DOE/EH-0332P

Disposal of Low-Level and Mixed Low-Level Radioactive Waste During 1990

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U.S. Department of Energy
Assistant Secretary for Environment, Safety and Health
Office of Environmental Guidance
Air, Water and Radiation Division
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ABSTRACT

Isotopic inventories and other data are presented for low-level radioactive waste (LLW) and mixed LLW disposed (and occasionally stored) during calendar year 1990 at commercial disposal facilities and Department of Energy (DOE) sites. Detailed isotopic information is presented for the three commercial disposal facilities located near Barnwell, SC, Richland, WA, and Beatty, NV. Less information is presented for the Envirocare disposal facility located near Clive, UT, and for LLW stored during 1990 at the West Valley site. DOE disposal information is included for the Savannah River Site (including the saltstone facility), Nevada Test Site, Los Alamos National Laboratory, Idaho National Engineering Laboratory, Hanford Site, Y-12 Site, and Oak Ridge National Laboratory. Summary information is presented about stored DOE LLW. Suggestions are made about improving LLW disposal data.

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ACKNOWLEDGMENTS

Several individuals contributed to the development of this report. The author would particularly like to thank the assistance of A. Al-Daouk, J. Betchart, R. Dodge, G. Duggan, J.R. Forgy, J. Fowler, D. Hagel, P. Jenkins, W. Lahs, J. Mack, D. Litteer, C. Martinson, L. O'Neill, E. Regnier, S. Rice, J. Shaffner, S. Storch, and A. Wallo III.

DISPOSAL OF LOW-LEVEL AND MIXED LOW-LEVEL RADIOACTIVE WASTE DURING 1990

I. INTRODUCTION

This report presents isotopic inventories and other data for low-level radioactive waste (LLW) and mixed low-level waste disposed (and occasionally stored) during calendar year 1990 at commercial disposal facilities and Department of Energy (DOE) sites. When waste is delivered to LLW and mixed LLW disposal facilities, disposal facility operators routinely transfer information from waste shipment manifests to computer recordkeeping systems. This report compiles data collected from the different computer systems.

For commercial waste, detailed isotopic data is provided for LLW disposed at the Barnwell, SC, Richland, WA, and Beatty, NV disposal facilities; limited information is presented for waste disposed at the Envirocare disposal facility near Clive, UT. No information is provided about any mixed wastes that might have been disposed at these disposal facilities. (None were permitted to accept the hazardous portion of mixed waste during 1990.)

Almost all information on commercial waste disposal was obtained from the Nuclear Regulatory Commission (NRC), which had purchased the information from the two operators of the three operating commercial disposal facilities: Chem-Nuclear Systems, Inc. (CNSI), the operator of the Barnwell, SC disposal facility, and U.S. Ecology, Inc. (USE), the operator of the Richland, WA and Beatty, NV disposal facilities. Some information about the USE sites was obtained directly from USE. Envirocare provided information about its disposal facility.

Less detailed data is provided for waste that was generated and stored during 1990 as part of the West Valley Demonstration Project (WVDP). For this project, among other activities, DOE is to vitrify high-level waste that had been generated and stored as part of former operation of a commercial fuel reprocessing plant. Since 1986, low-level waste generated from this project has been stored onsite pending completion of an environmental impact statement for site closure.

For DOE waste, isotopic data is provided for LLW and mixed LLW disposed at Savannah River Site (SRS), Nevada Test Site (NTS), Los Alamos National Laboratory (LANL), Idaho National Engineering Laboratory (INEL), Hanford Site, Y-12 Site, and Oak Ridge National Laboratory (ORNL). Data for SRS includes information about waste disposed at the SRS solid waste disposal facility as well as the SRS saltstone facility. Summary information is provided about stored LLW. Information about DOE waste disposal was obtained from DOE field offices and contractors.

Two of the DOE sites -- Hanford and NTS -- disposed of mixed LLW as well as LLW. Herein, "mixed waste" is used as a **general** term to describe waste that contains a mixture of radioactive isotopes and chemically or physically hazardous materials. The current definition of mixed waste in DOE 5820.2A, Radioactive Waste Management, is "waste containing both radioactive and hazardous components as defined by the Atomic Energy Act and the Resource Conservation and Recovery Act [RCRA], respectively" [1]. In practice, however, a broader and varying spectrum of materials are being managed for both their radioactive and hazardous characteristics. State definitions of hazardous materials can differ from one another and from those of the Environmental Protection Agency (EPA). For example, some states have defined used oil as a hazardous waste, while EPA has not [2]. In addition, polychorinated biphenyls (PCBs) are considered hazardous substances, and are regulated under the Toxic Substances Control Act (TSCA) rather than under RCRA.

The remainder of this report contains the following sections:

- Data limitations
- Commercial waste
- WVDP waste
- DOE waste
- Comparisons of commercial waste with DOE waste
- Discussion
- Conclusion

Attached is a list of elements and their symbols, plus three appendices. Appendix A summarizes reported isotopic inventories as a function of Part 61 waste class for the Barnwell, Richland, and Beatty commercial disposal facilities. Appendix B summarizes reported isotopic inventories for the six DOE sites listed above. Appendix C presents correspondence with NRC on overreporting of thorium and other radioactive elements.

II. DATA LIMITATIONS

Caution should be exercised in using the data contained in this report, and in reaching conclusions. First, the data presented in this report is only as complete and accurate as the data placed on shipment manifests by waste generators and transferred to disposal site recordkeeping systems. Waste generators tend to be only as complete and accurate as they are required to be. In addition, the source of all isotopic data used in this report was not the shipment manifests themselves, which are voluminous, but the computer recordkeeping systems. The computer systems reflected varying levels of sophistication. Furthermore, we were forced in some cases to interpret the data obtained from the disposal sites, and to make some approximations. This was especially the case for waste disposal at Hanford and at the SRS saltstone facility. For the saltstone facility, a few months of data from 1991 were included with the 1990 data.

Second, the data stored in the computer systems are subject to change. Changes could occur, for example, if subsequent to waste disposal a waste generator sends a modified shipment manifest to a disposal facility operator. These modifications might reflect an improved estimate of the radionuclide distribution in waste. Consequently, data obtained today about waste disposed during 1990 might be different from data obtained tomorrow for the same time period.

Third, the report represents only a snapshot of waste characteristics, in that only a single year is considered. Several years of data should be necessary to identify trends.

Fourth, the report does not consider radioactive material that was discharged as effluents into air, water, or soil columns at either commercial or DOE sites. Neither does it consider waste that may have been disposed on a generator's site pursuant to requirements in 10 CFR Part 20 or equivalent Agreement State regulation. Furthermore, it does not consider waste that may have been generated and disposed at disposal sites that no longer operate -- e.g., the commercial disposal sites located near Sheffield, IL and Maxey Flats, KY. At these sites, waste might have been generated during 1990 from site maintenance activities. However, disposal of such waste at these sites does not represent a gain in site inventories, but merely a redistribution of the radioactive material already there. West Valley is a different situation, however, and is considered separately.

Fifth, the report provides only limited information about waste that was generated and placed in storage during 1990, rather than delivered to disposal facilities. Waste placed in storage represents an indistinct source term, for a number of reasons. For one thing, waste storage is by definition temporary, and waste volumes and activities held in storage may fluctuate considerably throughout a period of time. In addition, it is often unclear if and when radioactive material, which may have a future use but currently doesn't, should be considered waste. Examples of such material may include unneeded sealed sources or process residues that may contain material that is temporarily uneconomical to recover. In other cases, it may be clear that material should be considered waste, but there may be no intent to dispose of it immediately upon generation. For example, commercial nuclear power plants routinely generate activated metals containing high levels of short-lived activity. For reasons of economics and ease of handling, freshly-generated activated metals might be stored for several years before disposal. Then, a decision to dispose might hinge on other factors such as a need for storage space.

Perhaps of most significance to this report is waste that was generated and placed in storage because of a lack of disposal capacity. Other than economics, three principal reasons why this might occur include (1) the waste is greater-than-Class C (GTCC) waste, (2) the waste is mixed waste, and (3) disposal capacity is otherwise unavailable for some generators.

Regarding GTCC waste, pursuant to the Low-Level Radioactive Waste Policy Amendments Act of 1985 (Amendments Act), disposal of commercially-generated GTCC waste is the responsibility of the Federal government; but because Federal disposal capacity does not yet exist, commercial generators are currently storing any GTCC waste that may be generated. DOE generators are also storing GTCC waste, in compliance with Order DOE 5820.2A which indicates that disposal of DOE-generated GTCC waste must be justified by a specific performance assessment [1].

Regarding mixed waste, relatively small quantities have been identified in commercial LLW, while much larger quantities have been identified in DOE LLW. Mixed waste was not knowingly accepted by any commercial disposal facility operator during 1990, while some mixed waste was disposed during 1990 at the DOE NTS and Hanford sites.

Regarding disposal capacity, except for GTCC waste and mixed waste, most commercial LLW generators that intended to dispose of LLW during 1990 were probably able to do so. There were some exceptions, however. In early February 1990, regulatory agencies in Nevada, South Carolina, and Washington ruled that the District of Columbia, New Hampshire, Puerto Rico, Rhode Island, and Vermont did not comply with a 1 January 1990 milestone set forth in the Amendments Act. As a result, waste generators in Puerto Rico and Vermont were denied access to all three commercial LLW disposal facilities. The District of Columbia, New Hampshire, and Rhode Island were denied access to the Barnwell and Richland disposal facilities [3].

Reduced disposal capacity was available for a number of DOE generators during 1990, and this resulted in storage of much LLW that otherwise might have been delivered to a DOE disposal site. For example, because of a Tiger Team inspection in November 1989, few shipments of waste were delivered to the NTS during 1990 [4]. Persons normally shipping waste to NTS generally stored waste during this time. ORNL was another DOE site that during this time accepted only a limited quantity of waste for disposal.

Only a limited amount of information is presented about waste placed in storage. Regarding storage of commercial wastes, a projection of GTCC waste characteristics is available in [5], and information about mixed waste characteristics is available in [6]. Because [6] provides the results of a survey of commercial LLW generators, and this survey specifically addresses the year 1990, a small amount of the information from [6] is included herein.

Regarding storage of DOE waste, limited isotopic information is available, although general information is presented about volumes and gross activities.

III. COMMERCIAL WASTE

The following information is presented in this section:

- Regulatory drivers;
- Basic volume and activity distributions;
- Volumes and gross activities per waste stream;
- Radionuclides in LLW in significant quantities;
- Distribution of long-lived and other radionuclides;
- Overreporting of long-lived radionuclides; and
- Average concentrations of Part 61 radionuclides.
- Generation and storage of mixed waste

The disposal facility operators provided waste volume data in units of cubic feet, and activity data in millicuries. These units correspond to those used in commercial LLW shipment manifests. Both operators provided volume data to a hundredth of a cubic foot. CNSI provided activity data to a hundredth of a millicurie, and USE to a microcurie. All data was provided in fixed notation.

In this section, all activities are presented in units of curies (Ci).[1] All volumes are presented in units of cubic feet (ft^3). This format allows for easier comparison with commercial LLW disposal information for previous years [7]. (Reference [7] provides commercial LLW disposal information for the years 1987

[1] One curie is equal to 3.7E+10 becquerels under the Système Internationale system of units.

through 1989, as well as a short background about the use of computer systems by commercial disposal facility operators to record information about disposed waste.)

Regulatory drivers. Commercial generators characterize waste as required to complete shipment manifests: according to NRC requirements in Appendix F of 10 CFR Part 20 (formerly in 10 CFR 20.311), or equivalent State regulation; according to Department of Transportation (DOT) regulations in Subpart C of 49 CFR Part 172; and according to disposal facility license conditions and waste acceptance policies imposed by the disposal facility operators. Appendix F indicates that shipment manifests must indicate "as completely as practicable...radionuclide identity and quantity," as well as the total quantity of H-3, C-14, Tc-99, and I-129. Appendix F also requires information about the waste volume, the total activity, the principal chemical form, and the presence of chelating agents. A physical description of the waste must be provided.

Subpart C of 49 CFR Part 172 provides requirements for preparation of shipping papers for hazardous materials, including radionuclides. Among other provisions, Subpart C requires the name of each radionuclide, the activity in each package in the shipment, and a description of the physical and chemical form of the material.

Each of the disposal site operators has devised a manifest form that it requires for shipments of waste to the facilities it operates. The manifest forms are intended to be in compliance with all Federal and State requirements, and have, in fact, been approved by appropriate State regulatory agencies. (State regulatory agencies have prime responsibility for regulating commercial disposal facility operations.) The information on the different manifest forms is similar, but not identical.

NRC provides further guidance on manifesting in its 1983 Technical Position on Waste Classification [8]. This guidance calls for generators to report the four radionuclides listed above, to report the radionuclides listed in 10 CFR 61.55 if they exceed a specified concentration, and otherwise to comply with transportation safety requirements. As a rule of thumb, this vague admonition has been often interpreted to mean reporting any isotope exceeding about 1% of the total inventory in a container. NRC has proposed to codify this interpretation as part of instructions to complete its proposed uniform manifest form [9].

Basic volume and activity distributions. Tables 1 and 2 summarize gross volume and activity distributions for the Barnwell, Richland, and Beatty commercial disposal facilities. Tables 1 and 2 present the same information, although the focus is different: Table 2 emphasizes the comparison of one disposal facility with another.

Table 1. Commercial Gross Volume and Activity Distribution

Site and Class	Volume (ft^3)	Activity (Ci)
Barnwell		
Class A	7.586E+5 (96.3%)	1.714E+4 (3.9%)
Class B	2.316E+4 (2.9%)	4.008E+4 (9.0%)
Class C	6.312E+3 (0.8%)	3.864E+5 (87.1%)
Total	7.880E+5	4.436E+5
Richland		
Class A	2.924E+5 (99.0%)	4.357E+3 (4.7%)
Class B	2.058E+3 (0.7%)	8.797E+4 (94.6%)
Class C	8.085E+2 (0.3%)	6.537E+2 (0.7%)
Total	2.953E+5	9.298E+4
Beatty		
Class A	5.578E+4 (93.8%)	2.966E+3 (26.2%)
Class B	1.312E+3 (2.2%)	5.473E+3 (48.3%)
Class C	2.391E+3 (4.0%)	2.884E+3 (25.5%)
Total	5.948E+4	1.132E+4
Total		
Class A	1.107E+6 (96.8%)	2.446E+4 (4.5%)
Class B	2.653E+4 (2.3%)	1.335E+5 (24.4%)
Class C	9.511E+3 (0.8%)	3.899E+5 (71.2%)
Total	1.143E+6	5.479E+5

Table 2. Commercial Gross Volume and Activity Distribution by Class and Facility

Class	Barnwell	Richland	Beatty	Total
Class A				
Vol. (ft^3)	758,559	292,432	55,776	1,106,767
	(68.5%)	(26.4%)	(5.0%)	
Act. (Ci)	17,140	4,357	2,966	24,464
	(70.1%)	(17.8%)	(12.1%)	
Class B				
Vol. (ft^3)	23,161	2,058	1,312	26,531
	(87.3%)	(7.8%)	(4.9%)	
Act. (Ci)	40,079	87,974	5,473	133,527
	(30.0%)	(65.9%)	(4.1%)	
Class C				
Vol. (ft^3)	6,312	809	2,391	9,511
	(66.4%)	(8.5%)	(25.1%)	
Act. (Ci)	386,374	654	2,884	389,912
	(99.1%)	(0.2%)	(0.7%)	
Total				
Vol. (ft^3)	788,032	295,299	59,479	1,142,810
	(69.0%)	(25.8%)	(5.2%)	
Act. (Ci)	443,594	92,985	11,324	547,903
	(81.0%)	(17.0%)	(2.1%)	

Table 3. Gross Distribution of Volume and Activity in 1990 Class A Waste

Disposal Site	Variable	Class AS[a]	Class AU[a]	Total A
Barnwell	Vol. (ft^3)	9.312E+4	6.654E+5	7.586E+5
	Act. (Ci)	1.243E+4	4.713E+3	1.714E+4
Richland	Vol. (ft^3)	2.282E+3	2.901E+5	2.924E+5
	Act. (Ci)	3.203E+2	4.037E+3	4.357E+3
Beatty	Vol. (ft^3)	5.768E+2	5.520E+4	5.578E+4
	Act. (Ci)	3.442E+1	2.932E+3	2.966E+3
Total	Vol. (ft^3)	9.598E+4	1.011E+6	1.107E+6
		(9%)	(91%)	
	Act. (Ci)	1.278E+4	1.168E+4	2.446E+4
		(52%)	(48%)	

[a] AS: Class A, stable; AU: Class A, unstable.

About 97% of the volume is contained in Class A waste as defined in 10 CFR 61.55. However, Class A waste contains less than 5% of the activity, and just over half of this activity was disposed in a structurally stable form or container pursuant to 10 CFR 61.56 (see Table 3). On the other hand, Class C waste consists of less than 1% of the volume but 71% of the activity. Most (87%) of the activity in Class C waste consists of Co-60 and Fe-55 which have short half-lives.

Consistent with previous years [7], most of the commercial LLW volume and activity was disposed at the Barnwell facility. This preferential disposal at Barnwell is mainly because of its proximity to a greater number of waste generators routinely shipping large quantities of LLW.

Over the past three years [7], and 1991, reported waste volumes and activities have fluctuated:

	1987	1988	1989	1990	1991
Volume (ft^3)	1.845E+6	1.429E+6	1.628E+6	1.143E+6	1.369E+6
Activity (Ci)	2.697E+5	2.598E+5	8.669E+5	5.479E+5	8.002E+5

The rise in 1989 waste volume, followed by the drop in volume in 1990 and the rebound in 1991, was probably caused by waste generator reaction to the 1 January 1990 milestone of the Amendments Act. This milestone may also have influenced the fluctuation in activity. However, significant fluctuations in commercial LLW activity could result simply from relatively minor changes in the quantities of activated metals delivered to disposal facilities. Because activated metals represent a small fraction of the LLW waste volume but a large fraction of the activity, a few shipments more or less can result in a significant difference in disposed activity (see below).

Pursuant to license conditions, in 1990 the Envirocare site accepted only naturally-occurring radioactive material (NORM) in concentrations not exceeding 2 nCi/g. During 1990, 2,227,782.2 ft^3 of waste was accepted from 14 customers, totaling only 6.91 curies of activity. Most of the waste consisted of soil and debris [10].

Volumes and gross activities per waste stream. This section presents a distribution of waste volume and gross activity as a function of waste stream for the Barnwell, Richland, and Beatty disposal facilities.

Tables 4 and 5 present data for the Barnwell facility in two ways. Table 4 presents volumes and activities for each waste stream as a function of waste class. Table 5 is limited to waste volume but provides more information about the physical form of the waste. For example, information is provided about the use of solidification media. In addition, a distinction is made between

Table 4. Barnwell Waste Volume and Activity

by Waste Stream and Class

Waste Stream	Class A	Class B	Class C	Total
Volume (ft^3)				
Resin	1.674E+5	1.854E+4	1.805E+3	1.878E+5
Solid combustibles	4.800E+0	1.801E+2		1.849E+2
Solid noncombustibles	4.263E+4	1.601E+2	3.446E+2	4.313E+4
Filter media[a]	2.100E+4	8.890E+2	3.822E+2	2.227E+4
Cartridge/mechanical filters[b]	6.818E+3	4.696E+2	1.239E+3	8.527E+3
Solidified liquids[c]	1.689E+4	1.381E+3		1.827E+4
Equipment, components	1.380E+3	2.588E+2	2.355E+3	3.993E+3
Biological	6.221E+3			6.221E+3
Incinerator ash	2.909E+3			2.909E+3
Air filtration filters	4.830E+3			4.830E+3
Combustibles and non-combustibles (mixed)	4.884E+5	1.285E+3	1.864E+2	4.899E+5
Total	7.586E+5	2.316E+4	6.312E+3	7.880E+5

Waste Stream	Class A	Class B	Class C	Total
Activity (Ci)				
Resin	1.159E+4	1.642E+4	4.494E+3	3.251E+4
Solid combustibles	1.700E-4	6.903E+1		6.903E+1
Solid noncombustibles	9.064E+1	1.551E+3	3.539E+1	1.677E+3
Filter media[a]	2.545E+3	2.533E+3	6.900E+3	1.198E+4
Cartridge/mechanical filters[b]	5.661E+2	5.496E+2	1.094E+3	2.209E+3
Solidified liquids[c]	4.201E+2	1.474E+3		1.894E+3
Equipment, components	1.927E+1	3.409E+3	3.738E+5	3.772E+5
Biological	3.029E+0			3.029E+0
Incinerator ash	3.454E+1			3.454E+1
Air filtration filters	1.781E+0			1.781E+0
Combustibles and non-combustibles (mixed)	1.866E+3	1.407E+4	4.155E+1	1.598E+4
Total	1.714E+4	4.008E+4	3.864E+5	4.436E+5

[a] Used in liquids and other than resin and cartridges.
[b] Used in liquids.
[c] Includes concentrates and sludges.

Table 5. Barnwell Waste Volume (ft^3) by Waste Stream and Physical Form

Waste Stream	Physical Form	Fuel Cycle	Non Fuel Cycle	Total	Waste Total
Resin	Dewatered	1.702E+5	1.348E+3	1.715E+5	1.878E+5
	Cement	1.467E+4	1.539E+3	1.621E+4	
Solid combustibles	Cement	1.801E+2	4.800E+0	1.849E+2	1.849E+2
Solid non-combustibles	Cement	3.444E+2	2.632E+3	2.976E+3	4.313E+4
	Solid	2.531E+4	1.387E+4	3.918E+4	
	SSD&G[a]	2.112E+2	7.628E+2	9.740E+2	
Filter media[b]	Dewatered	7.970E+3	2.972E+3	1.094E+4	2.227E+4
	Cement	4.989E+3	3.870E+3	8.859E+3	
	Asphalt	2.468E+3		2.468E+3	
Cartridge/mechanical filters[c]	Dewatered	7.847E+3	2.881E+2	8.135E+3	8.527E+3
	Cement	8.720E+1	3.043E+2	3.915E+2	
Solidified liquids[d]	Cement	1.423E+4	4.042E+3	1.827E+4	1.827E+4
	Solid		2.100E+0	2.100E+0	
Equipment, components	Solid	3.850E+3	1.431E+2	3.993E+3	3.993E+3
Biological	Cement		2.668E+2	2.668E+2	6.221E+3
	Solid		5.954E+3	5.954E+3	
Incinerator ash	Cement	1.504E+3	3.465E+2	1.850E+3	2.909E+3
	Solid	7.920E+2	2.671E+2	1.059E+3	
Air filtration filters	Cement		9.350E+1	9.350E+1	4.830E+3
	Solid	3.743E+3	9.933E+2	4.736E+3	
Combustibles & noncombustibles (mixed)	Cement		9.080E+1	9.080E+1	4.899E+5
	Solid	3.360E+5	1.537E+5	4.898E+5	
	Gas		5.452E+1	5.452E+1	
Total		5.944E+5	1.936E+5	7.880E+5	7.880E+5

[a] Sealed sources, devices, and gauges.
[b] Used in liquids and other than resin.
[c] Used in liquids.
[d] Includes concentrates and sludges.

fuel cycle and non-fuel cycle waste, where fuel cycle waste consists of waste from nuclear utilities and uranium fuel fabrication plants. Tables 6 through 9 present data about waste delivered to the Richland and Beatty disposal facilities.

Consistent with previous years [7], activated metals account for most of the activity in commercial LLW -- for 1990 about 69%. Most of this activity consists of short-lived radionuclides such as Co-60 or Fe-55. Using reference [7], we compare the total volume and activity reported in activated metals with total commercial LLW activity for the years 1988 through 1990:

	1988	1989	1990
Metal Volume (ft^3)	1.692E+3	4.970E+3	4.012E+3
Metal Activity (Ci)	1.508E+5	6.413E+5	3.772E+5
Total Activity (Ci)	2.598E+5	8.669E+5	5.479E+5

Activated metals represent a small fraction of the LLW volume, but small fluctuations in the activated metal volume result in large fluctuations in total activity. Comparing 1988 with 1989, activated metal volume increased by 3,278 ft^3, while activated metal activity increased by 490,500 curies and total activity increased by 607,100 curies. Comparing 1989 with 1990, activated metal volume decreased by 958 ft^3, while activated metal activity decreased by 264,100 curies and total activity decreased by 319,000 curies.

In addition, the tables indicate that waste accounting for much of the volume and activity in commercial LLW is described in only general terms. For such waste, it is more difficult to estimate the propensity for release of radioactive isotopes to the environment through mechanisms such as leaching by water. At Richland, 45% of the volume and 93% of the activity is described as a "dry solid." At Beatty, 36% of the volume and 49% of the activity is described similarly.

Radionuclides in LLW in Significant Quantities. Table 10 lists radionuclides reported in commercial LLW in quantities exceeding 100 curies, as summed over the activity disposed in the Barnwell, Richland, and Beatty disposal facilities during 1990. The activity disposed at the Envirocare site is not included, but in any case should be too small to significantly affect Table 10. The thirty listed radionuclides represent 99.9% of all reported commercial LLW activity.

Most of the activity is contributed by only a handful of radionuclides, mainly activation products. This is illustrated by the following list of 13 radionuclides, each accounting for at least 1000 curies:

Table 6. Richland 1990 Waste Volume (ft^3) by Waste Stream and Class[a]

	Class AS	Class AU	Class A	Class B	Class C	Total
Activated reactor hardware		7.500E+0	7.500E+0			7.500E+0
Animal carcasses in lime & sorbent		7.287E+3	7.287E+3			7.287E+3
Aqueous liquid in vials in sorbent		3.731E+3	3.731E+3			3.731E+3
Biological (non-carcass waste)		1.560E+3	1.560E+3			1.560E+3
Cartridge-type filter media	9.980E+1	1.314E+3	1.414E+3	5.000E+1	3.047E+2	1.769E+3
Compacted dry active waste (DAW)		4.616E+4	4.616E+4		1.308E+2	4.629E+4
Dewatered resins	1.658E+3	1.668E+4	1.834E+4	5.294E+2	1.819E+2	1.905E+4
Dry solid	1.593E+2	1.328E+5	1.329E+5	1.360E+3	4.160E+1	1.343E+5
Evaporator bottoms		1.885E+4	1.885E+4			1.885E+4
Non-aqueous liquid in vials in sorbent		7.500E+0	7.500E+0			7.500E+0
Non-cartridge filter media		5.458E+3	5.458E+3			5.458E+3
Non-compacted DAW		1.521E+4	1.521E+4			1.521E+4
Other		1.800E+2	1.800E+2	4.010E+0		1.840E+2
Solidified chelates		1.423E+3	1.423E+3			1.423E+3
Solidified liquid		5.263E+3	5.263E+3	7.500E+0	7.500E+0	5.278E+3
Solidified oil		1.713E+3	1.713E+3			1.713E+3
Solidified resins	3.655E+2	4.414E+3	4.779E+3	1.070E+2		4.886E+3
Sorbed aqueous liquid		2.764E+4	2.764E+4		1.420E+2	2.778E+4
Sorbed non-aqueous liquid		4.775E+2	4.775E+2			4.775E+2
Total	2.282E+3	2.901E+5	2.924E+5	2.058E+3	8.085E+2	2.953E+5

[a] Class AS: Class A-Stable; Class AU: Class A-Unstable; Class A: Total Class A.

Table 7. Richland 1990 Waste Activity (Ci) by Waste Stream and Class[a]

	Class AS	Class AU	Class A	Class B	Class C	Total
Activated reactor hardware		2.400E-2	2.400E-2			2.400E-2
Animal carcasses in lime & sorbent		6.622E+0	6.622E+0			6.622E+0
Aqueous liquid in vials in sorbent		1.148E+1	1.148E+1			1.148E+1
Biological (non-carcass waste)		2.561E+0	1.561E+0			2.561E+0
Cartridge-type filter media	3.884E+1	2.197E+1	6.081E+1	3.748E+1	6.503E+1	1.633E+2
Compacted dry active waste (DAW)		1.489E+2	1.489E+2		9.675E+0	1.585E+2
Dewatered resins	2.528E+2	6.368E+2	8.897E+2	6.595E+2	5.748E+2	2.124E+3
Dry solid	9.800E-2	7.135E+2	7.136E+2	8.609E+4	1.580E-1	8.680E+4
Evaporator bottoms		5.593E+1	5.593E+1			5.593E+1
Non-aqueous liquid in vials in sorbent		3.000E-4	3.000E-4			3.000E-4
Non-cartridge filter media		1.306E+3	1.306E+3			1.306E+3
Non-compacted DAW		3.204E+1	3.024E+1			3.204E+1
Other		2.600E-2	2.600E-2	1.020E-1		1.280E-1
Solidified chelates		6.996E+1	6.996E+1			6.996E+1
Solidified liquid		4.541E+2	4.541E+2	9.500E+2	1.650E+0	1.406E+3
Solidified oil		3.689E+0	3.689E+0			3.689E+0
Solidified resins	2.854E+1	2.762E+2	3.047E+2	2.368E+2		5.415E+2
Sorbed aqueous liquid		2.969E+2	2.969E+2		2.432E+0	2.993E+2
Sorbed non-aqueous liquid		3.500E-2	3.500E-2			3.500E-2
Total	3.203E+2	4.037E+3	4.357E+3	8.797E+4	6.537E+2	9.298E+4

[a] Class AS: Class A-Stable; Class AU: Class A-Unstable; Class A: Total Class A.

Table 8. Beatty 1990 Waste Volume (ft^3) by Waste Stream and Class[a]

	Class AS	Class AU	Class A	Class B	Class C	Total
Activated reactor hardware		1.100E+1	1.100E+1			1.100E+1
Animal carcasses in lime & sorbent		4.498E+3	4.498E+3			4.498E+3
Biological (non-carcass waste)		2.325E+2	2.325E+2			2.325E+2
Cartridge-type filter media		1.013E+2	1.013E+2		5.000E+1	1.513E+2
Compacted dry active waste (DAW)		1.443E+4	1.443E+4			1.443E+4
Dewatered resins		3.750E+1	3.750E+1			3.750E+1
Dry solid	4.493E+2	1.806E+4	1.851E+4	1.147E+3	1.515E+3	2.118E+4
Evaporator bottoms		1.858E+3	1.858E+3			1.858E+3
Non-cartridge filter media		2.643E+3	2.643E+3		7.640E+1	2.719E+3
Non-compacted DAW		9.074E+3	9.074E+3	7.500E+0	1.308E+2	9.212E+3
Other		4.457E+2	4.457E+2			4.457E+2
Solidified liquid	3.000E+1	1.685E+3	1.715E+3	7.500E+0	6.116E+2	2.334E+3
Solidified oil		2.561E+2	2.561E+2			2.561E+2
Solidified resins	9.000E+1	2.550E+2	3.450E+2	1.500E+2	7.500E+0	5.025E+2
Sorbed aqueous liquid	7.500E+0	1.605E+3	1.612E+3			1.612E+3
Total	5.768E+2	5.520E+4	5.578E+4	1.312E+3	2.391E+3	5.948E+4

[a] Class AS: Class A-Stable; Class AU: Class A-Unstable; Class A: Total Class A.

Table 9. Beatty 1990 Waste Activity (Ci) by Waste Stream and Class[a]

	Class AS	Class AU	Class A	Class B	Class C	Total
Activated reactor hardware		3.505E+1	3.505E+1			3.505E+1
Animal carcasses in lime & sorbent		7.015E+0	7.015E+0			7.015E+0
Biological (non-carcass waste)		2.800E-2	2.800E-2			2.800E-2
Cartridge-type filter media		7.222E+0	7.222E+0		3.601E+1	4.323E+1
Compacted dry active waste (DAW)		7.051E+1	7.051E+1			7.051E+1
Dewatered resins		3.800E-2	3.800E-2			3.800E-2
Dry solid	7.125E+0	6.583E+2	6.655E+2	2.978E+3	1.952E+3	5.595E+3
Evaporator bottoms		2.669E+2	2.669E+2			2.669E+2
Non-cartridge filter media		1.831E+3	1.831E+3		6.651E+2	2.496E+3
Non-compacted DAW		1.089E+1	1.089E+1	1.430E+3	3.687E+1	1.478E+3
Other		3.350E-1	3.350E-1			3.350E-1
Solidified liquid	2.270E-1	3.189E+0	3.416E+0	9.500E+2	1.940E+2	1.147E+3
Solidified oil		1.630E-1	1.630E-1			1.630E-1
Solidified resins	2.706E+1	8.980E-1	2.796E+1	1.148E+2	4.890E-1	1.432E+2
Sorbed aqueous liquid	5.000E-3	4.054E+1	4.055E+1			4.055E+1
Total	3.442E+1	2.932E+3	2.966E+3	5.473E+3	2.884E+3	1.132E+4

[a] Class AS: Class A-Stable; Class AU: Class A-Unstable; Class A: Total Class A.

Table 10. Radionuclides in Commercial LLW in Quantities Exceeding 100 Curies

Nuclide	Half-Life (Years)	Activity (Ci) Class A	Class B	Class C	Total
C-14	5.73E+3	1.344E+2	1.769E+1	2.838E+2	4.359E+2
Ce-141	8.90E-2	9.179E+0	2.324E+2	2.591E+0	2.442E+2
Ce-144	7.80E-1	5.068E+1	1.467E+3	1.074E+1	1.529E+3
Co-58	1.94E-1	7.601E+2	1.747E+3	5.739E+3	8.246E+3
Co-60	5.27E+0	5.070E+3	7.882E+3	1.676E+5	1.806E+5
Cr-51	7.62E-2	1.114E+3	1.413E+3	4.601E+3	7.128E+3
Cs-134	2.06E+0	2.796E+2	9.664E+2	8.415E+2	2.088E+3
Cs-137	3.02E+1	7.044E+2	2.339E+3	6.313E+3	9.356E+3
Fe-55	2.69E+0	8.422E+3	5.944E+3	1.711E+5	1.855E+5
Fe-59	1.22E-1	7.931E+1	3.040E+1	3.560E+2	4.657E+2
H-3	1.23E+1	1.377E+3	9.992E+4	3.622E+2	1.017E+5
Hf-175	1.92E-1	2.880E+0		2.667E+2	2.696E+2
Hf-181	1.16E-1	5.556E-1		4.194E+2	4.200E+2
Mn-54	8.55E-1	1.449E+3	1.028E+3	1.262E+4	1.509E+4
Nb-95	9.59E-2	5.369E+1	1.688E+3	2.851E+1	1.770E+3
Ni-59	7.50E+4	5.981E+0	4.442E+1	1.156E+2	1.660E+2
Ni-63	1.00E+2	3.306E+2	2.306E+3	1.367E+4	1.630E+4
Pm-147	2.62E+0	6.857E+0	2.702E+2	1.613E+2	4.384E+2
Ru-103	1.08E-1	4.537E+0	1.483E+2	1.297E+0	1.542E+2
S-35	2.39E-1	2.626E+2	4.732E-3	1.000E-5	2.626E+2
Sb-124	1.65E-1	2.572E+1	2.721E+1	4.965E+2	5.494E+2
Sb-125	2.70E+0	2.205E+1	9.647E+1	3.116E+2	4.301E+2
Sr-89	1.39E-1	2.123E+1	6.066E+2	8.242E-1	6.287E+2
Sr-90	2.88E+1	7.199E+0	3.630E+2	4.392E+3	4.762E+3
Th-232	1.41E+10	3.386E+2	5.342E-2	4.040E-4	3.387E+2
U-238	4.47E+9	1.958E+2	6.671E-2	6.127E-3	1.959E+2
U-DEP[a]	-	1.063E+2		2.000E-2	1.063E+2
Y-91	1.60E-1	2.233E+1	9.568E+2		9.792E+2
Zn-65	6.69E-1	3.171E+3	2.819E+3	6.372E+1	6.054E+3
Zr-95	1.75E-1	4.004E+1	9.225E+2	1.774E+1	9.803E+2
Total		2.407E+4	1.332E+5	3.898E+5	5.471E+5
All nuclides		2.446E+4	1.335E+5	3.899E+5	5.479E+5

[a] U-DEP: depleted uranium.

Nuclide	Activity (Ci)	Contribution (%)	Nuclide	Activity (Ci)	Contribution (%)
Ce-144	1.529E+3	0.3	H-3	1.017E+5	18.6
Co-58	8.246E+3	1.5	Mn-54	1.509E+4	2.8
Co-60	1.806E+5	33.0	Nb-95	1.770E+3	0.3
Cr-51	7.128E+3	1.3	Ni-63	1.630E+4	3.0
Cs-134	2.088E+3	0.4	Sr-90	4.762E+3	0.9
Cs-137	9.356E+3	1.7	Zn-65	6.054E+3	1.1
Fe-55	1.855E+5	33.9			98.8

Cobalt-60 and Fe-55 account for 67% of all reported activity. These two isotopes plus H-3 account for 85% of the activity. Just over 90% of the activity is contributed by these three isotopes plus Mn-54 and Ni-63.

Distribution of long-lived and other radionuclides. Table 11 presents the distribution of long-lived radionuclides over the three Part 61 waste classes, where a long-lived radionuclide is taken *ad hoc* to mean a radionuclide having a half-life exceeding that of Cs-137, or about 30 years. The table presents data summed over the Barnwell, Richland, and Beatty disposal facilities. Any potential contribution from the Envirocare facility is excluded from the table, although we expect that most of the 6.91 curies disposed during 1990 at the Envirocare facility consists of Ra-226. Some of the activity in Table 11 may be contributed by short-lived daughters in equilibrium with thorium or uranium parents.

The half-life of Cs-137 should not be considered a precise demarcation between short- and long-lived radionuclides, but should be considered as the lower end of a rough band of half-lives that extend from a few tens of years to about a hundred years. About 70% of the 200+ radionuclides that were reported in commercial LLW during 1990 have half-lives less (frequently much less) than 30 years. Conversely, Table 11 indicates that the great majority of radionuclides that have half-lives exceeding 30 years have half-lives on the order of thousands or millions of years. Only a handful of radionuclides have half-lives in the approximate range of 30 to 100 years.

Hence, most radionuclides in commercial LLW clearly can be considered short-lived for purposes of waste disposal. For these radionuclides, several hundred years of decay -- such as the decay that would be associated with an institutional control period at a disposal facility -- would be sufficient to significantly reduce their activity. On the other hand, many radionuclides have half-lives lasting for thousands of years or longer. For these radionuclides, several hundred years of decay has essentially no effect on their activity. Finally, a handful of radionuclides, most prominently Ni-63, fall in a gray area. Several hundred years of radioactive decay have a moderate effect

Table 11. Radionuclides in Commercial LLW Having Half-Lives Exceeding that of Cs-137[a]

Nuclide	Half-Life (Years)	Activity (Ci) Class A	Class B	Class C	Total
Ag-108m	1.27E+2	3.000E-5		8.093E-1	8.093E-1
Am-241	4.33E+2	1.261E-1	4.005E-2	3.054E+0	3.220E+0
Am-243	7.95E+3	2.830E-4	8.900E-4		1.173E-3
Bi-207	3.34E+1	3.983E-3		3.000E-6	3.986E-3
C-14	5.73E+3	1.344E+2	1.769E+1	2.838E+2	4.359E+2
Cl-36	3.00E+5	2.008E-1		5.000E-4	2.013E-1
Cs-135	3.00E+6	7.000E-5			7.000E-5
Ho-166m	1.20E+3	4.000E-3			4.000E-3
I-129	1.60E+7	3.293E-1	3.391E-2	4.161E-2	4.048E-1
K-40	1.28E+9	7.380E-4			7.380E-4
Kr-81	2.10E+5	5.500E-2			5.500E-2
Nb-94	2.03E+4	5.578E-2	3.866E-1	8.930E-2	5.316E-1
Ni-59	7.50E+4	5.981E+0	4.442E+1	1.156E+2	1.660E+2
Ni-63	1.00E+2	3.306E+2	2.306E+3	1.367E+4	1.630E+4
Np-237	2.14E+6	6.810E-4	2.000E-5	5.010E-4	1.202E-3
Pd-107	7.00E+6	1.000E-6			1.000E-6
Pt-193	5.00E+1	2.000E-4			2.000E-4
Pu-238	8.78E+1	4.702E-1	8.373E-2	5.413E-2	6.080E-1
Pu-239	2.41E+4	8.241E-2	3.029E-2	1.200E-1	2.327E-1
Pu-240	6.57E+3	1.458E-2	2.947E-3	3.763E-2	5.515E-2
Pu-242	3.76E+5	6.391E-3	1.300E-5	3.000E-6	6.407E-3
Pu-244	7.60E+7	1.500E-5			1.500E-5
Ra-226	1.60E+3	1.621E+1	6.121E-1	4.175E-1	1.724E+1
Rb-87	4.80E+10	4.000E-5			4.000E-5
Re-187	4.30E+7	2.000E-6			2.000E-6
Sm-151	9.00E+1			7.860E-4	7.860E-4
Tc-99	2.14E+5	2.137E+0	9.558E-1	5.352E+0	8.445E+0
Te-123	1.20E+13	2.977E-2			2.977E-2
Th-230	8.00E+4	5.930E-4			5.930E-4
Th-232	1.41E+10	3.386E+2	5.342E-2	4.040E-4	3.387E+2
Th-NAT[b]	-	3.958E+0			3.958E+0
TRU-NOS[b]	-	1.144E-1	3.606E-2	1.522E-2	1.657E-1
U-232	7.20E+1	1.000E-6			1.000E-6
U-233	1.59E+5	2.200E-5		6.000E-6	2.800E-5
U-234	2.45E+5	2.100E+0	3.507E-2	6.620E-4	2.136E+0
U-235	7.04E+8	3.316E+0	5.010E-3	8.420E-4	3.321E+0
U-236	2.34E+7	1.192E-2		3.000E-6	1.193E-2
U-238	4.51E+9	1.958E+2	6.671E-2	6.127E-3	1.959E+2
U-DEP[b]	-	1.063E+2		2.000E-2	1.063E+2
U-NAT[b]	-	1.403E+0	1.070E-4		1.403E+0
Total		1.142E+3	2.371E+3	1.408E+4	1.759E+4

[a] This does not include 6.91 Ci disposed at Envirocare.

[b] Th-NAT: natural thorium; TRU-NOS: transuranic isotopes, not otherwise specified; U-DEP: depleted uranium; U-NAT: natural uranium.

on their activity (e.g., decay of Cs-137 over 500 years reduces its activity by a factor of 96,000, while decay of Ni-63 over 500 years reduces its activity by a factor of 32).

Ni-63 is primarily found in Class C waste, and as it decays, the activity distribution shifts among the three waste classes (Ci):

	Class A	Class B	Class C	Total
Total long-lived activity	1.142E+3 (6%)	2.371E+3 (13%)	1.408E+4 (80%)	1.759E+4
Total activity without Ni-63	8.117E+2 (63%)	6.445E+1 (5%)	4.094E+2 (32%)	1.286E+3

Consistent with previous years [7], Class C waste initially contains the bulk of the LLW activity, followed by Class B waste and then Class A waste. But eventually, Class A waste should contain most of the activity, followed by Class C waste. Class B waste should contain the least activity. The time after disposal that Class C activity drops to Class A levels appears to be largely driven by the decay of Ni-63, and will probably occur within about 300 to 500 years.

Absent Ni-63, most of the long-lived activity in commercial LLW is contributed by Ni-59, C-14, and various uranium and thorium isotopes. Ni-59 is principally reported in activated metal wastes from nuclear power reactors, as is Nb-94. We expect that Ni-63 would be reported in a variety of waste streams from nuclear power reactors, although mostly in activated metals. Uranium and thorium should be found in a variety of waste streams generated by licensees other than nuclear power reactors. Some C-14 is contained in waste generated by nuclear power reactors, although we expect that most is contained in waste from industrial sources (e.g., manufacturers of labeled compounds).

Table 12 lists many of these radionuclides, as well as certain short-lived radionuclides listed in 10 CFR 61.55, as a function of disposal facility. As would be expected, radionuclides found primarily in wastes from nuclear reactors were disposed at the Barnwell facility. However, most tritium was reported disposed at Richland while most C-14 was disposed at Beatty. Neither radionuclide would be expected to be primarily associated with reactor wastes. Most uranium and thorium was reported disposed at Barnwell, as were most plutonium isotopes, while most Am-241 was disposed at Beatty, as was most Ra-226. One would expect that most plutonium isotopes in commercial LLW would be associated with wastes from nuclear reactors, while most Am-241 would be associated with scrap from sealed source and device manufacturers. During 1990, Beatty was the only one of the three LLW disposal facilities that accepted Ra-226 in significant quantities, and probably mostly in the form of sealed radioactive sources.

Table 12. Distribution of Selected Radionuclides by Disposal Facility (Ci)

Nuclide	Richland	Beatty	Barnwell	Total
Am-241	4.892E-02	2.812E+00	3.585E-01	3.220E+00
Am-242	0.000E+00	0.000E+00	1.000E-05	1.000E-05
Am-243	1.000E-06	2.000E-06	1.170E-03	1.173E-03
C-14	8.992E+01	2.410E+02	1.049E+02	4.359E+02
Cm-242	6.674E-03	9.145E-03	2.969E-01	3.127E-01
Cm-243	9.456E-03	1.210E-03	5.897E-02	6.964E-02
Cm-244	5.568E-03	2.232E-01	7.155E-02	3.004E-01
Co-60	1.459E+03	1.319E+03	1.778E+05	1.806E+05
Cs-137	5.741E+02	2.419E+03	6.363E+03	9.356E+03
H-3	8.663E+04	4.885E+03	1.014E+04	1.017E+05
I-129	4.338E-02	7.605E-03	3.539E-01	4.048E-01
Nb-94	4.682E-03	2.415E-02	5.028E-01	5.316E-01
Ni-59	1.013E+00	6.927E-02	1.650E+02	1.660E+02
Ni-63	3.321E+02	3.854E+01	1.593E+04	1.630E+04
Np-237	1.000E-06	5.010E-04	7.000E-04	1.202E-03
Pu-234	0.000E+00	0.000E+00	8.340E-03	8.340E-03
Pu-237	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Pu-238	2.993E-02	1.004E-02	5.781E-01	6.180E-01
Pu-239	5.382E-02	5.498E-02	1.239E-01	2.327E-01
Pu-240	2.338E-02	1.521E-02	1.656E-02	5.515E-02
Pu-241	1.966E+00	8.342E-01	1.657E+01	1.937E+01
Pu-242	8.700E-05	0.000E+00	6.320E-03	6.407E-03
Pu-244	1.500E-05	0.000E+00	0.000E+00	1.500E-05
Ra-226	2.712E-01	1.687E+01	9.639E-02	1.724E+01
Sr-90	1.709E+02	4.711E+02	4.120E+03	4.762E+03
Tc-99	1.483E+00	1.254E+00	5.708E+00	8.445E+00
Th-228	5.570E-04	2.300E-04	0.000E+00	7.870E-04
Th-230	5.910E-04	2.000E-06	0.000E+00	5.930E-04
Th-232	8.760E-02	2.563E-01	3.383E+02	3.387E+02
Th-234	3.000E-06	0.000E+00	1.719E-02	1.719E-02
Th-NAT[a]	3.958E+00	3.600E-05	0.000E+00	3.958E+00
TRU-NOS[a]	0.000E+00	0.000E+00	1.657E-01	1.657E-01
U-232	0.000E+00	1.000E-06	0.000E+00	1.000E-06
U-233	1.100E-05	7.000E-06	1.000E-05	2.800E-05
U-234	2.746E-02	6.418E-03	2.102E+00	2.136E+00
U-235	4.300E-03	1.060E-04	3.317E+00	3.321E+00
U-236	1.330E-04	3.000E-06	1.179E-02	1.193E-02
U-238	8.917E-01	7.340E+01	1.216E+02	1.959E+02
U-DEP[a]	2.240E-02	5.660E-02	1.062E+02	1.063E+02
U-NAT[a]	1.402E+00	6.550E-04	0.000E+00	1.403E+00

[a] Th-NAT: natural thorium; TRU-NOS: transuranic isotopes, not otherwise specified; U-DEP: depleted uranium; U-NAT: natural uranium.

Overreporting of long-lived radionuclides. Although we cannot verify the accuracy of the data reported on commercial LLW shipment manifests, evidence (and human nature) suggests that the activity of some of the radionuclides listed in Table 11 may be overreported.

Some overreporting occurs as part of transfer of manifest information to computer data bases. For example, U.S. Ecology records any radionuclide having an activity of one microcurie or less as one microcurie. This practice is probably driven by equipment and roundoff considerations.

Tc-99 and I-129 are reported mostly in wastes from nuclear power reactors, and as such, are routinely overreported. As observed in [11], generators determine quantities of these radionuclides in reactor wastes by periodically sampling wastes and developing scaling factors to ratio the radionuclides to an easy-to-measure radionuclide such as Cs-137. Because of limitations in the sensitivity of measurement techniques, the analytical results of measurements for these radionuclides (and particularly for I-129) are generally below the lower limit of detection (LLD) for the measurement technique. Generators will then use the LLD's to develop scaling factors. Then, the inventories listed on shipment manifests may or may not be marked as LLD values, and disposal facility operators may or may not record LLD values into computer recordkeeping systems as "real" values.

Reference [11] predicts that I-129 is being overreported by a factor of from 2,800 to 15,000 in wastes from pressurized water reactors (PWRs), and by a factor of from 96 to 560 in wastes from boiling water reactors (BWRs). Similarly, Tc-99 is being overreported by a factor of from 7,100 to 31,000 in wastes from PWRs, and by a factor of from 8.9 to 39 in wastes from BWRs [11]. Because these radionuclides never influence the classification status of wastes from nuclear reactors, over the short term, waste generators can be highly conservative about reporting these radionuclides without jeopardizing their ability to ship waste to LLW disposal facilities. But unfortunately, the total inventories of these radionuclides in disposal facilities tend to strongly influence calculations of impacts caused by possible long-term release of radioactive elements from the disposal facilities. This places disposal facility operators and regulatory agencies in a difficult situation. On the one hand, an inflated source term exaggerates the possible impacts that could be associated with the disposal facility. On the other hand, it is difficult to ignore a citation on a manifest, even if an LLD value, for regulatory compliance as well as practical considerations. One cannot add "less-than" citations to real citations without assuming that all citations are real.

We believe that most C-14 in commercial LLW would be reported by generators other than nuclear reactors. But in wastes from nuclear reactors, [11] indicates that C-14 may be underestimated by a factor of from 8 to 42 in wastes from PWRs, and overestimated by a factor of from 15 to 730 in wastes from BWRs.

Little transuranic activity is reported in commercial LLW, where in 10 CFR Part 61, transuranic activity refers to alpha-emitting transuranic radionuclides having half-lives exceeding five years. (DOE has a different transuranic definition as addressed in Section V.) Nearly 70% of the reported transuranic activity in commercial LLW consists of Am-241.

Because of difficulties in measuring tiny concentrations of plutonium isotopes in reactor wastes, resulting in sample results that can be below LLD levels, inventories of plutonium in commercial wastes are probably somewhat exaggerated, especially for the Barnwell disposal facility. Even before the Part 61 rule was promulgated in December 1982, operators of nuclear power reactors were required to sample wastes and report trace quantities of transuranic isotopes -- generally plutonium isotopes -- that might appear in waste. (Waste in which the activity is dominated by transuranic isotopes is prohibited from disposal at Barnwell, although trace quantities of transuranic isotopes may be accepted when the primary activity is contributed by other radionuclides.) Because of this regulatory emphasis, and because most waste from nuclear utilities has been historically delivered to Barnwell [7], the total quantities of transuranics reported in shipments to Barnwell may be overestimated to a greater degree than at other commercial disposal facilities.

The reported Ni-59 inventory seems slightly elevated. Although we lack a knowledge of the radionuclide inventories specifically within commercial activated metals, we can compare the total inventories of Ni-59 and Ni-63 reported for other years [7]:

	1988	1989	1990	1991
Ni-59 Activity (Ci)	4.968E+1	6.952E+1	1.660E+2	1.878E+2
Ni-63 Activity (Ci)	8.431E+3	2.827E+4	1.630E+4	2.233E+4
Metal Activity (Ci)	1.508E+5	6.413E+5	3.772E+5	6.306E+5

Ratios for the activity of Ni-63 to Ni-59, and total metal activity to Ni-59, are as follows:

	1988	1989	1990	1991
Ratio, Ni-63/Ni-59	170	410	98[a]	120
Ratio, Metal/Ni-59	3,000	9,200	2,300	3,400

[a] In 1990, the Ni-63/N-59 ratio over all DOE waste was 142, and over all submarine waste was 145.

We would not expect a precise correlation between total Ni-59 and total activated metal activities, nor a precise correlation between total Ni-59 and Ni-63 activities. Nonetheless, we do note that the ratios of the activity of Ni-63 to that of Ni-59, and the activity of all activated metals to that of Ni-59, are the lowest in 1990 of the four years considered.

We particularly note the reported quantities of thorium and uranium. At Barnwell, 572 Ci of uranium and thorium were reported in 758,559 ft^3 of Class A waste. On a mass basis, these activities imply delivery of about 0.17 metric tons (MT) per cubic meter of Class A waste:

Nuclide	Act. (Ci)	Mass (MT)	Nuclide	Act. (Ci)	Mass (MT)
U-233	1.0E-5	-	U-238	121.6	365
U-234	2.067	.0003	U-DEP	106.2	295
U-235	3.311	1.5	Th-232	338.3	3,093
U-236	1.2E-2	.0002	Th-234	1.7E-2	-
			Total	571.6	3,755

At Beatty, 73.33 Ci of U-238 were reported in 55,776 ft^3 of Class A waste. This implies about 220 metric tons of U-238, or about 0.14 metric tons per cubic meter of Class A waste.

But most waste generators would not ship uranium or thorium in large quantities -- certainly not utilities, hospitals, or universities. About the only significant source of uranium or thorium waste should be from a few industrial generators such as nuclear fuel fabrication facilities or some source material licensees. We have no data about the number of waste shipments in 1990, but do know that in the years 1987 through 1989, Barnwell received an annual average of 2804 waste shipments, while Beatty received an annual average of 437 waste shipments [7]. During these years, 28% of the volume of all LLW delivered to Barnwell was reported from industrial generators, who reported 58% of all the volume of LLW delivered to Beatty. If we assume that all uranium and thorium was delivered from industrial generators and that all shipments contain the same waste volume (although radiation shielding considerations imply that utility shipments should average smaller volumes than shipments from other generators), and project the average numbers of shipments and generator volume distributions as obtained from [7] to the 1990 data, we conclude that during 1990, shipments from industrial generators to Barnwell averaged about 3.9 metric tons of pure thorium and 0.8 metric tons of pure uranium per shipment. Similarly, shipments from industrial generators to Beatty averaged about 0.9 metric tons of U-238 per shipment.

Because this conclusion appeared unrealistic, we communicated with NRC on the issue of apparent overreporting of uranium, thorium, and other radionuclides. We suspected a situation similar to that for Tc-99 and I-129, where in the short term a grossly conservative estimate of waste intentories might not result in a significant cost penalty for waste disposal.[2] In response, NRC indicated that in general, they believed that the total quantity of uranium was correct but that the thorium inventory may be high. (See Appendix C for copies of correspondence.)

Most uranium appears to be generated from the defense industry. We understand that a single generator (an armaments manufacturer) was responsible for disposal of roughly 90% of the depleted uranium (as uranium conversion slag), and that the person responsible for signing the manifest certifications indicated that the inventories were correct. However this may be, it still leaves the question of the accuracy of the inventories for other uranium isotopes such as U-238.

Regarding thorium, NRC indicated that most thorium was shipped as natural uranium by a single licensee, again performing defense activities. However, when transferring the data on shipment manifests to the disposal site computer recordkeeping system, the Barnwell site operator mistakenly recorded natural thorium (with its daughter activity in equilibrium) as Th-232. NRC thought that the actual quantity of Th-232 was "about one-tenth of what was reported in the inventory by the disposal site operator."

We are unsure about the actual inventories of thorium delivered to the Barnwell site. However, we understand that shipment manifest records suggest that the principal generator of thorium waste delivered slightly over 90% of the thorium activity to the Barnwell site. In turn, this suggests that the actual reported Th-232 inventory during 1990 may be closer to 30-60 curies.

For perspective, we investigated reported uranium and thorium inventories for a few other years, and the results of this investigation is provided below, where data for 1987 through 1989 were obtained from [7], and data for 1991 was obtained from NRC. The results are in units of curies, for total uranium and total thorium, with no corrections to account for misrecording natural thorium at Barnwell:

[2] LLW disposal facilities impose diposal charges on a cubic foot basis, as well as surcharges for shipment activities exceeding a set amount (plus other surcharges). Provided that the activity in the shipment does not exceed the amount required for the surcharge, it may be less expensive to use a quick, conservative, method of estimating waste activity (e.g., multiplying the mass of the waste by the specific activity of uranium or thorium, as applicable) than to expend the resources required for a more accurate estimate. To our knowledge, no waste generator has ever been at regulatory compliance risk by being overconservative.

Disp. Site	Element	1987	1988	1989	1990	1991
Beatty	Th	8.22E-2	3.09E-2	1.01E+0	2.57E-1	1.15E+0
	U	1.10E+2	1.37E+1	1.50E+1	7.35E+1	1.96E+1
Richland	Th	1.04E+1	2.20E+1	8.02E+0	4.05E+0	6.60E+0
	U	3.15E+1	1.73E+1	1.70E+1	2.35E+0	8.59E+0
Barnwell	Th	4.09E+2	4.24E+2	2.80E+2	3.38E+2	1.77E+0
	U	3.39E+2	4.64E+2	4.16E+2	2.33E+2	2.70E+2
Total	Th	4.20E+2	4.46E+2	2.89E+2	3.43E+2	9.52E+0
	U	4.80E+2	4.95E+2	4.48E+2	3.09E+2	2.98E+2

During these years, reported disposal of uranium appears to have been consistent, although one can observe a general decreasing trend, from about 500 to about 300 curies. Most of the uranium was delivered to Barnwell, as was most of the thorium. During 1987 through 1989, all but 90 microcuries of thorium reported at Barnwell was recorded as Th-232 (see [7]). For these years, we suspect a situation similar to that for 1990, whereby actual Th-232 inventories were much less than those recorded. Thorium inventories for 1991 dropped considerably compared with those recorded for previous years.

Average concentrations of Part 61 radionuclides. Table 13 presents average concentrations in commercial LLW, as a function of disposal facility, for the radionuclides listed in 10 CFR 61.55. The citations are in units of Ci/m^3, and were obtained by dividing the total radionuclide activity in the class by the total volume in the class. No alterations were made to account for radionuclide overreporting. The citation for TRU represents the sum of alpha-emitting transuranic radionuclides having half-lifes exceeding five years.

Comparisons with Part 61 Class C limits are provided in Table 14, assuming an average waste density of 2 g/cm^3. In most cases, the average concentrations are more than an order of magnitude below the Class C limits for the radionuclides. Exceptions to this generalization include Class C disposal of C-14 and transuranic radionuclides at Beatty, where average activities in Class C waste averaged, respectively, 3.5 and 0.046 Ci/m^3.[3]

[3] However, only 2400 cubic feet of Class C waste were disposed at Beatty during 1990, and this Class C waste would have been disposed mingled with Class B waste and stable Class A waste. This would reduce the concentration over the mass of stable Class A, B, and C wastes (e.g., C-14 and transuranic concentrations averaged over combined Class B and C wastes are 2.3 and 0.03 Ci/m^3, respectively). In addition, disposal trenches at Beatty are typically dug to depths greater than 50 feet, as are disposal trenches at the Richland commercial facility. Thus, we would expect that Class C waste at these disposal facilities would be disposed at a greater depth than at Barnwell.

Table 13. Average Radionuclide Concentrations (Ci/m^3) in Commercial Waste for Part 61 Radionuclides

Nuclide & Site	Class A	Class B	Class C
Barnwell			
C-14	2.13E-03	2.33E-02	2.45E-01
Cm-242	2.95E-06	8.02E-05	1.01E-03
Co-60	1.56E-01	1.07E+01	9.37E+02
Cs-137	2.94E-02	2.53E+00	2.28E+01
H-3	1.01E-02	1.49E+01	1.01E+00
I-129	1.43E-05	4.96E-05	8.09E-05
Nb-94	1.72E-06	5.89E-04	4.43E-04
Ni-59	2.68E-04	6.66E-02	6.46E-01
Ni-63	1.25E-02	3.32E+00	7.55E+01
Pu-241	3.25E-04	5.95E-03	3.19E-02
Sr-90	2.66E-04	1.57E-01	2.24E+01
Tc-99	6.24E-05	7.15E-04	2.18E-02
TRU[a]	3.82E-05	3.35E-04	1.85E-03
Richland			
C-14	1.03E-02	4.09E-02	1.07E-01
Cm-242	5.30E-07	2.49E-05	3.63E-05
Co-60	8.79E-02	1.05E+01	5.14E+00
Cs-137	7.76E-03	6.83E+00	4.87E+00
H-3	1.28E-01	1.47E+03	1.74E-02
I-129	1.89E-06	2.17E-05	1.16E-03
Nb-94	5.65E-07		
Ni-59	1.98E-05	1.22E-02	6.06E-03
Ni-63	5.64E-03	2.24E+00	6.75E+00
Pu-241	5.77E-05	3.99E-03	5.48E-02
Sr-90	1.13E-04	5.00E-02	7.29E+00
Tc-99	8.05E-05	8.35E-03	1.44E-02
TRU[a]	7.98E-06	2.16E-04	4.04E-03
Beatty			
C-14	2.23E-03	9.53E-04	3.51E+00
Cm-242	3.54E-06	6.73E-07	5.21E-05
Co-60	6.30E-01	7.46E+00	6.81E-01
Cs-137	5.74E-03	7.63E+00	3.14E+01
H-3	6.21E-02	1.24E+02	2.66E+00
I-129	4.33E-06	2.83E-06	9.75E-06
Nb-94	8.93E-06		1.48E-04
Ni-59	4.05E-05	1.41E-04	1.48E-08
Ni-63	9.79E-03	1.89E-02	3.30E-01
Pu-241	2.43E-05	3.39E-05	1.17E-02
Sr-90	3.53E-04	6.92E+00	3.15E+00
Tc-99	8.31E-05	2.31E-06	1.66E-02
TRU[a]	2.95E-06	1.16E-05	4.60E-02

[a] Sum of alpha-emitting transuranic radionuclides having half-lives exceeding five years.

Table 14. Comparison of Class C Concentrations with Part 61 Class C Limits

Nuclide	Class C Limit[a]	Fraction of Limit[b] Barnwell	Richland	Beatty
C-14	8	3.07E-02	1.34E-02	4.38E-01
	(80)	3.07E-03	1.34E-03	4.38E-02
Cm-242	20,000	2.53E-05	9.08E-07	1.30E-06
Cs-137	4600	4.96E-03	1.06E-03	6.83E-03
I-129	0.08	1.01E-03	1.44E-02	1.22E-04
Nb-94	(0.2)	2.22E-03		7.42E-04
Ni-59	(220)	2.94E-03	2.75E-05	6.71E-11
Ni-63	700	1.08E-01	9.64E-03	4.72E-04
	(7000)	1.08E-02	9.64E-04	4.72E-05
Pu-241	3500	4.55E-03	7.83E-03	1.68E-03
Sr-90	7000	3.21E-03	1.04E-03	4.51E-04
Tc-99	3	7.27E-03	4.80E-03	5.53E-03
TRU[c]	100	9.23E-03	2.02E-02	2.30E-01

[a] Limits are in units of Ci/m^3 except for Cm-242, Pu-241, and TRU, which are in units of nCi/g. Citations in parentheses indicate limits for activated metals.

[b] Tabulated values were determined by dividing average Class C concentrations in Table 13 by Class C limits. An average waste density of 2 g/cm^3 is assumed for Cm-242, Pu-241, and TRU.

[c] Sum of alpha-emitting transuranic radionuclides having half-lives exceeding 5 years.

The comparison is uncertain for radionuclides normally found in activated metals, particularly Ni-63. (Ni-63 generally has the most influence over the classification status of activated metal wastes, but is also frequently reported in other waste streams.) We possess no data about the 1990 distribution of Ni-63 within activated metals and other waste streams. However, at the Richland and Beatty sites, activated metals are normally disposed mingled with other waste forms. But at Barnwell, activated metals emitting very high levels of radiation are normally disposed in a separate slit trench. Ni-63 concentrations in waste in the slit trench may be relatively close to the Class C limits for activated metals. Activated metals containing less activity may be disposed in a trench mixed with other Class B, C, and stable Class A wastes.

Generation and storage of mixed waste. Reference [6] presents the results of a survey undertaken by NRC and EPA to compile a national profile on the volumes, characteristics, and treatability of commercially-generated low-level mixed waste for 1990. Five major types of facilities were considered: nuclear utilities, academic facilities, industrial facilities, including fuel cycle and non-fuel cycle facilties, medical facilities, and NRC- or Agreement State-licensed government facilities.

For the purposes of the survey, mixed wastes included oils and sludges as well as other wastes regulated as hazardous wastes solely under state law, but not under the Federal RCRA definition of hazardous waste. Oils and sludges may be listed as a hazardous waste under state law. (EPA at one time considered listing used oil as a hazardous waste but recently decided not to do so [2].) The survey apparently did not specifically request information about PCBs in LLW.

Some of the results of this survey are presented in Tables 15 and 16. Table 15 presents, as a function of type of generating facility, the projected mixed waste volumes generated during 1990 across all commercial LLW generators, the projected mixed waste volumes in storage as of the end of 1990, and the projected mixed waste volumes generated during 1990 for which no treatment capacity is currently available. Generated waste volumes are volumes before treatment. Stored waste volumes include volumes that were being accumulated for planned treatment.

Table 15 does not include the contribution of one generator who reported generation during 1990 of three waste streams consisting of over two million cubic feet of liquid mixed waste. This citation was not included because (1) waste generation appeared to have been a one-time event; (2) the generator had petitioned the appropriate state agency to delist the waste streams (if granted, the wastes would not be considered mixed); and (3) there was concern that inclusion of the wastes would have invalidated

Table 15. Projected Commercial Mixed Waste Volumes Generated, Stored, and Lacking Treatment Capacity[a]

Generator	Amount Generated in 1990 (ft^3)	Amount in Storage as of 12/31/90 (ft^3)	Amount Generated in 1990 Which Lacks Treatment Capacity (ft^3)
Academic	28,982	5,447	353
Government	26,500	2,788	1,455
Industrial	50,430	42,281	834
Medical	19,904	2,227	726
Utilities	13,625	21,984	1,470
Total	139,441	74,727	4,838

[a] Source: [6].

Table 16. Major Reported Commercial Mixed Wastes[a]

Haz. Characteristic	Amount Generated in 1990 (ft^3)	Amount in Storage as of 12/31/90 (ft^3)	Comments
Organics:			
Liq. scintillation fluids	100,196	12,834	Liquid scintillation cocktails and similar organic solvents such as toluene and xylene (H-3, C-14, P-32, P-35, I-125, Ca-45).
Waste oil	5,259	6,290	Various pump, maintenance, and equipment oils (Cs-137, Co-60, Cs-134, H-3, Zn-65, Mn-54).
Chlorinated organics	2,504	953	Chloroform, trichloroethane, methylene chloride, pesticides, and other organochlorides (C-14, H-3, P-32, S-35, I-125).
Fluorinated organics	0	122	No generation.
Chlorinated fluorocarbons (CFCs)	3,998	8,993	Freon, halogenated solvents, and filters contaminated with CFCs from dry cleaning, refrigeration, degreasing, and decontamination operations (Cs-137, Co-60, Mn-54).
Other organics	9,697	4,162	Miscellaneous organic solvents, reagents, and other organic compounds, plus materials such as rags, wipes, etc. contaminated with these compounds, primarily from research labs (C-14, H-3, P-32, S-35, I-125).
Metals:			
Cadmium	9	26,316	Grit blast from decontamination operations and activated reactor control rods (Cs-134, Cs-137, Co-60). Inventory is mainly industrial sewer cleanup waste containing U-238.

Table 15 (Continued)

Haz. Characteristic	Amount Generated in 1990 (ft^3)	Amount in Storage as of 12/31/90 (ft^3)	Comments
Chromium	1,002	1,883	Chromium-contaminated solutions, including chromates or chromic acid from research, maintenance, and waste treatment (e.g., ion exchange (Cr-51, Co-60).
Lead	2,883	4,899	Mainly lead shielding and lead-bearing solutions, the latter from research labs. Some wastes are also corrosive. Also stack ash, penetration sealant, oil, and other wastes containing lead, including industrial batteries (I-125, P-32, Cs-137, Co-60).
Mercury	442	2,865	Mercury and equipment or debris contaminated with mercury, mostly lab derived. Most are also corrosive (H-3, C-14, I-125).
Aqueous corrosives	2,838	431	Inorganic and organic acids (in some cases bases) (H-3, P-32, I-125, C-14, S-35, Co-60, Cs-137).
Other hazardous mats.	10,613	4,979	Various wastes including metal-contaminated organic sludges and aqueous solutions, incinerator ash, alloys, trash, chemicals, biological wastes, and sealed sources (H-3, C-14, P-32, S-35, Co-60, Cs-137, Ni-63, I-125, Cs-134, Cr-51).
Total	139,441	74,727	

[a] Source: [6].

the statistical interpretation of the mixed waste data base and prevented its usefulness as a predictive tool [6].

Table 16 presents a listing of the major types of mixed wastes that were reported, as well as a listing of typical radionuclides found in these wastes [6].

Other than the wastes from the one generator discussed above, mixed waste volumes generated and stored appear to be a fraction of the volumes of LLW that were delivered to LLW disposal facilities during 1990.

IV. WASTE FROM THE WEST VALLEY DEMONSTRATION PROJECT

The Western New York Nuclear Services Center near West Valley, New York, currently owned by the New York State Energy Research and Development Authority (NYSERDA), was the only commercial nuclear fuel reprocessing facility ever to have operated in the United States. From 1966 to 1972, the plant operator, Nuclear Fuel Services Company (NFS), processed about 640 metric tons of spent nuclear fuel assemblies. In so doing, NFS generated about 600,000 gallons of high-level liquid wastes, which have been stored in two steel tanks. In 1972, NFS closed the plant with the intent of expanding it, but in the face of new federal and state regulations that would have significantly increased the required investment, decided to close the plant permanently. The site was returned to NYSERDA [12].

Two disposal areas have operated at the West Valley site. One disposal area is licensed by NRC and was used for disposal of a variety of wastes generated from plant operations. The other disposal area is licensed by the State of New York and was used for commercial disposal of low-level waste received from off-site generators. It operated from November 18, 1963 to March 11, 1975 [13]. After disposal operations ceased at the State-licensed disposal facility, small quantities of wastes continued to be generated from maintenance of the closed reprocessing plant and were disposed in the NRC-licensed disposal area.

In 1980, Congress passed the West Valley Demonstraton Project Act, which authorizes DOE, among other activities, to demonstrate solidification of the liquid high-level waste, to develop containers suitable for disposal, and to eventually transport the solidified high-level waste to a Federal repository. In addition, DOE is to decontaminate and decommission various tanks, facilities, and equipment used for the project, and to dispose of low-level and transuranic wastes produced by the project. For purposes of the project, the Act defines transuranic waste as "material contaminated with elements which have an atomic number greater than 92, including neptunium, plutonium, americium, and curium, and which are in concentrations greater than 10 nanocuries per gram, or in such other concentrations as the

[Nuclear Regulatory] Commission may prescribe to protect the public health and safety." In carrying out the project, the law requires DOE to consult with NRC (and others) with respect to the project, although NRC does not have licensing authority over DOE's project activities.

DOE assumed control of the West Valley premises in February 1982 [12]. As part of project activities, various solidified materials, sludges and resins, dry active waste, gravel, rubble, and other wastes have been generated. From 1982 through 1986, about 5,786 m^3 (204,300 ft^3) of waste was generated, containing 625 curies of activity, and disposed at the NRC-licensed disposal area [13]. However, a question arose regarding the disposal status of certain wastes which were to be generated as part of pre-treatment of the liquid high-level wastes to remove inert constituents such as water and sodium salts. Pre-treatment produces a contaminated liquid waste stream that was to be solidified in cement into square 71-gallon drums. This waste was projected to contain transuranic isotopes in concentrations exceeding 10 nCi/g. NRC took the position that existence of the Part 61 classification system, which prescribes a 100 nCi/g limit for Class C low-level waste, did not automatically constitute a redefinition of transuranic waste pursuant to the West Valley Demonstration Project Act. In addition, a lawsuit was filed by various groups that addressed, among other things, disposal of waste generated by the project.

In a May 1987 compromise settlement with the Coalition of West Valley Nuclear Waste, DOE agreed to include the disposition of LLW and transuranic waste in a planned environmental impact statement for project and site closure [14]. Therefore, since the beginning of 1987, wastes generated as part of the project have been stored in engineered facilities pending completion of the environmental impact statement and a decision about the disposition of the wastes [13]. As of March 1992, over 10,000 71-gallon drums of solidified wastes had been placed in storage, along with other wastes [12].

Tables 17 and 18 present a summary of the wastes that were placed in storage during 1990, which totaled (5,015 m^3) 177,073 ft^3 [15]. Some of the stored waste has been classified pursuant to 10 CFR Part 61, and some has not. Average radionuclide-specific concentrations for the classified wastes are presented, as are the total activity and volume. Estimated total activity and volume for the unclassified wastes are also presented. The total activity, including classified and unclassified wastes, is estimated to be 1,199 Ci.

Table 17. LLW Placed in Storage at West Valley During 1990[a]

Nuclide	Cement-Solidified Supernatent	Sludges & Resins	Soil	Dry Active Waste Boxes	Dry Active Waste Drums
Cs-137[b]	1.74E-1	2.49E-3	1.41E-2	5.24E-2	1.19E-3
Sr-90	2.41E-1	3.83E-3	1.41E-2	5.24E-2	1.19E-3
Tc-99	5.34E-1	4.97E-7	2.81E-6	1.05E-5	2.37E-7
I-129	7.00E-5	1.00E-9	3.80E-8	2.60E-8	5.94E-10
Ni-59	3.55E-5				
Ni-63	2.36E-3	2.48E-7	1.41E-6	5.24E-6	1.18E-7
Cs-134		6.22E-6	1.16E-4	4.33E-4	3.16E-6
Pm-147		1.02E-4	1.91E-3	7.13E-3	5.18E-5
Sm-151		1.86E-5	3.48E-4	1.30E-3	9.44E-6
Eu-154		1.86E-4	3.48E-4	1.30E-3	9.44E-6
Eu-155		4.19E-6	7.84E-5	2.92E-4	2.13E-6
Co-60	2.72E-6	2.96E-5	5.21E-5	1.94E-4	1.68E-5
C-14	7.01E-4	7.95E-10	1.00E-9	4.00E-9	9.71E-11
Sb-125	6.12E-3	1.39E-5	2.61E-4	9.73E-4	7.09E-6
H-3	9.15E-4				
Total Pu[c]	2.18E+1	1.81E-2	1.02E-3		
Pu-241	1.92E+2	3.13E-1	7.08E-3	5.91E-3	8.17E+0
Am-241	2.23E-2	1.49E-2	2.37E-4	1.96E-4	2.72E-1
Total Class. Act. (Ci)	7.80E+1	1.64E-1	4.38E+1	2.53E+1	4.70E-2
Tot. Est. Un-class. Act. (Ci)	1.05E+3	2.42E-1	3.09E-1	1.19E+0	2.20E-2
Volume (ft^3)	3.55E+4	2.07E+3	4.94E+4	8.75E+3	
Net weight (#)	3.40E+6	7.22E+4	3.81E+6	2.86E+5	
Volume Clas-sified (ft^3)	2.11E+3	8.31E+2	4.92E+4	7.65E+3	5.00E+2

[a] Total volume: 117,073 ft^3; total activity of classified waste: 149.88 Ci; total estimated activity of unclassified waste: 1049.553 Ci.
[b] Units for Cs-137 and other radionuclides are Ci/m^3.
[c] Units for total plutonium and other transuranics are nCi/g.

Table 17 (Continued)

Nuclide	Gravel & Rubble	Miscellaneous	Processed, Compacted, Reclassified, Repackaged Waste
Cs-137[b]	5.86E-3	6.76E-2	2.14E-3
Sr-90	8.06E-3	6.76E-2	2.16E-3
Tc-99	5.02E-3	1.34E-5	4.28E-7
I-129	8.82E-7	3.30E-8	1.00E-9
Ni-59	1.14E-6		
Ni-63	7.68E-5	6.76E-6	2.13E-7
Cs-134	4.56E-5	8.13E-6	1.23E-5
Pm-147	7.50E-4	1.34E-4	2.03E-4
Sm-151	1.37E-4	2.43E-5	3.69E-5
Eu-154	1.37E-4	2.43E-5	3.69E-5
Eu-155	3.06E-5	5.48E-6	8.31E-6
Co-60	2.07E-5	9.17E-5	3.18E-5
C-14	1.42E-5	5.00E-9	2.16E-10
Sb-125	2.11E-4	1.82E-5	2.77E-5
H-3	1.92E-5		
Total Pu[c]	2.92E-1	3.02E-4	3.41E-4
Pu-241		9.53E+0	3.91E-1
Am-241	1.29E-3	3.17E-1	1.33E-1
Total Class. Act. (Ci)	1.68E+0	6.80E-2	7.93E-1
Tot. Est. Unclass. Act. (Ci)	2.37E-1	4.53E-1	1.10E+0
Volume (ft^3)	3.53E+3	5.07E+3	1.27E+4
Net weight (#)	2.66E+5	1.37E+4	5.15E+4
Volume Classified (ft^3)	3.40E+3	6.62E+1	1.30E+3

[a] Total volume: 117,073 ft^3; total activity of classified waste: 149.88 Ci; total estimated activity of unclassified waste: 1049.553 Ci.

[b] Units for Cs-137 and other radionuclides are Ci/m^3.

[c] Units for total plutonium and other transuranics are nCi/g.

Table 18. Summary of Disposal Containers Used for West Valley Demonstration Project Wastes

Waste Stream	Description of Containers
Cement-solidified supernatent	9.19 ft^3 square steel drums
Sludges & resins	7.35 ft^3 steel drums 9.19 ft^3 square steel drums
Soil	70 & 90 ft^3 steel boxes 7.35 ft^3 steel drums
Dry active waste	90 ft^3 steel boxes (high density) 7.35 ft^3 steel drums (low density)
Gravel & rubble	7.35 ft^3 steel drums 70 ft^3 steel boxes 90 ft^3 steel boxes
Miscellaneous	Various poly. and steel drums Various steel boxes
Processed, compacted reclassified, repackaged waste	Various poly. and steel drums Various steel boxes

V. DOE WASTE

This section summarizes volumes and isotopic inventories for solid low-level and mixed low-level wastes disposed during 1990 at DOE sites. Isotopic inventories for seven DOE sites where waste disposal took place are listed in Appendix B.

Volume data was generally provided by the sites in units of cubic meters; activity data was always provided in units of curies. The data was provided in a mixture of scientific and fixed notations over a range of significant figures. Inventories for some isotopes were sometimes provided as zero quantities. For data provided in scientific notation, we assumed that although the isotope was reasonably expected to be present, no activity was reported for that isotope for that year. For data provided in fixed notation, we were unsure whether the citation represented truncation or "none reported."

Occasionally, the sites provided isotopic data using special notations. An example is the notation "Pu-52" to signify a mixture of plutonium isotopes including Pu-238, Pu-239, Pu-240, Pu-241, and Pu-242. Another special notation is the denotation of radionuclide pairs in the data for the Hanford site. Many radionuclides -- e.g., Sr-90 and Y-90 -- normally exist in secular equilibrium, and the Hanford notation serves as a reminder of this situation. However, the listed activities only apply to the parent of the equilibrium pair.

Some sites (particularly Hanford) provided data as a mixture of activity and mass units. In addition, alone among all DOE and commercial disposal sites, when a disposal manifest is received that cites one of several isotopes such as Cs-137 that contain daughters in equilibrium, in the process of transferring the manifest data to the site computer recordkeeping system, Hanford personnel add the activity of the daughters to the total disposed activity for the site. But they don't identify these daughters specifically in the computer system but merely include the added activity with the total beta-gamma activity computed for the site (see Appendix B).

To reduce the data to common units, we converted mass quantities to curies according to several assumptions as described in Appendix B. Then, total inventories were summed as a function of disposal site and across all DOE disposal sites. In so doing, zero quantities were eliminated. Equilibrium pairs denoted by Hanford were added to the appropriate parents reported by other sites (i.e., Cs137-Ba137m activity disposed at Hanford was added to Cs-137 activity disposed at ORNL). In addition, we added daughter products to the Hanford data in a manner comparible with the Hanford practice for recording and storing disposal data.

We added data for the SRS saltstone facility to the DOE inventory even though the data obtained for the saltstone facility included waste disposed for a few months of 1991 in addition to 1990. We decided to include the SRS data because it was by far the most significant source of Tc-99 in DOE waste during 1990. Total activity, however, was very low (67 curies).

The remainder of this section summarizes regulatory drivers, gross volume and activities disposed at the sites, radionuclides present in DOE waste in significant quantities, long-lived radionuclides, and the distributions of selected radionuclides by site. No data was obtained about the distribution of volume and activity within different DOE waste streams. In addition, we make some brief comparisons between the information presented here and that reported to DOE's Integrated Data Base (IDB). Finally, we present some limited information about DOE LLW placed in storage during 1990.

We generally present the results to three significant figures, which corresponds to the number of significant figures provided in the SRS solid waste disposal data. It should not be interpreted as an estimate of the actual accuracy of the data. Volumes are provided in units of both cubic feet and cubic meters to facilitate comparison with data for commercial sites.

Regulatory drivers. Basic requirements for characterizing and reporting radionuclides in DOE wastes are contained in DOE 5820.2A, Radioactive Waste Management [1]. Section III.3.d.2 of DOE 5820.2A addresses waste characterization. It requires recording "major radionuclides and their concentrations" on waste manifests, as well as other information such as the physical and chemical characteristics of the waste, the waste volume and weight, and the package weight and external volume. Section III.3.m.2 addresses waste manifests. It requires the "quantity of each major radionuclide present" as well as the waste physical and chemical characteristics, the weight and volume of the waste, and any other data necessary to determine compliance with disposal site waste acceptance criteria. This and other DOE Orders (e.g., [16]) incorporate by reference DOT requirements for shipments of radioactive material.

Otherwise, requirements for radionuclide characterization vary depending on the specific language of disposal site waste acceptance criteria. For waste delivered to DOE disposal sites during 1990, some sites were less stringent than commercial practices, while other sites were as stringent or perhaps more so. Some sites specified particular radionuclides that should be identified and quantified if present in waste; other sites did not. Some sites required reporting any radionuclide in quantities exceeding 1% of the total activity within a disposal container; others sites were less stringent.

Since 1990, many DOE sites have modified waste acceptance criteria to specify in more detail requirements for characterizing waste and reporting radionuclides. This process is continuing, and further modifications should be expected in response to an ongoing DOE effort to revise Order 5820.2A.

Gross waste volumes and activities. Table 19 lists gross waste volumes and activities in DOE low-level and mixed low-level wastes as obtained from DOE field offices and contractors. Most of the waste volume was disposed at SRS, while most of the activity was disposed at INEL and Hanford.

Of the 68,400 m^3 (2,420,000 ft^3) of waste listed in Table 19, containing 546,000 Ci, about 10,400 m^3 (366,000 ft^3) was mixed waste, containing 249,000 Ci. Mixed waste totaled 4,970 m^3 (175,000 ft^3) at NTS (29 Ci) and 5,395 m^3 (190,500 ft^3) at Hanford (249,000 Ci). The Hanford mixed waste consisted primarily of submarine reactor compartments containing lead and very small quantities of PCBs.

Radionuclides in DOE LLW in significant quantities. Table 20 lists radionuclides reported in DOE waste in quantities exceeding 100 curies, not including the contribution from LLW placed in storage during 1990. Similar to commercial LLW, only a few radionuclides dominate the total activity, although there are differences in the distribution of radionuclide activity. According to the data provided by the sites, 88% of the activity reported in DOE waste was contributed by Co-60, H-3, Fe-55, and Ni-63. Otherwise, Co-58, Cs-137, Cr-51, Sn-119m, and Mn-54 constituted, respectively, about 5%, 0.6%, 2%, 0.5%, and 3% of the total reported activity. These 9 radionuclides contributed 98.9% of all reported activity in DOE waste. About 0.1% of the activity was described only as mixed activation products.

Radionuclides having long half-lives. Table 21 lists radionuclides having long half-lives. Similar to Table 12 for commercial LLW, the half-life of Cs-137 is used as an approximate demarcation between short- and long-lived radionuclides. Again, however, the half-life of Cs-137 should be regarded as the lower end of a band of half-lives that extends from a few tens of years to about a hundred years.

About 99% of the activity listed in Table 21, which totals 129,000 Ci, consists of Ni-63, and 0.7% Ni-59. About 0.02% consists of C-14. The citations in Table 21 do not include any long-lived radionuclides that may be associated with mixed activation or mixed fission product activity, but may include small quantities of short-lived daughter activity in equilibrium with long-lived parents, or possibly some short-lived transuranic isotopes such as Pu-241.

Table 19. DOE Gross Volume and Activity Reported Disposed by Site[a]

DOE Site	Activity (Ci)	Volume	
		Cubic Feet	Cubic Meters
SRS Solid Waste	2.65E+4	8.46E+5	2.39E+4
SRS Saltstone	6.73E+1	2.14E+5	6.05E+3
NTS	1.46E+4	4.98E+5	1.41E+4
LANL	9.09E+2	1.60E+5	4.53E+3
INEL	2.08E+5	6.22E+4	1.76E+3
Hanford	2.96E+5	4.73E+5	1.34E+4
ORNL	7.20E+2	8.98E+3	2.54E+2
Y-12	6.00E+0	1.54E+5	4.36E+3
Total	5.46E+5	2.42E+6	6.84E+4

[a] Does not include low-level and mixed wastes placed in storage during this year. (See Appendix B.)

Table 20. Radionuclides in DOE Waste in Quantities Exceeding 100 Curies

Nuclide	Half-Life (Years)	Activity (Ci)	Percent of Total
Ba-137m	4.86E-6	2.29E+2	4.19E-2
Co-58	1.94E-1	2.51E+4	4.60E+0
Co-60	5.27E+0	1.97E+5	3.61E+1
Cr-51	7.62E-2	9.91E+3	1.81E+0
Cs-137	3.02E+1	3.12E+3	5.71E-1
Eu-152	1.36E+1	1.00E+2	1.83E-2
Eu-154	8.80E+0	1.08E+2	1.98E-2
Fe-55	2.69E+0	6.98E+4	1.28E+1
Fe-59	1.22E-1	6.39E+2	1.17E-1
H-3	1.23E+1	8.49E+4	1.56E+1
Mn-54	8.55E-1	1.88E+4	3.43E+0
MAP[a]	-	6.38E+2	1.17E-1
Nb-95	9.59E-2	1.06E+3	1.95E-1
Ni-59	7.50E+4	9.03E+2	1.65E-1
Ni-63	1.00E+2	1.28E+5	2.35E+1
Sb-125	2.70E+0	7.80E+2	1.43E-1
Sn-119m	6.85E-1	2.82E+3	5.15E-1
Sr-90	2.88E+1	5.24E+2	9.59E-2
Y-90	7.32E-3	1.84E+2	3.37E-2
Zr-95	1.75E-1	7.82E+2	1.43E-1
Total		5.46E+5	9.99E+1
All nuclides		5.46E+5	1.00E+2

[a] MAP: mixed activation products.

Table 21. Radionuclides Having Half-Lives Exceeding that of Cs-137

Nuclide	Half-life (yr)	Activity (Ci)
Am-241	4.33E+02	1.07E+00
Am-243	7.95E+03	1.04E-03
Be-10	1.60E+06	2.82E-07
C-14	5.73E+03	3.11E+01
Cl-36	3.00E+05	3.52E-03
I-129	1.60E+07	1.24E-02
K-40	1.28E+09	1.06E-02
Mo-93	3.50E+03	5.85E-02
Nb-94	2.03E+04	9.22E-02
Ni-59	7.50E+04	9.03E+02
Ni-63	1.00E+02	1.28E+05
Np-237	2.14E+06	9.91E-03
Pa-231	3.28E+04	6.84E-03
Pu[a]	-	5.98E-01
Pu-238	8.78E+01	4.27E-01
Pu-239	2.41E+04	1.13E-01
Pu-240	6.57E+03	4.49E-04
Pu-242	3.76E+05	1.57E-07
Pu-52[a]	-	3.07E+01
Ra-226	1.60E+03	3.80E-01
Rb-87	4.80E+10	1.51E-09
Re-187	4.30E+07	2.00E-04
Se-79	6.50E+04	1.00E-01
Sm-147	1.06E+11	2.00E-04
Sm-151	9.00E+01	5.85E-01
Sn-126	1.00E+05	3.00E-01
Tc-99	2.14E+05	4.01E+01
Th-232	1.41E+10	5.05E+00
Th-88	-	2.00E-09
Total alpha	-	2.00E-01
U-232	7.20E+01	3.21E-02
U-233	1.59E+05	1.82E-02
U-234	2.45E+05	4.06E+00
U-235	7.04E+08	6.64E-01
U-236	2.34E+07	1.07E-01
U-238	4.51E+09	1.12E+01
U-38[a]	-	2.00E-02
U-81[a]	-	3.46E-06
U-DEP[a]	-	1.38E+01
U-ENRICH[a]	-	9.90E-01
U-NAT[a]	-	7.22E-03
Zr-93	1.53E+06	3.00E-05
Total		1.29E+05

[a] Pu: unspecified Pu; Pu-52: plutonium, including Pu-238, Pu-239, Pu-240, Pu-241, & Pu-242; Th-88: total thorium; U-38: uranium enriched between 92 and 94%; U-81: normal uranium (0.711%); U-DEP: depleted uranium; U-ENRICH: unspecified enriched uranium; U-NAT: natural uranium.

Distribution of Selected Radionuclides by Site. Table 22 lists several selected radionuclides as a function of disposal site, including several long-lived radionuclides as well as shorter-lived radionuclides cited in 10 CFR 61.55. A complete listing of radionuclides reported as a function of disposal site is provided in Appendix B.

Most Ni-59 and Ni-63 activity was disposed at Hanford, although significant quantities were also disposed at INEL. However, although most Nb-94 was reported disposed at Hanford, relatively little Nb-94 was reported disposed at INEL. About as much Co-60 was reported disposed at Hanford as was reported disposed at INEL. Most Cs-137 was reported disposed at INEL while most Sr-90 was reported disposed at ORNL. Most Tc-99 was reported disposed at the SRS saltstone facility, as was most I-129, while most C-14 was reported disposed at Hanford. Otherwise, plutonium was mostly reported disposed at NTS, and most Th-232 at SRS, although uranium was distributed through a number of DOE disposal sites.

Comparisons with IDB report. We estimated 546,000 curies of activity in 1990, which may be compared with the 297,000 curies of activity reported for 1990 in the 1991 IDB report [13]. In the 1992 IDB report, the total activity for 1990 was changed to 588,000 curies [17]. Neither IDB report lists activities as a function of disposal site, although the IDB program does maintain this data. Below, we compare the activities provided by each DOE site, as well as total activities, with the LLW activities supplied by the DOE sites [18] for the IDB Report for 1991 [13]:

DOE Site	LLW Activity (Ci) Provided to 1991 IDB[a]	Activity (Ci) Provided or Calculated for this report
SRS	26,675	26,500
SRS Saltstone	-	67
NTS	14,610	14,639
LANL	900	909
INEL	207,600	207,500
ORNL	720	720
Y-12	6	6
HANF	>46,468	295,800
	297,000	546,000

[a] Source: [18].

LLW volumes for 1990 as listed in Table 4.4 of the 1991 and 1992 IDB reports are provided below [17], as well as waste volumes provided to us by the individual sites:

Table 22. Distribution of Selected Radionuclides as Reported by DOE Site (Ci)

Nuclide	SRS Solid Waste	SRS Saltstone	NTS	LANL	INEL	ORNL	Hanford	Y-12	Total
Am-241	0.00E+00	0.00E+00	2.25E-03	9.30E-03	4.47E-04	7.12E-03	1.05E+00	0.00E+00	1.07E+00
Am-243	0.00E+00	0.00E+00	2.00E-08	0.00E+00	0.00E+00	0.00E+00	1.04E-03	0.00E+00	1.04E-03
C-14	2.56E-07	5.00E-01	6.03E-03	2.00E-09	2.78E+00	5.46E-02	2.77E+01	0.00E+00	3.11E+01
Cm-242	0.00E+00	0.00E+00	2.00E-08	0.00E+00	9.84E-08	0.00E+00	0.00E+00	0.00E+00	1.18E-07
Cm-244	2.59E+00	0.00E+00	4.30E-07	0.00E+00	7.85E-06	3.31E-03	2.54E-01	0.00E+00	2.85E+00
Co-60	7.70E+01	3.00E-03	6.01E-02	5.25E+01	9.89E+04	1.01E+01	9.80E+04	0.00E+00	1.97E+05
Cs-137	3.12E+01	2.00E+00	1.82E-01	6.19E-02	2.59E+03	2.51E+02	2.42E+02	0.00E+00	3.12E+03
H-3	2.63E+04	2.00E+01	1.46E+04	1.12E+02	9.64E-01	1.50E-01	4.39E+04	0.00E+00	8.49E+04
I-129	1.39E-06	1.00E-02	0.00E+00	0.00E+00	5.37E-04	0.00E+00	1.82E-03	0.00E+00	1.24E-02
Nb-94	5.40E-09	8.00E-04	0.00E+00	0.00E+00	6.90E-06	0.00E+00	9.14E-02	0.00E+00	9.22E-02
Ni-59	2.31E-04	5.00E-04	0.00E+00	0.00E+00	2.59E+02	0.00E+00	6.44E+02	0.00E+00	9.03E+02
Ni-63	7.87E-01	2.00E-03	0.00E+00	1.00E-05	3.47E+04	0.00E+00	9.35E+04	0.00E+00	1.28E+05
Np-237	0.00E+00	3.00E-05	0.00E+00	0.00E+00	1.21E-07	0.00E+00	9.88E-03	0.00E+00	9.91E-03
Pu[a]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.98E-01	0.00E+00	5.98E-01
Pu-238	0.00E+00	0.00E+00	3.99E-01	2.00E-03	6.15E-04	0.00E+00	2.50E-02	0.00E+00	4.27E-01
Pu-239	0.00E+00	0.00E+00	3.73E-02	7.26E-02	3.03E-03	2.00E-06	0.00E+00	0.00E+00	1.13E-01
Pu-240	0.00E+00	0.00E+00	1.75E-04	0.00E+00	2.73E-04	0.00E+00	0.00E+00	0.00E+00	4.49E-04
Pu-241	0.00E+00	4.00E-04	2.09E-02	7.52E-05	1.30E-02	0.00E+00	0.00E+00	0.00E+00	3.43E-02
Pu-242	0.00E+00	0.00E+00	1.32E-07	0.00E+00	2.45E-08	0.00E+00	0.00E+00	0.00E+00	1.57E-07
Pu-52[a]	0.00E+00	0.00E+00	3.04E+01	3.61E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.07E+01
Ra-226	0.00E+00	0.00E+00	2.85E-01	1.00E-03	0.00E+00	0.00E+00	9.38E-02	0.00E+00	3.80E-01
Sr-90	3.09E+01	7.00E-03	2.60E-01	0.00E+00	8.36E+01	2.48E+02	1.61E+02	0.00E+00	5.24E+02
Tc-99	8.19E-04	4.00E+01	0.00E+00	1.15E-05	5.92E-03	0.00E+00	7.73E-02	0.00E+00	4.01E+01
Th-228	0.00E+00	0.00E+00	2.75E-03	1.00E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.75E-03
Th-232	5.03E+00	0.00E+00	1.25E-02	1.09E-06	0.00E+00	1.73E-04	5.56E-03	0.00E+00	5.05E+00
Th-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.60E-06	0.00E+00	0.00E+00	0.00E+00	1.60E-06
Th-88[a]	0.00E+00	0.00E+00	0.00E+00	2.00E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E-09
Tot alph[a]	0.00E+00	2.00E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E-01
U-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.21E-02	0.00E+00	3.21E-02
U-233	0.00E+00	0.00E+00	3.00E-08	0.00E+00	0.00E+00	6.00E-04	1.76E-02	0.00E+00	1.82E-02

Table 22 (Continued)

Nuclide	SRS Solid Waste	SRS Saltstone	NTS	LANL	INEL	ORNL	Hanford	Y-12	Total
U-234	8.58E-01	3.20E+00	0.00E+00	0.00E+00	7.76E-04	0.00E+00	0.00E+00	0.00E+00	4.06E+00
U-235	2.57E-02	6.00E-02	5.27E-03	5.70E-01	1.71E-03	5.36E-04	0.00E+00	0.00E+00	6.64E-01
U-236	1.07E-01	0.00E+00	0.00E+00	0.00E+00	1.10E-06	0.00E+00	0.00E+00	0.00E+00	1.07E-01
U-238	7.09E-01	1.00E-04	8.00E+00	2.27E+00	2.37E-01	1.00E-02	0.00E+00	0.00E+00	1.12E+01
U-38[a]	0.00E+00	0.00E+00	0.00E+00	2.00E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E-00
U-81[a]	0.00E+00	0.00E+00	0.00E+00	3.46E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.46E-06
U-DEP[a]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.75E+00	6.00E+00	1.38E+01
U-ENRICH[a]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.90E-01	0.00E+00	9.90E-01
U-NAT[a]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.22E-03	0.00E+00	7.22E-03

[a]Pu: unspecified Pu; Pu-52: plutonium, including Pu-238, Pu-239, Pu-240, Pu-241, and Pu-242; Th-88: total thorium; Tot alph: unspecified alpha activity; U-38: uranium enriched between 92 and 94%; U-81: normal uranium (0.711%); U-DEP: depleted uranium; U-ENRICH: unspecified enriched uranium; U-NAT: natural uranium.

Waste Volume, 10^3 m^3	HANF	INEL	LANL	NTS	ORNL	SRS	Salt	Y-12	TOTAL
Reported in 1991 IDB:	7.9	1.8	4.5	9.1	0.3	26.6	-	4.4	54.6
Reported in 1992 IDB:	13.4	1.8	4.5	9.1	0.3	26.6	-	4.4	60.1
Provided by sites:	13.4	1.8	4.5	14.1	0.3	23.9	6.1	4.4	68.4

For some sites, there are differences in the activity and volume citations between those provided by the sites and those reported to the IDB. Some differences would be expected, and would reflect normal fluctuations in data bases resulting from generator revisions to disposal manifests, operator corrections to data bases, and similar adjustments.

The biggest differences are for the Hanford site, and these differences primarily result from the reclassification of submarine reactor compartments from stored to disposed waste. We estimate that this waste consists of about 249,000 Ci of activity in 5,395 m^3. We also understand that the activity reported by Hanford annually to the IDB is usually the total beta-gamma activity that had been reported in waste shipments in units of curies, including inferred progeny, and does not include activity reported in gram units.

In addition, the revised figure of 588,000 curies in the 1992 IDB report includes a revised total of 337,822 curies of activity reported by Hanford to the IDB. This activity, however, includes 42,985 curies of tritium that was inadvertently double-counted as both beta-gamma activity and tritium. This error will be corrected in subsequent Hanford updates to the IDB [19].

The activity and volume differences for the NTS site result from the inclusion of mixed waste in this report, consisting of 29 curies of activity in 4,970 m^3, whereas the volume and activity reported to the IDB included only LLW. The activity difference for INEL waste results entirely from roundoff.

We have no explanation for the differences in the data for solid waste disposal at SRS versus that data reported to the IDB. Waste disposed in the SRS saltstone facility was not reported to the IDB.

Stored LLW. In addition to LLW reported disposed in 1990, considerable quantities of low-level and mixed wastes were placed in storage during this year. If this stored waste had all been disposed in 1990, the inventories of some radionuclides would have significantly changed, as well as their percent distributions. Changes would be particularly apparent for inventories and distributions of Sr-90 and Cm-244.

As summarized in Appendix B, the stored LLW volume totaled 12,700 m^3 (448,000 ft^3), while the stored activity totaled 196,000 curies. The stored activity represents about 36% of the total activity that was reported disposed in DOE sites in 1990.

We lack a detailed site-by-site isotopic inventory of the stored LLW. We also lack an estimate of how much of this activity is contained in waste that exceeds Class C concentrations as defined in 10 CFR Part 61. DOE 5820.2A requires that disposal of DOE waste in concentrations exceeding Class C concentrations must be considered as a special case to be justified by a specific performance assessment consistent with the requirements of the National Environmental Policy Act [1].

Nonetheless, 70% of the stored activity was reported stored at ORNL, and an isotopic distribution for this waste has been estimated (see Appendix B). Of interest is the large quantities of Sr-90 and Cm-244 placed in storage at ORNL, in comparison with quantities of these isotopes reported disposed. At all DOE sites where LLW disposal took place during 1990, only 2.85 curies of Cm-244 and 524 curies of Sr-90 were reported buried. This may be with contrasted with the 97 curies of Cm-244 placed in storage during 1990 at ORNL, in addition to the 134,000 curies of Sr-90. Although some of the stored waste containing these isotopes may exceed Part 61 Class C concentration limits, it still suggests that care should be exercised when reaching conclusions about the distributions of radionuclides in DOE LLW, based only on data about LLW sent to disposal.

Regarding mixed waste, immediately available information focuses more on the chemical content of the waste than the radiological content, although the latter can be occasionally significant. The reader is referred to Appendix B and [13].

VI. COMPARISON OF COMMERCIAL WASTE WITH DOE WASTE

Comparisons between commercial and DOE disposal data are difficult. Nonetheless, we have generated Table 23, which juxtapositions reported DOE and commercial activities of selected radionuclides. The selected radionuclides include those specifically listed in 10 CFR 61.55, plus a few additional radionuclides of interest.

The data indicates that commercial disposal facilities accepted considerably larger quantities of C-14 than did DOE disposal facilities. Otherwise, significant differences seem to be apparent in disposal of Ra-226, Ni-59, Ni-63, Sr-90, Tc-99, uranium and thorium, and transuranic isotopes.

Table 23 should be perused with caution. First, it covers only LLW that was disposed during 1990, and not waste that was placed in storage. Second, the table is only as accurate as the

Table 23. Comparison of Reported DOE and Commercial Activities of Selected Radionuclides

Nuclide	DOE Activity (Ci)[a]	Comm'l Activity (Ci)
C-14	3.11E+1	4.36E+2
Cm-242	1.18E-7	3.13E-1
Co-60	1.97E+5	1.81E+5
Cs-137	3.12E+3	9.36E+3
H-3	8.49E+4	1.02E+5
I-129	1.24E-2	4.05E-1[c]
Nb-94	9.22E-2	5.32E-1
Ni-59	9.03E+2	1.66E+2
Ni-63	1.28E+5	1.63E+4
Pu-241	3.43E-2	1.94E+1
Ra-226	3.80E-1	1.72E+1[d]
Sr-90	5.24E+2	4.76E+3
Tc-99	4.01E+1	8.44E+0[c]
TRU (> 5 yrs)[b]	3.60E+1	4.66E+0
TRU (> 20 yrs)[b]	3.32E+1	4.36E+0
Total Thorium	5.05E+0	3.43E+2[c]
Total Uranium	3.09E+1	3.09E+2

[a] Not considering mixed activation products and mixed fission products.
[b] Alpha-emitting transuranic radionuclides having half-lifes exceeding either 5 or 20 years. The difference in the citations is the activity of Cm-244, which has a half-life of 17.6 years.
[c] Inventories of these radionuclides are probably significantly overreported.
[d] Not including waste activity disposed at Envirocare, which is probably mostly Ra-226.

reported data. At some disposal facilities, the inventories of a number of long-lived radionuclides may have been overreported,while at other disposal facilities, some of these long-lived radionuclides may have been underreported. (See Sections III and VII.)

VII. DISCUSSION

A more complete and uniform approach is needed for characterizing and reporting waste radiological inventories and physical and chemical attributes.

Notational concerns. Consistency in notation is needed. One issue is the practice at some DOE sites of reporting inventories as mixtures of mass and activity units. Although there may be a need or custom to track the mass of some radioactive material in waste -- e.g., special nuclear material -- a consistent activity unit is needed to properly add and compare quantities of disposed wastes. Radionuclide quantities reported only in gram units should be disallowed.

Also, it is apparent that to obtain consistent information from different entities, one must be careful to specify the notation to be used -- for example, whether to report in fixed or scientific notation, and the number of significant figures.

Progeny in equilibrium. A consistent approach is needed for describing radionuclides that exist in equilibrium with daughters. Shippers sometimes provide parent and daughter activities, but usually only provide the parent activity, as illustrated in the data for radionuclide pairs provided by INEL (see Table B-5). Shippers to INEL occasionally reported the yttrium daughter of Sr-90, and the barium daughter of Cs-137, but in all cases reported the rhodium daughter of Ru-106. Except for Hanford, none of the DOE and commercial sites adds the activity for daughter radionuclides when transferring information on LLW disposal manifests to site computer recordkeeping systems.

Consider the following six radionuclides reported in DOE waste:

Parent	Half-Life (yr)	Parent Activity (Ci)	Daughter in Equilibrium	Daughter Activity (Ci)[a]
Ba-140	3.51E-2	8.47E-2	La-140	1.00E-1
Ce-144	7.80E-1	4.89E+1	Pr-144	4.70E+1
Cs-137	3.02E+1	3.12E+3	Ba-137m	2.29E+0
Ru-103	1.08E-1	1.04E-1	Rh-103m	8.40E-4
Ru-106	1.01E+0	2.30E+1	Rh-106	2.27E+1
Sr-90	2.88E+1	5.24E+2	Y-90	1.84E+2
		3.72E+3		2.56E+2

[a] Reported and derived (in the case of Hanford) activity.

The activity reported for the six parent radionuclides accounts for 0.7% of all the activity reported in DOE LLW during 1990. However, because the six daughters are in equilibrium with their parents, the actual activity that was disposed during 1990 was actually about 3500 curies higher than the 546,000 curies estimated in Section V.

Regarding commercial waste, the above six parent radionuclides amounted to 15,900 curies, or about 3% of the total activity, although only 49 curies of daughter activity was reported. More La-140 activity was reported than Ba-140 activity.

Dropping the activity of radionuclide daughters is understandable. It stems from the way in which health and safety assessments are made, for which the contribution of daughter radiation to a dose analysis is normally automatically included with that of the parent. This is practical, because the radiation from daughter radionuclides directly derives from the decay of parent radionuclides. However, inconsistent reporting practices can lead to confusion. With no consistent way of reporting radionuclides, a comparison between two different sources of data -- such as two different sites -- becomes one of comparing apples with oranges.

A more significant concern lies with the vagueness by which uranium and thorium activity is sometimes reported. Both elements are commonly found in nature, for which progeny customarily exist in equilibrium. But as the elements are recovered and processed by various means for various applications, the isotopic distribution changes. This means that the isotopic makeup within waste is not necessarily clear. If one receives a millicurie of "natural thorium" or "natural uranium" as waste, one may not be sure if the material retains the daughter radionuclides in the distributions found in nature, or if the daughter radionuclides have been largely or partly removed by a refining or manufacturing process.

A consistent approach is needed. The most straightforward approach would seem to be to require that disposal manifests provide the activities of parents and daughters separately. This would be the most accurate way of providing disposal data, but it would add size and complexity to the manifest documentation. This change would also cause an apparent, and possibly confusing, spike in disposed LLW activity.

For simple pairs of radionuclides such as Cs-137 and Ba-137m, a conceptually simpler alternative could be to list a daughter radionuclide only when its presence in waste is <u>not</u> associated with a parent radionuclide; otherwise, one would merely list the activity of the parent with the understanding that appropriate quantities of the daughter would also be present. Under this alternative, however, the identity of the parent should be specially denoted. For example, a shipment of 30 curies of Sr-90 in equilibrium with Y-90 could be identified as 30 curies of Sr-90+D.

The issue is more complicated for radioactive elements such as uranium or thorium. However, for some common cases one could probably devise nomenclature to describe the radionuclide distributions (e.g., use "U-NAT" for natural uranium for which the progeny had been largely removed, and "U-NAT+D" for natural uranium for which the progeny was still largely present). Otherwise, one would probably have to separately list and characterize daughters.

In any case, practices for reporting and recording daughter activity should be consistent among all DOE sites, consistent with the approach used in the commercial industry, and compatible with Department of Transportation regulations for preparation of shipping papers.

Use of imprecise descriptors. A related concern is the use of imprecise descriptors for reported radionuclides. Such descriptors provide little information about the distribution of radionuclides within waste, and little information that can be used to demonstrate compliance with the performance objectives for LLW disposal in 10 CFR Part 61 and DOE 5820.2A.

Regarding commercial wastes, as noted above, the biggest concern involves the vague manner by which uranium and thorium activity is sometimes reported. It is also noted that small quantities of vaguely specified transuranic radionuclides were reported in commercial waste.

Regarding DOE waste, at Los Alamos, fully 70% of the reported activity was described as "mixed activation products" and "mixed fission products," with no other indication as to the identity of the radionuclides (see Table B-3). Small quantities of mixed fission and activation products were also reported disposed at the Nevada Test Site and INEL, and was inferred from data provided by Hanford. In all, about 700 curies of activity were characterized using these vague descriptors, accounting for 0.1% of all DOE activity disposed during 1990.

Since 1990, DOE sites have implemented steps to require improved characterization of waste, to prohibit or at least greatly discourage the use of vague radionuclide descriptions. In NRC's uniform manifest form proposed on 21 April 1992, use of vague radionuclide descriptions is prohibited [9].

Criteria for reporting radionuclides. A significant concern is to ensure that the radionuclides that are of prime importance are reported accurately. In this sense, ensuring that these radionuclides are not overreported is as important as ensuring that the radionuclides are not underreported.

When developing instructions for characterizing waste and radionuclides in manifests, much more specific guidance should be provided than the mere statement that "all" or the "most significant" radionuclides should be provided. First, such statements are open to interpretation (e.g., does one report the radionuclides important for operational or transportation safety or does one report the radionuclides important from environmental considerations?). Second, it would be unrealistic to require a generator to analyze waste for all radionuclides that might be present in waste. Although hundreds of radioactive isotopes have been identified, many might not be associated with the process that generated the waste. Many may have half-lives that are too short to be of concern, or may be in concentrations that are too small to measure (or matter).

A workable approach may be to couple a set of general criteria for reporting isotopes that are of safety importance, with requirements to report specific radionuclides that are of particular environmental importance. A largely accepted criterion seems to be one that would mandate identification and quantification of all radionuclides that represent at least 1% of the contents of a waste container. Requirements to report specific radionuclides could be developed on either a generic or a site-specific basis or both.

Even so, for both commercial and DOE waste disposal, requirements to report specific radionuclides are not sufficient. One also needs to be specific about the procedures for reporting the particular radionuclides of interest. (The radionuclides that tend to be of most concern from an environmental impact viewpoint also tend to be difficult to measure.) Otherwise, one can be faced with a significant overreportage problem, as has been the case for for Tc-99 and I-129 in commercial waste.

Overreporting of long-lived radionuclides may not seem much of a concern from the standpoint of an individual waste shipment, but the cumulative effect is that the inventories of these long-lived radionuclides at individual disposal facilities can become grossly inflated. The long-term risk of release of activity from the disposal facility is thus greatly exaggerated. This leads to inefficient use of disposal sites.

Therefore, in addition to specifying particular radionuclides to be reported, one should also specify procedures which will minimize problems with overreporting long-lived radionuclides. As one approach, a concentration could be specified for each radionuclide (hopefully exceeding typical measurement LLDs for that radionuclide) below which reporting is not required. Such a concentration would be selected so that even if the radionuclide would be present in a large quantity of waste at a concentration just below the cutoff limit, the combined inventory represented by the unreported activity would not be significant. Hopefully, such a concentration could be specified on a generic rather than a site-specific basis. At least at commercial LLW disposal facilities, the problem might also be eased by a revamped pricing scheme for which a surcharge is applied to long-lived radionuclides in addition to a surcharge on gross activity.

Radionuclide misidentification. Radionuclides are sometimes misidentified, suggesting deficiencies in quality control in characterizing and reporting wastes. To illustrate, we identified the following anomolies in reported commercial data:

Nuclide	Activity (Ci)	Nuclide	Activity (Ci)
Ag-100	4.640E-4	In-113	1.300E-2
As-75	1.100E-3	Nb-93	1.003E+0
Ca-46	1.100E-5	Rb-85	5.000E-4
Cl-35	2.000E-5	Ru-109	9.670E-3
Co-59	3.228E-2	Sn-117	2.000E-6
Cr-53	4.300E-5	Sn-119	1.500E-2
Fe-57	5.500E-4	Xe-131	4.000E-6
		Total	1.076E+0

All these isotopes are stable, except for Ag-100 and Ru-109 which don't appear to exist. In some cases, the discrepancies probably result from typographical errors involving metastable isotopes. For example, In-113, Nb-93, Sn-117, Sn-119, and Xe-131 can all exist in a metastable state. In a similar vein, we suspect that some Tc-99m activity was erroneously reported as Tc-99.

Reporting other information. Information is needed about the physical and chemical characteristics of waste that is sufficient to ensure defensible assessments of disposal facility performance over time. As noted previously, the physical and chemical characteristics of much commercial waste is described in only vague terms. This was also the case for some DOE wastes during 1990. On the other hand, unlike commercial disposal manifests, few DOE shipment manifests required reporting of chelating agents.

Since 1990, steps have been taken to improve the information reported in NRC and DOE shipment manifests. An example is an NRC rulemaking on a uniform manifest form [9]. This process is ongoing.

Information storage. A final concern is to ensure that disposal manifest information is stored electronically in a consistent way and in sufficient detail to enable performance assessments of LLW disposal facilities in compliance with 10 CFR Part 61 and DOE Order 5820.2A. Information about wastes delivered to disposal facilities is contained in very large numbers of documents, and computer data bases are needed to enable storage and manipulation of data.

Computer data bases should normally store manifest information on a container basis, to enable maximum use of the data. In so doing, one of the difficulties to be resolved is that of roundoff. Use of the data base will require storage and addition of hundreds of thousands of data points that differ in absolute value by many orders of magnitude. If one proceeds through calculations, for example, in which one adds the activity on a container, shipment, and yearly basis, it is possible to lose significant figures, resulting in the appearance of error. As another example, if a generator lists radionuclide activities on a container basis, and also provides a shipment total activity, each set of data will be given according to a given number of significant figures. If one adds the activity over all containers, because the data points vary considerably in absolute value, one will probably arrive at a slightly different number than that listed by the generator. Again, the appearance is one of error. As noted in Section III, efforts to address problems such as these can lead to exaggerated inventories of radioactive isotopes in computer data systems.

VIII. CONCLUSIONS

This report presents isotopic inventories and other data for LLW and mixed LLW disposed (and occasionally stored) during calendar year 1990 at commercial disposal facilities and DOE sites. For commercial waste, isotopic data is provided for waste disposed at the Barnwell, SC, Richland, WA, and Beatty, NV disposal facilities; limited information is provided for the Envirocare disposal facility near Clive, UT.

Isotopic concentration data is presented as a function of waste stream for LLW generated as part of the West Valley Demonstration Project and stored during 1990.

For DOE waste, isotopic data is provided for waste disposed at Savannah River Site, including the saltstone facility, Nevada Test Site, Los Alamos National Laboratory, Idaho National Engineering Laboratory, Hanford Site, and Oak Ridge National Laboratory. Detailed inventories for the Y-12 Site were not obtained, although we understand that waste disposal at Y-12 only amounted to a half-dozen curies of depleted uranium. Summary information is presented for LLW placed in storage during 1990.

The data indicated the need for a more complete and uniform approach to characterizing and reporting LLW radionuclide inventories and physical and chemical attributes. Some of the major concerns include:

- Notational issues, including development of a consistent way to characterize and report radionuclides that may exist in chains or in secular equilibrium.

- o Ensuring that radionuclides that are important for long-term environmental impacts are consistently reported without undue conservatism.

- o Ensuring that all significant radionuclides within waste shipments are identified specifically, and reported using consistent units.

- o Eliminating the use of vague descriptors such as mixed fission products or beta-gamma activity.

- o Ensuring that information about the physical and chemical characteristics of waste sufficient to conduct performance assessments of LLW disposal facilities are recorded on shipment manifests.

- o Ensuring that the physical, chemical, and radiological characteristics of LLW as described on LLW shipment manifests are stored in sufficient detail in electronic form.

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ELEMENTS AND SYMBOLS

Element	Symbol	Element	Symbol	Element	Symbol
Actinium	Ac	Hafnium	Hf	Praseodymium	Pr
Aluminum	Al	Hahnium	Ha	Promethium	Pm
Americium	Am	Helium	He	Protactinium	Pa
Antimony	Sb	Holmium	Ho	Radium	Ra
Argon	Ar	Hydrogen	H	Radon	Rn
Arsenic	As	Indium	In	Rhenium	Re
Astatine	At	Iodine	I	Rhodium	Rh
Barium	Ba	Iridium	Ir	Rubidium	Rb
Berkelium	Bk	Iron	Fe	Ruthenium	Ru
Beryllium	Be	Krypton	Kr	Rutherfordium	Rf
Bismuth	Bi	Lanthanum	La	Samarium	Sm
Boron	B	Lawrencium	Lr	Scandium	Sc
Bromine	Br	Lead	Pb	Selinium	Se
Cadmium	Cd	Lithium	Li	Silicon	Si
Calcium	Ca	Lutetium	Lu	Silver	Ag
Californium	Cf	Magnesium	Mg	Sodium	Na
Carbon	C	Manganese	Mn	Strontium	Sr
Cerium	Ce	Mendelevium	Md	Sulfur	S
Cesium	Cs	Mercury	Hg	Tantalum	Ta
Chlorine	Cl	Molybdenum	Mo	Technetium	Tc
Chromium	Cr	Neodymium	Nd	Tellurium	Te
Cobalt	Co	Neon	Ne	Terbium	Tb
Copper	Cu	Neptunium	Np	Thallium	Tl
Curium	Cm	Nickel	Ni	Thorium	Th
Dysprosium	Dy	Niobium	Nb	Thulium	Tm
Einsteinium	Es	Nitrogen	N	Tin	Sn
Erbium	Er	Nobelium	No	Titanium	Ti
Europium	Eu	Osmium	Os	Tungsten	W
Fermium	Fm	Oxygen	O	Uranium	U
Fluorine	F	Palladium	Pd	Vanadium	V
Francium	Fr	Phosphorus	P	Xenon	Xe
Gadolinium	Gd	Platinum	Pt	Ytterbium	Yb
Gallium	Ga	Plutonium	Pu	Yttrium	Y
Germanium	Ge	Polonium	Po	Zinc	Zn
Gold	Au	Potassium	K	Zirconium	Zr

APPENDIX A

COMMERCIAL DISPOSAL FACILITY RADIONUCLIDE DISTRIBUTION

BY WASTE CLASS

APPENDIX A

COMMERCIAL DISPOSAL FACILITY RADIONUCLIDE DISTRIBUTION BY WASTE CLASS

This appendix contains three tables listing radionuclide distributions in low-level waste (LLW) disposed during 1990 in three commercial LLW disposal facilities. These disposal facilities are, in tabulated order, the Barnwell, S.C. disposal facility operated by Chem-Nuclear Systems, Inc. (CNSI), and the Richland, WA, and Beatty, NV, disposal facilities operated by U.S. Ecology (USE). Each of the three tables lists radionuclide activities in units of curies and as a function of waste class.

A fourth table lists total radionuclide activities, in units of curies and as a function of waste class, as summed over all three disposal facilities. A final table lists total activity for each radionuclide as a function of disposal facility.

The tables were created from lists of radionuclide activities purchased from the disposal facility operators by the Nuclear Regulatory Commission. A few observations are in order.

Isotopic data originally obtained from the disposal facility operators were in units of millicuries, which corresponds to the common activity unit used on commercial disposal manifests. CNSI data was presented to hundredths of millicuries, while USE data was presented to thousandths of millicuries. Consistent with the approach in [1], these data were converted to curie units and are presented in scientific notation assuming four significant figures. No predictions are made as to the actual accuracy of the data.

Anomalies in the commercial data can be occasionally found. For example, Co-59 is listed in the data, as are a few other stable radionuclides. Occasionally, isotopes are listed which don't appear to exist. These anomalies do not represent a significant activity.

Otherwise, the following abbreviations are used: U-NAT means natural uranium, U-DEP means depleted uranium, Th-NAT means natural thorium, and TRU-NOS means an unspecified mixture of transuranic radionuclides.

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Table A-1. Barnwell Radionuclide Inventories (Ci)

Nuclide	Class A	Class B	Class C	Total
Ag-108m	3.000E-05	0.000E+00	8.090E-01	8.090E-01
Ag-110	2.181E+00	1.721E+01	0.000E+00	1.940E+01
Ag-110m	1.624E+01	1.928E+01	1.363E+01	4.915E+01
Ag-111	1.750E-02	0.000E+00	0.000E+00	1.750E-02
Am-241	8.541E-02	3.879E-02	2.343E-01	3.585E-01
Am-242	1.000E-05	0.000E+00	0.000E+00	1.000E-05
Am-243	2.800E-04	8.900E-04	0.000E+00	1.170E-03
Au-195	4.670E-03	0.000E+00	1.970E-03	6.640E-03
Au-198	1.500E-03	0.000E+00	0.000E+00	1.500E-03
Au-199	1.500E-03	0.000E+00	0.000E+00	1.500E-03
Ba-131	1.180E-01	0.000E+00	0.000E+00	1.180E-01
Ba-133	3.794E-01	0.000E+00	1.810E-03	3.812E-01
Ba-140	2.141E+01	4.609E+00	8.126E-01	2.683E+01
Be-7	3.111E-01	1.057E+01	8.455E+00	1.934E+01
Bi-205	1.000E-05	0.000E+00	0.000E+00	1.000E-05
Bi-207	1.560E-03	0.000E+00	0.000E+00	1.560E-03
Bi-210	1.000E-05	0.000E+00	0.000E+00	1.000E-05
C-14	4.579E+01	1.527E+01	4.386E+01	1.049E+02
Ca-45	2.406E-01	0.000E+00	0.000E+00	2.406E-01
Cd-109	1.872E-01	1.545E+00	0.000E+00	1.732E+00
Ce-139	4.100E-04	2.523E-02	0.000E+00	2.564E-02
Ce-141	8.449E+00	2.320E+02	2.579E+00	2.430E+02
Ce-143	0.000E+00	9.440E+00	0.000E+00	9.440E+00
Ce-144	4.992E+01	1.467E+03	9.652E+00	1.527E+03
Cf-252	2.000E-05	0.000E+00	0.000E+00	2.000E-05
Cl-36	8.937E-02	0.000E+00	0.000E+00	8.937E-02
Cm-242	6.345E-02	5.258E-02	1.808E-01	2.969E-01
Cm-243	2.964E-02	2.057E-02	8.760E-03	5.897E-02
Cm-244	4.004E-02	1.722E-02	1.429E-02	7.155E-02
Co-56	8.600E-04	0.000E+00	0.000E+00	8.600E-04
Co-57	2.774E+00	1.154E+01	2.165E+01	3.597E+01
Co-58	6.345E+02	1.661E+03	5.729E+03	8.025E+03
Co-60	3.347E+03	6.992E+03	1.675E+05	1.778E+05
Cr-51	9.659E+02	1.083E+03	4.598E+03	6.647E+03
Cs-134	2.412E+02	7.625E+02	8.108E+02	1.815E+03
Cs-135	7.000E-05	0.000E+00	0.000E+00	7.000E-05
Cs-136	7.501E-01	5.437E-02	0.000E+00	8.045E-01
Cs-137	6.311E+02	1.657E+03	4.075E+03	6.363E+03
Cu-67	1.000E-05	0.000E+00	0.000E+00	1.000E-05
Dy-159	3.000E-04	0.000E+00	0.000E+00	3.000E-04
Eu-152	2.420E-02	0.000E+00	0.000E+00	2.420E-02
Eu-154	1.990E-02	0.000E+00	5.281E-01	5.480E-01
Eu-155	9.730E-03	7.800E-04	0.000E+00	1.051E-02
Fe-55	5.584E+03	5.715E+03	1.710E+05	1.823E+05
Fe-57	3.800E-04	0.000E+00	0.000E+00	3.800E-04

Table A-1 (Continued)

Nuclide	Class A	Class B	Class C	Total
Fe-59	5.014E+01	2.972E+01	3.558E+02	4.357E+02
Ga-67	2.890E-03	0.000E+00	0.000E+00	2.890E-03
Gd-153	2.345E-02	0.000E+00	0.000E+00	2.345E-02
Ge-68	1.216E-02	0.000E+00	0.000E+00	1.216E-02
H-3	2.165E+02	9.746E+03	1.813E+02	1.014E+04
Hf-175	0.000E+00	0.000E+00	2.667E+02	2.667E+02
Hf-181	2.518E-02	0.000E+00	4.194E+02	4.194E+02
Hg-203	2.858E-02	0.000E+00	0.000E+00	2.858E-02
I-123	6.210E-02	0.000E+00	0.000E+00	6.210E-02
I-124	5.558E-02	0.000E+00	0.000E+00	5.558E-02
I-125	2.627E+01	0.000E+00	1.100E-03	2.627E+01
I-129	3.069E-01	3.254E-02	1.447E-02	3.539E-01
I-131	6.544E+01	1.903E+01	2.029E+00	8.650E+01
I-133	3.537E+00	6.838E-01	0.000E+00	4.221E+00
I-135	2.206E-02	0.000E+00	0.000E+00	2.206E-02
In-111	2.487E-02	0.000E+00	0.000E+00	2.487E-02
In-114	2.910E-03	0.000E+00	0.000E+00	2.910E-03
In-114m	6.570E-02	0.000E+00	0.000E+00	6.570E-02
Ir-192	1.400E-03	0.000E+00	4.500E-04	1.850E-03
K-40	2.000E-04	0.000E+00	0.000E+00	2.000E-04
Kr-85	7.268E+00	4.754E+00	0.000E+00	1.202E+01
La-140	3.657E+01	6.153E+00	0.000E+00	4.272E+01
Mn-54	1.087E+03	9.237E+02	1.261E+04	1.462E+04
Mn-57	1.000E-05	0.000E+00	0.000E+00	1.000E-05
Mo-99	2.118E-01	4.472E-02	0.000E+00	2.565E-01
Na-22	1.127E-01	0.000E+00	0.000E+00	1.127E-01
Na-24	4.187E-02	1.000E-04	0.000E+00	4.197E-02
Nb-94	3.699E-02	3.866E-01	7.925E-02	5.028E-01
Nb-95	5.097E+01	1.678E+03	2.739E+01	1.757E+03
Nd-147	4.739E-02	0.000E+00	0.000E+00	4.739E-02
Ni-59	5.752E+00	4.371E+01	1.155E+02	1.650E+02
Ni-63	2.684E+02	2.175E+03	1.349E+04	1.593E+04
Np-237	6.800E-04	2.000E-05	0.000E+00	7.000E-04
Np-239	6.599E-02	9.503E-02	0.000E+00	1.610E-01
P-32	1.066E+01	3.123E+00	0.000E+00	1.379E+01
P-33	1.000E-04	0.000E+00	0.000E+00	1.000E-04
Pb-210	6.000E-05	0.000E+00	0.000E+00	6.000E-05
Pb-214	1.000E-05	0.000E+00	0.000E+00	1.000E-05
Pd-103	6.400E-02	0.000E+00	0.000E+00	6.400E-02
Pm-147	6.769E+00	2.659E+02	1.473E+02	4.199E+02
Po-210	3.812E-02	5.000E-04	0.000E+00	3.862E-02
Pr-143	2.000E-05	0.000E+00	0.000E+00	2.000E-05
Pu-234	8.340E-03	0.000E+00	0.000E+00	8.340E-03
Pu-238	4.625E-01	7.638E-02	2.919E-02	5.681E-01
Pu-239	7.122E-02	2.834E-02	2.434E-02	1.239E-01

Table A-1 (Continued)

Nuclide	Class A	Class B	Class C	Total
Pu-240	1.138E-02	1.260E-03	3.920E-03	1.656E-02
Pu-241	6.975E+00	3.900E+00	5.697E+00	1.657E+01
Pu-242	6.310E-03	1.000E-05	0.000E+00	6.320E-03
Ra-226	9.583E-02	5.400E-04	2.000E-05	9.639E-02
Rb-86	1.984E-01	0.000E+00	0.000E+00	1.984E-01
Re-186	1.100E-02	0.000E+00	0.000E+00	1.100E-02
Rh-105	3.170E-03	0.000E+00	0.000E+00	3.170E-03
Rh-106	4.700E-03	0.000E+00	0.000E+00	4.700E-03
Ru-103	4.302E+00	1.483E+02	1.288E+00	1.539E+02
Ru-106	4.949E+00	6.674E+01	1.627E+01	8.796E+01
S-35	1.307E+01	0.000E+00	0.000E+00	1.307E+01
Sb-122	1.916E-01	3.392E+00	4.160E+00	7.743E+00
Sb-124	1.673E+01	2.220E+01	4.958E+02	5.348E+02
Sb-125	1.819E+01	9.193E+01	3.087E+02	4.188E+02
Sc-46	1.230E-01	5.285E+01	1.000E-05	5.297E+01
Se-75	9.814E-02	0.000E+00	0.000E+00	9.814E-02
Sn-113	7.688E-01	1.806E+00	2.374E+00	4.949E+00
Sr-82	1.000E-03	0.000E+00	0.000E+00	1.000E-03
Sr-85	8.497E-02	0.000E+00	0.000E+00	8.497E-02
Sr-89	1.950E+01	6.065E+02	8.231E-01	6.268E+02
Sr-90	5.704E+00	1.031E+02	4.011E+03	4.120E+03
Ta-182	5.530E-03	6.000E+00	2.327E-01	6.238E+00
Tb-160	0.000E+00	1.070E-03	0.000E+00	1.070E-03
Tc-99	1.340E+00	4.689E-01	3.899E+00	5.708E+00
Tc-99m	6.984E-01	1.331E+01	0.000E+00	1.400E+01
Te-123m	0.000E+00	3.770E-02	0.000E+00	3.770E-02
Te-125m	2.664E-01	4.437E-01	1.773E-01	8.874E-01
Te-132	1.145E-01	0.000E+00	0.000E+00	1.145E-01
Th-232	3.383E+02	1.700E-04	0.000E+00	3.383E+02
Th-234	1.719E-02	0.000E+00	0.000E+00	1.719E-02
Tl-201	1.971E-02	0.000E+00	0.000E+00	1.971E-02
Tl-202	3.550E-02	0.000E+00	0.000E+00	3.550E-02
Tl-204	8.361E-02	0.000E+00	0.000E+00	8.361E-02
Tm-171	4.000E-05	0.000E+00	0.000E+00	4.000E-05
TRU-NOS	1.144E-01	3.606E-02	1.522E-02	1.657E-01
U-233	1.000E-05	0.000E+00	0.000E+00	1.000E-05
U-234	2.067E+00	3.507E-02	8.000E-05	2.102E+00
U-235	3.311E+00	5.010E-03	8.200E-04	3.317E+00
U-236	1.179E-02	0.000E+00	0.000E+00	1.179E-02
U-238	1.216E+02	2.000E-05	5.000E-05	1.216E+02
U-DEP	1.062E+02	0.000E+00	0.000E+00	1.062E+02
W-178	1.000E-04	0.000E+00	0.000E+00	1.000E-04
Xe-131m	5.828E+00	6.234E-01	3.000E-05	6.451E+00
Xe-133	4.815E-01	1.367E-02	0.000E+00	4.952E-01
Y-88	1.570E-03	0.000E+00	0.000E+00	1.570E-03
Y-90	2.210E-03	0.000E+00	0.000E+00	2.210E-03

Table A-1 (Continued)

Nuclide	Class A	Class B	Class C	Total
Y-91	2.233E+01	9.568E+02	0.000E+00	9.792E+02
Zn-65	3.017E+03	2.528E+03	6.372E+01	5.609E+03
Zr-95	3.903E+01	9.158E+02	1.719E+01	9.720E+02
Zr-97	0.000E+00	6.080E-01	0.000E+00	6.080E-01
Total	1.714E+04	4.008E+04	3.864E+05	4.436E+05

Table A-2. Richland Radionuclide Inventories (Ci)

Nuclide	Class A	Class B	Class C	Total
Ag-108m	0.000E+00	0.000E+00	2.690E-04	2.690E-04
Ag-110	5.000E-06	0.000E+00	0.000E+00	5.000E-06
Ag-110m	1.202E+01	6.166E+00	4.777E-01	1.867E+01
Am-241	3.798E-02	8.240E-04	1.012E-02	4.892E-02
Am-243	1.000E-06	0.000E+00	0.000E+00	1.000E-06
As-73	3.070E-04	0.000E+00	0.000E+00	3.070E-04
As-75	1.100E-03	0.000E+00	0.000E+00	1.100E-03
Au-195	2.921E-02	0.000E+00	0.000E+00	2.921E-02
Ba-133	3.393E-01	0.000E+00	0.000E+00	3.393E-01
Ba-140	1.733E+00	3.650E+00	0.000E+00	5.383E+00
Be-7	7.659E-02	0.000E+00	0.000E+00	7.659E-02
Bi-207	2.407E-03	0.000E+00	0.000E+00	2.407E-03
Bi-210	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Bi-214	2.000E-06	0.000E+00	0.000E+00	2.000E-06
C-14	8.507E+01	2.385E+00	2.463E+00	8.992E+01
Ca-45	1.535E+00	0.000E+00	0.000E+00	1.535E+00
Ca-47	3.100E-05	0.000E+00	0.000E+00	3.100E-05
Cd-109	1.528E-01	3.972E+00	0.000E+00	4.125E+00
Cd-115	2.500E-05	0.000E+00	0.000E+00	2.500E-05
Cd-115m	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Ce-134	8.000E-05	0.000E+00	0.000E+00	8.000E-05
Ce-139	1.030E-04	0.000E+00	0.000E+00	1.030E-04
Ce-141	4.935E-01	4.680E-01	1.185E-02	9.734E-01
Ce-144	7.410E-01	3.690E-02	9.135E-01	1.691E+00
Cf-252	1.000E-05	0.000E+00	0.000E+00	1.000E-05
Cl-35	2.000E-05	0.000E+00	0.000E+00	2.000E-05
Cl-36	6.953E-02	0.000E+00	0.000E+00	6.953E-02
Cm-242	4.390E-03	1.452E-03	8.320E-04	6.674E-03
Cm-243	2.927E-03	3.050E-04	6.224E-03	9.456E-03
Cm-244	4.610E-03	4.540E-04	5.040E-04	5.568E-03
Co-56	8.559E-03	0.000E+00	0.000E+00	8.559E-03
Co-57	2.663E+00	1.191E+00	1.908E-01	4.045E+00
Co-58	1.132E+02	8.498E+01	8.081E+00	2.062E+02
Co-60	7.281E+02	6.131E+02	1.177E+02	1.459E+03
Cr-51	1.002E+02	3.303E+02	2.458E+00	4.330E+02
Cs-134	3.534E+01	1.974E+02	2.747E+01	2.602E+02
Cs-136	5.440E-02	1.805E-01	0.000E+00	2.349E-01
Cs-137	6.425E+01	3.982E+02	1.116E+02	5.741E+02
Cs-139	6.800E-02	0.000E+00	0.000E+00	6.800E-02
Cu-64	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Cu-67	1.250E-04	0.000E+00	0.000E+00	1.250E-04
Dy-159	2.000E-04	0.000E+00	0.000E+00	2.000E-04
Dy-165	5.000E-06	0.000E+00	0.000E+00	5.000E-06
Er-171	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Eu-152	1.106E-02	0.000E+00	5.100E-05	1.111E-02
Eu-154	8.100E-05	0.000E+00	5.160E-03	5.241E-03

Table A-2 (Continued)

Nuclide	Class A	Class B	Class C	Total
Eu-155	4.683E-03	0.000E+00	6.054E-02	6.522E-02
Fe-52	4.000E-06	0.000E+00	0.000E+00	4.000E-06
Fe-55	1.443E+03	2.219E+02	4.889E+01	1.714E+03
Fe-57	1.700E-04	0.000E+00	0.000E+00	1.700E-04
Fe-59	7.858E+00	6.809E-01	1.694E-01	8.708E+00
Ga-67	1.441E-01	0.000E+00	0.000E+00	1.441E-01
Ga-68	3.800E-05	0.000E+00	0.000E+00	3.800E-05
Gd-153	2.023E+00	0.000E+00	0.000E+00	2.023E+00
Ge-68	3.613E-02	0.000E+00	0.000E+00	3.613E-02
H-3	1.062E+03	8.556E+04	3.992E-01	8.663E+04
Hf-181	3.930E-04	0.000E+00	0.000E+00	3.930E-04
Hg-203	4.232E-03	0.000E+00	0.000E+00	4.232E-03
I-123	1.345E-01	0.000E+00	0.000E+00	1.345E-01
I-125	3.521E+01	0.000E+00	0.000E+00	3.521E+01
I-129	1.563E-02	1.262E-03	2.648E-02	4.338E-02
I-131	5.968E+00	4.901E+00	0.000E+00	1.087E+01
In-111	2.252E-01	0.000E+00	0.000E+00	2.252E-01
In-114	1.656E-03	0.000E+00	0.000E+00	1.656E-03
In-114m	1.453E-02	0.000E+00	0.000E+00	1.453E-02
Ir-192	2.522E-03	0.000E+00	0.000E+00	2.522E-03
K-40	5.340E-04	0.000E+00	0.000E+00	5.340E-04
Kr-81	5.500E-02	0.000E+00	0.000E+00	5.500E-02
Kr-85	2.284E+00	0.000E+00	0.000E+00	2.284E+00
La-140	1.637E+00	4.150E+00	0.000E+00	5.787E+00
Mn-54	1.702E+02	8.458E+01	3.060E+00	2.578E+02
Mo-99	5.850E-02	0.000E+00	0.000E+00	5.850E-02
Na-22	3.399E-01	0.000E+00	0.000E+00	3.399E-01
Na-24	1.170E-04	0.000E+00	0.000E+00	1.170E-04
Nb-94	4.682E-03	0.000E+00	0.000E+00	4.682E-03
Nb-95	2.314E+00	9.563E+00	1.114E+00	1.299E+01
Ni-59	1.643E-01	7.099E-01	1.388E-01	1.013E+00
Ni-63	4.673E+01	1.307E+02	1.547E+02	3.321E+02
Np-237	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Np-239	8.000E-06	1.455E-01	0.000E+00	1.455E-01
P-32	1.812E+01	0.000E+00	0.000E+00	1.812E+01
Pa-234	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Pb-210	2.100E-04	0.000E+00	0.000E+00	2.100E-04
Pb-212	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Pm-147	7.848E-02	0.000E+00	5.130E-01	5.915E-01
Po-208	1.000E-05	0.000E+00	0.000E+00	1.000E-05
Po-210	5.020E+00	0.000E+00	0.000E+00	5.020E+00
Pr-144	3.242E-02	0.000E+00	0.000E+00	3.242E-02
Pu-237	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Pu-238	7.246E-03	7.346E-03	1.534E-02	2.993E-02
Pu-239	1.013E-02	1.948E-03	4.174E-02	5.382E-02
Pu-240	3.075E-03	1.687E-03	1.862E-02	2.338E-02

Table A-2 (Continued)

Nuclide	Class A	Class B	Class C	Total
Pu-241	4.776E-01	2.328E-01	1.255E+00	1.966E+00
Pu-242	8.100E-05	3.000E-06	3.000E-06	8.700E-05
Pu-244	1.500E-05	0.000E+00	0.000E+00	1.500E-05
Ra-226	1.508E-01	0.000E+00	1.203E-01	2.712E-01
Ra-228	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Rb-86	1.000E-01	0.000E+00	0.000E+00	1.000E-01
Re-184m	9.000E-06	0.000E+00	0.000E+00	9.000E-06
Re-187	2.000E-06	0.000E+00	0.000E+00	2.000E-06
Rh-106	2.330E-02	0.000E+00	0.000E+00	2.330E-02
Ru-103	6.565E-02	0.000E+00	6.508E-03	7.215E-02
Ru-105	5.000E-06	0.000E+00	0.000E+00	5.000E-06
Ru-106	3.285E-01	4.540E-01	1.007E+00	1.789E+00
S-35	2.354E+02	0.000E+00	0.000E+00	2.354E+02
Sb-113	2.990E-04	0.000E+00	0.000E+00	2.990E-04
Sb-124	8.547E+00	5.008E+00	6.500E-01	1.421E+01
Sb-125	3.773E+00	4.545E+00	1.962E+00	1.028E+01
Sc-44	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Sc-46	8.590E-02	0.000E+00	0.000E+00	8.590E-02
Sc-47	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Se-75	2.292E-02	0.000E+00	0.000E+00	2.292E-02
Sm-153	7.910E-02	0.000E+00	0.000E+00	7.910E-02
Sn-113	1.185E-01	0.000E+00	0.000E+00	1.185E-01
Sn-119m	1.009E-03	0.000E+00	0.000E+00	1.009E-03
Sr-82	5.000E-05	0.000E+00	0.000E+00	5.000E-05
Sr-85	4.602E-02	0.000E+00	0.000E+00	4.602E-02
Sr-89	1.729E+00	1.128E-01	8.710E-04	1.843E+00
Sr-90	9.377E-01	2.915E+00	1.671E+02	1.709E+02
Sr-91	2.000E-06	0.000E+00	0.000E+00	2.000E-06
Sr-95	2.000E-06	0.000E+00	0.000E+00	2.000E-06
Ta-182	1.203E-01	0.000E+00	0.000E+00	1.203E-01
Ta-183	2.000E-04	0.000E+00	0.000E+00	2.000E-04
Tc-99	6.666E-01	4.868E-01	3.299E-01	1.483E+00
Tc-99m	7.091E-01	0.000E+00	0.000E+00	7.091E-01
Te-123	2.977E-02	0.000E+00	0.000E+00	2.977E-02
Te-125m	3.379E-02	1.732E-01	2.461E-01	4.531E-01
Te-132	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Th-228	5.570E-04	0.000E+00	0.000E+00	5.570E-04
Th-230	5.910E-04	0.000E+00	0.000E+00	5.910E-04
Th-232	8.750E-02	0.000E+00	1.000E-04	8.760E-02
Th-234	3.000E-06	0.000E+00	0.000E+00	3.000E-06
Th-NAT	3.958E+00	0.000E+00	0.000E+00	3.958E+00
Tl-201	1.135E-01	0.000E+00	0.000E+00	1.135E-01
Tl-202	6.000E-04	0.000E+00	0.000E+00	6.000E-04
Tl-204	1.079E-02	0.000E+00	0.000E+00	1.079E-02
Tm-171	5.000E-05	0.000E+00	0.000E+00	5.000E-05
U-233	1.100E-05	0.000E+00	0.000E+00	1.100E-05

Table A-2 (Continued)

Nuclide	Class A	Class B	Class C	Total
U-234	2.706E-02	0.000E+00	3.980E-04	2.746E-02
U-235	4.286E-03	0.000E+00	1.400E-05	4.300E-03
U-236	1.330E-04	0.000E+00	0.000E+00	1.330E-04
U-238	8.895E-01	0.000E+00	2.168E-03	8.917E-01
U-DEP	2.399E-03	0.000E+00	2.000E-02	2.240E-02
U-NAT	1.402E+00	0.000E+00	0.000E+00	1.402E+00
W-187	2.455E-02	0.000E+00	0.000E+00	2.455E-02
W-188	5.000E-04	0.000E+00	0.000E+00	5.000E-04
Xe-131	4.000E-06	0.000E+00	0.000E+00	4.000E-06
Xe-131m	6.381E-02	6.847E-02	0.000E+00	1.323E-01
Xe-133	7.918E-02	0.000E+00	0.000E+00	7.918E-02
Y-88	1.466E-03	0.000E+00	0.000E+00	1.466E-03
Y-90	3.758E-02	0.000E+00	0.000E+00	3.758E-02
Yb-169	3.700E-05	0.000E+00	0.000E+00	3.700E-05
Zn-65	1.460E+02	2.897E+02	5.000E-06	4.357E+02
Zr-89	2.000E-03	0.000E+00	0.000E+00	2.000E-03
Zr-95	9.450E-01	6.742E+00	4.762E-01	8.163E+00
Total	4.357E+03	8.797E+04	6.537E+02	9.298E+04

Table A-3. Beatty Radionuclide Inventories (Ci)

Nuclide	Class A	Class B	Class C	Total
Ac-227	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Ag-100	4.630E-04	1.000E-06	0.000E+00	4.640E-04
Ag-108	2.300E-03	0.000E+00	0.000E+00	2.300E-03
Ag-108m	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Ag-110	1.950E-03	0.000E+00	0.000E+00	1.950E-03
Ag-110m	7.920E-01	1.696E+00	7.221E-02	2.560E+00
Al-28	4.000E-06	0.000E+00	0.000E+00	4.000E-06
Am-241	2.712E-03	4.310E-04	2.809E+00	2.812E+00
Am-243	2.000E-06	0.000E+00	0.000E+00	2.000E-06
As-73	4.100E-05	0.000E+00	0.000E+00	4.100E-05
As-75	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Au-195	5.001E-03	1.000E-06	0.000E+00	5.002E-03
Au-198	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Ba-131	1.000E-03	0.000E+00	0.000E+00	1.000E-03
Ba-133	1.640E+00	6.080E-04	3.510E-04	1.641E+00
Ba-140	1.341E-03	0.000E+00	0.000E+00	1.341E-03
Be-7	7.101E-03	0.000E+00	0.000E+00	7.101E-03
Bi-206	0.000E+00	2.000E-06	1.000E-06	3.000E-06
Bi-207	1.600E-05	0.000E+00	3.000E-06	1.900E-05
Bi-210	2.000E-06	1.000E-06	1.000E-06	4.000E-06
Bi-214	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Br-82	1.000E-06	0.000E+00	0.000E+00	1.000E-06
C-14	3.525E+00	3.541E-02	2.375E+02	2.410E+02
Ca-45	1.127E+00	4.000E-06	0.000E+00	1.127E+00
Ca-46	1.100E-05	0.000E+00	0.000E+00	1.100E-05
Ca-47	5.000E-06	0.000E+00	0.000E+00	5.000E-06
Cd-107	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Cd-109	6.759E-01	4.468E-02	1.787E-01	8.992E-01
Cd-115	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cd-115m	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Ce-134	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Ce-139	6.020E-04	0.000E+00	0.000E+00	6.020E-04
Ce-141	2.366E-01	1.000E-06	1.200E-05	2.366E-01
Ce-144	9.310E-03	1.000E-06	1.786E-01	1.879E-01
Cf-252	0.000E+00	1.000E-06	0.000E+00	1.000E-06
Cl-35	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cl-36	4.188E-02	0.000E+00	5.000E-04	4.238E-02
Cm-242	5.594E-03	2.500E-05	3.526E-03	9.145E-03
Cm-243	1.550E-04	0.000E+00	1.055E-03	1.210E-03
Cm-244	1.640E-04	0.000E+00	2.231E-01	2.232E-01
Co-56	2.620E-04	0.000E+00	0.000E+00	2.620E-04
Co-57	2.707E+00	4.726E-02	6.962E-02	2.823E+00
Co-58	1.245E+01	1.105E+00	1.344E+00	1.489E+01
Co-59	3.228E-02	0.000E+00	0.000E+00	3.228E-02
Co-60	9.953E+02	2.773E+02	4.610E+01	1.319E+03
Cr-51	4.801E+01	3.065E-01	2.229E-03	4.832E+01

Table A-3 (Continued)

Nuclide	Class A	Class B	Class C	Total
Cr-53	4.300E-05	0.000E+00	0.000E+00	4.300E-05
Cs-134	3.092E+00	6.520E+00	3.230E+00	1.284E+01
Cs-136	2.000E-03	0.000E+00	0.000E+00	2.000E-03
Cs-137	9.074E+00	2.835E+02	2.127E+03	2.419E+03
Cs-139	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cu-64	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Cu-67	2.422E-03	0.000E+00	0.000E+00	2.422E-03
Dy-159	1.000E-04	0.000E+00	0.000E+00	1.000E-04
Dy-165	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Er-171	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Eu-152	8.724E-03	2.500E-04	2.307E-03	1.128E-02
Eu-154	8.801E-03	2.420E-04	1.760E-04	9.219E-03
Eu-155	0.000E+00	0.000E+00	2.608E-03	2.608E-03
Fe-52	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Fe-55	1.395E+03	6.720E+00	3.084E+01	1.433E+03
Fe-57	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Fe-59	2.131E+01	3.400E-05	2.861E-03	2.131E+01
Ga-67	4.837E-02	0.000E+00	0.000E+00	4.837E-02
Ga-68	1.390E-01	0.000E+00	0.000E+00	1.390E-01
Gd-153	7.611E-01	8.137E-02	5.675E-01	1.410E+00
Gd-159	1.001E-03	0.000E+00	0.000E+00	1.001E-03
Ge-67	1.000E-05	0.000E+00	0.000E+00	1.000E-05
Ge-68	5.349E-01	0.000E+00	0.000E+00	5.349E-01
H-3	9.802E+01	4.606E+03	1.805E+02	4.885E+03
Hf-175	2.880E+00	0.000E+00	0.000E+00	2.880E+00
Hf-181	5.300E-01	0.000E+00	0.000E+00	5.300E-01
Hg-203	9.230E-02	4.500E-05	0.000E+00	9.235E-02
Ho-166m	4.000E-03	0.000E+00	0.000E+00	4.000E-03
I-123	1.177E-01	0.000E+00	0.000E+00	1.177E-01
I-124	1.500E-04	0.000E+00	0.000E+00	1.500E-04
I-125	2.791E+01	3.265E-01	4.542E-03	2.824E+01
I-129	6.840E-03	1.050E-04	6.600E-04	7.605E-03
I-131	1.466E-01	2.000E-06	0.000E+00	1.466E-01
In-111	5.478E-02	0.000E+00	0.000E+00	5.478E-02
In-113	1.300E-02	0.000E+00	0.000E+00	1.300E-02
In-114	3.690E-03	0.000E+00	0.000E+00	3.690E-03
In-114m	1.359E-01	0.000E+00	0.000E+00	1.359E-01
Ir-192	1.513E-01	5.267E-01	0.000E+00	6.779E-01
K-40	4.000E-06	0.000E+00	0.000E+00	4.000E-06
Kr-81	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Kr-85	2.490E-01	5.540E+00	2.126E-01	6.002E+00
Kr-87	0.000E+00	0.000E+00	3.100E-05	3.100E-05
Kr-89	0.000E+00	0.000E+00	1.039E-02	1.039E-02
La-140	0.000E+00	1.000E-06	0.000E+00	1.000E-06
Mn-54	1.914E+02	1.938E+01	3.260E-01	2.111E+02
Mn-56	5.000E-03	0.000E+00	0.000E+00	5.000E-03

Table A-3 (Continued)

Nuclide	Class A	Class B	Class C	Total
Mo-99	9.650E-02	0.000E+00	1.000E-06	9.650E-02
Na-22	2.089E+00	4.000E-06	4.470E-04	2.089E+00
Na-24	4.079E-01	0.000E+00	0.000E+00	4.079E-01
Nb-93	1.003E+00	0.000E+00	0.000E+00	1.003E+00
Nb-94	1.410E-02	0.000E+00	1.005E-02	2.415E-02
Nb-95	4.109E-01	1.000E-06	6.840E-03	4.178E-01
Nb-96	1.000E-04	0.000E+00	0.000E+00	1.000E-04
Ni-59	6.403E-02	5.245E-03	1.000E-06	6.927E-02
Ni-63	1.546E+01	7.014E-01	2.238E+01	3.854E+01
Np-237	0.000E+00	0.000E+00	5.010E-04	5.010E-04
Np-239	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Os-185	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Os-191	3.000E-04	0.000E+00	0.000E+00	3.000E-04
P-32	1.150E+01	1.000E-06	1.050E-02	1.151E+01
Pa-234	1.000E-06	1.000E-06	0.000E+00	2.000E-06
Pb-203	1.100E-02	0.000E+00	0.000E+00	1.100E-02
Pb-210	4.178E-02	8.000E-06	1.940E-02	6.118E-02
Pb-212	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Pd-107	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Pm-147	1.000E-02	4.347E+00	1.351E+01	1.787E+01
Po-208	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Po-210	2.814E-02	1.090E-04	4.948E-03	3.320E-02
Pr-144	1.513E-03	0.000E+00	0.000E+00	1.513E-03
Pt-193	2.000E-04	0.000E+00	0.000E+00	2.000E-04
Pu-237	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Pu-238	4.330E-04	0.000E+00	9.606E-03	1.004E-02
Pu-239	1.064E-03	0.000E+00	5.392E-02	5.498E-02
Pu-240	1.230E-04	0.000E+00	1.508E-02	1.521E-02
Pu-241	3.835E-02	1.260E-03	7.946E-01	8.342E-01
Pu-242	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Pu-244	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Ra-226	1.597E+01	6.116E-01	2.972E-01	1.687E+01
Ra-228	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Rb-85	5.000E-04	0.000E+00	0.000E+00	5.000E-04
Rb-86	3.924E-01	0.000E+00	0.000E+00	3.924E-01
Rb-87	4.000E-05	0.000E+00	0.000E+00	4.000E-05
Re-184m	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Re-186	3.000E-03	0.000E+00	0.000E+00	3.000E-03
Re-187	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Rh-106	0.000E+00	3.000E-05	0.000E+00	3.000E-05
Ru-103	1.693E-01	1.000E-06	2.240E-03	1.715E-01
Ru-105	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Ru-106	4.199E-03	0.000E+00	3.585E-01	3.627E-01
Ru-109	0.000E+00	0.000E+00	9.670E-03	9.670E-03
S-35	1.410E+01	4.732E-03	1.000E-05	1.411E+01

Table A-3 (Continued)

Nuclide	Class A	Class B	Class C	Total
Sb-113	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Sb-124	4.458E-01	0.000E+00	7.816E-03	4.536E-01
Sb-125	8.722E-02	0.000E+00	9.632E-01	1.050E+00
Sc-44	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Sc-46	8.481E-01	4.000E-06	0.000E+00	8.481E-01
Sc-47	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Se-75	2.958E-01	0.000E+00	1.000E-06	2.958E-01
Sm-145	3.000E-02	0.000E+00	0.000E+00	3.000E-02
Sm-151	0.000E+00	0.000E+00	7.860E-04	7.860E-04
Sm-153	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Sn-113	1.641E+00	1.100E-05	5.440E-04	1.641E+00
Sn-117	2.000E-06	0.000E+00	0.000E+00	2.000E-06
Sn-119	1.500E-02	0.000E+00	0.000E+00	1.500E-02
Sn-119m	8.600E-03	0.000E+00	0.000E+00	8.600E-03
Sn-125	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Sr-82	3.415E-02	0.000E+00	0.000E+00	3.415E-02
Sr-85	6.784E-02	3.000E-06	0.000E+00	6.785E-02
Sr-89	2.082E-03	0.000E+00	2.320E-04	2.314E-03
Sr-90	5.573E-01	2.570E+02	2.136E+02	4.711E+02
Sr-91	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Sr-95	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Ta-182	5.020E-04	1.000E-06	0.000E+00	5.030E-04
Ta-183	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Tc-96	1.500E-05	0.000E+00	0.000E+00	1.500E-05
Tc-99	1.312E-01	8.600E-05	1.122E+00	1.254E+00
Tc-99m	5.213E-02	1.000E-06	0.000E+00	5.213E-02
Te-123	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Te-123m	5.000E-04	0.000E+00	0.000E+00	5.000E-04
Te-125m	0.000E+00	0.000E+00	7.341E-02	7.341E-02
Te-132	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Th-228	2.170E-04	0.000E+00	1.300E-05	2.300E-04
Th-230	2.000E-06	0.000E+00	0.000E+00	2.000E-06
Th-232	2.027E-01	5.325E-02	3.040E-04	2.563E-01
Th-234	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Th-NAT	3.600E-05	0.000E+00	0.000E+00	3.600E-05
Tl-201	3.096E-02	0.000E+00	0.000E+00	3.096E-02
Tl-202	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Tl-204	3.517E-03	9.120E-04	2.431E-02	2.874E-02
Tm-170	6.010E-03	0.000E+00	0.000E+00	6.010E-03
Tm-171	1.000E-02	0.000E+00	0.000E+00	1.000E-02
U-232	1.000E-06	0.000E+00	0.000E+00	1.000E-06
U-233	1.000E-06	0.000E+00	6.000E-06	7.000E-06
U-234	6.234E-03	0.000E+00	1.840E-04	6.418E-03
U-235	9.800E-05	0.000E+00	8.000E-06	1.060E-04
U-236	0.000E+00	0.000E+00	3.000E-06	3.000E-06
U-238	7.333E+01	6.669E-02	3.909E-03	7.340E+01

Table A-3 (Continued)

Nuclide	Class A	Class B	Class C	Total
U-DEP	5.660E-02	0.000E+00	0.000E+00	5.660E-02
U-NAT	5.480E-04	1.070E-04	0.000E+00	6.550E-04
V-48	1.100E-05	0.000E+00	0.000E+00	1.100E-05
W-181	1.000E-05	0.000E+00	0.000E+00	1.000E-05
W-187	0.000E+00	0.000E+00	0.000E+00	0.000E+00
W-188	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Xe-131	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Xe-131m	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Xe-133	2.031E-03	0.000E+00	0.000E+00	2.031E-03
Y-88	2.227E-03	1.000E-06	0.000E+00	2.228E-03
Y-90	5.926E-03	1.000E-06	0.000E+00	5.927E-03
Yb-169	5.000E-04	0.000E+00	0.000E+00	5.000E-04
Zn-65	8.096E+00	6.539E-01	0.000E+00	8.750E+00
Zr-89	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Zr-95	6.220E-02	0.000E+00	6.986E-02	1.321E-01
Total	2.966E+03	5.473E+03	2.884E+03	1.132E+04

Table A-4. Total Radionuclide Inventories (Ci)

Nuclide	Class A	Class B	Class C	Total
Ac-227	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Ag-100	4.630E-04	1.000E-06	0.000E+00	4.640E-04
Ag-108	2.300E-03	0.000E+00	0.000E+00	2.300E-03
Ag-108m	3.000E-05	0.000E+00	8.093E-01	8.093E-01
Ag-110	2.183E+00	1.721E+01	0.000E+00	1.940E+01
Ag-110m	2.905E+01	2.715E+01	1.418E+01	7.038E+01
Ag-111	1.750E-02	0.000E+00	0.000E+00	1.750E-02
Al-28	4.000E-06	0.000E+00	0.000E+00	4.000E-06
Am-241	1.261E-01	4.005E-02	3.054E+00	3.220E+00
Am-242	1.000E-05	0.000E+00	0.000E+00	1.000E-05
Am-243	2.830E-04	8.900E-04	0.000E+00	1.173E-03
As-73	3.480E-04	0.000E+00	0.000E+00	3.480E-04
As-75	1.100E-03	0.000E+00	0.000E+00	1.100E-03
Au-195	3.888E-02	1.000E-06	1.970E-03	4.085E-02
Au-198	1.501E-03	0.000E+00	0.000E+00	1.501E-03
Au-199	1.500E-03	0.000E+00	0.000E+00	1.500E-03
Ba-131	1.190E-01	0.000E+00	0.000E+00	1.190E-01
Ba-133	2.359E+00	2.418E-03	2.161E-03	2.362E+00
Ba-140	2.315E+01	8.259E+00	8.126E-01	3.222E+01
Be-7	3.948E-01	1.057E+01	8.455E+00	1.942E+01
Bi-205	1.000E-05	0.000E+00	0.000E+00	1.000E-05
Bi-206	0.000E+00	2.000E-06	1.000E-06	3.000E-06
Bi-207	3.983E-03	0.000E+00	3.000E-06	3.986E-03
Bi-210	1.300E-05	1.000E-06	1.000E-06	1.500E-05
Bi-214	2.000E-06	0.000E+00	0.000E+00	2.000E-06
Br-82	1.000E-06	0.000E+00	0.000E+00	1.000E-06
C-14	1.344E+02	1.769E+01	2.838E+02	4.359E+02
Ca-45	2.902E+00	4.000E-06	0.000E+00	2.902E+00
Ca-46	1.100E-05	0.000E+00	0.000E+00	1.100E-05
Ca-47	3.600E-05	0.000E+00	0.000E+00	3.600E-05
Cd-107	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Cd-109	1.016E+00	5.562E+00	1.787E-01	6.756E+00
Cd-115	2.500E-05	0.000E+00	0.000E+00	2.500E-05
Cd-115m	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Ce-134	8.000E-05	0.000E+00	0.000E+00	8.000E-05
Ce-139	1.115E-03	2.523E-02	0.000E+00	2.635E-02
Ce-141	9.179E+00	2.324E+02	2.591E+00	2.442E+02
Ce-143	0.000E+00	9.440E+00	0.000E+00	9.440E+00
Ce-144	5.068E+01	1.467E+03	1.074E+01	1.529E+03
Cf-252	3.000E-05	1.000E-06	0.000E+00	3.100E-05
Cl-35	2.000E-05	0.000E+00	0.000E+00	2.000E-05
Cl-36	2.008E-01	0.000E+00	5.000E-04	2.013E-01
Cm-242	7.343E-02	5.406E-02	1.852E-01	3.127E-01
Cm-243	3.272E-02	2.088E-02	1.604E-02	6.964E-02
Cm-244	4.481E-02	1.767E-02	2.379E-01	3.004E-01
Co-56	9.681E-03	0.000E+00	0.000E+00	9.681E-03

Table A-4 (Continued)

Nuclide	Class A	Class B	Class C	Total
Co-57	8.144E+00	1.278E+01	2.191E+01	4.284E+01
Co-58	7.601E+02	1.747E+03	5.739E+03	8.246E+03
Co-59	3.228E-02	0.000E+00	0.000E+00	3.228E-02
Co-60	5.070E+03	7.882E+03	1.676E+05	1.806E+05
Cr-51	1.114E+03	1.413E+03	4.601E+03	7.128E+03
Cr-53	4.300E-05	0.000E+00	0.000E+00	4.300E-05
Cs-134	2.796E+02	9.664E+02	8.415E+02	2.088E+03
Cs-135	7.000E-05	0.000E+00	0.000E+00	7.000E-05
Cs-136	8.065E-01	2.349E-01	0.000E+00	1.041E+00
Cs-137	7.044E+02	2.339E+03	6.313E+03	9.356E+03
Cs-139	6.800E-02	0.000E+00	0.000E+00	6.800E-02
Cu-64	2.000E-06	0.000E+00	0.000E+00	2.000E-06
Cu-67	2.557E-03	0.000E+00	0.000E+00	2.557E-03
Dy-159	6.000E-04	0.000E+00	0.000E+00	6.000E-04
Dy-165	5.000E-06	0.000E+00	0.000E+00	5.000E-06
Er-171	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Eu-152	4.398E-02	2.500E-04	2.358E-03	4.659E-02
Eu-154	2.878E-02	2.420E-04	5.334E-01	5.625E-01
Eu-155	1.441E-02	7.800E-04	6.315E-02	7.834E-02
Fe-52	4.000E-06	0.000E+00	0.000E+00	4.000E-06
Fe-55	8.422E+03	5.944E+03	1.711E+05	1.855E+05
Fe-57	5.500E-04	0.000E+00	0.000E+00	5.500E-04
Fe-59	7.931E+01	3.040E+01	3.560E+02	4.657E+02
Ga-67	1.954E-01	0.000E+00	0.000E+00	1.954E-01
Ga-68	1.390E-01	0.000E+00	0.000E+00	1.390E-01
Gd-153	2.807E+00	8.137E-02	5.675E-01	3.456E+00
Gd-159	1.001E-03	0.000E+00	0.000E+00	1.001E-03
Ge-67	1.000E-05	0.000E+00	0.000E+00	1.000E-05
Ge-68	5.832E-01	0.000E+00	0.000E+00	5.832E-01
H-3	1.377E+03	9.992E+04	3.622E+02	1.017E+05
Hf-175	2.880E+00	0.000E+00	2.667E+02	2.696E+02
Hf-181	5.556E-01	0.000E+00	4.194E+02	4.200E+02
Hg-203	1.251E-01	4.500E-05	0.000E+00	1.252E-01
Ho-166m	4.000E-03	0.000E+00	0.000E+00	4.000E-03
I-123	3.143E-01	0.000E+00	0.000E+00	3.143E-01
I-124	5.573E-02	0.000E+00	0.000E+00	5.573E-02
I-125	8.939E+01	3.265E-01	5.642E-03	8.972E+01
I-129	3.293E-01	3.391E-02	4.161E-02	4.048E-01
I-131	7.155E+01	2.393E+01	2.029E+00	9.752E+01
I-133	3.537E+00	6.838E-01	0.000E+00	4.221E+00
I-135	2.206E-02	0.000E+00	0.000E+00	2.206E-02
In-111	3.048E-01	0.000E+00	0.000E+00	3.048E-01
In-113	1.300E-02	0.000E+00	0.000E+00	1.300E-02
In-114	8.256E-03	0.000E+00	0.000E+00	8.256E-03
In-114m	2.161E-01	0.000E+00	0.000E+00	2.161E-01
Ir-192	1.552E-01	5.267E-01	4.500E-04	6.823E-01
K-40	7.380E-04	0.000E+00	0.000E+00	7.380E-04

Table A-4 (Continued)

Nuclide	Class A	Class B	Class C	Total
Kr-81	5.500E-02	0.000E+00	0.000E+00	5.500E-02
Kr-85	9.801E+00	1.029E+01	2.126E-01	2.031E+01
Kr-87	0.000E+00	0.000E+00	3.100E-05	3.100E-05
Kr-89	0.000E+00	0.000E+00	1.039E-02	1.039E-02
La-140	3.821E+01	1.030E+01	0.000E+00	4.851E+01
Mn-54	1.449E+03	1.028E+03	1.262E+04	1.509E+04
Mn-56	5.000E-03	0.000E+00	0.000E+00	5.000E-03
Mn-57	1.000E-05	0.000E+00	0.000E+00	1.000E-05
Mo-99	3.668E-01	4.472E-02	1.000E-06	4.115E-01
Na-22	2.541E+00	4.000E-06	4.470E-04	2.542E+00
Na-24	4.499E-01	1.000E-04	0.000E+00	4.500E-01
Nb-93	1.003E+00	0.000E+00	0.000E+00	1.003E+00
Nb-94	5.578E-02	3.866E-01	8.930E-02	5.316E-01
Nb-95	5.369E+01	1.688E+03	2.851E+01	1.770E+03
Nb-96	1.000E-04	0.000E+00	0.000E+00	1.000E-04
Nd-147	4.739E-02	0.000E+00	0.000E+00	4.739E-02
Ni-59	5.981E+00	4.442E+01	1.156E+02	1.660E+02
Ni-63	3.306E+02	2.306E+03	1.367E+04	1.630E+04
Np-237	6.810E-04	2.000E-05	5.010E-04	1.202E-03
Np-239	6.600E-02	2.405E-01	0.000E+00	3.065E-01
Os-185	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Os-191	3.000E-04	0.000E+00	0.000E+00	3.000E-04
P-32	4.029E+01	3.123E+00	1.050E-02	4.342E+01
P-33	1.000E-04	0.000E+00	0.000E+00	1.000E-04
Pa-234	2.000E-06	1.000E-06	0.000E+00	3.000E-06
Pb-203	1.100E-02	0.000E+00	0.000E+00	1.100E-02
Pb-210	4.205E-02	8.000E-06	1.940E-02	6.145E-02
Pb-212	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Pb-214	1.000E-05	0.000E+00	0.000E+00	1.000E-05
Pd-103	6.400E-02	0.000E+00	0.000E+00	6.400E-02
Pd-107	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Pm-147	6.857E+00	2.702E+02	1.613E+02	4.384E+02
Po-208	1.000E-05	0.000E+00	0.000E+00	1.000E-05
Po-210	5.086E+00	6.090E-04	4.948E-03	5.092E+00
Pr-143	2.000E-05	0.000E+00	0.000E+00	2.000E-05
Pr-144	3.393E-02	0.000E+00	0.000E+00	3.393E-02
Pt-193	2.000E-04	0.000E+00	0.000E+00	2.000E-04
Pu-234	8.340E-03	0.000E+00	0.000E+00	8.340E-03
Pu-237	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Pu-238	4.702E-01	8.373E-02	5.413E-02	6.080E-01
Pu-239	8.241E-02	3.029E-02	1.200E-01	2.327E-01
Pu-240	1.458E-02	2.947E-03	3.763E-02	5.515E-02
Pu-241	7.491E+00	4.134E+00	7.747E+00	1.937E+01
Pu-242	6.391E-03	1.300E-05	3.000E-06	6.407E-03
Pu-244	1.500E-05	0.000E+00	0.000E+00	1.500E-05
Ra-226	1.621E+01	6.121E-01	4.175E-01	1.724E+01
Ra-228	1.000E-06	0.000E+00	0.000E+00	1.000E-06

Table A-4 (Continued)

Nuclide	Class A	Class B	Class C	Total
Rb-85	5.000E-04	0.000E+00	0.000E+00	5.000E-04
Rb-86	6.908E-01	0.000E+00	0.000E+00	6.908E-01
Rb-87	4.000E-05	0.000E+00	0.000E+00	4.000E-05
Re-184m	9.000E-06	0.000E+00	0.000E+00	9.000E-06
Re-186	1.400E-02	0.000E+00	0.000E+00	1.400E-02
Re-187	2.000E-06	0.000E+00	0.000E+00	2.000E-06
Rh-105	3.170E-03	0.000E+00	0.000E+00	3.170E-03
Rh-106	2.800E-02	3.000E-05	0.000E+00	2.803E-02
Ru-103	4.537E+00	1.483E+02	1.297E+00	1.542E+02
Ru-105	6.000E-06	0.000E+00	0.000E+00	6.000E-06
Ru-106	5.281E+00	6.720E+01	1.764E+01	9.012E+01
Ru-109	0.000E+00	0.000E+00	9.670E-03	9.670E-03
S-35	2.626E+02	4.732E-03	1.000E-05	2.626E+02
Sb-113	2.990E-04	0.000E+00	0.000E+00	2.990E-04
Sb-122	1.916E-01	3.392E+00	4.160E+00	7.743E+00
Sb-124	2.572E+01	2.721E+01	4.965E+02	5.494E+02
Sb-125	2.205E+01	9.647E+01	3.116E+02	4.301E+02
Sc-44	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Sc-46	1.057E+00	5.285E+01	1.000E-05	5.391E+01
Sc-47	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Se-75	4.168E-01	0.000E+00	1.000E-06	4.168E-01
Sm-145	3.000E-02	0.000E+00	0.000E+00	3.000E-02
Sm-151	0.000E+00	0.000E+00	7.860E-04	7.860E-04
Sm-153	7.910E-02	0.000E+00	0.000E+00	7.910E-02
Sn-113	2.528E+00	1.806E+00	2.375E+00	6.709E+00
Sn-117	2.000E-06	0.000E+00	0.000E+00	2.000E-06
Sn-119	1.500E-02	0.000E+00	0.000E+00	1.500E-02
Sn-119m	9.609E-03	0.000E+00	0.000E+00	9.609E-03
Sn-125	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Sr-82	3.520E-02	0.000E+00	0.000E+00	3.520E-02
Sr-85	1.988E-01	3.000E-06	0.000E+00	1.988E-01
Sr-89	2.123E+01	6.066E+02	8.242E-01	6.287E+02
Sr-90	7.199E+00	3.630E+02	4.392E+03	4.762E+03
Sr-91	2.000E-06	0.000E+00	0.000E+00	2.000E-06
Sr-95	2.000E-06	0.000E+00	0.000E+00	2.000E-06
Ta-182	1.263E-01	6.000E+00	2.327E-01	6.359E+00
Ta-183	2.000E-04	0.000E+00	0.000E+00	2.000E-04
Tb-160	0.000E+00	1.070E-03	0.000E+00	1.070E-03
Tc-96	1.500E-05	0.000E+00	0.000E+00	1.500E-05
Tc-99	2.137E+00	9.558E-01	5.352E+00	8.445E+00
Tc-99m	1.460E+00	1.331E+01	0.000E+00	1.477E+01
Te-123	2.977E-02	0.000E+00	0.000E+00	2.977E-02
Te-123m	5.000E-04	3.770E-02	0.000E+00	3.820E-02
Te-125m	3.002E-01	6.169E-01	4.968E-01	1.414E+00
Te-132	1.145E-01	0.000E+00	0.000E+00	1.145E-01
Th-228	7.740E-04	0.000E+00	1.300E-05	7.870E-04
Th-230	5.930E-04	0.000E+00	0.000E+00	5.930E-04

Table A-4 (Continued)

Nuclide	Class A	Class B	Class C	Total
Th-232	3.386E+02	5.342E-02	4.040E-04	3.387E+02
Th-234	1.719E-02	0.000E+00	0.000E+00	1.719E-02
Th-NAT	3.958E+00	0.000E+00	0.000E+00	3.958E+00
Tl-201	1.642E-01	0.000E+00	0.000E+00	1.642E-01
Tl-202	3.610E-02	0.000E+00	0.000E+00	3.610E-02
Tl-204	9.792E-02	9.120E-04	2.431E-02	1.231E-01
Tm-170	6.010E-03	0.000E+00	0.000E+00	6.010E-03
Tm-171	1.009E-02	0.000E+00	0.000E+00	1.009E-02
TRU-NOS	1.144E-01	3.606E-02	1.522E-02	1.657E-01
U-232	1.000E-06	0.000E+00	0.000E+00	1.000E-06
U-233	2.200E-05	0.000E+00	6.000E-06	2.800E-05
U-234	2.100E+00	3.507E-02	6.620E-04	2.136E+00
U-235	3.316E+00	5.010E-03	8.420E-04	3.321E+00
U-236	1.192E-02	0.000E+00	3.000E-06	1.193E-02
U-238	1.958E+02	6.671E-02	6.127E-03	1.959E+02
U-DEP	1.063E+02	0.000E+00	2.000E-02	1.063E+02
U-NAT	1.403E+00	1.070E-04	0.000E+00	1.403E+00
V-48	1.100E-05	0.000E+00	0.000E+00	1.100E-05
W-178	1.000E-04	0.000E+00	0.000E+00	1.000E-04
W-181	1.000E-05	0.000E+00	0.000E+00	1.000E-05
W-187	2.455E-02	0.000E+00	0.000E+00	2.455E-02
W-188	5.000E-04	0.000E+00	0.000E+00	5.000E-04
Xe-131	4.000E-06	0.000E+00	0.000E+00	4.000E-06
Xe-131m	5.892E+00	6.918E-01	3.000E-05	6.584E+00
Xe-133	5.627E-01	1.367E-02	0.000E+00	5.764E-01
Y-88	5.263E-03	1.000E-06	0.000E+00	5.264E-03
Y-90	4.572E-02	1.000E-06	0.000E+00	4.572E-02
Y-91	2.233E+01	9.568E+02	0.000E+00	9.792E+02
Yb-169	5.370E-04	0.000E+00	0.000E+00	5.370E-04
Zn-65	3.171E+03	2.819E+03	6.372E+01	6.054E+03
Zr-89	2.000E-03	0.000E+00	0.000E+00	2.000E-03
Zr-95	4.004E+01	9.225E+02	1.774E+01	9.803E+02
Zr-97	0.000E+00	6.080E-01	0.000E+00	6.080E-01
Total	2.446E+04	1.335E+05	3.899E+05	5.479E+05

Table A-5. Total Radionuclide Distribution (Ci) by Site

Nuclide	Richland	Beatty	Barnwell	Total
Ac-227	0.000E+00	1.000E-06	0.000E+00	1.000E-06
Ag-100	0.000E+00	4.640E-04	0.000E+00	4.640E-04
Ag-108	0.000E+00	2.300E-03	0.000E+00	2.300E-03
Ag-108m	2.690E-04	0.000E+00	8.090E-01	8.093E-01
Ag-110	5.000E-06	1.950E-03	1.940E+01	1.940E+01
Ag-110m	1.867E+01	2.560E+00	4.915E+01	7.038E+01
Ag-111	0.000E+00	0.000E+00	1.750E-02	1.750E-02
Al-28	0.000E+00	4.000E-06	0.000E+00	4.000E-06
Am-241	4.892E-02	2.812E+00	3.585E-01	3.220E+00
Am-242	0.000E+00	0.000E+00	1.000E-05	1.000E-05
Am-243	1.000E-06	2.000E-06	1.170E-03	1.173E-03
As-73	3.070E-04	4.100E-05	0.000E+00	3.480E-04
As-75	1.100E-03	0.000E+00	0.000E+00	1.100E-03
Au-195	2.921E-02	5.002E-03	6.640E-03	4.085E-02
Au-198	0.000E+00	1.000E-06	1.500E-03	1.501E-03
Au-199	0.000E+00	0.000E+00	1.500E-03	1.500E-03
Ba-131	0.000E+00	1.000E-03	1.180E-01	1.190E-01
Ba-133	3.393E-01	1.641E+00	3.812E-01	2.362E+00
Ba-140	5.383E+00	1.341E-03	2.683E+01	3.222E+01
Be-7	7.659E-02	7.101E-03	1.934E+01	1.942E+01
Bi-205	0.000E+00	0.000E+00	1.000E-05	1.000E-05
Bi-206	0.000E+00	3.000E-06	0.000E+00	3.000E-06
Bi-207	2.407E-03	1.900E-05	1.560E-03	3.986E-03
Bi-210	1.000E-06	4.000E-06	1.000E-05	1.500E-05
Bi-214	2.000E-06	0.000E+00	0.000E+00	2.000E-06
Br-82	0.000E+00	1.000E-06	0.000E+00	1.000E-06
C-14	8.992E+01	2.410E+02	1.049E+02	4.359E+02
Ca-45	1.535E+00	1.127E+00	2.406E-01	2.902E+00
Ca-46	0.000E+00	1.100E-05	0.000E+00	1.100E-05
Ca-47	3.100E-05	5.000E-06	0.000E+00	3.600E-05
Cd-107	0.000E+00	1.000E-06	0.000E+00	1.000E-06
Cd-109	4.125E+00	8.992E-01	1.732E+00	6.756E+00
Cd-115	2.500E-05	0.000E+00	0.000E+00	2.500E-05
Cd-115m	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Ce-134	8.000E-05	0.000E+00	0.000E+00	8.000E-05
Ce-139	1.030E-04	6.020E-04	2.564E-02	2.635E-02
Ce-141	9.734E-01	2.366E-01	2.430E+02	2.442E+02
Ce-143	0.000E+00	0.000E+00	9.440E+00	9.440E+00
Ce-144	1.691E+00	1.879E-01	1.527E+03	1.529E+03
Cf-252	1.000E-05	1.000E-06	2.000E-05	3.100E-05
Cl-35	2.000E-05	0.000E+00	0.000E+00	2.000E-05
Cl-36	6.953E-02	4.238E-02	8.937E-02	2.013E-01
Cm-242	6.674E-03	9.145E-03	2.969E-01	3.127E-01
Cm-243	9.456E-03	1.210E-03	5.897E-02	6.964E-02
Cm-244	5.568E-03	2.232E-01	7.155E-02	3.004E-01
Co-56	8.559E-03	2.620E-04	8.600E-04	9.681E-03

Table A-5 (Continued)

Nuclide	Richland	Beatty	Barnwell	Total
Co-57	4.045E+00	2.823E+00	3.597E+01	4.284E+01
Co-58	2.062E+02	1.489E+01	8.025E+03	8.246E+03
Co-59	0.000E+00	3.228E-02	0.000E+00	3.228E-02
Co-60	1.459E+03	1.319E+03	1.778E+05	1.806E+05
Cr-51	4.330E+02	4.832E+01	6.647E+03	7.128E+03
Cr-53	0.000E+00	4.300E-05	0.000E+00	4.300E-05
Cs-134	2.602E+02	1.284E+01	1.815E+03	2.088E+03
Cs-135	0.000E+00	0.000E+00	7.000E-05	7.000E-05
Cs-136	2.349E-01	2.000E-03	8.044E-01	1.041E+00
Cs-137	5.741E+02	2.419E+03	6.363E+03	9.356E+03
Cs-139	6.800E-02	0.000E+00	0.000E+00	6.800E-02
Cu-64	1.000E-06	1.000E-06	0.000E+00	2.000E-06
Cu-67	1.250E-04	2.422E-03	1.000E-05	2.557E-03
Dy-159	2.000E-04	1.000E-04	3.000E-04	6.000E-04
Dy-165	5.000E-06	0.000E+00	0.000E+00	5.000E-06
Er-171	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Eu-152	1.111E-02	1.128E-02	2.420E-02	4.659E-02
Eu-154	5.241E-03	9.219E-03	5.480E-01	5.625E-01
Eu-155	6.522E-02	2.608E-03	1.051E-02	7.834E-02
Fe-52	4.000E-06	0.000E+00	0.000E+00	4.000E-06
Fe-55	1.714E+03	1.433E+03	1.823E+05	1.855E+05
Fe-57	1.700E-04	0.000E+00	3.800E-04	5.500E-04
Fe-59	8.708E+00	2.131E+01	4.357E+02	4.657E+02
Ga-67	1.441E-01	4.837E-02	2.890E-03	1.954E-01
Ga-68	3.800E-05	1.390E-01	0.000E+00	1.390E-01
Gd-153	2.023E+00	1.410E+00	2.345E-02	3.456E+00
Gd-159	0.000E+00	1.001E-03	0.000E+00	1.001E-03
Ge-67	0.000E+00	1.000E-05	0.000E+00	1.000E-05
Ge-68	3.613E-02	5.349E-01	1.216E-02	5.832E-01
H-3	8.663E+04	4.885E+03	1.014E+04	1.017E+05
Hf-175	0.000E+00	2.880E+00	2.667E+02	2.696E+02
Hf-181	3.930E-04	5.300E-01	4.194E+02	4.200E+02
Hg-203	4.232E-03	9.235E-02	2.858E-02	1.252E-01
Ho-166m	0.000E+00	4.000E-03	0.000E+00	4.000E-03
I-123	1.345E-01	1.177E-01	6.210E-02	3.143E-01
I-124	0.000E+00	1.500E-04	5.558E-02	5.573E-02
I-125	3.521E+01	2.824E+01	2.627E+01	8.972E+01
I-129	4.338E-02	7.605E-03	3.539E-01	4.048E-01
I-131	1.087E+01	1.466E-01	8.650E+01	9.752E+01
I-133	0.000E+00	0.000E+00	4.221E+00	4.221E+00
I-135	0.000E+00	0.000E+00	2.206E-02	2.206E-02
In-111	2.252E-01	5.478E-02	2.487E-02	3.048E-01
In-113	0.000E+00	1.300E-02	0.000E+00	1.300E-02
In-114	1.656E-03	3.690E-03	2.910E-03	8.256E-03
In-114m	1.453E-02	1.359E-01	6.570E-02	2.161E-01
Ir-192	2.522E-03	6.779E-01	1.850E-03	6.823E-01
K-40	5.340E-04	4.000E-06	2.000E-04	7.380E-04

Table A-5 (Continued)

Nuclide	Richland	Beatty	Barnwell	Total
Kr-81	5.500E-02	0.000E+00	0.000E+00	5.500E-02
Kr-85	2.284E+00	6.002E+00	1.202E+01	2.031E+01
Kr-87	0.000E+00	3.100E-05	0.000E+00	3.100E-05
Kr-89	0.000E+00	1.039E-02	0.000E+00	1.039E-02
La-140	5.787E+00	1.000E-06	4.272E+01	4.851E+01
Mn-54	2.578E+02	2.111E+02	1.462E+04	1.509E+04
Mn-56	0.000E+00	5.000E-03	0.000E+00	5.000E-03
Mn-57	0.000E+00	0.000E+00	1.000E-05	1.000E-05
Mo-99	5.850E-02	9.650E-02	2.565E-01	4.115E-01
Na-22	3.399E-01	2.089E+00	1.127E-01	2.542E+00
Na-24	1.170E-04	4.079E-01	4.197E-02	4.500E-01
Nb-93	0.000E+00	1.003E+00	0.000E+00	1.003E+00
Nb-94	4.682E-03	2.415E-02	5.028E-01	5.316E-01
Nb-95	1.299E+01	4.178E-01	1.757E+03	1.770E+03
Nb-96	0.000E+00	1.000E-04	0.000E+00	1.000E-04
Nd-147	0.000E+00	0.000E+00	4.739E-02	4.739E-02
Ni-59	1.013E+00	6.927E-02	1.650E+02	1.660E+02
Ni-63	3.321E+02	3.854E+01	1.593E+04	1.630E+04
Np-237	1.000E-06	5.010E-04	7.000E-04	1.202E-03
Np-239	1.455E-01	0.000E+00	1.610E-01	3.065E-01
Os-185	0.000E+00	1.000E-06	0.000E+00	1.000E-06
Os-191	0.000E+00	3.000E-04	0.000E+00	3.000E-04
P-32	1.812E+01	1.151E+01	1.379E+01	4.342E+01
P-33	0.000E+00	0.000E+00	1.000E-04	1.000E-04
Pa-234	1.000E-06	2.000E-06	0.000E+00	3.000E-06
Pb-203	0.000E+00	1.100E-02	0.000E+00	1.100E-02
Pb-210	2.100E-04	6.118E-02	6.000E-05	6.145E-02
Pb-212	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Pb-214	0.000E+00	0.000E+00	1.000E-05	1.000E-05
Pd-103	0.000E+00	0.000E+00	6.400E-02	6.400E-02
Pd-107	0.000E+00	1.000E-06	0.000E+00	1.000E-06
Pm-147	5.915E-01	1.787E+01	4.199E+02	4.384E+02
Po-208	1.000E-05	0.000E+00	0.000E+00	1.000E-05
Po-210	5.020E+00	3.320E-02	3.862E-02	5.092E+00
Pr-143	0.000E+00	0.000E+00	2.000E-05	2.000E-05
Pr-144	3.242E-02	1.513E-03	0.000E+00	3.393E-02
Pt-193	0.000E+00	2.000E-04	0.000E+00	2.000E-04
Pu-234	0.000E+00	0.000E+00	8.340E-03	8.340E-03
Pu-237	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Pu-238	2.993E-02	1.004E-02	5.781E-01	6.180E-01
Pu-239	5.382E-02	5.498E-02	1.239E-01	2.327E-01
Pu-240	2.338E-02	1.521E-02	1.656E-02	5.515E-02
Pu-241	1.966E+00	8.342E-01	1.657E+01	1.937E+01
Pu-242	8.700E-05	0.000E+00	6.320E-03	6.407E-03
Pu-244	1.500E-05	0.000E+00	0.000E+00	1.500E-05
Ra-226	2.712E-01	1.687E+01	9.639E-02	1.724E+01

Table A-5 (Continued)

Nuclide	Richland	Beatty	Barnwell	Total
Ra-228	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Rb-85	0.000E+00	5.000E-04	0.000E+00	5.000E-04
Rb-86	1.000E-01	3.924E-01	1.984E-01	6.908E-01
Rb-87	0.000E+00	4.000E-05	0.000E+00	4.000E-05
Re-184m	9.000E-06	0.000E+00	0.000E+00	9.000E-06
Re-186	0.000E+00	3.000E-03	1.100E-02	1.400E-02
Re-187	2.000E-06	0.000E+00	0.000E+00	2.000E-06
Rh-105	0.000E+00	0.000E+00	3.170E-03	3.170E-03
Rh-106	2.330E-02	3.000E-05	4.700E-03	2.803E-02
Ru-103	7.215E-02	1.715E-01	1.539E+02	1.542E+02
Ru-105	5.000E-06	1.000E-06	0.000E+00	6.000E-06
Ru-106	1.789E+00	3.627E-01	8.796E+01	9.012E+01
Ru-109	0.000E+00	9.670E-03	0.000E+00	9.670E-03
S-35	2.354E+02	1.411E+01	1.307E+01	2.626E+02
Sb-113	2.990E-04	0.000E+00	0.000E+00	2.990E-04
Sb-122	0.000E+00	0.000E+00	7.743E+00	7.743E+00
Sb-124	1.421E+01	4.536E-01	5.348E+02	5.494E+02
Sb-125	1.028E+01	1.050E+00	4.188E+02	4.301E+02
Sc-44	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Sc-46	8.589E-02	8.481E-01	5.297E+01	5.391E+01
Sc-47	1.000E-06	0.000E+00	0.000E+00	1.000E-06
Se-75	2.292E-02	2.958E-01	9.814E-02	4.168E-01
Sm-145	0.000E+00	3.000E-02	0.000E+00	3.000E-02
Sm-151	0.000E+00	7.860E-04	0.000E+00	7.860E-04
Sm-153	7.910E-02	0.000E+00	0.000E+00	7.910E-02
Sn-113	1.185E-01	1.641E+00	4.949E+00	6.709E+00
Sn-117	0.000E+00	2.000E-06	0.000E+00	2.000E-06
Sn-119	0.000E+00	1.500E-02	0.000E+00	1.500E-02
Sn-119m	1.009E-03	8.600E-03	0.000E+00	9.609E-03
Sn-125	0.000E+00	1.000E-06	0.000E+00	1.000E-06
Sr-82	5.000E-05	3.415E-02	1.000E-03	3.519E-02
Sr-85	4.602E-02	6.785E-02	8.497E-02	1.988E-01
Sr-89	1.843E+00	2.314E-03	6.268E+02	6.287E+02
Sr-90	1.709E+02	4.711E+02	4.120E+03	4.762E+03
Sr-91	2.000E-06	0.000E+00	0.000E+00	2.000E-06
Sr-95	2.000E-06	0.000E+00	0.000E+00	2.000E-06
Ta-182	1.203E-01	5.030E-04	6.238E+00	6.359E+00
Ta-183	2.000E-04	0.000E+00	0.000E+00	2.000E-04
Tb-160	0.000E+00	0.000E+00	1.070E-03	1.070E-03
Tc-96	0.000E+00	1.500E-05	0.000E+00	1.500E-05
Tc-99	1.483E+00	1.254E+00	5.708E+00	8.445E+00
Tc-99m	7.091E-01	5.213E-02	1.400E+01	1.477E+01
Te-123	2.977E-02	0.000E+00	0.000E+00	2.977E-02
Te-123m	0.000E+00	5.000E-04	3.770E-02	3.820E-02
Te-125m	4.531E-01	7.341E-02	8.874E-01	1.414E+00
Te-132	1.000E-06	0.000E+00	1.145E-01	1.145E-01
Th-228	5.570E-04	2.300E-04	0.000E+00	7.870E-04

Table A-5 (Continued)

Nuclide	Richland	Beatty	Barnwell	Total
Th-230	5.910E-04	2.000E-06	0.000E+00	5.930E-04
Th-232	8.760E-02	2.563E-01	3.383E+02	3.387E+02
Th-234	3.000E-06	0.000E+00	1.719E-02	1.719E-02
Th-NAT	3.958E+00	3.600E-05	0.000E+00	3.958E+00
Tl-201	1.135E-01	3.095E-02	1.971E-02	1.642E-01
Tl-202	6.000E-04	0.000E+00	3.550E-02	3.610E-02
Tl-204	1.079E-02	2.874E-02	8.361E-02	1.231E-01
Tm-170	0.000E+00	6.010E-03	0.000E+00	6.010E-03
Tm-171	5.000E-05	1.000E-02	4.000E-05	1.009E-02
TRU-NOS	0.000E+00	0.000E+00	1.657E-01	1.657E-01
U-232	0.000E+00	1.000E-06	0.000E+00	1.000E-06
U-233	1.100E-05	7.000E-06	1.000E-05	2.800E-05
U-234	2.746E-02	6.418E-03	2.102E+00	2.136E+00
U-235	4.300E-03	1.060E-04	3.317E+00	3.321E+00
U-236	1.330E-04	3.000E-06	1.179E-02	1.193E-02
U-238	8.917E-01	7.340E+01	1.216E+02	1.959E+02
U-DEP	2.240E-02	5.660E-02	1.062E+02	1.063E+02
U-NAT	1.402E+00	6.550E-04	0.000E+00	1.403E+00
V-48	0.000E+00	1.100E-05	0.000E+00	1.100E-05
W-178	0.000E+00	0.000E+00	1.000E-04	1.000E-04
W-181	0.000E+00	1.000E-05	0.000E+00	1.000E-05
W-187	2.455E-02	0.000E+00	0.000E+00	2.455E-02
W-188	5.000E-04	0.000E+00	0.000E+00	5.000E-04
Xe-131	4.000E-06	0.000E+00	0.000E+00	4.000E-06
Xe-131m	1.323E-01	0.000E+00	6.451E+00	6.584E+00
Xe-133	7.918E-02	2.031E-03	4.952E-01	5.764E-01
Y-88	1.466E-03	2.228E-03	1.570E-03	5.264E-03
Y-90	3.758E-02	5.927E-03	2.210E-03	4.572E-02
Y-91	0.000E+00	0.000E+00	9.792E+02	9.792E+02
Yb-169	3.700E-05	5.000E-04	0.000E+00	5.370E-04
Zn-65	4.357E+02	8.750E+00	5.609E+03	6.054E+03
Zr-89	2.000E-03	0.000E+00	0.000E+00	2.000E-03
Zr-95	8.163E+00	1.321E-01	9.720E+02	9.803E+02
Zr-97	0.000E+00	0.000E+00	6.080E-01	6.080E-01
Total	9.298E+04	1.132E+04	4.436E+05	5.479E+05

APPENDIX B

DEPARTMENT OF ENERGY RADIONUCLIDE DISTRIBUTION BY SITE

APPENDIX B

DEPARTMENT OF ENERGY RADIONUCLIDE DISTRIBUTION BY SITE

This appendix presents isotopic inventories and other data for low-level radioactive waste (LLW) and mixed LLW disposed during calendar year 1990 at Department of Energy (DOE) sites. Information on DOE waste disposal was obtained from personnel in DOE field offices and DOE contractors [1-11, 28]. In addition, a limited amount of information is provided about low-level waste and mixed low-level waste placed in storage during 1990.

B.1 Disposed Low-Level and Mixed Low-Level Waste

Isotopic inventories for six DOE sites where disposal of solid low-level and mixed waste took place during 1990 are provided in Tables B-1 through B-8. In order, these six sites are Savannah River Site (SRS), Nevada Test Site (NTS), Los Alamos National Laboratory (LANL), Idaho National Engineering Laboratory (INEL), Oak Ridge National Laboratory (ORNL), and the Hanford Site. Information presented for SRS includes solid waste disposal as well as saltstone. LLW disposal took place at all these sites during 1990; mixed waste disposal took place only at NTS and at Hanford.

Herein, the phrase "mixed waste" is used as a **general** term to describe waste that contains a mixture of radioactive isotopes and chemically or physically hazardous materials. The current definition of mixed waste in DOE 5820.2A, Radioactive Waste Management, is "waste containing both radioactive and hazardous components as defined by the Atomic Energy Act and the Resource Conservation and Recovery Act [RCRA], respectively" [32]. In practice, however, a broader and varying spectrum of materials are being managed for both their radioactive and hazardous characteristics. For one reason, state definitions of hazardous materials can differ from those of the Environmental Protection Agency (EPA). In addition, polychlorinated biphenyls (PCBs) must be managed as hazardous substances, but are regulated under the Toxic Substances Control Act (TSCA) rather than RCRA.

For Tables B-1 through B-7, we reproduced the format and notation of the data obtained from different DOE sites. In some cases, data was provided in scientific notation, and in other cases, data was provided in fixed notation. Different sets of data were obtained using different numbers of significant figures.

Occasionally, inventories for some isotopes were provided as zero quantities. For data provided in scientific notation (e.g., see Table B-4), we assumed that although the isotope was reasonably

Table B-1. Low-Level Waste Disposal at Savannah River Site[a]

Nuclide	Activity (Ci)
Am-241	Not identified on disposal receipt
Am-243	Not identified on disposal receipt
C-14	2.56E-07
Cf-252	1.98E+01
Cm-244	2.59E+00
Co-60	7.70E+01
Cs-137	3.12E+01
Eu-154	1.04E-01
H-3	2.63E+04
I-129	1.39E-06
Nb-94	5.40E-09
Ni-59	2.31E-04
Ni-63	7.87E-01
Np-237	Not identified on disposal receipt
Pu-238	Not identified on disposal receipt
Pu-239	Not identified on disposal receipt
Pu-240	Not identified on disposal receipt
Pu-241	Not identified on disposal receipt
Pu-242	Not identified on disposal receipt
Rb-87	1.51E-09
Se-75	6.92E+00
Se-79	2.38E-05
Sm-151	3.95E-02
Sr-90	3.09E+01
Tc-99	8.19E-04
Th-232	5.03E+00
U-233	Not identified on disposal receipt
U-234	8.58E-01
U-235	2.57E-02
U-236	1.07E-01
U-238	7.09E-01
Total	2.65E+04

[a] Contained in 845,540 ft^3 of waste [1, 2].

Table B-2. Saltstone Disposal at Savannah River Site[a]

Nuclide	Activity (Ci)	Concentration (nCi/g)[b]
Vault 1, Cell A:		
H-3	2E+1	3
C-14	0.5	8E-2
Ni-59	<5E-4	<8E-5
Ni-63	2E-3	3E-4
Co-60	3E-3	5E-4
Se-79	0.1	2E-2
Sr/Y90[c]	<7E-3	<1E-3
Nb-94	<8E-4	<1E-4
Tc-99	4E+1	7
Ru-106	0.2	3E-2
Sb-125	0.7	0.1
Sn-126	0.3	5E-2
I-129	1E-2	2E-3
Cs-137[c]	2	0.4
Eu-154	<8E-4	1E-4
Np-237	3E-5	5E-6
Pu-241	<4E-4	<7E-5
Total alpha	0.2	4E-2
Vault 4,[d] Cell A:		
U-234	3.2	1.2
U-235	6E-2	2E-2
U-238	1E-4	4E-5
Total U	3.3	1.2
Total	67.3[e]	

[a] Vault 1 contains 140,000 ft^3 of radioactive saltstone; Vault 4 contains 10,032 55-gal. drums of waste (73,800 ft^3), plus clean grout backfill.
[b] Concentrations listed for Vault 1 refer to average concentrations across all saltstone; concentrations listed for Vault 4 refer only to waste within drums, and not to clean grout used as backfill.
[c] Activity only refers to the parent isotope.
[d] Formerly named Vault 6.
[e] As estimated by summing over all citations, including "less-than" citations.

Table B-3. Waste Disposal at Nevada Test Site[a]

Nuclide	NTS Area 5 (Ci)[b]	NTS Area 3 (Ci)	Total (Ci)
Ac-227	0.0000001		0.0000001
Am-241	0.00225225		0.00225225
Am-243	0.00000002		0.00000002
Ba-140	0.0000202903	0.001079	0.0010992903
C-14	0.00602561		0.00602561
Ce-141	0.0004395041	0.002362	0.0028015041
Ce-144	0.0042574954	0.0013840027	0.0056414981
Cm-242	0.00000002		0.00000002
Cm-244	0.00000043		0.00000043
Co-60	0.06001208813	0.0000381	0.06005018813
Cs-134	0.01200472542		0.01200472542
Cs-137	0.18184245813	0.000044600054	0.181887058184
Eu-152	0.00000002		0.00000002
Eu-154	0.0031891		0.0031891
Fe-59	0.00000945084	0.0000508	0.00006025084
H-3	14,599.56915	0.055296	14,599.624446
Kr-85	0.00009	0.012833782	0.012923782
Mn-54	0.00021242439	0.00011430018	0.00032672457
MFP[c]	0.078626		0.078626
Na-22	0.00001		0.00001
Nb-95	0.0005858721	0.00314900054	0.00373487264
P-32	0.01105		0.01105
Po-210	0.00025432		0.00025432
Pu-238	0.3390000000001	0.0004	0.3394000000001
Pu-239	0.03727143577	0.000000268	0.03727170377
Pu-240	0.000175184	0.000000188	0.000175372
Pu-241	0.0208826	0.0	0.0208826
Pu-242	0.0000001320001	0.0	0.0000001320001
Pu-52[c]	30.37503284963		30.37503284963
Ra-226	0.285		0.285
Ru-103	0.0002741144	0.001473000027	0.001747114427
Ru-106	0.00004489149	0.000243	0.00028789149
S-35	0.000001		0.000001
Sb-124	0.00003071523	0.0001651	0.00019581523
Sb-125	0.00005197962	0.0002794	0.00033137962
Sr-85		0.00000000036	0.00000000036
Sr-90	0.26001013		0.26001013
Th-228	0.00267605	0.00007451	0.00275056
Th-232	0.01243305	0.00007412	0.01250717
U-233	0.00000003		0.00000003
U-235	0.001011918	0.004262952	0.00527487
U-238	7.862279189	0.1370718	7.999350989
Zr-95	0.0004205824	0.0022600027	0.00268058267
Total	14,639.1266189133502	0.222655924131	14,639.3492748374832

[a] Area 5: 9819.18051959 m^3; Area 3: 4277.855354 m^3 [3].

[b] Mixed waste disposal at Area 5 totaled 29 Ci and 4,970 m^3.

[c] MFP: mixed fission products; Pu-52: a SWIMS category used by Rocky Flats Plant for Pondcrete and including Pu-238, Pu-239, Pu-240, Pu-241, and Pu-242.

Table B-4. Low-Level Waste Disposal at Los Alamos National Laboratory[a]

Nuclide	Activity (Ci)	Nuclide	Activity (Ci)
Am-241	9.2960E-03	Pu-239	7.2645E-02
Am-243	0.0000E+00	Pu-241	7.5170E-05
C-14	2.0000E-09	Pu-52[b]	3.6122E-01
Ce-144	2.1421E-03	Ra-226	1.0000E-03
Co-60	5.2508E+01	Ru-106	9.2401E-04
Cs-134	1.1000E-07	Sr-82	2.0000E+00
Cs-137	6.1900E-02	Sr-90	4.0350E+00
Eu-152	2.0000E-08	Tc-99	1.1550E-05
H-3	1.1196E+02	Th-228	1.0000E-06
I-125	0.0000E+00	Th-232	1.0900E-06
MAP[b]	6.3234E+02	Th-88[b]	2.0000E-09
MFP[b]	1.1248E+01	U-233	0.0000E+00
Na-22	9.2000E+01	U-235	5.7035E-01
Ni-63	1.0000E-05	U-238	2.2661E+00
Np-237	0.0000E+00	U-239	0.0000E+00
P-32	0.0000E+00	U-38[b]	2.0037E-02
Pa-231	9.0000E-09	U-81[b]	3.4600E-06
Pu-238	2.0000E-03	Zr-95	2.0807E-02
		Total	9.0948E+02[c]

[a] Contained in 4534.1 m^3 of waste [4, 8].

[b] MAP: mixed activation products; MFP: mixed fission products; Pu-52: a SWIMS category used by Rocky Flats Plant for Pondcrete and including Pu-238, Pu-239, Pu-240, Pu-241, and Pu-242; Th-88: total thorium; U-38: uranium enriched between 92 and 94% U-235; U-81: normal uranium (0.711%).

[c] Reference 8 indicates a total of 899.5 Ci.

Table B-5. Low-Level Waste Disposal at Idaho National Engineering Laboratory[a]

Nuclide	Activity (Ci)	Nuclide	Activity (Ci)
Ag-110m	3.106E-3	Ni-63	3.470E+4
Am-241	4.475E-4	Np-237	1.214E-7
Ba-137m	1.298E-1	Pr-144	4.264E+1
Ba-140	8.357E-2	Pu-238	6.147E-4
C-14	2.782E+0	Pu-239	3.035E-3
Ce-141	2.244E-1	Pu-240	2.732E-4
Ce-144	4.451E+1	Pu-241	1.296E-2
Cm-242	9.835E-8	Pu-242	2.450E-8
Cm-244	7.848E-6	Rh-106	2.114E+1
Co-57	1.529E-2	Ru-103	1.015E-1
Co-58	2.494E+4	Ru-106	2.144E+1
Co-60	9.889E+4	Sb-124	6.800E-4
Cr-51	9.908E+3	Sb-125	7.797E+2
Cs-134	2.117E+1	Sc-46	2.870E-2
Cs-137	2.593E+3	Se-75	1.014E-2
Eu-152	1.806E-3	Sn-113	3.300E-3
Eu-154	1.872E-3	Sn-119m	2.815E+3
Eu-155	6.429E-3	Sr-89	4.769E-1
Fe-55	1.188E+4	Sr-90	8.357E+1
Fe-59	6.371E+2	Sr-92	1.600E-3
H-3	9.638E-1	Ta-182	6.050E-3
Hf-181	3.395E-1	Tc-99	5.916E-3
I-129	5.370E-4	Th-234	1.600E-6
K-40	1.446E-3	U-234	7.764E-4
La-140	1.004E-1	U-235	1.706E-3
Mn-54	1.802E+4	U-236	1.096E-6
MAP[b]	5.450E+0	U-238	2.370E-1
MFP[b]	7.174E+0	Y-88	3.000E-3
Na-22	7.093E-4	Y-90	2.114E+1
Nb-94	6.900E-6	Y-91m	9.324E-22
Nb-95	1.064E+3	Zn-65	1.232E+0
Ni-59	2.590E+2	Zr-95	7.822E+2
		Total	2.075E+5

[a] Contained in 1,762 cubic meters of waste [6].
[b] MAP: mixed activation products; MFP: mixed fission products.

Table B-6. Low-Level Waste Disposal at Oak Ridge National Laboratory[a]

Nuclide	Activity (Ci)
Am-241	0.007116
C-14	0.054599
Cm-244	0.003312
Co-58	0.000100
Co-60	10.134429
Cs-134	0.200000
Cs-137	251.446578
Eu-152	99.860000
Eu-154	107.620000
Fe-59	0.000100
Gd-153	0.083000
H-3	0.149517
I-125	0.000510
Ir-192	0.280000
Mn-54	0.001000
Os-191	0.052517
P-32	0.000085
Pd-103	0.282340
Pm-147	0.000017
Pt-195	0.000017
Pu-239	0.000002
Sr-90	248.336872
Ta-179	0.001700
Th-232	0.000173
U-233	0.000600
U-235	0.000536
U-238	0.010011
Y-90	1.741100
Total	720.266231

[a] Contained in 254.3 m^3 of waste [11, 12].

Table B-7. Data Obtained for Waste Disposed at Hanford Site[a]

Nuclide	West[b]	East[b]	Submarines[b]	Units
Ag-108	0.00001			CI
Ag-110	0.00002			CI
Al-28	0.00003			CI
Am-241	0.30726			GM
Am-243	0.00521			GM
Au-195	0.00005			CI
Ba-133	0.00000			CI
Be-10	0.00000		2.82E-07	CI
Be-7	0.00000			CI
C-14	0.09445	0.00000	27.64100	CI
Ca-45	0.00105			CI
Cd-109	0.01111			CI
Ce-141	0.00000			CI
Ce144/Pr144	3.94454	0.43410		CI
Cf-252	0.02402			GM
Cl-36	0.00010		0.00342	CI
Cm-244	0.00314		0.00000	GM
Co-57	0.00031			CI
Co-58	0.19167		207.07360	CI
Co-60	2639.66192	0.00520	95365.00000	CI
Cr-51	0.00281		0.37860	CI
Cs-134	0.92165	0.00750	0.00700	CI
Cs137/Ba137	237.02271	4.92094	0.02385	CI
Es-254	0.00000			CI
Eu-152	0.24107			CI
Eu-154	0.30814			CI
Eu-155	0.02464			CI
Fe-55	0.46480		57871.00000	CI
Fe-59	1.05076		0.50114	CI
Gd-153	0.00059			CI
Ge-68	0.00003			CI
H-3	42985.36985	0.00041	905.70142	CI
Hf-181			0.0001613	CI
I-123	0.00000			CI
I-125	0.06226			CI
I-129	0.00005		0.00177	CI
I-131	0.00221			CI
K-40	0.00011	0.00905		CI
Kr-85	0.22000			CI
Mn-54	1.43742		731.43700	CI
Mo-93			0.05850	CI
Na-22	0.02364			CI
Nb-91	0.00002			CI
Nb-93m	0.00009			CI
Nb-94	0.00010		0.09132	CI
Nb-95	0.01075		0.00002	CI
Ni-59	0.00033		644.20000	CI

Table B-7 (Continued)

Nuclide	West[b]	East[b]	Submarines[b]	Units
Ni-63	0.05877		93500.00000	CI
Np-237	14.01274			GM
P-32	0.15270			CI
Pa-231	0.00684			CI
Pb-212	0.00000			CI
Pb-214	0.00000			CI
PE-CI[c]	0.00000			CI
Pm-147	3.04560	0.20990		CI
Pu[c]	6.87832		0.00054	GM
Pu-238	0.00146			GM
Pu239FGE[c]	0.00000			GM
Ra-226	0.09480			GM
Rb-86	0.00387			CI
Re-187	0.00020			CI
Ru103/Rh103m	0.00084			CI
Ru106/Rh106	1.41634	0.11190		CI
S-35	0.09516			CI
Sb-122	0.00000			CI
Sb-124	0.00002			CI
Sb-125	0.00038			CI
Sc-46	0.00017			CI
Se-75	0.00029			CI
Se-79			0.00000	CI
Sm-147	0.00020			CI
Sm-151	0.47605	0.06900		CI
Sn-113	0.00068			CI
Sn-123m	0.00002			CI
Sr-82	0.00014			CI
Sr-85	0.07416			CI
Sr90/Y90	153.22036	7.63356	0.023741	CI
Ta-182	0.20064			CI
Tc-99	0.06055		0.01679	CI
Te-121	0.00010			CI
Te-127	0.00025			CI
Te-129m	0.00000			CI
Th-232	50525.00000			GM
Th-234	0.00000			GM
Tm-170	0.00020			CI
Tot Beta-Gamma[c]	46433.08145	26.50218		CI
Total alpha[c]	0.00000			CI
U-232	0.00150			GM
U-233	1.82165			GM
U-DEP[c]	2305728.43651			GM
U-ENRICH[c]	45791.96703			GM
U-NAT[c]	10486.90070			GM
V-49	0.00000			CI
Y-87	0.00150			CI

Table B-7 (Continued)

Nuclide	West[b]	East[b]	Submarines[b]	Units
Y-88	0.00002			CI
Y-90	0.16030			CI
Zn-65	0.00088			CI
Zr-93			0.00003	CI
Zr95/Nb95m	0.01006		0.00927	CI

[a] Contained in 13,394 m^3 of waste [7].

[b] Respectively, 200-West disposal area, 200-East disposal area, and submarine reactor compartment disposal area.

[c] PE-CI: plutonium equivalent, curies; Pu: unspecified Pu; Pu239FGE: plutonium fissile gram equivalent; Tot Beta-Gamma: sum of all beta-gamma activity, including inferred progeny; Total alpha: sum of alpha activity reported in Ci; U-DEP: depleted uranium; U-ENRICH: enriched uranium; U-NAT: natural uranium.

Table B-8. Estimated Radionuclide Activity of Hanford Waste (Ci)

Nuclide	West[a]	East[a]	Subs[a]	Total
Ag-108	1.000E-05			1.000E-05
Ag-110	2.000E-05			2.000E-05
Al-28	3.000E-05			3.000E-05
Am-241	1.055E+00			1.055E+00
Am-243	1.040E-03			1.040E-03
Au-195	5.000E-05			5.000E-05
Be-10			2.820E-07	2.820E-07
C-14	9.445E-02		2.764E+01	2.774E+01
Ca-45	1.050E-03			1.050E-03
Cd-109	1.111E-02			1.111E-02
Ce144/Pr144	3.945E+00	4.341E-01		4.379E+00
Cf-252	1.290E+01			1.290E+01
Cl-36	1.000E-04		3.420E-03	3.520E-03
Cm-244	2.540E-01			2.540E-01
Co-57	3.100E-04			3.100E-04
Co-58	1.917E-01		2.071E+02	2.073E+02
Co-60	2.640E+03	5.200E-03	9.537E+04	9.800E+04
Cr-51	2.810E-03		3.786E-01	3.814E-01
Cs-134	9.217E-01	7.500E-03	7.000E-03	9.362E-01
Cs137/Ba137m	2.370E+02	4.921E+00	2.385E-02	2.420E+02
Eu-152	2.411E-01			2.411E-01
Eu-154	3.081E-01			3.081E-01
Eu-155	2.464E-02			2.464E-02
Fe-55	4.648E-01		5.787E+04	5.787E+04
Fe-59	1.051E+00		5.011E-01	1.552E+00
Gd-153	5.900E-04			5.900E-04
Ge-68	3.000E-05			3.000E-05
H-3	4.299E+04	4.100E-04	9.057E+02	4.389E+04
Hf-181			1.613E-04	1.613E-04
I-125	6.226E-02			6.226E-02
I-129	5.000E-05		1.770E-03	1.820E-03
I-131	2.210E-03			2.210E-03
K-40	1.100E-04	9.050E-03		9.160E-03
Kr-85	2.200E-01			2.200E-01
Mn-54	1.437E+00		7.314E+02	7.329E+02
Mo-93			5.850E-02	5.850E-02
Na-22	2.364E-02			2.364E-02
Nb-91	2.000E-05			2.000E-05
Nb-93m	9.000E-05			9.000E-05
Nb-94	1.000E-04		9.132E-02	9.142E-02
Nb-95	1.075E-02		2.000E-05	1.077E-02
Ni-59	3.300E-04		6.442E+02	6.442E+02
Ni-63	5.877E-02		9.350E+04	9.350E+04
Np-237	9.876E-03			9.876E-03
P-32	1.527E-01			1.527E-01
Pa-231	6.840E-03			6.840E-03
Pm-147	3.046E+00	2.099E-01		3.256E+00
Pu	5.977E-01		4.693E-05	5.978E-01
Pu-238	2.499E-02			2.499E-02

Table B-8 (Continued)

Nuclide	West[a]	East[a]	Subs[a]	Total
Ra-226	9.380E-02			9.380E-02
Rb-86	3.870E-03			3.870E-03
Re-187	2.000E-04			2.000E-04
Ru103/Rh103m	8.400E-04			8.400E-04
Ru106/Rh106	1.416E+00	1.119E-01		1.528E+00
S-35	9.516E-02			9.516E-02
Sb-124	2.000E-05			2.000E-05
Sb-125	3.800E-04			3.800E-04
Sc-46	1.700E-04			1.700E-04
Se-75	2.900E-04			2.900E-04
Sm-147	2.000E-04			2.000E-04
Sm-151	4.761E-01	6.900E-02		5.451E-01
Sn-113	6.800E-04			6.800E-04
Sn-123m	2.000E-05			2.000E-05
Sr-82	1.400E-04			1.400E-04
Sr-85	7.416E-02			7.416E-02
Sr90/Y90	1.532E+02	7.634E+00	2.374E-02	1.609E+02
Ta-182	2.006E-01			2.006E-01
Tc-99	6.055E-02		1.679E-02	7.734E-02
Te-121	1.000E-04			1.000E-04
Te-127	2.500E-04			2.500E-04
Th-232	5.558E-03			5.558E-03
Tm-170	2.000E-04			2.000E-04
U-232	3.210E-02			3.210E-02
U-233	1.756E-02			1.756E-02
U-DEP	7.752E+00			7.752E+00
U-ENRICH	9.900E-01			9.900E-01
U-NAT	7.215E-03			7.215E-03
Y-87	1.500E-03			1.500E-03
Y-88	2.000E-05			2.000E-05
Y-90	1.603E-01			1.603E-01
Zn-65	8.800E-04			8.800E-04
Zr-93			3.000E-05	3.000E-05
Zr95/Nb95m	1.006E-02		9.270E-03	1.933E-02
*Ba-137m[b]	2.242E+02	4.655E+00	2.256E-02	2.289E+02
*Nb-95	2.654E-03		2.448E-03	5.102E-03
*Nb-95m	3.725E-06		3.432E-06	7.157E-06
*Pr-144	3.945E+00	4.341E-01		4.379E+00
*Rh-103m	8.400E-04			8.400E-04
*Rh-106	1.416E+00	1.119E-01		1.528E+00
*Te-125	3.800E-04			3.800E-04
*Y-90	1.532E+02	7.634E+00	2.374E-02	1.609E+02
Total Progeny	3.828E+02	1.283E+01	4.875E-02	3.957E+02
Tot NOS[b]	2.021E+01	2.659E-01	2.341E+01	4.389E+01
Total	4.646E+04	2.650E+01	2.493E+05	2.958E+05

[a] Respectively, West, East, and Submarine disposal areas.
[b] *Ba-137m, etc.: Estimated progeny activity; Tot NOS: estimated MAP, MFP, etc.

expected to be present, no activity was reported for that isotope for that year. The data that was originally provided by NTS was in fixed notation using four significant figures to the right of the decimal point, and contained numerous citations of zero quantities which were generally artifacts of computer truncation [16]. This problem was alleviated by a resubmittal of data incorporating additional significant figures [3]. For a few other sites, citations for some isotopes were also presented as zeros, leaving the question whether the citations were truncated or not reported.

Occasionally, the sites provided isotopic data using special notations. Explanations for these notations are usually provided in footnotes to the tables. An example is the notation "Pu-52" to signify a mixture of plutonium isotopes including Pu-238, Pu-239, Pu-240, Pu-241, and Pu-242. Another special notation is the denotation of radionuclide pairs in the data for the Hanford site (Table B-7). Many radionuclides normally exist in equilibrium (e.g., Sr-90 and Y-90), and the Hanford notation serves as a reminder of this situation. However, the listed activities only apply to the parent of the equilibrium pair.

The data occasionally required interpretation. For example, DOE plans to use the SRS saltstone facility for disposal of solidified liquid waste generated incidental to processing and solidifying liquid high-level waste. These processing operations have not yet commenced, and the disposal vaults that have been constructed have been used for disposal of non-radioactive grout (to test and demonstrate process and disposal capacity), as well as some low-activity liquid and solid radioactive wastes.

Radioactive operations began in June 1990 at the saltstone facility, and Table B-2 summarizes the activity that had been disposed as of 13 February 1991 [28]. Up to that time, 577,750 gallons of radioactive solution had been solidified in Cell A of Vault 1, resulting in about 140,000 ft^3 of solidified radioactive saltstone weighing 6765 tons. (Cell A also contains about 100,000 ft^3 of non-contaminated simulated saltstone.) In addition, 10,032 55-gallon drums containing solidified chemical waste and low-levels of uranium were placed in Cell A of Vault 4 (formerly termed Vault 6), and backfilled with clean grout. Before disposal, void spaces within the drums were filled with non-contaminated grout, resulting in a total waste volume of 551,760 gallons contained within the drums. The drummed waste and surrounding clean grout occupy about 240,000 ft^3 of space within Cell A of Vault 4 [28]. Reference [28] does not provide total activities for Vault disposal, but the listed citations (including "less-than" values) sum to about 67 Ci.

The Hanford data required the most interpretation. As illustrated in Table B-7, Hanford provided three sets of data as mixtures of activity and mass citations. The data sets correspond to waste disposed in the 200-East disposal area, waste disposed in the 200-West disposal area, and defueled submarine reactor compartments, which were disposed in the 218-E-12B Burial Ground [7, 26]. Total waste volume was 13,394 m^3.

The first defueled submarine reactor compartment arrived at Hanford in 1986 as LLW. (Each reactor compartment is about 32 feet in diameter and 38 feet in length, weighing about 1000 tons.) Subsequently, the discovery of very small quantities of PCBs within the compartments (2.5E-8% by weight of waste), plus questions about the application of State and EPA regulations to lead shielding within the compartments, resulted in the initiation of negotiations with the EPA and the Washington State Department of Ecology. Because of the lead shielding, the compartments are considered state-only dangerous waste pursuant to the Washington State Department of Ecology's Dangerous Waste Regulations.[1] In addition, because of the presence of PCBs, disposal of the compartments is subject to regulation under TSCA. There was also a question about the presence of small quantities of residual liquids in compartment systems [24, 31].

A number of studies were completed, procedures for management of the compartments were changed, and DOE requested an exemption from certain Washington State requirements for management of dangerous wastes [31]. During these negotiations, reactor compartments delivered to Hanford were classified as stored waste. But recently, the status of the compartments, of which 6 were delivered in 1990, totaling 5,395 m^3, was changed from storage to disposal.

In addition, Table B-7 includes citations for thousands of curies of "total beta-gamma" activity. This signifies the summation of all beta-gamma activity delivered to the disposal site, including activity identified without specific isotopic references (e.g., "mixed activation products") as well as daughters in equilibrium.

Regarding the latter point, if a disposal manifest indicates activity for any of several radionuclides (e.g., Cs-137, Ce-144), Hanford personnel add appropriate quantities of daughter radionuclides when transferring the information on the manifest to the Hanford Solid Waste Information and Tracking System

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[1] Each reactor compartment contains over 100 tons of elemental solid lead used as shielding. EPA does not consider lead used as shielding within disposal packages to constitute a hazardous waste under RCRA, and each compartment is disposed as a complete, sealed unit, constituting a disposal package. However, the State of Washington considers the lead shielding a dangerous waste under state law [31].

(SWITS).[2] Reference [7] provided neither the total activity nor the activity of the individual daughters added during input of data to SWITS.

For this report, we needed to convert all citations to units of curies, to determine the total activity, and to cite all nuclides that were included in the total activity. First, we converted units of grams to units of curies using the following specific activities:

Nuclide	SA (Ci/gm)	Nuclide	SA (Ci/gm)
Am-241	3.433	Ra-226	0.9895
Am-243	0.1996	Th-232	1.1E-7
Cf-252	537.25	Th-234	23200
Cm-244	80.89	U-232	21.4
Np-237	0.0007048	U-233	0.009637
Pu	0.0869	U-DEP	3.362E-6
Pu-238	17.12	U-Enrich	2.162E-5
Pu239FGE	0.9503	U-NAT	6.88E-7

For most nuclides, we converted grams to curies using the specific activities that were listed in Tables D-6 and D-7 of the Hanford Site Solid Waste Acceptance Criteria [18]. For Ra-226, we converted gram quantities to curies assuming a 1600-year half-life obtained from [19]. For natural uranium, depleted uranium, and enriched uranium, we used specific activities as cited in [17]. For Pu, we used a conversion estimate obtained from Table D-1 of the Hanford WAC [18]. We used a conversion estimate from Table D-3 of the Hanford WAC [18] for Pu239FGE (plutonium fissile gram equivalent).

Then, we assumed that "total beta-gamma" activity indicates the summation of (1) the total activity of all isotopes that were reported in units of curies rather than grams, (2) the total activity associated with daughters in equilibrium, and (3) the total activity that was reported using vague identifiers such as "mixed fission products."[3] The radionuclides assumed to have daughters in equilibrium were Sr-90 (Y-90), Ru-106 (Rh-106), Ru-103 (Rh-103m), Zr-95 (Nb-95, Nb-95m), Cs-137 (Ba-137m), Ce-144 (Pr-144), Sb-125 (Te-125), and Tm-129m (Te-129). A production rate of 94.6% was assumed for Ba-137m [19], and a

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[2] Other DOE disposal sites do not record daughter products with Hanford's zeal. For these sites, daughters were recorded only when waste generators shipping waste to the sites recorded the daughter activity on shipment manifests. The activity reported by Hanford to the IDB includes daughter activity, but not activity reported in gram units; the activity reported by other sites to the IDB generally does not include daughter activity.

[3] Total beta-gamma activity was estimated for submarine compartments based on information provided by [7] and [26].

production rate of 100% for all others except Zr-95, which decays in a more complex manner. For this isotope, Nb-95 and Nb-95m ingrowth was calculated, and maximum quantities estimated, using Bateman equations and decay data from [19].

We estimated the activity associated with vague identifiers by subtracting the total beta-gamma activity from the total activity determined by adding the radionclide activity for the isotopes reported in units of curies with the total activity calculated for daughters in equilibrium.

All these assumptions resulted in the estimated radionuclide activities presented in Table B-8 and summarized below:

Total from nuclides reported in Ci:	295,297
Total daughters in equilibrium:	396
Total inferred other activity:	44
Total given & inferred beta-gamma:	295,736
Total from converting Gm to Ci:	24
Grand total:	295,760

Waste was also disposed at the Y-12 Site during 1990. Detailed inventories for Y-12 are not presented here, although we understand that essentially two landfills were in operation during 1990, one for unclassified LLW and the other for classified LLW. About 4,355 m^3 of LLW containing about 6 curies of depleted uranium (as well as a few parts per million of thorium) were disposed in the unclassified landfill [12, 14]. About half of this waste consisted of air filters [15].

Considering all the data, we prepared Tables B-9 and B-10 which list the combined radionuclide inventories reported and estimated for 1990, including the six curies of depleted uranium disposed at Y-12 (but not including any trace contribution of thorium in Y-12 waste), and the activity reported disposed in Cell A at the SRS Saltstone Facility. Table B-9 summarizes total radionuclide inventories as well as the percentage distribution of the activity of each listed radionuclide. Table B-10 presents the distribution of each radionuclide as a function of disposal site.

For these tables, quantities listed as zeros in other tables were eliminated. Daughters in equilibrium as inferred by the Hanford data were added to the total. However, daughter activity was not added to inventories provided by other sites, because to do so would have been inconsistent with practices for obtaining and storing manifest information at these sites.

Although the SRS saltstone data apparently included some waste disposed in 1991, it was included in this report because disposal of the great majority of the waste that was cited in [28] probably occurred in 1990, and because the data was presented in a single significant figure. (Little additional accuracy would

Table B-9. Total DOE Activity Estimated Disposed in 1990

Nuclide	Activity (Ci)	Percent of Total
Ac-227	1.00E-07	1.83E-11
Ag-108	1.00E-05	1.83E-09
Ag-110	2.00E-05	3.66E-09
Ag-110m	3.11E-03	5.69E-07
Al-28	3.00E-05	5.49E-09
Am-241	1.07E+00	1.97E-04
Am-243	1.04E-03	1.90E-07
Au-195	5.00E-05	9.16E-09
Ba-137m	2.29E+02	4.19E-02
Ba-140	8.47E-02	1.55E-05
Be-10	2.82E-07	5.16E-11
C-14	3.11E+01	5.69E-03
Ca-45	1.05E-03	1.92E-07
Cd-109	1.11E-02	2.03E-06
Ce-141	2.27E-01	4.16E-05
Ce-144	4.89E+01	8.95E-03
Cf-252	3.27E+01	5.99E-03
Cl-36	3.52E-03	6.45E-07
Cm-242	1.18E-07	2.17E-11
Cm-244	2.85E+00	5.21E-04
Co-57	1.56E-02	2.86E-06
Co-58	2.51E+04	4.60E+00
Co-60	1.97E+05	3.61E+01
Cr-51	9.91E+03	1.81E+00
Cs-134	2.23E+01	4.09E-03
Cs-137	3.12E+03	5.71E-01
Eu-152	1.00E+02	1.83E-02
Eu-154	1.08E+02	1.98E-02
Eu-155	3.11E-02	5.69E-06
Fe-55	6.98E+04	1.28E+01
Fe-59	6.39E+02	1.17E-01
Gd-153	8.36E-02	1.53E-05
Ge-68	3.00E-05	5.49E-09
H-3	8.49E+04	1.56E+01
Hf-181	3.40E-01	6.22E-05
I-125	6.28E-02	1.15E-05
I-129	1.24E-02	2.26E-06
I-131	2.21E-03	4.05E-07
Ir-192	2.80E-01	5.13E-05
K-40	1.06E-02	1.94E-06
Kr-85	2.33E-01	4.27E-05
La-140	1.00E-01	1.84E-05
Mn-54	1.88E+04	3.43E+00
Mo-93	5.85E-02	1.07E-05
MAP[a]	6.38E+02	1.17E-01
MFP[a]	1.85E+01	3.39E-03

Table B-9 (Continued)

Nuclide	Activity (Ci)	Percent of Total
Han NOS[a]	4.39E+01	8.04E-03
Na-22	9.20E+01	1.69E-02
Nb-91	2.00E-05	3.66E-09
Nb-93m	9.00E-05	1.65E-08
Nb-94	9.22E-02	1.69E-05
Nb-95	1.06E+03	1.95E-01
Nb-95m	7.16E-06	1.31E-09
Ni-59	9.03E+02	1.65E-01
Ni-63	1.28E+05	2.35E+01
Np-237	9.91E-03	1.81E-06
Os-191	5.25E-02	9.62E-06
P-32	1.64E-01	3.00E-05
Pa-231	6.84E-03	1.25E-06
Pd-103	2.82E-01	5.17E-05
Pm-147	3.26E+00	5.96E-04
Po-210	2.54E-04	4.66E-08
Pr-144	4.70E+01	8.61E-03
Pt-195	1.70E-05	3.11E-09
Pu[a]	5.98E-01	1.09E-04
Pu-238	4.27E-01	7.82E-05
Pu-239	1.13E-01	2.07E-05
Pu-240	4.49E-04	8.21E-08
Pu-241	3.43E-02	6.28E-06
Pu-242	1.57E-07	2.87E-11
Pu-52[a]	3.07E+01	5.63E-03
Ra-226	3.80E-01	6.95E-05
Rb-86	3.87E-03	7.09E-07
Rb-87	1.51E-09	2.76E-13
Re-187	2.00E-04	3.66E-08
Rh-103m	8.40E-04	1.54E-07
Rh-106	2.27E+01	4.15E-03
Ru-103	1.04E-01	1.91E-05
Ru-106	2.32E+01	4.24E-03
S-35	9.52E-02	1.74E-05
Sb-124	8.96E-04	1.64E-07
Sb-125	7.80E+02	1.43E-01
Sc-46	2.89E-02	5.29E-06
Se-75	6.93E+00	1.27E-03
Se-79	1.00E-01	1.83E-05
Sm-147	2.00E-04	3.66E-08
Sm-151	5.85E-01	1.07E-04
Sn-113	3.98E-03	7.29E-07
Sn-119m	2.82E+03	5.15E-01
Sn-123m	2.00E-05	3.66E-09
Sn-126	3.00E-01	5.49E-05
Sr-82	2.00E+00	3.66E-04
Sr-85	4.11E+00	7.52E-04

Table B-9 (Continued)

Nuclide	Activity (Ci)	Percent of Total
Sr-89	4.77E-01	8.73E-05
Sr-90	5.24E+02	9.59E-02
Sr-92	1.60E-03	2.93E-07
Ta-179	1.70E-03	3.11E-07
Ta-182	2.07E-01	3.78E-05
Tc-99	4.01E+01	7.34E-03
Te-121	1.00E-04	1.83E-08
Te-125	3.80E-04	6.96E-08
Te-127	2.50E-04	4.58E-08
Th-228	2.75E-03	5.04E-07
Th-232	5.05E+00	9.24E-04
Th-234	1.60E-06	2.93E-10
Th-88[a]	2.00E-09	3.66E-13
Tm-170	2.00E-04	3.66E-08
Total alpha	2.00E-01	3.66E-05
U-232	3.21E-02	5.88E-06
U-233	1.82E-02	3.32E-06
U-234	4.06E+00	7.43E-04
U-235	6.64E-01	1.22E-04
U-236	1.07E-01	1.96E-05
U-238	1.12E+01	2.05E-03
U-38[a]	2.00E-02	3.67E-06
U-81[a]	3.46E-06	6.34E-10
U-DEP[a]	1.38E+01	2.52E-03
U-ENRICH[a]	9.90E-01	1.81E-04
U-NAT[a]	7.21E-03	1.32E-06
V-49	0.00E+00	0.00E+00
Y-87	1.50E-03	2.75E-07
Y-88	3.02E-03	5.53E-07
Y-90	1.84E+02	3.37E-02
Y-91m	9.32E-22	1.71E-25
Zn-65	1.23E+00	2.26E-04
Zr-93	3.00E-05	5.49E-09
Zr-95	7.82E+02	1.43E-01
Total	5.46E+05	1.00E+02

[a] MAP: mixed activation products; MFP: mixed fission products; Han NOS: inferred unspecified activity disposed at Hanford; Pu: unspecified Pu; Pu-52: plutonium isotopes, including Pu-238, Pu-239, Pu-240, Pu-241, and Pu-242; Th-88: total thorium; U-38: uranium enriched between 92 and 94%; U-81: normal uranium (0.711%), U-DEP: depleted uranium; U-ENRICH: unspecified enriched uranium; U-NAT: natural uranium.

Table B-10. Summary of DOE Radionuclide Distribution by Site (Ci)

Nuclide	SRS Solid Waste	SRS Salt-stone	NTS	LANL	INEL	ORNL	Hanford	Y-12	Total
Ac-227	0.00E+00	0.00E+00	1.00E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E-07
Ag-108	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E-05	0.00E+00	1.00E-05
Ag-110	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E-05	0.00E+00	2.00E-05
Ag-110m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.11E-03	0.00E+00	0.00E+00	0.00E+00	3.11E-03
Al-28	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.00E-05	0.00E+00	3.00E-05
Am-241	0.00E+00	0.00E+00	2.25E-03	9.30E-03	4.47E-04	7.12E-03	1.05E+00	0.00E+00	1.07E+00
Am-243	0.00E+00	0.00E+00	2.00E-08	0.00E+00	0.00E+00	0.00E+00	1.04E-03	0.00E+00	1.04E-03
Au-195	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.00E-05	0.00E+00	5.00E-05
Ba-137m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.30E-01	0.00E+00	2.29E+02	0.00E+00	2.29E+02
Ba-140	0.00E+00	0.00E+00	1.10E-03	0.00E+00	8.36E-02	0.00E+00	0.00E+00	0.00E+00	8.47E-02
Be-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.82E-07	0.00E+00	2.82E-07
C-14	2.56E-07	5.00E-01	6.03E-03	2.00E-09	2.78E+00	5.46E-02	2.77E+01	0.00E+00	3.11E+01
Ca-45	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.05E-03	0.00E+00	1.05E-03
Cd-109	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.11E-02	0.00E+00	1.11E-02
Ce-141	0.00E+00	0.00E+00	2.80E-03	0.00E+00	2.24E-01	0.00E+00	0.00E+00	0.00E+00	2.27E-01
Ce-144	0.00E+00	0.00E+00	5.64E-03	2.14E-03	4.45E+01	0.00E+00	4.38E+00	0.00E+00	4.89E+01
Cf-252	1.98E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.29E+01	0.00E+00	3.27E+01
Cl-36	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.52E-03	0.00E+00	3.52E-03
Cm-242	0.00E+00	0.00E+00	2.00E-08	0.00E+00	9.84E-08	0.00E+00	0.00E+00	0.00E+00	1.18E-07
Cm-244	2.59E+00	0.00E+00	4.30E-07	0.00E+00	7.85E-06	3.31E-03	2.54E-01	0.00E+00	2.85E+00
Co-57	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.53E-02	0.00E+00	3.10E-04	0.00E+00	1.56E-02
Co-58	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.49E+04	1.00E-04	2.07E+02	0.00E+00	2.51E+04
Co-60	7.70E+01	3.00E-03	6.01E-02	5.25E+01	9.89E+04	1.01E+01	9.80E+04	0.00E+00	1.97E+05
Cr-51	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.91E+03	0.00E+00	3.81E-01	0.00E+00	9.91E+03
Cs-134	0.00E+00	0.00E+00	1.20E-02	1.10E-07	2.12E+01	2.00E-01	9.36E-01	0.00E+00	2.23E+01
Cs-137	3.12E+01	2.00E+00	1.82E-01	6.19E-02	2.59E+03	2.51E+02	2.42E+02	0.00E+00	3.12E+03
Eu-152	0.00E+00	0.00E+00	2.00E-08	2.00E-08	1.81E-03	9.99E+01	2.41E-01	0.00E+00	1.00E+02
Eu-154	1.04E-01	8.00E-04	3.19E-03	0.00E+00	1.87E-03	1.08E+02	3.08E-01	0.00E+00	1.08E+02
Eu-155	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.43E-03	0.00E+00	2.46E-02	0.00E+00	3.11E-02
Fe-55	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.19E+04	0.00E+00	5.79E+04	0.00E+00	6.98E+04
Fe-59	0.00E+00	0.00E+00	6.03E-05	0.00E+00	6.37E+02	1.00E-04	1.55E+00	0.00E+00	6.39E+02
Gd-153	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.30E-02	5.90E-04	0.00E+00	8.36E-02
Ge-68	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.00E-05	0.00E+00	3.00E-05

Table B-10 (Continued)

Nuclide	SRS Solid Waste	SRS Salt-stone	NTS	LANL	INEL	ORNL	Hanford	Y-12	Total
H-3	2.63E+04	2.00E+01	1.46E+04	1.12E+02	9.64E-01	1.50E-01	4.39E+04	0.00E+00	8.49E+04
Hf-181	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.40E-01	0.00E+00	1.16E-03	0.00E+00	3.41E-01
I-125	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.10E-04	6.23E-02	0.00E+00	6.28E-02
I-129	1.39E-06	1.00E-02	0.00E+00	0.00E+00	5.37E-04	0.00E+00	1.82E-03	0.00E+00	1.24E-02
I-131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.21E-03	0.00E+00	2.21E-03
Ir-192	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.80E-01	0.00E+00	0.00E+00	2.80E-01
K-40	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.45E-03	0.00E+00	9.16E-03	0.00E+00	1.06E-02
Kr-85	0.00E+00	0.00E+00	1.29E-02	0.00E+00	0.00E+00	0.00E+00	2.20E-01	0.00E+00	2.33E-01
La-140	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E-01	0.00E+00	0.00E+00	0.00E+00	1.00E-01
Mn-54	0.00E+00	0.00E+00	3.27E-04	0.00E+00	1.80E+04	1.00E-03	7.33E+02	0.00E+00	1.88E+04
Mo-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.85E-02	0.00E+00	5.85E-02
MAP[a]	0.00E+00	0.00E+00	0.00E+00	6.32E+02	5.45E+00	0.00E+00	0.00E+00	0.00E+00	6.38E+02
MFP[a]	0.00E+00	0.00E+00	7.86E-02	1.12E+01	7.17E+00	0.00E+00	0.00E+00	0.00E+00	1.85E+01
HAN NOS[a]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.39E+01	0.00E+00	4.39E+01
Na-22	0.00E+00	0.00E+00	1.00E-05	9.20E+01	7.09E-04	0.00E+00	2.36E-02	0.00E+00	9.20E+01
Nb-91	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E-05	0.00E+00	2.00E-05
Nb-93m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.00E-05	0.00E+00	9.00E-05
Nb-94	5.40E-09	8.00E-04	0.00E+00	0.00E+00	6.90E-06	0.00E+00	9.14E-02	0.00E+00	9.22E-02
Nb-95	0.00E+00	0.00E+00	3.73E-03	0.00E+00	1.06E+03	0.00E+00	1.59E-02	0.00E+00	1.06E+03
Nb-95m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.16E-06	0.00E+00	7.16E-06
Ni-59	2.31E-04	5.00E-04	0.00E+00	0.00E+00	2.59E+02	0.00E+00	6.44E+02	0.00E+00	9.03E+02
Ni-63	7.87E-01	2.00E-03	0.00E+00	1.00E-05	3.47E+04	0.00E+00	9.35E+04	0.00E+00	1.28E+05
Np-237	0.00E+00	3.00E-05	0.00E+00	0.00E+00	1.21E-07	0.00E+00	9.88E-03	0.00E+00	9.91E-03
Os-191	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.25E-02	0.00E+00	0.00E+00	5.25E-02
P-32	0.00E+00	0.00E+00	1.11E-02	0.00E+00	0.00E+00	8.50E-05	1.53E-01	0.00E+00	1.64E-01
Pa-231	0.00E+00	0.00E+00	0.00E+00	9.00E-09	0.00E+00	0.00E+00	6.84E-03	0.00E+00	6.84E-03
Pd-103	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.82E-01	0.00E+00	0.00E+00	2.82E-01
Pm-147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.70E-05	3.26E+00	0.00E+00	3.26E+00
Po-210	0.00E+00	0.00E+00	2.54E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.54E-04
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.26E+01	0.00E+00	4.38E+00	0.00E+00	4.70E+01
Pt-195	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.70E-05	0.00E+00	0.00E+00	1.70E-05
Pu[a]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.98E-01	0.00E+00	5.98E-01
Pu-238	0.00E+00	0.00E+00	3.99E-01	2.00E-03	6.15E-04	0.00E+00	2.50E-02	0.00E+00	4.27E-01

Table B-10 (Continued)

Nuclide	SRS Solid Waste	SRS Salt-stone	NTS	LANL	INEL	ORNL	Hanford	Y-12	Total
Pu-239	0.00E+00	0.00E+00	3.73E-02	7.26E-02	3.03E-03	2.00E-06	0.00E+00	0.00E+00	1.13E-01
Pu-240	0.00E+00	0.00E+00	1.75E-04	0.00E+00	2.73E-04	0.00E+00	0.00E+00	0.00E+00	4.49E-04
Pu-241	0.00E+00	4.00E-04	2.09E-02	7.52E-05	1.30E-02	0.00E+00	0.00E+00	0.00E+00	3.43E-02
Pu-242	0.00E+00	0.00E+00	1.32E-07	0.00E+00	2.45E-08	0.00E+00	0.00E+00	0.00E+00	1.57E-07
Pu-52[a]	0.00E+00	0.00E+00	3.04E+01	3.61E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.07E+01
Ra-226	0.00E+00	0.00E+00	2.85E-01	1.00E-03	0.00E+00	0.00E+00	9.38E-02	0.00E+00	3.80E-01
Rb-86	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.87E-03	0.00E+00	3.87E-03
Rb-87	1.51E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.51E-09
Re-187	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E-04	0.00E+00	2.00E-04
Rh-103m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.40E-04	0.00E+00	8.40E-04
Rh-106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.11E+01	0.00E+00	1.53E+00	0.00E+00	2.27E+01
Ru-103	0.00E+00	0.00E+00	1.75E-03	0.00E+00	1.02E-01	0.00E+00	8.40E-04	0.00E+00	1.04E-01
Ru-106	0.00E+00	2.00E-01	2.88E-04	9.24E-04	2.14E+01	0.00E+00	1.53E+00	0.00E+00	2.32E+01
S-35	0.00E+00	0.00E+00	1.00E-06	0.00E+00	0.00E+00	0.00E+00	9.52E-02	0.00E+00	9.52E-02
Sb-124	0.00E+00	0.00E+00	1.96E-04	0.00E+00	6.80E-04	0.00E+00	2.00E-05	0.00E+00	8.96E-04
Sb-125	0.00E+00	7.00E-01	3.31E-04	0.00E+00	7.80E+02	0.00E+00	3.80E-04	0.00E+00	7.80E+02
Sc-46	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.87E-02	0.00E+00	1.70E-04	0.00E+00	2.89E-02
Se-75	6.92E+00	0.00E+00	0.00E+00	0.00E+00	1.01E-02	0.00E+00	2.90E-04	0.00E+00	6.93E+00
Se-79	2.38E-05	1.00E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E-01
Sm-147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E-04	0.00E+00	2.00E-04
Sm-151	3.95E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.45E-01	0.00E+00	5.85E-01
Sn-113	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.30E-03	0.00E+00	6.80E-04	0.00E+00	3.98E-03
Sn-119m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.82E+03	0.00E+00	0.00E+00	0.00E+00	2.82E+03
Sn-123m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E-05	0.00E+00	2.00E-05
Sn-126	0.00E+00	3.00E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.00E-01
Sr-82	0.00E+00	0.00E+00	0.00E+00	2.00E+00	0.00E+00	0.00E+00	1.40E-04	0.00E+00	2.00E+00
Sr-85	0.00E+00	0.00E+00	3.60E-10	4.04E+00	0.00E+00	0.00E+00	7.42E-02	0.00E+00	4.11E+00
Sr-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.77E-01	0.00E+00	0.00E+00	0.00E+00	4.77E-01
Sr-90	3.09E+01	7.00E-03	2.60E-01	0.00E+00	8.36E+01	2.48E+02	1.61E+02	0.00E+00	5.24E+02
Sr-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.60E-03	0.00E+00	0.00E+00	0.00E+00	1.60E-03
Ta-179	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.70E-03	0.00E+00	0.00E+00	1.70E-03
Ta-182	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.05E-03	0.00E+00	2.01E-01	0.00E+00	2.07E-01
Tc-99	8.19E-04	4.00E+01	0.00E+00	1.15E-05	5.92E-03	0.00E+00	7.73E-02	0.00E+00	4.01E+01

Table B-10 (Continued)

Nuclide	SRS Solid Waste	SRS Salt-stone	NTS	LANL	INEL	ORNL	Hanford	Y-12	Total
Te-121	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E-04	0.00E+00	1.00E-04
Te-125	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.80E-04	0.00E+00	3.80E-04
Te-127	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.50E-04	0.00E+00	2.50E-04
Th-228	0.00E+00	0.00E+00	2.75E-03	1.00E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.75E-03
Th-232	5.03E+00	0.00E+00	1.25E-02	1.09E-06	0.00E+00	1.73E-04	5.56E-03	0.00E+00	5.05E+00
Th-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.60E-06	0.00E+00	0.00E+00	0.00E+00	1.60E-06
Th-88[a]	0.00E+00	0.00E+00	0.00E+00	2.00E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E-09
Tm-170	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E-04	0.00E+00	2.00E-04
Tot alph[a]	0.00E+00	2.00E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E-01
U-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.21E-02	0.00E+00	3.21E-02
U-233	0.00E+00	0.00E+00	3.00E-08	0.00E+00	0.00E+00	6.00E-04	1.76E-02	0.00E+00	1.82E-02
U-234	8.58E-01	3.20E+00	0.00E+00	0.00E+00	7.76E-04	0.00E+00	0.00E+00	0.00E+00	4.06E+00
U-235	2.57E-02	6.00E-02	5.27E-03	5.70E-01	1.71E-03	5.36E-04	0.00E+00	0.00E+00	6.64E-01
U-236	1.07E-01	0.00E+00	0.00E+00	0.00E+00	1.10E-06	0.00E+00	0.00E+00	0.00E+00	1.07E-01
U-238	7.09E-01	1.00E-04	8.00E+00	2.27E+00	2.37E-01	1.00E-02	0.00E+00	0.00E+00	1.12E+01
U-38[a]	0.00E+00	0.00E+00	0.00E+00	2.00E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E-00
U-81[a]	0.00E+00	0.00E+00	0.00E+00	3.46E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.46E-06
U-DEP[a]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.75E+00	6.00E+00	1.38E+01
U-ENRICH[a]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.90E-01	0.00E+00	9.90E-01
U-NAT[a]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.22E-03	0.00E+00	7.22E-03
Y-87	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.50E-03	0.00E+00	1.50E-03
Y-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.00E-03	0.00E+00	2.00E-05	0.00E+00	3.02E-03
Y-90	0.00E+00	7.00E-03	0.00E+00	0.00E+00	2.11E+01	1.74E+00	1.61E+02	0.00E+00	1.84E+02
Y-91m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.32E-22	0.00E+00	0.00E+00	0.00E+00	9.32E-22
Zn-65	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.23E+00	0.00E+00	8.80E-04	0.00E+00	1.23E+00
Zr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.00E-05	0.00E+00	3.00E-05
Zr-95	0.00E+00	0.00E+00	2.68E-03	2.08E-02	7.82E+02	0.00E+00	1.93E-02	0.00E+00	7.82E+02
Total	2.65E+04	6.73E+01	1.46E+04	9.09E+02	2.08E+05	7.20E+02	2.96E+05	6.00E+00	5.46E+05

[a]MAP: mixed activation products; MFP: mixed fission products; HAN NOS: unspecified Hanford beta-gamma activity; Pu: unspecified Pu; Pu-52: plutonium, including Pu-238, Pu-239, Pu-240, Pu-241, and Pu-242; Th-88: total thorium; Tot alph: unspecified alpha activity; U-38: uranium enriched between 92 and 94%; U-81: normal uranium (0.711%); U-DEP: depleted uranium; U-ENRICH: unspecified enriched uranium; U-NAT: natural uranium.

likely be gained by subtracting waste disposed during an additional month and a half.) Most of the Tc-99 reported disposed in DOE waste during 1990 was reported in saltstone.

The results in Tables B-9 and B-10 are presented in three significant figures, which should not be interpreted as an estimate of the accuracy of the estimates.[4]

We estimated a total activity of 546,000 curies, which may be compared with the 297,000 curies of activity reported for 1990 in the 1991 IDB report [21]. In the 1992 IDB report, the total activity for 1990 was changed to 588,000 curies [29]. Neither IDB report lists activities as a function of disposal site, although the IDB program does maintain this data. Below, we compare the activities provided by each site, as well as total activities, with the LLW activities supplied by the sites [20] for the IDB Report for 1991 [21]:

DOE Site	LLW Activity (Ci) Provided to IDB[a]	Activity (Ci) Provided or Calculated for this report
SRS	26,675	26,500
SRS Saltstone	-	67
NTS	14,610	14,639
LANL	900	909
INEL	207,600	207,500
ORNL	720	720
Y-12	6	6
HANF	>46,468	295,800
	297,000	546,000

[a] Source: [20].

LLW volumes for 1990 as listed in Table 4.4 of the 1991 and 1992 IDB reports are provided below [21], as well as waste volumes provided to us by the individual sites:

Waste Volume, 10^3 m^3

	HANF	INEL	LANL	NTS	ORNL	SRS	Salt	Y-12	TOTAL
As reported in 1991 IDB:	7.9	1.8	4.5	9.1	0.3	26.6	-	4.4	54.6
As reported in 1992 IDB:	13.4	1.8	4.5	9.1	0.3	26.6	-	4.4	60.1
As provided by sites:	13.4	1.8	4.5	14.1	0.3	23.9	6.1	4.4	68.4

[4] In addition to uncertainties about the accuracy and completeness of the data in disposal manifests, there are uncertainties associated with the different data formats, with adding data from different sites (the site data sets were provided in different units and in different numbers of significant figures), and in the case of the saltstone facility the inclusion of some 1991 data as well as "less-than" values.

There are differences in the activity and volume citations between those provided by some sites and those reported to the IDB. Some differences would be expected, and would reflect normal fluctuations in data bases resulting from generator revisions to disposal manifests, operator corrections to data bases, and similar adjustments.

The biggest differences are for the Hanford site, and these differences primarily result from the reclassification of submarine reactor compartments from stored to disposed waste. We estimate that this waste consists of about 249,000 Ci of activity in 5,395 m^3. We also understand that the activity reported by Hanford annually to the IDB is usually the total beta-gamma activity that had been reported in waste shipments in units of curies, including inferred progeny, and does not include activity reported in gram units.

In addition, the revised figure of 588,000 curies in the 1992 IDB report includes a revised total of 337,822 curies of activity reported by Hanford to the IDB. This activity, however, includes 42,985 curies of tritium that was inadvertently double-counted as both beta-gamma activity and tritium. This error will be corrected in subsequent Hanford IDB updates [30].

The activity and volume differences for the NTS site result from the inclusion of mixed waste in this report, consisting of 29 curies of activity in 4,970 m^3, whereas the volume and activity reported to the IDB included only LLW. The activity difference for INEL waste results entirely from roundoff.

We have no explanation for the differences in the data for LLW disposal at SRS versus that data reported to the IDB. Waste disposed in the saltstone facility was not reported to the IDB.

B.2 Stored Low-Level and Mixed Wastes

In addition to LLW reported disposed in 1990, considerable low-level and mixed wastes were placed in storage during this year. Tables B-11 and B-12 respectively list the volumes and activities of LLW reported to the IDB as placed in storage during 1990 [22]. The stored volume totals 12,685.5 m^3, while the stored activity totals 195,888.87 curies. This volume and activity represent a significant inventory of waste which must be eventually disposed. The stored activity, in fact, represents 36% of the total activity that was reported disposed in 1990.

We possess neither a site-by-site isotopic inventory of the stored LLW, nor an estimate of the fraction of the stored activity contained in waste that exceeds Class C concentrations as listed in 10 CFR Part 61. DOE 5820.2A indicates that disposal of DOE waste in concentrations exceeding Class C limits must be handled as a special case and justified by a performance

Table B-11. Volume of DOE LLW Placed in Storage During 1990 (m^3)

Site	Uranium Thorium	Fission Product	Induced Activity	Tritium	Alpha	Other	Total
AMES[a]	3.9						3.9
BNL	NA	NA	NA	NA	NA	NA	NA
FNAL	5.24		49.11	2			56.35
HANF		33.3					33.3
K-25						1548.5	1548.5
KCP						.20828	.20818
LBL	1.0	0.3	26.0	7.3	1.0		35.6
LLNL	1.2	<<.001	<<.001	<<.001	<<.001	<<.001	1.2
MOUND				434.2	2300.5		2734.7
NTS	NA	NA	NA	NA	NA	NA	NA
ORNL	54.9	292.8	83.4	8.0	31.5	0.4	471.0
PAD	NA	NA	NA	NA	NA	NA	NA
PANT	114.264			72.686			186.95
PINEL				145			145
PORTS	4197	7					4204
PPPL				23			23
RFP	57.37				1487		1544.37
SLAC			45				45
SNLA	2.919	32.665	35.681	.923		.527	72.72
SNLL	13.35			17.35		4	34.7
Y-12	1545						1545
Total	5996.14	366.07	239.19	710.46	3820	1553.64	12,685.5

[a] AMES: Ames Laboratory; BNL: Brookhaven National Laboratory; FNAL: Fermi National Accelerator Laboratory; HANF: Hanford Reservation; K-25: Oak Ridge K-25 Site; KCP: Kansas City Plant; LBL: Lawrence Berkeley Laboratory; LLNL: Lawrence Livermore National Laboratory; MOUND: Mound Plant; NTS: Nevada Test Site; ORNL: Oak Ridge National Laboratory; PAD: Paducah Gaseous Diffusion Plant; PANT: Pantex Plant; PINEL: Pinellas Plant; PORTS: Portsmouth Gaseous Diffusion Plant; PPPL: Princeton Plasma Physics Laboratory; RFP: Rocky Flats Plant; SLAC: Stanford Linear Accelerator Center; SNLA: Sandia National Laboratories, Albuquerque; SNLL: Sandia National Laboratories, Livermore; Y-12: Oak Ridge Y-12 Plant.

Table B-12. Activity of DOE LLW Placed in Storage During 1990 (Ci)

Site	Uranium Thorium	Fission Product	Induced Activity	Tritium	Alpha	Other	Total
AMES[a]	.000092						.000092
BNL	NA	NA	NA	NA	NA	NA	NA
FNAL	.00108		87.16027	.23			87.39135
HANF		.019			UKN	UKN	>0.019
K-25						UKN	>0
KCP				225		.004	225.004
LBL	.1322	.00031	.082	17,653	.0004		17,653.21
LLNL	.85	1.47	.43	628.89	.04	2313.7	2945.38
MOUND				6368	4.5		6372.5
NTS	NA	NA	NA	NA	NA	NA	NA
ORNL	9	133,609.44	4755.63	1.16	8.32	.0044	138,383.55
PAD	NA	NA	NA	NA	NA	NA	NA
PANT	.000493			1.34			1.34
PINEL				14,259			14,259
PORTS	NA	NA					NA
PPPL				0.5			0.5
RFP	.08732				7.465		7.552
SLAC			.06				.06
SNLA	1.052E-6	.005	.007	50.773	.008	0.001	50.794
SNLL	0.2			15,798		103.6	15,901.8
Y-12	0.77						0.77
Total	11.04	133,610.93	4843.37	54,985.89	20.33	2417.31	195,888.87

[a] AMES: Ames Laboratory; BNL: Brookhaven National Laboratory; FNAL: Fermi National Accelerator Laboratory; HANF: Hanford Reservation; K-25: Oak Ridge K-25 Site; KCP: Kansas City Plant; LBL: Lawrence Berkeley Laboratory; LLNL: Lawrence Livermore National Laboratory; MOUND: Mound Plant; NTS: Nevada Test Site; ORNL: Oak Ridge National Laboratory; PAD: Paducah Gaseous Diffusion Plant; PANT: Pantex Plant; PINEL: Pinellas Plant; PORTS: Portsmouth Gaseous Diffusion Plant; PPPL: Princeton Plasma Physics Laboratory; RFP: Rocky Flats Plant; SLAC: Stanford Linear Accelerator Center; SNLA: Sandia National Laboratories, Albuquerque; SNLL: Sandia National Laboratories, Livermore; Y-12: Oak Ridge Y-12 Plant.

assessment consistent with the requirements of the National Environmental Policy Act [32].

Nonetheless, 70% of the stored activity was reported stored at ORNL, and we do have an isotopic distribution for this waste. Table B-13 represents this distribution, which we estimated by subtracting data representing total inventories -- both stored and disposed [23] -- from disposed inventories [11]. Total stored activity calculated by this procedure seems reasonably consistent with that obtained from [22].

Of interest is the large quantities of Sr-90 and Cm-244 placed in storage at ORNL, in comparison with quantities of these isotopes reported disposed. At all DOE sites where LLW disposal took place during 1990, only 2.85 curies of Cm-244 and 524 curies of Sr-90 were reported buried. This may be contrasted with the 97 curies of Cm-244 placed in storage during 1990 at ORNL, in addition to the 134,000 curies of Sr-90. Although some of the stored waste containing these isotopes may exceed Part 61 Class C concentration limits, it still suggests that care should be exercised when reaching conclusions about the distributions of radionuclides in DOE LLW, based only on data about LLW sent to disposal. Waste sent to storage represents a source term that will eventually require disposal.

Also of interest is Table B-14, which presents an isotopic distribution of activity placed in storage at INEL in 1990 (at the Argonne National Laboratory-West site), as obtained from [5]. About 2800 curies of activity, in 1.024 m^3 of waste, were placed in storage. However, this waste was apparently not included in information supplied to IDB [22].

Regarding mixed waste, immediately available information focuses more on the chemical hazard than the radiological hazard. Reference [21], for example, reports the following totals for mixed waste generation during 1990:

Characteristic	Mass (kg)	Volume (m^3)
PCB	402,982	764.59
Listed	13,641,009	13,925.60
Ignitable	19,288	25.52
Reactive	1,816,000	1,812.80
Corrosive	1,182,109	1,182.85
TCLP/EP Toxic	4,026,041	4,451.44
Total	21,087,429	22,162.80

These values do not reflect any treatment that may, or will occur, before interim storage.

Table B-13. Radionuclide Distribution in Solid Low-Level Waste Reported Stored at Oak Ridge National Laboratory During 1990

Nuclide	Activity (Ci)	Nuclide	Activity (Ci)
Am-241	7.05E-1	Pd-103	9.37E-3
Am-243	1.85E-4	Pm-147	2.28E+0
C-14	1.06E-1	Pt-197	1.70E-4
Cf-252	1.08E-2	Pu-238	2.03E-2
Cm-244	9.70E+1	Pu-239	1.05E+0
Co-60	4.75E+3	Pu-241	7.29E+2
Cs-137	1.50E+1	Ra-226	1.75E-3
Eu-152	2.80E-1	S-35	1.70E-5
Eu-154	1.19E-2	Sr-90	1.34E+5
Fe-55	8.30E-4	Ta-179	1.60E-2
Gd-153	4.46E-2	Tc-99	1.70E-4
I-125	2.53E-2	Th-232	1.03E-3
I-131	8.65E-3	U-233	5.80E-1
Ir-192	2.70E-3	U-235	4.50E-5
Na-22	1.70E-4	U-236	2.00E-5
Ni-63	1.70E-2	U-238	3.38E-3
Np-237	1.40E-1	Y-90	1.14E-3
P-32	1.57E-4	Total	1.39E+5

Table B-14. Activity of LLW Reported Stored at INEL During 1990[a]

Nuclide	Activity (Ci)	Nuclide	Activity (Ci)
Am-241	1	Pr-144	71
Ba-137m	177	Pu-239	6
Ce-144	758	Pu-240	<1
Cm-244	<1	Rh-106	114
Co-60	134	Ru-106	114
Cs-134	134	Sb-125	43
Cs-137	473	Se-75	65
Eu-154	5	Sm-151	4
Eu-155	5	Sr-90	394
H-3	<1	U-235	<1
Kr-85	15	U-238	<1
Mn-54	22	Y-90	153
Pm-147	85	Total	2,774

[a] Stored at ANL-West; contained in 1.024 m^3 of waste [5].

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[1] Note from Pam Jenkins, DOE-Savannah River, to G. Roles, DOE EH232, January 28, 1992.

[2] Personal communication from Pam Jenkins, DOE-Savannah River, with G. Roles, DOE EH232, March 27, 1992.

[3] Note from Bob Dodge, Reynolds Electrical & Engineering Co., Inc. to G. Roles, DOE EH232, March 10, 1992.

[4] Memorandum from K.J. Twombly, DOE Albuquerque Field Office, to G. Roles, DOE EH232, February 25, 1992.

[5] Litteer, D.L., C.N. Peterson, and A.M. Sims, Radioactive Waste Management Information for 1990 and Record-to-Date, DOE/ID-10054(90), EG&G-Idaho, Inc. for DOE, July 1991.

[6] Note from D.L. Litteer, EG&G Idaho, Inc., to G. Roles, DOE EH232, November 2, 1992.

[7] Note from Darlene Hagel, WHC, to G. Roles, DOE EH232, January 14, 1993.

[8] Note from Jon Mack, DOE-Los Alamos, to G. Roles, DOE EH232, March 31, 1992.

[9] Note from W. Jasen, Westinghouse Hanford Company, to G. Roles, DOE EH232, May 7, 1992.

[10] Note from W. Jasen, Westinghouse Hanford Company, to G. Roles, DOE EH232, May 11, 1992.

[11] Note from Bob Forgy, Martin Marietta Energy Systems, Inc. (MMES), Oak Ridge National Laboratory, to G. Roles, DOE EH232, October 6, 1992.

[12] Note from Steve Storch, Integrated Data Base (IDB) Program, to G. Roles, DOE EH232, October 1, 1992.

[13] Personal communication from Rod Kimmitt, Y-12 Site, with G. Roles, DOE EH232, October 29, 1992.

[14] Personal communication from Ken Delius, Y-12 Site, with G. Roles, DOE EH232, October 29, 1992.

[15] Personal communication from J. Sease, MMES, to G. Roles, DOE EH232, January 9, 1992.

[16] Note from L.J. O'Neill, DOE-NV, to G. Roles, DOE EH232, December 24, 1991.

[17] Note from Darlene Hagel, Westinghouse Hanford Company, to G. Roles, DOE EH232, August 25, 1992.

[18] Willis, N.P. and G.C. Triner, Hanford Site Solid Waste Acceptance Criteria, WHC-EP-0063-3, Westinghouse Hanford Company, September 1991.

[19] Kocher, D.C., Radioactive Decay Data Tables, A Handbook of Decay Data for Application to Radiation Dosimetry and Radiological Assessments, DOE/TIC-11026, Technical Information Center, U.S. Department of Energy, 1981.

[20] Note from Steve Storch, IDB Program, to Josh Williams and Gregg Duggan, DOE EM30, September 18, 1992.

[21] U.S. Department of Energy, Integrated Data Base for 1991: U.S. Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics, DOE/RW-0006, Rev. 7, Oak Ridge National Laboratory, October 1991.

[22] Note from Steve Storch, IDB Program, to G. Roles, DOE EH232, November 9, 1992.

[23] Note from John Sease, MMES, to G. Roles, DOE EH, February 6, 1992.

[24] Nickels, J.M., Quarterly Briefing Book on Environmental and Waste Management Activities, WHC-SP-0434-16, Westinghouse Hanford Company, October 1992.

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[26] Letter from G.D. Kirk, Puget Sound Naval Shipyard, to J.M. Hennig, U.S. Department of Energy Richland Operations Office, March 18, 1993.

[27] Letter from E.W. Kendall, Reynolds Electrical & Engineering Co., Inc., to G. Roles, DOE EH232, March 10, 1993.

[28] Memorandum from J.R. Fowler, Westinghouse Savannah River Company, to R.M. Yarborough, DOE-SR, June 17, 1991.

[29] U.S. Department of Energy, Integrated Data Base for 1992: U.S. Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics, DOE/RW-0006, Rev. 8, Oak Ridge National Laboratory, October 1992.

[30] Note from Darlene Hagel, Westinghouse Hanford Company, to G. Roles, DOE EH232, December 30, 1992.

[31] U.S. Department of Energy, Low-Level Burial Grounds Dangerous Waste Permit Application, Request for Exemption from Lined Trench Requirements and from Land Disposal Restrictions for Residual Liquid at 218-E-12B Burial Ground Trench 94, DOE/RL-88-20, Supplement 1, Rev. 1, October 1992.

[32] U.S. Department of Energy, Radioactive Waste Management, Order DOE 5820.2A, September 26, 1988.

APPENDIX C

<u>CORRESPONDENCE WITH NRC ABOUT OVERREPORTING RADIONUCLIDE INVENTORIES</u>

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

DEC 0 3 1992

Mr. Andrew Wallo III, Director
Air, Water, and Radiation Programs
Department of Energy

Air, Water, and Radiation Division
Office of Environmental Guidance
Washington, D.C. 20585

Dear Mr. Wallo:

This is in response to your letter (dated November 2, 1992) to W. E. Brach, formerly the Acting-Branch Chief of the Low-Level Waste Management Branch.' That letter requested additional information regarding the U. S. Nuclear Regulatory Commission's conclusion that overreporting may have occured in the case of thorium waste sent to disposal at the Chem-Nuclear Systems Incorporated, Barnwell, South Carolina disposal facility.

With regard to reported thorium inventories, for the year 1990, we discovered that the quantity of source material in pounds (reported from waste manifest data) when divided by the specific activity in curies per pound only accounted for one tenth of the reported thorium activity in the site inventory Follow-up examination of shipping manifest for the same year also revealed that most of the thorium source material shipped was coming from one company. It was further discovered that thorium, reported as natural thorium by this waste generator, was transposed by the site operator into thorium-232 This apparently accounts for the descrepancy between site inventory data and shipment manifest data. We did not look at this data for the years 1987-1989 for any of the three operating disposal sites.

NRC has attempted to reduce the incidence of overreporting of waste inventory by making waste generators, disposal site operators and Agreement State Authorities aware of practices which cause overreporting. Further studies to identify more accurate methods for reporting long-lived radionuclides in waste may help reduce the overreporting. However, unless the activities are related to public health and safety or common defense, these studies would be beyond the scope of NRC funded activities.

We have informed the NRC Office of State Programs (see enclosure) that overreporting of thorium source material quantities may be occuring at the currently operating waste disposal sites and that the Agreement States where these sites are located would be the proper authority to initiate any corrective action. We will provide you with comments from the Agreement States when they are received.

We trust this responds to your concerns and if you have questions please contact Roy Person of my staff at 301-504-2575.

Sher Bahadur, Acting Chief
Low-Level Waste Management Branch
Division of Low-Level Waste Management
and Decommissioning
Office of Nuclear Materials Safety
and Safeguards

Enclosure: As stated

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON. D.C. 20556

DEC 0 4 1992

MEMORANDUM FOR: Vandy L. Miller, Assistant Director
State Agreements Program
Office of State Programs

FROM: Sher Bahadur, Acting Chief
Low-Level Waste Management Branch
Division of Low-Level Waste Management
Office of Nuclear Material Safety
and Safeguards

SUBJECT: OVERREPORTING OF LONG-LIVED RADIONUCLIDES
GOING TO SHALLOW LAND BURIAL

On June 23, 1992, we received a letter from Mr. Andrew Wallow III requesting our review of the draft report entitled, "Disposal of Solid Low-Level Waste During 1990." In addition to our review of the report, we examined waste generator manifest data and disposal site inventory records for the year 1990. We found that there was a descrepancy between quantities of thorium-232 reported on waste manifest and that recorded in disposal site inventory records. The Office of State Programs was given this information along with the report, for forwarding to the appropriate Agreement State Authorities The State of South Carolina indicated (Enclosure I) that it agrees with NRC's conclusions and has committed to take into consideration any overreporting when performance assessments are conducted at the Barnwell Site.

LLWM has now received a second letter from Mr. Wallow (Enclosure 2) requesting additional information on the Barnwell site and similar information on the Beatty and Hanford sites. We request that the Office of State Programs contact the appropriate Agreement State Authorities and determine their response to Mr. Wallo's concerns. Please contact me (504-2553) or Roy Person of my staff (504-2575) if we may be of further assistance in this matter.

Sher Bahadur

Sher Bahadur, Acting Chief
Low-Level Waste Management Branch
Division of Low-Level Waste Management
and Decommissioning
Office of Nuclear Material Safety
and Safeguards

Enclosures: As stated

Department of Energy
Washington, DC 20585

November 2, 1992

E. William Brach, Acting Chief
Low-Level Waste Management Branch
Division of Low-Level Waste Management
and Decommissioning
U.S. Nuclear Regulatory Commission
Washington, DC 20555 (WF: 5E2)

Dear Mr. Brach:

Thank you for your September 16, 1992, letter in which you responded to our June 23 request for a review of a draft report on radionuclide inventory data for low-level waste (LLW) disposed during 1990. In your letter, you indicated that reported inventories of uranium in commercial LLW disposal facilities might be correct but that thorium inventories might be incorrect.

Although we appreciate your review of the draft report, your response prompts some additional questions.

The purposes of the draft report are to document and compare as accurately as possible, the inventories of LLW being disposed in commercial and DOE disposal facilities. Given this, if you believe that the thorium inventories are incorrect could you provide additional input as to what the thorium inventories might actually be? In addition, your response focuses on data for the Chem-Nuclear Systems, Inc. site. Do you believe that similar problems might exist for data from the U.S. Ecology disposal facilities as well? Might similar questions exist for data from previous years -- e.g., for the years 1987 through 1989?

Finally, we expressed concern about the apparent overreporting of long-lived radionuclide data in LLW disposal manifests and indicated that we would be interested in hearing from NRC about actions that could be taken to reduce such overreporting and improve source term estimates. Based on your September 16 letter, you have similar concerns. Is NRC considering taking any actions to resolve the issue?

Thank you again for your response. If you have questions, please contact Mr. G. Roles of my staff (202-586-0289).

Sincerely,

Andrew Wallo III
Air, Water and Radiation Division
Office of Environmental Guidance

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON. D.C. 20555

September 16, 1992

Mr. Andrew Wallo III, Director
Air, Water, and Radiation Programs
Department of Energy
EH-232
Air, Water, and Radiation Division
Office of Environmental Guidance
Washington, DC 20585

Dear Mr. Wallo:

This is in response to the letter from G. Roles of your staff dated June 23, 1992, in which he indicated that his review of radionuclide inventory data for 1990 revealed a "practice by commercial waste generators of overreporting" the quantities of uranium and thorium that are shipped to LLW disposal sites.

Our preliminary examination of shipment records for 1990 indicates, that in general, the total quantity of uranium is correct, but the thorium, as reported in the inventory data may be high. For example, our review of the manifests of one large shipper of thorium indicates a potential discrepancy between the values reported on the waste shipment manifest for natural thorium, and the actual quantities reported as being disposed of by the disposal site. Apparently, this situation is due to the procedure used in preparing the waste shipment manifest. The procedure did not require a precise delineation of thorium-232, thorium-228, and each of the thorium daughters. The total thorium and daughter activity was thus reported as natural thorium. The disposal site operator, however has apparently been reporting this activity inventory as thorium-232. This implies that the actual quantity of thorium-232 is about one-tenth of what was reported in the inventory by the disposal site operator.

At the same time, we identified one facility apparently responsible for disposal in 1989 of most of the depleted uranium. A conversation with the individual responsible for signing the manifest certification has indicated that the uranium inventories are apparently correct.

The site operator and the State of South Carolina have been made aware of this preliminary finding and indicate that they will make appropriate corrections to recording procedures. In comments submitted by the State of South Carolina on the Roles report, the State indicates that they will consider information from the Roles report when doing performance assessment and assessing site closure (see enclosed letter from Virgil Autry, South Carolina to Vandy Miller, NRC, dated 8/21/92).

The Department of Energy should also note that the State recommends further study of the practice of generators overestimating long-lived radionuclides (such as I-129 and C-14). Jene Vance of Vance Associates has attempted to better quantify some of these estimates in his report entitled "Iodine-129 and Technetium-99 Release Rates from Six Reactors in the Southeast Compact." Since the results of the Vance study could potentially provide a generic solution to overestimating I-129 and Tc-99 concentrations in waste, NRC would consider review of this report under its topical report review program if full cost recovery for the review could be assured.

We hope this preliminary information is helpful and appreciate your sharing your thoughts with us.

Sincerely,

John O. Thoma

E. William Brach, Acting Chief
Low-Level Waste Management Branch
Division of Low-Level Waste Management
and Decommissioning
Office of Nuclear Material Safety
and Safeguards

Enclosure: As stated

cc: G. Roles

South Carolina
DHEC
Department of Health and Environmental Control
2600 Bull Street, Columbia, SC 29201

September 1, 1992

Mr. Vandy L. Miller, Assistant Director
for State Agreement Programs
Office of State Programs
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Miller:

This Department has reviewed the DOE report prepared by Gary Roles entitled "Disposal of Solid Low-Level Waste During 1990" and the copy of the draft comments prepared by the NRC. As identified in the report, Quantities of uranium and thorium may be overestimated on manifests along with concentrations of carbon-14, iodine-129, and technetium-99. This will be taken into consideration when performance assessments are conducted at the Barnwell site. We also believe that a study of the practice of overestimating long-lived radionuclides would provide useful information for performance assessments and when assessing the closure of the site.

We do not have specific comments on the report and *agree with* the comments drafted by the NRC's Low-Level Waste Management Branch. Thank you for allowing us the Opportunity to review the report.

Very truly yours,

Virgil R. Autry, Director
Division of Radioactive Materials
Licensing and Compliance
Bureau of Radiological Health

HJP/em
vlm90192/0992

Enclosure

JUN 23 1992

Paul H. Lohaus, Chief
Low-Level Waste Management Branch
Division of Low-Level Waste
Management and Decommissioning
U.S. Nuclear Regulatory commission
Washington, DC 20555

Dear Paul:

Enclosed for your information and review is a copy of a draft . report entitled "Disposal of Solid Low-Level Waste During 1990." The report presents radionuclide inventory data in low-level waste (LLW) disposed during 1990 at Department of Energy and commercial LLW disposal sites. The inventory data was obtained from LLW disposal manifests.

One' of the striking aspects of the commercial data is the practice of commercial waste generators of overreporting inventories of long-lived radionuclides. This seems to be the case not only for Tc-99 and I-129, but for uranium and thorium This practice is undesirable because it gives the appearance that LLW is more hazardous than it actually is, leading to inefficient use of LLW disposal capacity.

If you have comments on the &aft report, I would appreciate them by the end of July. Otherwise, I would be interested in hearing from you about actions 'that could be taken to reduce overreporting in LLW disposal manifests. I can be reached at 202-586-0289.

Sincerely,

G.W. Roles
Air, Water, and Radiation
Division
Office of Environmental
Guidance

Enclosure

CONCURRENCE
RTG. SYMBOL EH232
INITIALS/SIG. GRoles
DATE 6/23/92
RTG. SYMBOL EH232
INITIALS/SIG. ERegnier
DATE 6/22/92
RTG. SYMBOL
INITIALS/SIG.
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