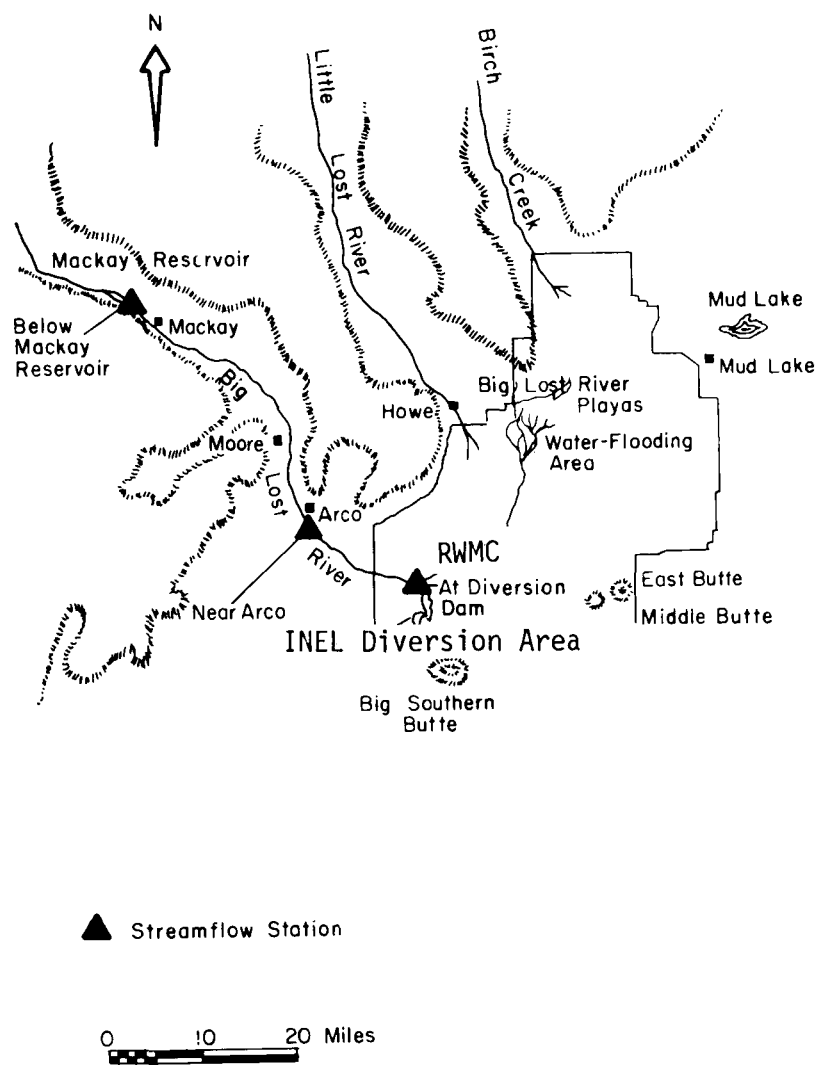


Fig. 13-6. Map of Big Lost River basin downstream from Mackay Reservoir showing location of streamflow stations.

(3) The 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 of these preliminary results is needed.

The hypothesized event could cause a radiological hazard to the public by means of two pathways for radionuclides released as a result of the flood: (1) ingestion of contaminated drinking water, and (2) inhalation of airborne radionuclides released via resuspension.

The ingestion pathway would entail (1) infiltration of floodwaters into the buried waste pits and trenches, (2) leaching of radionuclides from uncontained buried waste and contaminated soil, (3) percolation of the leached 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 RWMC, floodwaters would percolate in a saturated flow (i.e., at full flow capacity in porous media) toward the aquifer. Radionuclides migrating with percolating water would be in a dissolved or colloidal suspension form. Some of the dissolved species might be chelated or otherwise complexed. Radionuclides that are sorbed or filtered would not have a flow pathway to reach the aquifer. Thus, their migration would be significantly retarded.

It was assumed that less than 10% of the radionuclide inventory would be in a dissolved, chelated, or colloidal suspension form appropriate for migration. At low solute concentrations, ion-exchange and adsorption mechanisms would be extremely effective. It was therefore assumed that less than 0.1% of the migrating waste would travel the approximately 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 (DOE 1978a).

As the radionuclides migrate through the aquifer, their concentrations would be decreased 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 Figure 3-9 of DOE 1979b, and in Figures 13-4 and 13-5 of this document. 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 of DOE 1979b). 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 of DOE 1979b.) 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 27,000 people would ingest 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 13-24.

Maximum individual doses and population doses were summed for each of the contributing radionuclides regardless of arrival time. The results are

TABLE 13-24

CONCENTRATION OF PRINCIPAL^(a) RADIONUCLIDES IN WELL WATER
DUE TO GROUNDWATER TRANSPORT FOLLOWING MACKAY DAM FAILURE SCENARIO

Radio-nuclide	Time to Peak After Accident (Years)	Peak Concentration (pCi/ml) for Specified Time of Accident after 1985		
		0 Yr	25,000 Yr	1,000,000 Yr
<u>3-MILE WELL</u>				
Sr-90	222	1×10^{-7}	$<< 10^{-18(b)}$	$<< 10^{-18}$
Ra-226	2,160	2×10^{-11}	2×10^{-9}	2×10^{-7}
Ni-59	22,200	1×10^{-6}	9×10^{-7}	2×10^{-10}
Pu-239	42,700	3×10^{-6}	1×10^{-6}	1×10^{-18}
Th-230	44,100	6×10^{-10}	8×10^{-10}	2×10^{-8}
U-234	44,500	5×10^{-9}	6×10^{-9}	3×10^{-8}
U-238	44,700	3×10^{-8}	3×10^{-8}	3×10^{-8}
<u>80-MILE WELL</u>				
Ni-59	613,000	2×10^{-10}	2×10^{-10}	4×10^{-14}
U-233	615,000	2×10^{-10}	2×10^{-12}	2×10^{-11}
Np-237	618,000	3×10^{-10}	3×10^{-10}	2×10^{-10}
U-234	1,230,000	1×10^{-9}	1×10^{-9}	1×10^{-9}
U-238	1,240,000	1×10^{-9}	1×10^{-9}	1×10^{-9}

(a) Other radionuclides that were studied, such as Pu-238, Pu-241, Am-241, were found to give much lower values of peak concentration than those listed.

(b) $<<$ = much less than.

reported in summary Table 13-8. 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 13-8, because the final phase of radionuclide transport to man is airborne transport. It was assumed that 0.1% of the waste would be scoured via movement of soil from the waste pits and trenches to a new area of 10 square miles (see Figure 13-7). 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 1 in. 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 total inventory release fraction would be $(1 \times 10^{-3} \text{ fraction of transported waste} \times 1 \times 10^{-1} \text{ fraction of waste near soil surface} \times 3 \times 10^{-3} \text{ fraction of waste particles available for lofting}) = 3 \times 10^{-7}$.

13.4.3 Long-Term Effects

As described in Subsection 13.2.1, long-term risks were not calculated in this study. 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,

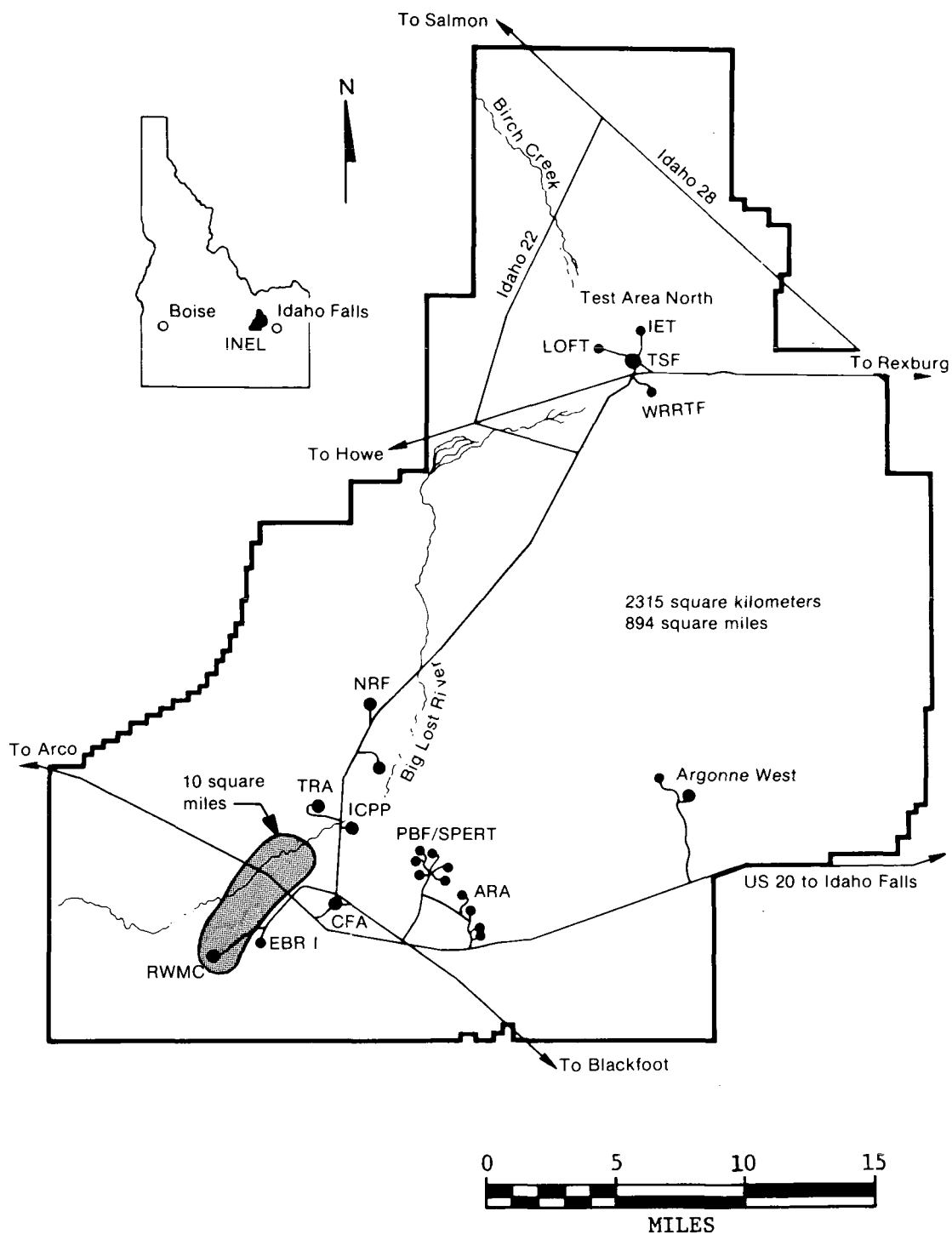


Fig. 13-7. Area contaminated by hypothetical Mackay Dam failure.

additional calculations were performed for a time 2,000 yr into the future. Lava flow over the waste was the only such case for 2085. In addition, waterborne doses were also estimated at 1×10^6 yr into the future. For estimates of long-term effects beyond 2,000 yr, the assumption was made that the buried waste would be homogeneously mixed with soil and clay, and that all of the combustible material would have been completely oxidized.

13.4.3.1 Airborne Accidental Releases

13.4.3.1.1 Explosive Volcanic Action

Subsection 13.4.2.1.1 described the bases for the assumed volcanic actions, including explosive action and lava flow. Over the long term, it would be expected that the explosive eruption scenario would be essentially unchanged. Thus, the consequences of explosive eruption would decrease over the long term, due to radioactive decay.

The doses for 100 yr are reported in Table 13-8. Since the dose was much less than for a lava flow (discussed below), doses were not calculated for longer time periods.

A discussion of the probability of explosive volcanic action is given in Subsection 13.4.2.1.1.

13.4.3.1.2 Lava Flow Over the Waste

Subsection 13.4.2.1.2 describes a volcanic event that could result in covering the entire RWMC with lava. For a worst-case analysis of long-term effects, the 2-ft clay cover and the 3-ft soil cover over the waste were assumed to have been essentially completely removed by erosion soon after the year 2085. 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 soon after 2085.

It was assumed that the buried waste would be mixed with the lava, and that all combustible material would burn. The total inventory release fraction was assumed to be 1×10^{-2} .

Because the calculated dose was significant for this scenario occurring in 2085, the dose was also calculated for the scenario occurring 2,000 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.

13.4.3.1.3 Intrusion

It was assumed that there would be no maintenance and surveillance of the RWMC after 100 yr. See Guideline (8) 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 5% 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 41-acre area of soil covering the buried waste. For both scenarios, the following assumptions were used: (1) the intrusion would begin in 2085; (2) the waste containers would have completely deteriorated and compressed, causing the waste cover to slump, forming fairly level ground over the waste area; (3) approximately 0.5% of the 2085 radionuclide inventory, or 340 Ci, would have migrated into, and been homogeneously distributed in, the top 3 ft of soil over the waste. The remaining inventory would be homogeneously distributed in the lower portion of the waste pits and trenches. With a soil density of 80 lb/ft³, the total concentration of radionuclides in the upper portion of the soil would be about 8×10^{-7} 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 maximum concentration of 1 mg/m^3 . 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 entire body of waste would be $1.5 \times 10^{-6} \text{ Ci/g}$ (Table 13-6). Because the individual would be active, his air breathing rate was assumed to be $1.25 \text{ m}^3/\text{hr}$. The amount of radioactivity inhaled by the individual can be calculated by the following: $(100 \text{ hr} \times 1.25 \text{ m}^3/\text{hr} \times 0.1 \text{ mg waste dust/m}^3 \times 1.5 \times 10^{-6} \text{ Ci/g} \times 1\text{g}/10^3 \text{ mg}) = 2 \times 10^{-8} \text{ Ci}$. The dust cloud could 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 13-8, 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 13.4.3.1.5, is the one for which the calculated doses appear in Table 13-8.

In the farming scenario, both ingestion and inhalation pathways were considered. In evaluating ingestion, it was assumed that the people living on the 41-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. 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 compiled in an unpublished report indicate that the transfer factor for americium would be a factor of 10 higher. Multiplication of the transfer factors by the individual radionuclide concentrations in the soil gave the activity of each radionuclide ingested per year. The maximum individual radioactivity ingested would be about $3 \times 10^{-6} \text{ Ci/yr}$. It was conservatively assumed that the same group of

people would remain on the site for 50 yr, with the maximum individual ingesting 3×10^{-6} Ci each year. The calculated doses are given in Table 13-8.

For calculations of population dose by the ingestion pathways, it was assumed that a maximum of 10 people would be involved onsite. The 10 people would derive their entire diet, including animal products, from food produced on the 41 acres.

In evaluating inhalation from farming activities, it was assumed that the farm would be plowed and cultivated in 24 hr/yr, developing a localized airborne dust loading of 1 mg/m^3 (Leddicotte et al. 1978). Other farming activities, conducted for 8 hr/day, 150 days/yr would develop a dust loading of 0.07 mg/m^3 . The dust loading due to normal air movement would be 0.05 mg/m^3 for the remaining time (see Subsection 5.2 of DOE 1979b). The total concentration of radionuclides in the surface soil was taken to be the same as for the ingestion pathway, 8×10^{-7} Ci/lb. The maximum individual radioactivity inhaled was calculated to be 7×10^{-10} Ci/yr. It was conservatively assumed that the same group would remain on the site for 50 yr, with the maximum individual inhaling 7×10^{-10} Ci each year. The calculated doses appear in Table 13-8.

Approximately 95% of the dust inhaled annually would be during activities other than plowing and cultivating. Thus, the population dose would be $(9 \text{ people} \times 0.95 \text{ maximum individual dose}) + (1 \text{ person} \times \text{maximum individual dose}) = 9.55 \times \text{maximum individual dose}$.

13.4.3.1.4 Erosion

It was assumed that the cover over the waste would have completely eroded soon 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.

13.4.3.1.5 Intrusion Following Erosion

It was conservatively assumed that the surface cover over the waste would have eroded completely soon 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 10, than that in the excavation scenario of Subsection 13.4.3.1.3. The results for this scenario appear in Table 13-8.

It was concluded that raising crops directly in the exposed waste material, after the soil cover had eroded away, would be unrealistic.

13.4.3.1.6 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^{-4} was assumed.

13.4.3.1.7 Other Events

Other events that could lead to an airborne release include earthquakes and airplane crashes. Neither event poses a hazard as serious as that of a volcanic eruption with lava flow. The lava flow event could involve all the buried 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 10 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 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 frequency 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.

For long-term analysis, the inhalation scenario again considered scouring of soil and waste from the pits and trenches followed by deposition of radionuclides upon evaporation of the water, and subsequent resuspension. It was assumed that the soil and clay cover would be sufficiently deteriorated that 1% of the waste would be scoured by the flood, of which 10% would remain in the top 1 in. of sediment. The fraction of the top particles less than 10 microns was again assumed to be 3×10^{-3} as was assumed in Subsection 13.4.2.2.2. The total inventory release fraction would thus be about 3×10^{-6} .

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 5,000 yr. The largest climatic change in that area occurred about 3,000 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 1,000 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 4,900-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, 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 4,900 ft), the maximum depth would probably not exceed 100 ft. The RWMC is located at an elevation slightly above 5,000 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 buried waste area could be entirely covered with detrital material. To determine which effect (erosion versus deposition) would more 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 1,000 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, which could result in severe flooding or erosion at the RWMC.

A cross-sectional view of the RWMC (see Figure 3-6 of DOE 1979b) 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 CO₂ released into the atmosphere by fossil-fuel burning during the past few centuries. The overall effect of CO₂ 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 1,000 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 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 1,000 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. 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 II)

13.5.1 Add Top Barrier (Concept II-A)

13.5.1.1 Summary

For Concept II-A, the calculated dose and risk for events leading to accidental releases are summarized in Table 13-9. Subsection 13.4, which addresses Alternative I, 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 many orders of magnitude smaller than that for airborne release due to lava flow over the waste. The dominant long-term waterborne releases are associated with alteration of river channels and with glaciation and climate changes.

13.5.1.2 Short-Term Risks

13.5.1.2.1 Airborne Accidental Releases

Emplacing an additional barrier over the top 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 minimize exposure of the buried waste. The earthquake scenario was assumed to lead to dose and risk values 25% of those of Alternative I. As with Alternative I, a tornado would not be expected to result in radionuclide releases.

No scenario was identified whereby radionuclides could be released as a result of operations-related accidents during emplacement of the cover over the waste.

13.5.1.2.2 Waterborne Accidental Releases

Flooding of the RWMC could occur as described for Alternative I 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 I, 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, soon 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 I (see Subsection 13.4.3.1).

13.5.1.3.2 Waterborne Accidental Releases

Because the engineered improvements were assumed to have negligible benefit soon after 2085, the waterborne releases would be the same as described for Alternative I in Subsection 13.4.3.2.

13.5.2 Add Top and Side Barriers (Concept II-B)

13.5.2.1 Summary

For Concept II-B, the calculated dose and risk for events leading to accidental releases are presented in Table 13-10. Only differences from the evaluation of Alternative I (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 many orders of magnitude smaller than that for airborne release due to lava flow over the waste. The dominant long-term waterborne releases are associated with alteration of river channels and with glaciation and climate change.

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 I 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 side walls) 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 minimize exposure of the waste. The earthquake scenario was assumed to lead to dose and risk values 25% of those of Alternative I. As with Alternative I, a tornado would not be expected to result in radionuclide releases.

The doses and risks due to accidental breach of waste containers during construction of engineered confinement were found to be small compared with doses and risks caused by natural events.

13.5.2.2.2 Waterborne Accidental Releases

The cover over the waste would reduce the effects of flooding. The side walls would form an additional barrier to prevent infiltration of water into the waste. It was assumed that, compared with Alternative I, 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 because of the side barriers around the waste, the infiltration would be reduced by a factor of 10, 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 II-A in Subsection 13.5.1.3.1. The walls around the waste 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 I (see Subsection 13.4.3.2).

13.5.3 Add Top, Side, and Bottom Barriers (Concept II-C)

13.5.3.1 Summary

For Concept II-C, the calculated dose and risk for events leading to accidental releases are presented in Table 13-11. Only differences from the evaluation of Alternative I 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 many orders of magnitude smaller than that for airborne release due to lava flow. The dominant long-term waterborne releases are associated with alteration of river channels and with glaciation and climate change.

13.5.3.2 Short-Term Risks

13.5.3.2.1 Airborne Accidental Releases

It was assumed that the effects of volcanic eruption under the waste would be the same as described for Alternative I in Subsection 13.4.2.1.1. The effect of lava flow would be similar to that described in Subsection 13.4.2.1.2, but with a lower release fraction. The clay and riprap cover, travertine and clay side walls, and grout-injected bottom barrier were assumed to reduce the release fraction to 1×10^{-4} , or a factor of 100 less than Alternative I.

In a strong earthquake or in a tornado, the clay cover would minimize exposure of the waste. The earthquake scenario was assumed to lead to dose and risk values 25% of those of Alternative I. As with Alternative I, radionuclide releases would not be expected as a result of a tornado.

Again, the doses and risks due to accidental breach of containers during construction were estimated to be small compared with those from natural forces.

13.5.3.2.2 Waterborne Accidental Releases

The cover and side walls would reduce the effects of flooding. The grout-sealed barrier under the waste would inhibit water migration to the aquifer. Compared with Alternative I, the scouring effect from Mackay Dam floodwaters was assumed to be reduced by a factor of 50, as would the doses and risks from the resuspension and airborne pathway. Because of the additional barrier at the bottom of the waste, it was also assumed that the water transport from the waste pits and trenches would be reduced by a factor of 20, compared to the "leave as is" alternative. The resulting doses and risks for the waterborne pathway via the Snake River Plain aquifer would also be reduced by the same factor of 20.

13.5.3.3 Long-Term Risks

13.5.3.3.1 Airborne Accidental Releases

The addition of a bottom grout-seal barrier would have little, if any, effect on airborne releases after 2085. Therefore, the long-term releases would be about the same as described for Concept II-A in Subsection 13.5.1.3.1.

13.5.3.3.2 Waterborne Accidental Releases

It was assumed that, in the long term, the engineered improvements would deteriorate and would have negligible benefit in reducing waterborne releases. Thus, the waterborne releases would be the same as for Alternative I, Subsection 13.4.3.2.

13.5.4 Immobilize in Place (Concept II-D)

13.5.4.1 Summary

For Concept II-D, the calculated dose and risk for events leading to accidental releases are presented in Table 13-12. Only differences from the evaluation of Alternative I 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 many orders of magnitude smaller than that for airborne release due to lava flow over the waste. The dominant long-term waterborne releases are associated with alteration of river channels and with glaciation and climate change.

13.5.4.2 Short-Term Risks

13.5.4.2.1 Airborne Accidental Releases

It was assumed that, as a result of immobilization, the release fractions 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 doses and risks for disruptions caused by the forces of nature.

13.5.4.2.2 Waterborne Accidental Releases

Compared with Alternative I, the immobilization would reduce the release fractions in flooding. It was assumed that, compared with Alternative I, the scouring effect from Mackay Dam floodwaters would be reduced by a factor of 1,000, 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.

13.5.4.3 Long-Term Effects

13.5.4.3.1 Airborne Accidental Releases

It was assumed that immobilization would reduce the release fractions 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 13-12 reflect the factor of 100 reduction in release fractions assumed for scenarios occurring in 2085. For lava flow, results are also given for the scenario occurring 2,000 yr in the future. Because the confinement would have deteriorated by

that time, no credit was taken for reduction in source release. For the intrusion scenarios also, results are given for 2,000 yr into the future. In these cases, the radionuclides were assumed to be homogeneously distributed throughout the waste/soil/deteriorated-grout mixture, rather than having 0.5% of the nuclide inventory in the top 3 ft of soil (see Subsection 13.4.3.1.3). Because in all Alternative II concepts, confinement is expected to fail in 2,000 yr or less, these concepts would all show approximately the same 2000-yr intrusion results, and would be approximately the same as the 2,000-yr intrusion results for Alternative I.

13.5.4.3.2 Waterborne Accidental Releases

It was estimated that for the first 400 yr, compared with Alternative I, the scouring effect and the resulting doses would be reduced by a factor of 1,000 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 13-12 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 I results for scenarios occurring at the same point in time after 400 yr.

13.6 RETRIEVE, PROCESS, AND SHIP TO AN OFFSITE GEOLOGIC REPOSITORY (ALTERNATIVE III)

This subsection discusses the dose and risk calculated for the various modules within Alternative III. These dose and risk results are combined in Table 13-22 to give the total dose and total risk for the alternative.

Only short-term doses and risks are relevant for this alternative. After 10 yr, the waste would be located at an offsite geologic repository. (The risk presented by the waste at an offsite geologic repository is being addressed in other DOE-funded studies.) The same discussion holds for Alternatives IV and VI, except that the waste would not all be at a repository until 30 yr had passed.

The possibility of volcanic action, discussed under Alternative I, 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. During the campaign, the amount of waste in the ground would decrease, reaching zero at the campaign completion.

For convenience, the volcanic action scenarios were addressed in connection with retrieval in Subsection 13.6.1. In the interest of conservatism, the same release fractions were assumed as for the corresponding scenarios in Alternative I.

The above rationale applies also to most other natural phenomena, e.g. flooding of the RWMC, discussed in the short-term risk analysis for Alternative I.

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 13-13. Waterborne accidental releases would be negligible. The dominant event was determined to be release caused by lava flow over the waste, as in Alternative I. During the operational period, the event leading to the largest short-term population risk was determined to be a destructive tornado occurring during retrieval of the waste.

13.6.1.2 Accident Analysis

An accident analysis for the direct-control retrieval facility was carried out to determine the potential events that could cause releases of radionuclides to the environment. In this analysis, events were categorized into those that could have trivial, minor, or major consequences. Trivial events are defined as those causing equipment upset or shutdown, but with no

releases of radionuclides to the environment, beyond those from normal operations. Minor events are those resulting in small releases of radionuclides to the environment. Major events are those resulting in the largest releases of radionuclides to the environment.

Tables describing trivial and minor events from direct-control retrieval will be presented in the EIS. In order to indicate their relative magnitude, doses resulting from major releases, as well as from some minor releases, are described in the following subsections for the direct-control retrieval module. All natural occurrences, aircraft impact, and transfer accident (with or without fire) were considered to be major events. The minor events described below are dropping a waste transfer container and a fire involving the waste.

13.6.1.3 Airborne Accidental Releases

13.6.1.3.1 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.

13.6.1.3.2 Tornado

A tornado could strike the RWMC during the 10-yr retrieval campaign. The tornado history of the area is discussed in Subsection 13.4.2.1.4. The total projected area of the two buried waste retrieval facilities would be approximately $2 \times 150 \times 300$ ft, or 4×10^{-3} square mile. The estimated probability of tornado damage to the facilities is based on the tornado damage zone area of 0.01 square mile, since this area is larger than the combined area of the facilities. The probability would be $(0.01 \text{ mi}^2 / 25,000 \text{ mi}^2) \times (1.3/\text{yr}) = 5 \times 10^{-7}/\text{yr}$.

If a tornado were to touch down while retrieval was under way, the retrieval building could be damaged and some of the waste could be released. It was assumed that if there were sufficient warning of an impending tornado, all of the filled waste containers would be moved from the retrieval building

into the processing facility. Waste would then be released only from the excavation face of the pit. Assuming that a 2-in. depth is involved with a face area of 16 x 130 ft, the volume of waste would then be about 350 ft³. An airborne release fraction of 1×10^{-2} was assumed because of the high-velocity wind. The total volume of TRU waste, beta-gamma-waste, and contaminated soil amounts to 6.25×10^6 ft³. Thus, the inventory release fraction is $(350 \text{ ft}^3 \times 10^{-2} \text{ airborne fraction}) / (6.25 \times 10^6 \text{ ft}^3) = 6 \times 10^{-7}$.

13.6.1.3.3 Earthquake

The effect of an earthquake during retrieval would be expected to be about the same as described in Subsection 13.4.2.1.3. In addition, ground motion could cause a spill of waste in the retrieval building, but the effects would be much less than the effects due to ground cracking. The waste spill is considered a minor release; the results are discussed in Subsection 13.6.1.3.6.

13.6.1.3.4 Aircraft Impact

The evaluations included the possibility of impact of a large aircraft on the retrieval facilities, with a resulting fire. It was assumed that the collision and ensuing fire would involve waste at the face of the excavation pit.

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 one-third of such accidents (McSweeney and Hall 1975). Based on the projected area of the retrieval facilities of 90,000 ft² (2.8×10^{-3} square mile), the frequency of an aircraft impact accompanied by a fire was estimated to be approximately $(2.8 \times 10^{-3} \text{ mi}^2 / 0.14 \text{ mi}^2) \times (4.6 \times 10^{-7} / \text{yr}) \times (1/3) = 4 \times 10^{-9} / \text{yr}$.

The amount of waste involved on the open pit face was assumed to be 350 ft³, as in the tornado accident. It was assumed 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 the same as in the tornado accident, 6×10^{-7} .

13.6.1.3.5 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 $(1.6 \times 10^{-7} \text{ accident/mile} \times 0.25 \text{ mile/trip} \times 0.07 \text{ conditional probability of release/accident} \times 2,347 \text{ trips/yr}) = 7 \times 10^{-6}/\text{yr}$.

An airborne release fraction of 1×10^{-3} from one breached box was assumed. The total inventory release fraction would be $(90 \text{ ft}^3 \times 10^{-3}) / (6.25 \times 10^6 \text{ ft}^3) = 1 \times 10^{-8}$.

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 $(1.6 \times 10^{-7} \text{ accident/mile} \times 0.25 \text{ miles/trip} \times 1.6 \times 10^{-2} \text{ conditional probability} \times 2,347 \text{ trips/yr}) = 2 \times 10^{-6}/\text{yr}$. It was assumed that one container 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 1×10^{-7} .

13.6.1.3.6 Dropping a Waste Container

One of the accidents with minor consequences would be spilling the contents of a full, open waste transfer container as a result of an accident involving the container hauler. Other similar accidents may be described resulting in such a spill. On the average, 32 containers per day would be

handled in the retrieval building. An accidental drop was estimated to occur at a frequency of 1×10^{-5} per handling operation, based on RWMC experience. The accident frequency would then be $(32 \text{ containers/day} \times 220 \text{ days/yr} \times 1 \times 10^{-5}/\text{container}) = 7 \times 10^{-2}/\text{yr}$.

A waste container (4 x 4 x 7 ft) at 80% fill capacity would contain about 90 ft³ of waste. This amounts to 1.9 Ci based on a concentration of 0.021 Ci/ft³ for the TRU, beta-gamma, and soil mixture. A fraction, 1×10^{-4} , would become airborne when the accidental drop occurred. Using a DF of 10^6 for the filter system results in a total inventory release fraction of $(1.9 \text{ Ci} \times 10^{-4} \text{ airborne fraction} \times 10^{-6} \text{ filter DF}^{-1}) / (1.33 \times 10^5 \text{ Ci}) = 1 \times 10^{-15}$.

The retrieval facility filter system 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 the 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.

13.6.1.3.7 Fire in the Waste

Another hypothetical accident with minor consequences is a fire in the waste. It was assumed that the fire occurs in a waste transfer container and that all of the combustibles in the waste container, 7.2 ft³, would be burned before the fire is contained. The probability of such a fire was estimated to be $1 \times 10^{-2}/\text{yr}$, based on consideration of unpublished data for fires at United States nuclear power plants. (The buried TRU waste contains pyrophoric materials.)

An airborne fraction of 1×10^{-2} (Mishima 1974) was assumed. The building filter DF was assumed to be 10^6 . The TRU waste plus beta-gamma waste contains $(1.33 \times 10^5 \text{ Ci} / 2.5 \times 10^6 \text{ ft}^3) = 0.053 \text{ Ci/ft}^3$. Thus, the total inventory fraction released to the environment would be $(7.2 \text{ ft}^3 \times 0.053 \text{ Ci/ft}^3 \times 10^{-2} \times 10^{-6}) / (1.33 \times 10^5 \text{ Ci}) = 3 \times 10^{-14}$.

13.6.1.3.8 Loss of Electrical Power

The retrieval building would depend on power from a trailer-mounted diesel generator located outside the enclosure. In case of loss of power, workers could evacuate the building quickly and safely.

Although subatmospheric pressure would be lost, it was estimated that leakage of radionuclides from the building would be less than normal operating releases (DOE 1978a).

13.6.1.4 Waterborne Accidental Releases

Migration of radionuclides to the aquifer as a result of retrieval operations would not be expected.

13.6.2 Remote-Control Retrieval

13.6.2.1 Summary

For remote-control retrieval, the calculated dose and risk for events leading to airborne accidental releases are presented in Table 13-14. The results were estimated to be the same as for the direct-control retrieval for all events except those resulting from handling accidents. Waterborne accidental releases would be negligible.

The dominant event was determined to be lava flow over the waste as in Alternative I. During the operational period, the event leading to the largest short-term population risk was determined to be a destructive tornado occurring during retrieval of the waste.

13.6.2.2 Accident Analysis

An accident analysis led to the same events that could cause releases of radionuclides in the direct-control retrieval module. Therefore, the tables describing trivial and minor events for direct-control retrieval (Subsection 13.6.1.2) are applicable also to remote-control retrieval. The

major events described in Subsection 13.6.1 are the same for remote-control retrieval as for direct-control retrieval.

13.6.2.3 Airborne Accidental Releases

Major events that could lead to releases from the facility itself (in contrast to releases from the SDA) could be such events as a tornado or an aircraft impact. The effects of such events would be the same for both direct-control and remote-control retrieval. Most minor events that could occur during operations, such as power outage, a fire or explosion in the waste, equipment failure, and procedural error, would also have the same effects in both types of facility. Therefore, as far as releases of radio-nuclides are concerned, the consequences (doses) would be the same for direct-control and remote-control retrieval.

It would also be expected that the frequency of events such as those above would be the same, except for handling operations. In the remote-control facility, procedures and equipment would be more complicated, and operator error would tend to be greater. It might be expected, therefore, that the frequency of handling accidents would be greater than in direct-control operations.

Thus, with the exception of handling accidents, all airborne accident doses and risks for remote-control retrieval were assumed to be the same as for direct-control retrieval. These handling accidents have been determined to lead to minor releases. One such accident, dropping a waste container, is described in the following subsection.

13.6.2.3.1 Dropping a Waste Container

This accident has been described for the direct-control retrieval module in Subsection 13.6.1.3.6. It was assumed for remote-control retrieval that the frequency of handling accidents is a factor of 10 greater than for direct-control retrieval. Thus, the estimated accident frequency would be increased from $7 \times 10^{-2}/\text{yr}$ to $7 \times 10^{-1}/\text{yr}$.

The release of radionuclides would be the same as in direct-control retrieval, a total inventory release fraction of 1×10^{-15} .

13.6.2.3.2 Loss of Electrical Power

In the case of remote-retrieval operation, there would not be any personnel in the building under normal operating conditions. Thus, loss of power would pose no potential problem for workers.

As for direct-control retrieval, it would be expected that release of waste from the building due to loss of subatmospheric pressure would be less than releases from normal operations.

13.6.3 Slagging Pyrolysis and Packaging

13.6.3.1 Summary

For slagging pyrolysis, the calculated dose and risk for events leading to airborne accidental releases are presented in Table 13-15. Waterborne accidental releases would be negligible. The event with the largest population risk was a highly unlikely criticality event, resulting in a release of fission gases to the environment.

13.6.3.2 Accident Analysis

An accident analysis for the SP Facility was carried out to determine the potential events that could cause releases of radionuclides to the environment. Trivial, minor, and major events, as defined in Subsection 13.6.1.2, were considered. A description of the trivial and minor events will be included in the EIS. Risks for major releases, as well as for some minor releases, are described in the following subsections.

The accident analysis was carried out after DOE 1979b was published. However, the events identified in the present study would also apply to slagging pyrolysis of stored TRU waste, with adjustment for the waste volume and radionuclide inventory.

The major releases, in terms of doses to the public, were determined to be due to earthquake, waste heat boiler rupture, gasifier rupture, and a criticality event. The minor releases described below include dropping a waste container and fire. Although doses from minor events are less than those from major events, the risks in general are approximately equal to the risks from the major events, due to a greater probability for the occurrence of the minor events.

13.6.3.3 Airborne Accidental Releases

13.6.3.3.1 Earthquake

It was assumed that the facility would be designed to shut down safely for earthquakes having ground accelerations of up to 0.4 g [corresponding to an MMI of VIII to IX (Otway 1969)]. Such an earthquake could, however, cause sufficient displacement of waste containers in the storage area that they might fall and be breached. It was assumed that the top three rows of the stack of containers, with 10 containers in each row, could fall 12 ft or more. It was conservatively assumed that all of the waste contents would be released from the containers. Each container would hold 90 ft^3 of the waste plus soil mixture. Assuming an airborne fraction of 1×10^{-4} and a filter DF of 10^6 , the total inventory release fraction would be $(90 \text{ ft}^3/\text{container} \times 30 \text{ containers} \times 0.021 \text{ Ci/ft}^3 \times 10^{-4} \times 10^{-6}) / (1.33 \times 10^5 \text{ Ci}) = 4 \times 10^{-14}$.

The conservatively estimated probability of occurrence of such an earthquake is $2 \times 10^{-6}/\text{yr}$ (Agbabian Associates 1977).

An earthquake more severe than MMI IX could cause damage to the facility such that not only would the waste containers be displaced, but the walls to the storage area also would be breached. In this scenario, no credit can be taken for the ventilation system DF. The total inventory release fraction would then be 10^6 times larger than that found above for the lesser earthquake, or 4×10^{-8} .

The overall probability of an earthquake greater than MMI IX (having ground accelerations of 0.4 g or larger) has been estimated to be $4 \times 10^{-8}/\text{yr}$ (DOE 1978a).

13.6.3.3.2 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 2.5 acres, an area 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.)

In a reassessment of the earlier study of damage to the SP facility (DOE 1979b), it was concluded that the offgas ductwork, which is located inside the processing building, would be designed to withstand pressure changes associated with a tornado. Incinerator shutdown was estimated to take place in about 30 min. (DOE 1979b). If the tornado struck during this time, damage could occur to the HEPA filters and an increased release of radioactivity could result over that normally expected. Since the remainder of the offgas treatment system would be expected to remain intact, the overall offgas DF might change from 1×10^8 to as low as 1×10^2 , if it is assumed that the HEPA filters are completely breached. In this analysis, a DF value of 1×10^2 was conservatively assumed.

The residence time of waste in the incinerator would be about 6 hr. Based on a volumetric flow rate of about 134 ft^3 of waste/hr, the incinerator inventory of waste would be about 800 ft^3 . A stack gas flow rate of $1.5 \times 10^6 \text{ ft}^3/\text{hr}$ ($4 \times 10^4 \text{ m}^3/\text{hr}$) was used (Figure 10-1). 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 $(4 \times 10^4 \text{ m}^3/\text{hr} \times 0.5 \text{ hr} \times 0.1 \text{ g}/\text{m}^3) = 2,000 \text{ g}$. From Table 13-2, the concentration of radionuclides is $7.8 \times 10^{-7} \text{ Ci}/\text{g}$. Thus, the total inventory

release fraction would be $(2,000 \text{ g} \times 7.8 \times 10^{-7} \text{ Ci/g} \times 10^{-2}) / (1.33 \times 10^5 \text{ Ci}) = 1 \times 10^{-10}$.

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 $2,000 \text{ ft}^3$ 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 $(2,000 \text{ ft}^3 \times 10^{-4} \times 10^{-1}) / (6.25 \times 10^6 \text{ ft}^3) = 3 \times 10^{-9}$.

13.6.3.3.3 Waste Heat Boiler Explosive Rupture

An explosive rupture of the waste heat boiler could potentially cause catastrophic rupture of the sintered metal filter housings. The filter cake on the filters could be dispersed into the offgas treatment system cell, resulting in an airborne release of particulates.

It was assumed that the maximum amount of filter cake, 52 ft^3 , is released to the cell. The cake would consist of 52% ash and 48% spray dryer salt, and would weigh an estimated 4,200 lb. Because of the very small particulate size (<25 microns) (Christian, Girton, Kirstein, and Pence, 1978), and the nature of the release, it was assumed that all of the filter material would remain airborne. The volume of waste feed equivalent to the dispersed material was estimated to be 14 ft^3 . The relative amounts of radionuclides in the filter material were assumed to be the same as in the feed. Using a filter DF of 10^6 , the total inventory release fraction would be $(14 \text{ ft}^3 \times 0.053 \text{ Ci/ft}^3 \times 10^{-6}) / (1.33 \times 10^5 \text{ Ci}) = 6 \times 10^{-12}$.

There have been no waste heat boiler failures in over 30,000 hr of operation of existing commercial slagging pyrolysis systems. Based on failure rates for fossil and nuclear power plant boilers, built in accordance with the ASME Code, the frequency of waste heat boiler failures was estimated to be $1 \times 10^{-6}/\text{yr}$ (AEC 1974b).

13.6.3.3.4 Gasifier Rupture

A wall rupture of the gasifier would potentially involve a release to the gasifier cell of a large inventory of radionuclides. The ejected material was assumed to be equivalent to 6 tons of feed. The feed contains 12.5% waste by weight. The amount of waste exposed to the cell atmosphere would be 37.5 ft^3 . The relative amounts of radionuclides in the ejected material were assumed to be the same as in the feed. Using a filter DF of 10^6 and an airborne fraction of 1×10^{-2} , the total inventory fraction released was estimated to be $(37.5 \text{ ft}^3 \times 0.053 \text{ Ci/ft}^3 \times 10^{-2} \times 10^{-6}) / (1.33 \times 10^5 \text{ Ci}) = 1 \times 10^{-13}$.

For this event to occur, explosive material would have to pass through the waste preparation and sorting cell undetected. The separation of hazardous materials would be part of the standard processing operation. Operator error data (NRC 1975) were reviewed. For the operations involved, with their increased training and controls, operator error was estimated to be 1×10^{-4} per demand. It is unknown, of course, how many potentially explosive objects are present in the waste. Assuming there are ten such devices or containers of material, the overall frequency would be $(1 \times 10^{-4} / \text{object} \times 10 \text{ objects} / 10 \text{ yr}) = 1 \times 10^{-4} / \text{yr}$.

13.6.3.3.5 Criticality Event

While extremely unlikely, a nuclear would be criticality accident conceivably could occur. Extensive safeguards would be included in the facility design to prevent such events. To assess the effects of a criticality accident, such an accident was postulated to occur in the lower part of the gasifier.

Plutonium-239 is the principal nuclide that would be involved in a criticality accident. The inventory of ^{239}Pu in the incinerator during processing might range from 27 g to 2.7 kg. (The ^{241}Pu mass would be less than 0.1% of the mass of the ^{239}Pu .) The unmoderated, but fully reflected, critical mass of ^{239}Pu is approximately 5 kg (Thomas 1978). Criticality limits depend on the geometry and extent of moderation and reflection.

An accident was postulated in which multiple excursions totaling 2×10^{19} fissions would occur over a 24-hr period. Physical damage would be highly unlikely. For conservatism in this analysis, the fission-produced energy was assumed to release all of the fission gases to the cell atmosphere through relief valves, to be carried through the ventilation system to the environment. Some passage would take place through the offgas treatment system also, but it was assumed that no removal of fission product gases would occur. The quantities of gaseous fission products were calculated using the ORIGEN code (Bell 1973). Estimated quantities of noble gases and iodine that would be released are listed in Table 13-25.

The possibility of criticality would be minimized by monitoring and control of the waste containers as they are brought into the facility. For criticality to occur, the assay and control system would have to fail and, at the same time, high levels of fissile material would have to enter into the system. The frequency of system failure was assumed to be $1 \times 10^{-3}/\text{yr}$ (NRC 1975). It was arbitrarily assumed that amounts of fissile material great enough to be a potential hazard might be present 10 days out of the total of 2,200 operating days. Thus, the frequency of criticality for this facility was assumed to be $(1 \times 10^{-3}/\text{yr}) \times (10/2200) = 5 \times 10^{-6}/\text{yr}$. The possibility of criticality is being addressed in ongoing studies.

13.6.3.3.6 Dropping of a Waste Container

Two operations for handling waste containers were studied. The first involved handling of waste transfer containers; the second, handling of containers of processed waste.

As a worst case, it was assumed all waste transfer containers would be placed in the storage area of the processing building. It was assumed that, if a container were dropped from a height of more than 12 ft, it would be breached. Half of the containers were assumed to be stacked to heights of more than 12 ft. For an airborne fraction of 1×10^{-4} and a filter DF of 10^6 , the total inventory release fraction would be 1×10^{-15} , the same as in Subsection 13.6.1.3.6.

TABLE 13-25

ESTIMATED RADIONUCLIDE RELEASES
FROM A CRITICALITY EVENT IN THE GASIFIER
OF THE SLAGGING PYROLYSIS FACILITY

Radio- nuclide	Release From Facility Stack (curies)			
	(0-1/2 hr)	(1/2-8 hr)	(8-24 hr)	Total
Kr-83m	1.4×10^0	8.5×10^0	8.9×10^0	1.9×10^1
Kr-85m	8.7×10^0	5.2×10^1	5.5×10^1	1.2×10^2
Kr-85	1.3×10^4	7.8×10^{-4}	8.3×10^{-4}	1.7×10^{-3}
Kr-87	3.8×10^1	2.3×10^2	2.4×10^2	5.1×10^2
Kr-88	3.5×10^1	2.1×10^2	2.2×10^2	4.7×10^2
Kr-89	1.3×10^2	8.0×10^2	8.5×10^2	1.8×10^3
I-131	1.5×10^0	9.2×10^0	9.6×10^0	2.0×10^1
I-132	5.6×10^0	3.2×10^1	3.4×10^1	7.2×10^1
I-133	2.4×10^1	1.5×10^2	1.5×10^2	3.2×10^2
I-134	2.7×10^2	1.6×10^3	1.7×10^3	3.6×10^3
I-135	6.0×10^1	3.6×10^2	3.8×10^2	8.0×10^2
Xe-131m	3.9×10^{-3}	2.3×10^{-2}	2.5×10^{-2}	5.2×10^{-2}
Xe-133m	1.4×10^{-1}	8.2×10^{-1}	8.6×10^{-1}	1.8×10^0
Xe-133	3.2×10^0	1.9×10^{-1}	2.0×10^1	4.2×10^1
Xe-135m	1.8×10^1	1.1×10^2	1.1×10^2	2.4×10^2
Xe-135	2.6×10^1	1.5×10^2	1.6×10^2	3.4×10^2
Xe-137	1.1×10^2	6.6×10^2	6.9×10^2	1.5×10^3
Xe-138	1.5×10^2	9.0×10^2	9.5×10^2	2.0×10^3
Xe-139	2.9×10^3	1.7×10^4	1.8×10^4	3.8×10^4

The frequency of breached containers would be $7 \times 10^{-2}/\text{yr}$, from Subsection 13.6.1.3.6, multiplied by 0.5 for the containers handled at heights above 12 ft, and multiplied by two for the two handling operations per container (in and out of storage) for an overall frequency of $7 \times 10^{-2}/\text{yr}$.

Dropping a container of waste^(a) 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 waste fractured into particles less than 10 microns in diameter. Thus, even if a container were to fail, only an insignificant fraction of the slag would become airborne.

13.6.3.3.7 Fire in the Waste Preparation Area

A fire in the slagging pyrolysis facility was assumed to involve about 90 ft³ of waste from one open waste container. The waste could be undergoing preparation for feeding to the incinerator. It was assumed that all of the combustible material in the waste, amounting to 7.2 ft³, would be burned before complete control of the fire is established. The fire protection system on the filter system would protect the HEPA filters. Assuming an airborne fraction of 1×10^{-2} and a filter DF of 10^6 , the total inventory release fraction was estimated to be $(7.2 \text{ ft}^3 \times 0.053 \text{ Ci/ft}^3 \times 10^{-2} \times 10^{-6}) / 1.33 \times 10^5 = 3 \times 10^{-14}$.

(a) Hereafter, for simplicity, only dropping of containers is discussed under handling accidents. Other types of handling accidents are also possible, such as a penetration accident, which is discussed in Subsection 13.8.4.1.2. The total risk of all such accidents is expected to be similar to the risk estimated for the accident involving a dropped container.

The probability of a fire in the processing facility was conservatively estimated to be 1×10^{-2} /yr, based on consideration of unpublished data for fires at United States nuclear power plants.

13.6.3.4 Waterborne Accidental Releases

The facility would be designed and built so that no water entry into any part of the facility would be expected to occur during precipitation or flood conditions. Thus, no accidental waterborne releases of radionuclides would be expected.

13.6.4 Shipping of Slag to an Offsite Geologic Repository

13.6.4.1 Summary

For shipment to an offsite geologic repository, the calculated dose and risk for events leading to airborne releases are presented in Table 13-16. Because most of the assumed shipping route would pass through rural areas, 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.

13.6.4.2 Airborne Accidental Releases

The shipment route assumed for the risk calculations is shown in Figure 9-11. The actual route has not yet been selected. A one-way trip of approximately 1,411 miles would require about 6 days. The estimated shipping rate would be 434 cars/yr.

The population densities along the postulated route have been categorized as "urban" for the Denver-Boulder area, "suburban" for the Colorado Springs, Pueblo, Amarillo, and Pocatello areas, and "rural" for the remainder. Distances through "urban," "suburban," and "rural" areas were estimated to be 35, 50, and 1,326 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 the RFP 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. Four 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 railcar (Adcock and McCarthy 1977). The evaluation concluded that most of the railcar 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 railcar. 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 confinement 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), 4×10^{-8} (suburban), and 9×10^{-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 0.056 Ci/ft^3 (see Subsection 13.8.3). The total inventory release fraction for the postulated accident would therefore be $(3 \times 7.4 \text{ ft}^3 \times 0.056 \text{ Ci/ft}^3 \times 10^{-6}) / (1.33 \times 10^5 \text{ Ci}) = 9 \times 10^{-12}$.

13.6.4.3 Waterborne Accidental Releases

Waterborne releases of radionuclides resulting from the shipping accident described in Subsection 13.6.4.2 would result in a low level of risk. The frequency of such an event was estimated as two to three orders of magnitude less than those in Table 13-16. 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 puncture 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 ft^2 before the accident, an area increase of a factor of 5 due to the accident (Smith and Ross 1975), slag weight of 1,300 lb, solubility of $1 \times 10^{-6} \text{ g/cm}^2/\text{day}$ (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 frequency 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 AN OFFSITE GEOLOGIC REPOSITORY 20 YR (ALTERNATIVE IV)

The risks associated with retrieval and processing by slagging pyrolysis for Alternative IV would be the same as those for corresponding modules of Alternative III (see Subsections 13.6.1, 13.6.2, and 13.6.3). The risks for shipping slag to an offsite geologic repository would be similar to those discussed in Subsection 13.6.4, 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 prestressed concrete facilities for 20-yr storage would be expected to provide confinement superior to that currently provided in the SDA. Because of these factors, the risks associated with this module would be considerably smaller than the short-term risks for Concept II-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 13.6.3.3.6.

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 13.6.1.3.5). 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 V)

The risks associated with retrieval and processing by slagging pyrolysis for Alternative V would be the same as those for corresponding modules for Alternative III (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 13-17. Waterborne accidental releases would be negligible. The event with the largest population risk was determined to be an earthquake of greater intensity than the design basis earthquake, resulting in breaching the containment of the feed storage area. The largest risk associated with operational events was found to be due to a fire in the waste preparation area.

13.8.1.2 Accident Analysis

An accident analysis for the compaction and immobilization facility was performed to determine the potential events that could cause release of radionuclides to the environment. Accidents that could occur during compaction and immobilization of the buried waste were generally found to be similar to those discussed for slagging pyrolysis in Subsection 13.6.3. Trivial, minor, and major events, as defined in Subsection 13.6.1.2, were considered. A description of the trivial and minor events will be included in the EIS. The accident analysis was carried out after DOE 1979b was published. However, the events identified in the present study would also apply to compaction and immobilization of stored TRU waste, with adjustment for the waste volume and radionuclide inventory.

Estimates of risks for major releases, as well as for some minor releases, are described in the following subsections. Only the extra severe earthquake was considered a major event. The minor events described below are dropping a waste transfer container and a fire.

13.8.1.3 Airborne Accidental Releases

13.8.1.3.1 Earthquake

The effects of a severe earthquake on the compaction and immobilization facility would be the same as described for the slagging pyrolysis facility in Subsection 13.6.3.3.1.

13.8.1.3.2 Dropping of a Waste Transfer Container

The effects of dropping a waste transfer container in the storage area of the compaction and immobilization facility would be the same as described for the slagging pyrolysis facility in Subsection 13.6.3.3.6.

13.8.1.3.3 Fire in the Waste Preparation Area

The procedures and equipment for waste preparation in the compaction and immobilization facility would be essentially the same as those for the slagging pyrolysis facility. Therefore, the effects of a fire in the waste preparation area would be the same as described for the slagging pyrolysis facility in Subsection 13.6.3.3.7.

13.8.1.4 Waterborne Accidental Releases

As discussed in Subsection 13.6.3.4, no pathways were identified leading to waterborne releases.

13.8.2 Packaging Only

For packaging of the buried waste, the calculated dose and risk for events leading to airborne releases are presented in Table 13-18. Waterborne accidental releases would be negligible. Accidental releases during packaging operations would be the same as those described in Subsection 13.8.1. The event with the largest population risk was determined to be an earthquake of greater intensity than design basis, resulting in breaching the containment of the feed storage area. The largest risk associated with operational events was found to be a fire in the waste preparation area.

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. Annual shipping rates are listed in Table 13-26. Accidents would result only in airborne releases; no waterborne releases were postulated. The calculated dose and risk are presented in Table 13-19.

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 and 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} accident/vehicle-mile (AEC 1972). Such an accident scenario is considerably more severe than might be expected during onsite shipment of processed waste.

TABLE 13-26

ANNUAL SHIPPING RATES FOR PROCESSED BURIED WASTE

<u>Process Method</u>	<u>Waste Volume Cubic feet per Container</u>	<u>Shipping Rate Containers per year</u>
Slagging pyrolysis	7.4	32,120
Compact, immobilize, and package	65.4 ^(a)	7,260
Package only	6.7 ^(b)	106,480

(a) This volume is the sum of the four containers of about 16.4 ft³ each that are enclosed in each concrete shipping block (Subsection 10.2.2).

(b) Based on a 7.4-ft³ capacity drum at 90% fill factor (see Table 10-1).

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 13.6.1.3.5, 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 container 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 radioactivity concentration of each waste form would be different from the concentration of the "as buried" waste depending on the amount of contaminated soil mixed with the waste during processing and the density of the final form. Tables 4-2 and 4-3 list approximately 133,000 Ci for the total amount of radioactive material, as of January 1985. Figures 10-1, 10-2, and 10-7 list the processed waste output volume per day. The average radioactivity concentrations were calculated as follows:

Slag

$$(1.33 \times 10^5 \text{ Ci}) / (1,077 \text{ ft}^3/\text{day})(220 \text{ days/yr})(10 \text{ yr}) = 0.056 \text{ Ci/ft}^3$$

Compact and Immobilize

$$(1.33 \times 10^5 \text{ Ci}) / (2,178 \text{ ft}^3/\text{day})(220 \text{ days/yr})(10 \text{ yr}) = 0.028 \text{ Ci/ft}^3$$

(The $2,178 \text{ ft}^3$ waste product does not include the encasing concrete as in Figure 10-2; e.g., $3,288 \text{ ft}^3$ product/day - $1,110 \text{ ft}^3$ concrete/day = $2,178 \text{ ft}^3/\text{day}$.)

Package Only

$$(1.33 \times 10^5 \text{ Ci}) / (3,225 \text{ ft}^3/\text{day})(220 \text{ days/yr})(10 \text{ yr}) = 0.019 \text{ Ci/ft}^3$$

The airborne release fractions assumed for the waste in the breached containers were 1×10^{-5} for slag, 1×10^{-4} for compacted and immobilized waste, and 1×10^{-3} for packaged only. By reference to Table 10-1 and Figures 10-1, 10-2, and 10-7 for the shipping logistics, the total fractions of the waste inventory released in a shipping accident were estimated as follows:

Slag

$$(10^{-5} \times 0.056 \text{ Ci/ft}^3 \times 7.4 \text{ ft}^3/\text{container} \times 50 \text{ containers/load} \times 10^{-1} \text{ breached}) / (1.33 \times 10^5 \text{ Ci}) = 2 \times 10^{-10}$$

Compact and Immobilize

$$(10^{-4} \times 0.028 \text{ Ci/ft}^3 \times 16.4 \text{ ft}^3/\text{container} \times 1 \text{ container breach/load}) / (1.33 \times 10^5 \text{ Ci}) = 3 \times 10^{-10}$$

Package Only

$$(10^{-3} \times 0.019 \text{ Ci/ft}^3 \times 6.7 \text{ ft}^3/\text{container} \times 144 \text{ containers/load} \times 10^{-1} \text{ breached}) / (1.33 \times 10^5 \text{ Ci}) = 1 \times 10^{-8}$$

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 Table 13-20. Both operations-related accidental releases and releases due to natural events were considered. For deep rock disposal at the Lemhi site, with shaft access, the events resulting in the largest population dose and risk were determined to be an equipment malfunction or operator error leading to the drop of a waste container down the access shaft, or dropping and breaching a waste container during handling. For all other disposal modules, the event leading to the largest population risk was determined to be penetration of a waste container by handling equipment.

13.8.4.1.2 Operations-Related Accidental Releases

(1) Lemhi Range - Shaft or Tunnel

The operations-related accidents identified for the Lemhi Range disposal site were breaching of a dropped waste container and penetration of a waste container during handling operations. These events could be caused by an equipment malfunction or a personnel error. The resulting releases 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. It was assumed that all of the waste containers involved would be breached. The fractions of the total waste activity released to the environment would be as follows:

Slag

$$(6 \text{ drums} \times 7.4 \text{ ft}^3/\text{drum} \times 0.056 \text{ Ci/ft}^3 \times 10^{-5} \text{ airborne fraction} \times 10^{-3} \text{ DF}^{-1}) / (1.33 \times 10^5 \text{ Ci}) = 2 \times 10^{-13}$$

Compact and Immobilize

$$(4 \text{ containers/block} \times 16.4 \text{ ft}^3/\text{container} \times 0.028 \text{ Ci/ft}^3 \times 10^{-4} \text{ airborne fraction} \times 10^{-3} \text{ DF}^{-1}) / (1.33 \times 10^5 \text{ Ci}) = 1 \times 10^{-12}$$

Package Only

$$(12 \text{ drums} \times 6.7 \text{ ft}^3/\text{drum} \times 0.019 \text{ Ci/ft}^3 \times 10^{-3} \text{ airborne fraction} \times 10^{-3} \text{ DF}^{-1}) / (1.33 \times 10^5 \text{ Ci}) = 1 \times 10^{-11}$$

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 the failure rate is 2.5×10^{-7} /trip. For the contemplated waste emplacement rates, the estimated probability of failure would range from 2×10^{-4} to 4×10^{-4} /yr, 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. With either shaft or tunnel design, a waste container could be dropped from the handling equipment during placement in disposal rooms. The waste containers for slagged or repackaged waste would be new DOT 17C 55-gal steel drums. The drums would be stacked six high; thus a maximum drop height of about 15 ft could occur. Only about one in six, or 17%, of the total drums handled would be raised to this level. A conditional probability of 1×10^{-1} was assumed for breaching a dropped drum of slag or of packaged waste. 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 (based on Smith and Ross 1975) and 1×10^{-4} for packaged waste. The total inventory release fractions resulting from this event would be $(10^{-7} \times 7.4 \text{ ft}^3 \times 0.056 \text{ Ci/ft}^3 \times 10^{-3} \text{ DF}^{-1}) / (1.33 \times 10^5 \text{ Ci}) = 3 \times 10^{-16}$ for slag and $(10^{-4} \times 6.7 \text{ ft}^3 \times 0.019 \text{ Ci/ft}^3 \times 10^{-3} \text{ DF}^{-1}) / (1.33 \times 10^5 \text{ Ci}) = 1 \times 10^{-13}$ for waste which had been packaged only. Based on RWMC experience with handling operations accidents, the processing output rates in Table 13-26, and on the assumptions described in the preceding paragraph, the frequencies for this event would be $5 \times 10^{-3}/\text{yr}$ for slag and $2 \times 10^{-2}/\text{yr}$ for packaged waste.

Another accident could be penetration of a drum of slagged or packaged waste by handling equipment during emplacement. Based on RWMC experience, the estimated probability of a container penetration by a forklift is 1×10^{-5} per container handled. Because the containers would be handled by forklifts equipped with drum grabbers, this probability was reduced by a factor of 10. The frequency of a breach was thereby estimated to be $3 \times 10^{-2}/\text{yr}$ for slagged waste and $1 \times 10^{-1}/\text{yr}$ for packaged waste. A concrete block for compacted and immobilized waste could not be breached in this manner.

The fraction of the waste per container that would become involved was estimated to be 1×10^{-2} , because of the expected small size of the breach. 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 $(10^{-2} \times 10^{-7} \times 7.4 \text{ ft}^3 \times 0.056 \text{ Ci/ft}^3 \times 10^{-3} \text{ DF}^{-1}) / (1.33 \times 10^5 \text{ Ci}) = 3 \times 10^{-18}$ for slag and $(10^{-2} \times 10^{-4} \times 6.7 \text{ ft}^3 \times 0.019 \text{ Ci/ft}^3 \times 10^{-3} \text{ DF}^{-1}) / (1.33 \times 10^5 \text{ Ci}) = 1 \times 10^{-15}$ for waste that had been packaged only.

(2) Site 14 and the RWMC

The only significant operations-related accident identified for disposal at the RWMC or for either the massive or less massive variations of the disposal facility at Site 14 was penetration of a waste container by handling equipment. Because there would be no ventilation and filtration systems at these facilities, the doses and risks resulting from this event would be about 3 orders of magnitude greater than from the comparable event described for deep rock disposal at the Lemhi site.

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 retrievability phase [see Guideline (7) in Subsection 7.4.1.1], unless the emplaced waste were indeed retrieved. If retrieval were carried out, the accident frequencies 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 conducted. 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 13-21. 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 consequences to large populations for the Site 14 and RWMC disposal modules was also determined to be an explosive volcano. The dominant event for maximum individual doses for the Site 14 and RWMC modules was determined to be intrusion.

13.8.4.3.2 Lemhi Range

Long-term effects from postclosure releases for both of the Lemhi Range disposal modules 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 Subsection 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.

For this analysis, the fraction of inventory released was assumed to be equal to the corresponding (short-term) fraction for Concept II-D. The assumed inventory release fraction (2×10^{-6}) is a factor of 100 lower than for Alternative I. 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 similar to those for Alternative I (see Subsection 13.4.3.1), with the exception of lava flow over the area. However, the effects for Alternative I 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, and for the greater land area that would be used for this disposal module.

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 about 20 ft of basalt riprap, clay, and bentonite. For a worst-case scenario, it was assumed that weathering and natural phenomena would displace the cover material to the level of the surrounding area within a few hundred years.

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 because some concrete structures from the Roman era, nearly 2,000 yr old, are still standing.) A uniform mixture of disintegrated waste, soil, 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, soil, 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.

After disintegration of the concrete structures, a uniform mixture of disintegrated waste, concrete, and soil was assumed to remain. For processing by slagging pyrolysis, the waste would not have contained any combustibles at the time of emplacement. For the other processing methods, it was assumed that the combustible fraction of the waste would have oxidized as the waste and structures disintegrated. Based on the above assumptions, the effects of lava flow over the disposal areas would be negligible.

The expected frequency of an explosive volcano, 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.) 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 4,100 yr old (Kuntz 1978), but are located about 20 miles southeast 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).

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 engineered surface disposal structures at the RWMC 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 similar to those described for Alternative I (Subsection 13.4.3.1). However, no significant release was assumed to result from lava flow over the disposal area. The effects for Alternative I 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, and for the greater land area that would be used for this disposal module.

The period of time for which the structures would remain intact is difficult to estimate. For a worst-case scenario, erosion was assumed to remove the protective cover of basalt riprap, 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 structures were assumed to have completely disintegrated. A uniform mixture of disintegrated concrete, soil, 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. In addition, waterborne results for climate change, glaciation, etc. were estimated for a time 1×10^6 yr in the future.

13.9 DELAY RETRIEVAL 20 YR (ALTERNATIVE VI)

Accidental releases during the 20-yr delay period (1985-2005) would be the same as those for Alternative I (Table 13-8) during a corresponding period. Operations-related accidental releases from delayed retrieval, slagging pyrolysis and packaging, and shipment of slag to an offsite geologic repository would be nearly identical to those for the same operations beginning in 1985 and described in Section 13.6. There would be a small reduction in the radioactivity during the 20-yr delay, but an increase of approximately 20% in the population.

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 2-yr period immediately following the main 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 and would be minor in magnitude and hazard, compared with the other D&D operations.

The volume of D&D waste would be about 85,000 ft³ [Guideline (2) in Subsection 7.4.1.2 and Subsection 9.1.5], or about 1.4% of the total volume of waste and contaminated soil handled during the 10-yr campaign. Because the D&D campaign would last only 2 yr, the waste volume handled annually would be approximately 7% of that handled annually during the main campaign. If the concentration of radionuclides in the D&D waste were 10% of that in the buried waste, the number of curies managed annually in D&D would be about 0.7% of that handled annually for the retrieval, processing, and transfer/shipment modules. As a first approximation, one might expect the annual risk to the public from accidents during D&D activities to be about a factor of 150 lower than those associated with the main campaign.

The procedure for D&D of processing equipment would be similar to that described for processing the waste. However, because of the lower concentration of radionuclides, the severity of an accident 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 (NCRP 1971, NRC 1975).

13.11.1 Short-Term Effects

Short-term health effects are usually not observed below an acute dose (a dose received over a time period generally measured in minutes or hours) of about 25 rem. However, changes in blood cells have been detected at doses as low as 5 rem (NCRP 1971).

It is generally believed that damage to the bone marrow is the most important contributor to early death from large doses to the whole body (NRC 1975). For this reason, and because the whole-body dose commitments calculated in Section 13 are much smaller than the bone dose commitments, short-term effects from whole-body dose commitments are not discussed further. The bone dose commitments would be the dominant contributors to the bone marrow dose.

The acute bone dose estimated to be lethal to 50% of the exposed individuals within 60 days after exposure is approximately 510 rem (NRC 1975). This value is based on the assumption that the individuals receive suitable medical treatment. With only minimal medical treatment, the estimated value is 340 rem.

In Section 13, 50-yr dose commitments, rather than acute doses, were calculated. The dose commitment is the time-integrated dose that results from an intake of radioactive material when the dose is evaluated from the beginning of intake until a later time (50 yr in this case) or until the material is completely removed from the body. The dose commitment is the more comprehensive and relevant measure of radiation exposure for the scenarios studied in this report. However, the 50-yr dose commitments should not be compared directly with the acute lethal doses just discussed, because of the great difference in the time periods over which the dose is received. Clinical evidence indicates that radiation received over a long time period (for example, 50-yr) is tolerated more than the same amount of acute radiation (NRC 1975).

The largest 50-yr bone dose commitment to an individual was calculated in Section 13 to be 100 rem. The scenario of interest is the excavation-intrusion scenario for Alternative I and Concepts II-A, II-B, and II-C. In this scenario, the maximum dose received in any 1 yr of the 50-yr dose commitment period would be about 3 rem. It is highly unlikely that early death would result from this dose rate. (The long-term effects of radiation on such an individual are discussed in Subsection 13.11.2.) In the farming intrusion scenario, the 50-yr bone dose commitment would be about 10 rem. In this scenario, the dose in any 1 yr of the 50 yr of farming would be less than 1 rem. The possibility of early death is as remote in this scenario as it is in the excavation-intrusion scenario.

Another possible short-term health effect is respiratory impairment. Pulmonary mortality would be expected to occur among 50% of the subjects after a 1-yr lung exposure of about 20,000 rem and among 1% after about 2,700 rem. By contrast, the largest calculated 50-yr lung dose commitment to an individual was 100 rem, again in the excavation-intrusion scenario.

Thus, short-term public health effects would be unlikely even if the accidental or nature-caused releases studied here did occur.

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 per 10⁶ man-rem</u>
Lung	22.2
Bone	6.9
Total (all organs except thyroid)	121.6

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.

(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.

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 buried 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 (integrated for various times up to the first 100 yr at risk), summarized in Table 13-27, indicate that the largest impact on the public would be expected to derive from Alternative I (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 average individual in the 50-mile radius population contracting cancer due to the waste was estimated using the results of Table 13-27. 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 (252,000). Based on the worst-case alternative, the probability of an individual contracting cancer would be only about 8×10^{-10} /yr.

The projected numbers of cancer cases associated with long-term risk (integrated for various times starting with 100 yr) are given in Table 13-28. The alternative of greatest risk, Alternative I, 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 Section 13, risks were not estimated for 100 yr and beyond, because it was thought 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

TABLE 13-27

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)
I	100	1.7×10^2	2×10^{-3}	4×10^0	3×10^0	4×10^{-5}	5×10^{-3}	1×10^{-2}	2×10^{-2}
II-A	100	1.7×10^2	2×10^{-5}	4×10^{-2}	3×10^{-2}	4×10^{-7}	5×10^{-5}	1×10^{-4}	2×10^{-4}
II-B	100	1.7×10^2	2×10^{-5}	4×10^{-2}	3×10^{-2}	4×10^{-7}	5×10^{-5}	1×10^{-4}	2×10^{-4}
II-C	100	1.7×10^2	2×10^{-5}	4×10^{-2}	3×10^{-2}	4×10^{-7}	5×10^{-5}	1×10^{-4}	2×10^{-4}
II-D	100	1.7×10^2	2×10^{-5}	4×10^{-2}	3×10^{-2}	4×10^{-7}	5×10^{-5}	1×10^{-4}	2×10^{-4}
III-A, III-B ^(e)	10	1.1×10^1	2×10^{-3}	4×10^0	3×10^0	3×10^{-6}	3×10^{-4}	7×10^{-4}	1×10^{-3}
IV-A, IV-B ^(e)	10 ^(f)	1.1×10^1	2×10^{-3}	4×10^0	3×10^0	3×10^{-6}	3×10^{-4}	7×10^{-4}	1×10^{-3}
V-A, V-DD ^(e,g)	10 ^(h)	1.1×10^1	2×10^{-3}	4×10^0	3×10^0	3×10^{-6}	3×10^{-4}	7×10^{-4}	1×10^{-3}
VI-A, VI-B ^(e)	30	4.2×10^1	2×10^{-3}	4×10^0	3×10^0	1×10^{-5}	1×10^{-3}	3×10^{-3}	4×10^{-3}
						All Other Organs	Bone	Lung	Total ^(d)
Normal incidence of cancer cases ⁽ⁱ⁾									
100 ^(j)						3×10^4	2×10^2	9×10^3	4×10^4
10 ^(j)						2×10^3	1×10^1	5×10^2	2×10^3

(a) Limited to 100 yr for this short-term analysis. See Table 13-28 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 buried 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 1,000,000.

(f) It was assumed, based on the discussion of Subsection 13.7, that the annual risk during the 20-yr storage phase would be less than 1% of that during the 10-yr operations phase (including natural events such as lava flow). Thus, the time-integrated risk for the 20-yr storage phase would add a negligible amount to the 10-yr time-integrated risk shown here.

(g) Analysis with LMV module, where applicable, yields identical results.

(h) 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.

(i) Incidence rates taken from NRC 1975.

(j) Multiplication includes effects of population growth.

for Table 13-28, it was necessary to make an assumption concerning the probabilities of future releases. The probabilities estimated 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 13-28 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 I (four cases) is negligible compared with that from normal incidence. Furthermore, the fraction relating the two parameters decreases from about 10^{-6} for 100 yr to about 10^{-8} for 10^6 yr, reflecting the impact of radioactive decay of the waste.

The possibility that the maximally exposed individual in the intrusion scenarios (see Subsection 13.11.1) would contract cancer was also examined. If the intrusion scenarios occurred as described in Section 13, the chance of contracting cancer would be about 1 out of 500 for the maximally exposed individual.

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.

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).

TABLE 13-28

PROJECTIONS OF CANCER CASES IN 50-MILE RADIUS POPULATION DUE TO LONG-TERM RELEASES

Time at Risk (for Integration)		(a) Projected Number of Cancer Cases				(b) Normal Incidence of Cancer Cases			
No. of Yr	Multiplier (c)	(d)				(d)			
		Whole Body	Bone	Lung	Total	All Other Organs	Bone	Lung	Total
10^2	1.7×10^2	4×10^{-5}	5×10^{-3}	1×10^{-2}	1×10^{-2}	3×10^4	2×10^2	9×10^3	4×10^4
10^3	2.0×10^3	5×10^{-4}	6×10^{-2}	1×10^{-1}	2×10^{-1}	4×10^5	3×10^3	1×10^5	6×10^5
10^4	1.2×10^4	3×10^{-3}	3×10^{-1}	8×10^{-1}	1×10^0	5×10^6	3×10^4	1×10^6	6×10^6
10^5	4.0×10^4	1×10^{-2}	1×10^0	3×10^0	4×10^0	5×10^7	3×10^5	1×10^7	6×10^7
10^6	4.6×10^4	1×10^{-2}	1×10^0	3×10^0	4×10^0	5×10^8	3×10^6	1×10^8	6×10^8

(a) Values presented are for Alternative I (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.

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 0.3 man-rem in the short-term period. This value is associated with the lava flow scenario for Alternative I. From Table 13-8, 2×10^{-3} man-rem/yr $\times$ 170 yr (population risk multiplier for 100 yr from Table 13-1) = 0.3 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 event, would be approximately 1×10^{-5} , 2×10^{-5} , and 2×10^{-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 13-8, 1×10^{-6} rem/yr $\times$ 88 yr (individual risk multiplier for 100 yr from Table 13-1) = 9×10^{-5} rem. The expected fractional increase in the possibility of mutations for this individual would be about 9×10^{-7} (NRC 1975). This value compares with a fractional increase on the order of 1×10^{-9} , based on the preceding paragraph, for the 50-mile radius population as a whole.

On the other hand, if the intrusion scenarios occurred as described in Section 13, the expected fractional increase in the possibility of mutations among the offspring of the maximally exposed individual would be 2×10^{-2} . In other words, the possibility of mutations would increase by 2% for this group. This result is very conservative since many of the hypothetical genetic effects would be recessive and only a very few people would be irradiated to the calculated levels. The methodology used is based on a large population being uniformly irradiated.

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 releases 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 fraction during normal operations is postulated to be 1×10^{-12} for retrieval. Inventory release fractions for slagging pyrolysis are postulated to be about 2×10^{-8} for TRU and 1×10^{-5} for fission and activation products. Inventory release fractions for accidents would range from 1×10^{-2} to about 1×10^{-15} , depending on the postulated event and the alternative.

Contamination levels from the accidents described in Section 13 can be estimated by using a table such as Table 12-16, which presents the maximum

soil contamination levels from operation of the slagging pyrolysis facility. First, the inventory release fraction postulated for the accident is divided by 2×10^{-8} for transuranics and 1×10^{-5} for fission and activation products. Then the resulting ratios are multiplied by the appropriate soil concentrations in Table 12-16. Fission and activation product contamination levels for postulated accidents would depend on the time of the accident. The ^{60}Co , ^{90}Sr , and ^{137}Cs may have decayed to much lower levels prior to the accident. Thus, the use of the Table 12-16 values as a basis could overestimate soil concentrations for those nuclides. A second difference between accident and normal operation contamination levels is that contamination from an accident might be more limited in area and reflect specific air or water movements during a brief time period.

Transport to biota of contaminants released during normal operation was discussed in Subsection 12.4.5. The same mechanisms would apply to contamination resulting from postulated accidents. Soil concentrations estimated using the technique described above could form the basis for estimating doses to biota. Lung doses to small mammals resulting from soil contamination due to normal operations would be 2 to 3 mrad/yr. Doses received by large mammals would be more dependent on meteorological conditions during the accident. The distribution of antelope and domestic sheep and cattle on the INEL is far from uniform and the herds may or may not be in the area affected by the accident. An effort would be made to keep domestic animals out of highly contaminated areas following an accident. However, antelope could be exposed to such areas. Maximum antelope doses due to soil contamination from normal operation of the slagging pyrolysis facility would be about 3 mrad. This value could be scaled for postulated accident consequences. Most of this dose would be due to ^{60}Co and ^{137}Cs that could have decayed to low levels prior to some of the accidents considered. A fair approximation of the lung dose to individual animals resulting from a postulated accident would be the projected lung dose to humans for that accident.

14.0 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, cave-ins, exposures to toxic substances, fire, 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; pyrophoric materials, such as unreacted plutonium, uranium, and zirconium; and possibly biological agents. The reactive or toxic substances may have been in the waste at the time of disposal, or they may have been formed by reactions with other substances. 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 I and II would not involve any normal operational hazards from unavoidable contact with hazardous materials, because waste would not be handled.

Alternatives III through VI would involve handling the waste. Therefore, contact with hazardous materials could occur. Quantities of waste materials might be disturbed during retrieval, or waste materials might be dispersed through the air as they are processed. Small quantities of dust would also become airborne within the operating cells during processing operations. Exposure of workers to extremely small amounts of such airborne contaminants

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, cave-ins, and fires.	Extreme injuries or fatalities.	Acute radiation exposures with health effects.

would be possible. 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 direct-control retrieval equipment, or the equipment would be operated remotely. Processing

operations would be conducted remotely. Maintenance would be conducted by remote means to the greatest extent practicable. These preventive measures would assure that direct exposures to hazardous materials would be extremely small.

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.

The following paragraphs list the various waste management operations and the industries whose injury and fatality 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 I, II, and V. For Alternatives III, IV, and VI, such activities would 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

TABLE 14-2
INJURY AND FATALITY RATES FOR COMPARABLE INDUSTRIES^(a)

<u>Category</u>	<u>Industry</u>	<u>Injury Rate^(b) (Injuries/10⁶ man-hr)</u>	<u>Fatality Rate (Deaths and Permanent Total Disabilities/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 (non- coal)	25.26	0.53

(a) Data from Work Injury Rates, 1977 Edition (National Safety Council 1977).

(b) Includes fatalities.

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.

Operations for direct-control retrieval were taken to be comparable in hazard level to surface mining activities. For remote-control retrieval, the aerospace industry was used. 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. Because control and maintenance operations on contaminated equipment would generally be performed remotely, these accident rates are conservative.

Disposal operations at the Lemhi Range locations were taken to be analagous 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 offsite geologic 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 III, IV, V, and VI, and onsite shipment in Alternative V 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 III through VI.

TABLE 14-3
TRANSPORT ACCIDENT STATISTICS^(a)

<u>Mode of Transport</u>	<u>Accidents Per Vehicle-Mile</u>	<u>Injuries Per Accident</u>	<u>Fatalities Per Accident</u>
Truck	1.7×10^{-6}	0.51	0.03
Rail ^(b)	$1.4 \times 10^{-7(b)}$	2.7	0.2

(a) Data taken from WASH-1238 (AEC 1972).

(b) Accidents/railcar-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 279. The expected number of fatalities ranges from zero to three. Alternatives I and II 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. Furthermore, the values presented here for slagging pyrolysis would be expected to overestimate the hazard, because nearly all associated operations would be performed by remote means.

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 involving radioactive materials.

TABLE 14-4

PROJECTED NONRADIOLOGICAL INJURIES AND FATALITIES TO WASTE MANAGEMENT WORKERS (BURIED WASTE)

Alternative or Concept	Manpower Commitment in Various ^(a) Activities (10 ⁶ man-hours)					Estimated Number of Injuries					Estimated Number of Fatalities ^(b)				
	Construction	Retrieval	Processing	Disposal/Storage	Surveillance	Construction	Retrieval	Processing	Disposal/Storage	Surveillance	Construction	Retrieval	Processing	Disposal/Storage	Surveillance
	NA ^(c)	NA	NA	NA	2.08(1)	NA	NA	NA	NA	4.31	NA	NA	NA	NA	0.0
I	NA	NA	NA	NA	2.08(1)	NA	NA	NA	NA	4.31	NA	NA	NA	NA	0.0
II-A	0.29(6)	NA	NA	NA	2.08(1)	4.25	NA	NA	NA	4.31	0.05	NA	NA	NA	0.0
II-B	0.29(6)	NA	NA	NA	2.08(1)	4.25	NA	NA	NA	4.31	0.05	NA	NA	NA	0.0
II-C	0.31(6)	NA	NA	NA	2.08(1)	13.34	NA	NA	NA	4.31	0.15	NA	NA	NA	0.0
II-D	0.37(6)	NA	NA	NA	2.08(1)	5.42	NA	NA	NA	4.31	0.06	NA	NA	NA	0.0
III-A	2.04(6)	3.24(3)	8.11(7)	NI ^(d)	NA	29.91	31.59	147.68	NI	NA	0.35	0.42	0.81	NI	NA
III-B	2.07(6)	3.24(1)	8.11(7)	NI	NA	30.35	6.71	147.68	NI	NA	0.35	0.0	0.81	NI	NA
IV-A	2.15(6)	3.24(3)	8.11(7)	1.00(4)+NI	0.21(1)	31.52	31.59	147.68	10.15+NI	0.43	0.37	0.42	0.81	0.0+NI	0.0
IV-B	2.18(6)	3.24(1)	8.11(7)	1.00(4)+NI	0.21(1)	31.96	6.71	147.68	10.15+NI	0.43	0.37	0.0	0.81	0.0+NI	0.0
V-A	2.23(6)	3.24(3)	8.11(7)	2.45(8)	2.08(1)	32.69	31.59	147.68	61.89	4.31	0.38	0.42	0.81	1.30	0.0
V-B	1.52(6)	3.24(3)	3.33(5)	2.37(8)	2.08(1)	22.28	31.59	39.30	59.87	4.31	0.26	0.42	0.20	1.26	0.0
V-C	1.41(6)	3.24(3)	2.66(4)	2.37(8)	2.08(1)	20.67	31.59	27.00	59.87	4.31	0.24	0.42	0.0	1.26	0.0
V-D	2.26(6)	3.24(1)	8.11(7)	2.45(8)	2.08(1)	33.13	6.71	147.68	61.89	4.31	0.38	0.0	0.81	1.30	0.0
V-E	1.55(6)	3.24(1)	3.33(5)	2.37(8)	2.08(1)	22.72	6.71	39.30	59.87	4.31	0.26	0.0	0.20	1.26	0.0
V-F	1.44(6)	3.24(1)	2.66(4)	2.37(8)	2.08(1)	21.11	6.71	27.00	59.87	4.31	0.24	0.0	0.0	1.26	0.0
V-G	2.22(6)	3.24(3)	8.11(7)	1.79(8)	2.08(1)	32.55	31.59	147.68	45.22	4.31	0.38	0.42	0.81	0.95	0.0
V-H	1.49(6)	3.24(3)	3.33(5)	1.71(8)	2.08(1)	21.84	31.59	39.30	43.19	4.31	0.25	0.42	0.20	0.91	0.0
V-I	1.36(6)	3.24(3)	2.66(4)	1.71(8)	2.08(1)	19.94	31.59	27.00	43.19	4.31	0.23	0.42	0.0	0.91	0.0
V-J	2.25(6)	3.24(1)	8.11(7)	1.79(8)	2.08(1)	32.99	6.71	147.68	45.22	4.31	0.38	0.0	0.81	0.95	0.0
V-K	1.52(6)	3.24(1)	3.33(5)	1.71(8)	2.08(1)	22.28	6.71	39.30	43.19	4.31	0.26	0.0	0.20	0.91	0.0
V-L	1.39(6)	3.24(1)	2.66(4)	1.71(8)	2.08(1)	20.38	6.71	27.00	43.19	4.31	0.24	0.0	0.0	0.91	0.0
V-M	2.13(6)	3.24(3)	8.11(7)	1.12(3)	2.08(1)	31.23	31.59	147.68	10.92	4.31	0.36	0.42	0.81	0.15	0.0
LMV ^(e)	2.09(6)	3.24(3)	8.11(7)	0.52(3)	2.08(1)	30.64	31.59	147.68	5.07	4.31	0.36	0.42	0.81	0.07	0.0
V-N	1.29(6)	3.24(3)	3.33(5)	1.37(3)	2.08(1)	18.91	31.59	39.30	13.36	4.31	0.22	0.42	0.20	0.18	0.0
LMV	1.25(6)	3.24(3)	3.33(5)	0.83(3)	2.08(1)	18.33	31.59	39.30	8.09	4.31	0.21	0.42	0.20	0.11	0.0
V-O	1.15(6)	3.24(3)	2.66(4)	1.64(3)	2.08(1)	16.86	31.59	27.00	15.99	4.31	0.20	0.42	0.0	0.21	0.0
LMV	1.04(6)	3.24(3)	2.66(4)	1.12(3)	2.08(1)	15.25	31.59	27.00	10.92	4.31	0.18	0.42	0.0	0.15	0.0
V-P	2.16(6)	3.24(1)	8.11(7)	1.12(3)	2.08(1)	31.67	6.71	147.68	10.92	4.31	0.37	0.0	0.81	0.15	0.0
LMV	2.12(6)	3.24(1)	8.11(7)	0.52(3)	2.08(1)	31.08	6.71	147.68	5.07	4.31	0.36	0.0	0.81	0.07	0.0
V-Q	1.32(6)	3.24(1)	3.33(5)	1.37(3)	2.08(1)	19.35	6.71	39.30	13.36	4.31	0.22	0.0	0.20	0.18	0.0
LMV	1.28(6)	3.24(1)	3.33(5)	0.83(3)	2.08(1)	18.76	6.71	39.30	8.09	4.31	0.22	0.0	0.20	0.11	0.0
V-R	1.18(6)	3.24(1)	2.66(4)	1.64(3)	2.08(1)	17.30	6.71	27.00	15.99	4.31	0.20	0.0	0.0	0.21	0.0
LMV	1.07(6)	3.24(1)	2.66(4)	1.12(3)	2.08(1)	15.69	6.71	27.00	10.92	4.31	0.18	0.0	0.0	0.15	0.0
V-S	2.10(6)	3.24(3)	8.11(7)	1.37(4)	2.08(1)	30.79	31.59	147.68	13.91	4.31	0.36	0.42	0.81	0.0	0.0
V-T	1.27(6)	3.24(3)	3.33(5)	1.04(4)	2.08(1)	18.62	31.59	39.30	10.56	4.31	0.22	0.42	0.20	0.0	0.0
V-U	1.13(6)	3.24(3)	2.66(4)	1.77(4)	2.08(1)	16.57	31.59	27.00	17.97	4.31	0.19	0.42	0.0	0.0	0.0
V-V	2.13(6)	3.24(1)	8.11(7)	1.37(4)	2.08(1)	31.23	6.71	147.68	13.91	4.31	0.36	0.0	0.81	0.0	0.0
V-W	1.30(6)	3.24(1)	3.33(5)	1.04(4)	2.08(1)	19.06	6.71	39.30	10.56	4.31	0.22	0.0	0.20	0.0	0.0
V-X	1.16(6)	3.24(1)	2.66(4)	1.77(4)	2.08(1)	17.01	6.71	27.00	17.97	4.31	0.20	0.0	0.0	0.0	0.0
VI-A	2.04(6)	3.24(3)	8.11(7)	NI	0.42(1)	29.91	31.59	147.68	NI	0.87	0.35	0.42	0.81	NI	0.0
VI-B	2.07(6)	3.24(1)	8.11(7)	NI	0.42(1)	30.35	6.71	147.68	NI	0.87	0.35	0.0	0.81	NI	0.0

TABLE 14-4 (Cont'd)

PROJECTED NONRADIOLOGICAL INJURIES AND FATALITIES TO WASTE MANAGEMENT WORKERS (BURIED WASTE)

Alternative or Concept	Hazards of Truck Shipment				Hazards of Rail Shipment				Totals for All Accidents	
	Truck Miles ^(f)	Accidents	Injuries	Fatalities	Car Miles	Accidents	Injuries	Fatalities	Injuries	Fatalities
I	NA	NA	NA	NA	NA	NA	NA	NA	4	0.0
II-A	NA	NA	NA	NA	NA	NA	NA	NA	9	0.1
II-B	NA	NA	NA	NA	NA	NA	NA	NA	9	0.1
II-C	NA	NA	NA	NA	NA	NA	NA	NA	18	0.2
II-D	NA	NA	NA	NA	NA	NA	NA	NA	10	0.1
III-A	2.8x10 ⁴	0.048	0.024	0.001	12.15x10 ⁶	1.7	4.59	0.34	214+NI	1.9+NI
III-B	2.8x10 ⁴	0.048	0.024	0.001	12.15x10 ⁶	1.7	4.59	0.34	189+NI	1.5+NI
IV-A	3.1x10 ⁴	0.053	0.027	0.002	12.15x10 ⁶	1.7	4.59	0.34	226+NI	1.9+NI
IV-B	3.1x10 ⁴	0.053	0.027	0.002	12.15x10 ⁶	1.7	4.59	0.34	202+NI	1.5+NI
V-A	4.13x10 ⁵	0.70	0.36	0.02	NA	NA	NA	NA	279	2.9
V-B	5.72x10 ⁵	0.97	0.49	0.03	NA	NA	NA	NA	158	2.2
V-C	4.67x10 ⁵	0.79	0.40	0.02	NA	NA	NA	NA	144	1.9
V-D	4.13x10 ⁵	0.70	0.36	0.02	NA	NA	NA	NA	254	2.5
V-E	5.72x10 ⁵	0.97	0.49	0.03	NA	NA	NA	NA	133	1.8
V-F	4.67x10 ⁵	0.79	0.40	0.02	NA	NA	NA	NA	119	1.5
V-G	4.13x10 ⁵	0.70	0.36	0.02	NA	NA	NA	NA	262	2.6
V-H	5.72x10 ⁵	0.97	0.49	0.03	NA	NA	NA	NA	141	1.8
V-I	4.67x10 ⁵	0.79	0.40	0.02	NA	NA	NA	NA	126	1.6
V-J	4.13x10 ⁵	0.70	0.36	0.02	NA	NA	NA	NA	237	2.2
V-K	5.72x10 ⁵	0.97	0.49	0.03	NA	NA	NA	NA	116	1.4
V-L	4.67x10 ⁵	0.79	0.40	0.02	NA	NA	NA	NA	102	1.2
V-M	2.84x10 ⁵	0.48	0.24	0.01	NA	NA	NA	NA	226	1.8
LMV ^(e)	2.84x10 ⁵	0.48	0.24	0.01	NA	NA	NA	NA	220	1.7
V-N	3.91x10 ⁵	0.66	0.34	0.02	NA	NA	NA	NA	108	1.0
LMV	3.91x10 ⁵	0.66	0.34	0.02	NA	NA	NA	NA	102	1.0
V-O	3.21x10 ⁵	0.55	0.28	0.02	NA	NA	NA	NA	96	0.9
LMV	3.21x10 ⁵	0.55	0.28	0.02	NA	NA	NA	NA	89	0.8
V-P	2.84x10 ⁵	0.48	0.24	0.01	NA	NA	NA	NA	202	1.3
LMV	2.84x10 ⁵	0.48	0.24	0.01	NA	NA	NA	NA	195	1.3
V-Q	3.91x10 ⁵	0.66	0.34	0.02	NA	NA	NA	NA	83	0.6
LMV	3.91x10 ⁵	0.66	0.34	0.02	NA	NA	NA	NA	78	0.6
V-R	3.21x10 ⁵	0.55	0.28	0.02	NA	NA	NA	NA	72	0.4
LMV	3.21x10 ⁵	0.55	0.28	0.02	NA	NA	NA	NA	65	0.4
V-S	3.1x10 ⁴	0.053	0.027	0.002	NA	NA	NA	NA	228	1.6
V-T	3.3x10 ⁴	0.056	0.029	0.002	NA	NA	NA	NA	104	0.8
V-U	3.2x10 ⁴	0.054	0.027	0.002	NA	NA	NA	NA	97	0.6
V-V	3.1x10 ⁴	0.053	0.027	0.002	NA	NA	NA	NA	204	1.2
V-W	3.3x10 ⁴	0.056	0.028	0.002	NA	NA	NA	NA	80	0.4
V-X	3.2x10 ⁴	0.054	0.027	0.002	NA	NA	NA	NA	73	0.2
VI-A	2.8x10 ⁴	0.048	0.024	0.001	12.15x10 ⁶	1.7	4.59	0.34	215+NI	1.9+NI
VI-B	2.8x10 ⁴	0.048	0.024	0.001	12.15x10 ⁶	1.7	4.59	0.34	190+NI	1.5+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. Injuries include fatalities.

(c) NA = not applicable.

(d) NI = not included (relates to operations at an offsite geologic repository).

(e) LMV = use of the less massive variation of engineered shallow land disposal at Site 14.

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

Limiting radiological exposures to levels as low as practicable is a major objective of all INEL operations.

Workers could 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 are 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 in the event that they would be required to enter contaminated areas.

Radiation monitors and alarms would be provided in all potentially contaminated areas for additional assurance that personnel exposures would be limited to levels as low as practicable (ERDA 1977a). Special procedures would be established for evacuating personnel, controlling contamination, and correcting accident conditions. Personal radiation exposure dosimeters would be used to provide a record of the exposures received by individual workers. Whole-body counters and the latest medical technology would also be 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 a maximum of 1,500 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 with doses received by other personnel. For a given operation, the total exposure to the group of workers was estimated assuming no workers were in supervisory or support categories. This exposure was then reduced by 25% to obtain the total dose shown in Table 14-5.

For Alternative I, 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 and an additional 2 ft of clay. Doses from direct radiation are limited to 1 mrem/hr at a height of 3 ft (Hedahl and Janke 1978). Over most of the SDA, the doses would be less than 0.05 mrem/hr. 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 1,500 hr/yr mentioned earlier.

For Alternative II, 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 1,000 hr/yr) and during maintenance and surveillance (same assumptions as for Alternative I).

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 ^(c)
	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)	
I	N/A ^(d)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	10	12	12
II-A	N/A	N/A	N/A	N/A	N/A	N/A	70 ^(e)	7	10	12	20
II-B	N/A	N/A	N/A	N/A	N/A	N/A	70 ^(e)	7	10	12	20
II-C	N/A	N/A	N/A	N/A	N/A	N/A	220 ^(e)	22	10	12	34
II-D	N/A	N/A	N/A	N/A	N/A	N/A	90 ^(e)	9	10	12	22
III-A	156	585	390	449	2	<1 ^(f)	NI ^(g)	NI	N/A	N/A	1035+NI
III-B	156	87	390	449	2	<1	NI	NI	N/A	N/A	537+NI
IV-A	156	585	390	449	2	<1	48+NI	180+NI	10	1.2	1216+NI
IV-B	156	87	390	449	2	<1	48+NI	180+NI	10	1.2	718+NI
V-A	156	585	390	449	6	65	118	443	10	12	1555
V-B	156	585	160	184	4	91	114	428	10	12	1301
V-C	156	585	128	147	4	74	114	428	10	12	1247
V-D	156	87	390	449	6	65	118	443	10	12	1057
V-E	156	87	160	184	4	91	114	428	10	12	803
V-F	156	87	128	147	4	74	114	428	10	12	749
V-G	156	585	390	449	6	65	86	323	10	12	1435
V-H	156	585	160	184	4	91	82	308	10	12	1181
V-I	156	585	128	147	4	74	82	308	10	12	1127
V-J	156	87	390	449	6	65	86	323	10	12	937
V-K	156	87	160	184	4	91	82	308	10	12	683
V-L	156	87	128	147	4	74	82	308	10	12	629
V-M	156	585	390	449	4	44	54	203	10	12	1294
LMV ^(h)	156	585	390	449	4	44	25	94	10	12	1185
V-N	156	585	160	184	4	61	66	248	10	12	1091
LMV	156	585	160	184	4	61	40	150	10	12	993
V-O	156	585	128	147	4	50	79	296	10	12	1091
LMV	156	585	128	147	4	50	54	203	10	12	998
V-P	156	87	390	449	4	44	54	203	10	12	796
LMV	156	87	390	449	4	44	25	94	10	12	687
V-Q	156	87	160	184	4	61	66	248	10	12	593
LMV	156	87	160	184	4	61	40	150	10	12	495
V-R	156	87	128	147	4	50	79	296	10	12	593
LMV	156	87	128	147	4	50	54	203	10	12	500
V-S	156	585	390	449	2	<1	66	248	10	12	1296
V-T	156	585	160	184	2	1	50	188	10	12	971
V-U	156	585	128	147	2	1	85	319	10	12	1065
V-V	156	87	390	449	2	<1	66	248	10	12	798
V-W	156	87	160	184	2	1	50	188	10	12	473
V-X	156	87	128	147	2	1	85	319	10	12	567
VI-A	156	195	390	148	2	<1	NI	NI	10	2.5	347+NI
VI-B	156	30	390	148	2	<1	NI	NI	10	2.5	182+NI

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

(b) Surveillance personnel for 10 yr for Alternative IV, 20 yr for Alternative VI, and 100 yr for Alternatives I, II, and V.

(c) Because of rounding, the totals may not exactly equal the sums of the listed entries.

(d) N/A = not applicable.

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

(f) < = less than.

(g) NI = not included in this estimate (applies to an offsite geologic repository).

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

The waste management activities for Alternatives III through VI 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 an offsite geologic 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 direct-control retrieval operations, workers would be in relatively close proximity to the waste. However, they would be in environmentally protected cabs located on the retrieval equipment. This protection would include shielding against high radiation levels that could be encountered near some of the beta-gamma waste. Should an unusually radioactive item of waste be uncovered, it would immediately be placed in a shielded container for special handling and processing. By virtue of this and other precautions, radiation exposures to operating personnel would be limited to a maximum of 500 mrem/yr.

During remote-control retrieval, workers would be entirely outside the retrieval area. Operating personnel would receive radiation exposures of approximately 0.05 mrem/hr, or about 75 mrem/yr.

The values just discussed were conservatively used as the average exposure for nonsupervisory, nonsupport personnel. For delayed retrieval, the dose would be reduced by an estimated factor of 3 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 would be maintenance workers and receive exposures of 500 mrem/yr; (2) 65% of the workers would be operating personnel and receive 100 mrem/yr; and (3) the remaining 25% of the workers would be supervisory and support personnel and receive doses that are very small compared with background. For delayed processing, the dose would be reduced by an estimated factor of 3 because of radioactive decay.

Estimated exposures during emplacement operations for disposal or storage were based on 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 V. Workers who would be 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 a maximum of 500 mrem/yr.

The second complication is that, in some cases, the number of emplacement workers would depend on the volume of the waste emplaced. The waste volume, in turn, would depend on the processing method. However, the total radioactivity of the waste does not depend on the processing method. It was therefore assumed, as a first approximation, that the total dose to a group of emplacement workers would be independent of the waste processing method.

For onsite shipping and transfer operations, temporary shielding would be placed around the waste containers as necessary to limit the dose rate to a maximum of 5 mrem/hr within the cab of the vehicle. The shielding would also result in a dose rate at 6 ft from the trailer surface of less than the 10 mrem/hr permitted by Federal Regulations (49 CFR 173.393, 1977). 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, trucks would travel a maximum total of 2.8×10^5 truck-miles loaded with waste. An average speed of 30 mph was assumed. Two men would be in each truck. Based on a maximum of 5 mrem/hr within the cab, the resulting total dose would be a maximum of 91 man-rem over the 10-yr campaign.

The estimated shipping distance to Site 14 would be two-thirds of that to the Lemhi Range locations, so the maximum total worker dose would be about 61 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 about 1% of that for shipment to the Lemhi Range sites. Thus, the total worker dose in these cases would be about 0.9 man-rem. For waste transfer from the retrieval facility to the processing facility the maximum total worker dose would be about 1 man-rem over the 10-yr campaign.

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. The workers would wear protective bubble suits supplied with breathing air from an external source and 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, but high radiation levels are present near a few items of beta-gamma waste. Accidental exposure to the levels of direct radiation expected from these few items would be a hazard.

The type of accident posing the greatest radiological hazard to workers would probably be 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 I, no credible accidents were identified that would result in exposures to the maintenance and surveillance workers.

For Alternative II, there is a small chance of accidentally uncovering waste during cover emplacement or during grout injection from above. Only a small quantity of waste 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 the exposed waste, was estimated to be 2×10^{-5} nCi/ml. An unprotected worker, 16 ft downwind, would receive an MPBB in about 33 hr. It is expected that, within 1 hr, the waste would be reburied. Thus, workers would not be expected to receive substantial doses from this type of accident.

The operations involved in Alternatives III through VI 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, transport containers of waste handled by the workers could be accidentally breached. The consequences of such an accident were evaluated, based on the amount of activity in a container and an assumed airborne fraction of from 1×10^{-9} to 1×10^{-3} (see Section 13) of the container contents, depending on the waste form, the container type, and the type and location of the accident. An unprotected worker would receive an MPBB in about 1 hr for an airborne fraction of 1×10^{-3} of unprocessed waste from a transfer container, and in much more than 100 hr for an airborne fraction of 1×10^{-9} of slag from a 55-gal drum. The airborne concentrations would be about 1×10^{-3} and $3 \times$

10^{-10} nCi/ml, respectively. The contents of the breached container could probably be repackaged within minutes.

A tornado striking the retrieval facility would be the accident of greatest risk to the public from retrieval operations (see Section 13). It is expected that retrieval workers would have sufficient warning to vacate the facility before the tornado would strike the facility and cause release of radionuclides. The workers would probably retreat to the safety of the processing facility.

The processing facility would be designed for remote operations and maintenance. 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.

On rare occasions, maintenance personnel could possibly 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.) If a worker lost his breathing air supply while in a contaminated area, the result could also be inhalation of contaminated air. Maximum airborne contamination levels would probably not exceed 8×10^{-5} nCi/ml. The worker would have about 8 hr to leave the contaminated area before receiving an MPBB. The assumptions on which these scenarios are based are very conservative. Provisions for emergency evacuation of contaminated areas would facilitate exit within 1 min.

If an explosion were to occur within the processing facility, high levels of contamination could result. If 37.5 ft^3 of waste were dispersed by the explosion and if 10% of the waste remained airborne, concentrations inside the facility might reach about 4×10^{-3} nCi/ml. Unprotected workers would have about 10 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, operations within the cells in which fires are most likely to occur would be performed remotely. In addition, special fire suppression systems would be installed, and cells would be designed to contain fires. 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

These analyses show that implementing any of the management alternatives for buried waste would not result in unacceptably high levels of occupational hazard. However, the worker hazards accompanying waste retrieval, processing, and disposal--in terms of radiation dose commitments and nonradiological hazards--would greatly exceed those associated with leaving the waste in place. The National Research Council Committee on Radioactive Waste Management cautioned (NAS-NRC 1976) that previously buried TRU waste should be retrieved only if justification could be given for retrieval. See Subsection 7.2.1.

The record of TRU waste management at the INEL suggests that abnormal radiation exposure or high contamination levels in areas frequented by unprotected workers would be very unlikely. Radiological doses expected during normal operations would be well 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 performing waste management functions within allowable levels of occupational hazard.

15.0 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 cost of shipping the waste to an offsite geologic repository and of managing the waste at the repository were included. All costs were based on mid-July 1979 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 facility 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 construction materials; labor; engineering, design, and inspection; and contingency. (Capital costs of the process facilities were based on remote operations and maintenance to the fullest extent practicable.) Among items in the total construction costs that were not included in these preliminary estimates are research and development, extra utilities outside the "5-ft line," 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 approximately 1.5 from the preliminary estimates given here.

The slagging pyrolysis facility for stored TRU waste provides an example of the cost of escalation, which was not included in the present estimate. For this facility, additional design and cost evaluations, beyond the scope of this study, were recently completed. The cost evaluations included the same items included in the estimates presented here. However, the total cost of the facility was escalated to the projected period of construction, which is

from 1982 to 1985. (A larger contingency was also applied to the subtotal.) The total estimated cost at the time of construction was \$500 million. If the estimated \$372 million capital cost for the slagging pyrolysis facility in Table 15-2 of DOE 1979b were escalated to the expected period of construction, and contingency applied to the new subtotal, the capital cost would increase to approximately \$500 million. Thus, the capital costs in Table 15-2 of either this document or DOE 1979b should not be interpreted as actual costs at the time of construction.

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 possibility of a major increase that could occur when more detailed design information is available and more complete estimates are made of total capital costs.

The O&M costs for Alternatives I and II include the costs of performing maintenance and surveillance for the assumed 100-yr period described in Guideline (8) Subsection 7.4.1.1. 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 III 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 IV include the same categories as for Alternative III. 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 V include (1) the same categories as for Alternative III; (2) the cost of the incremental construction described in Subsections 10.4.1.4, 10.4.2.4, 10.4.3.4, 10.4.3.5, 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 VI include the same categories as for Alternative III. 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 to 1997 time period is compounded by the uncertainty in the D&D criteria that will be in effect at that time. D&D cost 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 an offsite geologic repository, the estimated volume and weight of the waste were used to determine the number of railcars to be shipped. It was assumed that the present rate structure for waste shipment from the RFP to the INEL would apply to shipments from the INEL to the offsite repository. The rates were adjusted to reflect escalation to July 1979 and the differences in shipping distances. The cost was evaluated for standard trains, as opposed to specially committed trains. The cost of the railcars, 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 were included in the shipment costs.

The cost for long-term TRU waste management at an offsite geologic repository was taken to be \$60/ft³ (Cunningham 1977). The cost is highly uncertain and would depend on the quantity of waste shipped to the 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, the costs associated with the offsite geologic 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 - BURIED TRU WASTE^(a)

Alter- native or Concept	Capital Cost	Total O&M Cost	Shipment Costs		Cost at Reposi- tory	D&D Cost	Total Costs
			Onsite	Offsite			
I	0	60	N/A ^(b)	N/A	N/A	N/A	60
II-A	32	60	N/A	N/A	N/A	N/A	92
II-B	35	60	N/A	N/A	N/A	N/A	95
II-C	85	60	N/A	N/A	N/A	N/A	145
II-D	100	60	N/A	N/A	N/A	N/A	160
III-A	726	526	N/A	31	174	73	1,530
III-B	767	545	N/A	31	174	77	1,594
IV-A	742	555	N/A	31	174	73	1,575
IV-B	783	574	N/A	31	174	77	1,639
V-A	764	646	4.4	N/A	N/A	73	1,487
V-B	242	458	7.9	N/A	N/A	21	729
V-C	208	482	2.7	N/A	N/A	17	710
V-D	805	665	4.4	N/A	N/A	77	1,551
V-E	283	477	7.9	N/A	N/A	25	793
V-F	249	501	2.7	N/A	N/A	21	774
V-G	765	633	4.4	N/A	N/A	73	1,475
V-H	243	444	7.9	N/A	N/A	21	716
V-I	209	471	2.7	N/A	N/A	17	700
V-J	806	652	4.4	N/A	N/A	77	1,539
V-K	284	463	7.9	N/A	N/A	25	780
V-L	250	490	2.7	N/A	N/A	21	764
V-M	1,276	611	4.1	N/AN/A	73	1,964	
LMV ^(c)	799	598	4.1	N/A	N/A	73	1,474
V-N	1,040	414	5.6	N/A	N/A	21	1,481
LMV	325	402	5.6	N/A	N/A	21	754
V-O	1,906	434	1.5	N/A	N/A	18	2,359
LMV	337	423	1.5	N/A	N/A	18	779
V-P	1,317	630	4.1	N/A	N/A	77	2,028
LMV	840	617	4.1	N/A	N/A	77	1,538
V-Q	1,081	433	5.6	N/A	N/A	25	1,545
LMV	366	421	5.6	N/A	N/A	25	818
V-R	1,947	453	1.5	N/A	N/A	22	2,423
LMV	378	442	1.5	N/A	N/A	22	843
V-S	1,122	618	N/A	N/A	N/A	73	1,813
V-T	813	408	N/A	N/A	N/A	21	1,242
V-U	1,472	438	N/A	N/A	N/A	18	1,928
V-V	1,163	637	N/A	N/A	N/A	77	1,877
V-W	854	427	N/A	N/A	N/A	25	1,306
V-X	1,513	457	N/A	N/A	N/A	22	1,992
VI-A	726	538	N/A	31	174	73	1,542
VI-B	767	557	N/A	31	174	77	1,606

(a) All costs are millions of mid-July 1979 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 - BURIED TRU WASTE^(a,b)

<u>Module</u>	<u>Capital Cost</u>	<u>Total O&M Cost</u>	<u>D&D Cost</u>	<u>Total Cost</u>
<u>RETRIEVAL FACILITY</u>				
Direct Control	57	87	6	150
Remote Control	98	106	10	214
<u>DELAYED RETRIEVAL</u>				
Direct Control	57	99 ^(c)	6	162
Remote Control	98	118 ^(c)	10	226
<u>PROCESS FACILITY</u>				
SP	669	439	67	1,175
CPT	145	237	15	397
PKG	109	252	11	372
<u>DISPOSAL</u>				
<u>Deep Rock Disposal- Lemhi Site-Shaft Access</u>				
SP	38	120 ^(d)	0.3	158
CPT	40	134	0.3	174
PKG	42	143	0.3	185
<u>Deep Rock Disposal- Lemhi Site-Tunnel Access</u>				
SP	39	107	0.3	146
CPT	41	120	0.3	161
PKG	43	132	0.3	175
<u>Engineered Shallow Land Disposal Site 14</u>				
SP	550	85	0.5	635
LMV ^(e)	73	72	0.5	145
CPT	838	90	0.5	928
LMV	123	78	0.5	201
PKG	1,740	95	0.9	1,836
LMV	171	84	0.9	256
<u>Engineered Surface Facility Near RWMC</u>				
SP	396	92	0.4	488
CPT	611	84	0.5	695
PKG	1,306	99	0.7	1,406
<u>20-YR RETRIEVABLE STORAGE</u>	16	29 ^(f)	0.2	45

(a) All costs are in millions of mid-July 1979 dollars.

(b) SP: slagging pyrolysis and packaging.
CPT: compaction, immobilization, and packaging.
PKG: packaging only.

(c) Includes 20 yr maintenance and surveillance before start of retrieval.

(d) All onsite disposal modules include 100 yr of maintenance and surveillance.

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

(f) Includes 10 yr maintenance and surveillance after waste emplacement.

16.0 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 of all 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 of DOE 1979b.

16.2 REGULATORY REQUIREMENTS

Several federal, state, and local agencies have regulatory authority 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 workers, and the environment 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 buried TRU waste, no major program commitments will be made for developing any of the alternatives. 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) follow.

For Alternatives I and II, 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 II-D, a plot would be helpful 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 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. The utilization of an actual photon interrogation method to measure the quantity and type of fissile material present in the waste is being studied.

Baseline facility planning and design are now under way for a combustion-heated slagging pyrolysis process. Electromelting is also being studied as a possible replacement for combustion heating in slagging pyrolysis. 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 the following:

- (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 offgas system must be built and operated. Studies are under way 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. A study to provide this information has begun. The results will have a major impact on process and facility design.
- (5) The composition and integrity of the slag casting depends on many factors. Studies are under way in this important area.

While the exact concentrations of fissionable materials in the waste are not known, design and operating parameter limits for the waste treatment process must be determined to prevent accidental criticality. Preliminary work has been done in this area (Subsection 13.6.3.3.5). Refined calculations would be performed to determine more precisely which isotope concentrations could result in criticality. These calculations would provide detailed criteria for the required level of inspection for incoming waste and the margin of safety necessary with the planned quantities and geometries of waste. An early determination is needed of the criticality standards to be applied.

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 under way 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 under way to better establish the waste quantities and forms, and the potential radiation levels.

- (2) 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, ingestion by populations, and upward migration is in a state of continuing development to help establish the risk to the public from waterborne transport.
- (3) Additional risk analysis studies: Several studies are under way 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.
- (4) 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, DOE 1979b). An additional study of flora and fauna within the RWMC is under way to evaluate population density, range of movement, radionuclide uptake, and food-chain pathways.

17.0 COMPARISONS AMONG ALTERNATIVES, CONCEPTS, AND MODULES

17.1 INTRODUCTION

This section presents comparisons among the alternatives and concepts for long-term management of the buried 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 retrieval modules; (3) among processing modules; (4) among modules for onsite disposal; (5) among alternatives for retrieval, processing, and shipment to an offsite geologic repository; (6) among concepts for retrieval, processing, and disposal on the INEL; and (7) among alternatives and concepts covered in (1), (5), and (6) above. Thus, the approach is to start the comparisons on the modular level and to make successively broader comparisons. The comparisons presented in item (7) are the broadest in scope.

Some of the factors for comparisons, 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. However, the difficulty of making such comparisons does not lessen the importance of these factors.

The remaining factors, such as hazards to the workers and nonradiological 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.

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.

TABLE 17-1

SUMMARY TABLES USEFUL FOR COMPARISONS OF ALTERNATIVES
FOR LONG-TERM MANAGEMENT OF BURIED 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>	13-22, 13-23, 13-27
<u>Hazards to the Workers</u>	
Nonradiological	14-4
Radiological	14-5
<u>Costs</u>	15-1, 15-2

As indicated in Subsection 1.1, 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 presented in the 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 I, CONCEPTS II-A, II-B, II-C, AND II-D)

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 II-C and least for Alternative I, with

Concepts II-A, II-B, and II-D being intermediate in effect (Table 12-32). Even for Concept II-C, 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 II-C and II-D might reduce the spread of radionuclides by erosion processes and by groundwater leaching. The least protection would be provided by Alternative I. 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 II would reduce this risk in the short term (Table 13-22). In the long term (Table 13-23), the benefit would diminish as the confinement deteriorated, in perhaps a little more than 100 yr for Concepts II-A, II-B, and II-C and 400 yr for Concept II-D. 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 similar in magnitude. Radiological doses to the workers (Table 14-5) would be expected to be small compared with background levels. Radiological consequences of potential accidents affecting the workers would be very small for Alternative II. No credible operations-related accidents were identified for Alternative I.

The total cost over the 100-yr period studied would be \$60 million, \$92 million, \$95 million, \$145 million, and \$160 million, for Alternative I and Concepts II-A, II-B, II-C, and II-D, respectively (Table 15-1). Included in each case is \$60 million for maintenance and surveillance.

Although grouting is a proven technology, R&D would be necessary for Concepts II-C and II-D to determine the optimum grout mix and injection spacing and to attempt to project the long-term effectiveness.

17.3 RETRIEVAL MODULES (FOR ALTERNATIVES III, IV, V, AND VI)

Two retrieval modules were studied: (1) direct-control retrieval, and (2) remote-control retrieval. Both retrieval modules were studied in connection with all alternatives involving retrieval of the waste (Alternatives III through VI). Nonradiological environmental effects would be identical for either retrieval module (Tables 12-32 and 12-33). Radiological effects of normal operational releases would be the same for either retrieval module (Tables 12-11, 12-34, and 12-35).

During the retrieval campaign, risks to the public from operations-related accidental releases would be essentially identical for remote control and direct control (Tables 13-13, 13-14, and 13-22). The predominant risks for either retrieval module are from releases due to natural events, such as volcanic activity or tornadoes.

Nonradiological hazards to the workers would be greater for the direct-control module than for the remote-control module. Radiological doses to the workers from normal operations would be expected to be small compared with background levels for either retrieval module. Radiological consequences of potential accidents affecting the workers would be greater for the direct-control module than for the remote-control module.

Both capital costs and operating and maintenance costs would be higher for the remote-control than for the direct-control retrieval facilities. Total costs would be \$150 million for direct control and \$214 million for remote control (Table 15-2).

17.4 PROCESSING MODULES (FOR ALTERNATIVES III, IV, V, AND VI)

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 V). Only the waste form produced by slagging pyrolysis was assumed to be acceptable at an offsite geologic repository (Alternatives III, IV, and VI).

Radiological effects of normal operational releases from the slagging pyrolysis facility would be slightly larger than from 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 V-A through V-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 than for the other processes (Tables 13-15, 13-17, and 13-18). However, the predominant accident scenario in all cases is a release due to natural events. Therefore, the total risk for each processing module is virtually the same. 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 13-21, 13-22, and 13-23).

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 costs for the slagging facility would be four to six times those for the other processing modules (Table 15-2). Operating and maintenance (O&M) costs would be about twice those for the other modules. For both capital and O&M costs, the other two processing 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 V because of its expected low cost. For this module, the saving in total processing cost, over compaction and immobilization, would be \$25 million (Table 15-2). However, compared with compaction and immobilization, onsite disposal costs would be higher by from \$11 to \$908 million, depending on the disposal method. (Differences in onsite shipping costs would be quite small 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 V)

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 bentonite and other clay (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 13-21 and 13-23), 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 absorbing 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 volcanic action (Tables 13-21 and 13-23).

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 (massive variation) are about 10 to 41 times those for deep rock disposal, depending on the waste volume after processing (Table 15-2). The cost of the less massive variation at Site 14 would be about 2 to 4 times 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 AN OFFSITE GEOLOGIC REPOSITORY (ALTERNATIVES III, IV, AND VI)

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 an offsite geologic repository. In Alternative III, all the above operations would begin in 1985. In Alternative IV, the retrieval and processing would begin in 1985; the processed waste would be stored until 2005, when shipping to an offsite geologic repository would begin. In Alternative VI, 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 III and VI. 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 III, the waste would be disposed of in an offsite geologic

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 an offsite 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 13-21, 13-22, and 13-23).

Except for escalation, the cost of Alternative VI would be expected to be essentially the same as that for Alternative III. One small difference (about \$12 million, or 0.8%) would be the added cost of monitoring the waste for an extra 20 yr, awaiting retrieval (Tables 15-1 and 15-2).

17.6.2 Effects of Delaying Shipment

Alternative IV (delayed shipment) differs from Alternative III in the need for 20-yr storage and in the date of shipment to an offsite geologic 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 an offsite 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 \$45 million. The total cost includes an extra 10 yr of monitoring the waste after emplacement in 20-yr storage. (The cost of this item would be about \$6 million.) The net impact of \$45 million is about 3% of the total cost for the alternative.

17.7 CONCEPTS FOR RETRIEVAL, PROCESSING, AND DISPOSAL OF THE WASTE AT THE INEL (ALTERNATIVE V)

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 volume reduction achieved. Compaction and immobilization would be intermediate between the two. 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 largely overcome by use of the less massive variation for engineered shallow land disposal, although at some penalty in long-term safety (Table 13-23).

Site 14 would be less subject to flooding and volcanism than would the RWMC. The greater depth of sediments at Site 14 would better restrict the subsurface migration of radionuclides. The disposal modules at the Lemhi Range location are the only ones studied that would furnish positive protection against 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 of DOE 1979b).

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 I would cost \$60 million; Alternative II, from about \$90 million to \$160 million; Alternatives III, IV, and VI, about \$1.5 billion to \$1.7 billion; and Alternative V, from about \$700 million to \$2.4 billion. For the alternatives involving shipment to an offsite geologic 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 an offsite geologic repository (DOE 1979a) includes a number of cost factors not included in the disposal cost estimates for Alternative V. Therefore, the costs for Alternatives III, IV, and VI are not strictly comparable with those for Alternative V. Also, see Subsection 15.1 for an important caveat concerning all estimates given for facilities costs.

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 1979 dollars)
I	0	3×10^0	4×10^2	4	12	60
II-A	0	3×10^{-2}	4×10^2	9	20	92
II-B	0	3×10^{-2}	4×10^2	9	20	95
II-C	0	3×10^{-2}	4×10^2	18	34	145
II-D	0	3×10^{-2}	4×10^2	10	22	160
III-A	$3.7 \times 10^{-2}(c)$	4×10^{-6}	N/A(d)	214+NI(e)	1035+NI	1530
III-B	$3.7 \times 10^{-2}(c)$	4×10^{-6}	N/A	189+NI	537+NI	1594
IV-A	$3.7 \times 10^{-2}(c)$	4×10^{-6}	N/A	226+NI	1216+NI	1575
IV-B	$3.7 \times 10^{-2}(c)$	4×10^{-6}	N/A	202+NI	718+NI	1639
V-A	3.7×10^{-2}	4×10^{-6}	4×10^0	279	1556	1487
V-B	2.2×10^{-3}	3×10^{-6}	4×10^0	158	1298	729
V-C	2.2×10^{-3}	4×10^{-6}	4×10^0	144	1261	710
V-D	3.7×10^{-2}	4×10^{-6}	4×10^0	254	1058	1551
V-E	2.2×10^{-3}	3×10^{-6}	4×10^0	133	800	793
V-F	2.2×10^{-3}	4×10^{-6}	4×10^0	119	763	774
V-G	3.7×10^{-2}	4×10^{-6}	4×10^0	262	1436	1475
V-H	2.2×10^{-3}	3×10^{-6}	4×10^0	141	1178	716
V-I	2.2×10^{-3}	4×10^{-6}	4×10^0	126	1141	700
V-J	3.7×10^{-2}	4×10^{-6}	4×10^0	237	938	1539
V-K	2.2×10^{-3}	3×10^{-6}	4×10^0	116	680	780
V-L	2.2×10^{-3}	4×10^{-6}	4×10^0	102	643	764
V-M	3.7×10^{-2}	4×10^{-6}	1×10^2	226	1293	1964
LMV(f)	3.7×10^{-2}	4×10^{-6}	4×10^2	220	1184	1474
V-N	2.2×10^{-3}	3×10^{-6}	1×10^2	108	1096	1481
LMV	2.2×10^{-3}	3×10^{-6}	4×10^2	102	998	754
V-O	2.2×10^{-3}	4×10^{-6}	1×10^2	96	1107	2359
LMV	2.2×10^{-3}	4×10^{-6}	4×10^2	89	1014	779
V-P	3.7×10^{-2}	4×10^{-6}	1×10^2	202	795	2028
LMV	3.7×10^{-2}	4×10^{-6}	4×10^2	195	686	1538
V-Q	2.2×10^{-3}	3×10^{-6}	1×10^2	83	598	1545
LMV	2.2×10^{-3}	3×10^{-6}	4×10^2	78	500	818
V-R	2.2×10^{-3}	4×10^{-6}	1×10^2	72	609	2423
LMV	2.2×10^{-3}	4×10^{-6}	4×10^2	65	516	843
V-S	3.7×10^{-2}	4×10^{-6}	4×10^2	228	1296	1813
V-T	2.2×10^{-3}	3×10^{-6}	4×10^2	104	971	1242
V-U	2.2×10^{-3}	4×10^{-6}	4×10^2	97	1065	1928
V-V	3.7×10^{-2}	4×10^{-6}	4×10^2	204	798	1877
V-W	2.2×10^{-3}	3×10^{-6}	4×10^2	80	473	1306
V-X	2.2×10^{-3}	4×10^{-6}	4×10^2	73	567	1992
VI-A	$4.3 \times 10^{-2}(d)$	4×10^{-6}	N/A	215+NI	347+NI	1542
VI-B	$4.3 \times 10^{-2}(d)$	4×10^{-6}	N/A	190+NI	182+NI	1606
Source Table	12-35	13-22	13-23	14-4	14-5	15-1

(a) The risk for Alternatives III through VI 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 Alternatives III through VI to be similar to that for Alternative I during the campaign period.

(b) For volcanic action scenario occurring at a time 25,000 yr into the future.

(c) Dose does not include offsite transportation to a geologic repository. See Table 12-29.

(d) N/A = not applicable, for these concepts there would be no long-term management of waste at the INEL.

(e) NI = not included in this estimate (applies to offsite geologic repository).

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

Hazards to the waste management workers would be lowest for Alternative I, slightly higher for Alternative II, and considerably higher for Alternatives III through VI.

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 III, 30 yr for Alternatives IV and VI, and many thousands of years for Alternatives I, II, and V. The reason for this difference is that the long-term environmental effects and risks associated with an offsite geologic repository were not evaluated in this study. These topics are being addressed in other DOE-sponsored studies (DOE 1979a).

Of course, the long-term radiological effects at the INEL would be less for Alternatives III, IV, and VI than for Alternatives I, II, and V. However, these effects for Alternatives III, IV, and VI would not cease to exist. The effects would simply be transferred to the location of the offsite repository, probably at a reduced level.

Because Alternatives III, IV, and VI 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 I and II. (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 an offsite geologic repository, this conclusion could be reversed. The environmental effects and risks associated with long-term management at an offsite geologic 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 an offsite geologic repository might eventually outweigh the higher near-term risk associated with operations during the campaign.

Until the analyses of long-term environmental effects at an offsite repository are finalized and compared in detail with the results of the present study, only partial comparisons can be made of Alternatives I, II, and V with Alternatives III, IV, and VI.

REFERENCES

- Adcock, F. E., and J. D. McCarthy. 1977. Rockwell International Corporation, Atomics International Division, Rocky Flats Plant, ATMX-600 Rail Car Safety Analysis Report for Packaging, RFP-2244 (Rev. 1).
- AEC (U.S. Atomic Energy Commission). 1972. Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants, WASH-1238, Washington, D.C.: U.S. Government Printing Office.
- AEC (U.S. Atomic Energy Commission). 1974a. Proposed Final Environmental Statement, Liquid Metal Fast Breeder Reactor Program, Vol. IV, WASH-1535.
- AEC (U.S. Atomic Energy Commission). 1974b. Report on the Integrity of Reactor Vessels for Light-Water Power Reactors, WASH-1295.
- Agabian Associates. 1977. El Segundo, California, Evaluation of Seismic Criteria Used in Design of INEL Facilities, R-7741-4509.
- Bagnold, R. A. 1979. The Physics of Blown Sand and Desert Dunes, London: Methuen and Co., Ltd.
- Beck, H. L., et al. 1972. In Situ Ge(Li) and NaI(Tl) Gamma Ray Spectrometry, USAEC Report HASL-258.
- Bell, M. J. 1973. ORIGEN - The ORNL Isotope Generation and Depletion Code, ORNL-4628.
- Bennett, B. G. 1974. Health and Safety Laboratory, New York, New York, Fallout Pu-239, Pu-240 in Diet, CSAEC Report HASL-286.
- Bishoff, J. R. 1979. EG&G Idaho, Inc., TSA-1 Cell Penetration and Inspection. TREE-1311.

Bonneville Council of Governments. 1974. Population and Economic Trends and Projections, April 1974, Chart B, p 6.

Buchholz, J. R., et al. 1971. Los Alamos Scientific Laboratory, Los Alamos, New Mexico, Summary of a Study of the Uptake of Pu-239 by Alfalfa from Soils, USAEC Report LADC-12897.

Bureau of Radiological Health. 1970. U.S. Department of Health, Education, and Welfare, Radiological Health Handbook, Washington, D.C.: U.S. Government Printing Office.

Burkholder, H. 1976. "Nuclear Waste Partitioning Incentives," p 456 in Proceedings of the NRC Workshop on the Management of Radioactive Waste: Waste Partitioning as an Alternative, NF-CONF-001.

Burton, H. M., et al. 1978. EG&G Idaho, Inc. Final Report: Task Force Evaluation of TRU Waste Retrieval Methods, PR-W-78-016.

Carrigan, P. 1972. U.S. Department of Interior Geological Survey, Arlington, Virginia, Probability of Exceeding Capacity of Flood-Control System at the National Reactor Testing Station, Idaho, IDO-22052.

Casarett, A. P. 1968. Radiation Biology. Englewood Cliffs, New Jersey: Prentice-Hall, Inc.

Christian, J. D., R. L. Girton, B. E. Kirstein, and D. T. Pence. 1978. Science Applications, Inc. R&D for an Offgas Treatment System for a Slagging Pyrolysis Radioactive Waste Incinerator, Final Report for Phase II, SAI-78-904-LJ.

Christian, J. D., B. E. Kirstein, and D. T. Pence. 1978. Science Applications, Inc., Development of an Offgas Treatment System Conceptual Design for EG&G Radioactive Incinerator - Final Report for Phase I, SAI78-747-LJ.

Clarke, R. T., et al. 1976. Sandia Laboratories, Albuquerque, New Mexico, Severities of Transportation Accidents, 4 volumes, USAEC Report SLA-74-0001.

- Cline, J. F. 1968. Battelle Pacific Northwest Laboratories, "Uptake of Am-241 and Pu-239 by Plants," in Pacific Northwest Laboratory Annual Report for 1967 to the USAEC Division of Biology and Medicine, Vol. 1, by R. C. Thompson et al., BNWL-714.
- Code of Federal Regulations, U.S. (10 CFR 20.105). 1977. Title 10 - Energy, Part 20.105, "Permissible Levels of Radiation in Unrestricted Areas," Washington, D.C.: U.S. Government Printing Office.
- Code of Federal Regulations, U.S. (40 CFR 141). 1975. Title 40 - Protection of the Environment, Part 141, "National Interim Primary Drinking Water Regulations," Washington, D.C.: U.S. Government Printing Office.
- Code of Federal Regulations, U.S. (10 CFR 20 Appendix B). 1977. Title 10 - Energy, Part 20, Appendix B, "Concentrations in Air and Water Above Natural Background," Washington, D.C.: U.S. Government Printing Office.
- Code of Federal Regulations, U.S. (40 CFR 50). 1977. Title 40 - Protection of the Environment, Part 50, "National Primary and Secondary Ambient Air Quality Standards," Washington, D.C.: U.S. Government Printing Office.
- Code of Federal Regulations, U.S. (49 CFR 173.393). 1977. Title 49 - Transportation, Part 173.393, "General Packaging and Shipment Requirements," Washington, D.C.: U.S. Government Printing Office.
- Codell, R. B., and D. L. Schreiber. 1977. "NRC Models for Evaluating the Transport of Radionuclides in Groundwater," presented at the Symposium on Management of Low Level Radioactive Waste, Atlanta, Georgia, May 1977 (in press, Oxford: Pergamon Press).
- Cowan, G. A., et al., 1976. "Heavy Methanes as Atmospheric Tracers," Science, 191, p 1048.
- Cox, N. D., et al. 1978. EG&G Idaho, Inc. Figure-of-Merit Analysis for a TRU Waste Processing Facility at INEL, TREE-1293.

- Craig, T. H. 1977. Raptors of the Idaho National Engineering Laboratory Site, Masters Thesis, Idaho State University, Pocatello.
- Craig, T. H., and C. H. Trost. 1976. A Study of the Raptorial Species on the INEL Site, IDO-12080.
- Cunningham, G. W. 1977. U.S. Energy Research and Development Administration, "Management of Radioactive Wastes," Statement before Subcommittee on Energy and Environment; Committee on Interior and Insular Affairs, 94th Congress, 1st session, 16 May 1977.
- Denham, D. H., et al. 1973. Battelle Pacific Northwest Laboratories, Radio-logical Evaluations for Advanced Waste Management Studies, BNWL-1764.
- Dodson, W. J., J. E. Hopper, and M. D. McCormack. 1978. "An Incinerator for Transuranic Contaminated Waste," in Transactions of the American Nuclear Society, 28.
- DOE (U.S. Department of Energy). 1978a. Alternatives for Long-Term Management of Defense Transuranic Waste at the Idaho National Engineering Laboratory Site, Idaho Falls, Idaho, IDO-10075.
- DOE (U.S. Department of Energy). 1978b. Summary of INEL Personnel Data, March 1978 Personnel Questionnaire. Idaho National Engineering Laboratory, Idaho Falls, Idaho.
- DOE (U.S. Department of Energy). 1979a. Draft Environmental Impact Statement, Waste Isolation Pilot Plant, 2 volumes, DOE/EIS-0026-D.
- DOE (U.S. Department of Energy). 1979b. Environmental and Other Evaluations Alternatives for Long-Term Management of Stored INEL Transuranic Waste, DOE/ET-0081.

- Dolenc, M. R., and D. J. Janke. 1977. EG&G Idaho, Inc., Environmental Surveillance Report for the INEL Radioactive Waste Management Complex, Annual Report, 1976, TREE-1078.
- Dort, W. Jr. 1962. "Multiple Glaciation of the Southern Lemhi Mountains, Idaho; Preliminary Reconnaissance Report," Idaho State College Museum Journal, 4 pp 2-17.
- Duprey, R. L. 1968. U.S. Department of HEW Public Health Service, Compilation of Air Pollutant Emission Factors, PHS-Pub-999-AD-42.
- EG&G Idaho, Inc. 1977. Safety Review Document for the Radioactive Waste Management Complex at the Idaho National Engineering Laboratory, TREE-1064.
- EPA (U.S. Environmental Protection Agency). 1977. Proposed Guidance on Dose Limits for Persons Exposed to Transuranium Elements in the General Environment, EPA 520/4-77-016.
- EPA (U.S. Environmental Protection Agency). 1978. "Criteria for Radioactive Wastes," Federal Register, Vol. 43 (221), November 15, 1978. pp. 53262-53268.
- Epstein, H. H., and M. J. Barvenik. 1975. Grouting Applications in Civil Engineering, 2 volumes, ORNL/Sub-3960/1.
- ERDA (U.S. Energy Research and Development Administration). 1973a. ERDA Manual, Chapter 0511, "Radioactive Waste Management," Washington, D.C.: U.S. Government Printing Office.
- ERDA (U.S. Energy Research and Development Administration). 1973b. ERDA Manual, Chapter 6301, "General Design Criteria," Washington, D.C.: U.S. Government Printing Office.

ERDA (U.S. Energy Research and Development Administration). 1973c. ERDA Manual Appendix 6301, Part II, "General Design Criteria, Plutonium Facilities, Buildings, and Facilities Design," Washington, D.C.: U.S. Government Printing Office.

ERDA (U.S. Energy Research and Development Administration). 1975. Final Environmental Impact Statement: Waste Management Operations, Hanford Reservation, Richland, Washington, ERDA-1538, Washington, D.C.: U.S. Government Printing Office.

ERDA (U.S. Energy Research and Development Administration). 1976. ERDA Manual Chapter 0552, "Industrial Fire Protection," Washington, D.C.: U.S. Government Printing Office.

ERDA (U.S. Energy Research and Development Administration). 1977a. ERDA Manual Chapter 0524, "Standards for Radiation Protection," Washington, D.C.: U.S. Government Printing Office.

ERDA (U.S. Energy Research and Development Administration). 1977b. Final Environmental Impact Statement: Management of Intermediate Level Radioactive Waste, Oak Ridge National Laboratory, ERDA-1553, Washington D.C.: U.S. Government Printing Office.

ERDA (U.S. Energy Research and Development Administration). 1977c. Final Environmental Impact Statement: Waste Management Operations, INEL, ERDA-1536, Washington, D.C.: U.S. Government Printing Office.

Essington, E. H., and E. B. Fowler. 1977. "Distribution of Transuranic Nuclides in Soils: A Review," in Transuranics in Natural Environments, edited by M. G. White and P. B. Dunnaway, U.S. Energy Research and Development Administration, Las Vegas, Nevada, ERDA Report NVO-178.

Estcourt, V. F., et al. 1978. "Tests of a Two-Stage Combined Dry Scrubber/SO₂ Absorber Using Sodium or Calcium," in Proceedings of 40th Annual Meeting of the American Power Conference, Illinois Institute of Technology, Chicago, Illinois.

- FMC Corporation. 1977. Engineered Systems Division, Selection of Waste Treatment Process for Retrieved TRU Waste at Idaho National Engineering Laboratory, R-3689.
- FMC Corporation. 1978. Design of an Equipment System for Retrieval and Handling of Buried Radioactive Waste, R-3679R.
- Francis, P. 1976. Volcanoes, Harmondsworth, Middlesex, England: Penguin Books, Ltd.
- Fujita, T. T. 1971. "Estimates of Maximum Wind Speeds of Tornadoes in Three Northwestern States," Appendix 2 to Review of Tornado Considerations for FFTF, by D. F. Simpson, Hanford Engineering Development Laboratory, Richland, Washington, HEDL-TME-71-35.
- Gillete, D. A., I. H. Blifford, Jr., and C. R. Fenster. 1972. "Measurements of Aerosol Size Distributions and Vertical Fluxes of Aerosols on Land Subject to Erosion," Journal of Applied Meteorology, II.
- Harness, J. L., and R. W. Passmore. 1976a. EG&G Idaho, Inc., Onsite Environmental Surveillance Report for the INEL Radioactive Waste Management Complex: Annual Report - 1974, TREE-1014.
- Harness, J. L., and R. W. Passmore. 1976b. EG&G Idaho, Inc., Onsite Environmental Surveillance Report for the INEL Radioactive Waste Management Complex: Annual Report - 1975, TREE-1013.
- Hausser, C. J. 1956. "Post Glacial Environments in the Canadian Rocky Mountains," Ecology Monographs, 26 pp 263-302.
- Hausser, C. J. 1957. "Variations of the Blue, Roh, and White Glaciers during Recent Centuries," Arctic, 10 pp 139-150.
- Healy, J. W. 1974. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. A Proposed Interim Standard for Plutonium in Soils, USAEC Report LA-5483-MS.

- Hedahl, T. G., and Janke, D. H. 1978. EG&G Idaho, Inc., Environmental Surveillance Report for the INEL Radioactive Waste Management Complex, Annual Report - 1977, TREE-1251.
- Houston, J. R., D. L. Streng, and E. C. Watson. 1974. Battelle Pacific Northwest Laboratories, Richland, Washington, DACRIN - A Computer Program for Calculating Organ Dose from Acute or Chronic Radionuclide Inhalation, USAEC Report BNWL-B-389.
- Hsieh, T., D. Okrent, and G. Apostolakis. 1975. UCLA, School of Engineering and Applied Science, Los Angeles, California, On the Average Probability Distribution of Peak Ground Acceleration in the U.S. Continent due to Strong Earthquakes. UCLA-ENG-7516.
- ICRP (International Commission on Radiological Protection). 1959. Recommendations of the International Commission on Radiological Protection. ICRP Publication 2, Oxford: Pergamon Press.
- ICRP (International Commission on Radiological Protection). 1964. Recommendations of the International Commission on Radiological Protection, ICRP Publication 6, Oxford: Pergamon Press.
- ICRP (International Commission on Radiological Protection). 1965. Recommendations of the International Commission on Radiological Protection, ICRP Publication 8, Oxford: Pergamon Press.
- ICRP (International Commission on Radiological Protection). 1966. Task Group on Lung Dynamics, "Deposition and Retention Models for Internal Dosimetry of the Human Respiratory Tract," Health Physics, 12 p 173.
- ICRP (International Commission on Radiological Protection). 1969. Radio-sensitivity and Spatial Distribution of Dose, ICRP Publication 14, Oxford: Pergamon Press.
- ICRP (International Commission on Radiological Protection). 1972. Task Group of ICRP Committee 2, The Metabolism of Compounds of Plutonium and Other Actinides, ICRP Publication 19, Oxford: Pergamon Press.

- ICRP (International Commission on Radiological Protection). 1975.
W. S. Snyder, ed., Report of the Task Group on Reference Man, ICRP Publication 23, Oxford: Pergamon Press.
- Idaho Falls Chamber of Commerce, 1978. Idaho East, Summer 1978, p 28.
- Jakubick, A. T. 1976. "Migration of Plutonium Natural Soil," Transuranic Nuclides in the Environment, Vienna: International Atomic Energy Agency.
- Kaiser Engineers. 1977. A Comparison of Slagging Pyrolysis and Molten Salt Incinerators for Treating TRU Waste at the INEL. 77-92 RE.
- Karol, R. H. 1968. "Chemical Grouting Technology," Journal of the Soil Mechanics and Foundations Division. Proceedings of the American Society of Civil Engineers, 94 pp 175-204.
- Killough, C. G., and L. R. McKay. 1976. A Methodology for Calculating Radiation Doses from Radioactivity Released to the Environment, ORNL-4992.
- Kuntz, M. A. 1978. U.S. Department of the Interior, Geological Survey, Geology of the Arco-Big Southern Butte Area, Snake River Plain, and Potential Volcanic Hazards to the Radioactive Waste Management Complex, and Other Waste Storage and Reactor Facilities at the Idaho National Engineering Laboratory, Idaho, U.S. Geological Survey Open-File Report 78-691.
- LATA (Los Alamos Technical Associates, Inc.). 1977. ANL-W Radioactive Liquid Waste Treatment Facility - Labor Escalation Study, LATA-77-35.
- Leddicotte, G. W. et al. 1978. "Suggested Concentration Limits for Shallow Land Burial of Radionuclides," in Waste Management and Fuel Cycles 1978 (Proceedings of Symposium on Radioactive Waste Management, March 6-8, 1978, Tuscon, Arizona) edited by Roy G. Post, Chicago: Amercian Nuclear Society.
- Magno, P. J., P. E. Kauffman, and B. Shleien, 1967. "Plutonium in Environments and Biological Media," Health Physics, 13 p 1325.

- Markham, O. D., K. W. Puphal, and T. D. Filer. 1978. "Plutonium and Americium Contamination near a Transuranic Storage Area in Southeastern Idaho," Journal of Environmental Quality, 7(3) p 422.
- Matthews, W. H. 1951. "Historic and Prehistoric Fluctuations of Alpine Glaciers in the Mount Garibaldi Map Area, Southwestern British Columbia," Journal of Geology, 59 p 357.
- McBride, R., et al. 1978. U.S. Department of Energy, Idaho Falls, Idaho, Vegetation Types and Surface Soils of the Idaho National Engineering Laboratory Site, IDO-12048.
- McSweeney, T. I., and R. J. Hall. 1975. Battelle Pacific Northwest Laboratories, An Assessment of the Risk of Transporting Liquid Plutonium Oxide and Liquid Plutonium Nitrate by Truck, BNWL-1846.
- Mishima, J. 1974. "Fractional Airborne Release of Plutonium Under Shipping Accident Conditions," in Proceedings of the Fourth International Symposium on Packaging and Transportation of Radioactive Material, Miami Beach, Florida, Paper CONF-740901.
- Mishima, J., and L. Schwendiman. 1970. Battelle Pacific Northwest Laboratories, The Amount and Characteristics of Plutonium Made Airborne Under Thermal Stress, BNWL-SA-3879.
- Mishima, J., and L. Schwendiman. 1973a. Battelle Pacific Northwest Laboratories, Fractional Airborne Release of Uranium (Representing Plutonium) During the Burning of Contaminated Waste, BNWL-1730.
- Mishima, J., and L. Schwendiman. 1973b. Battelle Pacific Northwest Laboratories, Some Experimental Measurements of Airborne Uranium (Representing Plutonium) in Transportation Accidents, BNWL-1732.
- Morrison, R. B. 1961. Lake Lahontan Stratigraphy and History in the Carson Desert (Fallon) Area, Nevada, U.S. Geological Survey Professional Paper 424, pp 111-114.

- Morrison, R. B. 1964. Geology of the Southern Carson Desert, Nevada, U.S. Geological Survey Professional Paper 401, p 156.
- Morrison, R. B. 1965. New Evidence of Lake Bonneville Stratigraphy and History from Southern Promontory Point, Utah, U.S. Geological Survey Professional Paper 525.
- NAS-NRC (National Academy of Sciences, National Research Council). 1972. The Effects on Population of Exposure to Low Levels of Ionizing Radiation, The BEIR Report, Washington, D.C.: National Academy of Sciences.
- NAS-NRC (National Research Council). 1976. Committee on Radioactive Waste Management, The Shallow Land Burial of Low-Level Radioactive Contaminated Waste, Washington, D. C.: National Academy of Sciences.
- NAS-NRC (National Research Council). 1978. Committee on Radioactive Waste Management, Radioactive Wastes at the Hanford Reservation, A Technical Review, Washington, D.C.: National Academy of Sciences.
- National Safety Council. 1977. "Work Injury Rates," Chicago, Illinois.
- NBS (National Bureau of Standards). 1964. The International Commission on Radiation Units and Measurements, Physical Aspects of Irradiation, NBS Handbook 85, Washington, D.C.: U.S. Government Printing Office.
- NCRP (National Council on Radiation Protection and Measurements). 1971. Basic Radiation Protection Criteria, NCRP-39, Washington, D.C.: NCRP Publications Office.
- NCRP (National Council on Radiation Protection and Measurements). 1975a. Review of the Current State of Radiation Protection Philosophy, NCRP-43, Washington, D.C.: NCRP Publications Office.
- NCRP (National Council on Radiation Protection and Measurements). 1975b. Natural Background Radiation in the United States, NCRP-45, Washington, D. C.: NCRP Publications Office.

- NRC (U.S. Nuclear Regulatory Commission). 1974. Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR, Part 50, Appendix I, Regulatory Guide 1.109, Washington, D.C.: U.S. Government Printing Office.
- NRC (U.S. Nuclear Regulatory Commission). 1975. Reactor Safety Study, WASH-1400 and NUREG-75/014, Washington, D.C.: U.S. Government Printing Office.
- NSC 1977. Nuclear Services Corporation, Campbell, California, Risk Analysis Methodology and Data Study of Alternatives for Long-Term Management of Hanford Defense High-Level Radioactive Waste, NSC-PS-ARH 77001.
- Ollier, C. D. 1974. "Phreatic Eruptions and Maars," Developments in Solid Earth Geophysics, Vol. 6, New York: American Elsevier Publishing Company, Inc.
- ORNL 1970a. Oak Ridge National Laboratory, Oak Ridge, Tennessee, Highway Vehicle Impacts of Vehicle, Package, and Tie Down Systems Capable of Carrying Radioactive Material, ORNL-NSIC-61.
- ORNL 1970b. Oak Ridge National Laboratory, Oak Ridge, Tennessee, Siting of Fuel Reprocessing Plants and Waste Management Facilities, ORNL-4451.
- Otway, H. J. 1969. University of California, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, The Application of Risk Allocation to Reactor Siting and Design, LA-4316.
- Overton, C. K., D. A. Grove, and D. W. Johnson. 1976. "Big Lost River Fisheries," in Summaries of the Idaho National Engineering Laboratory Site Ecological Information Meeting, July 10-11, 1975, pp 42-43, edited by O. D. Markham, Idaho Operations Office, U.S. Energy Research and Development Administration.
- Pelletier, C. A., and P. G. Voillege. 1971. "The Behavior of Cesium-137 and Other Fallout Radionuclides on a Michigan Dairy Farm," Health Physics, 21 p 777.

- Price, K. R. 1972. Battelle Pacific Northwest Laboratories, Richland, Washington, Uptake of Np-237, Pu-239, Am-241, and Cm-244 from Soil by Tumbleweed and Cheatgrass, USAEC Report BNWL-1688.
- Robertson, J. B. 1974. Digital Modeling of Radioactive and Chemical Waste Transport in the Snake River Plain Aquifer at the National Reactor Testing Station, U.S. Geological Survey Open-File Report IDO-22054.
- Robertson, J. B., R. Schoen, and J. T. Barraclough. 1974. U.S. Department of Interior Geological Survey, Water Resources Division, Idaho Falls, Idaho, The Influence of Liquid Waste Disposal on the Geochemistry of Water at the National Reactor Testing Station, Idaho, 1952-1970, IDO-22053.
- Sansom, B. F. 1964. "The Transfer of Pu-239 from the Diet of a Cow to its Milk," British Veterinary Journal, 120 p 158.
- Schmalz, B. L. 1972. Radionuclide Distribution in Soil Mantle of the Lithosphere as a Consequence of Waste Disposal at the National Reactor Testing Station, IDO-10049.
- Schulman, E. 1956. Dendroclimate Changes in Semiarid America, Tucson: University of Arizona Press.
- Sehmel, G. A. 1977. Battelle Pacific Northwest Laboratories, Transuranic and Tracer Simulant Resuspension, BNWL-SA-6236.
- Sehmel, G. A., and W. H. Hodgson. 1976. "Predicted Dry Deposition Velocities," In Atmospheric Surface Exchange of Particulate and Gaseous Pollutants, ERDA Symposium Series No. 38, CONF-740921, U.S. Energy Research and Development Administration, Washington, D.C.
- Selby, J., et al. 1973. Battelle Pacific Northwest Laboratories, Richland, Washington, Considerations in the Assessment of the Consequences of Effluents from a Mixed Oxide Fuel Fabrication Plant, BNWL-1697.

- Shea, G. J. 1978. Andco-Torrax Group, Andco Inc., TRU Waste Analysis and Preliminary Operation Parameters for a Radioactive Waste Slagging Pyrolysis Incinerator.
- Sigafoos, R. S., and E. L. Hendricks. 1961. Botanical Evidence of the Modern History of Nisqually Glacier, Washington, U.S. Geological Survey Professional Paper 387-A.
- Smith, T. H., and W. A. Ross. 1975. Battelle Pacific Northwest Laboratories, Impact Testing of Vitreous Simulated High-Level Waste in Canisters, BNWL-1903.
- Soldat, J. K. 1974. Battelle Pacific Northwest Laboratories, Environmental Behavior and Radiation Doses from Iodine I-129, BNWL-SA-4879.
- Staley, G. B., G. P. Turi, and D. L. Schreiber. 1977. "Radionuclide Migration from Low-Level Waste: A Generic Overview," in Management of Low-Level Radioactive Waste, Vol. 2, edited by M. W. Carter, A. A. Moglissi, and B. Kahn, Oxford: Pergamon Press.
- Start, G. E., and L. L. Wendell. 1974. Regional Effluent Dispersion Calculations Considering Spatial and Temporal Meteorological Variations, NOAA Technical Memorandum ERL ARL-44.
- Strong, A. B., J. M. Smith, and R. H. Johnson, Jr. 1977. Office of Radiation Programs, U.S. Environmental Protection Agency, Washington, D.C. EPA Assessment of Fallout in the United States from Atmospheric Testing on September 26 and November 17, 1976 by the Peoples Republic of China, EPA Report EPA-520/5-77-002.
- Taylor, L. S., and H. O. Wyckoff. 1976. "Implications of the Man-Rem Concept," in Proceedings of the International Symposium on the Management of Wastes from the LWR Fuel Cycle, Paper CONF-760701.

- Thomas, J. T. ed., 1978. Nuclear Safety Guide, Rev. 2, TID-7016 and NUREG/CR-0095.
- UBC. 1961. International Conference of Building Officials, Uniform Building Code, 1961, 11th edition, Revised, Vol 1, Los Angeles, California.
- UBC. 1973. International Conference of Building Officials, Uniform Building Code, 1973 edition, Whittier, California.
- United Nations. 1964. Report of the United Nations Scientific Committee on the Effects of Atomic Radiation, U.N. General Assembly Official Records: Nineteenth Session, Supplement No. 14 (A/5814) United Nations, New York.
- United Nations. 1972. Report of the United Nations Scientific Committee on the Effects of Atomic Radiation, Ionizing Radiation: Levels and Effects, United Nations, New York.
- U.S. Bureau of the Census. 1973. U.S. Bureau of the Census, Census of Population: 1970, Detailed Characteristics, United States Summary, Final Report PC(1)-D1, Washington, D.C.: U.S. Government Printing Office.
- Voilleque, P. G. and C. A. Pelletier. 1974. "Comparison of External Irradiation and Consumption of Cows' Milk as Critical Pathways for Cs-137, Mn-54, and Ce-Pr-144 Released to the Atmosphere," Health Physics, 27 p 189.
- Wall, I. B. 1974. "Probabilistic Assessment of Aircraft Risk for Nuclear Power Plants," Nuclear Safety, 15 p 3.
- Wilcoxson, K. H. 1966. Chains of Fire: The Story of Volcanoes, Philadelphia: Chilton Book Company.

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 the Rocky Flats Plant (RFP) 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 RFP. Publicity stemming from the fire caused Idaho officials to raise questions regarding the safety of burying the RFP waste at the INEL.

The text of communications on this subject between the federal government and the State of Idaho is given in Appendix A of DOE 1979b.

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 listed were developed in some detail. (See Sections 8, 9, and 10). Environmental, risk, worker hazards, 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, five disposal methods and three INEL disposal locations are shown for Alternative V. 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 barrier" for Concept II-A could be effected using concrete, clay, asphalt, or other materials. If all the concepts and ideas generated during the study were placed 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 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.

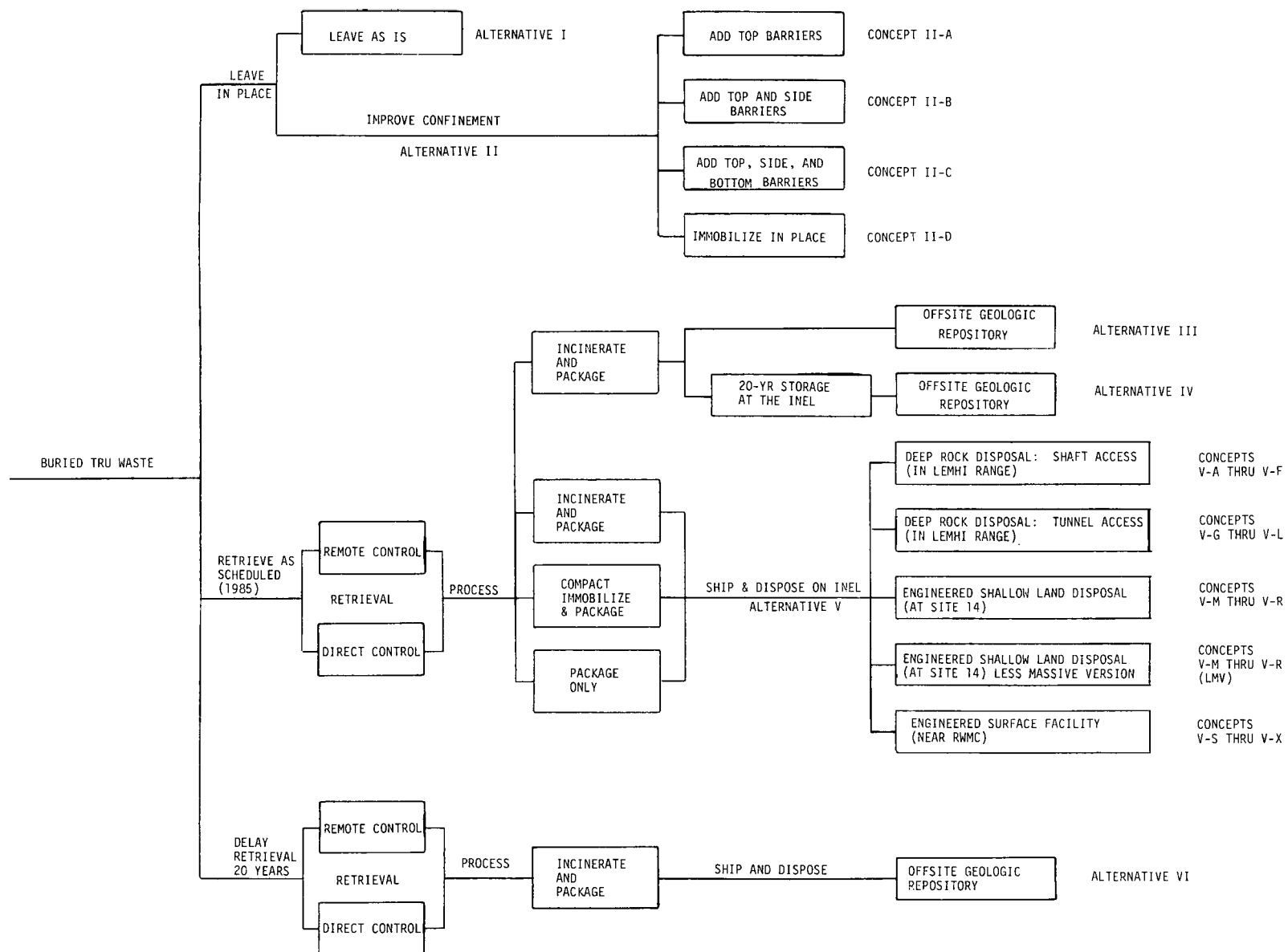


Fig. B-1. Alternatives and concepts studied for long-term management of buried INEL TRU waste.

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 I AND II: LEAVE IN PLACE

The ideas in this subsection relate to ways in which in-place confinement could be improved (Alternative II). The only variations identified in Alternative I involve different approaches to maintenance, surveillance, and security. These variations are addressed in Subsection B.8.4.

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.

Even for concepts studied, techniques or materials other than those selected could be used. Only representative approaches are listed; a complete list of all possible approaches is not attempted.

B.2.1 Top Cover: Concrete Cover

A layer of concrete or asphalt would be placed over the waste burial areas. The impermeable surface would be subject to cracking as the ground surface subsided due to waste settling. The degree of additional protection provided by this approach did not warrant further exploration.

TABLE B-1

WASTE BARRIER/IMMOBILIZATION COMBINATIONS FOR WASTE LEFT IN PLACE

<u>Barrier/ Immobilization Combinations (a)</u>	<u>Alternatives or Concepts Studied (See Figure B-1)</u>	<u>Alternatives or Concepts Identified But Not Studied^(b) (Subsection of Appendix B)</u>
None	I	
T	II-A	B.2.1 ^(c) , B.2.2 ^(c)
S		B.2.3
B		B.2.4
T+S	II-B	
T+B		
S+B		
T+S+B	II-C	B.2.5 ^(c)
I	II-D	
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) Combinations without a reference to a specific subsection could be derived by combining the appropriate ideas from the referenced subsections. For example, T+S could be produced by combining the ideas in B.2.1 and B.2.3. However, there is no guarantee that a reasonable combination would result.

(c) The method indicated here for emplacing the barrier(s) is different from that studied in the concepts that were developed.

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 burial areas. As the waste subsided, these slabs would settle and would tend to separate from one another. Weather protection for the waste pits and trenches would no longer be provided. Therefore, this concept was not explored further.

B.2.3 Side Barrier: Grout-Injected Walls

Walls would be constructed around each pit and trench by using injection grouting techniques. Because of (1) the potential displacement of the walls as the waste settles over time, and (2) the questionable long-term integrity of the grout, this approach was not developed further.

B.2.4 Bottom Barrier: Grout Slab Beneath the Waste

In this approach, trenches would be excavated along two sides of the buried waste area. The trenches would be about 6 ft wide, would extend down into the basalt, and would be located outside the buried TRU waste area. From the trenches, horizontal tunnels 6 ft wide and 3 ft high, would be excavated through the basalt beneath the waste. The tunnels would be 6 ft apart and would interconnect with the trenches. Grout would be forced into the tunnels from the trenches. When all tunnels were full and the grout had hardened, the basalt between the grout-filled tunnels would be excavated to form new tunnels. These tunnels would then be filled with grout. A continuous floor of grout would thus be constructed in the basalt beneath the waste. The trenches would be filled with cement and pieces of basalt.

This concept was not developed further because of (1) the excessive amount of grout required, (2) the resulting high cost, and (3) the possibility of poor bonding between the initial grout and that emplaced later.

B.2.5 Top, Side, and Bottom Barriers: Vaults Constructed Under Present Pits and Trenches

Without disturbing the waste, large caverns would be excavated beneath the waste pits and trenches. 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 cost of excavating the original vaults and constructing the linings for them, 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 buried waste have been studied (DOE 1978a, FMC 1978, Burton et al. 1978). Retrieval alternatives identified in those reports, but not studied in this document, are briefly described in the following subsections. More complete descriptions are given in the original reports.

Retrieval of the buried waste is complicated by the decomposition of the original containers, as well as by the presence of large, heavy items, such as lathes. Since the volume to be excavated is large and the size of some individual items requires substantial excavation equipment, pick-and-shovel approaches were not seriously considered.

B.3.1 Direct-Control Retrieval Module

In this type of retrieval, the excavation equipment would be controlled directly by the operators, either in self-contained environmental cabs or by operators in bubble suits.

B.3.1.1 Excavation Equipment

A system incorporating a forklift, mobile crane with grapple and clamshell, and conveyor belt was discussed in DOE 1978a. The operators were protected by bubble suits.

In the FMC study (1978), two categories of excavation equipment were considered, regular and heavy-duty. The bulk of the buried waste would be excavated by the regular equipment. The regular equipment recommended in the FMC report and selected for evaluation in the present study is the gantry crane-mounted shaft mucker (mobile waste retriever).

Regular equipment considered and rejected includes the front end loader, a digging crab supported by bridge crane, a digging crab supported by gantry crane, an undercutter excavator, and a mobile slope excavator. The digging crab is essentially a self-contained protective cab from which an operator can control several articulated arms and their attachments. Typical attachments would be a bucket, clamshell, and a grapple. The undercutter excavator is a variation of the equipment used in longwall coal mining. The mobile slope excavator consists of a conveyor mechanism that moves buckets closely along the working face. Articulated arms pull material from the face into the buckets.

One piece of heavy-duty equipment was considered necessary to handle heavy and bulky items. For this purpose the backhoe was found superior to the bridge crane with clamshell, mobile crane with clamshell, power scoop shovel, and front end loader.

Reasons for selecting these equipment items for further study are given (FMC 1978, Burton et al. 1978) in the form of evaluation matrices.

B.3.1.2 Enclosure

Air-supported buildings were eliminated from consideration by the guidelines of the present study [Subsection 7.4.1, Guideline (14)], because the direction of air leakage would be outward from the building rather

than inward. The DOE 1978a study proposed a double-wall aluminum building that moved on air pads.

B.3.2 Remote-Control Retrieval Module

Equipment and enclosures considered but not studied for the remote-control retrieval module are generally similar to those for direct control. The main difference is that the equipment would be operated remotely from a control booth. No operators would normally be present on the ground or on the equipment. The equipment and enclosures considered but not studied have been enumerated in Subsection B.3.1.

B.4 PROCESSING METHODS NOT STUDIED

B.4.1 Combinations of Processes

Four types of waste processing operations were identified for the purpose of this study:

- (1) Incineration - a high-temperature processing 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 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 eliminate trapped air or other gases.

- (4) Packaging - the placing of waste in a container that will result 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 4 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. This is particularly true for contaminated soil. 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 of the four processes considered. Combination 5 represents minimal processing. Combination 8 was assumed to be the only combination of these three that would satisfy the draft acceptance criteria for the Waste Isolation Pilot Plant, a proposed offsite geologic repository (see Appendix D of DOE 1979b and the beginning of Section 9). Combination 12 represents an intermediate case, in terms of the cost and the long-term isolation provided.

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.

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. This conclusion was confirmed by an independent task force (Cox et al. 1978). The interested reader should consult the referenced studies for further information on incinerator comparisons.

Based on these two studies 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, R&D studies of slagging pyrolysis, as applied to TRU waste at the INEL, are under way.

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 soil and 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 further.

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 of 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 AN OFFSITE GEOLOGIC 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 an offsite geologic 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 an Offsite Geologic 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 an offsite geologic repository. This approach is embodied in Alternative IV.

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 storage methods were considered.

B.5.1.1 Outdoor 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 upon the particular material selected and the method for securing the edges, it is expected that the covering would 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 has been evaluated as an alternative for long-term management of stored INEL TRU waste (DOE 1979b). Effects would be similar for processed waste.

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. This method was eliminated because of the large number of pipes that would be required due to the inefficiency of the storage method.

B.5.1.2 Outdoor Methods: Underground

B.5.1.2.1 Hole-in-Ground Storage

In this storage method, 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 vertical or placed horizontally in an earth wall. As each hole is filled with waste containers, the opening

would be closed off 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 the accumulation of water at the bottom. 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. Similar to 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 as a disposal concept for Alternative V 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, within the INEL, in Alternative V.

B.5.1.3 Indoor Storage Methods: Aboveground

Characteristics upon which an indoor storage method might be selected include:

- ease of monitoring the storage environment and detection of radiation leakage,

- siting flexibility,
- ease of accommodating waste containers of essentially all sizes and shapes,
- ease of accessibility for in-storage inspection,
- capability for year-round operations, and
- 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 upon 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 IV (20-yr delay in shipment of processed waste to an offsite geologic 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. 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 transuranic 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 constitutes 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 can be built to specifications that will meet minimum criteria for wind resistance, snow loading, and earthquake resistance. However, this type of 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 has been used in experimental retrieval projects (Subsection 4.4.4). 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 the interior of the building would have

to be maintained above ambient air pressure. Therefore, in the event of leakage from one of the waste containers, contamination could be forced out of the building by the pressure difference.

B.5.1.3.6 Structural Support Building

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 type of facility was eliminated due to the short life of the cover material.

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 have been 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. If the buried waste and contaminated soil were retrieved, at least minimum processing (i.e., packaging) would be required to facilitate handling of the waste and placement in storage. Therefore, this method was not considered.

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 the existence of a significant hazard resulting from degradation of the containment/confinement.

Monitoring of the buried TRU waste indicates that (1) the waste presently has virtually no confinement other than the soil and the clay cover and (2) a very small amount of migration through the soil has occurred (see DOE 1979b). However, no near-term hazards associated with the buried waste in its present location have been identified.

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 VI.

If the projections were unfavorable, a number of options would be available. If a near-term hazard to the environment existed, action would certainly be taken as soon as feasible. However, 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 buried waste as at present.

If it were judged that a hazard to the environment would ensue from continuing present management for 20 yr before retrieval, two approaches could be followed. Improved temporary confinement, such as contemplated in Alternative II, could be emplaced. (However, the retrievability of the waste could be made more difficult by any work to improve confinement.) The second approach would be to initiate retrieval and processing as soon as feasible. This approach would essentially be Alternative IV, although the dates for the retrieval, processing, and storage periods might not coincide.

If the projections of containment/confinement adequacy were uncertain, the retrieval decision could be delayed or the more cautious 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 an offsite geologic 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 and transfer vehicles would travel over committed roadways within the INEL.

The use of trucks for shipment to an offsite geologic 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. The conveyor approach was rejected for this application 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 Guideline (6) of Subsection 7.4.1.1.

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. 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 would be constructed completely within INEL boundaries. 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 the geologic/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 2,000 ft deep, each hole would hold approximately 14,000 ft³ of waste. Depending on the method of waste processing, hundreds of such holes would 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 present the possibility of groundwater transport of the radionuclides to distant populations. Disposal of the waste below the aquifer would risk the same transport of radionuclides.

B.7.2.2 Deep Well Injection of Liquified Waste

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 of application to TRU waste at the INEL.

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 concept 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 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 [Guideline 7.4.1.1 (7)]. Selection of an alternative that involves reversible disposal would leave open the way to a later 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 II-D 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 pursued further in the present study.

B.8.2 Separation of the Waste

It has been proposed that the waste material and contaminated soil 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 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 also be costly, possibly leading to no net overall cost reduction. For these reasons, the approach was not considered further in the present study.

B.8.3 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.8.4 Selection of a Period for Maintenance, Surveillance, and Security

Guideline (8) of Subsection 7.4.1.1 specifies 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 continuance 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 radionuclides 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.8.5 Nongeologic Disposal Methods

Nongeologic disposal methods have been considered in earlier studies and are summarized in DOE 1979a. 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. Pursuit of these disposal methods falls outside the scope of the present study.

B.8.6 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 Guideline (16) of Subsection 7.4.1.1 (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

Burial of TRU waste at the RWMC was discontinued in 1970. Therefore, no additional waste, received after 1985, would be added to the waste already buried in the pits and trenches.

APPENDIX D

WIPP ACCEPTANCE CRITERIA

The WIPP Acceptance Criteria for Defense Low-Level TRU Waste, July 1, 1977, are presented in Appendix D of DOE 1979b.

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 where 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 of DOE 1979b, 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 6-yr average (1972 to 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 at ground level for the INEL and surrounding areas. The results are for a stack release from the Idaho Chemical Processing Plant (about 8 miles northeast of the RWMC), 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 $180 \times 10^{-9} \text{ hr}^2/\text{m}^3$ at a distance of about 5 miles southeast of the source.

The atmospheric dilution factors, χ/Q (sec/m^3), required for dose commitment calculations were derived from the relative time-integrated concentrations by taking the appropriate χ/Q and dividing by the number of hours (8,760) 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, χ/Q , becomes

$$\frac{\chi}{Q} \left(\frac{\text{sec}}{\text{m}^3} \right) = 0.41 \frac{\psi}{Q} \left(\frac{\text{hr}^2}{\text{m}^3} \right) \quad (\text{E-1})$$

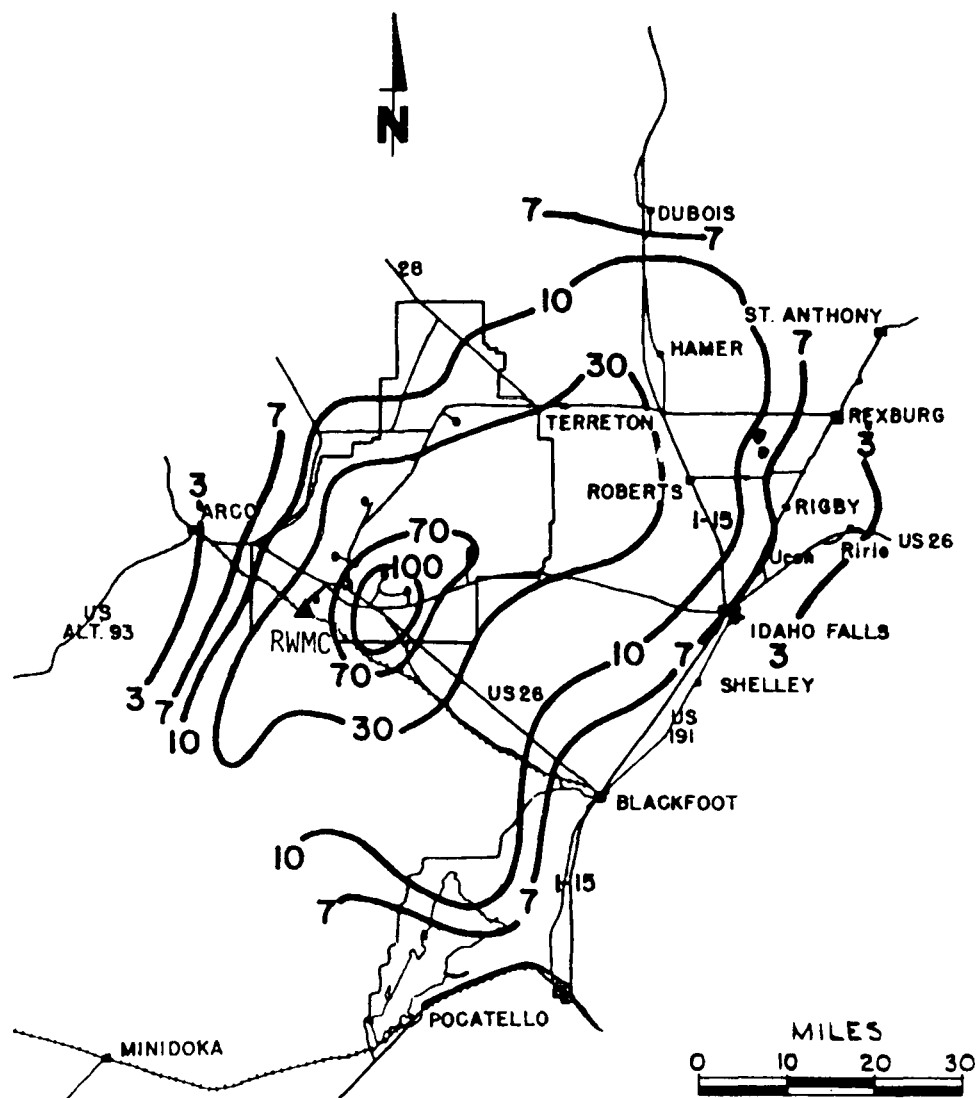


Fig. E-1. Average annual time-integrated concentrations 1972-1977.
(Multiply isopleth values by 10^{-9} for correct magnitude
in hr^2/m^3 .)

Annual average air concentrations, $\chi(\text{Ci}/\text{m}^3)$, for each radionuclide released were calculated by multiplying χ/Q by the annual average release rate, Q (Ci/sec). 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 χ/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 χ/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 deposition rate is related to the mean air concentration by

$$D = (V_d + gr)\chi \quad (\text{E-2})$$

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)

χ = average air concentration (Ci/m^3) of particulate material.

TABLE E-1
MEAN ANNUAL χ/Q (sec/m³) BY SECTOR AND DISTANCE^(a)

Sector	χ/Q For Specified Distance Interval (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^{-9}
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^{-8}	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. χ/Q is determined for the midpoint of each 10-mile radial interval.

The 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 μm AMAD)
 0.005 m/sec (normal operation: particle 0.3 μm AMAD)

g = 4,530 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 of DOE 1979b).

E.4 DISTRIBUTION OF RADIONUCLIDES IN THE SOIL

The distribution of a fallout radionuclide in the surface soil layer has frequently been found to decrease exponentially with increasing depth. The distribution can be approximated by Equation (E-4)

$$S(z) = S(0)\exp(-\beta z) \quad (E-4)$$

in which

z = distance below the soil surface (cm)

$S(z)$ = areal concentration (Ci/m^2) at depth z

$S(0)$ = areal concentration (Ci/m^2) at the surface

β = a parameter that characterizes the distribution (cm^{-1}).

The quantity $1/\beta$ (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 nuclides from atmospheric fallout at various depths below the surface of the INEL. The data (unpublished) from the 1- to 4-cm layer of soil indicate that the distributions of ^{239}Pu and ^{137}Cs are characterized by relaxation lengths of about 2 cm. Data for ^{90}Sr indicate a relaxation length of 3 to 4 cm. The deposition and downward migration have been under way for about 30 yr. The chemical and transport processes that yield the presently observed distributions are not well understood. However, the distributions of fallout nuclides in undisturbed soil at other locations (Essington and Fowler 1977) can also be described using Equation (E-4).

Approximately 40% of the fallout plutonium in the INEL soil lies in the top centimeter. About 60% of the total deposition occurred in the 1962 to 1964 period. Much of the remainder was deposited before that time. Approximately 20% of the total plutonium has moved from the top 1-cm 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, Jakubick used a higher value for the soil moisture content than that found in the relatively arid INEL environment.

E.5 RESUSPENSION OF DEPOSITED MATERIAL

The model of Healy (1974) was used to determine the resuspension in air of particulate matter that had been deposited on the ground. This model was used for both normal operational and accidental airborne puff releases; it is described below. For continuous accidental airborne releases that occur after waste exposure by erosion or flooding, a wind-pickup model was used; it is described in Subsection E.6.

Healy (1974) has examined several ways in which people in and near areas contaminated with plutonium could receive radiation doses from contact with contaminated soil. He found that resuspension was the most important mechanism of exposure. This finding was later confirmed by the U.S. Environmental Protection Agency (EPA 1977) in a detailed review of the surface-contamination problem.

In Healy's approach, two models were used to estimate the radiation doses received by people through the resuspension of deposited material. For the local area (within 50 miles of the representative site), the modified dust-concentration approach (EPA 1977), with airborne particulate concentrations measured in the vicinity of the INEL site (ERDA 1977c), was used to predict local air concentrations of resuspended nuclides. The following equation was used to compute the air concentrations:

$$x = (1.5)(6.67 \times 10^{-2}) x_d S_1 \quad (E-5)$$

where

x = concentration of resuspended radionuclides in air (fCi/m³)

x_d = concentration of dust in air (μg/m³)

S_1 = areal concentration of radioactivity in the top 1 cm of soil
(μCi/m²)

1.5 = enrichment factor (EPA 1977)

The quantity 6.67×10^{-2} contains factors for converting μCi to fCi , μg to g , and the reciprocal of the areal density of 1 cm thickness of soil:

$$(10^9 \text{ fCi}/\mu\text{Ci})(1 \text{ g}/10^6 \mu\text{g})[1/(1.5 \times 10^4 \text{ g}/\text{m}^2)]$$

For INEL and boundary locations, the average airborne concentration χ_d averages $28 \mu\text{g}/\text{m}^3$ (ERDA 1977), and thus Equation E-5 becomes

$$\chi = 2.8S_1 \quad (\text{E-6})$$

The observed average air concentration reflects local variations in snow cover, soil moisture, and wind speed, even though such variations cannot be considered explicitly.

For long-distance diffusion calculations, the resuspension-rate model (Healy 1974) was used with the average areal concentration of activity in the top centimeter of soil (S_1) to obtain a resuspension source term. 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 concluded that the resuspension-rate constant K varied from 10^{-9} to 10^{-8} per second for freshly deposited nuclides, and from 10^{-12} to 10^{-11} per second for older deposits. In the present calculations, an intermediate value of $K = 10^{-10}$ per second was used; it 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. For an existing surface deposit, these effects are described by Equation E-7:

$$dS_1/dt = -(\lambda_r + \lambda_m + \lambda_R)S_1 \quad (\text{E-7})$$

where

S_1 = average areal concentration in the top 1-cm layer (Ci/m^2)

λ_r = radioactive-decay rate constant (per yr)

λ_m = downward-migration rate constant (per yr)

λ_R = resuspension-rate constant (per yr)

Integration yields

$$S_1 = S_{1(0)} \exp (-\lambda_e t) \quad (E-8)$$

where $S_{1(0)}$ is the average initial areal concentration in Ci/m² and $\lambda_e = (\lambda_r + \lambda_m + \lambda_R)$ (per yr).

Equation E-7 was used to describe, for normal operational releases, the time dependence of the resuspension source term in calculations of the local and distant impacts of resuspended soil contamination.

E.6 WIND PICKUP AND TRANSPORT

For continuous accidental airborne releases, the wind-pickup model described below was used to estimate the concentration of radionuclides transported to the public from exposed waste. Over the long term, waste could be exposed because of erosion by wind or floodwater. Persistent wind and localized turbulence acting on the dry waste surfaces could suspend radioactive particles, and the entrained particles could be transported to the public.

Although windblown dust is a common phenomenon in arid environments, the mechanisms of suspension and transport have not been investigated in great detail. A model based on physical principles and limited field data was developed for this study. It was used to calculate airborne dispersion of particulates from saltation (defined below) and particle suspension data, coupled with atmospheric transport and dispersion using MESODIF (Subsection E-2). The air concentrations of suspended radionuclides were calculated for various distances from the source. Suspension of particles from exposed waste is discussed below in terms of a resuspension factor, as used in the discussion in Subsection E-5.

Saltation is a mechanism whereby large airborne particles (larger than 50 microns in diameter) impact on smaller surface particles, causing suspension of the latter in air. It is considered to be the principal mechanism for the airborne movement of fine particles. The suspension of dust by this process has been described by Bagnold (1959).

Agricultural studies of soil erosion by wind indicate that, for the smaller particles, the resuspension factor K is on the order of 10^{-5} per meter. It was assumed that the resuspension factor is dependent on time in the following way:

$$K(t) = K_o \exp(-\lambda_k t) + K_e \quad (E-9)$$

where

K_o = initial resuspension factor ($10^{-5}/m$)

λ_k = resuspension equivalent half-life constant (0.677/yr)

t = time after deposition (yr)

K_e = equilibrium resuspension factor ($10^{-9}/m$)

The particle size distribution of the surface contamination was based on soil measurements at the INEL site. The particles considered were smaller than 10 microns in diameter, the upper limit of respirable particles.

Particle suspension by saltation is mathematically proportional to the cube of the wind velocity (Bagnold 1959; Gillete et al. 1972). Thus, wind characteristics are important in the calculation of particle flux from a surface plane. Although winds blow at variable speeds, an average wind velocity of 7 mph was used to calculate suspension. The saltation rate q was taken to be

$$q = c(v - v_t)^3 \text{ (g/m-sec)} \quad (E-10)$$

where

c = experimental constant ($c = 2.8$) for assumed wide range of particle sizes

v = actual wind speed (m/sec)

v_t = threshold wind speed at which saltation starts (m/sec).

The threshold wind speed v_t used in Equation E-10 can be calculated from

$$v_t = \frac{A}{K_c} \sqrt{\frac{\eta - \rho}{\rho}} g d \ln\left(\frac{Z}{Z_0}\right) \quad (E-11)$$

where

$A = 0.1$ for air

K_c = von Kármán's constant = 0.4

η = density of particles

ρ = density of air

g = gravitational constant

d = diameter of particle (10 microns)

Z = height at which wind speed is measured

$Z_0 = 1$ cm.

The wind pickup rate Q ($\text{g/m}^2\text{-sec}$) can be calculated from the resuspension rate K given by Equation E-9 and the saltation rate given by Equations E-10 and E-11. For particles 0.4 to 6 microns in diameter, the expression is

$$Q = K (\text{m}^{-1}) q (\text{g/m-sec}) \quad (E-12)$$

Suspended dust was expressed in terms of the quantity of particles moving from the ground surface into a horizontal wind stream per unit of time (g/sec). Once suspended, the particles would be dispersed into the 16 population sectors. The source strength (Ci/sec) was obtained by multiplying the suspended mass rate (g/sec) by the specific activity of the particles (Ci/g) for specific areal sources. Given the source strength, the air

concentration was determined from the atmospheric dispersion factors calculated with the MESODIF code.

For purposes of calculating atmospheric transport, the waste area was considered to be a point source, with all the suspended dust being released from the center of the waste surface. For an annual average wind velocity of 7 mph and a source radius of 10 miles, corresponding to the flooding scenario (Subsection 13.4.2.2.2), the airborne concentration of the radioactive dust would not exceed $5 \times 10^{-5} \mu\text{g}/\text{m}^3$ within 10 miles from the assumed point source. This result was based on the peak sector χ/Q value. By comparison, the ambient airborne dust concentration averages $28 \mu\text{g}/\text{m}^3$ for the INEL and boundary locations (ERDA 1977c).

The calculated values for the dust suspension rate are shown in Table E-2. These values, based on average wind speeds, may be low because high-velocity wind events of short duration are not considered. Wind storms can suspend large amounts of dust. The amount of suspension increases with the cube of the wind velocity, as seen from the table.

TABLE E-2
DUST SUSPENSION RATE FOR DIFFERENT RELEASE SCENARIOS

<u>Average Wind Speed (mph)</u>	<u>Dust Suspension Rate (g/sec)</u>	
	<u>Flooding Scenario^(a)</u>	<u>Erosion Scenario^(b)</u>
7	6×10^{-4}	8×10^{-5}
30	7×10^{-2}	1×10^{-3}

(a) The flooding scenario assumes failure of Mackay Dam and distribution of waste over an area of 10 square miles (see Subsection 13.4.2.2.2).

(b) The erosion scenario assumes erosion over 10 acres of waste area (see Subsection 13.4.3.1.4).

E.7 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 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).

Fission and activation products contained in buried waste can be transferred to the human food chain. The most important of these in the INEL environment is ^{137}Cs . The deposition rate of ^{137}Cs from worldwide fallout has been correlated with the concentration of ^{137}Cs in meat. The data fit the equation:

$$C_m = 14.4[D(n) + 0.65 D(n-1) + D(n-2)] \quad (\text{E-13})$$

where C_m is the average meat concentration in pCi/kg in year n , and $D(n)$, $D(n-1)$, and $D(n-2)$ are the annual deposition rates in $\mu\text{Ci/m}^2$ in years n , $n-1$, and $n-2$, respectively (United Nations 1964). The average deposition rate for ^{137}Cs released from waste management facilities was calculated as described in Subsection E.3. This value was used for $D(n)$, $D(n-1)$, and $D(n-2)$ in the computation of the ^{137}Cs concentrations in meat of animals grazing around the INEL.

Maximum equilibrium body burdens and doses for four age groups were computed using the consumption rates given by Soldat (1974) and the age-dependent dose conversion factors developed by Voilleque and Pelletier (1974). The highest postulated dose was received by an adult.

E.8 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 1 Ci, the applicable solution would be

$$\chi = (n_e a)^{-1} XYZ \quad (E-14)$$

where

χ = concentration of the nuclide at a point (x,y) for an instantaneous 1 Ci release (Ci/cm³) 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/cm³)

n = total porosity

K_d = distribution coefficient (cm³/g)

X = $(4\pi D_x t/a)^{-1/2} \exp[-(x-ut/a)^2/(4D_x t/a) - \lambda t]$ (cm⁻¹)

Y = $(4\pi D_y t/a)^{-1/2} \exp[-y^2/(4D_y t/a)]$ (cm⁻¹)

Z = $1/h$ (cm⁻¹)

D_x = dispersion coefficient in the x direction (cm²/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-14) simplifies to:

$$C = \frac{1}{4\pi n_e h t (D_x D_y)^{1/2}} \exp \left[\frac{-(x - ut/a)^2}{4D_x t/a} - \lambda t \right] \quad (\text{E-15})$$

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 distribution coefficients for sand, silt, and clay. Distribution coefficients 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 retardation factors based on the sand distribution coefficients from Staley et al. (1977), effecting the quickest migration and least dilution. Values used for the retardation factor, along with their corresponding K_d values, are listed in Table E-3.

Dispersivities, $\alpha(x)$ and $\alpha(y)$, have been estimated and verified for the ICPP site, 6 miles NE of the RWMC (Robertson 1974). Using the equations

$$D_x = \alpha(x)u \quad (\text{E-16})$$

$$D_y = \alpha(y)u \quad (\text{E-17})$$

TABLE E-3
K_d VALUES AND RETARDATION FACTORS^(a)

Nuclide	K _d Value		Retardation Factor		
	Sand	Silt & Clay	Clay	Silt	Sand
⁵¹ Cr	10	100	340	360	43
²⁴² Cm	70	700	2400	2500	300
⁵⁴ Mn	10	100	340	360	43
¹³⁴ Cs	20	200	690	720	85
⁶⁰ Co	100	1000	3400	3600	420
⁵⁵ Fe	150	1500	5200	5400	630
³ H	0	0	1	1	1
²⁴¹ Pu	200	2000	6900	7200	840
²⁴⁴ Cm	70	700	2400	2500	300
⁹⁰ Sr	2	20	70	73	9
¹³⁷ Cs	20	200	690	720	85
²³⁸ Pu	200	2000	6900	7200	840
²⁴¹ Am	70	700	2400	2500	300
²³⁹ Pu	200	2000	6900	7200	840
⁵⁹ Ni	100	1000	3400	3600	420
⁹⁹ Tc	0.1	1	4	5	2
²³⁷ Np	70	700	2400	2500	300
¹²⁹ I	0.1	1	4	5	2
⁶³ Ni	100	1000	3400	3600	420

(a) Source: Staley et al. 1977.

and $u = 4.3$ ft/day (Codell and Schreiber 1977), the dispersion coefficients were calculated to be $D_x = 1,290$ ft²/day and $D_y = 1,935$ 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.9 DOSE CALCULATIONS

E.9.1 Dose Calculations - General

Both maximum individual and population doses were calculated as defined in Subsections 12.4.6, 12.4.7, and 13.2.2. 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 of DOE 1979b.

The pathways considered for calculating doses included 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 geometric population growth of 1%/yr from 1985 to 2085 was assumed in computing the dose 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.9.2 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

$$D_k = 51.2 \varepsilon_k / m_k \int_0^T q_k(t) dt \quad (E-18)$$

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/dis) (rem/rad)

m_k = mass of the k^{th} tissue (g)

$q_k(t)$ = activity (μCi) of the nuclide present in the k^{th} tissue as a function of time

$$51.2 = 3.7 \times 10^4 \frac{\text{dis/sec}}{\mu\text{Ci}} \times 1.6 \times 10^{-6} \frac{\text{erg}}{\text{MeV}} \times 10^{-2} \frac{\text{rad}}{\text{erg/g}} \times 8.64 \times 10^4 \frac{\text{sec}}{\text{day}} .$$

Values of the parameters ε_k and m_k were obtained from ICRP publications (1959, 1964, and 1975). The functions $q_k(t)$ 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, Strenge, 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 conversion factors (rem/ μ Ci 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 commitment 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 dose commitment conversion factors were used.

E.9.3 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 could be much smaller than the long-term effects of the resulting surface contamination.

All external dose commitment conversion factors for accidental releases were calculated from the EXREM III computer program developed at Oak Ridge National Laboratory (Killough and McKay 1976). For the normal releases, the surface deposition was calculated as described in Subsection E.3. The exposure rate at 1 m in air was then computed using data in Table 9 of Beck et al. (1972). For the relatively short period of operation and decommissioning, the deposited nuclides were assumed to remain on top of the soil and form an unshielded plane source. For the long-term dose calculations, the average relaxation length was assumed to be 2 cm. The soil density was assumed to be 1.5 g/cm³. A quality factor of 1 and the rad/R conversion factors from NBS Handbook 85 (1964) were used. To determine the genetically significant dose,

the multiplicative body screening and dwelling shielding factors of 0.8 and 0.4 (Voilleque and Pelletier 1974) were employed.

The average annual dose from deposited gamma-emitters during normal operations was found using

$$\dot{H} = 0.32 G_p S \quad (E-19)$$

where

$\dot{H}$ = average annual dose rate (rem/yr)

G_p = the product of the 1-m exposure rate for a unit plane source of surface activity, the quality factor, and the rad/R conversion factor and has units (rem/yr)/(nCi/m²)

S = areal activity concentration during operations (nCi/m²).

The maximum value of S was used to calculate the annual external radiation dose to an individual. The average value of S was used for population dose calculations.

E.9.4 Normal Release Population Dose Calculations

As stated earlier, the local population was assumed to grow geometrically at the rate of 1%/yr until 2085, after which it was assumed to remain constant. [See Guideline (6) in Subsection 7.4.1.5.] Figure 3-13 of DOE 1979b illustrates the 80 sectors into which the population is divided. The χ/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

$$\dot{\Sigma}(t) = Q (\chi/Q)(BR)(DCF) P \quad (E-20)$$

where

$\dot{\Sigma}(t)$ = the annual population dose commitment (man-rem/yr)

Q = the release rate of the nuclide ($\mu\text{Ci/sec}$)

χ/Q = the dispersion factor (sec/m^3)

BR = the breathing rate (m^3/yr)

DCF = the organ or tissue dose commitment conversion factor (rem/ μCi 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 1 yr 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 to 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 commitment to an organ from resuspension of a particular nuclide is

$$\dot{\Sigma}(t) = 2.8 \times 10^{-9} S_1 [\exp(-\lambda_e t)] (BR)(DCF)(1.3)P(t) \text{ (man-rem/yr)} . \quad (\text{E-21})$$

The factor of 10^{-9} converts fCi to μCi , 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 $\Sigma(t)$ (man-rem)

$$\Sigma(t) = \frac{3.64 \times 10^{-9} S_{1_0} (BR) (DCF) P(1995)}{(\lambda_e - \gamma)} \{1 - \exp[-(\lambda_e - \gamma)t]\} \quad (E-22)$$

where

S_{1_0} = the initial areal concentration ($\mu\text{Ci}/\text{m}^2$)

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

$$\Sigma(t) = \Sigma(2085) + \frac{3.64 \times 10^{-9} S_{1_0} (BR) (DCF) P(2085)}{\lambda_e} [1 - \exp(-\lambda_e t)] \quad (E-23)$$

$\Sigma(2085)$ 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 geometrically at the rate of 1%/yr until 2085. The resuspension rate approach was used to obtain the source term for long-distance diffusion calculations:

$$Q_r = KAS_{1_0} \exp(-\lambda_e t) \quad (E-24)$$

where

Q_r = resuspension source term ($\mu\text{Ci}/\text{sec}$)

K = resuspension rate (sec^{-1})

A = the area of the 50-mile circle (m^2)

λ_e = the effective source reduction rate 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

$$\Sigma(t) = \frac{S_{10} AK (\chi/Q)' (BR)(DCF)(1.3)P'(1995)}{(\lambda_e - \gamma)} \{1 - \exp [-(\lambda_e - \gamma)t]\} \quad (E-25)$$

where $(\chi/Q)'$ and $P'(1995)$ refer to dispersion factors and populations for the distant locations. For the period after 2085,

$$\Sigma(t) = \Sigma(2085) + \frac{S_{10} AK (\chi/Q)' (BR)(DCF)(1.3)P'(2085)}{\lambda_e} [1 - \exp (-\lambda_e t)]. \quad (E-26)$$

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-4. 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 nondepositing 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).

E.9.5 Accident Population 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

TABLE E-4

ESTIMATED POPULATIONS AND DISPERSION FACTORS FOR DISTANT LOCATIONS

<u>Regions of United States</u>	<u>States Included</u>	<u>Estimated Population Pⁱ (1985)</u>	<u>Estimated Dispersion (χ/Q)ⁱ (sec/m³)</u>
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}

resuspension, as well as external exposure due to contaminated ground. The following equation was used for the inhalation pathway:

$$P_k = \int_0^{50} \exp(-\lambda t) S_o K(t) \cdot BR \cdot DCF \cdot P_o \exp(\gamma t) dt \quad (E-27)$$

where

P_k = population dose commitment within the sector interval
(man-rem)

$\exp(-\lambda t)$ = correction for decay

P_o = population at time zero

$K(t)$ = resuspension function

S_0 = surface contamination at time zero

BR = breathing rate

DCF = dose commitment conversion factor

$\exp(\gamma t)$ = correction for population growth.

For external exposure due to contaminated ground, the equation used was

$$P_k = \int_0^{50} \exp(-\lambda t) S_0 W(t) F P_0 \exp(\gamma t) dt \quad (E-28)$$

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 commitment conversion factors were generated from the INREM code (Killough and McKay 1976), as indicated in Section E.9.2.

E.9.6 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 mixture of the radionuclides given in Table 13-2. An increase in population would increase the doses, while radioactive decay would decrease the doses. Daughter products of nuclides in the original mixture would contribute to the doses. Because each radionuclide has a different radioactive decay rate and different dose commitment conversion factors for each organ, it was necessary to derive the multiplicative factors in Table 13-1, based on a mixture of radionuclides. The effective dose due to each nuclide was taken as the quantity of the nuclide released, multiplied by its dose commitment 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 multipliers in Table 13-1 represent the integration of the time-varying doses of each released nuclide. The time-varying inventory released may be written as:

$$I(t) = I(0)e^{-\lambda t} + \int_0^t f(\tau)\exp[-\lambda(t-\tau)]d\tau \quad (E-29)$$

where

- $I(0)$ = inventory at zero time
- λ = radioactive decay constant
- $f(\tau)$ = rate of inventory increase at time τ .

For a parent nuclide, $f(\tau)$ is zero at $t = 0$. For the daughter products, $f(\tau)$ is a function of the immediate parent nuclide:

$$f(\tau) = I_p(\tau)\lambda_p \quad (E-30)$$

where

- $I_p(\tau)$ = inventory of the parent at time τ
- λ_p = radioactive decay constant of the parent.

The variation of population dose with time is:

$$RD_i(t) = D_i I_i(t) \exp(\gamma t) \text{ for } t < 100 \text{ years} \quad (E-31)$$

$$RD_i(t) = D_i I_i(t) \text{ for } t \geq 100 \text{ years} \quad (E-32)$$

where

$RD_i(t)$ = time-varying effective population dose from the nuclide i (rem)

D_i = dose conversion factor for nuclide i (rem/Ci)

$I_i(t)$ = inventory of nuclide i at time t (Ci)

γ = population growth factor for 1%/yr increase ($9.95 \times 10^3 \text{ yr}^{-1}$).

The time-integrated population dose is calculated by integrating $RD_i(t)$ over time:

$$DT_i = \int_0^T RD_i(t) dt \quad (E-33)$$

For $T < 100$ years:

$$DT_i = \int_0^T D_i \{ I(0) \exp(-\lambda t) + \int_0^t f(\tau) \exp[-\lambda(t-\tau)] d\tau \exp(\gamma t) \} dt \quad (E-34)$$

and for $T > 100$ years:

$$DT_i = \int_{100}^T D_i \{ I(0) \exp(-\lambda t) + \int_0^t f(\tau) \exp[-\lambda(t-\tau)] d\tau \} dt + DT_i(100) \quad (E-35)$$

where

T = time since release (yr)

DT_i = integrated effective dose from time 0 to T (rem-yr).

Equations E-34 and E-35 were solved numerically for each parent nuclide and its daughters. The multiplicative factors were then determined by summing over all nuclides in a chain and then over all chains (double summation), and dividing by the summation of the effective doses of all parent nuclides at release, $t = 0$ (daughter nuclide inventories were assumed to be zero at $t = 0$):

$$MT = \sum_{\substack{\text{All} \\ \text{Chains}}} \sum_{\substack{\text{Daughters} \\ \text{in a Chain}}} DT_i / \sum_{\substack{\text{All} \\ \text{Parents}}} D_p I_o \quad (E-36)$$

where

MT = multiplicative factor for time-integration from 0 to T (yr).

For the case of maximum individual dose, the procedure is the same except that there is no population effect ($\gamma = 0$).

The preceding method indicates the effect of population growth and radionuclide decay on time-integrated risk. Table 13-1 contains a summary of 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 would approach a constant.

APPENDIX F

SCIENTIFIC NOTATION

When dealing with very large or very small numbers, the conventional notation is awkward and cumbersome. Writing 0.0000000000000001, 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 10 that is indicated. If the power of 10 is positive, for example, the decimal is moved to the right the number of places indicated by the power. If the power of 10 is negative, the decimal is moved to the left the number of places indicated by the power. Examples of positive and negative powers of 10 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)
AMAD	activity median aerodynamic diameter
ANL	Argonne National Laboratory
ANL-E	Argonne National Laboratory East
ANL-W	Argonne National Laboratory West
ASME	American Society of Mechanical Engineers
ASWS	Air Support Weather Shield
BLM	Bureau of Land Management
Btu	British thermal unit
c	centi (see Appendix F)
CEQ	President's Council on Environmental Quality
CFA	Central Facilities Area
CFR	Code of Federal Regulations
cfs	cubic feet per second
χ/Q (Chi/Q)	atmospheric dilution factor
Ci	curie
cm	centimeter
CPT	compaction, immobilization, and packaging
D&D	decontamination and decommissioning
DF	decontamination factor
DOE	Department of Energy
DOT	Department of Transportation
DOT Spec	Department of Transportation Specification
EBR-I	Experimental Breeder Reactor I
EG&G	EG&G Idaho, Inc.
EIS	environmental impact statement
EPA	Environmental Protection Agency
ERDA	Energy Research and Development Administration (now DOE)
ERDAM	ERDA Manual
eV	electron volt
EWR	Early Waste Retrieval
f	femto (see Appendix F)

ft	feet
FY	fiscal year
g	gram
gal	gallon
HEPA	high efficiency particulate air (filter)
hr	hour
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)
kWh	kilowatt hour
LASL	Los Alamos Scientific Laboratory (Los Alamos, New Mexico)
LATA	Los Alamos Technical Associates, Inc.
lb	pound
LMV	less massive variation (for shallow land disposal facility)
M	Mega (see Appendix F)
m	meter
m	milli (see Appendix F)
min	minute
ml	milliliter
m/m	man/materials
MMI	Modified Mercalli Intensity
Mound	Mound Facility (Miamisburg, Ohio)
MPBB	maximum permissible body burden
MPC	maximum permissible concentration
mph	miles per hour
mR	milliroentgen
mrem	milliroentgen equivalent man
MSI	Molten Salt Incineration
μ(mu)	micro (see Appendix F)
n	nano (see Appendix F)
NAS	National Academy of Sciences
NBS	National Bureau of Standards

NCRP	National Council on Radiation Protection and Measurements
NOAA	National Oceanic & Atmospheric Administration
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 and maintenance
ORNL	Oak Ridge National Laboratory (Oak Ridge, Tennessee)
OSHA	Occupational Safety and Health Administration
p	pico (see Appendix F)
PKG	packaging only
PLO	Public Land Order
ψ/Q (Psi/Q)	relative time integrated concentration
R	roentgen
R&D	research and development
rem	roentgen equivalent man
RESL	Radiological and Environmental Sciences Laboratory
RF	release fraction
RFP	Rocky Flats Plant (Golden, Colorado)
RWMC	Radioactive Waste Management Complex (INEL)
SDA	Subsurface Disposal Area (part of RWMC)
sec	second
SP	slagging pyrolysis and packaging
TDA	Transuranic Disposal Area (part of RWMC)
TRU	transuranic
TSA	Transuranic Storage Area (part of RWMC)
UBC	Uniform Building Code
USGS	United States Geological Survey
WIPP	Waste Isolation Pilot Plant
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, (e.g., many 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 that emit alpha particles, particularly transuranic elements.

alternative: As used in this report, a general method of managing the TRU waste. For example, Alternative V is "Retrieve as Scheduled, Process, and Dispose of on the INEL."

aluminosilicate: A combined aluminate (aluminum oxide) and silicate (silicon oxide).

aquifer: A water-bearing stratum or zone of permeable rock, sand, or gravel below the surface of the earth.

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 the 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.

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 electron 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. 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. Chelated metal ions are often more soluble than unchelated ions.

chert: A rock resembling flint and consisting essentially of micro-crystalline 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 V, Concept V-A would entail direct-control retrieval, incineration by slagging pyrolysis, followed by 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 the 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 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 a portion of a body.

dosimeter: A device carried on the person for measuring the quantity of radiation to which one has been exposed.

drift: A nearly horizontal mine passageway.

dust palliative: A substance used to reduce or lessen the severity of airborne dust.

ecology: A branch of biological science concerned with the interrelationships of organisms and their concerned environments.

ecosystem: An assemblage of biota (community) and their environment.

effluent: Something that flows out such as waste material discharged to the environment.

erg: A unit of energy or work in the centimeter-gram-second system of units.

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.

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.

finest: Finely crushed or powdered material; very small particles in a mixture of various sizes.

fissile: Material capable of undergoing nuclear fission with neutrons of any energy.

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.

geologic repository: A planned facility for the long-term management of nuclear waste. The waste is isolated by placing it within a geologic formation.

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 in which 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: Formed in or by a lake.

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.

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.

mil: Unit of thickness, 1/1,000 in.

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.

natural background radiation: Radiation in the human environment from naturally occurring elements and from cosmic radiation.

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.

offgas: Gas produced by a reaction or by a process.

overburden: Material overlying a deposit of useful geological materials.

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 medium, such as dust in air.

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.

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 aeri ally 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: Abbreviated 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 that 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 that gives the same biological effect as one roentgen of x rays; one rem approximately equals one rad for X, gamma, or beta radiation.

remote-control retrieval: Retrieval of buried waste in which the retrieval equipment is controlled remotely by operators at a location outside of the retrieval enclosure.

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.

scouring: Erosion, especially by moving water.

seismicity: The tendency for the occurrence of an earthquake.

shale: A finely stratified rock formed by the consolidation of clay, mud, or silt.

sheet flood: Movement of nearly uniform sheets of flood water down the surface of a slope.

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 absorption.

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).

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 radionuclides. 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

Eon	Era	System-Period	System-Period Subdivisions	Series-Epoch	Approx. Age (10 ⁶ yr)	
Phanerozoic	Cenozoic	Quaternary		Recent (Holocene)	0.01	
				Pleistocene	2	
				Tertiary		Neogene
		Miocene				
		Paleogene	Oligocene			62
			Eocene			
		Paleocene				
		Mesozoic	Cretaceous		130	
			Jurassic		180	
			Triassic		230	
	Permian		280			
	Carboniferous		Pennsylvanian	340		
			Mississippian			
	Devonian		400			
	Silurian		450			
	Ordovician		500			
	Cambrian		570			
	Precambrian	Proterozoic			2,600	
		Archean			3,600	
		No record				