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Integrated Data Base for 1993: U.S. Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics

March 1994

Prepared by

Oak Ridge National Laboratory
Managed by Martin Marietta Energy Systems, Inc., for the
U.S. Department of Energy under contract DE-AC05-84OR21400

Prepared for

U.S. Department of Energy
Office of Civilian Radioactive Waste Management
Office of Environmental Restoration and Waste Management
Washington, D.C. 20585

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PREFACE

The information in this report summarizes the U.S. Department of Energy (DOE) data base for inventories, projections, and characteristics of domestic spent nuclear fuel and radioactive waste. This report is updated annually to keep abreast of continual waste inventory and projection changes in both government and commercial sectors. Baseline information is provided for planning purposes and to support program decisions. Although the primary purpose of this document is to provide background information for program planning within the DOE community, it has also been found useful by state and local governments, the academic community, and a number of private citizens. To sustain the objectives of this program in providing accurate and complete data in this field of operation, comments and suggestions to improve the quality and coverage are encouraged. Such comments and any general inquiries should be directed to the U.S. Department of Energy at either of the following:

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Office of Environmental Restoration and Waste Management
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This report was prepared by the Integrated Data Base Program, which is jointly sponsored by the DOE Office of Civilian Radioactive Waste Management and the DOE Office of Environmental Restoration and Waste Management. Suggestions, questions, and requests for information may be directed to any of the following:

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An important part of the Integrated Data Base Program is the Steering Committee, whose members provide both generic guidance and technical input. The membership of this committee, shown on the following page, represents all of the major DOE sites and programs for spent fuel and radioactive waste management. Each support committee member is assisted by a technical liaison as needed. The participation and assistance of these individuals are acknowledged with appreciation.

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Major sources providing spent fuel and radioactive waste type information for the 1993 Integrated Date Base Program report

Waste type information/data	Source(s)
Spent fuel	
Commercial	DOE/EIA
DOE	DOE Office of Spent Fuel Management (DOE/EM-37)
High-level waste	Waste Management Information System (WMIS)[a]
Transuranic waste	WMIS
Low-level waste	
Commercial	National Low-Level Waste Management Program[b]
DOE	WMIS
Uranium mill tailings	DOE/EIA
Environmental restoration wastes	DOE Office of Environmental Restoration (DOE/EM-40)
Commercial decommissioning wastes	Public utilities, supporting fuel cycle facilities
Mixed low-level waste	
Commercial	NRC study (NUREG/CR-5938)
DOE	Interim Mixed Waste Inventory Report (DOE/NBM-1100) WMIS
Miscellaneous radioactive materials	
Commercial	Commercial storage sites
DOE	DOE inventory sites

[a]Maintained by the Hazardous Waste Remedial Actions Program.
[b]Maintained by EG&G Idaho, Inc.

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GLOSSARY OF ABBREVIATIONS

AEA	Atomic Energy Act of 1954
AEC	Atomic Energy Commission
AMES	Ames Laboratory, Ames, Iowa
ANL-E	Argonne National Laboratory-East, Argonne, Illinois
ANL-W	Argonne National Laboratory-West, INEL, Idaho
APPR	Army Package Power Reactor
ATL 1	Atlantic Site 1 (38'30'N, 72'06'W)
ATL 2	Atlantic Site 2 (37'50'N, 70'35'W)
ATR	Advanced test reactor
BAPL	Bettis Atomic Power Laboratory, West Mifflin, Pennsylvania
BARN	Barnwell, South Carolina (commercial waste site)
BCL	Battelle Columbus Laboratories, Columbus, Ohio
BCLDP	Battelle Columbus Laboratories Decommissioning Project, Columbus, Ohio
BDM	BDM International, Inc., Germantown, Maryland
BETY	Beatty, Nevada (commercial waste site)
BMI	Battelle Memorial Institute
BNI	Bechtel National, Inc., Oak Ridge, Tennessee
BNL	Brookhaven National Laboratory, Upton, New York
BR	Belgium reactor
B&W	Babcock and Wilcox Nuclear Environmental Services, Lynchburg, Virginia
BWR	Boiling-water reactor
CANDU	Canadian Deuterium Reactor
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CEU	Consolidated Edison Uranium
CFC	Chlorinated fluorocarbon
CH	Contact-handled (transuranic waste)
CISS	Colonie Interim Storage Site, Colonie, New York
CRWMS-M&O	Civilian Radioactive Waste Management System—Management and Operating (contractor)
CY	Calendar year
DAW	Dry active waste
DOD	Department of Defense, U.S.
DOE	Department of Energy, U.S.
DOE/AL	DOE Albuquerque Operations Office, Albuquerque, New Mexico
DOE/CH	DOE Chicago Operations Office, Argonne, Illinois
DOE/DP	DOE/Office of Defense Programs (Headquarters), Germantown, Maryland
DOE/EIA	DOE/Energy Information Administration, Washington, D.C.
DOE/EM	DOE/Office of Environmental Restoration and Waste Management (Headquarters), Germantown, Maryland (recently changed to the Office of Environmental Management)
DOE/FN	DOE Fernald Site Office, Cincinnati, Ohio
DOE/HQ	DOE Headquarters, Washington, D.C. and Germantown, Maryland
DOE/ID	DOE Idaho Operations Office, Idaho Falls, Idaho
DOE/NV	DOE Nevada Operations Office, Las Vegas, Nevada
DOE/OR	DOE Oak Ridge Operations Office, Oak Ridge, Tennessee

DOE/OSTI	DOE/Office of Scientific and Technical Information, Oak Ridge, Tennessee
DOE/RF	DOE Rocky Flats Office, Golden, Colorado
DOE/RL	DOE Richland Operations Office, Richland, Washington
DOE/RW	DOE/Office of Civilian Radioactive Waste Management (Headquarters), Washington, D.C.
DOE/SAN	DOE San Francisco Operations Office, Oakland, California
DOE/SR	DOE Savannah River Operations Office, Aiken, South Carolina
DOE/WIPP	DOE/WIPP Project Office, Carlsbad, New Mexico
DOE/WVP	DOE/West Valley Project Office, West Valley, New York
DOT	Department of Transportation, U.S.
DRCT	Dry rod consolidation technology
DWCS	Defueling water cleanup system
DWMP	Defense Waste Management Plan
DWPF	Defense Waste Processing Facility
D&D	Decontamination and decommissioning
EA	Environmental assessment
EBR	Experimental Breeder Reactor
EBWR	Experimental boiling-water reactor
EG&G/ID	EG&G Idaho, Inc., Idaho Falls, Idaho
EIA	Energy Information Administration
EIS	Environmental impact statement
EMAD	Engine maintenance assembly and disassembly
EPA	Environmental Protection Agency, U.S.
EPR	Experimental power reactor
ERR	Elk River Reactor
ETEC	Energy Technology Engineering Center, Canoga Park, California [also referred to as the Santa Susana Field Laboratory (SSFL)]
FEMP	Fernald Environmental Management Project, Fernald, Ohio
FFCA	Federal Facility Compliance Act of 1992
FFTF	Fast Flux Test Facility, Hanford, Washington
FIS	Farallon Islands (Pacific Ocean off Central California)
FNAL	Fermi National Accelerator Laboratory, Batavia, Illinois
FSVR	Fort St. Vrain Reactor, Platteville, Colorado
FUSRAP	Formerly Utilized Sites Remedial Action Program
FY	Fiscal year
GA	General Atomic, San Diego, California
GAP CON	Gap conductance
GCRE	Gas-cooled reactor experiment
GDP	Gaseous diffusion plant
GE	General Electric
GETR	General Electric test reactor
GEVNC	General Electric Vallecitos Nuclear Center, Vallecitos, California
GJPO	(DOE) Grand Junction Projects Office, Grand Junction, Colorado
GJRAP	Grand Junction Remedial Action Project
GPU	General Public Utilities Corporation, Parsippany, New Jersey
GTCC	Greater-than-Class-C (low-level waste)
HANF	Hanford Site, Richland, Washington
HAZWRAP	Hazardous Waste Remedial Actions Program
HEDL	Hanford Engineering Development Laboratory
HEN	Cape Henry (Atlantic Ocean off Virginia)
HFBR	High-Flux Beam Reactor
HIC	High-integrity containers
HLW	High-level waste
HTGR	High-temperature, gas-cooled reactor

HTRE	High-temperature reactor experiment
HWCTR	Heavy-water components test reactor
HWVP	Hanford Waste Vitrification Plant, Hanford Site
ICPP	Idaho Chemical Processing Plant, Idaho National Engineering Laboratory
IDB	Integrated Data Base (Program)
IE	Irradiation effects
I/I	Industrial and institutional (waste)
IMWIR	Interim Mixed Waste Inventory Report
INEL	Idaho National Engineering Laboratory, Idaho Falls, Idaho
ISL	In situ leaching
ITRI	Inhalation Toxicology Research Institute, Kirtland Air Force Base, Albuquerque, New Mexico
JAI	(E.R.) Johnson Associates, Inc., Oakton, Virginia
JIO	Joint Integration Office, Albuquerque, New Mexico
K-25	Oak Ridge K-25 Site, Oak Ridge, Tennessee (formerly called the Oak Ridge Gaseous Diffusion Plant)
KAPL	Knolls Atomic Power Laboratory, Schenectady, New York
KCP	Kansas City Plant, Kansas City, Missouri
LANL	Los Alamos National Laboratory, Los Alamos, New Mexico
LBL	Lawrence Berkeley Laboratory, Berkeley, California
LEHR	Laboratory for Energy-Related Health Research
LEU	Low-enriched uranium
LFRSB	Loose fuel-rod shipping basket
LGR	Light-water cooled, graphite-moderated reactor
LLNL	Lawrence Livermore National Laboratory, Livermore, California
LLR	LOFT lead rod
LLRWPA	Low-Level Radioactive Waste Policy Act of 1980
LLRWPAA	Low-Level Radioactive Waste Policy Amendments Act of 1985
LLW	Low-level waste
LLWMP	Low-Level Waste Management Program
LMFBR	Liquid Metal Fast Breeder Reactor
LOC	Loss of coolant
LOFT	Loss-of-fluid test
LSA	Low specific activity
LTC	Lynchburg Technology Center, Lynchburg, Virginia
LWBR	Light-water breeder reactor
LWR	Light-water reactor
MAPI	Mitsubishi Atomic Power Industries
MASS	Massachusetts Bay
MED	Manhattan Engineer District (Manhattan Project)
MFKY	Maxey Flats, Kentucky (commercial waste site)
MFRP	Midwest Fuel Recovery Plant, Morris, Illinois (commercial spent fuel storage site)
MIMS	Manifest Information Management System
MMES	Martin Marietta Energy Systems, Inc.
MOUND	Mound Plant, Miamisburg, Ohio
MRM	Miscellaneous radioactive material
MSRE	Molten Salt reactor experiment
MTIHM	Metric tons initial heavy metal
MTU	Metric tons uranium
MURR	Missouri University Research Reactor
MW	Mixed waste

NA	Not applicable
NARM	Nuclear accelerator-generated radioactive material
NEPA	National Environmental Policy Act of 1969
NFS	Nuclear Fuel Services, Erwin, Tennessee
NORM	Naturally occurring radioactive material
NPL	National priorities list
NR	Naval reactors
NRC	Nuclear Regulatory Commission
NRF	Naval Reactors Facility, INEL, Idaho
NTIS	National Technical Information Service, Springfield, Virginia
NTS	Nevada Test Site, Mercury, Nevada
NUMEC	Nuclear Uranium Materials and Equipment Corporation
NUS	NUS Corporation, Gaithersburg, Maryland
NWPA	Nuclear Waste Policy Act of 1982
NYSERDA	New York State Energy Research and Development Authority, Albany, New York
OPTRAN	Operational transit
OR	Oak Ridge complex: Oak Ridge National Laboratory, K-25 Site, and Y-12 Plant, Oak Ridge, Tennessee
ORAU	Oak Ridge Associated Universities, Oak Ridge, Tennessee
ORIGEN2	Oak Ridge Isotope Generation and Depletion Code (Version 2)
ORISE	Oak Ridge Institute for Science and Education, Oak Ridge, Tennessee
ORNL	Oak Ridge National Laboratory, Oak Ridge, Tennessee
ORR	Oak Ridge Research Reactor
OTS	Office of Technical Services, Roy F. Weston, Inc./H&R Technical Associates, Inc., Germantown, Maryland
PAD	Paducah Gaseous Diffusion Plant, Paducah, Kentucky
PANT	Pantex Plant, Amarillo, Texas
PBF	Power Burst Facility
PCB	Polychlorinated biphenyl
PCM	Power coolant mismatch
PINELLAS	Pinellas Plant, Largo, Florida
PNL	Pacific Northwest Laboratory, Richland, Washington
PNRO	DOE Pittsburgh Naval Reactors Office, West Mifflin, Pennsylvania
PORTS	Portsmouth Gaseous Diffusion Plant, Portsmouth, Ohio
PPPL	Princeton Plasma Physics Laboratory, Princeton, New Jersey
PWR	Pressurized-water reactor
PUREX	Plutonium uranium extraction
RA	Remedial action
RAP	Remedial action project
RCF	RCRA (see below) facility assessment
RCRA	Resource Conservation and Recovery Act of 1976
REECO	Reynolds Electrical and Engineering Co., Inc., Mercury, Nevada
RFP	Rocky Flats Plant, Golden, Colorado
RH	Remote-handled (TRU waste)
RI	Rockwell International Corporation, Pittsburgh, Pennsylvania
RIA	Reactivity initiated accident
RICH	Richland, Washington (commercial waste site)
RMI	Reactive Metals, Incorporated Titanium Company Extrusion Plant, Ashtabula, Ohio
SCB	Santa Cruz Basin (Pacific Ocean off Santa Cruz, California)
SDG	San Diego (Pacific Ocean off San Diego, California)
SDS	Submerged demineralizer system
SEG	Scientific Ecology Group, Inc., Oak Ridge, Tennessee
SF	Spent fuel

SFD	Severe fuel damage
SFMP	Surplus Facilities Management Program
SHEF	Sheffield, Illinois (commercial waste site)
SLAC	Stanford Linear Accelerator Center, Palo Alto, California
SM	Stationary media
SNAP	Space Nuclear Auxiliary Power
SNLA	Sandia National Laboratories, Albuquerque, New Mexico (recently changed to Sandia National Laboratories–New Mexico)
SNLL	Sandia National Laboratories, Livermore, California (recently changed to Sandia National Laboratories–California)
SNM	Special nuclear material
SNRO	DOE Schenectady Naval Reactors Office, Schenectady, New York
SPERT	Special power excursion reactor test
SRE	Sodium reactor experiment
SRS	Savannah River Site, Aiken, South Carolina
SS	Stainless steel
SSFL	Santa Susana Field Laboratory, Canoga Park, California [also referred to as the Energy Technology Engineering Center (ETEC)]
SWIMS	Solid Waste Information Management System
SWU	Separative work unit
TAN	Test area north
TBD	To be determined
TC	Thermocouple
TCLP	Toxicity characteristic leaching procedure
TESS	TRW Environmental Safety Systems, Inc.
THOREX	Thorium extraction
TMI	Three Mile Island reactor site, Middletown, Pennsylvania
TRIGA	Training Reactor, Isotopes, General Atomic
TRU	Transuranic
TSCA	Toxic Substances Control Act of 1976
T/S/D	Treatment, storage, and disposal
TVA	Tennessee Valley Authority, Knoxville, Tennessee
UMTRAP	Uranium Mill Tailings Remedial Action Program
VBWR	Vallecitos Boiling-Water Reactor
VEPCO	Virginia Electric Power Company
WEC	Westinghouse Electric Corporation, Pittsburgh, Pennsylvania
WHC	Westinghouse Hanford Company, Richland, Washington
WHPP	(TRU) Waste Handling and Packaging Plant, Oak Ridge National Laboratory
WIPP	Waste Isolation Pilot Plant, Carlsbad, New Mexico
WMin	Waste minimization
WMIS	Waste Management Information System
WPIO	Waste Isolation Pilot Plant Project Integration Office, Albuquerque, New Mexico
WSSRAP	Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri
WVDP	West Valley Demonstration Project, West Valley, New York
WVNS	West Valley Nuclear Services Company, Inc., West Valley, New York
WVNY	West Valley, New York (commercial waste site from 1963–1981)
W/WIPP	Westinghouse/WIPP Project, Carlsbad, New Mexico
Y-12	Oak Ridge Y-12 Plant, Oak Ridge, Tennessee

INTEGRATED DATA BASE FOR 1993: U.S. SPENT FUEL AND RADIOACTIVE WASTE INVENTORIES, PROJECTIONS, AND CHARACTERISTICS

ABSTRACT

The Integrated Data Base (IDB) Program has compiled historic data on inventories and characteristics of both commercial and DOE spent fuel; also, commercial and U.S. government-owned radioactive wastes through December 31, 1992. These data are based on the most reliable information available from government sources, the open literature, technical reports, and direct contacts. The information forecasted is consistent with the latest U.S. Department of Energy/Energy Information Administration (DOE/EIA) projections of U.S. commercial nuclear power growth and the expected DOE-related and private industrial and institutional (I/I) activities.

The radioactive materials considered, on a chapter-by-chapter basis, are spent nuclear fuel, high-level waste (HLW), transuranic (TRU) waste, low-level waste (LLW), commercial uranium mill tailings, environmental restoration wastes, commercial reactor and fuel-cycle facility decommissioning wastes, and mixed (hazardous and radioactive) LLW. For most of these categories, current and projected inventories are given through the calendar-year (CY) 2030, and the radioactivity and thermal power are calculated based on reported or estimated isotopic compositions. In addition, characteristics and current inventories are reported for miscellaneous radioactive materials that may require geologic disposal.

0. OVERVIEW

0.1 INTRODUCTION

This report is an update of the previous document[1] on radioactive waste inventories and projections that was prepared for use in the planning and analysis of waste management functions. Historical waste inventories compiled as of December 31, 1992, are reported. Projections of future wastes are generally reported through CY 2030. Such projections may change in future revisions of this report as waste minimization, environmental restoration, and decontamination and decommissioning (D&D) programs and activities at various government and commercial sites are defined and become operative. In many tables of this report, historical waste inventories and projection data are reported on a CY basis. These tables use a horizontal line to mark the point in time when past history ends and future projections begin. Because historical waste inventories are reported as of December 31, 1992, the line is drawn between the data entries for 1992 and 1993. Data reported for 1993 in this document are regarded as projected information.

This document contains information that has been assembled as a part of the IDB Program at Oak Ridge National Laboratory (ORNL), which has the lead responsibility for maintaining and reporting summary files of pertinent data on current and projected inventories and characteristics of permanently discharged domestic spent nuclear fuel and radioactive wastes.

Radioactive waste originates from five major sources: (1) the commercial nuclear fuel cycle; (2) DOE-related activities; (3) institutions such as hospitals, universities, and research foundations; (4) industrial uses of radioisotopes;

and (5) mining and milling of uranium ore. The waste is broadly categorized as spent nuclear fuel, HLW, TRU waste, LLW, and uranium mill tailings. Large quantities of radioactive waste will also result from future activities such as DOE environmental restoration activities and the D&D programs of DOE and commercial nuclear facilities.

The primary purpose of this document is to report U.S. spent fuel and radioactive waste inventories, projections, and characteristics. The data presented were obtained through the cooperation and assistance of the offices and programs that were established by DOE to oversee the management of the various radioactive wastes and spent fuels. In addition, the recent literature was reviewed to aid in selecting the data that are presented here and to help establish a basis for many of the calculated radioactivity levels and heat-generation rates that are included. In this report, spent fuel and radioactive wastes are characterized from the standpoint of their volumes (or masses) and their nuclear, physical, and chemical properties. The data reported are selected from more extensive information; that information is available upon request.

This annual inventory report contains summarized data of types found to be useful for programmatic planning purposes within the DOE community. The data are intended to provide a common basis for both DOE management-level planning and for more detailed analyses of the waste management system that are conducted by DOE contractors and field offices. However, this report is not intended to present the detailed types of information required as input to such analyses. The best sources of such information are the appropriate operations offices, waste sites, or relevant documents previously issued, some of which may be referenced in this report.

This report does not address the programmatic implications of the data presented, such as the possible future need for interim spent-fuel storage facilities. Discussion of the data is limited to the minimum extent needed to explain what the data represent and the sources from which they were derived. Likewise, discussions of packaging details, shielding and transportation requirements, health and environmental effects, and costs are purposely avoided. Questions regarding the data presented may be addressed to the IDB Program.

The DOE waste data contained in this report are furnished by DOE contractor sites through the 1993 Waste Management Information System (WMIS) data call for the IDB Program. The DOE site data (waste inventories, projections, and characteristics) are used by DOE-Headquarters (DOE-HQ), operations offices, and operating contractors for the management and strategic planning of various waste programs. The objective of this report is to provide waste information that is consistent, reflects current inventories and projections, and includes the types of basic data best suited to meet DOE waste program planning needs.

Information for this report is provided by a variety of sources. The waste data reported to WMIS are received from DOE contractors through DOE operations offices. DOE-HQ assigns to selected organizations major responsibilities for providing information on particular topics involving spent fuel and radioactive waste management. Further detailed information is generally available from data bases maintained at the specific DOE and commercial sites. A list of reference sites and facilities referred to in this report is provided in Appendix D.

0.2 CHARACTERIZATION OF WASTE FORMS

The major characteristics of radioactive materials and wastes are described below.

- **Spent Fuel**

  Spent fuel consists of irradiated fuel discharged from a nuclear reactor. Unless otherwise identified, all spent fuels discussed in this report are assumed to be permanently discharged and eligible for repository disposal. Three categories of permanently discharged spent fuel are considered: (1) fuel from commercial light-water reactors (LWRs); (2) fuel from non-LWR commercial reactors [e.g., the Fort St. Vrain high-temperature, gas-cooled reactor (HTGR)]; and (3) special fuels associated with government-sponsored research and demonstration programs, universities, and private industries. This report does not track the inventories of government production reactor spent fuels that have been reprocessed in the manufacture of nuclear weapons for national defense. However, the inventories of HLW resulting from the reprocessing of these fuels are reported in Chapter 2. Also, Chapter 1 reports quantities of DOE spent fuel not scheduled for reprocessing.

  Currently, most LWR spent-fuel assemblies are stored in pools at the reactor sites. The bulk of the remainder is in storage at the West Valley Demonstration Project (WVDP) site at West Valley, New York; the Idaho National Engineering Laboratory (INEL) at Idaho Falls, Idaho; and the Midwest Fuel Recovery Plant (MFRP) at Morris, Illinois. The WVDP facility is currently being decommissioned. All utility-owned spent-fuel assemblies previously stored there have been returned to the utilities, and the fuel remaining is DOE-owned material.

  Spent fuels discharged from a variety of reactors are currently stored at the Hanford Site (HANF) and INEL. HANF contains inventories of fuel from the N Reactor, the Fast Flux Test Facility (FFTF), and pressurized-water reactor (PWR)–Core II fuel from

Shippingport. Fuel from the damaged Three Mile Island (TMI)–Unit 2 reactor, as well as some of the spent fuel from the Fort St. Vrain HTGR, are stored at INEL. Some special spent fuels are stored at the Savannah River Site (SRS) and at INEL. These special fuels are government owned and are not scheduled for reprocessing in support of DOE activities.

- **HLW**

For this report, HLW means the highly radioactive material resulting from the reprocessing of spent nuclear fuel. This includes mainly the liquid wastes remaining from the recovery of uranium and plutonium in a fuel reprocessing plant. This HLW may also be in the form of sludge, calcine, or other products into which such liquid wastes are converted to facilitate their handling and storage. Such waste contains fission products that result in the release of considerable decay energy.[2] For this reason, heavy shielding is required to absorb penetrating radiation, and provisions (e.g., cooling systems) are needed to dissipate decay heat from HLW.

- **TRU Waste**

TRU wastes refer to radioactive wastes that contain more than 100 nCi/g of alpha-emitting isotopes with atomic numbers greater than 92 and half-lives greater than 20 years.[3,4] Such wastes result primarily from fuel reprocessing and from the fabrication of plutonium weapons and plutonium-bearing reactor fuel. Generally, little or no shielding is required ("contact-handled" TRU waste), but energetic gamma and neutron emissions from certain TRU nuclides and fission-product contaminants may require shielding or remote handling ("remote-handled" TRU waste).

- **LLW**

Several statutes (refs. 2, 4, and 5) define LLW not by what it is, but by what it is not. In general, LLW is radioactive waste not classified as spent fuel, HLW, TRU waste, or by-product materials such as uranium or thorium mill tailings. However, there are slight differences between the specific regulatory definitions of DOE-generated LLW and commercial LLW.

The definition of DOE LLW is based on DOE Order 5820.2A,[4] which specifies DOE's policy for radioactive waste management. According to this order, LLW includes all radioactive waste not classified as either HLW, TRU waste, spent nuclear fuel or the bulk of the by-product tailings containing uranium or thorium from processed ore. The DOE policy as stated in Order 5820.2A allows small volumes of fissionable material to be irradiated for research and development (R&D) only—but not for the production of power or plutonium—and small concentrations of TRU (<100 nCi/g) radionuclides to be managed as LLW. The same DOE policy allows small volumes of DOE waste containing by-product material [specified in Sect. 11e(2) of the Atomic Energy Act (AEA)][6] or naturally occurring and accelerator-produced radioactive material (NARM) to be managed as LLW. Any LLW that also contains hazardous chemicals covered by either the Resource Conservation Recovery Act (RCRA)[7] or the Toxic Substances Control Act (TSCA)[8] requires management as a "mixed waste."

The definition of commercial LLW is based on two statutes, the Nuclear Waste Policy Act (NWPA)[2] and the Low-Level Radioactive Waste Policy Amendments Act (LLRWPAA).[5] According to both the NWPA and the LLRWPAA, commercial LLW is radioactive material that (a) is not HLW, spent nuclear fuel, TRU waste, or by-product material as defined in Sect. 11e(2) of the AEA; and (b) the U.S. Nuclear Regulatory Commission (NRC), consistent with existing law, classifies as LLW.

The radiation level from LLW waste may sometimes be high enough to require shielding for handling and transport. For commercial LLWs, the NRC has defined, in ref. 9, four disposal categories of LLW that require differing degrees of confinement and/or monitoring: classes A, B, C, and Greater-Than-Class-C (GTCC). The NRC excludes NARM from the LLW category. DOE LLWs are classified by groupings of disposal categories that are site specific, yet similar to the NRC categories. This report documents only those inventories of solid LLW destined for disposal. It includes no liquid or gas waste in storage nor inventories of soils contaminated with LLW.

- **Commercial Uranium Mill Tailings**

Commercial uranium mill tailings are the earthen residues that remain after the extraction of uranium from ores. Tailings are generated in very large volumes and contain low concentrations of naturally occurring radioactive materials. These materials comprise a potential health hazard; the isotopes of major concern are ^{226}Ra and its daughter, ^{222}Rn.

- **Miscellaneous Radioactive Materials**

A variety of miscellaneous radioactive materials (MRMs) are currently stored at some DOE and commercial sites. These materials include hot cell solid wastes as well as whole, sectioned, or damaged spent-fuel rods or assemblies that originated in commercial

reactors and were used in various DOE-related experimental programs. Many of these materials are highly radioactive and may eventually require geologic disposal.

- **Mixed LLW**

Mixed LLW contains concentrations of both low-level radioactive materials and hazardous chemicals. The hazardous component of mixed waste has characteristics identified by any or all of the following statutes: the RCRA, as amended;[7] the TSCA;[8] and state regulations. Typically, mixed LLW from activities supporting DOE programs includes a variety of contaminated materials, such as air filters, cleaning solutions, engine oils and grease, paint residues, soils, construction and building materials, water-treatment chemicals, and decommissioned plant equipment. This report documents inventories and generation rates of various types of mixed wastes stored at DOE sites based on information reported in the Federal Facilities Compliance Act (FFCA) Interim Mixed Waste Inventory Report (IMWIR)[10] and TSCA waste information collected and reviewed for the WMIS. The WMIS contains information on wastes generated, stored, and disposed at DOE sites and is maintained by the Hazardous Wastes Remedial Actions Program (HAZWRAP) in support of the DOE Office of Environmental Restoration and Waste Management.

- **Generated, Treated, Stored, and Disposed Wastes**

It should be emphasized that all of the types of radioactive materials and wastes discussed in this report can exist either as material generated, treated, stored, or disposed. The distinctions among these various waste conditions or "states" are as follows:

— *Generated waste.* A material recently discharged from a facility production process or operation that can be regarded as a waste because it has no economic value. In this report, quantities of generated waste are measured in units of volume [cubic meters (m^3)] or mass (kg) produced during a calendar year.

— *Treated waste.* A waste that, following generation, has been altered chemically or physically to reduce its toxicity or prepare it for storage or disposal on- or off-site. Waste treatment can include volume-reduction activities, such as incineration or compaction, which may be done prior to either storage or disposal or both (discussed next).

— *Stored waste.* A waste that, following generation (and usually some treatment), is being (temporarily) retained and monitored in a retrievable manner pending disposal. In this report, inventories and projections of stored radioactive materials or wastes are reported in volume (m^3) or mass (kg) units or both.

— *Disposed waste.* A waste that has been put in final emplacement to ensure its isolation from the biosphere, with no intention of retrieval. Deliberate action is required to regain access to the waste. Disposed waste includes materials placed in a geologic repository, buried underground in shallow pits, dumped at sea, or discarded by hydrofracture injection. The latter two techniques were past practices and are no longer performed.

Throughout this report, the reader is urged to note the distinctions between these waste conditions. Such conditions have a great impact on the regulatory status of the waste materials considered in this report.

0.3 METHODS AND ASSUMPTIONS USED IN REPORT PREPARATION

This report consolidates a large amount of information from many sources. Some of these data are historical in nature, some are current, and some are projected; some have been calculated or estimated, and some have been measured. Over the years, waste regulations have been revised, waste category definitions have changed, measurement instruments and calibration methods have been improved, and record-keeping has been upgraded at all waste-generating and -receiving sites. In preparing this report, a major effort has been made to integrate waste data from many sources and to strive for a consistent and technically rational approach for the entire scope of coverage. Our primary sources of data are referenced, and, for calculated values (e.g., decayed radioactivity and thermal power), the bases for the calculations are identified. To achieve adequate integration of data, numerous factors had to be considered; these are cited in footnotes that generally accompany the tables and figures of this report. In some cases, a more thorough explanation is provided in the text.

Each chapter details the assumptions on which its waste inventories and projections are based. The broader assumptions are mentioned here and are listed in Table 0.1. These include the projected time frame and specific assumptions used for estimating commercial and government (DOE) waste projections. For the commercial fuel cycle, the spent-fuel and waste projections depend upon the nuclear power growth scenario. The commercial fuel cycle waste projections reported in this document assume a reference projection of nuclear power growth and no spent fuel reprocessing. The reference nuclear power

electrical growth projection (and associated discharged spent-fuel schedule) used throughout this report is the 1993 DOE/EIA No New Orders Case.[11] In addition, this document also includes a set of nuclear capacity and spent-fuel projections associated with the 1993 DOE/EIA Lower Reference Case to illustrate, for planning purposes, a conservative upper bound of commercial nuclear power growth.[11] The No New Orders and Lower Reference spent-fuel and power-capacity projection cases are each based on a unique set of assumptions involving nuclear electricity generation growth, reactor fuel burnup levels, reactor construction schedules, and reactor operating lifetimes and capacity factors. These assumptions are documented by DOE/EIA in ref. 11. In particular, the No New Orders Case assumes that all reactors will be retired upon the expiration date of their respective operating licenses. By contrast, the 1993 Lower Reference Case assumes that 50% of the reactors will have their respective operating licenses renewed for 20 years past the 40-year period for nominal operation.

Detailed information about reactors already built, being built, or planned in the United States for domestic use or export as of December 31, 1992, is provided in report DOE/OSTI-8200-R56 (ref. 12). That document contains a comprehensive listing of all domestic reactors categorized by primary function or purpose: viz., civilian, production, military, export, and critical assembly.

The data for total waste inventories (which comprise historical data) are obviously less accurate than the values recorded for recent waste additions. The number of digits used in reporting these values is generally greater than justified in terms of numerical significance, but this proves useful and necessary for bookkeeping purposes. In some cases, the values cited are significantly different from those previously reported. This is generally a result of improved estimates, new measurements, or redefinition of terms. Explanations are given in such cases. Many of the comments received during the final review stage of this report deal with changes that have occurred after December 31, 1992—some as recently as February 1994. These changes are generally cited in footnotes.

For the sake of brevity, many of the figures and tables of this report use the exponential (E) notation. As examples of this notation, the constant 1.234E+2 means 1.234×10^2, or 123.4; and 1.234E−4 means 1.234×10^{-4}, which is 0.0001234.

0.4 WASTE CHARACTERISTICS AND UNITS REPORTED

Principal characteristics reported for most radioactive wastes discussed in this report include volume, radioactivity, and thermal power. All characteristics are reported in metric units and, depending on the waste form, can be significant considerations in meeting the requirements for waste treatment, storage, and disposal. Waste volume is reported in cubic meters (m^3) and generally reflects the amount of space occupied by the waste and its container. Radioactivity represents the rate of spontaneous disintegration of the radionuclides comprising the waste. In this report, radioactivity is measured by a unit called a curie (Ci), which is 3.7×10^{10} nuclear disintegrations per second. Over time, radionuclides decay to nonradioactive, stable isotopes. As an example, the short-lived radionuclides found in spent nuclear fuel rapidly decay during the first few years after the fuel is removed from a reactor.

It should be noted that while waste volumes accumulate with time by conventional addition, total radioactivity does not. Because of radioactive decay, cumulative activity cannot be based on reported annual additions; rather it must be estimated from knowledge of the waste composition, which includes the radionuclides comprising the waste, their concentrations, and decay attributes (e.g., half-lives and decay schemes). In this report, decayed radioactivity is generally estimated for various wastes by an abridged version of the ORIGEN2 code (ref. 13).

Thermal power is a measure of the rate of heat-energy emission resulting from the decay of radionuclides in a waste. Like radioactivity, thermal power is not cumulative by conventional addition because of radioactive decay. Information on thermal power is needed in the design of shipping casks, storage facilities, and repositories where temperature rise, especially with regard to spent fuel and HLW, is an important concern. Thermal energy generation rates are highest for spent fuel, HLW, and remote-handled TRU waste. They may also be important for certain types of LLW. The unit of thermal power used in this report is the watt (W), which represents 1 joule of thermal energy emitted per second. Estimates of thermal power are based on radionuclide composition as well as total activity. While levels of thermal power may not be significant for certain waste forms (particularly some types of LLW), they are nevertheless reported for the major radioactive waste categories referenced in this report to provide a standard for comparison.

For spent fuel and TRU waste, mass is reported to provide better assurances of accountability. Spent fuel is reported in units of metric tons of *initial* heavy metal (MTIHM) to avoid difficulties and confusion arising from the need to estimate ranges of varied heavy-metal content (MTHM) that result from different levels of enrichment and reactor fuel burnup. Mass is reported in kilograms (kg) for the TRU radionuclides comprising TRU wastes.

In this report, quantities of generated wastes are expressed in terms of either the amount of mass (kg) or volume (m^3) produced in a given calendar year. Thus, generation rates for wastes are expressed in either kilograms per year (kg/year) or cubic meters per year (m^3/year), depending on the availability of site information. Annual generation rates are reported in this document for spent fuel, TRU waste, LLW, and mixed LLW. Annual

generation rates are not reported for HLW in part because of security restrictions for the DOE nuclear weapon production activities that produce these wastes. Additionally, there are problems in accurately estimating HLW generation levels. One major difficulty is accounting for net waste-quantity changes due to the combined effects of various modes of site waste management operations such as evaporation and calcination.

Quantities of wastes can also be reported in terms of the number and types of waste containers. LWR spent-fuel inventories and projections can be expressed in terms of the number of permanently discharged boiling-water reactor (BWR) and pressurized-water reactor (PWR) fuel assemblies. HLW will be immobilized in either borosilicate glass or a glass/ceramic matrix solidified in stainless steel canisters. Estimates of the quantities of HLW to be disposed of in a geologic repository are based on the number and types of these canisters. Quantities of LLW and stored TRU waste can be based on the number and types of drums, boxes, or containers used or scheduled for use.

Waste characteristics are also identified by waste composition. Throughout this report, waste composition is expressed in terms of the following:

- radioactivity (Ci) or specific-activity (Ci/m^3) breakdown by radionuclide (with accompanying daughter products) and
- physical form (solid, liquid, gas, or sludge) or chemical content (by chemical component), expressed in terms of either volume (m^3) or mass (kg) or as a percentage of total weight (wt %), volume (vol %), or activity (act %).

This annual report also provides some information on the status of land usage at LLW burial and disposal sites. Such information includes total site area, estimated total usable land area, and estimated area currently utilized. To conform with the metric unit format used in this report, these land-usage-area parameters are reported in units of hectares, where 1 hectare (ha) = 10,000 m^2, or 2.4710 acres.

0.5 SUMMARY DATA AND CHAPTER OVERVIEWS

A few graphical presentations and summary tables are included in this chapter to provide a broad overview. Figures 0.1 and 0.2, respectively, show the volumes and radioactivities of commercial and DOE wastes and spent fuel accumulated through 1992.

Summaries of spent-fuel and radioactive waste inventories and projections are provided in Tables 0.2 and 0.3. In general, material to be sent to R&D facilities or to the proposed national geologic repository for spent fuel and HLW is still listed in each individual site's inventory.

A brief summary of each chapter in this report is presented in the following paragraphs.

0.5.1 Spent Fuel

Chapter 1 of this report presents national data on the quantities of permanently discharged spent fuel from commercial nuclear power reactors. Historical data on commercial spent-fuel inventories[14] are reported along with two sets of DOE/EIA projections,[11] the No New Orders and Lower Reference cases. The No New Orders Case (without reactor license renewal) is the baseline commercial scenario used throughout this report to make waste projections. In contrast, the Lower Reference Case (with reactor license renewal) is used in this report to represent a conservative upper limit of spent-fuel projections. For the projection period considered in this report (CYs 1993–2030), the No New Orders Case assumes that no new reactors will be ordered.

DOE spent-fuel inventories that are not scheduled for reprocessing are reported in Chapter 1 and Appendix A. These include various types of research reactor spent fuels which are stored at the SRS and the INEL.

In this report, the mass of discharged spent fuel is measured in MTIHM. The term "initial heavy metal" refers to the original mass of the actinide elements of the fuel, most of which is uranium. (Elements of the actinide group are those with atomic numbers greater than 89.)

0.5.2 HLW

The inventories of HLW in storage at the end of CY 1992 and projected through CY 2030 are given in Chapter 2. The waste forms include liquid, sludge, salt cake, slurry, calcine, precipitate, zeolite, glass, and capsules of separated strontium and cesium. Vitrified defense HLW is projected after the startup of the Defense Waste Processing Facility (DWPF) at SRS in 1996, and projections of vitrified HLW from commercial reprocessing activities are given for the WVDP. Projections recently made of the number of canisters containing the final immobilized form for the DOE HLW at HANF and the INEL are also reported. In addition, Chapter 2 gives the locations, volumes, and radioactivities of HLW.

In 1992, DOE decided to phase out the reprocessing of its production reactor spent fuels. Until then, the reprocessing activities recovered enriched uranium and plutonium which were used to support nuclear weapons production. As a consequence of ceasing to reprocess reactor spent fuels, little additional HLW is expected to be generated at DOE sites in the future. However, DOE site D&D activities may generate some wastes with radioactivity levels high enough to require disposal in a deeply mined geologic repository.

0.5.3 TRU Waste

The locations, inventories, and projections of TRU waste buried and stored at DOE sites are presented in Chapter 3. Current inventories of TRU waste are virtually all derived from government operations. The inventories documented in this report are based on data provided by the sites and include waste volumes and the masses and radioactivities of contained radionuclides. Projected future TRU waste volumes through CY 2020 were also requested from the sites, but the sites were not able to make such estimates in all cases. Projections are reported through CY 2020 for those sites that provided estimates.

In 1984, DOE (with input from other federal agencies) revised the minimum radioactivity concentration level for defining TRU waste from greater than 10 nCi/g to greater than 100 nCi/g.[15] Consequently, the waste currently in the inventory contains wastes stored under both criteria. This redefinition, as well as the development of instrumentation to detect these low levels of radioactivity, will reduce the volume of TRU waste. As the waste is assayed, that portion of it which is greater than 10 nCi/g and less than 100 nCi/g will be reclassified to other waste categories.

0.5.4 LLW

Data for LLW from commercial and government activities are given in Chapter 4 and Appendix A. Commercial fuel-cycle LLW is generated from the conversion of yellowcake to uranium hexafluoride (UF_6), enrichment, fuel fabrication, and reactor operation. LLW also results from commercial operations by private organizations that are licensed to use radioactive materials. These include institutions and industries engaged in research and various medical and industrial activities. DOE LLW is similar in nature to the commercial I/I waste and the commercial fuel cycle LLW.

A wide variety of radionuclides are found in LLW. Uranium isotopes and their daughters dominate in the conversion, enrichment, and fuel-fabrication steps of the nuclear fuel cycle. Reactor operations produce LLW containing mostly activation products and fission products. A significant fraction of institutional LLW that is shipped to disposal sites is contaminated with small quantities of ^{3}H and ^{14}C.

By the end of 1992, approximately 66% of the total cumulative volume of disposed LLW resulted from various DOE activities. The remaining 34% resulted from domestic commercial activities. About 54% of the volume of LLW disposed during 1992 resulted from commercial activities.

0.5.5 Commercial Uranium Mill Tailings

Current inventories and projections of tailings from commercial uranium mill operations are summarized in Chapter 5. Twenty-six licensed uranium mills have accumulated tailings from their operations. Half of these mills have accumulated both commercial and government tailings. By the end of 1992, only two of the NRC-licensed mills were still active. To date, almost all domestic uranium has been produced by conventional mining and milling methods from which these tailings derive. A small portion has been obtained via in situ leaching, recovery from mine water, recovery from copper/vanadium dump leach liquor, and recovery from wet-process phosphoric acid effluents. Projections of uranium mill tailings are based on commercial fuel-cycle requirements, adjusted for foreign imports, as specified by the DOE/EIA Lower Reference Case projection of commercial reactor power growth. Tailings from the now inactive mills that produced uranium only for government operations are classified as environmental restoration wastes (see Chapter 6).

0.5.6 Environmental Restoration Wastes

The DOE Assistant Secretary for Environmental Restoration and Waste Management (DOE/EM) oversees the assessment and remediation (environmental restoration) of contaminated inactive facilities at all DOE sites and some non-DOE sites for which DOE has responsibility. Recently, the Office of Environmental Restoration and Waste Management was renamed the Office of Environmental Management. This modification will be incorporated in other sections in future updates of this document.

An overview of DOE environmental restoration projects and activities is given below. Further details are provided in Chapter 6. The scope of Chapter 6 is limited to radioactive and mixed (radioactive and chemically hazardous) wastes that could be generated by environmental restoration activities. Nonradioactive hazardous and sanitary wastes are outside the scope of this report.

The major objective for DOE environmental restoration activities is to ensure that risks to the environment and to human health and safety posed by inactive and surplus facilities and sites contaminated by radioactive and chemically hazardous materials are either eliminated or reduced to prescribed, safe levels. Projects within the Office of Environmental Restoration (EM-40) are comprised of remedial action (RA) and D&D activities. RA involves the assessment and cleanup of inactive sites and deals mainly with contaminated environmental media

such as soil, sediment, and ground water. D&D activities are primarily concerned with the safe caretaking of surplus nuclear facilities following shutdown and for either their ensuing decontamination for reuse or their complete dismantlement. About 500 contaminated facilities are currently included under the EM-40 D&D Program. Activities associated with environmental restoration projects are found in 31 states.

DOE EM-40 is currently undertaking a major initiative to determine the volumes and types of waste that may be generated during future environmental restoration activities. These studies have not yet reached the point at which realistic waste projections can be made. Results from these studies should be available within the next few years. For this reason, inventories and projections for actual environmental restoration wastes are not provided in this report. However, the volumes of contaminated solid media, such as soils and debris from which environmental restoration wastes will be generated, are known to a reasonable degree at many EM-40 project sites. Estimates of the volumes of such contaminated media are reported in Chapter 6.

0.5.7 Commercial Decommissioning Wastes

Chapter 7 presents waste projections for the decommissioning of commercial power reactors and fuel cycle facilities. The D&D activities at such installations may result in very large volumes of LLW, depending on the methods selected. The major LLW volumes will result from the decommissioning of power reactors, which will also produce a small volume of high-activity waste. Unlike that for other waste generation activities, the timing of decommissioning operations is very uncertain, since facilities may be either decommissioned upon shutdown or put into a mothballed or protective storage condition to allow for sufficient radioactive decay before decommissioning. Chapter 7 reports a set of projected characteristics for wastes from commercial LWR decommissioning activities. These projections are based on the assumption that each power reactor is decommissioned soon after it is shut down. To date, only a few commercial reactors have been fully decommissioned, and several have been placed in protective storage. Wastes from completed decommissioning actions have been included with existing inventories discussed in other chapters. Because of timing uncertainties, projected commercial decommissioning wastes are not included in the projections of LLW (Chapter 4). Rather, commercial decommissioning waste projections are reported separately in Chapter 7.

0.5.8 Miscellaneous Radioactive Materials

Inventories and characteristics of miscellaneous radioactive materials are reported in Appendix A. Such materials consist mainly of permanently discharged or damaged spent fuel (pellets, rods, and other fuel-assembly components) from civilian and government-sponsored experimental nuclear programs.

0.5.9 Mixed LLW

Current inventories and generation rates of mixed LLW from both DOE and commercial sources are summarized in Chapter 8. These wastes are contaminated with both low-level radioactivity and chemically hazardous substances. The radioactive components are defined by the Atomic Energy Act of 1954 (AEA),[15] while the hazardous components are defined by the RCRA,[6] the TSCA,[7] and pertinent state regulations. As of the end of 1992, inventories of mixed LLW at DOE sites totaled about 182,400 m^3. It is estimated that about 60,000 m^3 of additional mixed LLW will be generated during the period 1993–1997.

0.5.10 Appendixes

In addition to Appendix A, which documents miscellaneous radioactive materials that may possibly require repository disposal, several other appendixes are included in this report. A tabulation of the properties of important radionuclides is given in Appendix B. Appendix C is a compilation of waste flowsheets, source terms, and characteristics used for waste projections. Source terms include both quantitative and descriptive characteristics used to describe radioactive wastes. As developed and used in the IDB Program, the source term for a particular waste is comprised of two components unique to that waste: (1) the number of curies of radioactivity, expressed either per unit of facility production or per unit of waste volume or mass, and (2) a listing of the relative contributions of component radioisotopes per curie of radioactivity of the waste. Appendix D lists the sites and facilities referred to in this report, and Appendix E describes a reader comment form, which is provided at the end of this report.

0.6 REFERENCES

1. 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, Oak Ridge, Tennessee (October 1992).

2. U.S. Congress, Nuclear Waste Policy Act of 1982, Pub. L. 97–425, Jan. 7, 1983, as amended by the Budget Reconciliation Act for Fiscal Year 1988, Title V—Energy and Environment Programs, Pub. L. 100–203, Dec. 22, 1987.

3. U.S. Environmental Protection Agency, "Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," *Code of Federal Regulations*, 40 CFR Part 191 (1985).

4. U.S. Department of Energy, DOE Order 5820.2A, *Radioactive Waste Management*, Washington, D.C., Sept. 26, 1988.

5. U.S. Congress, The Low-Level Radioactive Waste Policy Amendments Act of 1985, Pub. L. 99–240, Jan. 15, 1986.

6. U.S. Congress, Atomic Energy Act of 1954, Pub. L. 83–703, Aug. 15, 1954.

7. U.S. Congress, Resource Conservation and Recovery Act of 1976, Pub. L. 94–580, Oct. 21, 1976, as amended by the Hazardous and Solid Waste Amendments Acts of 1984, Pub. L. 98–616, Nov. 9, 1984.

8. U.S. Congress, Toxic Substances Control Act of 1976, Pub. L. 94–469, Oct. 11, 1976.

9. U.S. Nuclear Regulatory Commission, "Licensing Requirements for Land Disposal of Radioactive Waste—Waste Classification," *Code of Federal Regulations*, 10 CFR Part 61, Sect. 61.55 (1982).

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11. U.S. Department of Energy, Energy Information Administration, *World Nuclear Capacity and Fuel Cycle Requirements 1993*, DOE/EIA-0436(93), Washington, D.C. (November 1993).

12. U.S. Department of Energy, Office of Scientific and Technical Information, *Nuclear Reactors Built, Being Built, or Planned: 1992*, DOE/OSTI-8200-R56, Oak Ridge, Tennessee (August 1993).

13. A. G. Croff, *ORIGEN2—A Revised and Updated Version of the Oak Ridge Isotope Generation and Depletion Code*, ORNL-5621, Oak Ridge National Laboratory, Oak Ridge, Tennessee (July 1980).

14. U.S. Department of Energy, Energy Information Administration, Nuclear Fuel Data Form RW-859 (data as of Dec. 31, 1992), Washington, D.C.

15. U.S. Department of Energy, DOE Order 5820.2, *Radioactive Waste Management*, Washington, D.C., Feb. 6, 1984 (updated by DOE Order 5820.2A, ref. 4).

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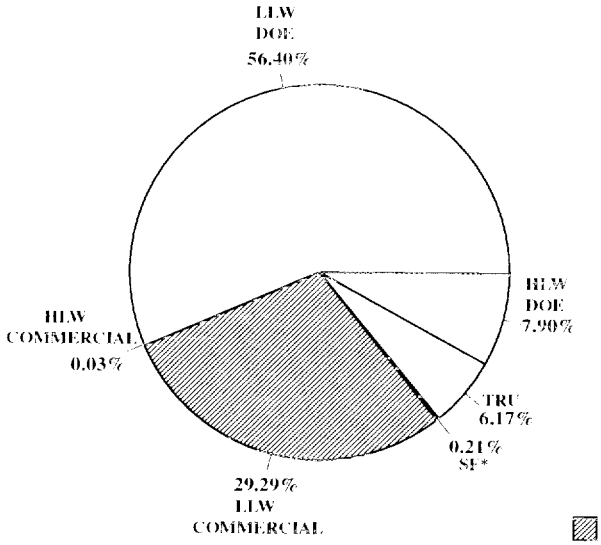


SITE	CUBIC METERS
HLW	
A) Commercial	1.550E+03
B) DOE	3.968E+05
Total HLW	3.984E+05
LLW	
A) Commercial	1.472E+06
B) DOE	2.835E+06
Total LLW	4.307E+06
TRU Waste	3.104E+05
SF*	1.045E+04
TOTAL	5.026E+06

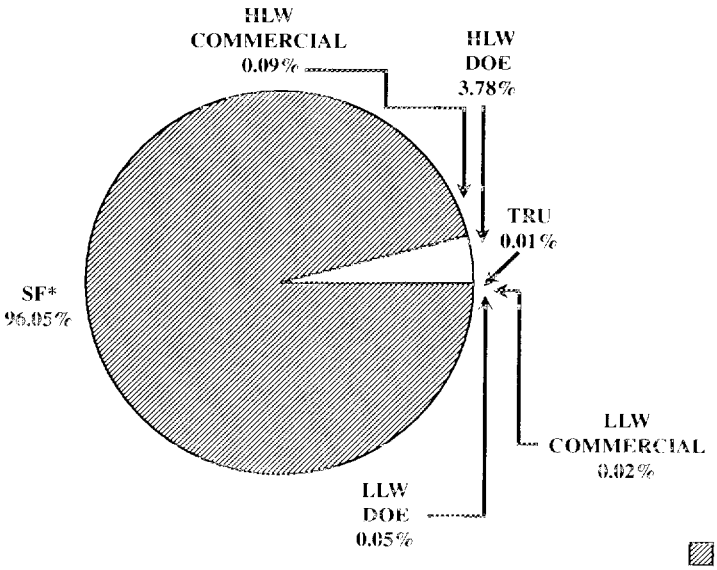
COMMERCIAL

DOE

*Commercial LWR spent fuel permanently discharged.
Includes spacing between fuel assembly rods.

Fig. 0.1. Total volumes of commercial and DOE wastes and spent fuel through 1992.

ORNL DWG 94-6689



SITE	CURIES
HLW	
A) Commercial	2.590E+07
B) DOE	1.038E+09
Total HLW	1.064E+09
LLW	
A) Commercial	5.708E+06
B) DOE	1.241E+07
Total LLW	1.812E+07
TRU Waste	2.591E+06
SF*	2.641E+10
TOTAL	2.749E+10

COMMERCIAL

DOE

*Commercial LWR spent fuel permanently discharged.

Fig. 0.2. Total radioactivities of commercial and DOE wastes and spent fuel through 1992.

Table 0.1. Major assumptions used in this report

Inventory/projection basis

- Inventories are reported for December 31, 1992
- Projections are made for the CYs 1993-2030

HLW solidification activities

- For WVDP, HLW solidification (glass production) starts in 1996 and is completed in 1998
- For SRS, HLW solidification [glass production at the Defense Waste Processing Facility (DWPF)] starts in 1996 and continues through 2015
- For INEL, HLW solidification (immobilization) starts in 2007 and continues through 2030
- For HANF, HLW solidification (borosilicate glass production at the Hanford Waste Vitrification Plant) starts in 2000 and continues through 2030

Commercial activities

- DOE/EIA projections of installed net LWR electrical capacity for the No New Orders[a] and Lower Reference cases of ref. 9:

No New Orders Case

Year	1993	1995	2000	2005	2010	2015	2020	2025	2030
GW(e)	99	100	101	102	88	64	49	24	5

Lower Reference Case

Year	1993	1995	2000	2005	2010	2015	2020	2025	2030
GW(e)	99	100	101	104	102	108	113	116	119

- DOE/EIA assumptions for LWR fuel enrichment and burnup:

LWR fuel	CYs fuel is loaded	Fuel enrichment (% ^{235}U)	Design burnup (MWd/MTIHM)
BWR	1993-1994	3.016	33,000
	1995-2001	3.193	36,000
	2002-2010	3.320	39,000
	2011-2030	3.554	43,000
PWR	1993-1997	3.775	42,000
	1998-2003	4.009	46,000
	2004-2006	4.319	50,000
	2007-2030	4.695	55,000

- Spent fuel from commercial reactors is not reprocessed. Thus, a fuel cycle without reprocessing is assumed for all commercial projections

[a]This case assumes that each reactor will be retired when the expiration date specified in its operating license is reached.

Table 0.2. Spent fuel and radioactive waste inventories as of December 31, 1992

Waste category	TRU isotopes (kg)	Mass (MTIHM)	Volume (m^3)	Activity[a] (10^6 Ci)	Thermal power (10^3 W)
Spent fuel					
Commercial					
BWRs		9,547	3,849[b]	7,037	25,900
PWRs		16,375	6,601[b]	19,374	74,300
DOE		>123.5	c	c	c
High-level waste					
Savannah River (DOE)			126,900	632.4	1,724
Idaho (DOE)			11,200	44.9	130
Hanford (DOE)[d]			258,700	360.7	1,041
West Valley (commercial)			1,550	25.9	79
Transuranic waste (DOE)					
Buried TRU waste	>352		204,438	>0.73	>5.2
Potentially contaminated soil	d		>32,000	>0.08	d
Stored TRU waste	2,975		105,948	1.86	33.9
Low-level waste					
DOE sites					
Generated			37,244	c	c
Stored			115,040	c	c
Disposed			2,834,878	12.4	17.4
Commercial sites					
Disposed			1,472,129	5.7	21.1
Uranium mill tailings (commercial)					
Licensed mill sites[e]			118,600,000	c	c
Environmental restoration program wastes (DOE)[f]			c	c	c
Commercial reactor decommissioning			g	g	g
Miscellaneous radioactive materials		243.2	c	c	c
Mixed LLW					
DOE		203,588[h]	182,372	c	c
Commercial		c	c	c	c

[a]Activity data are calculated decayed values as of December 31, 1992.

[b]Includes volume of spacing between the fuel rods of each assembly.

[c]Information not available.

[d]Hanford tank wastes consist of HLW, TRU waste, and LLW. However, in the interim storage mode, the tank wastes are managed as if they contain HLW and, therefore, are included in the HLW inventory.

[e]Includes contributions from 26 NRC-licensed mills.

[f]Information currently not available. DOE is undertaking several initiatives to determine the volumes and types of wastes currently in storage at environmental restoration sites and those which may be generated during future remediation activities across the entire DOE complex. This information, which should become known in a few years, will be included when available in future revisions of this report.

[g]Most of this activity has involved small test reactors. (Exceptions are the Shippingport and Three Mile Island-Unit 2 reactor facilities, whose inventories are reported in Chapter 7.) The LLW collected to date from such small reactors is included in the LLW inventories listed above.

[h]Mass of mixed LLW is expressed in metric tons (t) and includes other elements in addition to heavy metals.

Table 0.3. Current and projected cumulative quantities of radioactive waste and spent fuel

[Quantities are expressed as volume (10^3 m^3) unless otherwise indicated]

Source and type of material	End of calendar year				
	1992	2000	2010	2020	2030
DOE					
HLW					
Interim storage	397	342	318	302	301
Glass or glass/ceramic[a]	0	0.44	3.19	14.6	40.2
TRU[b]					
Buried	204	204	204	204	204
Stored	106	c	c	c	c
LLW (buried)[d]	2,835	3,763	4,645	5,432	5,945
Environmental restoration program wastes[e]	c	c	c	c	c
Mixed LLW	182.4	c	c	c	c
Miscellaneous radioactive materials, mass, MTIHM	243.2	c	c	c	c
Commercial					
LWR spent fuel, mass, MTIHM[f] (no reprocessing)					
No New Orders Case	25,922	42,100	61,700	76,700	84,300
Lower Reference Case	25,922	42,100	61,300	81,600	103,000
HLW (WVDP)					
Interim storage	1.550	0.0	0.0	0.0	0.0
Glass	0.0	0.24	0.24	0.24	0.24
LLW (no reprocessing)	1,472	c	c	c	c
D&D (LLW)[g]					
Classes A, B, and C LLW	--	0.00	25.86	628.21	1,239.65
Greater-than-Class-C LLW	--	0.00	0.01	0.22	0.44
Mill tailings (no reprocessing)	118,600	118,800	c	c	c
Mixed LLW	c	c	c	c	c

[a]Includes projections for glass at SRS and glass/ceramic at ICPP.

[b]Inventories and projections are updated mainly as a result of improvements in detection methods.

[c]Information not available.

[d]Projections include contributions from SRS saltstone.

[e]Information currently not available. DOE is undertaking several initiatives to determine the volumes and types of wastes currently in storage at environmental restoration sites and those which may be generated during future remediation activities across the entire DOE complex. This information, which should become know in a few years, will be included when available in future revisions of this report.

[f]Historically, spent fuel has been measured in units of mass (MTIHM) rather than units of volume. The 1992 discharged spent fuel mass is a BWR and PWR mass sum rounded to the nearest metric ton. Such rounding may result in slight differences between the spent fuel inventories and projections reported in this document and those reported by DOE/EIA.

[g]Projected D&D wastes from light-water reactors shut down after 1992. Wastes collected from historical D&D of reactors are included in the LLW inventories listed above.

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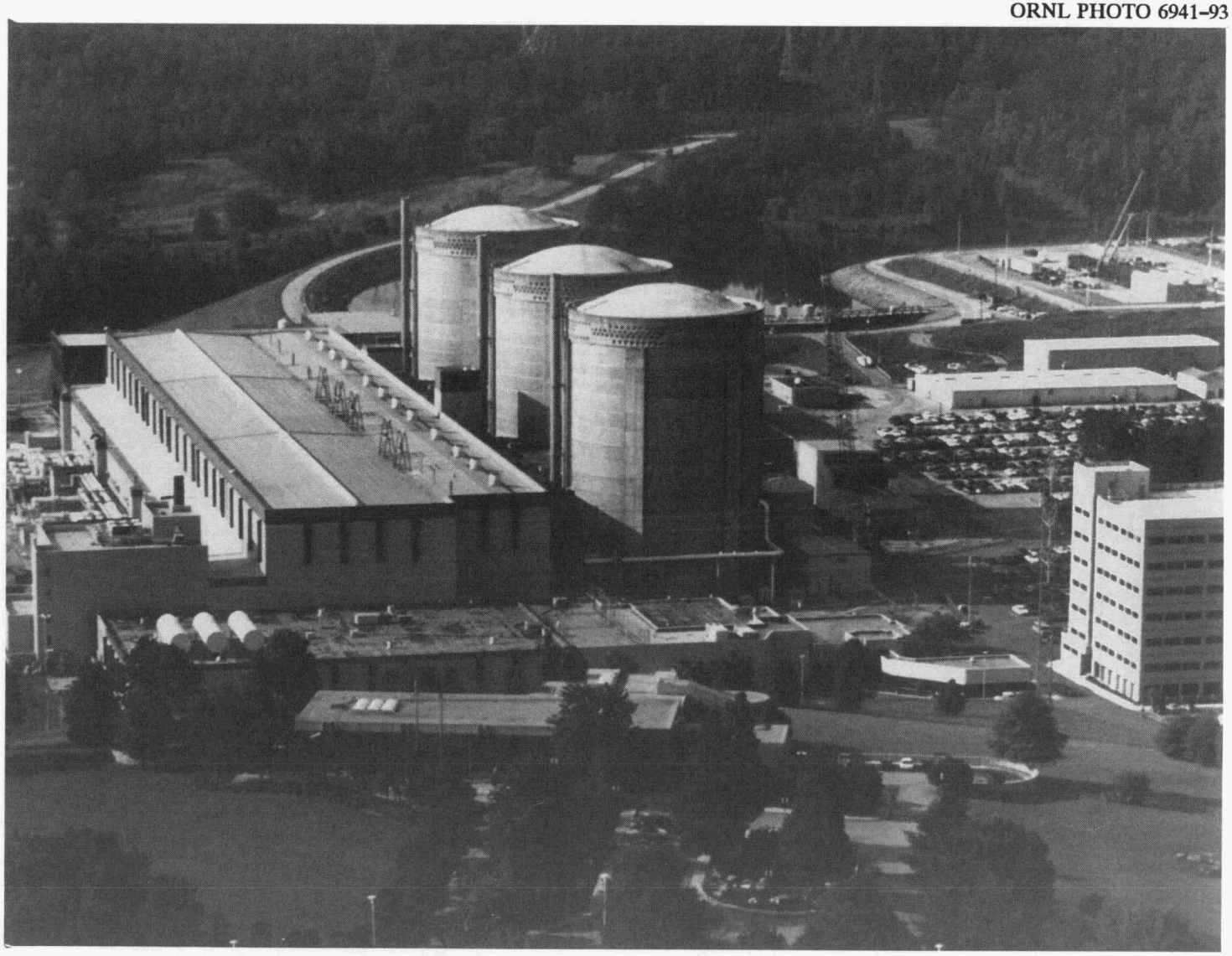

The Oconee Nuclear Power Station, three 846-MW(e) pressurized-water reactors, located in Seneca, South Carolina. (Courtesy of the Duke Power Company, Seneca, South Carolina.)

1. SPENT FUEL

1.1 INTRODUCTION

This chapter reports the quantities and characteristics of spent fuel that has been permanently discharged from commercial LWRs and one-of-a-kind reactors. In addition, this chapter contains a mass summary report of DOE spent fuel which is not scheduled for reprocessing. Though currently in storage at numerous commercial and DOE sites, this fuel in its entirety ultimately will require geologic disposal.

For inventories of special fuels (from DOE/civilian development programs) stored at various DOE and commercial sites as of December 31, 1992, the reader is referred to Sect. 1.4 and Appendix A. Though now in storage at the locations cited in Sect. 1.4 and Appendix A, these special fuels also may possibly require geologic disposal.

Some commercial spent fuel in inventory will be reinserted into reactors for further irradiation. However, this amount is relatively small, and the schedules for reinsertion are not always predictable. Therefore, for the purposes of this report, all spent fuel is considered permanently discharged from the reactors.

Historical inventories of LWR spent fuel have been updated through December 31, 1992.[1] The data reported in this chapter include the inventories of spent fuel stored at the WVDP, the MFRP, and the INEL sites in addition to those stored at the various reactor sites. The map in Fig. 1.1 shows the locations of existing and planned power reactor sites and commercial LWR spent fuel storage facilities. A list of commercial reactors is given also in report DOE/OSTI-8200-R56 (ref. 2).

Projections of nuclear capacity and spent fuel discharges are given for the years 1993–2030 for two forecast schedules, the DOE/EIA No-New-Orders-Case and the DOE/EIA Lower-Reference-Case forecasts, reported in ref. 3. The No-New-Orders-Case forecast projects installed capacity to increase from 98.9 GW(e) at the end of 1992 to 101.3 GW(e) by the year 2000, ultimately decreasing to 4.7 GW(e) by 2030. The Lower-Reference-Case forecast predicts that the installed U.S. commercial nuclear electrical generating capacity will increase from 98.9 GW(e) at the end of 1992 to 101.3 GW(e) by 2000 and to 118.8 GW(e) by 2030.

The reference scenarios considered for projecting accumulated spent fuel assume a fuel cycle with no reprocessing. Commercial spent fuel projections developed for the DOE/EIA No New Orders Case and the DOE/EIA Lower Reference Case are illustrated, along with historical discharge data, in Figs. 1.2–1.5. Spent fuel discharge projections for both schedules, in terms of annual mass discharged and accumulated radioactivity, are graphically illustrated in Figs. 1.2 and 1.3, respectively. A graph showing the increase in the cumulative mass of discharged spent fuel for the DOE/EIA No New Orders Case is shown in Fig. 1.4. This plot also shows both the age and mass distribution for spent fuel from 1970 to 2030. Figure 1.5 is a similar plot showing the increase in the cumulative mass of discharged spent fuel for the DOE/EIA Lower Reference Case.

DOE/EIA projections for both the No New Orders Case and the Lower Reference Case assume that burnup levels of discharged spent fuel will increase from their current average levels of 28,806 and 36,446 MWd/MTIHM for BWR and PWR fuel, respectively, at the rate of about 0.6% per year for BWR fuel and about 1.5% per year for PWR fuel. This increase in burnup is projected to occur from 1992 to approximately 2022 for BWR fuel and from 1992 to 2013 for PWR fuel, at which times the equilibrium cycle discharges will level out at values of roughly 42,000 and 53,000 MWd/MTIHM[3] for BWR and PWR fuel, respectively. The final cycle discharges will be somewhat lower because most of the final cycle cores will not have achieved the projected design burnups. Figure 1.6 graphically illustrates how the activity and thermal power of BWR and PWR spent fuels vary with burnup and time from discharge.[4]

1.2 COMMERCIAL SPENT FUEL

1.2.1 Inventories and projections

The total inventory of commercial LWR spent fuel in storage at the WVDP site, the MFRP, INEL, and the reactor sites as of December 31, 1992, amounted to 25,922 MTIHM. Of this total amount, 27 MTIHM are in

storage at the WVDP site,[5] 674 MTIHM are in storage at the MFRP,[1] and 43 MTIHM are in storage at INEL.[1] The remainder is stored at the reactor sites. These inventories do not include the spent fuel reprocessed at the WVDP site when the facility was operated as a fuel reprocessing plant. Additional information on WVDP spent fuel inventories is given in Chapter 7, Table 7.9. Details concerning the spent fuel reprocessed at West Valley may be obtained from ref. 6.

A BWR/PWR breakdown of the electric power generating capacity for both the No-New-Orders-Case and the Lower-Reference-Case forecasts is given in Table 1.1, along with historical reactor capacity data. Table 1.2 gives the projected cumulative mass of commercial spent fuel discharges associated with the DOE/EIA capacity-growth scenarios of Table 1.1. The historical and projected buildups of permanently discharged BWR and PWR spent fuel mass, radioactivity, and thermal power are given for the DOE/EIA No New Orders Case in Table 1.3 and for the DOE/EIA Lower Reference Case in Table 1.4. Projections of the number of permanently discharged BWR and PWR spent fuel assemblies for the DOE/EIA No New Orders Case and Lower Reference Case are given in Tables 1.5 and 1.6, respectively.

The historical and projected mass of spent fuel discharged from a one-of-a-kind reactor, the Fort St. Vrain HTGR,[7] is given in Table 1.7. All of the discharged fuel from the Fort St. Vrain reactor that has been shipped off-site is located at the ICPP (see Table A.6 in Appendix A). The Fort St. Vrain reactor was permanently shut down in 1989.

1.2.2 Characterization

Reference characteristics of BWR and PWR fuel assemblies, obtained from refs. 8 and 9, were used for this report. These characteristics are summarized in Table 1.8. Fuel assembly structural material masses and compositions, nonactinide fuel impurities, and other physical and irradiation characteristics of LWR spent fuel are discussed in ref. 10. More detailed information on spent fuel characteristics may be found in ref. 11. The BWR and PWR spent fuel annually discharged has a broad range of burnup levels, as illustrated in Tables 1.9 and 1.10, respectively. The mass, radioactivity, and thermal power of the nuclides contained in all stored domestic commercial LWR spent fuel as of December 31, 1992, are listed in Table C.2 in Appendix C.

1.3 DISPOSAL

Surface-based studies for the determination of the suitability of Yucca Mountain, Nevada, as a geologic repository continued. In addition, in April 1993, construction of the Exploratory Studies Facility was begun. Completion, by drilling and blasting, of the first 5000-ft section of tunnel is expected by the end of 1994. In May 1993, DOE awarded a contract for the 25-ft-diam tunnel boring machine, which is expected to begin the next sections of tunnel in the spring of 1994.

The Multi-Purpose Canister Implementation Program Conceptual Design Phase Report was published in September 1993.

1.4 DOE SPENT FUEL

Summary characteristics of current DOE spent fuel inventories not scheduled for reprocessing are given in Table 1.11 (based on refs. 12–19). Projected ten-year inventory increases reported by a few sites to the DOE Office of Spent Fuel Management and Special Projects (DOE/EM-37) are reported in Table 1.12 (based on ref. 12).

For purposes of clarification, the quantities of spent fuel reported in Tables 1.11 and 1.12 include contributions from other fuels besides those permanently discharged from production reactors. Spent fuels reported in these tables also include DOE-owned nuclear fuel that has been withdrawn from or resides for storage in a nuclear reactor following irradiation, the constituent elements of which have not been separated by processing. In addition to intact fuel, reactor-irradiated fuel materials requiring special handling (e.g., defective fuel and special fuel forms) are also considered spent fuel and are eligible for inclusion in Tables 1.11 and 1.12. These tables also list some commercially generated fuels and fuels from foreign reactors and university research reactors which are stored at DOE sites. More detailed information on these special fuels will be included in future updates of this report.

1.5 REFERENCES

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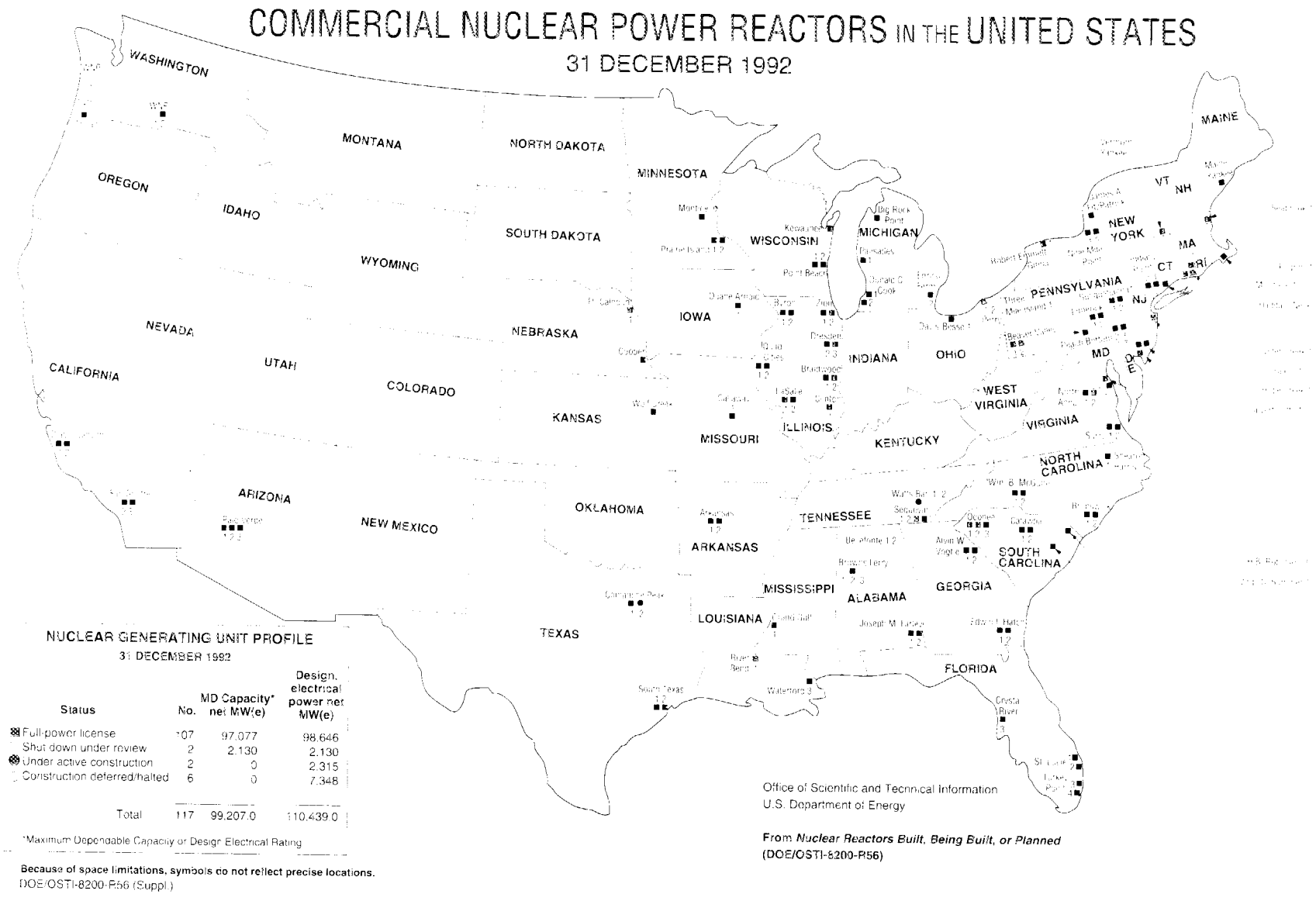

NUCLEAR GENERATING UNIT PROFILE
31 DECEMBER 1992

Status	No.	MD Capacity* net MW(e)	Design, electrical power net MW(e)
Full-power license	107	97,077	98,646
Shut down under review	2	2,130	2,130
Under active construction	2	0	2,315
Construction deferred/halted	6	0	7,348
Total	117	99,207.0	110,439.0

*Maximum Dependable Capacity or Design Electrical Rating

Because of space limitations, symbols do not reflect precise locations.
DOE/OSTI-8200-R56 (Suppl.)

Fig. 1.1. Locations of existing and planned commercial reactors as of December 31, 1992. (Courtesy of U.S. Department of Energy, Office of Scientific and Technical Information, Oak Ridge, Tennessee.)

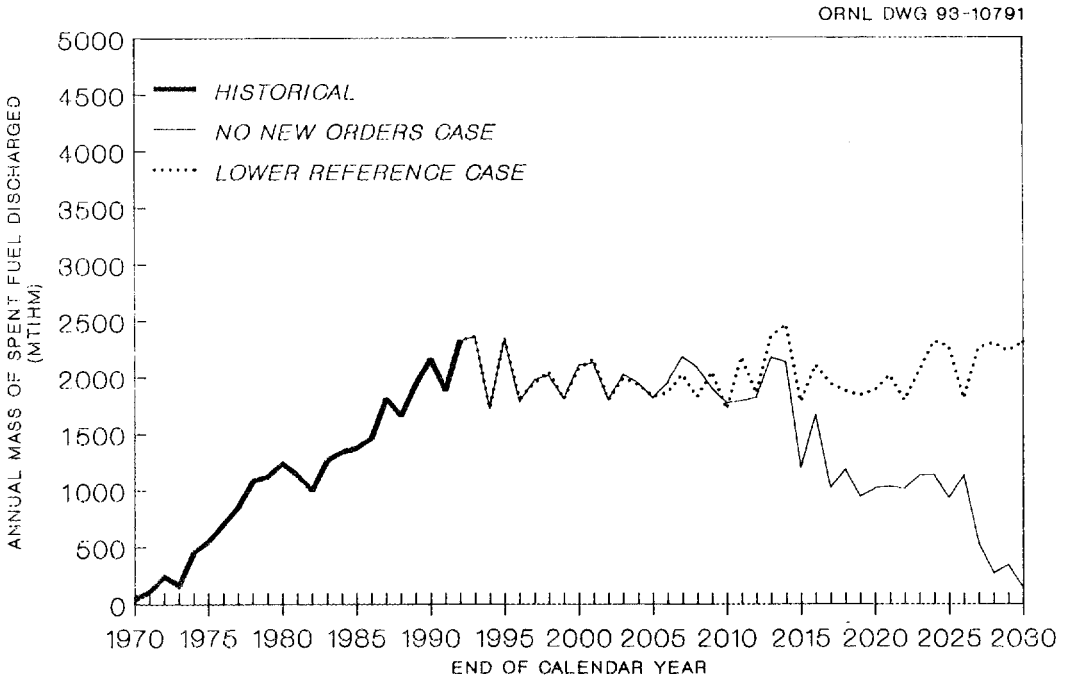

Fig. 1.2. Projected mass (MTIHM) of annual commercial spent fuel discharges for the DOE/EIA No New Orders and Lower Reference cases.

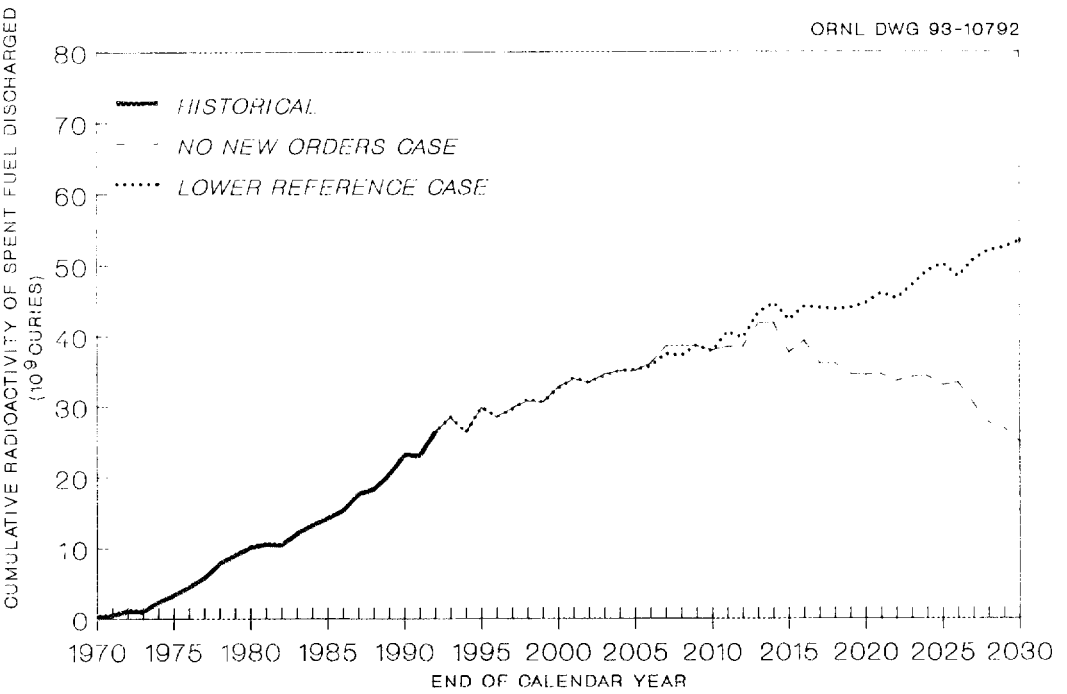

Fig. 1.3. Projected cumulative radioactivity of commercial spent fuel discharges for the DOE/EIA No New Orders and Lower Reference cases.

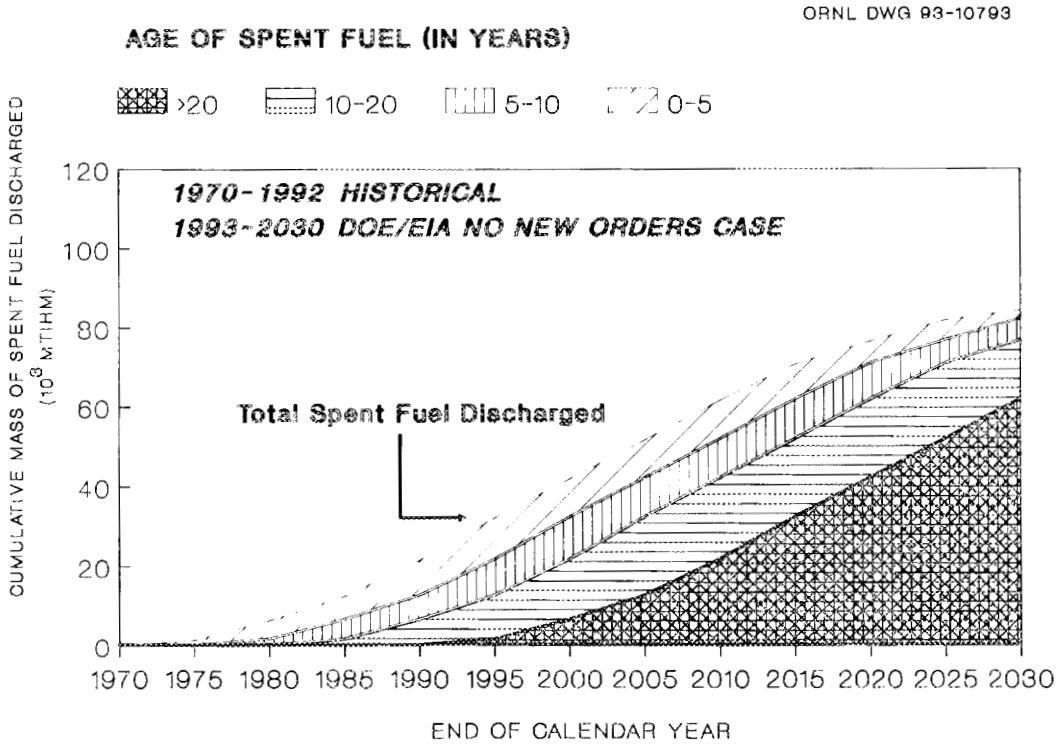

Fig. 1.4. Projected cumulative mass (MTIHM) of commercial spent fuel discharges for the DOE/EIA No New Orders Case.

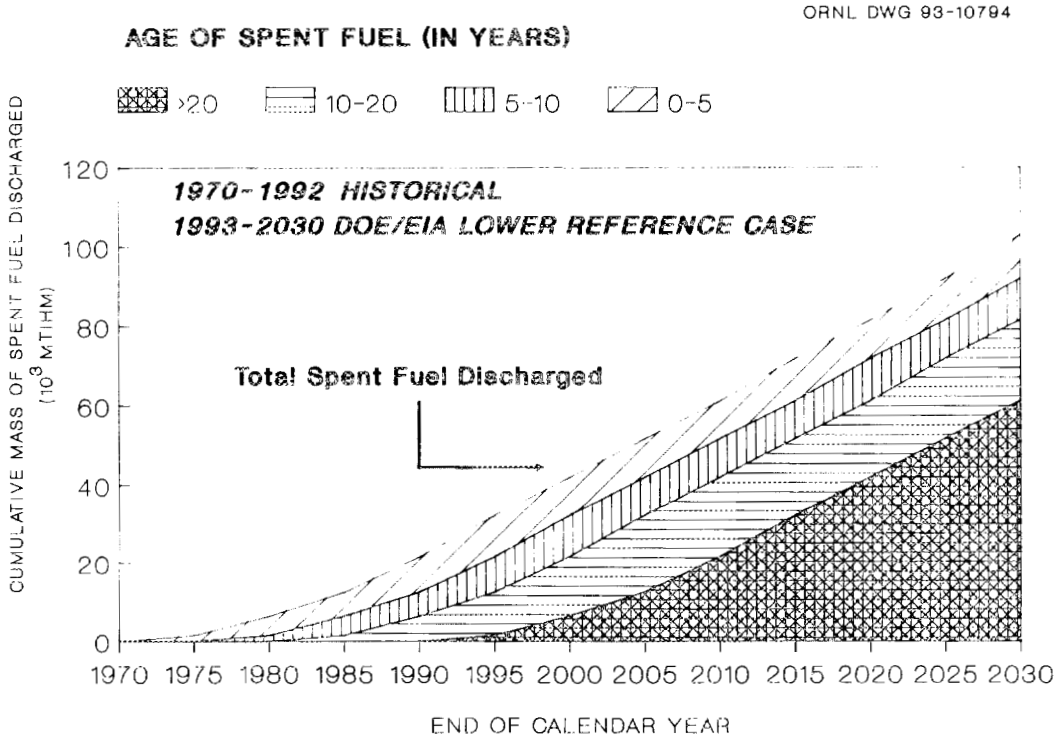

Fig. 1.5. Projected cumulative mass (MTIHM) of commercial spent fuel discharges for the DOE/EIA Lower Reference Case.

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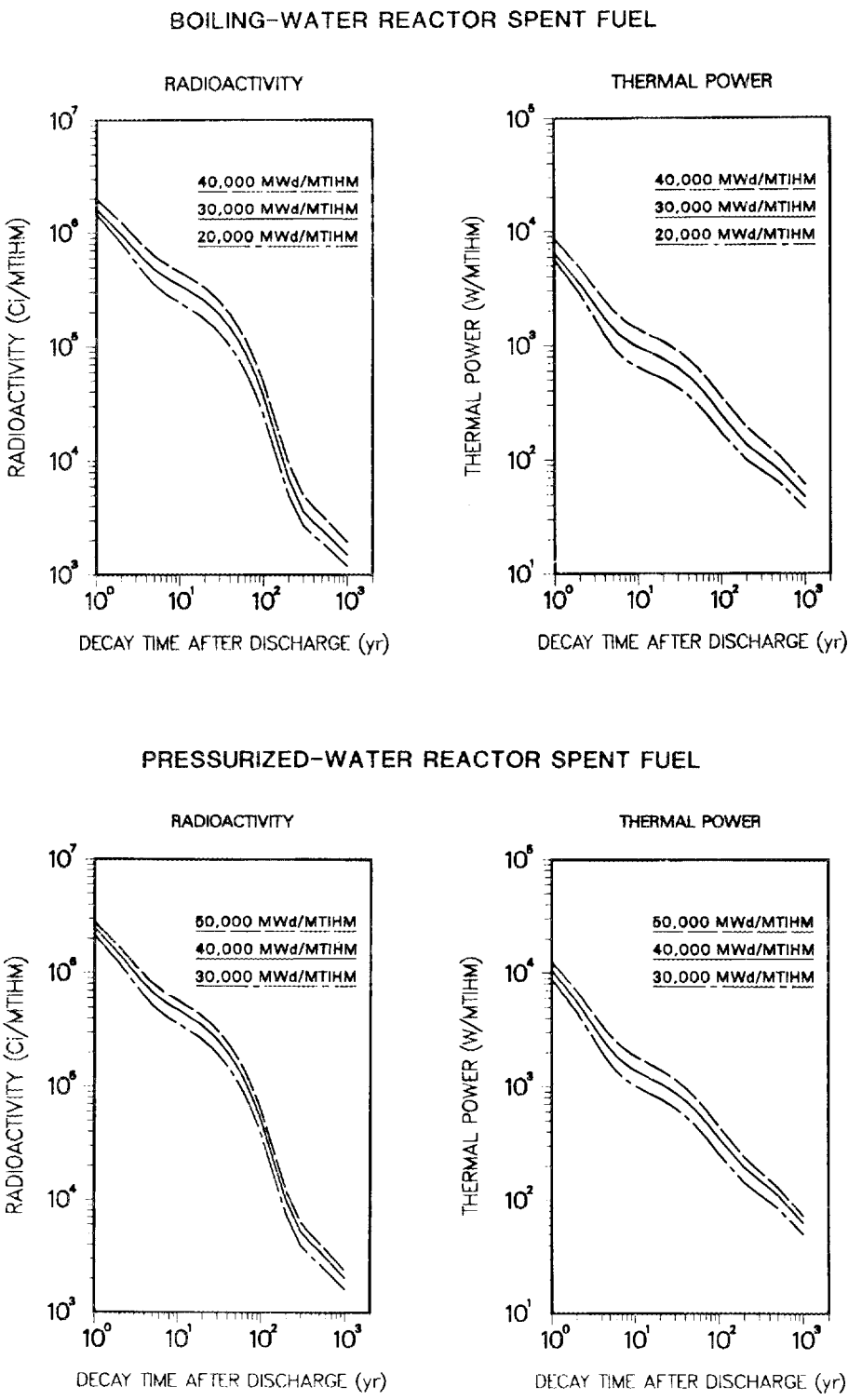

Fig. 1.6. Radioactivity and thermal power of 1 MTIHM of BWR and PWR spent fuel as a function of burnup and time from reactor discharge.

Table 1.1. Historical and projected installed LWR electric power generating capacity for the DOE/EIA No New Orders and Lower Reference cases

End of calendar year	Historical capacity[a] [GW(e)]			End of calendar year	No New Orders Case projected capacity[b,c] [GW(e)]			Lower Reference Case projected capacity[c,d] [GW(e)]		
	BWR	PWR	Total		BWR	PWR	Total	BWR	PWR	Total
1960	0.1	0.2	0.3	1993	31.8	67.2	99.0	31.8	67.2	99.0
1961	0.1	0.2	0.3	1994	31.8	67.2	99.0	31.8	68.4	100.2
1962	0.1	0.2	0.4	1995	31.8	68.4	100.2	31.8	68.4	100.2
1963	0.1	0.2	0.4	1996	31.8	69.5	101.4	31.8	69.5	101.4
1964	0.1	0.2	0.4	1997	31.8	69.5	101.4	31.8	69.5	101.4
1965	0.1	0.2	0.4	1998	31.8	69.5	101.4	31.8	69.5	101.4
1966	0.1	0.2	0.4	1999	31.8	69.5	101.4	31.8	69.5	101.4
1967	0.1	1.3	1.4	2000	31.8	69.5	101.3	31.8	69.5	101.3
1968	0.2	1.2	1.4	2001	31.8	70.7	102.5	31.8	70.7	102.5
1969	0.8	1.7	2.6	2002	31.8	70.7	102.5	31.8	70.7	102.5
1970	2.9	2.9	5.8	2003	31.8	70.7	102.5	31.8	71.3	103.1
1971	4.3	3.7	8.0	2004	31.2	70.7	101.9	31.8	71.3	103.1
1972	7.0	6.5	13.5	2005	31.2	70.7	101.9	31.8	72.6	104.4
1973	8.1	14.1	22.1	2006	30.4	70.7	101.1	31.8	72.6	104.4
1974	13.3	19.4	32.7	2007	30.4	68.1	98.5	31.8	72.6	104.4
1975	15.0	23.3	38.3	2008	28.3	65.7	94.0	31.8	72.6	104.4
1976	16.8	27.9	44.7	2009	27.7	64.2	91.9	30.6	72.6	103.2
1977	16.8	30.4	47.2	2010	26.5	62.0	88.5	29.8	72.6	102.4
1978	17.6	32.2	49.8	2011	25.8	62.0	87.7	29.7	75.9	105.6
1979	17.6	32.2	49.8	2012	23.0	61.2	84.2	29.5	77.7	107.2
1980	17.6	34.3	51.9	2013	22.0	52.0	74.0	29.5	76.8	106.3
1981	17.6	38.6	56.2	2014	17.3	47.2	64.5	25.8	77.7	103.5
1982	18.7	40.5	59.2	2015	17.3	46.3	63.7	27.0	81.0	108.0
1983	19.7	43.6	63.3	2016	15.5	41.9	57.4	27.1	78.3	105.4
1984	24.2	45.8	70.0	2017	15.5	39.2	54.7	28.6	77.5	106.2
1985	26.8	51.7	78.5	2018	14.7	37.4	52.2	27.9	79.4	107.3
1986	28.9	55.2	84.1	2019	14.7	37.4	52.2	29.1	80.9	110.0
1987	31.8	60.8	92.6	2020	14.7	34.3	49.0	30.6	82.2	112.8
1988	31.8	63.1	94.9	2021	14.7	31.2	45.9	30.6	82.7	113.3
1989	33.8	64.1	97.9	2022	11.5	30.3	41.8	31.8	83.2	115.0
1990	32.9	66.7	99.6	2023	9.4	28.4	37.7	33.4	83.4	116.7
1991	32.0	67.7	99.6	2024	7.3	22.6	29.9	31.1	85.0	116.2
1992	31.8	67.1	98.9	2025	5.3	19.1	24.4	31.4	84.4	115.8
				2026	1.1	13.8	14.8	32.6	86.4	119.0
				2027	1.1	8.2	9.3	31.8	86.9	118.7
				2028	1.1	7.0	8.0	33.0	87.6	120.6
				2029	0.0	5.8	5.8	33.1	86.7	119.8
				2030	0.0	4.7	4.7	33.7	85.2	118.8

[a]Based on ref. 1.

[b]Data from ref. 3 update. Assumes (1) that no new reactors will be ordered and (2) that a few units currently under construction will be canceled.

[c]The projections contained in this table show minor differences from those found in the publication World Nuclear Capacity and Fuel Cycle Requirements 1993, DOE/EIA-0436(93). The differences are attributable to the availability of updated data not available for this DOE/EIA report.

[d]Data from ref. 3 update. Assumes basically the same criteria as given in footnote "b", except the case further assumes that any generating capacity lost due to reactor shutdown will be replaced.

Table 1.2. Projected cumulative mass of commercial spent fuel discharges for alternative DOE/EIA scenarios

End of calendar year	Cumulative spent fuel discharged, 10^3 MTIHM	
	No New Orders Case	Lower Reference Case
1992[a]	25.9	25.9
1993[b]	28.3	28.3
1994	30.0	30.0
1995	32.4	32.4
1996	34.1	34.2
1997	36.1	36.1
1998	38.1	38.2
1999	40.0	40.0
2000	42.1	42.1
2001	44.2	44.2
2002	46.0	46.0
2003	48.0	48.0
2004	50.0	50.0
2005	51.8	51.8
2006	53.8	53.7
2007	55.9	55.7
2008	58.0	57.5
2009	59.9	59.6
2010	61.7	61.3
2011	63.5	63.5
2012	65.3	65.3
2013	67.5	67.7
2014	69.6	70.1
2015	70.8	71.9
2016	72.5	74.0
2017	73.5	76.0
2018	74.7	77.9
2019	75.7	79.7
2020	76.7	81.6
2021	77.7	83.6
2022	78.7	85.4
2023	79.9	87.5
2024	81.0	89.8
2025	81.9	92.1
2026	83.1	93.9
2027	83.6	96.1
2028	83.9	98.4
2029	84.2	100.7
2030	84.3	103.0

[a]Reported historical data from ref. 1.

[b]Data for years 1993-2030 from ref. 3 update. The projections contained in this table show minor differences from those found in the publication World Nuclear Capacity and Fuel Cycle Requirements 1993, DOE/EIA-0436(93). The differences are attributable to the availability of updated data not available for this DOE/EIA report.

Table 1.3. Historical and projected mass, radioactivity, and thermal power of permanently discharged spent fuel by reactor type for the DOE/EIA No New Orders Case

End of calendar year	Mass,[a,b] MTIHM		Radioactivity, 10^6 Ci		Thermal power, 10^6 W	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
			Boiling-water reactor			
1968-1970		16		11		0.0
1971	64	80	190	197	0.7	0.8
1972	142	222	431	466	1.7	1.8
1973	95	317	349	441	1.4	1.7
1974	245	561	908	1,042	3.6	4.0
1975	226	787	920	1,218	3.7	4.7
1976	297	1,084	1,151	1,581	4.5	6.1
1977	383	1,467	1,566	2,129	6.2	8.2
1978	383	1,850	1,618	2,412	6.5	9.3
1979	400	2,250	1,734	2,728	7.1	10.5
1980	620	2,870	2,685	3,888	10.9	15.1
1981	459	3,329	2,014	3,664	8.2	14.0
1982	357	3,686	1,582	3,362	6.5	12.6
1983	491	4,177	2,218	4,015	9.1	15.1
1984	498	4,675	2,211	4,283	9.0	16.0
1985	515	5,190	2,246	4,519	9.2	16.7
1986	458	5,648	1,963	4,404	8.0	16.0
1987	699	6,347	2,919	5,411	11.7	19.8
1988	536	6,883	2,363	5,177	9.7	18.8
1989	715	7,598	3,090	6,038	12.6	22.1
1990	633	8,231	2,821	6,101	11.6	22.3
1991	588	8,819	2,696	6,186	11.1	22.5
1992	729	9,547	3,359	7,037	13.9	25.9
1993	700	10,300	3,400	7,500	14.1	27.5
1994	600	10,800	2,800	7,200	11.6	26.2
1995	800	11,700	4,000	8,600	16.9	31.9
1996	500	12,200	2,500	7,600	10.7	27.8
1997	700	12,900	3,200	8,300	13.7	30.5
1998	700	13,500	3,200	8,600	13.6	31.5
1999	600	14,100	2,900	8,500	12.2	31.0
2000	700	14,800	3,300	9,100	14.0	33.1
2001	800	15,600	3,900	10,000	16.7	36.9
2002	400	16,000	1,900	8,400	8.0	30.1
2003	800	16,800	3,800	10,000	16.2	36.8
2004	600	17,400	3,100	9,900	13.0	35.7
2005	500	18,000	2,700	9,600	11.5	34.5
2006	800	18,800	3,900	10,800	16.4	39.5
2007	600	19,300	2,700	10,100	11.6	36.6
2008	800	20,200	3,900	11,300	16.5	41.3
2009	600	20,800	3,100	11,000	13.3	39.7
2010	700	21,500	3,200	11,100	13.4	40.0
2011	600	22,100	3,100	11,100	12.9	39.8
2012	900	23,000	4,400	12,500	18.3	45.5
2013	500	23,500	2,400	11,100	10.3	39.5
2014	900	24,500	4,300	12,800	17.9	46.0
2015	400	24,800	1,900	10,800	8.0	37.9
2016	500	25,400	2,600	11,100	10.9	39.2
2017	300	25,700	1,400	10,000	6.1	34.6
2018	400	26,100	2,000	10,300	8.6	35.8
2019	300	26,400	1,600	9,800	6.7	34.2
2020	300	26,700	1,500	9,600	6.4	33.5
2021	300	26,900	1,300	9,300	5.6	32.4
2022	500	27,500	2,500	10,400	10.3	36.6
2023	500	28,000	2,600	10,700	10.8	38.1
2024	400	28,400	1,700	10,000	7.0	35.3
2025	400	28,800	1,900	10,000	7.8	35.3
2026	500	29,300	2,300	10,400	9.1	36.6
2027	0	29,300	0	8,100	0.0	27.6
2028	0	29,400	200	7,700	1.0	26.0
2029	100	29,500	600	7,700	2.4	26.4
2030	0	29,500	0	7,000	0.0	23.6

Table 1.3 (continued)

End of calendar year	Mass,[a,b] MTIHM		Radioactivity, 10^6 Ci		Thermal power, 10^6 W	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
			Pressurized-water reactor			
1970	39	39	204	204	0.8	0.8
1971	44	83	247	296	1.0	1.2
1972	100	183	545	638	2.2	2.5
1973	67	250	374	571	1.5	2.2
1974	208	458	1,098	1,320	4.4	5.2
1975	322	780	1,683	2,098	6.7	8.2
1976	401	1,181	2,222	2,894	8.9	11.3
1977	467	1,648	2,660	3,677	10.8	14.5
1978	699	2,347	4,030	5,428	16.4	21.5
1979	721	3,068	4,185	6,254	17.1	24.7
1980	618	3,686	3,667	6,248	15.0	24.5
1981	676	4,362	4,025	6,887	16.5	26.9
1982	640	5,002	3,797	7,037	15.6	27.2
1983	772	5,775	4,590	8,077	18.8	31.2
1984	842	6,616	4,978	8,943	20.4	34.4
1985	861	7,478	5,196	9,641	21.4	37.0
1986	1,001	8,478	5,969	10,909	24.5	41.8
1987	1,114	9,592	6,687	12,240	27.5	46.9
1988	1,125	10,717	6,865	13,132	28.3	50.3
1989	1,227	11,944	7,422	14,347	30.5	54.8
1990	1,532	13,476	9,405	17,026	38.9	65.5
1991	1,298	14,774	8,049	16,881	33.4	64.4
1992	1,601	16,375	10,032	19,374	41.7	74.3
1993	1,600	18,000	10,600	21,100	44.2	81.1
1994	1,200	19,200	7,500	19,100	31.3	72.3
1995	1,500	20,700	9,800	21,400	41.1	81.4
1996	1,300	21,900	8,300	20,800	34.8	78.7
1997	1,300	23,200	8,500	21,400	36.0	80.8
1998	1,300	24,600	8,800	22,200	37.2	83.7
1999	1,200	25,800	8,000	22,000	33.9	82.5
2000	1,400	27,300	9,400	23,700	39.6	89.2
2001	1,300	28,600	8,700	23,900	36.9	89.5
2002	1,400	30,000	9,300	25,000	39.4	93.7
2003	1,200	31,200	8,200	24,600	34.8	91.5
2004	1,300	32,500	8,700	25,300	36.8	94.2
2005	1,300	33,800	8,500	25,500	35.9	95.2
2006	1,200	35,000	7,700	25,200	33.0	93.7
2007	1,600	36,600	10,700	28,500	45.3	106.7
2008	1,300	37,900	8,400	27,400	35.7	101.9
2009	1,300	39,100	8,500	27,600	36.3	102.8
2010	1,100	40,200	7,400	26,900	31.5	99.5
2011	1,200	41,400	7,800	27,400	33.8	101.6
2012	900	42,300	6,100	26,000	26.0	95.4
2013	1,700	44,000	11,000	30,700	46.4	114.6
2014	1,200	45,200	8,000	29,200	34.1	108.2
2015	800	46,000	5,600	26,800	24.1	98.3
2016	1,100	47,100	7,600	28,300	32.4	104.4
2017	700	47,900	5,000	26,100	21.2	94.9
2018	800	48,600	5,200	25,800	22.4	93.9
2019	600	49,300	4,300	24,700	18.6	89.5
2020	700	50,000	4,800	24,900	20.5	90.2
2021	800	50,800	5,200	25,200	22.2	91.7
2022	500	51,200	3,100	23,300	13.4	83.4
2023	600	51,800	4,000	23,500	17.1	84.6
2024	800	52,600	4,900	24,300	20.6	88.0
2025	500	53,100	3,500	23,000	14.5	82.6
2026	600	53,700	3,900	23,000	16.2	82.8
2027	500	54,300	3,300	22,300	13.7	79.7
2028	200	54,500	1,500	20,000	6.0	70.8
2029	200	54,700	1,400	19,100	5.8	67.4
2030	100	54,800	900	18,000	3.5	63.3

Table 1.3 (continued)

End of calendar year	Mass,[a,b] MTIHM		Radioactivity, 10^6 Ci		Thermal power, 10^6 W	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
			Total			
1968-1970		55		215		0.8
1971	108	163	438	492	1.7	1.9
1972	241	405	976	1,104	3.9	4.3
1973	162	567	724	1,013	2.9	3.9
1974	452	1,019	2,006	2,363	7.9	9.2
1975	547	1,567	2,603	3,316	10.3	12.9
1976	698	2,265	3,373	4,475	13.4	17.4
1977	850	3,115	4,225	5,806	17.0	22.6
1978	1,082	4,197	5,648	7,840	22.9	30.8
1979	1,121	5,318	5,920	8,982	24.1	35.2
1980	1,238	6,556	6,351	10,136	26.0	39.6
1981	1,135	7,691	6,039	10,551	24.7	40.9
1982	998	8,688	5,379	10,399	22.0	39.8
1983	1,264	9,952	6,808	12,092	27.9	46.3
1984	1,340	11,292	7,188	13,226	29.4	50.4
1985	1,376	12,667	7,442	14,160	30.6	53.8
1986	1,459	14,126	7,931	15,313	32.5	57.9
1987	1,813	15,940	9,606	17,651	39.2	66.8
1988	1,661	17,600	9,229	18,310	38.0	69.1
1989	1,942	19,542	10,512	20,385	43.1	76.9
1990	2,165	21,707	12,225	23,126	50.4	87.8
1991	1,886	23,592	10,745	23,067	44.5	87.0
1992	2,330	25,922	13,391	26,410	55.6	100.2
1993	2,400	28,300	13,900	28,500	58.3	108.6
1994	1,700	30,000	10,200	26,300	42.9	98.6
1995	2,300	32,400	13,800	29,900	58.0	113.3
1996	1,800	34,100	10,800	28,500	45.5	106.6
1997	2,000	36,100	11,800	29,800	49.7	111.3
1998	2,000	38,100	12,100	30,800	50.8	115.3
1999	1,800	40,000	10,900	30,600	46.1	113.5
2000	2,100	42,100	12,700	32,800	53.6	122.3
2001	2,100	44,200	12,700	33,900	53.5	126.4
2002	1,800	46,000	11,200	33,400	47.4	123.7
2003	2,000	48,000	12,000	34,600	51.0	128.3
2004	2,000	50,000	11,800	35,100	49.8	130.0
2005	1,800	51,800	11,200	35,100	47.4	129.7
2006	2,000	53,800	11,600	36,100	49.4	133.2
2007	2,200	55,900	13,500	38,600	56.9	143.3
2008	2,100	58,000	12,400	38,700	52.3	143.1
2009	1,900	59,900	11,600	38,600	49.6	142.5
2010	1,800	61,700	10,600	38,000	44.9	139.5
2011	1,800	63,500	10,900	38,500	46.6	141.4
2012	1,800	65,300	10,400	38,500	44.3	140.9
2013	2,200	67,500	13,500	41,800	56.7	154.1
2014	2,100	69,600	12,400	41,900	52.0	154.2
2015	1,200	70,800	7,500	37,600	32.0	136.2
2016	1,700	72,500	10,200	39,400	43.3	143.6
2017	1,000	73,500	6,400	36,100	27.4	129.6
2018	1,200	74,700	7,300	36,100	31.0	129.7
2019	900	75,700	5,900	34,600	25.4	123.7
2020	1,000	76,700	6,300	34,500	26.9	123.6
2021	1,000	77,700	6,500	34,600	27.7	124.0
2022	1,000	78,700	5,600	33,600	23.6	120.0
2023	1,100	79,900	6,600	34,200	27.8	122.7
2024	1,100	81,000	6,700	34,300	27.6	123.3
2025	900	81,900	5,300	33,000	22.3	117.8
2026	1,100	83,100	6,200	33,400	25.4	119.3
2027	500	83,600	3,300	30,400	13.7	107.3
2028	300	83,900	1,700	27,700	7.0	96.8
2029	300	84,200	2,000	26,900	8.2	93.8
2030	100	84,300	900	25,000	3.5	86.8

[a]Ref. 1 (1968-1992).
[b]Ref. 3 (1993-2030). Assumes no future reprocessing.

Table 1.4. Historical and projected mass, radioactivity, and thermal power of permanently discharged spent fuel by reactor type for the DOE/EIA Lower Reference Case

End of calendar year	Mass,[a,b] MTIHM		Radioactivity, 10^6 Ci		Thermal power, 10^6 W	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
			Boiling-water reactor			
1968-1970		16		11		0.0
1971	64	80	190	197	0.7	0.8
1972	142	222	431	466	1.7	1.8
1973	95	317	349	441	1.4	1.7
1974	245	561	908	1,042	3.6	4.0
1975	226	787	920	1,218	3.7	4.7
1976	297	1,084	1,151	1,581	4.5	6.1
1977	383	1,467	1,566	2,129	6.2	8.2
1978	383	1,850	1,618	2,412	6.5	9.3
1979	400	2,250	1,734	2,728	7.1	10.5
1980	620	2,870	2,685	3,888	10.9	15.1
1981	459	3,329	2,014	3,664	8.2	14.0
1982	357	3,686	1,582	3,362	6.5	12.6
1983	491	4,177	2,218	4,015	9.1	15.1
1984	498	4,675	2,211	4,283	9.0	16.0
1985	515	5,190	2,246	4,519	9.2	16.7
1986	458	5,648	1,963	4,404	8.0	16.0
1987	699	6,347	2,919	5,411	11.7	19.8
1988	536	6,883	2,363	5,177	9.7	18.8
1989	715	7,598	3,090	6,038	12.6	22.1
1990	633	8,231	2,821	6,101	11.6	22.3
1991	588	8,819	2,696	6,186	11.1	22.5
1992	729	9,547	3,359	7,037	13.9	25.9
1993	700	10,300	3,400	7,500	14.1	27.5
1994	600	10,800	2,800	7,200	11.6	26.2
1995	800	11,700	4,000	8,600	16.9	31.9
1996	500	12,200	2,500	7,600	10.7	27.8
1997	700	12,900	3,200	8,300	13.7	30.5
1998	700	13,500	3,200	8,600	13.6	31.5
1999	600	14,100	2,900	8,500	12.2	31.0
2000	700	14,800	3,300	9,100	14.0	33.1
2001	800	15,600	3,900	10,000	16.7	36.9
2002	400	16,000	1,900	8,400	8.0	30.1
2003	800	16,800	3,800	10,000	16.2	36.8
2004	600	17,400	2,800	9,600	12.0	34.7
2005	500	17,900	2,700	9,500	11.5	34.3
2006	700	18,600	3,400	10,300	14.7	37.6
2007	600	19,200	3,000	10,200	12.6	37.0
2008	600	19,800	3,000	10,400	12.8	37.5
2009	900	20,700	4,200	11,700	17.6	42.8
2010	600	21,300	2,800	10,900	11.8	39.1
2011	900	22,100	4,200	12,100	17.5	44.2
2012	800	22,900	3,600	12,100	15.1	43.7
2013	800	23,700	3,600	12,200	15.0	44.1
2014	1,100	24,700	5,100	13,800	21.0	50.5
2015	600	25,300	2,600	12,000	11.0	42.8
2016	600	25,900	2,800	11,900	11.7	42.1
2017	600	26,500	2,800	11,800	11.7	41.7
2018	600	27,100	3,100	12,100	13.0	43.1
2019	600	27,700	2,800	11,900	11.7	42.3
2020	600	28,300	2,900	12,000	12.2	43.0
2021	500	28,800	2,600	11,900	10.9	42.2
2022	600	29,400	2,800	12,100	12.0	43.3
2023	600	30,000	3,100	12,500	13.3	45.0
2024	900	30,900	4,200	13,700	17.5	50.2
2025	800	31,700	3,800	13,800	16.0	50.6
2026	600	32,200	2,800	13,100	11.8	47.3
2027	700	32,900	3,400	13,600	14.2	49.2
2028	800	33,700	3,900	14,200	16.6	52.1
2029	700	34,400	3,300	14,000	14.0	51.0
2030	800	35,200	3,900	14,600	16.5	53.5

Table 1.4 (continued)

End of calendar year	Mass,[a,b] MTIHM		Radioactivity, 10^6 Ci		Thermal power, 10^6 W	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
			Pressurized water reactor			
1970	39	39	204	204	0.8	0.8
1971	44	83	247	296	1.0	1.2
1972	100	183	545	638	2.2	2.5
1973	67	250	374	571	1.5	2.2
1974	208	458	1,098	1,320	4.4	5.2
1975	322	780	1,683	2,098	6.7	8.2
1976	401	1,181	2,222	2,894	8.9	11.3
1977	467	1,648	2,660	3,677	10.8	14.5
1978	699	2,347	4,030	5,428	16.4	21.5
1979	721	3,068	4,185	6,254	17.1	24.7
1980	618	3,686	3,667	6,248	15.0	24.5
1981	676	4,362	4,025	6,887	16.5	26.9
1982	640	5,002	3,797	7,037	15.6	27.2
1983	772	5,775	4,590	8,077	18.8	31.2
1984	842	6,616	4,978	8,943	20.4	34.4
1985	861	7,478	5,196	9,641	21.4	37.0
1986	1,001	8,478	5,969	10,909	24.5	41.8
1987	1,114	9,592	6,687	12,240	27.5	46.9
1988	1,125	10,717	6,865	13,132	28.3	50.3
1989	1,227	11,944	7,422	14,347	30.5	54.8
1990	1,532	13,476	9,405	17,026	38.9	65.5
1991	1,298	14,774	8,049	16,881	33.4	64.4
1992	1,601	16,375	10,032	19,374	41.7	74.3
1993	1,600	18,000	10,600	21,100	44.2	81.1
1994	1,200	19,200	7,500	19,100	31.3	72.3
1995	1,500	20,700	9,800	21,400	41.1	81.4
1996	1,300	22,000	8,400	21,000	35.5	79.4
1997	1,300	23,200	8,400	21,300	35.3	80.3
1998	1,400	24,600	9,000	22,400	38.0	84.5
1999	1,200	25,900	8,000	22,100	33.9	82.8
2000	1,400	27,300	9,200	23,600	38.8	88.5
2001	1,300	28,600	8,900	24,000	37.7	90.2
2002	1,400	30,000	9,300	25,000	39.4	93.9
2003	1,200	31,200	8,000	24,400	33.9	90.8
2004	1,400	32,600	9,000	25,500	38.1	95.3
2005	1,300	33,900	8,600	25,700	36.3	95.9
2006	1,200	35,000	7,800	25,400	33.1	94.1
2007	1,400	36,500	9,600	27,300	40.7	102.3
2008	1,200	37,700	8,200	26,900	35.1	100.2
2009	1,200	38,900	8,000	27,000	34.4	100.5
2010	1,100	40,000	7,600	26,900	32.9	100.1
2011	1,300	41,300	8,900	28,400	38.5	106.6
2012	1,100	42,400	7,400	27,700	31.6	103.0
2013	1,600	44,000	10,800	31,100	45.9	117.0
2014	1,400	45,400	9,300	30,800	39.4	115.7
2015	1,200	46,600	8,300	30,300	35.6	113.3
2016	1,500	48,100	10,200	32,300	43.4	121.5
2017	1,400	49,500	9,200	32,200	39.2	120.7
2018	1,200	50,700	8,300	31,600	35.6	118.3
2019	1,300	52,000	8,600	32,000	37.2	120.2
2020	1,300	53,300	8,900	32,700	37.9	122.5
2021	1,500	54,800	10,000	34,200	42.9	128.9
2022	1,200	56,000	8,200	33,200	35.0	124.1
2023	1,400	57,500	9,800	34,700	41.8	130.6
2024	1,500	58,900	9,800	35,400	42.2	133.7
2025	1,500	60,400	10,200	36,300	43.6	137.4
2026	1,300	61,700	8,500	35,300	36.7	133.1
2027	1,500	63,200	10,400	37,200	44.6	140.8
2028	1,500	64,700	10,400	37,900	44.4	143.7
2029	1,500	66,300	10,400	38,500	44.3	145.9
2030	1,500	67,800	10,200	38,800	43.4	146.7

Table 1.4 (continued)

End of calendar year	Mass,[a,b] MTIHM		Radioactivity, 10^6 Ci		Thermal power, 10^6 W	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
			Total			
1968-1970		55		215		0.8
1971	108	163	438	492	1.7	1.9
1972	241	405	976	1,104	3.9	4.3
1973	162	567	724	1,013	2.9	3.9
1974	452	1,019	2,006	2,363	7.9	9.2
1975	547	1,567	2,603	3,316	10.3	12.9
1976	698	2,265	3,373	4,475	13.4	17.4
1977	850	3,115	4,225	5,806	17.0	22.6
1978	1,082	4,197	5,648	7,840	22.9	30.8
1979	1,121	5,318	5,920	8,982	24.1	35.2
1980	1,238	6,556	6,351	10,136	26.0	39.6
1981	1,135	7,691	6,039	10,551	24.7	40.9
1982	998	8,688	5,379	10,399	22.0	39.8
1983	1,264	9,952	6,808	12,092	27.9	46.3
1984	1,340	11,292	7,188	13,226	29.4	50.4
1985	1,376	12,667	7,442	14,160	30.6	53.8
1986	1,459	14,126	7,931	15,313	32.5	57.9
1987	1,813	15,940	9,606	17,651	39.2	66.8
1988	1,661	17,600	9,229	18,310	38.0	69.1
1989	1,942	19,542	10,512	20,385	43.1	76.9
1990	2,165	21,707	12,225	23,126	50.4	87.8
1991	1,886	23,592	10,745	23,067	44.5	87.0
1992	2,330	25,922	13,391	26,410	55.6	100.2
1993	2,400	28,300	13,900	28,500	58.3	108.6
1994	1,700	30,000	10,200	26,300	42.9	98.6
1995	2,300	32,400	13,800	29,900	58.0	113.3
1996	1,800	34,200	11,000	28,600	46.2	107.3
1997	1,900	36,100	11,600	29,600	49.0	110.8
1998	2,100	38,200	12,300	31,000	51.6	116.0
1999	1,800	40,000	10,900	30,600	46.1	113.7
2000	2,100	42,100	12,500	32,600	52.7	121.6
2001	2,200	44,200	12,900	34,000	54.4	127.1
2002	1,800	46,000	11,200	33,400	47.4	123.9
2003	2,000	48,000	11,800	34,400	50.1	127.5
2004	1,900	50,000	11,800	35,100	50.1	130.0
2005	1,800	51,800	11,300	35,200	47.8	130.2
2006	1,900	53,700	11,200	35,700	47.8	131.8
2007	2,000	55,700	12,500	37,500	53.3	139.2
2008	1,800	57,500	11,200	37,200	47.8	137.7
2009	2,000	59,600	12,200	38,700	52.0	143.3
2010	1,700	61,300	10,500	37,800	44.7	139.2
2011	2,200	63,500	13,100	40,600	56.0	150.9
2012	1,900	65,300	11,000	39,700	46.8	146.7
2013	2,400	67,700	14,400	43,300	60.8	161.1
2014	2,500	70,100	14,300	44,700	60.3	166.2
2015	1,800	71,900	11,000	42,300	46.6	156.1
2016	2,100	74,000	13,000	44,200	55.1	163.6
2017	1,900	76,000	12,000	44,000	50.9	162.4
2018	1,900	77,900	11,400	43,800	48.7	161.4
2019	1,800	79,700	11,400	44,000	48.9	162.5
2020	1,900	81,600	11,700	44,700	50.1	165.5
2021	2,000	83,600	12,600	46,100	53.8	171.1
2022	1,800	85,400	11,000	45,300	47.0	167.4
2023	2,100	87,500	12,900	47,200	55.1	175.6
2024	2,300	89,800	14,000	49,200	59.6	183.9
2025	2,300	92,100	13,900	50,200	59.5	188.0
2026	1,800	93,900	11,300	48,400	48.6	180.4
2027	2,300	96,100	13,800	50,800	58.8	190.0
2028	2,300	98,400	14,200	52,100	61.0	195.7
2029	2,200	100,700	13,700	52,500	58.4	196.9
2030	2,300	103,000	14,100	53,400	59.8	200.3

[a]Ref. 1 (1968-1992).
[b]Ref. 3 (1993-2030). Assumes no future reprocessing.

Table 1.5. Projected number of permanently discharged LWR spent fuel assemblies for the DOE/EIA No New Orders Case

End of calendar year	BWR		PWR		Total	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1992[a]	4,024	52,597	3,713	38,274	7,737	90,871
1993[b]	4,000	56,600	3,800	42,000	7,800	98,700
1994	3,200	59,900	2,700	44,700	5,900	104,600
1995	4,700	64,600	3,500	48,200	8,200	112,800
1996	2,900	67,500	2,900	51,100	5,900	118,600
1997	3,800	71,300	3,000	54,200	6,800	125,500
1998	3,800	75,100	3,100	57,300	6,900	132,400
1999	3,400	78,500	2,900	60,100	6,200	138,600
2000	3,900	82,400	3,300	63,400	7,200	145,800
2001	4,600	87,000	3,100	66,500	7,700	153,500
2002	2,200	89,200	3,300	69,800	5,500	159,000
2003	4,500	93,700	2,800	72,700	7,300	166,400
2004	3,700	97,400	3,100	75,700	6,700	173,100
2005	3,100	100,500	2,900	78,700	6,100	179,200
2006	4,600	105,100	2,700	81,400	7,300	186,500
2007	3,200	108,300	3,800	85,200	7,000	193,400
2008	4,700	113,000	3,000	88,100	7,700	201,100
2009	3,700	116,600	2,900	91,000	6,600	207,700
2010	3,800	120,500	2,500	93,600	6,400	214,100
2011	3,700	124,100	2,700	96,300	6,400	220,400
2012	5,300	129,400	2,000	98,300	7,300	227,700
2013	2,800	132,200	3,900	102,200	6,700	234,400
2014	5,200	137,400	2,800	105,000	8,000	242,400
2015	2,100	139,600	1,900	106,900	4,000	246,400
2016	3,000	142,600	2,600	109,500	5,600	252,000
2017	1,600	144,200	1,700	111,100	3,300	255,300
2018	2,300	146,500	1,800	112,900	4,100	259,400
2019	1,800	148,300	1,400	114,400	3,200	262,600
2020	1,700	150,000	1,600	116,000	3,300	266,000
2021	1,500	151,500	1,700	117,700	3,200	269,200
2022	3,100	154,600	1,100	118,800	4,200	273,400
2023	3,000	157,600	1,400	120,200	4,400	277,800
2024	2,200	159,800	1,800	122,000	3,900	281,700
2025	2,200	162,000	1,200	123,200	3,400	285,200
2026	2,900	164,900	1,400	124,600	4,300	289,500
2027	0	164,900	1,200	125,800	1,200	290,700
2028	300	165,100	500	126,200	700	291,400
2029	800	165,900	500	126,700	1,200	292,600
2030	0	165,900	300	127,000	300	292,900

[a]Reported historical data (ref. 1).

[b]Data for years 1993-2030 are based on 101.3 GW(e) installed in the year 2000 and 4.7 GW(e) installed in the year 2030 (ref. 3). Number of projected fuel assemblies reported has been rounded to the nearest 100.

Table 1.6. Projected number of permanently discharged LWR spent fuel assemblies for the DOE/EIA Lower Reference Case

End of calendar year	BWR		PWR		Total	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1992[a]	4,024	52,597	3,713	38,274	7,737	90,871
1993[b]	4,000	56,600	3,800	42,000	7,800	98,700
1994	3,200	59,900	2,700	44,700	5,900	104,600
1995	4,700	64,600	3,500	48,200	8,200	112,800
1996	2,900	67,500	3,000	51,200	5,900	118,700
1997	3,800	71,300	3,000	54,200	6,800	125,500
1998	3,800	75,100	3,200	57,300	7,000	132,500
1999	3,400	78,500	2,900	60,200	6,200	138,700
2000	3,900	82,400	3,200	63,400	7,200	145,800
2001	4,600	87,000	3,100	66,600	7,800	153,600
2002	2,200	89,200	3,300	69,900	5,500	159,100
2003	4,500	93,700	2,800	72,700	7,300	166,400
2004	3,300	97,000	3,200	75,800	6,500	172,900
2005	3,100	100,100	3,000	78,800	6,100	179,000
2006	4,000	104,100	2,700	81,500	6,700	185,700
2007	3,400	107,600	3,300	84,800	6,700	192,400
2008	3,500	111,100	2,800	87,700	6,300	198,700
2009	5,000	116,000	2,700	90,400	7,700	206,400
2010	3,400	119,400	2,600	93,000	6,000	212,400
2011	5,000	124,400	3,100	96,000	8,100	220,500
2012	4,300	128,700	2,500	98,600	6,800	227,300
2013	4,300	133,000	3,700	102,300	8,000	235,300
2014	6,100	139,100	3,200	105,500	9,300	244,600
2015	3,100	142,200	2,800	108,400	6,000	250,600
2016	3,400	145,600	3,500	111,800	6,800	257,400
2017	3,300	148,900	3,100	115,000	6,400	263,900
2018	3,600	152,500	2,900	117,800	6,500	270,400
2019	3,300	155,800	2,900	120,700	6,200	276,500
2020	3,300	159,100	3,000	123,800	6,300	282,800
2021	3,000	162,100	3,400	127,100	6,400	289,200
2022	3,300	165,400	2,800	130,000	6,100	295,300
2023	3,500	168,900	3,400	133,300	6,800	302,200
2024	4,900	173,700	3,400	136,700	8,200	310,400
2025	4,400	178,100	3,400	140,100	7,800	318,200
2026	3,100	181,200	2,900	143,000	6,000	324,200
2027	4,100	185,300	3,500	146,500	7,600	331,800
2028	4,400	189,700	3,500	150,000	7,900	339,700
2029	3,900	193,600	3,500	153,500	7,400	347,100
2030	4,500	198,100	3,500	157,100	8,000	355,100

[a]Reported historical data (ref. 1).

[b]Data for years 1993-2030 are based on 101.3 GW(e) installed in the year 2000 and 118.8 GW(e) installed in the year 2030 (ref. 3). Number of projected fuel assemblies reported has been rounded to the nearest 100.

Table 1.7. Spent fuel discharges from the Fort St. Vrain HTGR[a]

End of calendar year	Number of fuel assemblies discharged		Mass of fuel discharged (MTIHM)	
	Annual	Cumulative	Annual	Cumulative
1979	246[b]	246	2.80	2.80
1980	0	246	0.00	2.80
1981	240	486	2.77	5.57
1982	0	486	0.00	5.57
1983	0	486	0.00	5.57
1984	240	726	2.85	8.42
1985	0	726	0.00	8.42
1986	0	726	0.00	8.42
1987	0	726	0.00	8.42
1988	0	726[c]	0.00	8.42
1989[d,e]	126	852	1.32	9.74
1990[d]	332	1,184	3.49	13.23
1991[f]	42	1,226	0.48	13.71
1992[g]	982	2,208	10.29	24.00
1993-1998[h]	0	2,208	0	24.00

[a]Based on ref. 7. Discharges identified in this table are those made directly from the reactor.

[b]This refueling replaced 240 standard fuel elements and 6 fuel test elements.

[c]All spent fuel discharged prior to December 31, 1988, is located at the ICPP (see Table A.6 of Appendix A).

[d]Fuel removed from the reactor in 1989 and 1990 was temporarily stored in on-site storage wells.

[e]Power operations effectively ceased on August 18, 1989.

[f]In 1991, 18 of the discharged spent fuel elements were sent to ICPP, 18 elements were transferred to an on-site independent spent fuel storage installation (ISFSI), and 6 elements were temporarily stored in on-site storage wells.

[g]All spent fuel elements have been discharged from the reactor and transferred to the ISFSI. All spent fuel elements in temporary on-site storage wells have been relocated to the ISFSI.

[h]During this period, Public Service Company of Colorado plans to ship the 1,464 elements currently in the ISFSI to ICPP. However, legal issues have not been fully resolved.

Table 1.8. IDB reference characteristics of LWR fuel assemblies

Characteristics	BWR[a]	PWR[b]
Overall assembly length, m	4.470	4.059
Cross section, cm	13.9 × 13.9	21.4 × 21.4
Fuel rod length, m	4.064	3.851
Active fuel height, m	3.759	3.658
Fuel rod outer diameter, cm	1.252	0.950
Fuel rod array	8 × 8	17 × 17
Fuel rods per assembly	63	264
Assembly total weight, kg	319.9	657.9
Uranium/assembly, kg	183.3	461.4
UO_2/assembly, kg	208.0	523.4
Zircaloy/assembly, kg	103.3[c]	108.4[d]
Hardware/assembly, kg	8.6[e]	26.1[f]
Total metal/assembly, kg	111.9	134.5
Nominal volume/assembly, m^3	0.0864[g]	0.186[g]

[a]Ref. 8.
[b]Ref. 9.
[c]Includes Zircaloy fuel-rod spacers and fuel channel.
[d]Includes Zircaloy control-rod guide thimbles.
[e]Includes stainless steel tie-plates, Inconel springs, and plenum springs.
[f]Includes stainless steel nozzles and Inconel-718 grids.
[g]Based on overall outside dimension. Includes spacing between the stacked fuel rods of an assembly.

Table 1.9. Historical mass of commercial BWR spent fuel discharged at various ranges of burnup[a,b]

End of calendar year	Annual mass of discharged spent fuel for various burnup ranges, MTIHM									Total annual mass over all burnup ranges (MTIHM)
	0-4,999[c]	5,000-9,999	10,000-14,999	15,000-19,999	20,000-24,999	25,000-29,999	30,000-34,999	35,000-39,999	40,000-44,999	
1968	0.6									0.6
1969		1.2	1.0	7.3	0.2	0.1				9.8
1970	5.6									5.6
1971	41.5	8.1	2.8	10.0	1.6					64.0
1972	97.9	12.1	27.6	4.0						141.5
1973	9.7	15.5	30.9	36.4	1.5	0.1				95.1
1974		78.4	117.7	44.7	3.8					244.6
1975	0.3	1.7	62.0	136.4	25.3					225.6
1976	0.9	67.1	108.7	118.4	2.3					297.4
1977		48.0	40.3	235.0	58.9	0.7				382.9
1978	6.3	32.4	13.1	84.2	232.0	15.2				383.2
1979			18.6	108.7	149.2	123.1	0.3			399.8
1980	14.0	0.4	0.6	93.3	413.3	87.6	10.7			619.9
1981		0.2	0.2	58.1	265.4	133.3	0.7	0.7		458.7
1982		0.2	4.6	25.6	136.5	173.6	13.8	0.6	0.4	357.2
1983			0.9	2.9	113.5	337.8	35.7	0.4		491.3
1984		7.9	43.0	0.3	136.2	239.5	70.8		0.4	498.0
1985	16.9	42.5	18.3	35.8	93.2	297.4	10.2		0.2	514.6
1986	50.8	32.4	42.5	66.6	43.1	180.7	41.7	0.4		458.2
1987	133.5	36.1	58.8	40.8	24.7	352.4	42.9		0.4	699.4
1988	17.0	24.5	1.8	42.9	168.3	192.4	88.7			535.6
1989	30.9	16.9	85.3	71.8	193.2	227.7	85.5	3.6		714.9
1990	17.0		34.0	67.6	106.2	247.5	158.9	1.6		632.8
1991	17.8	24.6		7.2	24.0	215.0	287.2	12.1		588.0
1992			7.6	86.1	85.1	83.9	362.7	103.4		728.7

[a]Based on ref. 1.
[b]Does not include commercial spent fuel reprocessed at WVDP.
[c]Burnup range is given in units of MWd/MTIHM.

Table 1.10. Historical mass of commercial PWR spent fuel discharged at various ranges of burnup[a,b]

End of calendar year	Annual mass of discharged spent fuel for various burnup ranges, MTIHM												Total annual mass over all burnup ranges (MTIHM)
	0-4,999[c]	5,000-9,999	10,000-14,999	15,000-19,999	20,000-24,999	25,000-29,999	30,000-34,999	35,000-39,999	40,000-44,999	45,000-49,999	50,000-54,999	55,000-59,999	
1970			1.7	37.3									39.0
1971		4.6			6.2	33.7							44.5
1972			11.9	29.3	27.8	8.9	22.1						99.9
1973				26.2		33.3	7.6						67.1
1974	7.4	1.5	86.4	13.6	40.5	57.2	1.1						207.7
1975	2.7	42.6	95.0	53.6	79.4	25.3	23.1						321.8
1976			5.6	194.2	82.4	63.3	55.4						401.0
1977			2.8	108.3	113.1	140.3	87.1	15.4					466.9
1978		1.4	47.9	89.8	39.1	336.9	123.1	60.4	0.4				699.0
1979			30.6	109.4	64.0	232.3	234.3	50.1	0.5				721.2
1980			0.4		66.8	241.8	280.6	26.3	2.0				618.1
1981			17.2	1.9	25.8	228.5	351.1	50.1	1.3				675.9
1982			1.8	81.1	80.4	61.4	292.0	118.3	2.7	0.4	1.3	0.9	640.4
1983		5.5	4.0	80.6	44.2	168.9	331.8	131.4	5.4		0.5		772.2
1984			58.0	45.2	56.3	198.4	374.8	104.8	4.1				841.7
1985				49.0	13.6	217.0	317.8	239.4	24.1	0.4			861.3
1986		0.8	27.6	132.0	19.3	180.2	335.4	268.0	35.0	1.3	1.3		1,000.9
1987			27.2	78.1	53.4	175.7	411.9	315.8	51.8				1,113.8
1988				83.9	15.0	139.2	349.6	427.4	103.1	4.6	0.4	2.0	1,125.2
1989			48.0	91.4	68.6	112.1	286.7	415.0	189.3	15.2		0.4	1,226.7
1990			24.0	85.2	24.0	127.5	398.0	616.4	249.4	7.0	0.3		1,531.9
1991		9.2	53.2	1.4	79.4	60.5	159.4	609.9	257.1	64.2	3.4		1,297.7
1992		19.8	14.8	43.7	15.0	111.8	304.1	453.0	505.0	119.0	14.8		1,601.0

[a]Based on ref. 1.
[b]Does not include commercial spent fuel reprocessed at WVDP.
[c]Burnup range is given in units of MWd/MTIHM.

Table 1.11. Summary inventory characteristics of DOE spent fuel not scheduled for reprocessing[a]

Site	Spent fuel source/type	Number/type of fuel components	Spent fuel mass		
			Total (t)	Initial heavy metal (MTIHM)	Discharged heavy metal (MTHM)
ANL-E	Hot cell experiment samples	Fuel pins, pieces, and pellets	b	b	0.080
	Research reactor targets		b	b	0.001
	ANL-E mass total		b	b	0.081
ANL-W	Experimental Breeder Reactor (EBR) II fuel	85 assemblies; 36 partial assemblies	b	b	17.500
	Hot Fuel Examination Facility Research Reactor fuel	2,047 elements and subassemblies	b	b	1.000
	Neutron Radiography Research Reactor fuel	116 elements	b	b	0.001
	Radioactive Scrap and Waste Facility reactor fuel	15,000 elements and subassemblies	b	b	7.000
	Transient Reactor Test Facility fuel	390 assemblies	b	b	0.014
	Zero Power Physics Reactor fuel	65,600 rods and plates	b	b	c
	ANL-W mass total		b	b	>25.515
BNL	Brookhaven Medical Research Reactor fuel	4 elements	b	b	0.001
	High Flux Beam Reactor fuel	839 elements	b	b	0.316
	BNL mass total		b	b	0.317
GA[d]	Hot cell fuel samples	Fuel pins, pieces, and pellets	b	b	0.004
HANF[e]	PNL fuel				
	• Full commercial assemblies	7 assemblies	b	b	2.400
	• Sectioned commercial rods and assemblies	b	b	b	0.012
	• Research reactor fuel pieces	b	b	b	0.025
	Fast Flux Test Facility fuel[f]	329 assemblies	b	b	13.000
	N-Reactor production fuel	103,680 assemblies	b	b	2,113.300
	Shippingport fuel (T-Plant Basin)	72 assemblies	b	b	16.400
	Single Pass Reactor production fuel[g] (other production reactors)	964 assemblies	b	3.4	3.300
	TRIGA Research Reactor fuel	101 assemblies	b	b	0.020

Table 1.11 (continued)

Site	Spent fuel source/type	Number/type of fuel components	Spent fuel mass		
			Total (t)	Initial heavy metal (MTIHM)	Discharged heavy metal (MTHM)
HANF[e] (contd.)	200-West Area Burial Ground fuel (from commercial reactors, FFTF, and TRIGA reactor)	90 fuel pieces	b	b	0.650
	HANF mass total				2,149.107
INEL	Advanced Test Reactor fuel elements and experimental debris	b	b	b	0.100
	Fort St. Vrain HTGR fuel	744 assemblies	b	8.9	8.9
	Fuel Element Cutting Facility	2 elements	b	b	b
	Irradiated Fuel Storage Facility commercial graphite fuel	b	b	b	0.500
	Materials Test Reactor commercial fuel and scrap	107 canisters	b	b	0.260
	Naval Reactors Expended Core Facility (naval fuel)	b	b	b	3.500
	Power Burst Facility reactor fuel	b	b	b	0.562
	Reactivity Measurements Facility fuel	b	b	b	0.230
	Test Area North fuels				
	• Intact commercial fuel elements	b	b	b	38.100
	• Commercial and Loss of Fluid Test (LOFT) fuel	Intact rods and canned debris	b	b	2.800
	• TMI-Unit 2 fuel	Damaged fuel debris	155.9	82.6	82.6
	Underground Storage Facility commercial and research fuel	Intact and sectioned rods and assemblies	b	b	92.940
	Underwater Fuel Storage (naval, commercial, research and production fuels)	b	b	b	7.580
	INEL mass total		>155.9	>91.5	>238.072
LANL	Chemistry and Metallurgy Research Building fuel	46 elements	b	b	0.010
	Omega West Reactor fuel	40 elements	b	b	0.009
	LANL mass total		b	b	0.019
LTC	Commercial fuel rods and sections	3 intact rods; 17 sectioned rods	b	b	0.044
MOUND	Californium Multiplier Facility fuel[h]	210 fuel plates	b	b	0.002

Table 1.11 (continued)

Site	Spent fuel source/type	Number/type of fuel components	Spent fuel mass		
			Total (t)	Initial heavy metal (MTIHM)	Discharged heavy metal (MTHM)
ORNL	Building 3019 fuels				
	• Commercial fuel (Canada/Con Ed)	405 cans	b	b	1.043
	• Hanford production fuel	41 cans	b	b	0.023
	• SRS production fuel	144 cans	b	b	0.070
	Building 4501 fuel sections	40 sections	0.007	0.007	0.007
	Bulk Shielding Reactor fuel storage				
	• Bulk Shielding Reactor fuel	41 elements	0.184	0.007	0.007
	• Oak Ridge Research Reactor	32 elements	0.143	0.052	0.052
	Classified burial ground	b	b	b	b
	High Flux Isotopes Reactor fuel	43 assemblies	5.864	0.404	0.404
	Homogeneous Reactor fuel	135 gal of uranyl sulphate	0.500	0.004	0.004
	Molten Salt Reactor Experiment fuel	LiF and BeF_2 salt mixture	11.550	0.038	0.038
	Research reactor fuel in Buildings 3525, 7920, 7823A, 7827, and 7829	Fuel samples and targets	>1.246	b	b
	Tower Shielding Reactor fuel	1 assembly	0.182	0.009	0.009
	ORNL mass total		>19.676	>1.657	>1.657
SNLA	Annual Core Research Reactor fuel	b	b	b	0.001
	Hot Cell Facility fuel components from research and production reactors	Intact rods, fuel pieces in dry and wet wells	b	b	0.009
	Manzano Storage Facility (research reactor fuel stored in dry casks)	b	b	b	0.025
	Sandia Pulse Reactor fuel in dry wells	b	b	b	0.029
	Special Nuclear Material Storage Facility fuel in DOT containers	2 elements	b	b	0.011
	SNLA mass total		b	b	0.076
SRS	Production reactor fuel assemblies and targets in disassembly basins and canyons	Assemblies and targets	b	b	153.700
	Receiving basin for off-site fuel:				
	• Commercial fuel	97 assemblies and cans	b	b	3.010
	• Experimental material	585 assemblies and cans	b	b	19.070
	• Foreign fuel	534 assemblies and cans	b	b	20.612
	• Research reactor fuel	1,304 assemblies and cans	b	b	0.355
	• Targets	b	b	b	17.400

Table 1.11 (continued)

Site	Spent fuel source/type	Number/type of fuel components	Spent fuel mass		
			Total (t)	Initial heavy metal (MTIHM)	Discharged heavy metal (MTHM)
SRS (contd.)	Research reactor fuel sections in Building 773-A	4 sections	b	b	b
	Test reactor pile (305-M) fuel	b	b	b	b
	SRS mass total				214.147
WVDP	Commercially generated fuel in Fuel Receiving and Storage Facility				
	• BWR fuel	85 assemblies	b	11.5	b
	• PWR fuel	40 assemblies	b	15.3	b
	WVDP mass total			26.8	25.6
Y-12	Health Physics Research Reactor (HPRR) fuel pieces	170 pieces	b	0.204	0.184
	Space Nuclear Auxiliary Power (SNAP-10) reactor fuel	36 rods	b	0.005	0.005
	Y-12 mass total		b	0.209	0.189
	DOE complex mass total		>2,654.8	>123.5	>2,654.8

[a]Information as of December 31, 1992, unless indicated otherwise. Based on refs. 12-20.
[b]Information not available.
[c]Classified.
[d]General Atomic, San Diego.
[e]Information as of October 1, 1993.
[f]Includes inventory of fresh and partially used fuel.
[g]Fuel from all other Hanford Site production reactors.
[h]This material at the MOUND Plant is not spent nuclear fuel since, by definition, it has not been irradiated in a reactor. The material is actually part of a neutron radiography facility. However, it is reported in this table because it was included in the DOE vulnerability assessment of reactor-irradiated nuclear materials (ref. 19).

Table 1.12. Projected 10-year inventory increases of DOE spent fuel not scheduled for reprocessing[a]

Site	Spent fuel source/type	Spent fuel mass: Total (t)	Spent fuel mass: Initial heavy metal (MTIHM)	Spent fuel mass: Discharged heavy metal (MTHM)	Number of assemblies
ANL-W	Test and experimental reactor fuel with stainless steel clad	b	b	2.7	b
BNL	High Flux Beam Reactor fuel with aluminum cladding	b	b	0.25	769[c]
INEL	Aluminum-based fuel	b	b	1.13	b
	Fort St. Vrain fuel to be shipped from Colorado[d]	b	b	16.7	b
	Naval reactor fuel	b	b	14.2	b
	Test and experimental reactor fuel with stainless steel cladding	b	b	0.27	b
	INEL total	b	b	32.3	b
ORNL	Aluminum-based fuel	b	b	1.1	b
Other	Foreign reactor fuel	b	b	8.51	b
	Research reactor fuels	b	b	0.05	b
	University reactor fuel	b	b	4.32	b
	Other total	b	b	12.88	b
	Grand total	b	b	49.23	>769

[a]Based on ref. 12. Projections cover the period 1993-2002.
[b]Information not available.
[c]Fuel elements.
[d]Public Service Company of Colorado plans to ship the remainder of the discharged Fort St. Vrain fuel currently being held in the independent spent fuel storage installation (ISFSI) to ICPP. However, legal issues have not been fully resolved.

ORNL PHOTO 1397-94

View of the Idaho Chemical Processing Plant New Waste Calcining Facility (NWCF), operational since 1982; old Waste Calcining Facility (WCF), operated as a pilot-scale demonstration and production facility from 1963-1980. (Courtesy of Westinghouse Idaho Nuclear Company, Inc., Idaho Falls, Idaho.)

2. HIGH-LEVEL WASTE

2.1 INTRODUCTION

High-level waste (HLW), which is waste that is generated by the reprocessing of spent reactor fuel and irradiated targets, generally contains more than 99% of the nonvolatile fission products produced in the fuel or targets during reactor operation. The HLW from a facility that recovers uranium and plutonium contains approximately 0.5% of these elements, while the HLW from a facility that recovers only uranium contains approximately 0.5% of the uranium and essentially all of the plutonium. Most of the current U.S. inventory of HLW is that which has resulted from DOE activities and which is stored at the Savannah River Site (SRS), Idaho National Engineering Laboratory (INEL) [at the Idaho Chemical Processing Plant (ICPP)], and Hanford Site (HANF). A small amount of HLW was generated at the commercial Nuclear Fuel Services (NFS) Plant near West Valley, New York, during the period 1966–1972. After 1972, fuel reprocessing operations at this plant were discontinued permanently.

The West Valley facility is now owned by the New York State Energy Research and Development Authority (NYSERDA). In 1980, Congress passed the West Valley Demonstration Project (WVDP) Act, which authorized DOE to decommission the facility and immobilize the radioactive wastes. The WVDP is the responsibility of the DOE Operations Office, Idaho, West Valley Project Office. The WVDP is a joint project of DOE (90% funding) and NYSERDA (10% funding). The DOE is not paying anything for lease of the premises. All the waste and all the facilities at the site are owned by NYSERDA in perpetuity—except for the solidified HLW canisters, which will become titled to DOE at the time the canisters are delivered to a federal repository.

West Valley Nuclear Services, Inc. (a subsidiary of Westinghouse Electric Corporation), is the prime contractor and site operator for the WVDP. The prime contractor and site operator for HLW at SRS is Westinghouse Savannah River Company; for INEL, Westinghouse Idaho Nuclear Company, Inc.; and for HANF, Westinghouse Hanford Company (all subsidiaries of Westinghouse Electric Corporation).

The historical and projected HLW inventories presented here (except for HLW solidified in glass or glass/ceramic forms) are for wastes in interim storage. These wastes are not as generated; they have already undergone one or more treatment steps (e.g., neutralization, precipitation, decantation, or evaporation). Their volumes depend strongly on the particular steps to which they have been subjected. Most of these wastes will require incorporation into a stable, solid medium (e.g., glass) for final disposal. Data on the volume, radioactivity, distribution, and location of HLW (through 1992) are shown in Figs. 2.1–2.4. Current (and projected) HLW operations at these sites are depicted in Figs. 2.5–2.8.

The DOE HLW at INEL (Fig. 2.6) results from the reprocessing of nuclear fuels from naval propulsion reactors and special research and test reactors at the ICPP. The acidic liquid portion of this waste is stored in tanks, although the bulk of this material has been converted to a stable, granular solid (calcine).

At SRS (Fig. 2.5) and HANF (Fig. 2.7), the acidic liquid waste from reprocessing production reactor fuel has been made alkaline (with the addition of caustic soda) and stored in tanks. During storage, these alkaline wastes separate into two phases: liquid and sludge. When the liquid phase is removed and reduced in volume by evaporation, a wet solid (called salt cake) is formed in the tanks holding evaporator concentrates (see Fig. 2.5). The relative proportions of liquid and salt cake depend upon how much water is removed by waste evaporators during interim waste management operations. The condensed water at HANF (114,600 m^3 are projected to be generated from 1993 to 1997) is to be placed into interim storage in a double-lined surface impoundment while the Effluent Treatment Facility is being constructed. This facility will provide destruction of trace organic contaminants and removal of all radionuclides, except tritium, prior to discharge to a permitted soil-column disposal site. The disposal site is located in a manner such as to maximize the ground-water travel time to the Columbia River, thus allowing enough time for tritium to decay. At SRS (Fig. 2.5), the condensate is sent to the Effluent Treatment Facility, where it is treated and discharged to the environment. Also at SRS (Fig. C.3 in Appendix C), the processing of salt cake for future glassmaking generates a waste called precipitate. At HANF, all the wastes contained in double-shell tanks consist of mixtures of HLW, TRU waste, and several LLWs (Fig. 2.7), which have unique rheological properties and are referred to as

slurry. In HANF storage practice, the double-shell tanks are managed as if they contain only HLW. Thus, their contents are included in the HLW inventory.

The commercial HLW at WVDP consists of both alkaline and acidic wastes (Fig. 2.8); the alkaline waste was generated by the reprocessing of commercial power reactor fuels and Hanford N-Reactor fuels, while the acidic waste was generated by reprocessing a small amount of commercial fuel containing thorium. Also at WVDP, the processing of liquid waste for future glassmaking generates a granular solid waste, which is a zeolite loaded with radioactive cesium (Fig. 2.8).

The historical and projected inventories of HLW that is stored in tanks, bins, and capsules are presented in Table 2.1. Projected inventories of HLW that is incorporated into glass or glass/ceramic are given in Table 2.2. A year-by-year estimate of the number of HLW canisters, by source, is presented in Table 2.3. The volume and radioactivity of HLW in storage at the end of 1992 are given in Tables 2.4 and Table 2.5, respectively. Historical and projected volume, radioactivity, and thermal power data for DOE and commercial HLW are given in Tables 2.6–2.8. The data for DOE sites represent a summary of information obtained from each of the sites.[1(a)-1(c)] In 1992, the DOE decided to phase out reprocessing of fuel to recover enriched uranium or plutonium in support of weapons production; thus, little additional HLW is expected to be generated by this source. Decontamination and decommissioning activities may generate wastes with activity levels high enough such as to require disposal in a mined, deep geologic repository. The information on commercial HLW at WVDP was taken largely from data given in ref. 1(d).

2.2 INVENTORIES

Inventories of HLW at the various DOE sites and the WVDP through 1992 are presented in this section. Significant changes affecting HLW inventories are shown in Table 2.9.

2.2.1 HLW Inventories at SRS (DOE)

Approximately 126,900 m^3 of alkaline HLW that has accumulated at the SRS during about the past 4 decades is being stored in underground, high-integrity, double-walled, carbon-steel tanks. The current inventories (Tables 2.4 and 2.5) include alkaline liquid (59,300 m^3), sludge (14,300 m^3), salt cake (53,100 m^3), and precipitate (172 m^3) that were generated primarily by the PUREX reprocessing of nuclear fuels and targets from production reactors. Most of the waste, as generated, is acidic liquid, and the sludge is formed during subsequent treatment with caustic soda and during aging. Salt cake results when the supernatant liquor is concentrated in evaporators. Precipitate results when salt cake is treated by the in-tank precipitation process.

2.2.2 HLW Inventories at INEL (DOE)

The 11,200 m^3 of HLW stored at INEL (at the ICPP) consist of 7,670 m^3 of liquid waste and 3,540 m^3 of calcine (Tables 2.4 and 2.5). Liquid HLW is generated at ICPP primarily by the reprocessing of spent fuel from naval propulsion nuclear reactors and reactor testing programs; a small amount is generated by reprocessing fuel from research reactors. This acidic liquid waste is stored in underground stainless-steel tanks that are housed in concrete vaults. The waste is then converted to a calcine and stored retrievably in stainless-steel bins that are housed in reinforced concrete vaults.

2.2.3 HLW Inventories at HANF (DOE)

The 258,700 m^3 of alkaline HLW stored at HANF is categorized as liquid (25,100 m^3), sludge (46,000 m^3), and salt cake (93,000 m^3) that are stored in single-shell tanks and as slurry (94,700 m^3) that is stored in double-shell tanks. This waste, which has been accumulating since 1944, was generated during the reprocessing of production reactor fuel which recovered plutonium, uranium, and neptunium for defense and other national programs in past years. Most of the high-heat-emitting nuclides (^{90}Sr, ^{137}Cs, and their daughters) were removed from the old waste, converted to solids (strontium fluoride and cesium chloride), placed in double-walled capsules, and stored in a water basin. Currently, 1,328 cesium capsules (2.45 m^3) and 605 strontium capsules (1.08 m^3) require storage. Of the 1,328 cesium capsules, 959 are in storage at HANF, and 369 are on lease off-site for beneficial uses. Of the 605 strontium capsules, 601 are in storage at HANF, and 4 are on lease off-site for beneficial uses. The liquid, sludge, salt-cake, and slurry wastes are stored in underground concrete tanks with carbon steel liners. Current inventories of these wastes at HANF are listed in Tables 2.4 and 2.5.

2.2.4 HLW Inventories at WVDP (Commercial)

Reprocessing at the NFS plant was terminated in 1972, and no additional HLW has been generated since. As of December 31, 1992, the 1,550 m^3 of HLW stored at WVDP consist of 1,440 m^3 of alkaline waste (1,390 m^3 of liquid plus 50 m^3 of sludge), 50 m^3 of acidic waste, and 60 m^3 of an inorganic ion-exchange material (a zeolite) loaded with radioactive cesium (^{134}Cs, ^{135}Cs, and ^{137}Cs). The alkaline waste was generated by reprocessing commercial and Hanford N-Reactor spent fuels. As generated, the waste was acidic; treatment with excess sodium hydroxide resulted in the formation of an alkaline sludge. The small amount of acidic waste now in storage was generated by

reprocessing a batch of thorium-uranium fuel from the Indian Point-1 Reactor. Storage for the alkaline waste is provided in an underground carbon- steel tank, while storage for acidic waste is provided in an underground stainless-steel tank.

In May 1988, the processing of high-level alkaline liquid waste started at the WVDP. This liquid was decontaminated to LLW in the WVDP Supernatant Treatment System (STS) in preparation for the incorporation of all HLW at the WVDP into a glass. In the STS, an ion-exchange process, operated in a batch mode, is employed to remove cesium from alkaline liquid waste, as depicted in Fig. 2.8. The ion-exchange columns are located in the underground carbon-steel tank, which was originally installed as a backup tank for the storage of alkaline HLW. The sludge in the bottom of the tank has been mixed with the residual supernatant and an alkaline wash solution. The first four sludge-wash processing cycles are in progress. The wash solutions are also treated in the STS prior to incorporation in cement.

The washed sludge, acidic waste, and loaded zeolite will be combined and incorporated into a glass. The current inventories of HLW at WVDP are presented in Tables 2.4 and 2.5.

2.3 WASTE CHARACTERIZATION

A generic characterization of HLW at any site is difficult, because over the years several different flowsheets have been used for the processes that generated the wastes and several methods have been used to prepare the wastes for storage (e.g., evaporation and precipitation). In some instances, various types of wastes have been blended. However, representative data on chemical and radionuclide compositions are given in Tables 2.10–2.21 for current and projected HLW at SRS, ICPP, HANF, and WVDP. The information used to construct these tables was taken from refs. 1(a)–1(d), as well as from the references cited in the footnotes to the tables.

2.4 PROJECTIONS

Projected inventories (volume, radioactivity, and thermal power) for HLW are presented in Tables 2.6–2.8. These projections were generated by each site (based on the assumptions given below) and should be considered only as current best estimates. An estimate by each site[1] of a potential number of canisters of solidified HLW that may be generated by the site is shown in Table 2.3.

The HLW projections for SRS are based on the assumptions that (1) one reactor for producing plutonium or tritium was operating during 1992 and will continue operating through 2007; (2) the irradiated (spent) fuel from this reactor will be reprocessed; and (3) the Defense Waste Processing Facility (DWPF) will begin to produce a glass waste form (see flowsheet in Fig. C.3 of Appendix C) in 1996, following the schedule shown in Table 2.3. These assumptions continue to be followed for projection purposes since no revised versions are currently available. The HLW glass will be stored on-site until a national repository[2-4] becomes available. Current plans call for the DWPF to produce 5,462 canisters of glass from 1996 until the end of year 2015.

The HLW projections for ICPP are based on predictions of no fuel reprocessing and continued operation of waste management through the year 2030. A facility to immobilize newly generated HLW at ICPP is planned for operation by the early part of the next century.[5] It will also be capable of processing the stored calcine. Evaluations of waste immobilization processes are continuing at ICPP, the identification of a reference waste form (glass, glass/ceramic, etc.) and process is scheduled for completion in the 1990s. The projections of HLW presented in Tables 2.6–2.8 for ICPP are based on waste immobilization in a glass/ceramic form.

The HLW projections for HANF are based on the assumptions that (1) the fuel reprocessing plant is not restarted and (2) the irradiated fuel remains in wet storage. A Hanford Waste Vitrification Plant (HWVP) is to begin operation in 1999.[5-6] The planned operations for the HWVP are discussed in ref. 7. Estimates of the number of canisters of HLW incorporated in borosilicate glass that might be generated annually by the HWVP are given in Table 2.3. The projections of HLW given in Tables 2.6–2.8 for HANF do not include vitrification because material balances for such processes are not yet available. At the WVDP, vitrification of the HLW (Fig. 2.8) is scheduled to begin in 1996 and to be completed in 1998.

The cost for the disposal of DOE HLW in a national repository will be paid by DOE into the Nuclear Waste Fund. Reference 8 states that the number of canisters used in the estimates of this cost will be published in the IDB. Table 2.3 includes potential production schedules for canisters which are not intended for use in DOE disposal cost estimates.

2.5 REFERENCES

1. U.S. Department of Energy, Waste Management Information System (WMIS), DOE site HLW data submittals (Attachment 7) issued, received, and maintained by the Hazardous Waste Remedial Actions Program (HAZWRAP), Martin Marietta Energy Systems, Inc., submitted to the IDB Program during August 1993–February 1994. The following HLW submittals from WMIS were received, reviewed, analyzed, and integrated by the IDB Program. Preceding each submittal is the site (in parentheses) to which it refers.

   a. (SRS) M. G. O'Rear, DOE Savannah River Operations Office, Aiken, South Carolina, memorandum to the DOE/EM Director of the Office of Technical Support (DOE/EM-35), Washington, D.C., "Department of Energy Waste Inventory Data Systems," dated Sept. 29, 1993.

   b. (INEL) D. A. Knecht, Westinghouse Idaho Nuclear Company, Inc., Idaho National Engineering Laboratory, Idaho Falls, Idaho, facsimile to H. W. Godbee, Oak Ridge National Laboratory, Oak Ridge, Tennessee, dated Feb. 15, 1994.

   c. (HANF) R. D. Wojtasek, Westinghouse Hanford Company, Hanford Site, Richland, Washington, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Request for Office of Waste Management, Waste Data Information Update," 9305688B R1, dated Aug. 30, 1993.

   d. (WVDP) J. P. Jackson, West Valley Nuclear Services Company, Inc., West Valley, New York, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Waste Information Update for Calendar Year 1992," dated Aug. 20, 1993.

2. U.S. Congress, The Nuclear Waste Policy Act of 1982, Pub. L. 97–425, Sect. 8, Jan. 7, 1983, as amended.

3. Ronald Reagan, President of the United States, Washington, D.C., letter to John S. Herrington, Secretary of Energy, "Disposal of Defense Waste in a Commercial Repository," dated Apr. 30, 1985.

4. U.S. Congress, The Nuclear Waste Policy Amendments Act of 1987, Pub. L. 100–203, Title V, Subtitle A, Dec. 22, 1987.

5. U.S. Department of Energy, Office of Defense Waste and Transportation Management, *Defense Waste and Transportation Management Program Implementation Plan*, DOE/DP-0059, Washington, D.C. (August 1988).

6. Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, *Hanford Federal Facility Agreement and Consent Order*, EPA Docket Number 1089-03-040120, Ecology Docket Number 89-54, Richland, Washington (May 1989).

7. U.S. Department of Energy, *Final Environmental Impact Statement, Disposal of Hanford Defense High-Level, Transuranic, and Tank Waste, Hanford Site, Richland, Washington*, DOE/EIS-0113, DOE Richland Operations Office, Richland, Washington (December 1987).

8. U.S. Department of Energy, "Civilian Radioactive Waste Management: Calculating Nuclear Waste Fund Disposal Fees for Department of Energy Defense Program Waste; Notice," *Fed. Regist.* 56(161), 31508 (Aug. 20, 1987).

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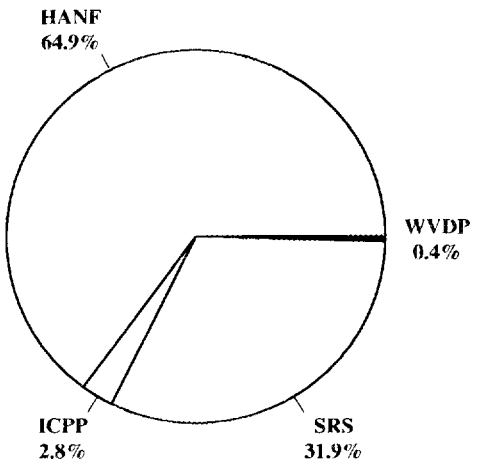


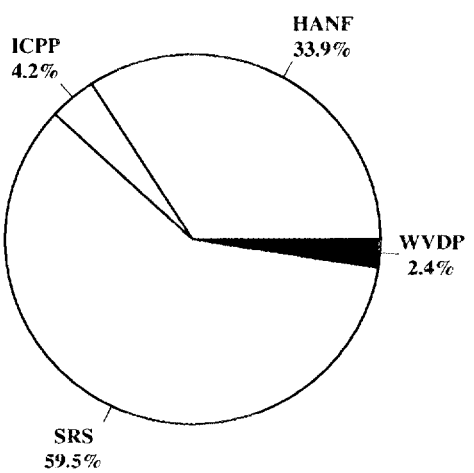
SITE	CUBIC METERS
SRS	1.269E+05
ICPP	1.120E+04
HANF	2.587E+05
WVDP	1.550E+03
TOTAL	3.984E+05

COMMERCIAL

DOE

Fig. 2.1. Total volume of HLW through 1992.

ORNL DWG 94-6688



SITE	CURIES
SRS	6.324E+08
ICPP	4.490E+07
HANF	3.607E+08
WVDP	2.590E+07
TOTAL	1.064E+09

COMMERCIAL

DOE

Fig. 2.2. Total radioactivity of HLW through 1992.

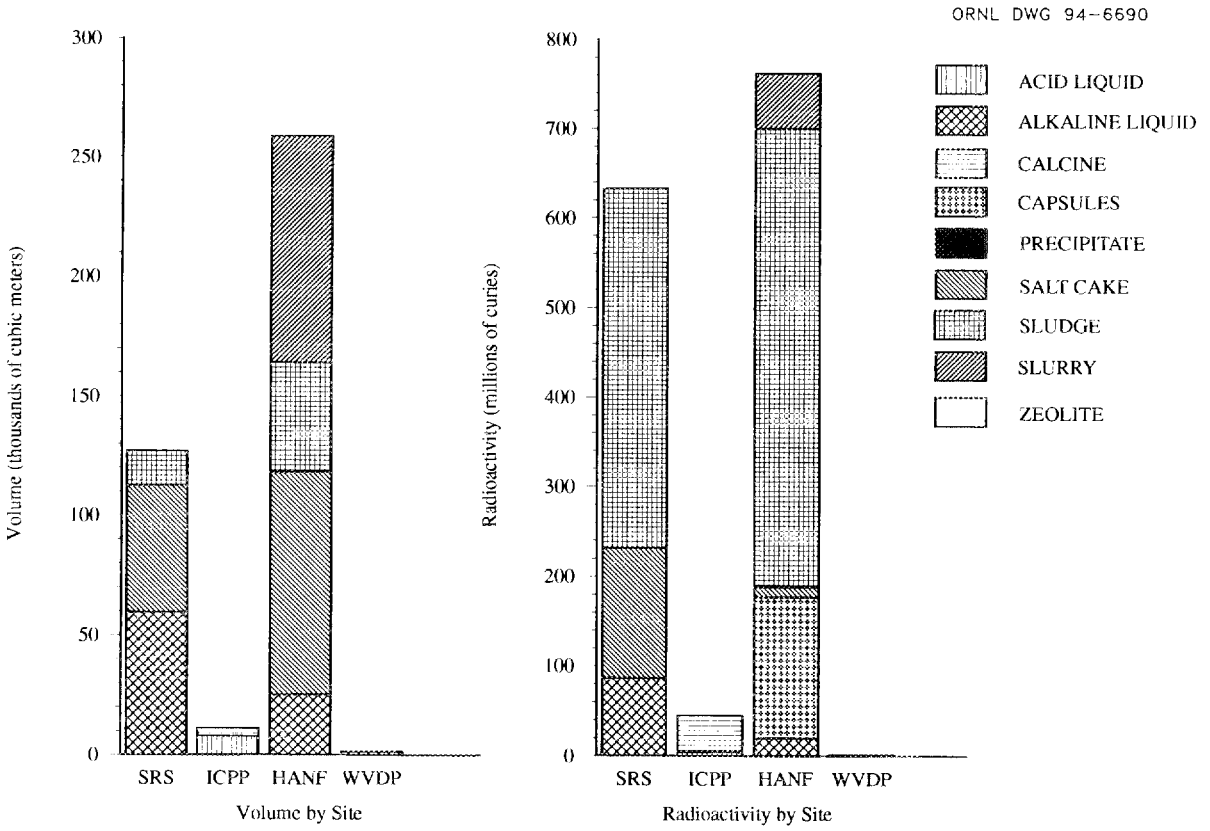


Fig. 2.3. Distribution of total volume and radioactivity of HLW by site and type through 1992.

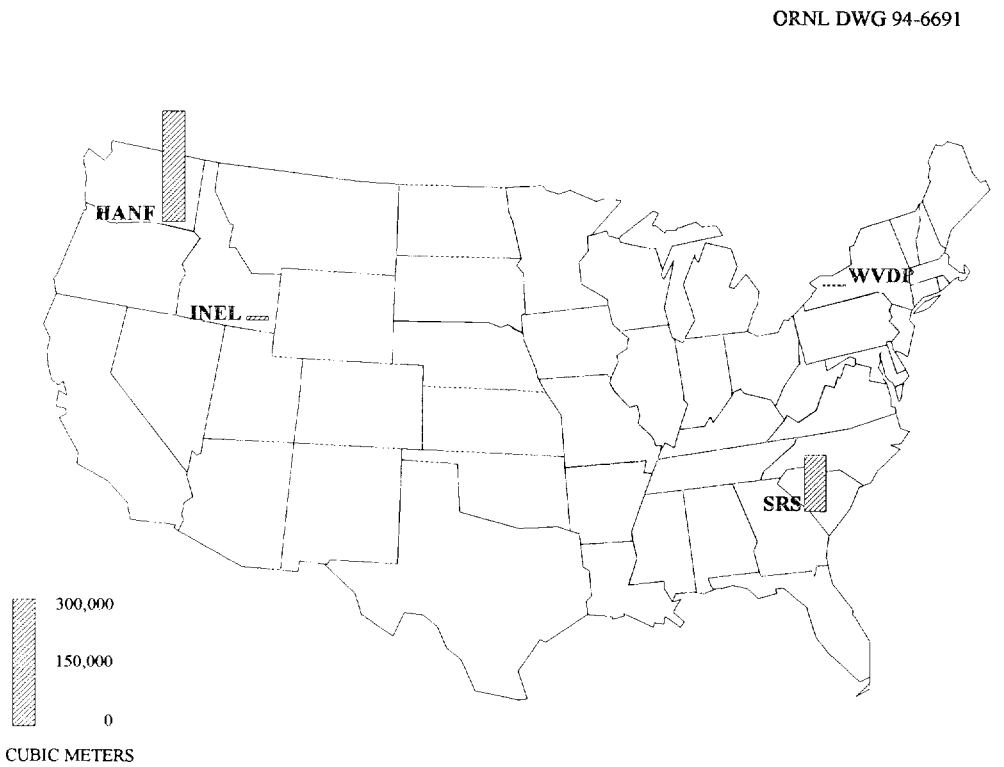


Fig. 2.4. Locations and total volumes of HLW through 1992.

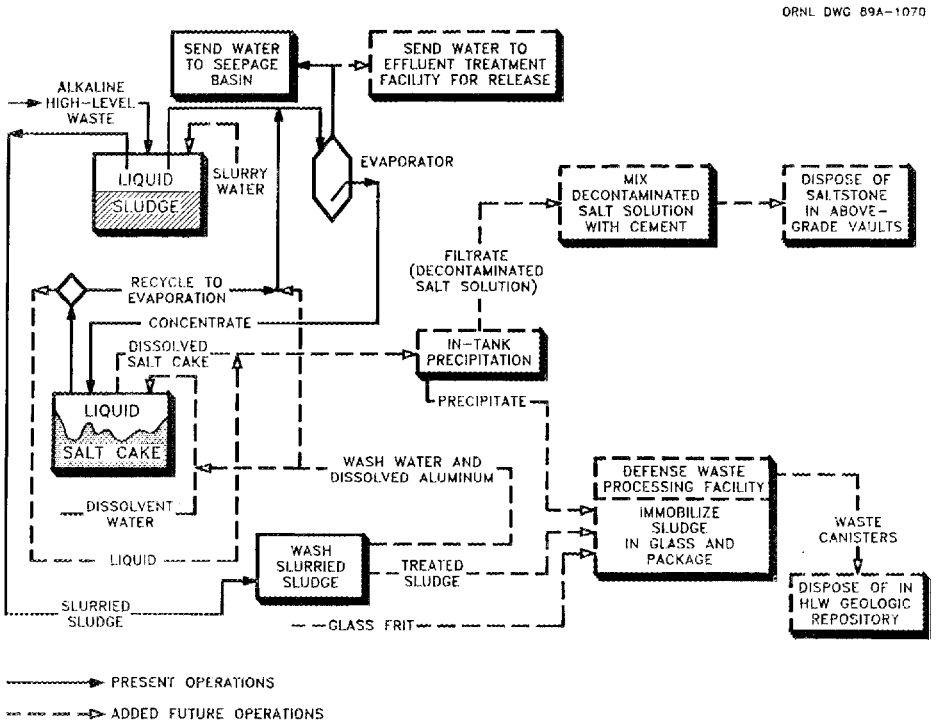


Fig. 2.5. Treatment methods for HLW in tanks and canisters at SRS.

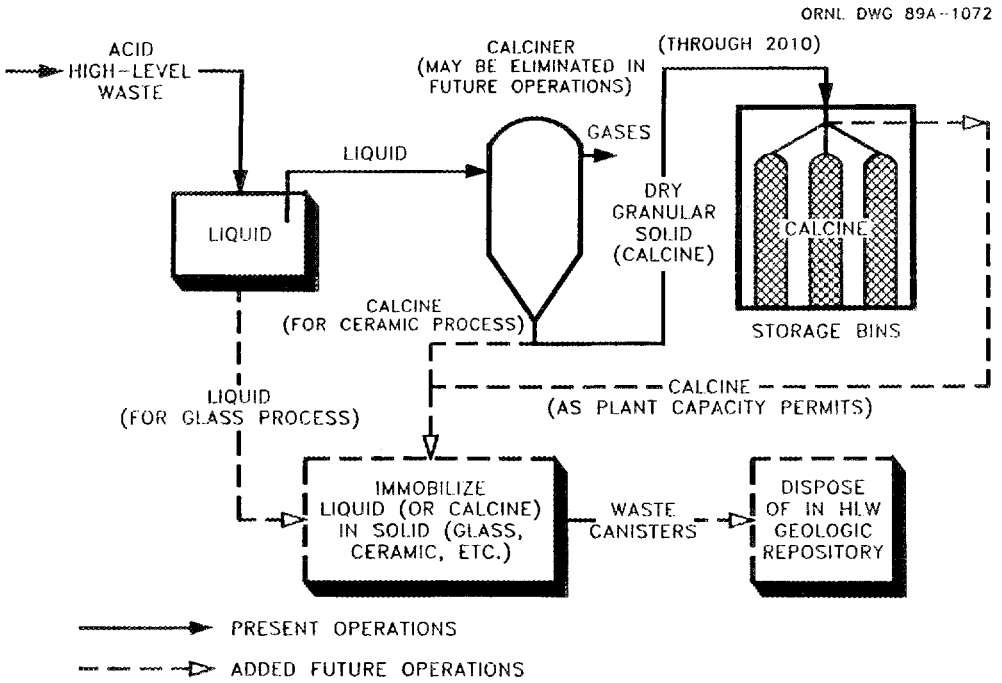


Fig. 2.6. Treatment methods for HLW in tanks, bins, and canisters at INEL.

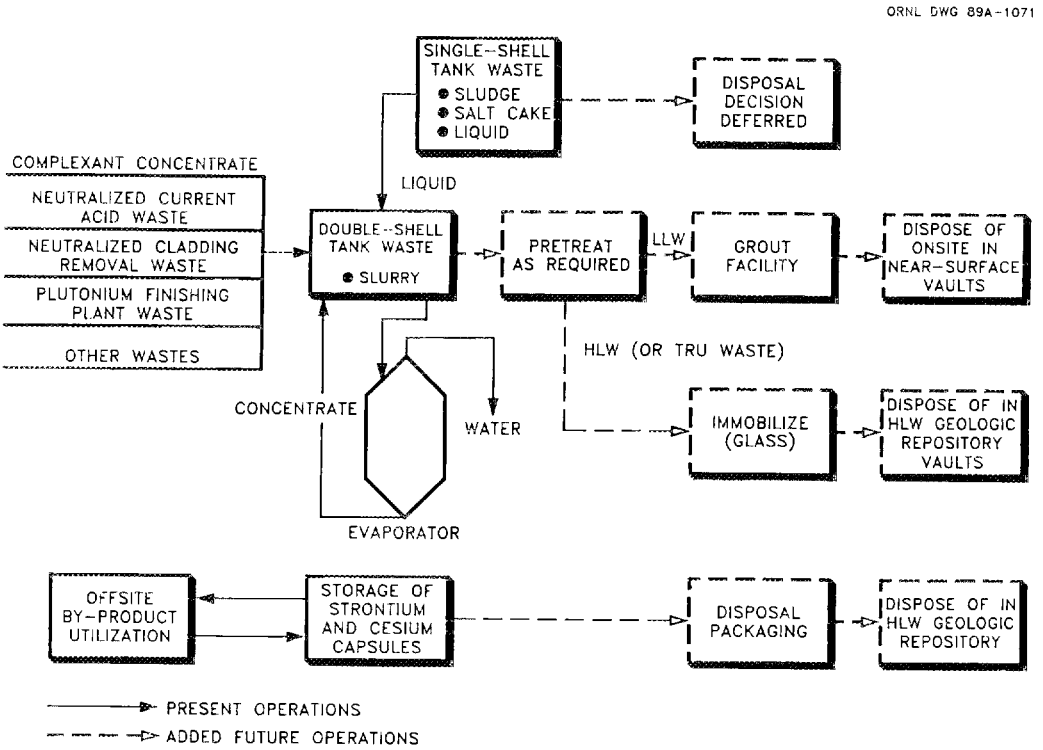


Fig. 2.7. Treatment methods for HLW in tanks, capsules, and canisters at HANF.

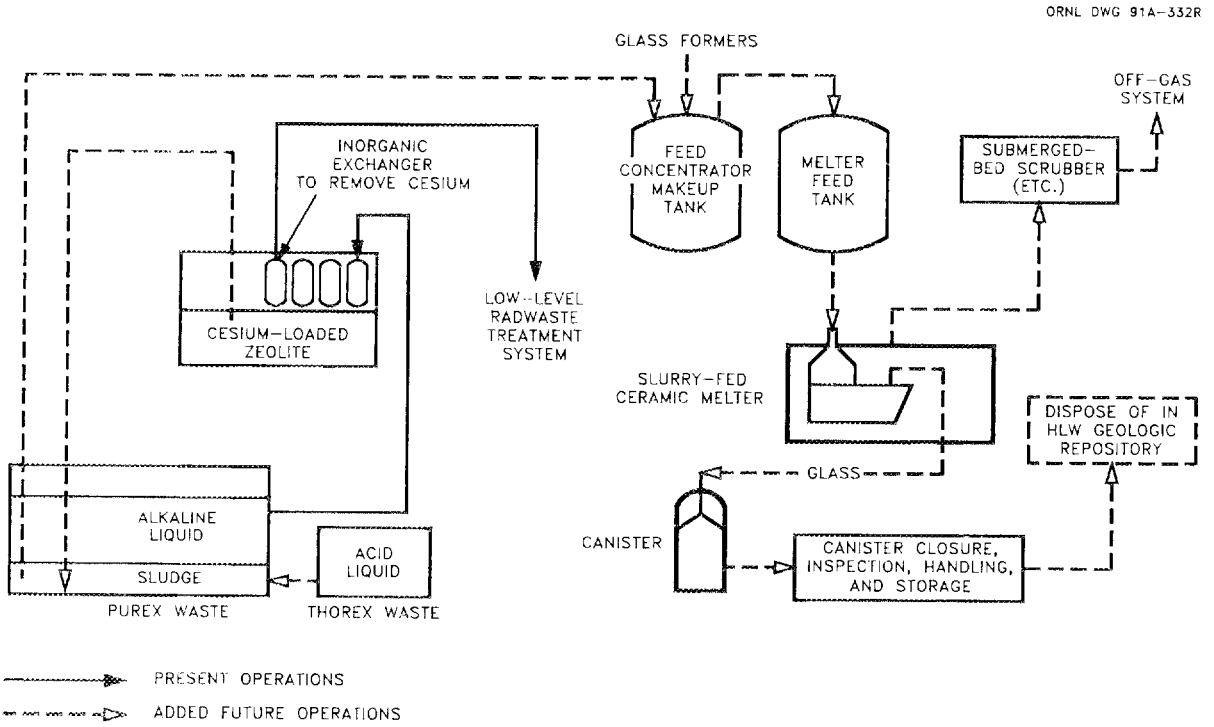


Fig. 2.8. Treatment methods for HLW in tanks and canisters at WVDP.

Table 2.1. Historical and projected cumulative volume, radioactivity, and thermal power of HLW stored in tanks, bins, and capsules by source[a,b,c]

End of calendar year	Cumulative		
	Volume (10^3 m^3)	Radioactivity (10^6 Ci)	Thermal power (10^3 W)
	DOE (SRS, ICPP, and HANF)		
1980	295	1,310	3,298
1981	305	1,577	4,748
1982	340	1,317	3,918
1983	351	1,248	3,653
1984	361	1,397	4,226
1985	355	1,465	4,466
1986	364	1,417	4,475
1987	379	1,277	3,750
1988	383	1,174	3,380
1989	379	1,081	3,072
1990	397	1,015	2,876
1991	395	971	2,758
1992	397	1,038	2,896
1993	417	1,004	2,802
1994	382	939	2,598
1995	362	912	2,526
1996	361	862	2,397
1997	356	776	2,187
1998	354	724	2,059
1999	345	683	1,952
2000	342	650	1,863
2001	339	619	1,776
2002	336	594	1,703
2003	332	570	1,632
2004	343	558	1,590
2005	342	536	1,523
2006	331	518	1,463
2007	327	481	1,361
2008	326	447	1,262
2009	320	417	1,174
2010	318	386	1,084
2011	314	362	1,012
2012	312	339	948
2013	309	311	874
2014	307	295	827
2015	304	278	781
2016	302	269	756
2017	302	261	733
2018	302	253	713
2019	302	246	692
2020	302	239	671
2021	302	232	652
2022	302	226	635
2023	302	220	619
2024	302	214	603
2025	302	209	588
2026	301	204	574
2027	301	199	561
2028	301	195	548
2029	301	190	535
2030	301	186	523
	Commercial (WVDP)		
1980	2.2	33.4	96.9
1981	2.2	32.7	94.7
1982	2.2	31.9	92.6

Table 2.1 (continued)

End of calendar year	Cumulative Volume (10^3 m^3)	Cumulative Radioactivity (10^6 Ci)	Cumulative Thermal power (10^3 W)
	Commercial (WVDP) (continued)		
1983	2.2	31.2	90.5
1984	2.2	30.5	88.4
1985	2.2	29.8	86.4
1986	2.2	29.1	84.5
1987	2.2	28.4	81.2
1988	2.1	27.9	80.8
1989	2.4	27.3	79.3
1990	1.2	26.7	77.0
1991	1.7	26.2	75.9
1992	1.6	25.9	79.1
1993	2.5	25.3	77.1
1994	2.5	24.7	75.3
1995	1.3	24.1	73.5
1996	0.6	15.8	48.1
1997	0.3	7.6	23.2
	Total		
1980	297	1,344	3,394
1981	307	1,610	4,843
1982	342	1,349	4,011
1983	353	1,279	3,743
1984	363	1,427	4,315
1985	357	1,495	4,553
1986	366	1,446	4,560
1987	381	1,305	3,831
1988	385	1,202	3,460
1989	381	1,108	3,151
1990	398	1,042	2,953
1991	397	997	2,833
1992	398	1,064	2,975
1993	420	1,030	2,879
1994	384	964	2,673
1995	364	936	2,600
1996	362	877	2,445
1997	357	783	2,211
1998	354	724	2,059
1999	345	683	1,952
2000	342	650	1,863
2001	339	619	1,776
2002	336	594	1,703
2003	332	570	1,632
2004	343	558	1,590
2005	342	536	1,523
2006	331	518	1,463
2007	327	481	1,361
2008	326	447	1,262
2009	320	417	1,174
2010	318	386	1,084
2011	314	362	1,012
2012	312	339	948
2013	309	311	874
2014	307	295	827
2015	304	278	781
2016	302	269	756
2017	302	261	733
2018	302	253	713
2019	302	246	692
2020	302	239	671

Table 2.1 (continued)

End of calendar year	Cumulative		
	Volume (10^3 m^3)	Radioactivity (10^6 Ci)	Thermal power (10^3 W)
	Total (continued)		
2021	302	232	652
2022	302	226	635
2023	302	220	619
2024	302	214	603
2025	302	209	588
2026	301	204	574
2027	301	199	561
2028	301	195	548
2029	301	190	535
2030	301	186	523

[a]Historical inventories for HLW are taken from the previous edition of this report [i.e., DOE/RW-0006, Rev. 8 (October 1992)]. The inventories for 1992, and the projections through 2030 are taken from ref. 1.

[b]Annual rates for volume are not given because they can fluctuate widely depending upon waste generation (or nongeneration) coupled with waste management operations such as evaporation and/or calcination. Annual rates for radioactivity and thermal power are not given for these same reasons and because radioactive decay, especially for short-lived activity, causes apparent perturbations.

[c]Radioactive decay is taken into account by each site through isotope generation/depletion codes.

Table 2.2. Projected volume, radioactivity, and thermal power of HLW glass and glass/ceramic stored in canisters by source[a]

End of calendar year	Volume (10^3 m^3)		Radioactivity (10^6 Ci)		Thermal power (10^3 W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
			DOE (SRS and ICPP)[b]			
1996	0.05	0.05	11	11	27	27
1997	0.08	0.13	61	71	147	175
1998	0.08	0.20	33	105	82	258
1999	0.08	0.28	12	117	30	289
2000	0.16	0.44	21	137	59	352
2001	0.24	0.69	19	156	62	419
2002	0.25	0.93	15	172	51	472
2003	0.19	1.13	14	185	48	522
2004	0.15	1.28	12	198	42	567
2005	0.18	1.46	14	212	51	620
2006	0.22	1.68	24	236	77	701
2007	0.25	1.93	32	269	99	801
2008	0.35	2.29	31	299	97	901
2009	0.41	2.69	26	326	83	986
2010	0.50	3.19	28	354	89	1,079
2011	0.59	3.77	16	370	56	1,136
2012	0.68	4.46	15	385	44	1,177
2013	0.84	5.30	27	413	79	1,261
2014	0.95	6.25	12	424	34	1,289
2015	1.11	7.36	16	440	49	1,341
2016	1.14	8.50	12	443	36	1,346
2017	1.29	9.79	14	448	39	1,355
2018	1.45	11.24	15	454	42	1,367
2019	1.60	12.84	16	461	46	1,392
2020	1.76	14.60	17	470	50	1,410
2021	1.91	16.52	18	479	53	1,443
2022	2.07	18.59	18	489	53	1,470
2023	2.23	20.81	18	501	54	1,499
2024	2.38	23.20	19	511	54	1,529
2025	2.53	25.72	19	522	54	1,561
2026	2.65	28.37	18	533	53	1,591
2027	2.77	31.14	18	543	52	1,622
2028	2.90	34.04	18	553	51	1,651
2029	3.02	37.06	17	564	50	1,681
2030	3.14	40.20	17	575	49	1,709
			Commercial (WVDP)[c]			
1996		0.08		7.8		23.7
1997		0.16		15.3		45.7
1998		0.24		22.3		65.9
1999		0.24		21.8		64.4
2000		0.24		21.3		62.9
2001		0.24		20.8		61.4
2002		0.24		20.3		60.0
2003		0.24		19.8		58.6
2004		0.24		19.4		57.2
2005		0.24		18.9		55.9
2006		0.24		18.5		54.6
2007		0.24		18.1		53.3
2008		0.24		17.6		52.1
2009		0.24		17.2		50.9
2010		0.24		16.8		49.7
2011		0.24		16.5		48.5
2012		0.24		16.1		47.4

Table 2.2 (continued)

End of calendar year	Volume (10^3 m^3)		Radioactivity (10^6 Ci)		Thermal power (10^3 W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
			Commercial (WVDP)[c] (continued)			
2013		0.24		15.7		46.3
2014		0.24		15.4		45.2
2015		0.24		14.9		44.2
2016		0.24		14.6		43.1
2017		0.24		14.2		42.1
2018		0.24		13.9		41.2
2019		0.24		13.6		40.2
2020		0.24		13.3		39.3
2021		0.24		13.0		38.4
2022		0.24		12.7		37.5
2023		0.24		12.4		36.6
2024		0.24		12.1		35.8
2025		0.24		11.8		34.9
2026		0.24		11.5		34.1
2027		0.24		11.2		33.4
2028		0.24		11.0		32.6
2029		0.24		10.7		31.8
2030		0.24		10.5		31.1
			Total			
1996	0.05	0.13	11	19	27	50
1997	0.08	0.28	61	87	147	221
1998	0.08	0.44	33	127	82	324
1999	0.08	0.52	12	139	30	354
2000	0.16	0.68	21	159	59	415
2001	0.24	0.93	19	177	62	480
2002	0.25	1.17	15	192	51	532
2003	0.19	1.37	14	205	48	581
2004	0.15	1.52	12	217	42	624
2005	0.18	1.70	14	231	51	676
2006	0.22	1.92	24	255	77	756
2007	0.25	2.17	32	287	99	854
2008	0.35	2.53	31	317	97	953
2009	0.41	2.93	26	343	83	1,037
2010	0.50	3.43	28	371	89	1,129
2011	0.59	4.01	16	387	56	1,185
2012	0.68	4.70	15	401	44	1,224
2013	0.84	5.54	27	428	79	1,308
2014	0.95	6.49	12	440	34	1,334
2015	1.11	7.60	16	454	49	1,385
2016	1.14	8.74	12	458	36	1,389
2017	1.29	10.03	14	463	39	1,397
2018	1.45	11.48	15	468	42	1,408
2019	1.60	13.08	16	474	46	1,432
2020	1.76	14.84	17	483	50	1,449
2021	1.91	16.76	18	492	53	1,481
2022	2.07	18.83	18	501	53	1,508
2023	2.23	21.05	18	513	54	1,536
2024	2.38	23.44	19	523	54	1,565
2025	2.53	25.96	19	533	54	1,596
2026	2.65	28.61	18	544	53	1,625
2027	2.77	31.38	18	555	52	1,655
2028	2.90	34.28	18	564	51	1,684
2029	3.02	37.30	17	575	50	1,713
2030	3.14	40.44	17	586	49	1,740

Table 2.2 (continued)

[a]Glass and glass/ceramic may be in storage at the site, in transit to a repository, or in a repository.

[b]Taken from, or calculated with, data given in refs. 1(a) and 1(b). At SRS, the DWPF (see Fig. C.3 in Appendix C) canisters are 2 ft in diam by 10 ft in length. Each is assumed to be filled with 0.625 m^3 of glass [i.e., 85% of the usable capacity (0.735 m^3)] made with HLW from the reprocessing of spent fuel at SRS. The glass incorporates 36 wt % oxides from waste (28 wt % from spent fuel and 8 wt % from processing chemicals) and 64 wt % oxides from nonradioactive glass frit. Volumes reported are for the glass waste form and not the canisters (see Table 2.3 for the number of canisters and Table 2.6 for the volume of glass). At ICPP, each canister is assumed to contain nominally 0.92 m^3 of a glass/ceramic waste form made with HLW from the reprocessing of spent fuel. See Table 2.3 for the number of canisters and Table 2.6 for the volume of glass/ceramic at ICPP.

[c]Taken from data given in ref. 1(d). It is assumed that 300 canisters (2 ft in diam by 10 ft in length) are filled with waste glass during 1996-1998 and that each canister contains 0.8 m^3 of glass at the filling temperature.

Table 2.3. Estimated potential number of HLW canisters by source[a]

	Number of canisters							
	SRS[b]		ICPP[c]		HANF[d]		WVDP[e]	
Year	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1996	73	73					100	100
1997	125	198					100	200
1998	125	324					100	300
1999	124	448						300
2000	257	706			290	290		300
2001	387	1,094			290	580		300
2002	390	1,484			320	900		300
2003	307	1,792			320	1,220		300
2004	243	2,035			320	1,540		300
2005	286	2,322			320	1,860		300
2006	351	2,673			320	2,180		300
2007	352	3,026	27	27	320	2,500		300
2008	402	3,428	82	110	320	2,820		300
2009	396	3,824	136	246	320	3,140		300
2010	403	4,228	215	461	320	3,460		300
2011	319	4,548	335	796	320	3,780		300
2012	249	4,797	458	1,254	320	4,100		300
2013	258	5,056	587	1,842	320	4,420		300
2014	203	5,259	717	2,559	320	4,740		300
2015	203	5,462	852	3,410	320	5,060		300
2016		5,462	988	4,399	320	5,380		300
2017		5,462	1,123	5,522	320	5,700		300
2018		5,462	1,259	6,781	320	6,020		300
2019		5,462	1,394	8,175	320	6,340		300
2020		5,462	1,530	9,705	320	6,660		300
2021		5,462	1,660	11,371	320	6,980		300
2022		5,462	1,801	13,172	320	7,300		300
2023		5,462	1,936	15,108	320	7,620		300
2024		5,462	2,072	17,180	320	7,940		300
2025		5,462	2,196	19,377	320	8,260		300
2026		5,462	2,304	21,680	320	8,580		300
2027		5,462	2,411	24,091	320	8,900		300
2028		5,462	2,518	26,609	320	9,220		300
2029		5,462	2,626	29,235	320	9,540		300
2030		5,462	2,733	31,967	320	9,860		300

[a]Taken from ref. 1. The projected waste volume, radioactivity, and thermal power values at SRS, ICPP, and WVDP are consistent with the number of canisters reported because these sites have developed material balances for their solidification facilities. The number of canisters at HANF is not related to projected waste volumes, radioactivity, and thermal power values because material balances for the solidification facility at this site are still in the planning stage.

[b]Canisters are 2 ft in diam by 10 ft in length. Each canister is assumed to contain 0.625 m^3 of glass made with HLW from the reprocessing of spent fuel at SRS. The glass incorporates 36 wt % oxides from waste (28 wt % from spent fuel and 8 wt % from processing chemicals) and 64 wt % oxides from nonradioactive glass frit.

[c]Dimensions of canisters have not been set. Each canister is assumed to contain nominally 0.98 m^3 of a glass/ceramic waste form.

[d]Canisters are 2 ft in diam by 10 ft in length. Each canister of vitrified waste is assumed to contain 0.62 m^3 of a borosilicate glass incorporating waste solids.

[e]Canisters are 2 ft in diam by 10 ft in length. Each canister is assumed to contain 0.8 m^3 of a borosilicate glass incorporating waste solids.

Table 2.4. Current volume of HLW in storage by site through 1992

Site[a]	Volume, 10^3 m^3									
								Capsules[d]		
	Liquid	Sludge	Salt cake	Slurry[b]	Calcine	Precipitate[c]	Zeolite	Sr	Cs	Total
DOE[e]										
SRS	59.3	14.3	53.1	f	f	0.2	f	f	f	126.9
ICPP	7.7	f	f	f	3.5	f	f	f	f	11.2
HANF[g]	25.1	46.0	93.0	94.7	f	f	f	0.00108	0.00245	258.7
Subtotal	92.1	60.3	146.1	94.7	3.5	0.2	f	0.00108	0.00245	396.8
Commercial[h]										
WVDP										
Acid waste	0.05	f	f	f	f	f	f	f	f	0.05
Alkaline waste	1.39	0.05	f	f	f	f	f	f	f	1.44
Zeolite waste	f	f	f	f	f	f	0.06	f	f	0.06
Subtotal	1.44	0.05	f	f	f	f	0.06	f	f	1.55
Total	93.54	60.3	146.1	94.7	3.5	0.2	0.06	0.00108	0.00245	398.35

[a]SRS is Savannah River Site, ICPP is Idaho Chemical Processing Plant, HANF is Hanford Site, and WVDP is West Valley Demonstration Project.

[b]Slurry refers to all waste (regardless of when it was generated) contained in double-shell tanks.

[c]Precipitate (non-Newtonian fluid) from the in-tank precipitation process.

[d]Capsules contain either strontium (^{90}Sr-^{90}Y) fluoride or cesium (^{137}Cs-^{137m}Ba) chloride.

[e]Taken from refs. 1(a)-1(c).

[f]Not applicable.

[g]Hanford single-shell tank wastes (i.e., liquid, sludge, and salt cake) and double-shell tank wastes (i.e., slurry) consist of HLW, TRU waste, and several LLWs. However, in storage practice, all tanks are managed as if they contain only HLW. Thus, their contents are included in the HLW inventory.

[h]Taken from ref. 1(d).

Table 2.5. Current radioactivity of HLW in storage by site through 1992

Site[b]	Radioactivity,[a] 10^6 Ci										Thermal power (10^6 W)
								Capsules[e]			
	Liquid	Sludge	Salt cake	Slurry[c]	Calcine	Precipitate[d]	Zeolite	Sr	Cs	Total	
DOE[f]											
SRS	86.4	400.9	145.0	g	g	0.1	g	g	g	632.4	1.724
ICPP	4.5	g	g	g	40.4	g	g	g	g	44.9	0.130
HANF[h]	19.9	110.3	11.5	62.1	g	g	g	49.0	108.0	360.7	1.041
Subtotal	110.8	511.2	156.5	62.1	40.4	0.1	g	49.0	108.0	1,038.0	2.894
Commercial[i]											
WVDP											
Acid waste	1.8	g	g	g	g	g	g	g	g	1.8	0.010
Alkaline waste	1.9	11.6	g	g	g	g	g	g	g	13.5	0.043
Zeolite waste	g	g	g	g	g	g	10.6	g	g	10.6	0.026
Subtotal	3.7	11.6	g	g	g	g	10.6	g	g	25.9	0.079
Total	114.5	522.8	156.5	62.1	40.4	0.1	10.6	49.0	108.0	1,063.9	2.973

[a]Calculated values allowing for radioactive decay.

[b]SRS is Savannah River Site, ICPP is Idaho Chemical Processing Plant, HANF is Hanford Site, and WVDP is West Valley Demonstration Project.

[c]Slurry refers to all waste (regardless of when it was generated) contained in double-shell tanks.

[d]Precipitate (non-Newtonian fluid) from the in-tank precipitation process.

[e]Capsules contain either strontium (^{90}Sr-^{90}Y) fluoride or cesium (^{137}Cs-^{137m}Ba) chloride. Radioactivity values are for the pair, that is, parent plus daughter radionuclide.

[f]Taken from refs. 1(a)-1(c).

[g]Not applicable.

[h]Hanford single-shell tank wastes (i.e., liquid, sludge, and salt cake) and double-shell tank wastes (i.e., slurry) consist of HLW, TRU waste, and several LLWs. However, in storage practice, all tanks are managed as if they contain only HLW. Thus, their contents are included in the HLW inventory.

[i]Taken from ref. 1(d).

Table 2.6. Historical and projected total volume of HLW in storage by site through 2030[a]

End of calendar year	Volume, 10^3 m^3									
	Liquid	Sludge	Salt cake	Slurry	Calcine	Precipitate	Zeolite	Capsules[b]	Glass or glass/ceramic[c]	Total
					Savannah River Site					
1980	59.8	10.5	26.4							96.7
1985	71.3	13.8	37.6							122.7
1986	72.8	13.8	41.2							127.8
1987	63.2	13.8	50.5			0.1				127.6
1988	64.2	14.1	50.0			0.1				128.5
1989	53.3	13.8	54.8			0.1				122.1
1990	61.3	14.8	55.5			0.1				131.7
1991	57.2	14.5	55.7			0.5				128.0
1992	59.3	14.3	53.1			0.2				126.9
1995	54.4	14.3	48.5			0.4				117.6
2000	51.6	12.5	30.6			0.1			0.4	95.2
2005	48.8	8.2	21.4			0.2			1.5	80.2
2010	46.3	3.2	13.5			0.3			2.7	66.0
2015	44.9		3.8			0.4			3.4	52.6
2020	44.9		2.6			0.2			3.4	51.2
2025	44.9		2.6			0.2			3.4	51.2
2030	44.9		2.6			0.2			3.4	51.2
					Idaho Chemical Processing Plant					
1980	9.3				2.1					11.4
1985	7.1				3.0					10.1
1986	6.5				3.0					9.5
1987	8.9				3.0					11.9
1988	7.6				3.4					11.0
1989	8.5				3.5					12.0
1990	8.5				3.5					12.0
1991	6.8				3.6					10.4
1992	7.7				3.5					11.2
1995	7.8				3.7					11.5
2000	4.8				5.0					9.8
2005	5.8				5.0					10.8
2010	0.1				4.9				0.5	5.5
2015	0.0				3.8				3.9	7.7
2020	0.1				2.5				11.2	13.8
2025	0.1				1.3				22.3	23.7
2030	0.1				0.1				36.8	37.0

Table 2.6 (continued)

End of calendar year	Volume, 10^3 m^3									
	Liquid	Sludge	Salt cake	Slurry	Calcine	Precipitate	Zeolite	Capsules[b]	Glass or glass/ceramic[c]	Total
					Hanford Site					
1980	39.0	49.0	95.0	4.0				0.0017		187.0
1985	28.1	46.0	93.0	55.1				0.0040		222.1
1986	28.0	46.0	93.0	59.5				0.0040		226.4
1987	27.3	46.0	93.0	73.4				0.0040		239.7
1988	26.8	46.0	93.0	77.7				0.0036		243.4
1989	26.5	46.0	93.0	79.3				0.0036		244.8
1990	26.4	46.0	93.0	88.2				0.0036		253.6
1991	25.5	46.0	93.0	92.0				0.0035		256.4
1992	25.1	46.0	93.0	94.7				0.0035		258.7
1995	12.2	46.0	93.0	82.2				0.0035		233.3
2000	12.0	46.0	93.0	86.7				0.0035		237.6
2005	12.0	46.0	93.0	102.0				0.0035		252.9
2010	12.0	46.0	93.0	98.3				0.0035		249.3
2015	12.0	46.0	93.0	99.7				0.0035		250.7
2020	12.0	46.0	93.0	100.7				0.0035		251.6
2025	12.0	46.0	93.0	101.5				0.0035		252.4
2030	12.0	46.0	93.0	102.1				0.0035		253.0
					West Valley Demonstration Project					
1980	2.145	0.046								2.191
1985	2.145	0.046								2.191
1986	2.145	0.046								2.191
1987	2.145	0.046								2.191
1988	2.065	0.046					0.013			2.124
1989	2.305	0.046					0.031			2.382
1990	1.135	0.046					0.045			1.226
1991	1.620	0.057					0.052			1.729
1992	1.440	0.050					0.060			1.550
1995		1.310								1.310[d]
2000									0.240	0.240
2005									0.240	0.240
2010									0.240	0.240
2015									0.240	0.240
2020									0.240	0.240
2025									0.240	0.240
2030									0.240	0.240

[a]Historical inventories for HLW are taken from the previous edition of this report [i.e., DOE/RW-0006, Rev. 8 (October 1992)]. The inventories for 1992 and the projections through 2030 are taken from ref. 1.

[b]Capsules contain either strontium (^{90}Sr-^{90}Y) fluoride or cesium (^{137}Cs-^{137m}Ba) chloride.

[c]Glass is waste form for SRS and WVDP. Glass/ceramic is waste form for ICPP. Glass is most likely waste form for HANF.

[d]Volume is a mixture of acidic liquid, alkaline sludge, zeolite, and any residual liquid.

Table 2.7. Historical and projected total radioactivity of HLW in storage by site through 2030[a]

End of calendar year	Radioactivity, 10^6 Ci									
	Liquid	Sludge	Salt cake	Slurry	Calcine	Precipitate	Zeolite	Capsules[b]	Glass or glass/ceramic[c]	Total
					Savannah River Site					
1980	187.4	429.0	82.6							699.0
1985	93.3	561.3	186.8							841.4
1986	88.1	517.2	189.4							794.7
1987	105.2	460.4	168.2			0.2				734.0
1988	99.0	403.1	162.1			0.2				664.4
1989	94.6	351.2	152.8			0.3				598.9
1990	91.6	319.8	150.1			0.1				561.6
1991	89.0	302.1	146.4			0.1				537.6
1992	86.4	400.9	145.0			0.1				632.4
1995	84.0	307.4	131.0			15.4				537.8
2000	79.8	175.4	63.3			1.7			137.3	457.5
2005	68.0	141.0	31.9			3.0			212.1	456.0
2010	57.7	50.3	15.7			6.2			349.0	478.9
2015	49.5	1.4	0.8			7.6			393.0	452.3
2020	44.1	0.8	0.3			6.1			349.7	401.0
2025	39.4	0.9	0.2			5.5			309.5	355.4
2030	35.1	0.8	0.2			4.9			275.3	316.3
					Idaho Chemical Processing Plant					
1980	17.0				36.4					53.4
1985	21.7				47.7					69.4
1986	12.9				47.7					60.6
1987	14.3				48.2					62.5
1988	10.1				56.9					67.0
1989	11.5				56.9					68.4
1990	7.5				55.7					63.2
1991	2.4				57.0					59.4
1992	4.5				40.4					44.9
1995	1.9				40.1					42.0
2000	1.2				35.3					36.5
2005	1.1				31.1					32.2
2010					25.3				4.8	30.1
2015					13.7				46.5	60.2
2020					4.8				120.0	124.8
2025					0.8				212.0	212.8
2030					0.1				300.0	300.1

Table 2.7 (continued)

End of calendar year	Radioactivity, 10^6 Ci									
	Liquid	Sludge	Salt cake	Slurry	Calcine	Precipitate	Zeolite	Capsules[b]	Glass or glass/ceramic[c]	Total
Hanford Site										
1980	34.6	175.0	16.0	0.3				332.0		557.9
1985	26.2	130.5	13.6	171.2				212.8		554.2
1986	25.5	127.4	13.3	187.3				207.9		561.3
1987	24.4	124.4	12.9	115.8				203.1		480.6
1988	23.3	121.4	12.6	110.9				174.7		442.9
1989	22.6	118.5	12.4	89.6				170.8		413.8
1990	22.0	115.7	12.1	74.6				166.1		390.4
1991	20.8	113.0	11.8	66.9				161.2		373.6
1992	19.9	110.3	11.5	62.1				157.0		360.7
1995	9.0	102.7	10.7	62.9				146.4		331.7
2000	7.9	91.0	9.5	54.1				130.3		292.8
2005	7.0	80.8	8.5	47.6				115.9		259.8
2010	6.3	71.7	7.5	42.2				103.2		230.9
2015	5.6	63.6	6.7	37.6				91.8		205.3
2020	5.0	56.4	6.0	33.4				81.7		182.5
2025	4.4	50.2	5.3	29.8				72.7		162.4
2030	4.0	44.6	4.7	26.5				64.7		144.6
West Valley Demonstration Project										
1980	18.5	15.0								33.4
1985	16.4	13.3								29.8
1986	16.1	13.0								29.1
1987	15.7	12.7								28.4
1988	12.9	12.4					2.6			27.9
1989	8.5	12.2					6.6			27.3
1990	5.5	11.9					9.3			26.7
1991	4.1	11.6					10.5			26.2
1992	3.7	11.6					10.6			25.9
1995		24.1								24.1[d]
2000									21.3	21.3
2005									18.9	18.9
2010									16.8	16.8
2015									14.9	14.9
2020									13.3	13.3
2025									11.8	11.8
2030									10.5	10.5

[a]Historical inventories for HLW are taken from the previous edition of this report [i.e., DOE/RW-0006, Rev. 8 (October 1992)]. The inventories for 1992 and the projections through 2030 are taken from ref. 1.

[b]Capsules contain either strontium (^{90}Sr-^{90}Y) fluoride or cesium (^{137}Cs-^{137m}Ba) chloride.

[c]Glass is waste form for SRS and WVDP. Glass/ceramic is waste form for ICPP. Glass is most likely waste form for HANF.

[d]Radioactivity is contained in a mixture (i.e., acidic liquid, alkaline sludge, zeolite, and any residual liquid).

Table 2.8. Historical and projected total thermal power of HLW in storage by site through 2030[a]

End of calendar year	Thermal power, 10^3 W									
	Liquid	Sludge	Salt cake	Slurry	Calcine	Precipitate	Zeolite	Capsules[b]	Glass or glass/ceramic[c]	Total
					Savannah River Site					
1980	213.5	1,440.5	396.0							2,050.0
1985	264.3	1,782.7	490.2							2,537.2
1986	302.2	1,794.1	479.0							2,575.3
1987	279.8	1,438.9	432.8			0.4				2,151.9
1988	231.9	1,280.5	370.9			0.4				1,883.7
1989	217.7	1,105.8	349.5			0.7				1,673.7
1990	209.0	1,015.6	341.7			0.4				1,566.7
1991	203.0	971.0	335.0			0.3				1,509.3
1992	197.0	1,194.0	333.0			0.3				1,724.3
1995	193.0	912.0	301.0			35.2				1,441.2
2000	182.0	572.0	145.0			3.9			352.4	1,255.3
2005	155.0	437.0	73.1			6.8			620.0	1,291.9
2010	132.0	154.1	36.1			14.1			1,065.0	1,401.3
2015	113.0	9.6	1.9			17.4			1,207.0	1,349.0
2020	101.0	8.2	0.6			14.0			1,063.0	1,186.8
2025	90.0	8.7	0.5			12.5			947.0	1,058.7
2030	80.2	8.4	0.5			11.1			840.0	940.2
					Idaho Chemical Processing Plant					
1980	53.8				115.2					169.0
1985	72.5				137.4					210.0
1986	38.5				137.4					175.9
1987	43.5				139.0					182.5
1988	30.4				165.2					195.6
1989	34.3				164.9					199.2
1990	22.9				161.5					184.4
1991	7.0				165.0					172.0
1992	13.3				117.0					130.3
1995	5.6				117.0					122.6
2000	3.5				103.0					106.5
2005	3.1				90.2					93.3
2010					73.3				13.8	87.1
2015					39.8				134.0	173.8
2020					14.1				347.0	361.1
2025					2.3				614.0	616.3
2030					0.2				869.0	869.2

Table 2.8 (continued)

End of calendar year	Thermal power, 10^3 W									
	Liquid	Sludge	Salt cake	Slurry	Calcine	Precipitate	Zeolite	Capsules[b]	Glass or glass/ceramic[c]	Total
					Hanford Site					
1980	75.1	325.9	32.8	0.5				644.4		1,078.6
1985	65.9	428.3	38.1	604.0				582.7		1,719.0
1986	64.1	418.1	37.3	635.0				569.4		1,723.9
1987	61.2	408.2	36.4	353.4				556.2		1,415.4
1988	58.6	398.4	35.5	328.5				479.3		1,300.4
1989	56.7	389.0	34.7	249.7				468.8		1,199.0
1990	55.1	379.7	33.9	200.4				455.8		1,125.0
1991	52.1	370.7	33.1	177.7				442.6		1,076.2
1992	50.0	361.9	32.3	165.2				431.7		1,041.2
1995	22.6	336.7	30.1	170.3				402.5		962.3
2000	19.9	298.6	26.8	150.0				358.1		853.4
2005	17.7	264.9	23.8	133.2				318.6		758.2
2010	15.8	235.0	21.2	118.6				283.5		674.0
2015	14.1	208.5	18.8	105.7				252.2		599.3
2020	12.5	185.0	16.7	94.2				224.5		533.0
2025	11.2	164.5	14.9	84.0				199.7		474.3
2030	9.9	146.4	13.2	75.0				177.6		422.2
					West Valley Demonstration Project					
1980	47.8	49.1								96.9
1985	42.2	44.2								86.4
1986	41.3	43.2								84.5
1987	38.9	42.3								81.2
1988	32.9	41.5					6.5			80.8
1989	22.3	40.6					16.4			79.3
1990	14.1	39.7					23.1			77.0
1991	11.0	38.9					26.0			75.9
1992	10.0	42.7					26.4			79.1
1995		73.5								73.5[d]
2000									62.9	62.9
2005									55.9	55.9
2010									49.7	49.7
2015									44.2	44.2
2020									39.3	39.3
2025									34.9	34.9
2030									31.1	31.1

[a]Historical inventories for HLW are taken from the previous edition of this report [i.e., DOE/RW-0006, Rev. 8 (October 1992)]. The inventories for 1992 and the projections through 2030 are taken from ref. 1.

[b]Capsules contain either strontium (^{90}Sr-^{90}Y) fluoride or cesium (^{137}Cs-^{137m}Ba) chloride.

[c]Glass is waste form for SRS and WVDP. Glass/ceramic is waste form for ICPP. Glass is most likely waste form for HANF.

[d]This thermal power is from the decay of radionuclides in a mixture (i.e., acidic liquid, alkaline liquid, zeolite, and residual liquid) to be incorporated into glass during 1995-1997.

Table 2.9. Significant revisions and changes in the current values for HLW compared to the values in the previous year[a,b]

Waste characteristics	1992 values[a]	Significant revisions and changes	1994 values[b]	Reasons for significant changes and revisions or for none
		Savannah River Site		
Volume and radioactivity (liquid, sludge, salt cake, and precipitate)	See Tables 2.5 and 2.6	None	See Tables 2.4 and 2.5	No revisions. Changes are explained by routine plant operations and decay of radionuclides
		Idaho Chemical Processing Plant		
Radioactivity of calcine	See Table 2.6	Radioactivity of calcine decreased from 59.4×10^6 Ci to 44.9×10^6 Ci	See Table 2.5	Change may be connected with new computer program being used. Values are being reevaluated
		Hanford Site		
Volume and radioactivity (liquid, sludge, salt cake, slurry, and capsules)	See Tables 2.5 and 2.6	None	See Tables 2.4 and 2.5	No significant revisions. Changes are explained by routine plant operation
		West Valley Demonstration Project		
Volume and radioactivity (acid liquid, alkaline liquid, sludge, and zeolite)	See Tables 2.5 and 2.6	None	See Tables 2.4 and 2.5	Changes are explained by routine plant operations, by radioactive decay, and by continued refinement of inplant measurements

[a]Year shown is publication date of report. Data are for December 31, 1991. See tables and text cited in Chapter 2 of U.S. Department of Energy, Integrated Data Base for 1991: Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics, DOE/RW-0006, Rev. 5 (October 1992).

[b]Year shown is publication date of report. Data are for December 31, 1992.

Table 2.10. Representative chemical composition of current and future HLW at SRS[a]

Liquid		Sludge		Salt cake		Precipitate[b]		Glass	
Component	Wt %	Component	Wt %	Component	Wt %	Component	Wt %	Component	Wt %
Ag	Trace	$Fe(OH)_3$	11.8	$NaNO_3$	65.4	$K(C_6H_5)_4B$	9.0	SiO_2	45.6
Hg	Trace	MnO_2	2.0	$NaNO_2$	0.9	$NaNO_3$	0.7	Na_2O	11.0
Pb	Trace	$UO_2(OH)_2$	1.3	NaOH	3.4	Others	1.8	B_2O_3	10.3
U	Trace	$Al(OH)_3$	13.7	$NaAl(OH)_4$	7.8	H_2O	88.5	Fe_2O_3	7.0
F^-	0.003	AlO(OH)	5.2	Na_2CO_3	2.7		100.0	Al_2O_3	4.0
Fe	Trace	$CaCO_3$	1.5	Na_2SO_4	9.4			K_2O	3.6
Cl^-	0.023	$CaSO_4$	0.2	Na_3PO_4	Trace			Li_2O	3.2
OH^-	1.63	CaC_2O_4	0.2	NaF	0.2			FeO	3.1
NO_2^-	1.10	$Ni(OH)_2$	0.8	$Na_2C_2O_4$	0.1			U_3O_8	2.2
NO_3^-	9.63	HgO	0.4	Insolubles	3.7			MnO	2.0
$Al(OH)_4^-$	4.54	SiO_2	0.2	H_2O	6.4			Others	8.0
CO_3^{2-}	0.72	ThO_2	1.8		100.0				100.0
CrO_4^{2-}	0.014	$Ce(OH)_3$	0.2						
SO_4^{2-}	0.22	$ZrO(OH)_2$	0.2						
PO_4^{3-}	0.12	$Cr(OH)_3$	0.2						
NH_4^+	Trace	$Mg(OH)_2$	0.2						
Na^+	11.0	$NaNO_3$	1.1						
H_2O	71.0	NaOH	1.3						
	100.0	Zeolite	1.5						
		Others	1.2						
		H_2O	55.0						
			100.0						
Density (25°C), g/mL	1.1		1.4		1.9		1.05		2.85

[a]Taken from ref. 1(a).
[b]Precipitate (non-Newtonian fluid) from the in-tank precipitation process.

Table 2.11. Representative radionuclide composition of current (end of 1992) HLW forms and future (to be generated in 1996) HLW glass at SRS[a]

Radionuclide	Radioactivity, Ci					
	Liquid	Sludge	Salt cake	Precipitate	Total[b]	Glass[c]
^{90}Sr	7.68E+05	1.22E+08	1.22E+06	1.83E+03	1.24E+08	2.00E+05
^{90}Y	7.68E+05	1.22E+08	1.22E+06	1.83E+03	1.24E+08	1.98E+05
^{99}Tc[b]	6.69E+02	2.33E+04	2.22E+03		2.62E+04	2.90E+01
^{106}Ru	4.55E+04	1.86E+05	1.66E+03		2.33E+05	
^{106}Rh	6.33E+04	1.86E+05	1.66E+03		2.33E+05	
^{125}Sb	6.87E+04	1.70E+05	1.62E+03		2.40E+05	6.39E+00
^{137}Cs	4.37E+07	6.91E+07	7.44E+07	7.44E+04	1.87E+08	2.75E+06
^{137m}Ba	4.02E+07	6.35E+07	6.85E+07	6.85E+04	1.72E+08	2.53E+06
^{144}Ce	4.53E+04	9.74E+06	1.02E+03		9.79E+06	
^{144}Pr	4.53E+04	9.74E+06	1.92E+03		9.79E+06	
^{147}Pm	7.20E+05	1.79E+07	1.69E+05		1.88E+07	4.42E+02
^{233}U		2.60E-01			2.60E-01	1.90E-02
^{235}U		2.80E-01			2.80E-01	2.00E-02
^{238}U		2.20E+01			2.20E+01	4.30E-02
^{238}Pu		1.60E+06			1.60E+06	6.60E+02
^{239}Pu		2.30E+04			2.30E+04	3.50E+01
^{240}Pu		1.00E+04			1.00E+04	2.30E+01
^{241}Pu		1.40E+06			1.40E+06	1.30E+02
^{242}Pu		1.70E+01			1.70E+01	3.30E-02
^{244}Cm		1.40E+04			1.40E+04	1.70E+03
Total	8.64E+07	4.01E+08	1.45E+08	1.47E+05	6.32E+08	1.08E+07
Specific activity,[d] Ci/L	1.46	20.0	2.73	0.74	4.98	108

[a]Taken or calculated from ref. 1(a).
[b]Liquid, sludge, salt cake, and precipitate curies are as of December 31, 1992.
[c]Glass curies are as of December 31, 1996 (the first year glass is to be generated).
[d]Specific activity is defined in this table to be the radioactivity of a waste type at a given time divided by the volume of that waste type at the given time.

Table 2.12. Representative chemical composition of current and future HLW liquid at ICPP[a]

Component	Composition, wt %			
	Zirconium fluoride	Sodium bearing	Nonfluoride	Fluorinel
Al	1.3	0.8-1.6	1.51	0.742
B	0.15	0.005-0.01	0.003	0.241
Ca		0.03-0.2	0.27	
Cl^-		0.06-0.1	0.023	
Cd			1.42	
Cr			0.036	0.0087
F^-	3.4	0.005-0.06	0.032	5.99
Fe	0.04	0.05-0.09	0.19	0.023
H^+	1.12	0.03-0.15	0.12	0.18
K	1.12	0.03-0.15	0.33	
Mg			0.062	
Mn			0.048	0.0004
Na	0.12	2.1-4.0	1.31	
Ni			0.016	0.0049
NO_3^-	13.7	19.4-23.3	23.1	11.47
SO_4^{2-}		0.33-0.5	0.65	1.52
Zr	2.47			3.80
H_2O	76.6	76.6-69.2	70.9	76.0
	100.0	100.0	100.0	100.0
Density, g/mL	1.2	1.2-1.3	1.2	1.2

[a]Taken from U.S. Department of Energy, Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics, DOE/RW-0006, Rev. 1 (December 1985).

Table 2.13. Representative chemical composition of current and future HLW calcine at ICPP[a]

Component	Composition, wt %				
	Alumina	Zirconium fluoride	Zirconium-sodium blend	Stainless steel sulfate	Fluorinel-sodium blend
Al_2O_3	82.0-95.0	13.0-17.0	10.0-16.0	4.4	6.5-7.5
$Al_2(SO_4)_3$				81.0	
B_2O_3	0.5-2.0	3.0-4.0	2.0-3.0		3.0-3.2
CaO		2.0-4.0	13.0-17.0		3.3-3.6
CaF_2		50.0-56.0	33.0-39.0		46.0-49.0
Cd					6.0-6.5
Cr_2O_3				2.0	0.05
Fe_2O_3				7.0	0.2-0.3
Na_2O	1.3		6.0-8.0		10.0-15.0
NiO				0.9	0.02-0.03
NO_3^-	5.0-9.0	0.5-2.0	7.0-9.5		10.0-15.0
SO_4^{2-}					
ZrO_2		21.0-27.0	16.0-19.0		19.0-20.0
Miscellaneous	0.5-1.5	0.5-1.5	0.5-1.5	4.4	
Fission products and actinides	0.2-1.0	0.2-1.0	0.2-1.0	0.2-1.0	0.2-1.0
Density, g/mL	1.1	1.4	1.8	1.2	1.4

[a]Taken from U.S. Department of Energy, Spent Fuel And Radioactive Waste Inventories, Projections, and Characteristics, DOE/RW-0006, Rev. 1 (December 1985).

Table 2.14. Representative radionuclide composition of current HLW at ICPP[a]

Radionuclide	Radioactivity, Ci	
	Liquid	Calcine
^{90}Sr	1.03E+06	9.60E+06
^{90}Y	1.03E+06	9.60E+06
^{106}Ru	4.56E+03	7.48E+01
^{106}Rh	4.56E+03	7.48E+01
^{134}Cs	3.46E+04	1.29E+04
^{137}Cs	1.18E+06	1.09E+07
^{137m}Ba	1.12E+06	1.03E+07
^{144}Ce	2.29E+04	8.22E+01
^{144}Pr	2.29E+04	8.22E+01
^{154}Eu	1.18E+04	4.09E+04
Total	4.47E+06	4.04E+07
Specific activity,[b] Ci/L	0.58	11.4

[a]Taken from ref. 1(b). Curies as of December 31, 1992. Similar values for actinide nuclides are not available.

[b]Specific activity is defined in this table to be the radioactivity of a waste type at a given time divided by the volume of that waste type at the given time.

Table 2.15. Representative chemical composition of current and future HLW at HANF[a]

Component	Composition, wt %			
	Liquid[b]	Sludge[b]	Salt cake[b]	Slurry[c]
$NaNO_3$	20.8	25.3	81.5	14.8
$NaNO_2$	15.8	3.8	1.7	5.6
Na_2CO_3	0.6	2.2	0.5	1.9
NaOH	6.2	5.3	1.5	7.0
$NaAlO_2$	12.5	1.2	1.4	6.0
NaF				0.4
Na_2SO_4		1.0	1.3	0.3
Na_3PO_4	2.3	15.8	1.6	0.8
KF				0.4
FeO(OH)		1.3		0.2
Organic carbon	0.17			1.2
NH_4^+				0.08
$Al(OH)_3$		2.9		4.9
$SrO \cdot H_2O$		0.1		
Na_2CrO_4	1.3			
$Cr(OH)_3$		0.2		0.02
$Cd(OH)_2$		0.1		
$Ni(OH)_2$				<0.1
$BiPO_4$		0.5		
Cl^-		0.1		
$Ni_2Fe(CN)_6$		0.6		
$P_2O_5 \cdot 24WO_2 \cdot 44H_2O$		<0.1		
$ZrO_2 \cdot 2H_2O$		0.5		0.2
Fission products				<0.01
H_2O	40.2	33.6	10.5	56.2
Other	<0.1	5.5		<0.01
Hg^+		0.12 ppm		
Total	100.0	100.0	100.0	100.0
Density, g/mL	1.6	1.7	1.4	~1.3

[a]Taken from U.S. Department of Energy, Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics, DOE/RW-0006, Rev. 1 (December 1985).

[b]Stored in single-shell tanks.

[c]Stored in double-shell tanks.

Table 2.16. Representative radionuclide composition (Ci) of current HLW at HANF[a]

Radionuclide	Liquid	Sludge	Salt cake	Slurry	Capsules	
					^{90}Sr-^{90}Y	^{137}Cs-^{137m}Ba
^{14}C	1.87E+03		2.50E+03	6.67E+02		
^{55}Fe				4.75E+03		
^{59}Ni				9.06E+00		
^{60}Co		3.22E+03		1.03E+04		
^{63}Ni		3.08E+05		1.05E+03		
^{79}Se				6.58E+01		
^{89}Sr				9.05E-06		
^{90}Sr	4.13E+05	5.10E+07	2.20E+06	1.09E+07	2.45E+07	
^{90}Y	4.13E+05	5.10E+07	2.20E+06	1.09E+07	2.45E+07	
^{91}Y				6.68E-04		
^{93}Zr		9.70E+03		3.21E+02		
^{93m}Nb		8.21E+03		1.18E+02		
^{95}Zr				7.10E-03		
^{95}Nb				1.57E-02		
^{95m}Nb				5.24E-05		
^{99}Tc	1.79E+04			1.43E+04		
^{103}Ru				1.64E-09		
^{103m}Rh				1.47E-09		
^{106}Ru		9.81E+00		3.04E+05		
^{106}Rh		9.81E+00		3.04E+05		
^{107}Pd				8.21E+00		
^{110m}Ag				1.64E+01		
^{110}Ag				2.17E-01		
^{113m}Cd				3.74E+03		
^{113}Sn				7.92E-02		
^{115m}Cd				2.04E-10		
^{119m}Sn				2.92E+02		
^{121m}Sn				6.39E+01		
^{123}Sn				1.76E+00		
^{123m}Te				5.99E-06		
^{124}Sb				4.48E-08		
^{125}Sb				2.96E+05		
^{125m}Te				7.22E+04		
^{126}Sn				1.04E+02		
^{126}Sb				1.46E+01		
^{126m}Sb				1.15E+02		
^{127m}Te				6.68E-01		
^{127}Te				6.54E-01		
^{129m}Te				8.20E-14		
^{129}I				2.65E-01		
^{134}Cs				1.40E+05		
^{135}Cs				5.91E+01		
^{137}Cs	9.80E+06	3.61E+06	3.65E+06	1.62E+07		5.55E+07
^{137m}Ba	9.27E+06	3.41E+06	3.46E+06	1.53E+07		5.25E+07
^{141}Ce				8.29E-13		
^{144}Ce				4.63E+05		
^{144}Pr				4.61E+05		
^{144m}Pr				5.54E+03		
^{147}Pm				6.18E+06		

Table 2.16 (continued)

Radionuclide	Liquid	Sludge	Salt cake	Slurry	Capsules	
					^{90}Sr-^{90}Y	^{137}Cs-^{137m}Ba
^{148}Pm				4.98E-12		
^{148m}Pm				8.84E-11		
^{151}Sm		8.33E+05		2.03E+05		
^{152}Eu				5.41E+02		
^{153}Gd				1.07E-01		
^{154}Eu				6.75E+04		
^{155}Eu				9.90E+04		
^{160}Tb				9.71E-07		
^{234}U				1.23E+00		
^{235}U				5.18E-02		
^{236}U				1.08E-01		
^{238}U				9.46E-01		
^{237}Np	2.55E-03			4.51E+01		
^{238}Np				2.17E-01		
^{238}Pu				3.67E+02		
^{239}Pu		2.20E+04		3.28E+03		
^{240}Pu		5.29E+03		8.85E+02		
^{241}Pu		5.25E+04		3.35E+04		
^{242}Pu				8.68E-02		
^{241}Am	7.36E+02	4.53E+04		5.24E+04		
^{242}Am				4.31E+01		
^{242m}Am				4.33E+01		
^{243}Am				7.16E+00		
^{242}Cm				3.65E+01		
^{244}Cm		1.57E+02		1.29E+03		
Total	1.99E+07	1.10E+08	1.15E+07	6.21E+07	4.90E+07	1.08E+08
Specific activity,[b] Ci/L	7.9E-01	2.4E+00	1.2E-01	6.6E-01	4.5E+04	4.4E+04

[a]Taken from ref. 1(c). Curies as of December 31, 1992.

[b]Specific activity is defined in this table to be the radioactivity of a waste type at a given time divided by the volume of that waste type at the given time.

Table 2.17. Chemical composition of alkaline liquid HLW (from reprocessing via a PUREX flowsheet) at WVDP[a]

Compound	Wet basis (wt %)	Dry basis (wt %)
$NaNO_3$	21.10	53.38
$NaNO_2$	10.90	27.57
Na_2SO_4	2.67	6.75
$NaHCO_3$	1.49	3.77
KNO_3	1.27	3.21
Na_2CO_3	0.884	2.24
NaOH	0.614	1.55
K_2CrO_4	0.179	0.45
NaCl	0.164	0.42
Na_3PO_4	0.133	0.34
Na_2MoO_4	0.0242	0.06
Na_3BO_3	0.0209	0.05
$CsNO_3$	0.0187	0.05
NaF	0.0176	0.04
$Sn(NO_3)_4$	0.00858	0.02
$Na_2U_2O_7$	0.00809	0.02
$Si(NO_3)_4$	0.00805	0.02
$NaTcO_4$	0.00620	0.02
$RbNO_3$	0.00417	0.01
Na_2TeO_4	0.00287	0.007
AlF_3	0.0027	0.0068
$Fe(NO_3)_3$	0.00151	0.004
Na_2SeO_4	0.00053	0.0013
$LiNO_3$	0.00049	0.0012
H_2CO_3	0.00032	0.00080
$Cu(NO_3)_3$	0.00021	0.00053
$Sr(NO_3)_2$	0.00014	0.00035
$Mg(NO_3)_2$	0.00007	0.00018
Subtotal	39.53	100.00
H_2O (by difference)	60.47	0.00
Grand total	100.00	100.00

[a]Taken from ref. 1(d).

Table 2.18. Chemical composition of alkaline sludge HLW (from reprocessing via a PUREX flowsheet) at WVDP[a]

Compound	Wt %
Fission products	
$Ge(OH)_3$	2.0364E-06
$SrSO_4$	2.2095E-03
$Y(OH)_3$	1.0487E-03
$Zr(OH)_4$	9.8154E-03
$Ru(OH)_4$	4.6633E-03
$Rh(OH)_4$	8.0437E-04
$Pd(OH)_2$	3.4619E-04
AgOH	7.1274E-06
$Cd(OH)_2$	1.7309E-05
$In(OH)_3$	3.0546E-06
$Sn(OH)_4$	2.5455E-05
$Sb(OH)_3$	7.1274E-06
$BaSO_4$	3.0851E-03
$La(OH)_3$	1.8837E-03
$Ce(OH)_3$	3.6044E-03
$Pr(OH)_3$	1.7309E-03
$Nd(OH)_3$	6.3230E-03
$Pm(OH)_3$	1.5273E-05
$Sm(OH)_3$	1.4560E-03
$Eu(OH)_3$	7.6365E-05
$Gd(OH)_3$	1.7309E-05
$Tb(OH)_3$	3.0546E-06
$Dy(OH)_3$	2.0364E-06
Subtotal	3.7147E-02
Actinides	
$UO_2(OH)_2$	3.1432E-02
NpO_2	3.5637E-04
PuO_2	3.7673E-04
AmO_2	2.7491E-04
CmO_2	4.0728E-06
Subtotal	3.2444E-02
Others	
$Fe(OH)_3$	6.7242E-01
$FePO_4$	6.4666E-02
$Al(OH)_3$	5.9585E-02
AlF_3	6.2415E-03
MnO_2	4.6644E-02
$CaCO_3$	3.2664E-02
SiO_2	1.2860E-02
$Ni(OH)_2$	1.1078E-02
$MgCO_3$	8.4103E-03
$Cu(OH)_2$	3.8284E-03
$Zr(OH)_4$	9.8154E-03[b]
$Zn(OH)_2$	1.3033E-03
$Cr(OH)_3$	6.6183E-04
$Hg(OH)_2$	2.3418E-04
Subtotal	9.3041E-01
Grand total	1.0000

[a]Taken from ref. 1(d).
[b]Excludes fission product zirconium.

Table 2.19. Chemical composition of acid liquid HLW (from reprocessing via a THOREX flowsheet) at WVDP[a]

Compound	Wt %	Total, kg
$Th(NO_3)_4$	36.42	31,054
$Fe(NO_3)_3$	9.92	8,462
$Al(NO_3)_3$	4.90	4,175
HNO_3	3.29	2,805
$Cr(NO_3)_3$	2.25	1,918
$Ni(NO_3)_2$	0.93	79
H_3BO_3	0.56	480
$NaNO_3$	0.27	227
KNO_3	0.22	191
Na_2SO_4	0.21	180
Na_2SiO_3	0.15	126
$KMnO_4$	0.11	98
$Nd(NO_3)_3$	0.086	73
$Mg(NO_3)_2$	0.067	57
Na_2MoO_4	0.063	54
NaCl	0.059	50
$Ce(NO_3)_4$	0.050	43
$Ru(NO_3)_4$	0.049	42
ZrO_2	0.041	35
$Ca(NO_3)_2$	0.035	30
$CsNO_3$	0.033	28
$Ba(NO_3)_2$	0.032	27
$La(NO_3)_3$	0.026	22
$Pr(NO_3)_3$	0.025	21
$Sr(NO_3)_2$	0.019	16
$Y(NO_3)_3$	0.016	14
$Sm(NO_3)_3$	0.016	14
$Zr(NO_3)_4$	0.014	12
Na_3PO_4	0.014	12
$NaTcO_4$	0.013	11
$Rh(NO_3)_4$	0.013	11
$Zn(NO_3)_2$	0.012	10
$Pd(NO_3)_4$	0.0094	8
$UO_2(NO_3)_2$	0.0070	6
$RbNO_3$	0.0070	6
Na_2TeO_4	0.0059	5
$Co(NO_3)_2$	0.0035	3
Na_2SeO_4	0.0012	1
NaF	0.0012	1
$Eu(NO_3)_3$	0.0012	1
$Np(NO_3)_4$	0.0011	0.9
$Cu(NO_3)_2$	0.00094	0.8
$Sn(NO_3)_3$	0.00082	0.7
$Pa(NO_3)_4$	0.00082	0.7
$Pu(NO_3)_4$	0.00082	0.7
$Gd(NO_3)_3$	0.00047	0.4
$Cd(NO_3)_2$	0.00035	0.3
$Sb(NO_3)_3$	0.00012	0.1
$AgNO_3$	0.000094	0.08
$In(NO_3)_3$	0.000047	0.04
$Ge(NO_3)_4$	0.000023	0.02
$Pm(NO_3)_2$	0.000011	0.01
$Tb(NO_3)_3$	0.0000047	0.004
$Dy(NO_3)_3$	0.0000023	0.002
Solids	59.95	51,125
H_2O (by difference)	40.05	34,148
Total	100.00	85,273

[a]Taken from ref. 1(d).

Table 2.20. Representative chemical composition of future (to be generated in 1996) HLW glass at WVDP[a]

Component	Wt %
Al_2O_3	6.00
B_2O_3	12.89
BaO	0.16
CaO	0.48
Ca_2O_3	0.31
CoO	0.02
Cr_2O_3	0.14
Cs_2O	0.08
CuO	0.03
Fe_2O_3	12.02
K_2O	5.00
La_2O_3	0.04
Li_2O	3.71
MgO	0.89
MnO	0.82
MoO_3	0.04
Na_2O	8.00
Nd_2O_3	0.14
NiO	0.25
P_2O_5	1.20
PdO	0.03
Pr_6O_{11}	0.04
Rh_2O_3	0.02
RuO_2	0.08
SO_3	0.23
SiO_2	40.98
Sm_2O_3	0.03
SrO	0.02
ThO_2	3.56
TiO_2	0.80
UO_3	0.63
Y_2O_3	0.02
ZnO	0.02
ZrO_2	1.32
Total	100.00
Density (25°C), g/mL	2.6

[a]Taken from ref. 1(d).

Table 2.21. Representative radionuclide composition of current (end of 1992) HLW forms and future (to be generated in 1996) HLW glass at WVDP[a]

Radionuclide	Alkaline waste (PUREX) Liquid (Ci)	Alkaline waste (PUREX) Sludge (Ci)	Acid waste (THOREX) Liquid (Ci)	Zeolite waste (Ion exchanger) Wet mixture (Ci)	Total[b] (Ci)	Glass[c] (Ci)
^{90}Sr		5.66E+06	4.58E+05		6.19E+06	1.83E+06
^{90}Y		5.66E+06	4.58E+05		6.19E+06	1.83E+06
^{106}Ru	3.54E-03	3.54E+00	2.01E+04		2.01E+04	7.53E-02
^{106}Rh	3.54E-03	3.54E+00	2.01E+04		2.01E+04	7.53E-02
^{134}Cs	2.56E+03		5.71E+01	2.56E+03	5.18E+03	4.42E+02
^{135}Cs	1.56E+02		5.47E+00	1.56E+02	3.17E+02	1.05E+02
^{137}Cs	9.57E+05		4.58E+05	5.46E+06	6.88E+06	2.07E+06
^{137m}Ba	9.05E+05		4.33E+05	5.17E+06	6.51E+06	1.96E+06
^{147}Pm	1.53E+02	4.94E+04	2.43E+03		5.20E+04	5.95E+03
^{238}Pu	1.22E+02	7.69E+03	4.61E+02		8.27E+03	2.92E+03
^{239}Pu	6.15E+00	1.94E+03	3.73E+00		1.95E+03	2.06E+02
^{241}Pu	1.15E+03	7.26E+04	6.68E+02		7.44E+04	1.99E+04
^{241}Am		5.25E+04	2.39E+02		5.27E+04	1.73E+04
^{244}Cm		7.60E+04	1.13E+01		7.60E+04	2.15E+04
Total	1.87E+06	1.16E+07	1.81E+06	1.06E+07	2.59E+07	7.76E+06
Specific activity,[d] Ci/L	1.34	232	36.2	177	16.7	97.0

[a]Taken or calculated from ref. 1(d).
[b]Liquid, sludge, and zeolite curies are as of December 31, 1992.
[c]Glass curies are as of December 31, 1996 (the first year glass is to be generated).
[d]Specific activity is defined in this table to be the radioactivity of a waste type at a given time divided by the volume of that waste type at the given time.

ORNL PHOTO 9610-93

Empty transuranic waste test containers (bins) located in an underground Waste Isolation Pilot Plant (WIPP) waste storage area where tests are being planned to demonstrate that the WIPP facility will suitably hold wastes for disposal and meet regulatory requirements. (Courtesy of Westinghouse Electric Corporation, WIPP Project Office, Carlsbad, New Mexico, and MAC Technical Services Company, Albuquerque, New Mexico.)

3. TRANSURANIC WASTE

3.1 INTRODUCTION

This chapter presents information on the inventories and characteristics of the transuranic (TRU) wastes at various sites in the United States.

TRU waste is a waste category peculiar to DOE; it does not apply to wastes regulated by the NRC. TRU waste is currently defined in DOE Order 5820.2A as "without regard to source or form, waste that is contaminated with alpha-emitting transuranium radionuclides with half-lives greater than 20 years, and concentrations greater than 100 nCi/g at the time of assay. Heads of Field Elements can determine that other alpha-contaminated waste, peculiar to a specific site, must be managed as transuranic waste."[1] This definition includes isotopes of neptunium (Np), plutonium (Pu), americium (Am), curium (Cm), and californium (Cf). Generally, DOE waste containing less than 100 nCi/g of TRU alpha contamination is classified and managed as low-level waste (LLW).

TRU waste is primarily generated by research and development activities, plutonium recovery, weapons manufacturing, environmental restoration, and decontamination and decommissioning (D&D) projects. Most TRU waste exists in solid form (e.g., items such as protective clothing, paper trash, rags, glass, miscellaneous tools, and equipment that have become contaminated with TRU radionuclides). Some TRU wastes are in liquid form (sludges) resulting from chemical processing for recovery of plutonium or other TRU elements. Prior to 1970, TRU waste was disposed of on-site in shallow, landfill-type configurations. TRU waste disposed of in this manner is referred to as "buried" TRU waste. In 1970, the U.S. Atomic Energy Commission (AEC), which was a predecessor to DOE, concluded that waste containing long-lived alpha-emitting radionuclides should have greater confinement from the environment. Thus, all TRU waste generated since the early 1970s has been segregated from other waste types and placed in retrievable storage pending shipment and final disposal in a permanent geologic repository.[2] This waste is referred to as "retrievably stored" TRU waste. Retrievably stored waste is contained in a variety of packagings (metal drums, wooden and metal boxes) and is stored in earth-mounded berms, concrete culverts, or other types of facilities.

TRU waste packages are classified as either "contact handled" (CH) or "remote handled" (RH) depending on the radiation level at the surface of the package at the time of packaging. If this level exceeds 200 mrem/h, the package is classified as RH.

CH TRU waste contains relatively small quantities of fission and activation products that produce highly penetrating radiation; typically, its emissions consist mostly of alpha particles and low-energy photons of little penetrating power. Most TRU waste (more than 90% by volume) is of the CH type. RH TRU waste typically contains a greater proportion of fission and activation products that produce highly penetrating radiation and therefore tends to produce a higher level of radiation at the surface of the package.

It is estimated that as much as 50 to 60% of TRU waste is mixed waste, meaning that it contains, in addition to radioactive constituents, hazardous constituents defined and regulated in accordance with the Resource Conservation and Recovery Act (RCRA). Examples of mixed waste are radionuclide-contaminated spent solvents, discarded materials contaminated with both solvents and radioactive materials, scintillation fluids, and discarded contaminated lead shielding. TRU mixed waste must be managed to comply with the applicable hazardous waste regulations (e.g., RCRA) as well as those applying to radioactive TRU waste only. Some TRU waste may be contaminated with hazardous materials defined by other regulations. DOE is currently developing strategies for identifying and managing TRU wastes containing hazardous contaminants defined by regulations other than RCRA.

Under existing arrangements, retrievably stored TRU waste is the responsibility of the DOE/EM Office of Waste Management (EM-30). It is planned that the retrievably stored TRU waste and newly generated TRU waste from defense-related activities will be shipped to the Waste Isolation Pilot Plant (WIPP) for disposal. Prior to the start of these shipments, it is planned that tests will be conducted over approximately the next 5 years to ensure that the wastes to be shipped to WIPP, and the criteria for their emplacement at WIPP, will meet all applicable federal and state requirements for TRU and mixed TRU wastes. If the test phase is successful, the retrievable TRU waste

inventory will be disposed of in WIPP over approximately the next 20 years.

Buried TRU waste and TRU waste generated from site remediation activities and D&D activities are the responsibility of the Office of Environmental Restoration (EM-40). The disposition of these TRU wastes is uncertain at this time.

3.2 TRU WASTE INVENTORIES

3.2.1 Sources of Data

Quantitative information contained in this chapter is derived from data furnished by the DOE sites through annual data calls, as described later in this section. As programs and plans evolve or change, modifications and/or additions will be made to the data and other information in this chapter. It is expected that the quality and accuracy of the data will improve with each annual revision of this document, thus improving the usefulness of the data for program planning and decision purposes.

Early TRU waste inventory practices were not as stringent as those of today in regard to requirements for waste identification, categorization, and segregation. Consequently, the early inventory data are based largely on process knowledge and on various studies and summaries related to site-specific practices.[3] As these efforts continue and TRU waste is further characterized by radioassay, significant revisions in the estimated overall quantities of TRU waste are anticipated.

3.2.2 Site Locations—Summarized Volumes and Radioactivity

TRU waste management activities (generation, retrievable storage, etc.) are performed at six major and ten minor DOE sites. The major sites, from the standpoint of TRU waste quantities, are (1) the Hanford Site (HANF), (2) Idaho National Engineering Laboratory (INEL), (3) Los Alamos National Laboratory (LANL), (4) Oak Ridge National Laboratory (ORNL), (5) Rocky Flats Plant (RFP), and (6) the Savannah River Site (SRS). HANF and RFP no longer generate TRU waste as part of weapons production processes but do generate TRU waste as part of environmental restoration (cleanup) activities. The ten minor sites are (1) Argonne National Laboratory-East (ANL-E), (2) Knolls Atomic Power Laboratory (KAPL), (3) Lawrence Berkeley Laboratory (LBL), (4) Lawrence Livermore National Laboratory (LLNL), (5) Santa Susana Field Laboratory (SSFL) [also referred to as the Energy Technology Engineering Center (ETEC)], (6) Mound Laboratory (MOUND), (7) Nevada Test Site (NTS), (8) Paducah Gaseous Diffusion Plant (PAD), (9) Sandia National Laboratory (SNLA), and (10) West Valley Demonstration Project (WVDP). Figure 3.1 shows the locations of these sites and gives an approximate indication of the relative volumes of stored TRU waste at each site. Figure 3.2 shows the volumes of CH and RH retrievably stored TRU waste at the major sites and clearly shows that the preponderance of TRU waste volume is in the CH category. Figure 3.3 shows the decayed radioactivities of retrievably stored CH and RH TRU waste at the major sites as of December 31, 1992.

Data on the volumes and radionuclide compositions of those remote-handled TRU wastes that were formerly listed as miscellaneous radioactive materials in the Hanford 200-Area burial grounds were not submitted to the IDB in time to be incorporated in the figures and tables of this chapter. Summary data on these wastes are presented in Table C.13 of Appendix C.

3.2.3 Development of Detailed Inventory Data

This year's IDB contains significant changes in the manner in which TRU waste data are collected, reviewed, and used for the calculation of decayed radioactivities.

3.2.3.1 Site data submittal process

All of the quantitative TRU waste data in the IDB are ultimately derived from the site data submitted to the DOE Waste Management Information System (WMIS), which is maintained by the Hazardous Waste Remedial Actions Program (HAZWRAP). The sites supply volumes, radionuclide compositions, and curies of each radionuclide added in each year of TRU waste accumulation. This is done for each TRU waste type (CH stored, RH stored, CH buried, and RH buried). The annual radioactivities in the site submittals are on an as-stored basis; that is, they represent the curies of each radionuclide added at the end of the year in which the waste was placed in storage. The data are entered by the sites on standardized forms supplied by HAZWRAP and are returned to HAZWRAP, which distributes copies to other organizations taking part in the process. The complete set of TRU waste site data submittals for this year's IDB is listed as ref. 4 (Sect. 3.6).

3.2.3.2 Site data review and modification

The site data submittals for TRU waste were reviewed to make certain, insofar as possible, that the data supplied met the requirements of the HAZWRAP data request forms with regard to completeness and consistency. This year, because the radioactive decay and accumulation code system RADAC was being used for the first time, the data review process included modifying the formats of the data so that they could be easily converted to input data files suitable for direct use in the RADAC decay module.

3.2.3.3 As-stored volumes and radioactivities

Tables 3.1 through 3.3 summarize a small portion of the information in the site submittals. These tables show the volumes and cumulative as-stored (undecayed) radioactivities of retrievably stored CH and RH TRU waste at each site in 5-year increments from 1970 to 1990 and at the end of 1992. Table 3.2 shows total radioactivities (i.e., all radionuclides included), and Table 3.3 shows TRU radioactivity (i.e., only TRU radionuclides included).

3.2.3.4 Calculation of annual decayed radioactivities

The computer code YIELD9FL is the decay and accumulation module of the RADAC system. It converts annual as-stored radioactivities to annual decayed radioactivities and accumulates these quantities to produce tables showing decayed grams, curies, and watts on a year-by-year, site-by-site, and radionuclide-by-radionuclide basis. Annual added and cumulative volumes are also shown; volumes are assumed to be unaffected by decay.

Comparisons of the results of the RADAC system with those of the previously used LIBGEN-WINPRO-SAS system have thus far shown excellent agreement. For example, on page 84 of the 1992 IDB report,[5] Table 3.1, which was calculated by the LIBGEN-WINPRO-SAS system, showed 1887.51 kCi of stored CH TRU waste accumulated at the end of year 1991. The same data were independently run on the RADAC system and showed 1887.67 kCi at the end of 1991. Other examples have been run on both systems with similar agreement.

In a number of cases, the site-submitted data were not sufficiently detailed to permit the desired calculations. The difficulty most frequently encountered was that radionuclide compositions were not adequately specified. Two other modules of the RADAC system, HANFUTIL and ALLSTDAT, were used to convert site-supplied input data to the radionuclide-specific forms required for decay calculations. These codes were used as follows:

1. Where the site-supplied data called for mixtures of fission products but did not give quantitative composition data for such mixtures, the assumption was made that the isotopic composition was the same as that specified by Hanford in their submittal.

2. Certain parent fission products are always accompanied by short-lived daughters. The ALLSTDAT code adds short-lived daughter fission products in cases where the site submittal shows the parent but does not specifically show the daughter and it is clear that the daughter must be present. For example, if a site shows 100 Ci of ^{90}Sr but does not show any ^{90}Y, the program assumes that the 100 Ci is the total activity of parent and daughter and changes the input to 50 Ci ^{90}Sr and 50 Ci ^{90}Y. Other fission product parent-daughter combinations are handled in the same manner, using the appropriate curie ratio for each combination.

3.2.4 Results of Inventory Calculations

3.2.4.1 Retrievably stored wastes

Tables 3.4 and 3.5 show the cumulative decayed radioactivities of retrievably stored CH and RH TRU wastes for each of the sites by 5-year increments from 1970 through 1990 and at the end of 1992. These tables are analogous to Tables 3.2 and 3.3, except that in Tables 3.4 and 3.5 the radioactivities are on a decayed basis; that is, they take into account the processes of radioactive decay and ingrowth of radioactive daughters. As before, Table 3.4 shows total radioactivities (all radionuclides included), and Table 3.5 shows only the radioactivities of TRU radionuclides. As previously stated, it is assumed throughout the tables that volumes of TRU waste are not affected by radioactive decay.

Tables 3.6 and 3.7 summarize the total system inventories (i.e., all sites combined) of retrievably stored CH and RH TRU wastes at DOE sites for the end of each year from 1970 to 1992. The cumulative masses, radioactivities, and thermal powers shown in these tables are decayed values. The difference between Tables 3.6 and 3.7 is that the masses, radioactivities, and thermal powers in Table 3.6 are based on all the radionuclides in the waste, whereas the quantities shown in Table 3.7 include only the contributions of the TRU radionuclides; daughters of TRU nuclides are not included in Table 3.7.

3.2.4.2 Buried TRU wastes

Buried TRU waste volumes and radioactivities are shown in Tables 3.8 through 3.14. These are based on data provided in the site submittals. The form of the site-submitted data for buried waste is identical to that of the retrievably stored waste except that no distinction is made between CH and RH buried wastes. The buried waste tables (Tables 3.8 through 3.14) are analogous in form and information content to the retrievably stored waste tables (Tables 3.1 through 3.7) and follow the same sequence. Table 3.8 shows as-stored volumes by sites and time periods. Tables 3.9 and 3.10 show cumulative as-stored total and TRU-only radioactivities by sites and time periods. Tables 3.11 and 3.12 show cumulative decayed total and TRU-only radioactivities. Tables 3.13 and 3.14 are for all sites combined. They show annual and cumulative volumes, radionuclide masses, radioactivities, and thermal powers for the end of each year from 1944 to 1992. In these tables, "total" radioactivity means that all radionuclides are included, and "TRU-only" radioactivity means that only TRU nuclides are included.

3.2.4.3 Contaminated soil

Over the years, many of the older buried waste containers have developed leaks and contaminated the adjacent soil. Also, at some sites, soil has become contaminated by liquid spills or has been used as an ion-exchange medium for dilute liquid waste streams. It is difficult to make accurate estimates of the actual quantity of contaminated soil. The data reported by the sites are shown in Table 3.15. Additional characterization efforts will be required to reduce the uncertainties in these data.

3.3 ESTIMATED MIXED WASTE CONTENT OF TRU WASTES

The sites were requested to submit estimates of the volumes of retrievably stored CH and RH TRU wastes that might fall into the category of mixed TRU wastes. These estimates were requested for three time periods: 1970–1986, 1987–1992, and 1993. Table 3.16 summarizes the site-submitted estimates of these volumes.

3.4 PROJECTED FUTURE QUANTITIES OF TRU WASTE

Table 3.17 shows the data submitted by the sites for estimated future volumes of TRU waste generation. The sites were not requested to estimate the radioactivities or isotopic compositions of these wastes, since it was felt that there would be little basis for such estimates. The estimated volumes are given in terms of average annual rates (m^3/year) for seven time periods from 1993 to 2020. An effort was made to obtain estimated rates in three categories: (1) general operations, (2) D&D, and (3) remedial action. The estimated effect of volume-reduction processes was also requested; however, little information on this was available.

3.5 TRU WASTE DISPOSAL

The goals of the DOE TRU Waste Program are to terminate interim storage and achieve permanent disposal of all DOE TRU waste.[6] One of the major efforts in this direction is the WIPP project. As stated in Public Law 96–164,[7] the WIPP project was to be constructed " . . . as a defense activity of the DOE for the purpose of providing a research and development facility to demonstrate the safe disposal of radioactive waste resulting from defense activities and programs of the United States." Construction of the facility is now essentially complete, and WIPP is now the only facility specifically designed for isolation of TRU waste. It is designed to emplace about 175,000 m^3 of TRU waste 650 m below ground in a mined salt formation.

Waste received at WIPP must meet the WIPP-WAC and associated quality assurance requirements specified in WIPP/DOE-069.[8] A number of other approvals remain to be completed before DOE can begin disposal operations at the facility. As previously stated, a test program of approximately 5 years will be conducted to ensure that the wastes to be shipped to WIPP, and their emplacement at WIPP, will comply with all applicable federal and state regulations. If the test phase is successful and all necessary approvals are obtained, it is planned that shipment and emplacement of wastes will begin and will continue through approximately the year 2018.

In the past year, the WIPP Legislative Land Withdrawal Act was passed, confirming congressional intent to have DOE continue with development and permitting of the facility. Since then, the DOE has stated its intent to accelerate processes leading to the start of waste disposal operations at the WIPP.

3.6 REFERENCES

1. U.S. Department of Energy, *Radioactive Waste Management*, DOE Order 5820.2A, Washington, D.C. (Sept. 26, 1988).

2. K. S. Hollingsworth, *Policy Statement Regarding Solid Waste Burial*, AEC Directive IAD No. 0511-21, Washington, D.C. (Mar. 20, 1970).

3. U.S. Department of Energy, *Defense Waste Management Plan for Buried Transuranic-Contaminated Waste, Transuranic-Contaminated Soil, and Difficult-to-Certify Transuranic Waste*, DOE/DP-0044, Washington, D.C. (June 1987).

4. U.S. Department of Energy, Waste Management Information System (WMIS), DOE site TRU waste data submittals (Attachment 6) issued, received, and maintained by the Hazardous Waste Remedial Actions Program (HAZWRAP), Martin Marietta Energy Systems, Inc., submitted to MAC Technical Service Company (MACTEC) and the IDB Program during August–December 1993. The following TRU waste submittals from WMIS were received, reviewed, analyzed, and integrated by MACTEC and the IDB Program. Preceding each submittal is the site (in parentheses) to which it refers.

   a. (AMES) Kay M. Hannasch, Ames Laboratory, Ames, Iowa, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, submitting Ames Laboratory TRU waste information, dated Aug. 11, 1993.

   b. (ANL–E) R. Max Schletter, Argonne National Laboratory, Argonne, Illinois, memorandum to A. L. Taboas, DOE Argonne Area Office, Argonne, Illinois, "Request for Office of Waste Management, Waste Data Information Update," dated Aug. 26, 1993.

   c. (ANL–W) No submittal received.

   d. (HANF) R. D. Wojtasek, Westinghouse Hanford Company, Hanford Site, Richland, Washington, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Request for Office of Waste Management, Waste Data Information Update," 9305688B R1, dated Aug. 30, 1993.

   e. (INEL) Virginia C. Randall, EG&G Idaho, Inc., letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Integrated Data Base Data for 1993," dated Feb. 14, 1994.

   f. (LANL) Thomas C. Gunderson, Los Alamos National Laboratory, Los Alamos, New Mexico, memorandum to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "WMIS Data Call," EM-DO: 93-941, dated Aug. 17, 1993.

   g. (LBL) Hannibal Joma, U.S. Department of Energy, San Francisco Operations Office, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, submitting Lawrence Berkeley Laboratory LLW waste information, 93W-332/5484.1.A.13, dated Aug. 23, 1993.

   h. (LLNL) Kevin Hartnett, U.S. Department of Energy, San Francisco Operations Office, memorandum to Millie Jeffers, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "WMIS Data Call for LLNL," dated Nov. 5, 1993.

   i. (MOUND) Mary E. Sizemore, EG&G Mound Applied Technologies, Miamisburg, Ohio, memorandum to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Request for DOE Waste Date (sic) Information Update," dated Aug. 20, 1993.

   j. (NR sites) J. J. Mangeno, U.S. Department of Energy, Naval Reactors Programs Office (NE-60), Crystal City, Virginia, memorandum to J. Coleman, DOE/EM Office of Technical Support (DOE/EM-35), Washington, D.C., "Update of Radioactive Waste Data on Waste Streams and Treatment, Storage, and Disposal Units for NE-60 Cognizant Facilities," dated Aug. 9, 1993.

   k. (NTS) Layton J. O'Neill, U.S. Department of Energy, Nevada Operations Office, Las Vegas, Nevada, memorandum to Joseph A. Coleman, DOE/EM Office of Technical Support (DOE/EM-35), Washington, D.C., "Request for Office of Waste Management, Waste Data Information Update," dated Sept. 2, 1993.

   l. (ORNL) D. W. Turner, Oak Ridge National Laboratory, Oak Ridge, Tennessee, facsimile to T. J. Abraham et al., "Draft Input for the Integrated Data Base," dated July 21, 1993.

   m. (PAD) Jimmy C. Massey, Martin Marietta Energy Systems, Inc., Paducah, Kentucky, letter to Donald C. Booher, DOE Paducah Site Office, Paducah, Kentucky, "Update of Department of Energy Low-Level Radioactive and Low-Level Mixed Waste Data for the 1993 Integrated Data Base Annual Report," detailing TRU waste information for the Paducah site, dated Aug. 20, 1993.

n. (RFP) W. T. Prymak, DOE Rocky Flats Office, Golden, Colorado, memorandum to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Submission of Waste Data Information to Support the Integrated Data Base," dated Aug. 27, 1993.

o. (SNLA) Steve Ward, Sandia National Laboratories, Albuquerque, New Mexico, letter to George K. Laskar, DOE Albuquerque Operations, "Transmittal of Waste Management Information System (WMIS) Update Information," dated Aug. 5, 1993.

p. (SRS) Michael G. O'Rear, Director, Solid Waste Division, DOE Savannah River Operations Office, letter to Director, Office of Technical Support (EM-35), HQ, [with copy to Lise J. Wachter (HAZWRAP)], "Department of Energy Waste Inventory Data Systems," dated Nov. 13, 1993.

q. (WVDP) J. P. Jackson, West Valley Nuclear Services Company, Inc., West Valley, New York, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Waste Information Update for Calendar Year 1992," dated Aug. 20, 1993.

r. (SSFL/ETEC) Hannibal Joma, DOE San Francisco Operations Office, letter to Lise Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, submitting Energy Technology Engineering Center (Santa Susana Field Laboratory) TRU waste information, 93W-332/5484.1.A.13, dated Aug. 23, 1993.

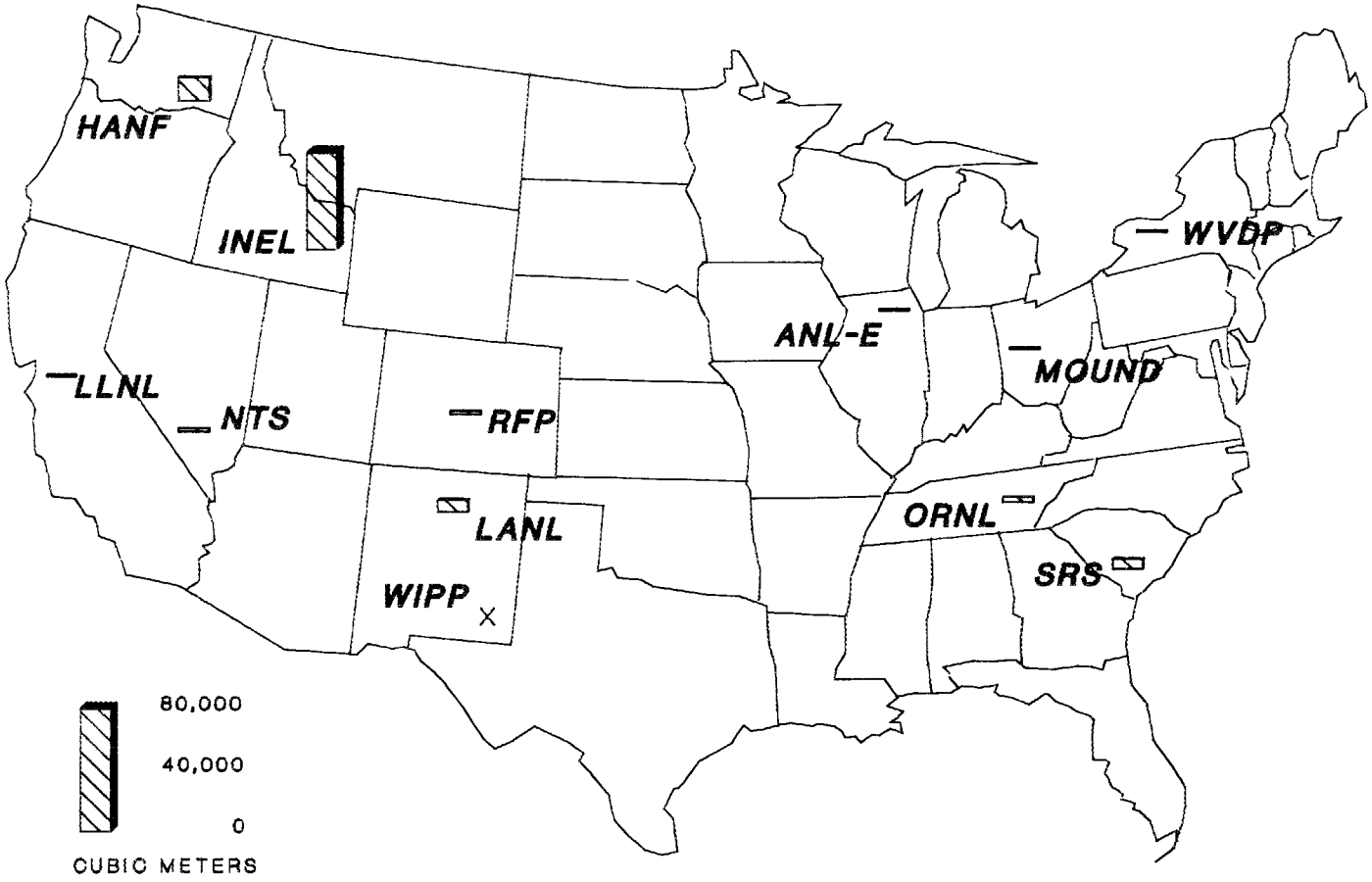
5. U.S. Department of Energy, *Integrated Data Base for 1992: U.S. Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, DOE/RW-0006, Rev. 8, Oak Ridge National Laboratory, Oak Ridge, Tennessee (October 1992).

6. U.S. Department of Energy, *Long Range Master Plan for Defense Transuranic Waste Program*, DOE/WIPP 88-028, Carlsbad, New Mexico (December 1988).

7. U.S. Congress, Department of Energy National Security and Military Application of Nuclear Energy Authorization Act of 1980, Pub. L. 96-164 (1980).

8. U.S. Department of Energy, *TRU Waste Acceptance Criteria for the Waste Isolation Pilot Plant*, WIPP/DOE-069, Rev. 4, Carlsbad, New Mexico (December 1991).

ORNL DWG 93-10799



* Sites having less than 10 cubic meters of stored TRU waste are not shown.

X Waste Isolation Pilot Plant

Fig. 3.1. Locations and total volumes of retrievably stored DOE TRU waste through 1992.

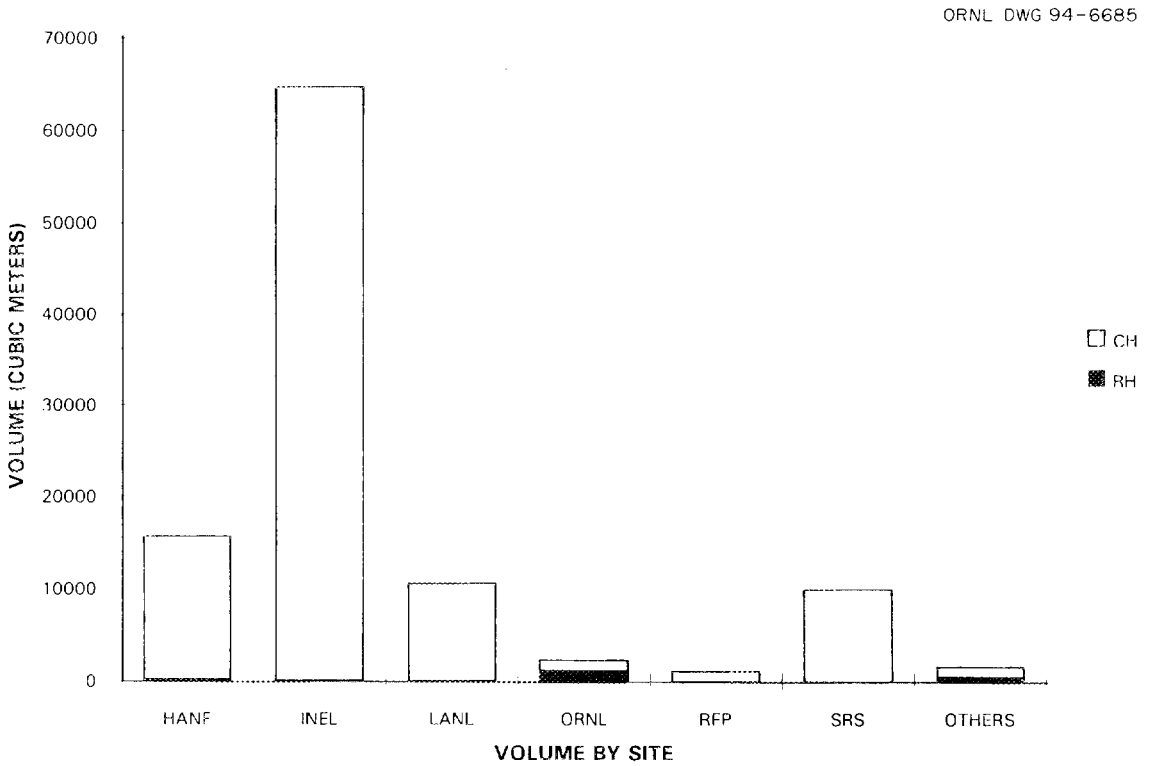


Fig. 3.2. Retrievably stored TRU waste volumes at the end of 1992, by site.

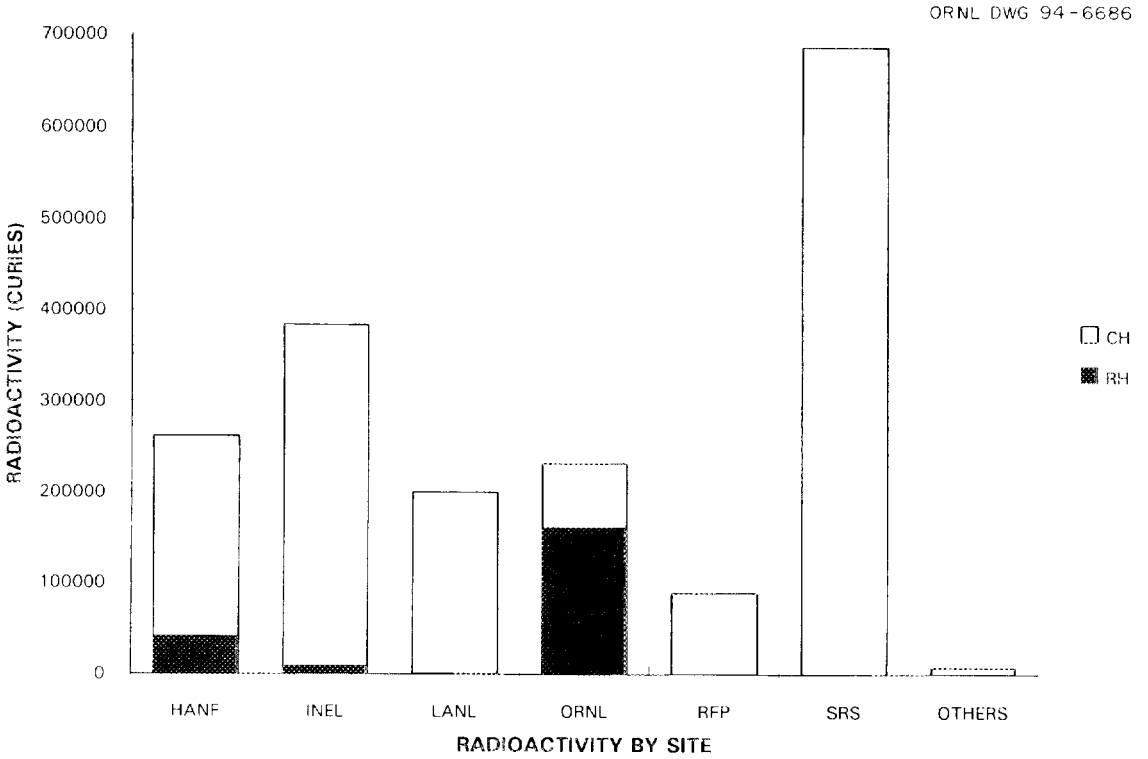


Fig. 3.3. Retrievably stored TRU waste decayed radioactivity at the end of 1992, by site.

Table 3.1. Summary of retrievably stored TRU waste by sites: cumulative as-stored volumes

Site name	Site acronym	Cumulative volume at end of calendar year, m^3					
		1970	1975	1980	1985	1990	1992
		Contact handled					
Argonne National Laboratory-East	ANL-E	0.0	0.0	0.0	0.0	25.5	32.9
Energy Technology Engineering Center	ETEC	0.0	0.0	0.0	0.0	2.5	2.5
Hanford Site	HANF	745.2	5,541.6	10,086.3	14,668.9	15,282.3	15,472.9
Idaho National Engineering Laboratory	INEL	1,420.0	28,356.0	42,341.0	57,615.0	64,774.0	64,774.0
Knolls Atomic Power Laboratory	KAPL	0.0	0.0	0.0	0.0	0.0	0.0
Lawrence Berkeley Laboratory	LBL	0.0	0.0	0.0	0.4	0.8	0.8
Lawrence Livermore National Laboratory	LLNL	0.0	0.0	0.0	0.0	194.5	222.7
Los Alamos National Laboratory	LANL	0.0	3,352.3	5,988.1	8,825.1	10,381.9	10,540.0
Mound	MOUND	0.0	23.0	61.2	99.5	137.7	153.0
Nevada Test Site	NTS	0.0	34.9	177.9	550.2	606.8	607.1
Oak Ridge National Laboratory	ORNL	12.6	539.9	725.6	900.3	1,047.6	1,069.1
Paducah Gaseous Diffusion Plant	PAD	0.0	0.0	0.0	0.0	4.3	4.3
Rocky Flats Plant	RFP	0.0	0.0	0.0	0.0	952.0	1,040.0
Sandia National Laboratory-Albuquerque	SNLA	0.0	0.0	0.0	0.0	0.0	0.0
Savannah River Site	SRS	a	a	a	a	a	9,974.3
West Valley Demonstration Project	WVDP	0.0	0.0	0.0	19.5	48.4	48.4
Total		2,177.8	37,847.6	59,380.1	82,678.9	93,458.4	103,942.0
		Remote handled					
Argonne National Laboratory-East	ANL-E	0.0	0.0	0.0	0.0	0.0	0.0
Energy Technology Engineering Center	ETEC	0.0	0.0	0.0	0.0	0.0	0.0
Hanford Site	HANF	10.3	127.8	194.9	198.2	201.0	201.0
Idaho National Engineering Laboratory	INEL	0.0	0.0	17.0	48.0	75.0	75.0
Knolls Atomic Power Laboratory	KAPL	0.0	0.0	0.0	0.0	0.0	2.4
Lawrence Berkeley Laboratory	LBL	0.0	0.0	0.0	0.0	0.0	0.0
Lawrence Livermore National Laboratory	LLNL	0.0	0.0	0.0	0.0	0.0	0.0
Los Alamos National Laboratory	LANL	0.0	0.0	7.9	27.4	27.4	78.4
Mound	MOUND	0.0	0.0	0.0	0.0	0.0	0.0
Nevada Test Site	NTS	0.0	0.2	0.6	5.3	5.3	5.3
Oak Ridge National Laboratory	ORNL	1.7	223.0	362.9	442.1	1,092.6	1,144.2
Paducah Gaseous Diffusion Plant	PAD	0.0	0.0	0.0	0.0	0.0	0.0
Rocky Flats Plant	RFP	0.0	0.0	0.0	0.0	0.0	0.0
Sandia National Laboratory-Albuquerque	SNLA	0.0	0.0	0.0	0.0	0.0	0.0
Savannah River Site	SRS	0.0	0.0	0.0	0.0	0.0	0.0
West Valley Demonstration Project	WVDP	0.0	0.0	0.0	499.2	499.2	499.2
Total		12.0	351.0	583.3	1,220.2	1,900.5	2,005.5

[a]No data supplied for these years. The site reported all CH waste inventoried prior to 1991 as part of the 1991 inventory.

Table 3.2. Summary of retrievably stored TRU waste by sites: cumulative as-stored radioactivity (all radionuclides)

Site name	Site acronym	Cumulative as-stored radioactivity at end of calendar year, 10^3 Ci					
		1970	1975	1980	1985	1990	1992
Contact handled							
Argonne National Laboratory-East	ANL-E	0.00	0.00	0.00	0.00	0.12	0.12
Energy Technology Engineering Center	ETEC	0.00	0.00	0.00	0.00	0.01	0.01
Hanford Site	HANF	1.05	19.61	191.49	278.46	325.64	329.50
Idaho National Engineering Laboratory	INEL	4.22	126.46	255.92	405.07	496.42	496.46
Knolls Atomic Power Laboratory	KAPL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Berkeley Laboratory	LBL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Livermore National Laboratory	LLNL	0.00	0.00	0.00	0.00	0.93	1.80
Los Alamos National Laboratory	LANL	0.00	49.18	108.46	151.01	212.92	218.70
Mound	MOUND	0.00	0.00	0.00	0.00	0.00	1.95
Nevada Test Site	NTS	0.00	0.27	1.21	2.83	3.45	3.45
Oak Ridge National Laboratory	ORNL	0.05	12.48	17.80	98.19	99.65	100.07
Paducah Gaseous Diffusion Plant	PAD	0.00	0.00	0.00	0.00	0.00	0.00
Rocky Flats Plant	RFP	0.00	0.00	0.00	0.00	48.66	93.59
Sandia National Laboratory-Albuquerque	SNLA	0.00	0.00	0.00	0.00	0.00	0.00
Savannah River Site	SRS	a	a	a	a	a	711.72
West Valley Demonstration Project	WVDP	0.00	0.00	0.00	0.03	0.05	0.05
Total		5.32	208.00	574.89	935.59	1,187.85	1,948.99
Remote handled							
Argonne National Laboratory-East	ANL-E	0.00	0.00	0.00	0.00	0.00	0.00
Energy Technology Engineering Center	ETEC	0.00	0.00	0.00	0.00	0.00	0.00
Hanford Site	HANF	27.09	55.70	471.69	480.11	482.10	482.10
Idaho National Engineering Laboratory	INEL	0.00	0.00	0.49	4.93	10.53	10.53
Knolls Atomic Power Laboratory	KAPL	0.00	0.00	0.00	0.00	0.00	0.11
Lawrence Berkeley Laboratory	LBL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Livermore National Laboratory	LLNL	0.00	0.00	0.00	0.00	0.00	0.00
Los Alamos National Laboratory	LANL	0.00	0.00	0.96	3.43	3.45	3.46
Mound	MOUND	0.00	0.00	0.00	0.00	0.00	0.00
Nevada Test Site	NTS	0.00	0.00	0.04	0.25	0.25	0.25
Oak Ridge National Laboratory	ORNL	0.00	0.16	0.32	0.54	166.80	177.68
Paducah Gaseous Diffusion Plant	PAD	0.00	0.00	0.00	0.00	0.00	0.00
Rocky Flats Plant	RFP	0.00	0.00	0.00	0.00	0.00	0.00
Sandia National Laboratory-Albuquerque	SNLA	0.00	0.00	0.00	0.00	0.00	0.00
Savannah River Site	SRS	0.00	0.00	0.00	0.00	0.00	0.00
West Valley Demonstration Project	WVDP	0.00	0.00	0.00	0.00	0.00	0.00
Total		27.09	55.87	473.50	489.26	663.14	674.13

[a]No data supplied for these years. The site reported all CH waste inventoried prior to 1991 as part of the 1991 inventory.

Table 3.3. Summary of retrievably stored TRU waste by sites: cumulative as-stored TRU radioactivity (TRU radionuclides only)

Site name	Site acronym	Cumulative as-stored TRU radioactivity at end of calendar year, 10^3 Ci					
		1970	1975	1980	1985	1990	1992
Contact handled							
Argonne National Laboratory-East	ANL-E	0.00	0.00	0.00	0.00	0.04	0.04
Energy Technology Engineering Center	ETEC	0.00	0.00	0.00	0.00	0.00	0.00
Hanford Site	HANF	0.19	3.22	106.81	119.34	123.87	124.46
Idaho National Engineering Laboratory	INEL	1.52	50.87	122.85	183.83	205.34	205.35
Knolls Atomic Power Laboratory	KAPL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Berkeley Laboratory	LBL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Livermore National Laboratory	LLNL	0.00	0.00	0.00	0.00	0.15	0.28
Los Alamos National Laboratory	LANL	0.00	48.66	104.85	144.69	206.42	212.20
Mound	MOUND	0.00	0.00	0.00	0.00	0.00	1.95
Nevada Test Site	NTS	0.00	0.26	1.02	2.49	2.70	2.70
Oak Ridge National Laboratory	ORNL	0.01	6.28	6.59	9.89	10.02	10.10
Paducah Gaseous Diffusion Plant	PAD	0.00	0.00	0.00	0.00	0.00	0.00
Rocky Flats Plant	RFP	0.00	0.00	0.00	0.00	12.73	28.06
Sandia National Laboratory-Albuquerque	SNLA	0.00	0.00	0.00	0.00	0.00	0.00
Savannah River Site	SRS	a	a	a	a	a	405.86
West Valley Demonstration Project	WVDP	0.00	0.00	0.00	0.00	0.00	0.00
Total		1.72	109.30	342.12	460.23	561.27	991.00
Remote handled							
Argonne National Laboratory-East	ANL-E	0.00	0.00	0.00	0.00	0.00	0.00
Energy Technology Engineering Center	ETEC	0.00	0.00	0.00	0.00	0.00	0.00
Hanford Site	HANF	0.02	0.19	0.41	0.52	0.56	0.56
Idaho National Engineering Laboratory	INEL	0.00	0.00	0.01	0.03	0.10	0.10
Knolls Atomic Power Laboratory	KAPL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Berkeley Laboratory	LBL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Livermore National Laboratory	LLNL	0.00	0.00	0.00	0.00	0.00	0.00
Los Alamos National Laboratory	LANL	0.00	0.00	0.04	0.09	0.09	0.09
Mound	MOUND	0.00	0.00	0.00	0.00	0.00	0.00
Nevada Test Site	NTS	0.00	0.00	0.00	0.00	0.00	0.00
Oak Ridge National Laboratory	ORNL	0.00	0.02	0.03	0.05	1.06	1.12
Paducah Gaseous Diffusion Plant	PAD	0.00	0.00	0.00	0.00	0.00	0.00
Rocky Flats Plant	RFP	0.00	0.00	0.00	0.00	0.00	0.00
Sandia National Laboratory-Albuquerque	SNLA	0.00	0.00	0.00	0.00	0.00	0.00
Savannah River Site	SRS	0.00	0.00	0.00	0.00	0.00	0.00
West Valley Demonstration Project	WVDP	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.02	0.21	0.49	0.69	1.81	1.87

[a]No data supplied for these years. The site reported all CH waste inventoried prior to 1991 as part of the 1991 inventory.

Table 3.4. Summary of retrievably stored TRU waste by sites: decayed radioactivity (all radionuclides)

Site name	Site acronym	Cumulative radioactivity at end of calendar year, 10^3 Ci					
		1970	1975	1980	1985	1990	1992
Contact handled							
Argonne National Laboratory-East	ANL-E	0.00	0.00	0.00	0.00	0.11	0.10
Energy Technology Engineering Center	ETEC	0.00	0.00	0.00	0.00	0.01	0.01
Hanford Site	HANF	1.05	18.23	183.76	244.40	229.40	221.38
Idaho National Engineering Laboratory	INEL	4.22	120.86	230.01	348.66	393.67	375.47
Knolls Atomic Power Laboratory	KAPL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Berkeley Laboratory	LBL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Livermore National Laboratory	LLNL	0.00	0.00	0.00	0.00	0.89	1.68
Los Alamos National Laboratory	LANL	0.00	48.71	102.16	139.36	195.26	199.07
Mound	MOUND	0.00	0.00	0.00	0.00	0.00	1.95
Nevada Test Site	NTS	0.00	0.27	1.20	2.78	3.29	3.24
Oak Ridge National Laboratory	ORNL	0.05	11.26	15.07	90.39	75.24	69.94
Paducah Gaseous Diffusion Plant	PAD	0.00	0.00	0.00	0.00	0.00	0.00
Rocky Flats Plant	RFP	0.00	0.00	0.00	0.00	47.04	88.23
Sandia National Laboratory-Albuquerque	SNLA	0.00	0.00	0.00	0.00	0.00	0.00
Savannah River Site	SRS	a	a	a	a	a	685.80
West Valley Demonstration Project	WVDP	0.00	0.00	0.00	0.03	0.05	0.04
Total		5.32	199.33	532.20	825.62	944.96	1,646.94
Remote handled							
Argonne National Laboratory-East	ANL-E	0.00	0.00	0.00	0.00	0.00	0.00
Energy Technology Engineering Center	ETEC	0.00	0.00	0.00	0.00	0.00	0.00
Hanford Site	HANF	27.09	28.85	293.19	64.16	45.02	40.39
Idaho National Engineering Laboratory	INEL	0.00	0.00	0.58	7.03	9.10	7.98
Knolls Atomic Power Laboratory	KAPL	0.00	0.00	0.00	0.00	0.00	0.11
Lawrence Berkeley Laboratory	LBL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Livermore National Laboratory	LLNL	0.00	0.00	0.00	0.00	0.00	0.00
Los Alamos National Laboratory	LANL	0.00	0.00	0.88	0.73	0.36	0.34
Mound	MOUND	0.00	0.00	0.00	0.00	0.00	0.00
Nevada Test Site	NTS	0.00	0.00	0.04	0.23	0.19	0.18
Oak Ridge National Laboratory	ORNL	0.00	0.15	0.28	0.43	159.79	160.78
Paducah Gaseous Diffusion Plant	PAD	0.00	0.00	0.00	0.00	0.00	0.00
Rocky Flats Plant	RFP	0.00	0.00	0.00	0.00	0.00	0.00
Sandia National Laboratory-Albuquerque	SNLA	0.00	0.00	0.00	0.00	0.00	0.00
Savannah River Site	SRS	0.00	0.00	0.00	0.00	0.00	0.00
West Valley Demonstration Project	WVDP	0.00	0.00	0.00	0.00	0.00	0.00
Total		27.09	29.00	294.97	72.58	214.46	209.78

[a]No data supplied for these years. The site reported all CH waste inventoried prior to 1991 as part of the 1991 inventory.

Table 3.5. Summary of retrievably stored TRU waste by sites: decayed radioactivity (TRU radionuclides only)

Site name	Site acronym	Cumulative radioactivity at end of calendar year, 10^3 Ci					
		1970	1975	1980	1985	1990	1992
Contact handled							
Argonne National Laboratory-East	ANL-E	0.00	0.00	0.00	0.00	0.04	0.04
Energy Technology Engineering Center	ETEC	0.00	0.00	0.00	0.00	0.00	0.00
Hanford Site	HANF	0.19	3.25	107.01	116.77	118.79	118.38
Idaho National Engineering Laboratory	INEL	1.52	50.91	122.40	181.58	201.41	200.73
Knolls Atomic Power Laboratory	KAPL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Berkeley Laboratory	LBL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Livermore National Laboratory	LLNL	0.00	0.00	0.00	0.00	0.15	0.28
Los Alamos National Laboratory	LANL	0.00	48.36	101.55	137.44	194.68	198.59
Mound	MOUND	0.00	0.00	0.00	0.00	0.00	1.95
Nevada Test Site	NTS	0.00	0.26	1.02	2.48	2.68	2.68
Oak Ridge National Laboratory	ORNL	0.01	6.14	6.27	9.46	9.83	9.99
Paducah Gaseous Diffusion Plant	PAD	0.00	0.00	0.00	0.00	0.00	0.00
Rocky Flats Plant	RFP	0.00	0.00	0.00	0.00	12.77	28.30
Sandia National Laboratory-Albuquerque	SNLA	0.00	0.00	0.00	0.00	0.00	0.00
Savannah River Site	SRS	a	a	a	a	a	403.05
West Valley Demonstration Project	WVDP	0.00	0.00	0.00	0.00	0.00	0.00
Total		1.72	108.92	338.25	447.71	540.36	963.90
Remote handled							
Argonne National Laboratory-East	ANL-E	0.00	0.00	0.00	0.00	0.00	0.00
Energy Technology Engineering Center	ETEC	0.00	0.00	0.00	0.00	0.00	0.00
Hanford Site	HANF	0.02	0.20	0.44	0.60	0.67	0.69
Idaho National Engineering Laboratory	INEL	0.00	0.00	0.01	0.03	0.10	0.10
Knolls Atomic Power Laboratory	KAPL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Berkeley Laboratory	LBL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Livermore National Laboratory	LLNL	0.00	0.00	0.00	0.00	0.00	0.00
Los Alamos National Laboratory	LANL	0.00	0.00	0.04	0.09	0.09	0.09
Mound	MOUND	0.00	0.00	0.00	0.00	0.00	0.00
Nevada Test Site	NTS	0.00	0.00	0.00	0.00	0.00	0.00
Oak Ridge National Laboratory	ORNL	0.00	0.02	0.03	0.05	1.04	1.09
Paducah Gaseous Diffusion Plant	PAD	0.00	0.00	0.00	0.00	0.00	0.00
Rocky Flats Plant	RFP	0.00	0.00	0.00	0.00	0.00	0.00
Sandia National Laboratory-Albuquerque	SNLA	0.00	0.00	0.00	0.00	0.00	0.00
Savannah River Site	SRS	0.00	0.00	0.00	0.00	0.00	0.00
West Valley Demonstration Project	WVDP	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.02	0.22	0.52	0.77	1.90	1.97

[a]No data supplied for these years. The site reported all CH waste inventoried prior to 1991 as part of the 1991 inventory.

Table 3.6. Retrievably stored TRU waste inventories and decayed characteristics, total of all sites, all radionuclides included

End of calendar year	Volume (m^3)		Total mass[a] (kg)		Radioactivity (10^3 Ci)		Thermal power (10^3 W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
Contact handled								
1970	2,177.8	2,177.8	47.1	47.1	5.32	5.32	0.06	0.06
1971	8,692.3	10,870.0	316.9	364.0	22.43	27.57	0.46	0.52
1972	7,518.3	18,388.3	1,085.5	1,449.4	34.13	60.93	0.52	1.03
1973	7,116.0	25,504.3	130.8	1,580.2	28.00	87.32	0.41	1.43
1974	5,617.9	31,122.2	3,947.9	5,528.1	64.18	149.23	1.50	2.93
1975	6,725.3	37,847.6	776.6	6,304.7	53.94	199.34	0.79	3.70
1976	2,319.2	40,166.8	4,369.0	10,673.6	38.88	238.20	0.94	4.62
1977	5,489.8	45,656.6	725.0	11,398.6	54.10	281.64	1.10	5.70
1978	3,825.5	49,482.1	185.9	11,584.5	56.52	330.59	1.30	6.96
1979	5,194.6	54,676.7	3,396.3	14,980.8	83.85	386.97	0.93	7.85
1980	4,703.4	59,380.1	4,601.0	19,581.7	153.53	532.19	3.44	11.26
1981	4,848.3	64,228.4	1,092.1	20,673.8	58.04	579.34	0.95	12.15
1982	4,598.1	68,826.5	1,070.9	21,744.7	48.79	616.29	0.77	12.85
1983	4,308.4	73,134.9	1,230.2	22,974.9	37.37	640.87	0.55	13.32
1984	4,618.5	77,753.4	721.9	23,696.8	135.61	763.34	0.82	14.07
1985	4,925.5	82,678.9	273.1	23,970.0	80.89	825.62	0.87	14.86
1986	4,393.7	87,072.6	346.1	24,316.0	86.10	883.68	0.85	15.61
1987	2,514.5	89,587.2	451.8	24,767.8	51.57	901.06	0.67	16.15
1988	2,039.2	91,626.4	282.8	25,050.6	39.71	914.38	0.76	16.81
1989	1,436.0	93,062.4	223.5	25,274.1	37.59	929.16	0.55	17.29
1990	395.9	93,458.4	200.8	25,474.9	37.29	944.95	0.48	17.70
1991[b]	10,158.0	103,616.4	361.5	25,836.4	733.40	1,657.31	15.24	32.88
1992	325.7	103,942.1	96.4	25,932.8	27.75	1,646.94	0.30	32.97
Remote handled								
1970	12.0	12.0	29.6	29.6	27.09	27.09	0.32	0.32
1971	15.9	27.8	22.5	52.1	7.86	29.87	0.09	0.36
1972	94.9	122.8	12.1	64.2	2.86	28.39	0.03	0.34
1973	61.5	184.2	0.5	64.7	7.29	31.90	0.03	0.33
1974	41.1	225.3	0.8	65.4	5.89	31.03	0.02	0.30
1975	125.7	351.0	1.4	66.8	4.88	29.00	0.05	0.30
1976	76.6	427.6	2.7	69.5	5.25	29.66	0.02	0.28
1977	56.6	484.2	2.1	71.6	14.35	38.44	0.16	0.40
1978	49.4	533.6	2.9	74.5	1.12	33.77	0.00	0.35
1979	23.1	556.7	8.1	82.5	235.03	264.86	1.10	1.41
1980	26.5	583.3	3.7	86.2	161.87	294.96	0.69	1.47
1981	33.2	616.5	9.5	95.7	5.13	163.93	0.05	0.88

Table 3.6 (continued)

End of calendar year	Volume (m^3)		Total mass[a] (kg)		Radioactivity (10^3 Ci)		Thermal power (10^3 W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1982	33.1	649.5	2.9	98.6	3.33	115.04	0.02	0.64
1983	34.2	683.8	15.6	114.2	3.80	92.51	0.01	0.52
1984	20.7	704.5	12.1	126.2	0.78	77.39	0.01	0.44
1985	515.8	1,220.3	3.1	129.3	2.73	72.58	0.01	0.40
1986	18.8	1,239.0	2.4	131.6	1.39	65.99	0.01	0.37
1987	88.8	1,327.8	6,456.0	6,587.6	19.45	80.88	0.07	0.41
1988	5.2	1,333.0	3.5	6,591.2	4.12	82.12	0.01	0.40
1989	537.0	1,870.0	153,569.2	160,160.4	144.29	220.19	0.64	1.01
1990	30.5	1,900.5	4,625.7	164,786.1	4.64	214.45	0.02	0.97
1991	78.4	1,978.9	6,475.8	171,261.9	6.12	212.36	0.03	0.95
1992	26.6	2,005.4	5,088.1	176,350.0	4.88	209.77	0.02	0.93
			Total					
1970	2,169.7	2,189.7	76.7	76.7	32.41	32.41	0.38	0.38
1971	8,708.1	10,897.9	339.4	416.1	30.29	57.43	0.55	0.87
1972	7,613.2	18,511.1	1,097.6	1,513.6	36.99	89.33	0.55	1.37
1973	7,177.4	25,688.6	131.2	1,644.9	35.29	119.22	0.44	1.76
1974	5,659.0	31,347.5	3,948.6	5,593.5	70.07	180.26	1.53	3.23
1975	6,851.0	38,198.6	778.0	6,371.4	58.83	228.33	0.84	4.00
1976	2,395.8	40,594.3	4,371.6	10,743.1	44.13	262.86	0.96	4.90
1977	5,546.5	46,140.8	727.1	11,470.2	68.46	320.08	1.26	6.10
1978	3,874.8	50,015.6	188.8	11,659.0	57.65	364.36	1.30	7.31
1979	5,217.8	55,233.4	3,404.3	15,063.3	298.88	651.83	2.03	9.26
1980	4,730.0	59,963.4	4,604.6	19,667.9	315.41	827.15	4.14	12.73
1981	4,881.5	64,844.9	1,101.5	20,769.4	63.16	743.27	1.00	13.02
1982	4,631.2	69,476.0	1,073.8	21,843.2	52.12	731.33	0.79	13.49
1983	4,342.6	73,818.7	1,245.8	23,089.1	41.17	733.38	0.56	13.84
1984	4,639.2	78,457.9	734.0	23,823.1	136.39	840.73	0.83	14.51
1985	5,441.3	83,899.2	276.2	24,099.3	83.62	898.21	0.87	15.26
1986	4,412.5	88,311.7	348.4	24,447.7	87.49	949.66	0.86	15.97
1987	2,603.3	90,915.0	6,907.8	31,355.4	71.02	981.95	0.74	16.56
1988	2,044.4	92,959.4	286.4	31,641.8	43.83	996.50	0.77	17.21
1989	1,973.0	94,932.4	153,792.7	185,434.5	181.87	1,149.35	1.19	18.30
1990	426.4	95,358.9	4,826.5	190,260.9	41.92	1,159.40	0.50	18.67
1991[b]	10,236.4	105,595.3	6,837.4	197,098.3	739.51	1,869.67	15.27	33.83
1992	352.3	105,947.5	5,184.5	202,282.8	32.63	1,856.72	0.32	33.90

[a]Mass means mass of radionuclides, not of total waste.
[b]SRS CH waste data not available for individual years prior to 1991 but is included in totals for years 1991 and 1992.

Table 3.7. Retrievably stored TRU waste inventories and decayed characteristics, total of all sites, TRU radionuclides only included[a]

End of calendar year	Volume (m^3)		TRU mass[b] (kg)		TRU radioactivity (10^3 Ci)		TRU thermal power (10^3 W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
				Contact handled				
1970	2,177.8	2,177.8	8.3	8.3	1.72	1.72	0.06	0.06
1971	8,692.3	10,870.0	25.0	33.2	13.17	14.89	0.43	0.49
1972	7,518.3	18,388.3	37.3	70.6	15.32	30.19	0.50	0.99
1973	7,116.0	25,504.3	39.0	109.6	10.51	40.67	0.34	1.33
1974	5,617.9	31,122.2	48.9	158.4	44.77	85.41	1.47	2.81
1975	6,725.3	37,847.6	74.8	233.3	23.81	108.92	0.78	3.57
1976	2,319.2	40,166.8	34.1	267.4	28.13	136.59	0.93	4.49
1977	5,489.8	45,656.6	59.4	326.8	33.10	169.25	1.09	5.56
1978	3,825.5	49,482.1	55.7	382.6	39.31	207.87	1.29	6.83
1979	5,194.6	54,676.7	116.8	499.3	28.10	235.06	0.91	7.71
1980	4,703.4	59,380.1	148.0	647.3	104.18	338.25	3.43	11.10
1981	4,848.3	64,228.4	141.3	788.6	28.96	365.56	0.94	11.99
1982	4,598.1	68,826.5	174.4	963.0	21.57	385.38	0.69	12.62
1983	4,308.4	73,134.9	158.0	1,121.0	17.09	400.69	0.54	13.11
1984	4,618.5	77,753.4	206.3	1,327.3	25.54	424.45	0.81	13.86
1985	4,925.5	82,678.9	208.6	1,535.9	24.95	447.71	0.79	14.60
1986	4,393.7	87,072.6	205.2	1,741.1	24.08	470.12	0.77	15.31
1987	2,514.5	89,587.2	141.0	1,882.1	20.37	488.82	0.65	15.91
1988	2,039.2	91,626.4	277.1	2,159.1	23.95	511.10	0.75	16.61
1989	1,436.0	93,062.4	212.9	2,372.1	17.52	526.93	0.55	17.10
1990	395.9	93,458.4	191.5	2,563.5	15.13	540.36	0.48	17.52
1991[c]	10,158.0	103,616.4	347.1	2,910.7	420.52	959.19	13.87	31.34
1992	325.7	103,942.1	52.4	2,963.1	9.21	963.90	0.30	31.48
				Remote handled				
1970	12.0	12.0	0.3	0.3	0.02	0.02	0.00	0.00
1971	15.9	27.8	0.2	0.5	0.02	0.05	0.00	0.00
1972	94.9	122.8	1.1	1.6	0.09	0.14	0.00	0.00
1973	61.5	184.2	0.3	1.9	0.03	0.17	0.00	0.01
1974	41.1	225.3	0.2	2.1	0.01	0.19	0.00	0.01
1975	125.7	351.0	0.3	2.4	0.03	0.22	0.00	0.01
1976	76.8	427.8	0.5	2.9	0.05	0.27	0.00	0.01
1977	56.8	484.2	0.6	3.5	0.06	0.33	0.00	0.01
1978	49.4	533.6	0.5	4.0	0.04	0.37	0.00	0.01
1979	23.1	556.7	1.1	5.1	0.09	0.47	0.00	0.01
1980	26.6	583.3	0.5	5.6	0.04	0.52	0.00	0.02
1981	33.2	616.5	0.7	6.3	0.05	0.58	0.00	0.02

Table 3.7 (continued)

End of calendar year	Volume (m^3)		TRU mass[b] (kg)		TRU radioactivity (10^3 Ci)		TRU thermal power (10^3 W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1982	33.1	649.5	0.4	6.7	0.03	0.62	0.00	0.02
1983	34.2	683.8	0.6	7.3	0.07	0.70	0.00	0.02
1984	20.7	704.5	0.4	7.7	0.03	0.74	0.00	0.02
1985	515.8	1,220.3	0.2	7.9	0.01	0.76	0.00	0.02
1986	18.8	1,239.0	0.2	8.0	0.01	0.78	0.00	0.02
1987	88.8	1,327.8	0.7	8.7	0.13	0.92	0.00	0.03
1988	5.2	1,333.0	0.2	8.9	0.02	0.95	0.00	0.03
1989	537.0	1,870.0	2.5	11.4	0.88	1.84	0.03	0.06
1990	30.5	1,900.5	0.1	11.5	0.08	1.91	0.00	0.06
1991	78.4	1,978.9	0.1	11.6	0.04	1.95	0.00	0.06
1992	26.6	2,005.4	0.1	11.7	0.03	1.97	0.00	0.06
				Total				
1970	2,189.7	2,189.7	8.5	8.5	1.74	1.74	0.06	0.06
1971	8,708.1	10,897.9	25.2	33.7	13.19	14.94	0.43	0.49
1972	7,613.2	18,511.1	38.5	72.2	15.42	30.33	0.51	1.00
1973	7,177.4	25,688.6	39.3	111.5	10.54	40.84	0.34	1.34
1974	5,659.0	31,347.5	49.1	160.5	44.78	85.60	1.48	2.81
1975	6,851.0	38,198.6	75.1	235.7	23.83	109.14	0.78	3.58
1976	2,395.8	40,594.3	34.7	270.3	28.17	136.96	0.93	4.50
1977	5,546.5	46,140.8	60.0	330.4	33.15	169.58	1.09	5.57
1978	3,874.8	50,015.6	56.2	386.5	39.36	208.24	1.30	6.84
1979	5,217.8	55,233.4	117.9	504.4	28.20	235.54	0.92	7.73
1980	4,730.0	59,963.4	148.5	653.0	104.22	338.78	3.43	11.12
1981	4,881.5	64,844.9	142.0	794.9	29.01	366.14	0.94	12.01
1982	4,631.2	69,476.0	174.8	969.7	21.61	386.01	0.69	12.64
1983	4,342.6	73,818.7	158.6	1,128.3	17.16	401.39	0.55	13.13
1984	4,639.2	78,457.9	206.7	1,335.0	25.57	425.19	0.82	13.89
1985	5,441.3	83,899.2	208.7	1,543.7	24.96	448.48	0.79	14.63
1986	4,412.5	88,311.7	205.4	1,749.1	24.09	470.90	0.77	15.34
1987	2,603.3	90,915.0	141.7	1,890.8	20.49	489.74	0.66	15.94
1988	2,044.4	92,959.4	277.3	2,168.0	23.97	512.05	0.75	16.64
1989	1,973.0	94,932.4	215.4	2,383.4	18.40	528.76	0.58	17.16
1990	426.4	95,358.9	191.6	2,575.0	15.21	542.27	0.48	17.59
1991[c]	10,236.4	105,595.3	347.3	2,922.3	420.56	961.14	13.87	31.40
1992	352.3	105,947.5	52.5	2,974.8	9.24	965.87	0.30	31.55

[a]Radioactive daughters of TRU radionuclides are not included.
[b]TRU mass means mass of TRU radionuclides, not of total waste.
[c]SRS CH waste data not available for individual years prior to 1991 but is included in totals for years 1991 and 1992.

Table 3.8. Summary of buried TRU waste by sites: cumulative as-stored volumes

Site name	Site acronym	Cumulative volume at end of calendar year, m^3									
		1945	1950	1955	1960	1965	1970	1975	1980	1985	1992
Contact and remote handled											
Argonne National Laboratory-East	ANL-E	0	0	0	0	0	0	0	0	0	0
Energy Technology Engineering Center	ETEC	0	0	0	0	0	0	0	0	0	0
Hanford Site	HANF	779	6,159	16,333	35,509	47,932	63,624	63,629	63,629	63,629	63,629[a]
Idaho National Engineering Laboratory	INEL	0	0	1,829	29,029	68,929	125,659	125,659	125,659	125,659	125,659
Knolls Atomic Power Laboratory	KAPL	0	0	0	0	0	0	0	0	0	0
Lawrence Berkeley Laboratory	LBL	0	0	0	0	0	0	0	0	0	0
Lawrence Livermore National Laboratory	LLNL	0	0	0	0	0	0	0	0	0	0
Los Alamos National Laboratory	LANL	0	0	0	0	0	0	0	0	0	0
Mound	MOUND	0	0	0	0	0	0	0	0	0	0
Nevada Test Site	NTS	0	0	0	0	0	0	0	0	0	0
Oak Ridge National Laboratory	ORNL	0	0	0	0	0	68	1,185	1,185	10,615	10,615
Paducah Gaseous Diffusion Plant	PAD	0	0	0	0	0	0	0	0	0	0
Rocky Flats Plant	RFP	0	0	0	0	0	0	0	0	0	0
Sandia National Laboratory-Albuquerque	SNLA	0	0	0	0.14	0.85	1.33	1.33	1.33	1.33	1.33
Savannah River Site	SRS	b	b	b	b	b	4,534	4,534	4,534	4,534	4,534
West Valley Demonstration Project	WVDP	0	0	0	0	0	0	0	0	0.02[c]	0.02
Total		779	6,159	18,162	64,538	116,862	193,886	195,008	195,008	204,438	204,438

[a]Reference 4 states that upon retrieval of this waste, a significant amount of the soil will become contaminated and will increase the volume of waste. The estimated waste and associated contaminated soil volume is 109,000 m^3.

[b]No data available for these years.

[c]WVDP submittal shows 0.018 m^3 buried in year 1984.

Table 3.9. Summary of buried TRU waste by sites: cumulative as-stored radioactivity (all radionuclides)

Site name	Site acronym	Cumulative radioactivity at end of calendar year, 10^3 Ci									
		1945	1950	1955	1960	1965	1970	1975	1980	1985	1992
Contact and remote handled											
Argonne National Laboratory-East	ANL-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Energy Technology Engineering Laboratory	ETEC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hanford Site	HANF	0.56	13.89	170.14	231.13	242.85	601.02	601.67	601.68	601.68	601.68
Idaho National Engineering Laboratory	INEL	0.00	0.00	0.02	72.24	1,472.24	4,849.24	4,849.24	4,849.24	4,849.24	4,849.24
Knolls Atomic Power Laboratory	KAPL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Berkeley Laboratory	LBL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Livermore National Laboratory	LLNL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Los Alamos National Laboratory	LANL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mound	MOUND	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nevada Test Site	NTS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oak Ridge National Laboratory	ORNL	0.00	0.00	0.00	0.00	0.00	0.01	24.90	24.90	702.60	702.60
Paducah Gaseous Diffusion Plant	PAD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rocky Flats Plant	RFP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sandia National Laboratory-Albuquerque	SNLA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Savannah River Site	SRS	b	b	b	b	b	9.83	9.83	9.83	9.83	9.83
West Valley Demonstration Project	WVDP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00[a]	0.00
Total		0.56	13.89	170.16	303.37	1,715.09	5,460.10	5,485.11	5,485.12	6,162.83	6,162.83

[a]WVDP submittal shows 0.91 Ci buried in year 1984.
[b]No data available for these years.

Table 3.10. Summary of buried TRU waste by sites: cumulative as-stored radioactivity (TRU radionuclides only)

Site name	Site acronym	Cumulative radioactivity at end of calendar year, 10^3 Ci									
		1945	1950	1955	1960	1965	1970	1975	1980	1985	1992
Contact and remote handled											
Argonne National Laboratory-East	ANL-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Energy Technology Engineering Laboratory	ETEC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hanford Site	HANF	0.10	2.37	103.41	110.90	112.64	114.45	114.45	114.45	114.45	114.45
Idaho National Engineering Laboratory	INEL	a	a	a	a	a	a	a	a	a	a
Knolls Atomic Power Laboratory	KAPL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Berkeley Laboratory	LBL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Livermore National Laboratory	LLNL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Los Alamos National Laboratory	LANL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mound	MOUND	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nevada Test Site	NTS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oak Ridge National Laboratory	ORNL	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	2.15	2.15
Paducah Gaseous Diffusion Plant	PAD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rocky Flats Plant	RFP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sandia National Laboratory-Albuquerque	SNLA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Savannah River Site	SRS	a	a	a	a	a	a	a	a	a	a
West Valley Demonstration Project	WVDP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.10	2.37	103.41	110.90	112.64	114.45	114.48	114.48	116.60	116.60

[a]No data available.

Table 3.11. Summary of buried TRU waste by sites: decayed radioactivity (all radionuclides)

Site name	Site acronym	Cumulative radioactivity at end of calendar year, 10^3 Ci									
		1945	1950	1955	1960	1965	1970	1975	1980	1985	1992
Contact and remote handled											
Argonne National Laboratory-East	ANL-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Energy Technology Engineering Laboratory	ETEC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hanford Site	HANF	0.56	13.40	161.70	189.75	177.37	452.07	308.59	256.77	218.37	178.71
Idaho National Engineering Laboratory	INEL	a	a	a	a	a	a	a	a	a	a
Knolls Atomic Power Laboratory	KAPL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Berkeley Laboratory	LBL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Livermore National Laboratory	LLNL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Los Alamos National Laboratory	LANL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mound	MOUND	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nevada Test Site	NTS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oak Ridge National Laboratory	ORNL	0.00	0.00	0.00	0.00	0.00	0.01	23.22	20.67	660.96	556.20
Paducah Gaseous Diffusion Plant	PAD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rocky Flats Plant	RFP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sandia National Laboratory-Albuquerque	SNLA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Savannah River Site	SRS	a	a	a	a	a	a	a	a	a	a
West Valley Demonstration Project	WVDP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.56	13.40	161.70	189.75	177.37	452.08	331.80	277.45	879.33	734.91

[a]No data available.

Table 3.12. Summary of buried TRU waste by sites: decayed radioactivity (TRU radionuclides only)

Site name	Site acronym	Cumulative radioactivity at end of calendar year, 10^3 Ci									
		1945	1950	1955	1960	1965	1970	1975	1980	1985	1992
Contact and remote handled											
Argonne National Laboratory-East	ANL-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Energy Technology Engineering Laboratory	ETEC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hanford Site	HANF	0.10	2.38	102.95	107.53	106.50	105.61	102.95	100.32	97.72	94.16
Idaho National Engineering Laboratory	INEL	a	a	a	a	a	a	a	a	a	a
Knolls Atomic Power Laboratory	KAPL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Berkeley Laboratory	LBL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Livermore National Laboratory	LLNL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Los Alamos National Laboratory	LANL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mound	MOUND	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nevada Test Site	NTS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oak Ridge National Laboratory	ORNL	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	2.14	2.10
Paducah Gaseous Diffusion Plant	PAD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rocky Flats Plant	RFP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sandia National Laboratory-Albuquerque	SNLA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Savannah River Site	SRS	a	a	a	a	a	a	a	a	a	a
West Valley Demonstration Project	WVDP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.10	2.38	102.95	107.53	106.50	105.61	102.98	100.34	99.85	96.26

[a]No data available.

Table 3.13. Buried TRU waste inventories and decayed characteristics, total of all sites, all radionuclides included[a]

End of calendar year	Volume (m^3)		Total mass[b] (kg)		Radioactivity (10^3 Ci)		Thermal power (10^3 W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
			Contact and remote handled					
1944	14.2	14.2	0.0	0.0	0.00	0.00	0.00	0.00
1945	764.6	778.7	100.5	100.5	0.56	0.56	0.00	0.00
1946	821.2	1,599.9	100.5	201.0	0.55	1.07	0.00	0.01
1947	962.8	2,562.7	100.5	301.5	0.56	1.56	0.00	0.01
1948	906.1	3,468.8	100.5	402.0	0.56	2.03	0.00	0.01
1949	991.1	4,459.9	105.5	507.4	2.67	4.60	0.01	0.03
1950	1,699.0	6,158.9	120.4	627.8	9.00	13.40	0.05	0.07
1951	1,755.7	7,914.6	130.3	758.1	13.23	26.09	0.07	0.15
1952	2,194.6	10,109.2	428.6	1,186.7	13.47	38.56	0.07	0.22
1953	2,075.6	12,184.8	376.9	1,563.6	12.70	49.78	0.07	0.29
1954	2,047.3	14,232.1	383.7	1,947.3	102.83	150.72	3.03	3.33
1955	2,101.1	16,333.2	380.1	2,327.5	14.02	161.70	0.07	3.38
1956	3,630.2	19,963.4	410.1	2,737.6	15.67	173.91	0.08	3.44
1957	4,502.4	24,465.8	9,915.7	12,653.2	18.25	187.40	0.09	3.51
1958	4,567.5	29,033.3	19,383.9	32,037.1	18.52	198.51	0.09	3.57
1959	4,482.6	33,515.9	39,278.6	71,315.7	7.66	197.65	0.04	3.57
1960	1,993.5	35,509.4	60,862.0	132,177.7	0.88	189.75	0.01	3.53
1961	2,642.5	38,151.9	41,487.7	173,665.3	2.15	185.99	0.01	3.52
1962	3,165.8	41,317.7	231,364.2	405,029.5	2.26	183.17	0.01	3.51
1963	2,236.5	43,554.2	70,911.5	475,941.0	2.41	181.09	0.01	3.51
1964	2,317.2	45,871.4	78,166.5	554,107.5	2.41	179.14	0.01	3.50
1965	2,060.3	47,931.7	134,494.5	688,602.1	2.49	177.37	0.01	3.49
1966	1,679.2	49,610.9	60,913.8	749,515.9	2.69	176.00	0.01	3.49
1967	3,735.3	53,346.2	23,042.9	772,558.8	4.08	176.07	0.02	3.49
1968	4,214.5	57,560.7	1,564.5	774,123.2	89.24	260.90	0.11	3.58
1969	5,130.0	62,690.7	54,601.9	828,725.1	100.85	345.14	0.33	3.85
1970	1,001.3	63,692.1	127.8	828,852.9	161.32	452.08	0.26	3.88
1971	177.0	63,869.1	0.4	828,853.3	0.37	389.37	0.00	3.65
1972	935.2	64,804.3	0.0	828,853.3	24.76	383.20	0.07	3.62
1973	1.7	64,806.0	0.0	828,853.3	0.08	362.09	0.00	3.56
1974	7.5	64,813.5	0.0	828,853.3	0.32	345.94	0.00	3.53
1975	0.0	64,813.5	0.0	828,853.3	0.00	331.80	0.00	3.50
1976	0.0	64,813.5	0.0	828,853.3	0.00	319.26	0.00	3.47
1977	0.0	64,813.6	0.0	828,853.3	0.01	307.77	0.00	3.45
1978	0.0	64,813.6	0.0	828,853.3	0.00	297.04	0.00	3.43
1979	0.0	64,813.6	0.0	828,853.3	0.00	286.96	0.00	3.41
1980	0.0	64,813.6	0.0	828,853.3	0.00	277.45	0.00	3.38
1981	0.0	64,813.6	0.0	828,853.3	0.00	268.44	0.00	3.36
1982	2,950.0	67,763.6	14.6	828,867.9	125.11	385.02	0.52	3.86
1983	4,930.0	72,693.6	15,325.2	844,193.1	498.09	871.63	1.90	5.72
1984	1,550.0	74,243.6	3.3	844,196.4	54.50	903.00	0.22	5.85

Table 3.13 (continued)

End of calendar year	Volume (m^3)		Total mass[b] (kg)		Radioactivity (10^3 Ci)		Thermal power (10^3 W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
Contact and remote handled (continued)								
1985	0.0	74,243.6	0.0	844,196.4	0.00	879.33	0.00	5.76
1986	0.0	74,243.6	0.0	844,196.4	0.00	856.50	0.00	5.67
1987	0.0	74,243.6	0.0	844,196.4	0.00	834.47	0.00	5.59
1988	0.0	74,243.6	0.0	844,196.4	0.00	813.19	0.00	5.50
1989	0.0	74,243.6	0.0	844,196.4	0.00	792.63	0.00	5.42
1990	0.0	74,243.6	0.0	844,196.4	0.00	772.75	0.00	5.34
1991	0.0	74,243.6	0.0	844,196.4	0.00	753.52	0.00	5.27
1992	0.0	74,243.6	0.0	844,196.4	0.00	734.91	0.00	5.20

[a]Does not include INEL and SRS because decayed data are not available. Volume data for INEL and SRS are shown in Table 3.8.

[b]Mass means mass of radionuclides, not of total waste.

Table 3.14. Buried TRU waste inventories and decayed characteristics, total of all sites, TRU radionuclides only included[a]

End of calendar year	Volume (m^3)		TRU mass[b] (kg)		TRU radioactivity (10^3 Ci)		TRU thermal power (10^3 W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1944	14.2	14.2	0.0	0.0	0.00	0.00	0.00	0.00
1945	764.6	778.7	1.2	1.2	0.10	0.10	0.00	0.00
1946	821.2	1,599.9	1.2	2.4	0.09	0.19	0.00	0.01
1947	962.8	2,562.7	1.2	3.6	0.09	0.28	0.00	0.01
1948	906.1	3,468.8	1.2	4.8	0.09	0.37	0.00	0.01
1949	991.1	4,459.9	6.2	11.0	0.46	0.83	0.01	0.03
1950	1,699.0	6,158.9	21.0	32.0	1.54	2.38	0.05	0.07
1951	1,755.7	7,914.6	30.9	62.9	2.27	4.66	0.07	0.14
1952	2,194.6	10,109.2	31.4	94.3	2.31	7.00	0.07	0.22
1953	2,075.6	12,184.8	29.3	123.6	2.28	9.33	0.07	0.29
1954	2,047.3	14,232.1	36.1	159.7	91.80	101.19	3.03	3.32
1955	2,101.1	16,333.2	32.5	192.2	2.39	102.95	0.07	3.38
1956	3,630.2	19,963.4	32.7	224.9	2.42	104.76	0.07	3.43
1957	4,502.4	24,465.8	30.5	255.4	2.24	106.40	0.07	3.48
1958	4,567.5	29,033.3	31.1	286.5	2.30	108.13	0.07	3.53
1959	4,482.6	33,515.9	5.7	292.1	0.42	107.98	0.01	3.53
1960	1,993.5	35,509.4	1.5	293.6	0.11	107.53	0.00	3.51
1961	2,642.5	38,151.9	4.1	297.7	0.38	107.36	0.01	3.51
1962	3,165.8	41,317.7	4.3	302.1	0.32	107.12	0.01	3.50
1963	2,236.5	43,554.2	4.8	306.9	0.35	106.92	0.01	3.49
1964	2,317.2	45,871.4	4.7	311.5	0.34	106.71	0.01	3.48
1965	2,060.3	47,931.7	4.7	316.2	0.34	106.50	0.01	3.47
1966	1,679.2	49,610.9	5.0	321.2	0.37	106.32	0.01	3.47
1967	3,735.3	53,346.2	7.0	328.2	0.51	106.29	0.02	3.47
1968	4,214.5	57,560.7	6.5	334.7	0.49	106.24	0.02	3.46
1969	5,130.0	62,690.7	4.5	339.2	0.34	106.04	0.01	3.46
1970	1,001.3	63,692.1	1.1	340.3	0.10	105.61	0.00	3.44
1971	177.0	63,869.1	0.3	340.6	0.02	105.10	0.00	3.42
1972	935.2	64,804.3	0.0	340.6	0.00	104.57	0.00	3.41
1973	1.7	64,806.0	0.0	340.6	0.00	104.04	0.00	3.39
1974	7.5	64,813.5	0.0	340.6	0.00	103.51	0.00	3.37
1975	0.0	64,813.5	0.0	340.6	0.00	102.98	0.00	3.35
1976	0.0	64,813.5	0.0	340.6	0.00	102.45	0.00	3.34
1977	0.0	64,813.6	0.0	340.6	0.00	101.92	0.00	3.32
1978	0.0	64,813.6	0.0	340.6	0.00	101.39	0.00	3.30
1979	0.0	64,813.6	0.0	340.6	0.00	100.87	0.00	3.28
1980	0.0	64,813.6	0.0	340.6	0.00	100.34	0.00	3.27
1981	0.0	64,813.6	0.0	340.6	0.00	99.82	0.00	3.25
1982	2,950.0	67,763.6	2.5	343.1	0.44	99.74	0.01	3.25
1983	4,930.0	72,693.6	8.0	351.1	1.28	100.50	0.04	3.27
1984	1,550.0	74,243.6	1.5	352.6	0.40	100.38	0.01	3.27
1985	0.0	74,243.6	0.0	352.6	0.00	99.85	0.00	3.25
1986	0.0	74,243.6	0.0	352.6	0.00	99.33	0.00	3.23

Table 3.14 (continued)

End of calendar year	Volume (m^3)		TRU mass[b] (kg)		TRU radioactivity (10^3 Ci)		TRU thermal power (10^3 W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1987	0.0	74,243.6	0.0	352.6	0.00	98.82	0.00	3.22
1988	0.0	74,243.6	0.0	352.6	0.00	98.30	0.00	3.20
1989	0.0	74,243.6	0.0	352.6	0.00	97.79	0.00	3.18
1990	0.0	74,243.6	0.0	352.6	0.00	97.27	0.00	3.16
1991	0.0	74,243.6	0.0	352.6	0.00	96.76	0.00	3.15
1992	0.0	74,243.6	0.0	352.6	0.00	96.26	0.00	3.13

[a]Does not include INEL and SRS because decayed data are not available. Volume data for INEL and SRS are shown in Table 3.8.

[b]TRU mass means mass of TRU radionuclides, not of total waste.

Table 3.15. TRU-contaminated soil

Site	Soil contaminated with solid TRU waste		Soil contaminated with liquid TRU waste	
	Volume (m^3)	Radioactivity (Ci)	Volume (m^3)	Radioactivity (Ci)
ANL-E	0	0	0	0
ETEC	0	0	0	0
HANF	a	a	32,000	80,591
INEL	b	b	b	b
KAPL	0	0	0	0
LANL	c	d	c	d
LBL	0	0	0	0
LLNL	0	0	0	0
MOUND	c	c	c	c
NTS	c	c	b	b
ORNL	c	c	c	c
PAD	b	b	b	b
RFP	2	40	b	b
SNLA	c	c	c	c
SRS	0	0	0	0
WVDP	e	e	e	e

[a]Included in buried TRU waste.
[b]Listed in submittal as N/A (not applicable).
[c]Unknown.
[d]Partial data submitted.
[e]No data submitted.

Table 3.16. Mixed TRU waste volumes[a]

Site	Category	Mixed CH TRU volume, m^3			Mixed RH TRU volume, m^3		
		1970-1986	1987-1992	1993	1970-1986	1987-1992	1993
ANL-E	Mixed (RCRA)	b		0	b		0
	Mixed (PCB)	b		0	b		0
	Mixed (state only)	b		0	b		0
	Suspect mixed	b		0	b		0
ETEC	Mixed (RCRA)		0.2	0		0	
	Mixed (PCB)		0	0		0	
	Mixed (state only)		0	0		0	
	Suspect mixed		0	0		0	
HANF	Mixed (RCRA)	0	160.6	11.2	0	1.4	0
	Mixed (PCB)	0	1.5	c	0	0	0
	Mixed (state only)	0	2.1	c	0	0	0
	Suspect mixed	193	3.8	d	4.46	0	0
INEL	Mixed (RCRA)	0	30,220	0	0	691	0
	Mixed (PCB)	0	364	0	0	0	0
	Mixed (state only)	0	0	0	0	0	0
	Suspect mixed	0	8,750	0	0	7.4	0
KAPL[e]							
LANL	Mixed (RCRA)	0	619.1	225	0	0	10
	Mixed (PCB)	0	0	0	0	0	0
	Mixed (state only)	0	0	0	0	0	0
	Suspect mixed	6,796.3	0	0	2.10	0	0
LBL[f]							
LLNL[g]	Mixed (RCRA)	d	8.37	1.04	0	0	0
	Mixed (PCB)	d	0	0	0	0	0
	Mixed (state only)	0	0	0	0	0	0
	Suspect mixed	0	0	0	0	0	0
MOUND	Mixed (RCRA)	0	1,020	0			
	Mixed (PCB)						
	Mixed (state only)						
	Suspect mixed						
NTS	Mixed (RCRA)	588	1.9	0	5.3	0	0
	Mixed (PCB)						
	Mixed (state only)						
	Suspect mixed						
ORNL	Mixed (RCRA)	176	6.8	d	231	665	d
	Mixed (PCB)						
	Mixed (state only)						
	Suspect mixed	752	110	d	225	9.9	d
PAD	Mixed (RCRA)	4.34	h	h	h	h	h
	Mixed (PCB)	h	h	h	h	h	h
	Mixed (state only)	h	h	h	h	h	h
	Suspect mixed						
RFP[i]	Mixed (RCRA)	110	823	18			
	Mixed (PCB)	d	0.94	0			
	Mixed (state only)d	d	h	h			
	Suspect mixed	d	h	h			
SNLA[j]	Mixed (RCRA)	d	d	d	0	0	0
	Mixed (PCB)	0	0	0	0	0	0
	Mixed (state only)	h	h	h	h	h	h
	Suspect mixed	0	0	0	0	0	0

Table 3.16 (continued)

Site	Category	Mixed CH TRU volume, m^3			Mixed RH TRU volume, m^3		
		1970-1986	1987-1992	1993	1970-1986	1987-1992	1993
SRS	Mixed (RCRA)	d	d	d			
	Mixed (PCB)	d	d	d			
	Mixed (state only)	d	d	d			
	Suspect mixed	d	d	d			
WVDP	Mixed (RCRA)	0.454	0	0	0	0	0
	Mixed (PCB)	0	0	0	0	0	0
	Mixed (state only)	0	0	0	0	0	0
	Suspect mixed	0	0	0	0	0	0

[a]Compiled from Table 4 of site submittals. The quantities shown in each column represent the total volume of a given waste type generated during the period indicated at the top of the column.

[b]Undetermined.

[c]Included in RCRA.

[d]Unknown.

[e]KAPL estimated their TRU waste contains about 10% LLW and 5% mixed waste.

[f]LBL reports that they do not generate or store TRU mixed waste.

[g]PCB and state-only not applicable to LLNL.

[h]Not applicable.

[i]There is no remote-handled TRU waste at RFP.

[j]SNLA appended the following notes to their Table 4 submittal:

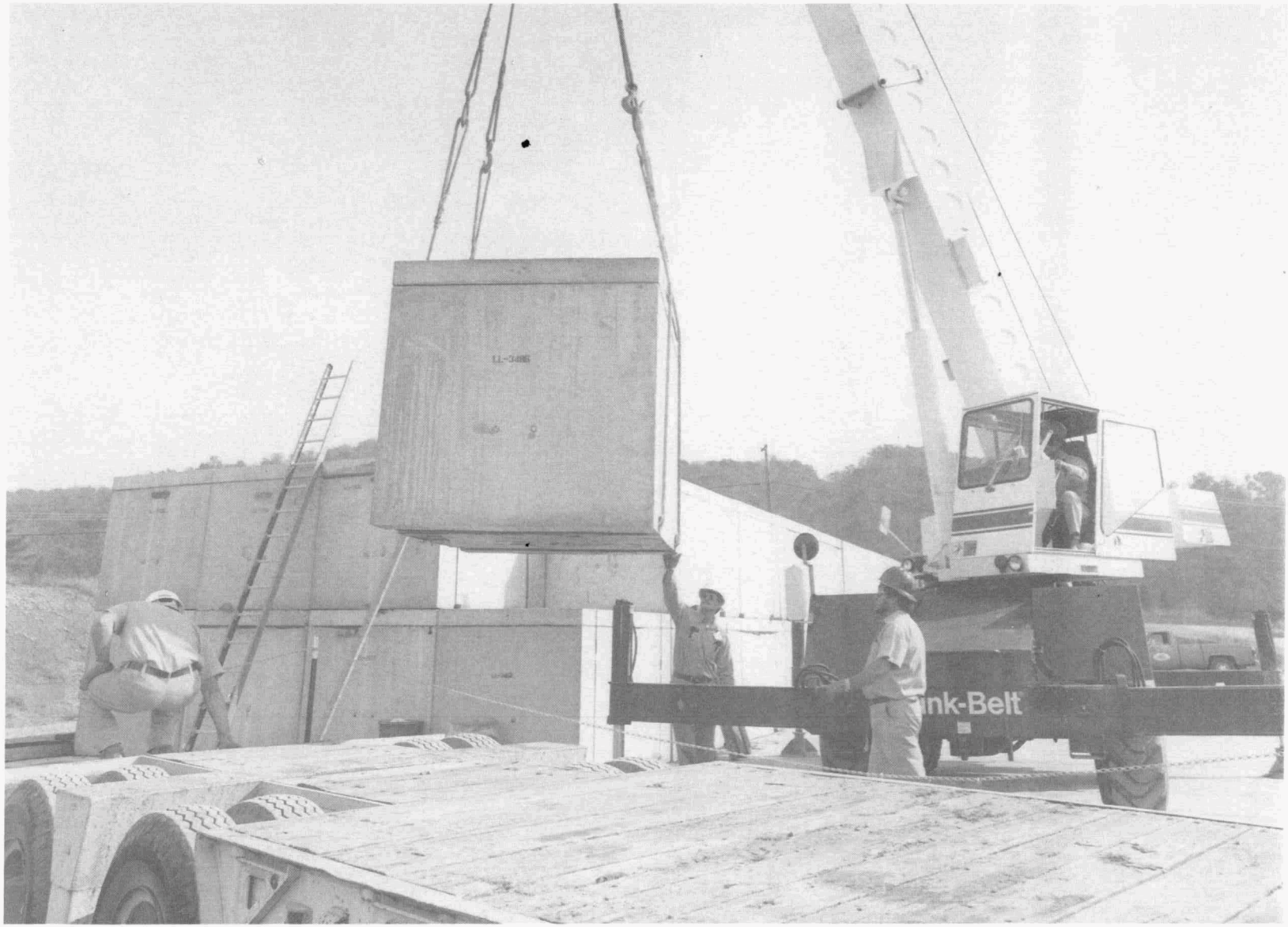
1. Includes only TRU waste included in SNL/NM's Disposal Request process.
2. With regard to instruction footnote c of Table 4: TRU material, which may be mixed and may be remote-handled material, is in storage in Technical Area V (TA-V) and the Manzano Site Structures. The years the material was generated or placed in storage is unknown. The material in TA-V is approximately 1 m^3 and is listed in the 180-day report, although it may not be categorized as waste under SNL/NM policy current at the time of this report. A recent inventory found two 55-gal containers of TRU material in the Manzanos, one contact-handled and one remote-handled. The material may be mixed and also may not yet be officially categorized as waste. None of this Manzano material was included in TRU estimates for the 180-day report. There is no activity information for the material at TA-V or the Manzanos. The TRU material at TA-V and the Manzanos has not been entered into the Disposal Request process. To be consistent with SNL/NM's approach for input into this report, no material that has not been entered into the Disposal Request process is included in the values listed in Table 4, "Mixed TRU waste and non-mixed TRU waste volumes (m^3)."
3. The estimated waste generation for 1993 for environmental restoration waste containing TRU contaminated with RCRA constituents was estimated in Table 2-4, "Projection of mixed waste to be generated by DOE environmental restoration activities (in cubic meters)," Volume 1: U.S. Department of Energy Interim Mixed Waste Inventory Report: Waste Streams, Treatment Capacities, and Technologies, DOE/NBM-1100, April 1993, as being 1 m^3. A more recent estimate puts 1993 CH TRU mixed (RCRA) environmental restoration waste generation at zero. (See Table 5, "Future generated TRU solid waste volumes--average annual.") The amount of TRU mixed operational or D&D waste in 1993 is unknown. Therefore, the volume of CH TRU waste contaminated with RCRA constituents in 1993 is unknown.
4. The amount of contact-handled non-mixed TRU waste to be generated by Dec. 31, 1993, is unknown.
5. An unknown amount of remote-handled non-mixed TRU waste has been generated in 1993 to date and it is not known what additional amounts will be generated by Dec. 31, 1993.

Table 3.17. Projected future TRU waste volumes generated annually[a]

Site	Waste type	Projected volumes generated, m^3/year						
		1993	1994-1996	1997-2000	2001-2005	2006-2010	2011-2015	2016-2020
ANL-E	CH	12.8	12.8[b]	5.9	5.9	5.9	5.9	5.9
	RH	1.7	1.7	1.7	1.7	1.7	1.7	1.7
ETEC	CH	0.2	0	0	0	0	0	0
	RH	0	0	0	0	0	0	0
HANF	CH	142.7	176.9	381.5	487.7	496.2	474.6	338.5
	RH	2.5	336.8	205.9	211.4	244.5	90.4	68.3
INEL	CH	0	0	0	0	0	0	0
	RH	0	0	0	0	0	0	0
KAPL	CH	c	c	c	c	c	c	c
	RH	0.2	0.6	0.8	1.0	1.0	1.0	1.0
LANL	CH	310	600	700	700	700	700	700
	RH	20	30	30	30	30	30	30
LBL	CH	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	RH	0	0	0	0	0	0	0
LLNL	CH	10.9	73.1	73.1	73.1	73.1	73.1	73.1
	RH	0	0	0	0	0	0	0
MOUND	CH	2	2	2	2	2	2	0
	RH	c	c	c	c	c	c	c
NTS	CH	e	e	e	e	e	e	e
	RH	e	e	e	e	e	e	e
ORNL	CH	81	55	20.3	20	20	20	20
	RH	28	25	25	20	12.4	12.4	12
PAD	CH	c	c	c	c	c	c	c
	RH	c	c	c	c	c	c	c
RFP	CH	27[f]	302[f]	110[f]	137[f]	137[f]	137[f]	137[f]
	RH	g	g	g	g	g	g	g
SNLA	CH	e	e	e, h	e, h	e	e	e
	RH	e	e	e	e	e	e	e
SRS	CH	5,210[i]	1,238[i]	e, i	e, i	e, i	e, i	e, i
	RH	c	c	c	c	c	c	c
WVDP	CH	c	c	c	c	c	c	c
	RH	c	c	c	c	c	c	c

[a]Compiled from Table 5 of site submittals.
[b]For year 1994 only.
[c]No estimates given.
[d]Waste from D&D operations not included; listed as "to be determined."
[e]Unknown.
[f]Remedial action and D&D waste unknown, not included in estimates.
[g]No RH waste at this site.
[h]Remedial action CH TRU waste of 9 m^3/year expected during 1997-2000 and 2 m^3/year expected during 2001-2005.
[i]D&D and remedial action waste unknown in all periods.

ORNL PHOTO 10488-88



Packaged dry active solid low-level waste being loaded onto the Oak Ridge National Laboratory Tumulus Facility. (Courtesy of Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Waste Management and Remedial Action Division, Oak Ridge, Tennessee.)

4. LOW-LEVEL WASTE

4.1 INTRODUCTION

As used in this chapter, LLW has the same meaning as in The Low-Level Waste Policy Act (Pub. L. 95–573, Dec. 22, 1980). Namely, LLW is radioactive waste not classified as high-level radioactive waste, transuranic (TRU) waste, spent nuclear fuel, or by-product material specified as uranium or thorium tailings and waste. The naturally occurring or accelerator-produced radioactive material that is disposed of at DOE burial or commercial disposal sites is included in the inventories given, but are not treated as separate entities in this chapter. Tailings (viz., mill tailings) are considered in Chapters 5 and 6. Another waste classification not delineated in this chapter is "mixed" waste that contains both chemically hazardous and radioactive constituents (see Chapter 8). Specific definitions of these waste types (as defined by DOE Order 5820.2A) are given in the glossary of this report. The DOE generates LLW through its defense activities, uranium enrichment operations, naval nuclear propulsion program, and various R&D activities. The data for DOE sites represent a summary of information obtained from each site.[1]

Disposal of LLW at commercial sites currently accounts for almost 55% of the LLW disposed (see Fig. 4.1). Commercially disposed LLW is generally divided into five types:[2] academic, government, industrial, medical, and utility. The academic type includes university hospitals and university medical and nonmedical research facilities. The government type includes state and non-DOE federal agencies. The industrial type is comprised of private entities such as R&D companies, manufacturers, nondestructive-testing operations, mining works, fuel fabrication facilities, and radiopharmaceutical manufacturers. The medical type includes hospitals and clinics, research facilities, and private medical offices. The utility type includes commercial nuclear reactors. In past IDB reports, commercially disposed waste was reported by fuel cycle and industrial/institutional (I/I) type activities. However, to achieve more consistency with other reporting agencies, the five types described are used.

Some LLW is also generated by DOE environmental restoration programs (see Chapter 6). Other LLW will be generated in future years by nonroutine D&D operations. Waste from past commercial D&D operations is included with the commercial waste disposal portion in this chapter since it has not been reported separately. However, projections of D&D waste are not included here but, instead, are discussed in Chapter 7.

The categorization of LLW according to DOE and commercial activities permits a comparison of the radioactivity levels and volumes of waste arising from each of these major sources (Figs. 4.1 and 4.2). Summary data on LLW (DOE and commercial) are given in Table 4.1. Historical and projected data by year for DOE LLW are presented in Table 4.2. In Table 4.3, similar data are shown for commercial LLW disposal.

4.2 DOE LLW

4.2.1 Inventories at DOE LLW Disposal Sites

An abridged picture of DOE LLW activities through 1992 is given in Figs. 4.1–4.4, as well as Tables 4.1, 4.2, and 4.4–4.13. Prior to October 1979, some LLW generated by DOE contractors was shipped to commercial disposal sites. Currently, all LLW generated by DOE activities is buried at DOE sites (Figs. 4.3 and 4.4). A summary of historical additions, cumulative volumes, and cumulative undecayed radioactivity for solid LLW buried at all DOE sites through 1992 is presented in Tables 4.1, 4.2, 4.4–4.6, 4.9, and 4.10. Summaries of DOE site-generated LLW volumes and activities are presented in Tables 4.7 and 4.8, respectively. The data in these tables are derived from the Waste Management Information System (WMIS) and subsequent site questionnaires obtained through the Hazardous Waste Remedial Actions Program (HAZWRAP).[1]

There are small quantities of DOE LLW that have been disposed of by sea dumping or by hydrofracture;[3] these wastes are not included in the WMIS data base. Table 4.11 shows the estimated quantity and radioactivity of LLW disposed of by these methods. Sea dumping of LLW was halted by the United States in 1970, and hydrofracture was terminated in 1983.

An estimate of DOE land usage for LLW burial is given in Table 4.12.

4.2.2 Characterization of LLW at DOE Sites

Based on information reported in ref. 1, summaries of radionuclide and physical characteristics for DOE LLW are reported in Tables 4.5–4.10. Summaries of representative radionuclide characteristics for generated, stored, and buried LLW at DOE sites are provided in Table 4.5. Representative radionuclide compositions for the buried waste types have been developed[4] and are given in Table C.3 of Appendix C. Summaries of physical characteristics for generated, stored, and buried wastes are given in Table 4.6. Breakdowns of radionuclide characteristics for buried LLW at each DOE site are provided for cumulative waste volume in Table 4.9 and for total gross waste activity in Table 4.10.

Most of the DOE wastes that were disposed of by sea dumping (see Table 4.11) were incorporated into cement matrix material and packaged in steel drums (55- or 80-gal capacity).

Hydrofracture was developed at ORNL for the permanent disposal of locally generated, low-level (approximately 0.25 Ci/L) liquid waste concentrates.[5] Waste was mixed with a blend of cement and other additives, and the resulting grout was injected into shale at a depth of 200 to 300 m. The injected grout hardened into thin, horizontal sheets several hundred meters wide.

Significant changes in DOE LLW inventory and characteristics data from that reported in the 1992 edition (1991 data) of this report are summarized in Table 4.13.

4.2.3 DOE LLW Disposal Sites

A digest of data on the current status of land usage at DOE sites with active LLW disposal areas is shown in Table 4.12 (data from refs. 1, 3, and 6–8). Most of the DOE site land usage information currently reported in Table 4.12 is based on data given in ref. 1 with land usage factors taken from ref. 3.

As previously discussed, the LLW ocean disposal sites have not been used for disposal purposes since 1970. All of the liquid LLW that had been held in long-term storage at ORNL was disposed of during 1982 and 1983 using the new hydrofracture facility.

4.2.4 DOE LLW Projections

An assumption used in this report is that the level of DOE waste burial activities will remain constant through 2030. Beginning in 1993, the volume and undecayed radioactivity added each year to each active LLW disposal area are assumed to remain constant through 2030 at the values projected for 1993. These volumes and activities are split into waste types using the radionuclide categories given in Tables 4.5, 4.9, and 4.10. The radioactivity (by waste type) is decayed from the year of addition through 2030 using the representative compositions given in Table C.3 of Appendix C.

Projections for burial of DOE LLW are presented in Tables 4.2, 4.14, and 4.15. Table 4.14 summarizes DOE LLW excluding saltstone. Table 4.15 summarizes projections of saltstone, an LLW by-product from the solidification of HLW at SRS. This saltstone (see Fig. C.3 and Table C.5 of Appendix C) is to be stored in concrete vaults at SRS. Grout-immobilized LLW derived from processing double-shell waste at Hanford (see Fig. 2.7 in Chapter 2) is excluded from the projections in Table 4.2 because the schedule and formulation for immobilization are not yet firmly defined.

4.3 COMMERCIAL LLW

4.3.1 Inventories at Commercial LLW Disposal Sites

There are six commercial shallow-land disposal sites for LLW (Figs. 4.2, 4.5, and 4.6), but only two are currently in operation. Commercial operations at the Maxey Flats, West Valley, and Sheffield sites have been halted. In addition, acceptance of LLW at Beatty stopped as of December 31, 1992. Until 1986, a second NRC-licensed burial ground at West Valley continued to receive wastes generated on-site from cleanup and water treatment operations. However, disposal operations at the WVDP have been suspended since 1986 pending the preparation of an environmental impact statement (EIS) report for the West Valley site closure. The historical data for annual additions and inventories of volume and radioactivity (undecayed) at each commercial disposal site through the end of 1992 are listed in Tables 4.16 and 4.17, respectively (compiled from refs. 3, 7, 9–12). The volumes are depicted in Figs. 4.2, 4.5, and 4.6. Sources of the historical reported data through 1984 are given in ref. 3 and through 1991 in ref. 7. Quantities of LLW shipped to disposal sites during 1992 are listed in Table 4.18 on a state-by-state basis.[9] These state-by-state values reflect the fact that the Manifest Information Management System (MIMS) is able to assign, to the original shippers, the LLW collected and treated by waste brokers. Table 4.3 is a summary of historical and projected volumes and radioactivity (decayed) for commercial LLW. Projections are only made through 1995 due to uncertainties in commercial disposal facilities operations. Not included in Table 4.3 are the drums of cemented LLW to be generated by the WVDP as a result of the vitrification of HLW. This LLW from the WVDP is described in Table C.8 of Appendix C.

4.3.2 Characterization of LLW at Commercial Disposal Sites

All of the LLW accepted for commercial disposal is categorized as Class A, B, or C in compliance with NRC specifications.[13] The LLW that exceeds these specifications is currently in storage at the generator site or at a DOE

site which has accepted it for study (see Sect. 4.3.3). A calculated representative radionuclide composition for disposed commercial LLW is given in Table C.4 of Appendix C. This composition is periodically updated to reflect changes in waste management practices and in the regulations governing LLW disposal.

4.3.3 Greater-Than-Class-C Low-Level Waste (GTCC LLW)

In 1980, federal law made each state responsible for providing the disposal capacity for LLW generated within its borders, except for certain waste generated by the federal government.[14] In 10 CFR Part 61 (ref. 13), the NRC codifies disposal requirements for three classes of LLW, as mentioned above, generally suitable for near-surface disposal, namely, Class A, B, and C (with Class C waste requiring the most rigorous disposal specifications). Waste with concentrations above Class C limits for certain short- and long-lived radionuclides (i.e., GTCC LLW) was found not generally suitable for near-surface disposal, except on a case-by-case evaluation of the waste and the proposed disposal method by NRC or state licensing agency. The Low-Level Radioactive Waste Policy Amendments Act (LLRWPAA)[15] made the states responsible for the disposal of Classes A, B, and C LLW and made the federal government (viz., DOE) responsible for disposal of GTCC LLW. The law also required that GTCC LLW generated by licensees of NRC be disposed of in a facility licensed by NRC. The projected amounts of GTCC LLW are uncertain, both because of regulatory uncertainties affecting the definition of HLW (i.e., a clearly defined all-inclusive list of wastes considered HLW may include more than those described in Chapter 2) and because of the lack of information on the sources, volumes, and characteristics of GTCC LLW.[16]

In May 1989, NRC promulgated a rule that requires disposal of GTCC LLW in a deep geologic repository unless disposal elsewhere has been approved by NRC. The rule as amended states: "Waste that is not generally acceptable for near-surface disposal is waste for which form and disposal methods must be different and, in general, more stringent than those specified for Class C waste. In the absence of specific requirements in this part, such waste must be disposed of in a geologic repository as defined in Part 60 of this chapter unless proposals for disposal of such waste in a disposal site licensed pursuant to this part are approved by the Commission."[17] A disposal facility (other than a deep geologic repository) for GTCC LLW will probably not be available for several decades because of the complexities of siting and NRC licensing. A generic description of estimated sources and forms of GTCC LLW is presented in Table C.7 of Appendix C.

Existing volume projections of GTCC LLW vary, ranging from 2,000 m^3 in the 1987 report to Congress[16] to 17,000 m^3 in the 1986 update of Part 61 Impacts Analysis Methodology.[18] In an effort aimed toward rectifying this situation, DOE initiated a study to provide information about estimates of present and future GTCC LLW to the year 2035 (2055 in some instances). Information garnered during the study[19] includes identification of generators, waste form characteristics, volumes, and radionuclide activities. The study categorizes GTCC LLW as (1) nuclear utilities waste, (2) sealed sources wastes, (3) DOE-held potential GTCC LLW, and (4) other generator waste. Three scenarios for data projection are used: (a) unpackaged volumes; (b) packaged volumes based on the application of packaging factors to the unpackaged volumes; and (c) concentration averaging, mixing or blending of similar materials with different radionuclide concentrations, values applied to the packaged volumes. Each of the three scenarios is treated for three cases: low, base, and high.

The study determined that the largest volume of GTCC wastes (approximately 57%) is generated by nuclear power plants. The other generator waste category contributes approximately 10% of the total GTCC LLW volume projected to the year 2035. Waste held by DOE, which is potential GTCC LLW, accounts for nearly 33% of all GTCC waste projected to the year 2035 (see Table 4.19). To date, no determination of a disposal method has been made for the latter waste. Sealed sources are less than 0.2% of the total projected volume of GTCC LLW. Data trends (1985–2035) among low, base, and high cases for packaged waste show an overall threefold increase. The low-case total (including DOE-held potential GTCC LLW) is approximately 2,220 m^3, while the high-case (to 2055) total is approximately 6,500 m^3. The increases (in the high case) are the result of nuclear power reactor life extension (additional operations waste) and less packaging efficiency. The volume and radioactivity totals for all base-case packaged GTCC LLW are about 3,250 m^3 and 6.58×10^7 Ci, respectively. A summary of light-water reactor GTCC LLW projections based on packaged waste volumes (with application of packing factors to the unpackaged volumes) for the three cases (low, base, and high) is presented in Table 4.20.

4.3.4 Commercial LLW Disposal Sites

Three commercial LLW disposal sites in the eastern United States (Maxey Flats, Sheffield, and West Valley) have been closed to further use. Additionally, reception of LLW at Beatty stopped as of December 31, 1992. Only a small amount of on-site generated LLW from site cleanup is occasionally buried at Maxey Flats. The closure of the eastern three commercial LLW disposal sites resulted in increasing volumes of LLW being shipped to the three remaining operating sites in South Carolina, Nevada, and Washington. The increase prompted South Carolina to impose an upper limit on the volume of LLW that could be accepted at Barnwell. Eventually, a general concern developed that the responsibility for LLW disposal should

not rest with only three states and that a coordinated national plan was needed. As described previously, the LLRWPA[14] was passed in 1980, making each state responsible for its own LLW and encouraging formation of regional interstate compacts to deal with the disposal problem. The Act provided that any compact approved by Congress could restrict access to its LLW disposal facility to member states after January 1, 1986. However, by 1984, it became evident that no new regional disposal facilities would be operating by the end of 1985. This gave rise to new legislation, the LLRWPAA,[15] which continued to encourage interstate compact formation while requiring that nonsited (i.e., without an operating disposal site) states and compacts meet specific milestones, leading to the operation of new regional facilities by January 1, 1993. Additionally, the LLRWPAA established rates and limits of acceptance at the three commercial disposal sites in operation, as well as space allocations for utility wastes. The utilities are required to meet certain waste volume reductions during a 7-year transition period, which is provided to allow for the opening of new LLW disposal sites under state compact arrangements.

However, no new regional facilities were in operation as of January 1, 1993. The site at Beatty, Nevada, ceased receiving waste December 31, 1992. Barnwell is currently scheduled to continue receiving out-of-region waste until June 30, 1994. Barnwell will then receive only Southeast Compact Waste until December 31, 1995. If a new North Carolina facility opens earlier than this date, then Barnwell will close. As of December 31, 1992, the disposal facility at Richland, Washington, allowed access only to members of the Northwest and Rocky Mountain compacts.[20]

During 1992, Barnwell received about 48% of the total volume of commercial LLW shipped for burial. The Beatty, Nevada, site received about 30%, while the site at Richland, Washington, received about 22% (see Table 4.16). Chem-Nuclear Systems, Inc., operates the Barnwell disposal site, and U.S. Ecology, Inc., operates the disposal sites at both Beatty and Richland. The land usage at existing commercial disposal sites is summarized in Table 4.12. Updated information reported for these commercial sites is based on data provided by state health and environmental control agencies (refs. 3, 6, 8, and 11).

Table 4.21 provides a breakdown of waste received at commercial sites in 1992 by type (academic, government, industrial, medical, or utility LLW).

4.3.5 Commercial LLW Projections

Previous IDB reports gave projections for the nuclear fuel cycle and I/I waste (see ref. 7). This report presents only summary information for disposed commercial waste. Historical volume, radioactivity, and thermal power data through 1979 are taken from ref. 7. After 1979, the source term for commercial LLW in Table C.4 of Appendix C is used to decay the annual waste additions to the commercial sites.

Projections for disposed commercial LLW are made only through 1995 because of uncertainties in current facility operations and the availability of future sites. Projections (1993–1995) are made for Barnwell and Richland and are based on ref. 20. Historical and projected volume, radioactivity, and thermal power for disposed commercial LLW are presented in Table 4.3.

Because of timing uncertainties, projected decommissioning wastes are not included in the projections of this chapter. Rather, decommissioning waste projections are reported separately in Chapter 7. Former DOE facilities that will be affected by environmental restoration activities are discussed in Chapter 6 and are also excluded from the projected values in this chapter.

4.4 REFERENCES

1. U.S. Department of Energy, Waste Management Information System (WMIS), DOE site LLW data submittals (Attachment 4) issued, received, and maintained by the Hazardous Waste Remedial Actions Program (HAZWRAP), Martin Marietta Energy Systems, Inc., submitted to the IDB Program during August–December 1993. The following LLW submittals from WMIS were received, reviewed, analyzed, and integrated by the IDB Program. Preceding each submittal is the site (in parentheses) to which it refers.

   a. (AMES) Kay M. Hannasch, Ames Laboratory, Ames, Iowa, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, submitting Ames Laboratory LLW information, dated Aug. 11, 1993.

   b. (ANL–E) R. Max Schletter, Argonne National Laboratory, Argonne, Illinois, memorandum to A. L. Taboas, DOE Argonne Area Office, Argonne, Illinois, "Request for Office of Waste Management, Waste Data Information Update," dated Aug. 26, 1993.

   c. (ANL–W) See footnotes in Tables C.11 and C.12 of Appendix C.

d. (BNL) Carson L. Nealy, U.S. Department of Energy, Brookhaven Area Office, Upton, New York, memorandum to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Brookhaven National Laboratory—1993 Waste Management Information System (WMIS) Update," dated Aug. 12, 1993.

e. (FNAL) J. Donald Cossairt, Fermi National Accelerator Laboratory, Batavia, Illinois, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Request for Office of Waste Management, Waste Data Information Update," dated Aug. 9, 1993.

f. (HANF) R. D. Wojtasek, Westinghouse Hanford Company, Hanford Site, Richland, Washington, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Request for Office of Waste Management, Waste Data Information Update," 9305688B R1, dated Aug. 9, 1993.

g. (INEL) See footnotes in Tables C.11 and C.12 of Appendix C.

h. (ITRI) Susan Umshler, U.S. Department of Energy, Kansas City Area Office, Kansas City, Missouri, memorandum to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, detailing LLW information for the Inhalation Toxicology Research Institute, dated Aug. 6, 1993.

i. (K-25) Jeff Wilson, Martin Marietta Energy Systems, Inc., Oak Ridge K-25 Site, Oak Ridge, Tennessee, facsimile to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, providing K-25 Site LLW information, dated Sept. 15, 1993.

j. (KCP) Patrick T. Hoopes, U.S. Department of Energy, Kansas City Area Office, Kansas City, Missouri, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, detailing LLW information for the Kansas City Plant, dated Aug. 12, 1993.

k. (LANL) Thomas C. Gunderson, Los Alamos National Laboratory, Los Alamos, New Mexico, memorandum to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "WMIS Data Call," EM-DO: 93-941, dated Aug. 17, 1993.

l. (LBL) Hannibal Joma, U.S. Department of Energy, San Francisco Operations Office, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, submitting Lawrence Berkeley Laboratory LLW waste information, 93W-332/5484.1.A.13, dated Aug. 23, 1993.

m. (LLNL) Kevin Hartnett, U.S. Department of Energy, San Francisco Operations Office, facsimile to Millie Jeffers, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, providing LLNL LLW information, dated Nov. 18, 1993.

n. (MOUND) Mary E. Sizemore, EG&G Mound Applied Technologies, Miamisburg, Ohio, memorandum to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Request for DOE Waste Date (sic) Information Update," dated Aug. 20, 1993.

o. (NR sites) J. J. Mangeno, U.S. Department of Energy, Naval Reactors Programs Office (NE-60), Crystal City, Virginia, memorandum to J. Coleman, DOE/EM Office of Technical Support (DOE/EM-35), Washington, D.C., "Update of Radioactive Waste Data on Waste Streams and Treatment, Storage, and Disposal Units for NE-60 Cognizant Facilities," dated Aug. 9, 1993.

p. (NTS) Layton J. O'Neill, U.S. Department of Energy, Nevada Operations Office, Las Vegas, Nevada, memorandum to Joseph A. Coleman, DOE/EM Office of Technical Support (DOE/EM-35), Washington, D.C., "Request for Office of Waste Management, Waste Data Information Update," dated Sept. 2, 1993.

q. (ORISE) Lynda H. McLaren, U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tennessee, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Waste Management Information System: Integrated Data Base—Oak Ridge Institute for Science and Education (ORISE) Submission," dated Sept. 21, 1993.

r. (ORNL) J. C. Patterson, Oak Ridge National Laboratory, Oak Ridge, Tennessee, facsimile to A. S. Icenhour, Oak Ridge National Laboratory, Oak Ridge, Tennessee, providing ORNL LLW information, dated Sept. 23, 1993.

s. (PAD) Jimmy C. Massey, Martin Marietta Energy Systems, Inc., Paducah, Kentucky, letter to Donald C. Booher, DOE Paducah Site Office, Paducah, Kentucky, "Update of Department of Energy Low-Level Radioactive and Low-Level Mixed Waste Data for the 1993 Integrated Data Base Annual Report," dated Aug. 20, 1993.

t. (PANT) R. M. Loghry, Mason & Hanger—Silas Mason Company, Inc., Amarillo, Texas, letter to Lise J. Wachter, Martin Marietta Energy Systems Inc., HAZWRAP, Oliver Springs, Tennessee, "Request for Office of Waste Management—Waste Data Information Update," dated Aug. 20, 1993.

u. (PINELLAS) Gary C. Schmidtke, DOE Pinellas Area Office, Largo, Florida, memorandum to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, detailing Pinellas Plant LLW information, dated July 30, 1993.

v. (PORTS) Eugene W. Gillespie, DOE Portsmouth Site Office, Piketon, Ohio, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Request for Office of Waste Management, Waste Data Information Update," EO-23-5379, dated Aug. 10, 1993.

w. (PPPL) No submittal

x. (RFP) W. T. Prymak, DOE Rocky Flats Office, Golden, Colorado, memorandum to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Submission of Waste Data Information to Support the Integrated Data Base," dated Aug. 27, 1993.

y. (SLAC) Matthew A. Allen, Stanford Linear Accelerator Center, Palo Alto, California, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Waste Data Information Update," dated Aug. 16, 1993.

z. (SNLA) Steve Ward, Sandia National Laboratories, Albuquerque, New Mexico, letter to George K. Laskar, DOE Albuquerque Operations, "Transmittal of Waste Management Information System (WMIS) Update Information," dated Aug. 5, 1993.

aa. (SNLL) K. K. Shepodd, Sandia National Laboratories, Livermore, California, memorandum to S. E. Umshler, DOE Kansas City Area Office, Kansas City, Missouri, "Updated Data for the Waste Management Information System," dated Aug. 9, 1993.

ab. (SRS) Michael G. O'Rear, U.S. Department of Energy, Savannah River Operations Office, memorandum to Director, Office of Technical Support (EM-35), HQ, "Department of Energy Waste Inventory Data Systems," dated Nov. 13, 1993.

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ad. (WVDP) J. P. Jackson, West Valley Nuclear Services Company, Inc., West Valley, New York, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Waste Information Update for Calendar Year 1992," dated Aug. 20, 1993.

2. R. L. Fuchs and S. D. McDonald, "1992 State-by-State Assessment of Low-Level Radioactive Wastes Received at Commercial Disposal Sites," DOE/LLW-181, Idaho National Engineering Laboratory, Idaho Falls, Idaho (September 1993).

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4. C. W. Forsberg, W. L. Carter, and A. H. Kibbey, *Flowsheets and Source Terms for Radioactive Waste Projections*, ORNL/TM-8462, Oak Ridge National Laboratory, Oak Ridge, Tennessee (March 1985).

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8. John Vaden, Nevada Division of Health, letter to A. S. Icenhour, Oak Ridge National Laboratory, Oak Ridge, Tennessee, dated Mar. 26, 1993.

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10. T. J. Rowland, U.S. Department of Energy, West Valley Project Office, West Valley, New York, letter to S. N. Storch, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Update to the DOE 1992 Integrated Data Base Report," dated Apr. 1, 1992.

11. D. Mills, Commonwealth of Kentucky, Department for Environmental Protection, Frankfort, Kentucky, letter to A. H. Kibbey, Oak Ridge National Laboratory, Oak Ridge, Tennessee, dated Feb. 5, 1990.

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16. U.S. Department of Energy, *Recommendations for Management of Greater-than-Class-C Low-Level Radioactive Waste*, report to Congress in response to Public Law 99–240, DOE/NE-0077 (February 1987).

17. U.S. Nuclear Regulatory Commission, amendments to 10 CFR Part 61, "Disposal of Radioactive Wastes," final rule, *Fed. Regist.* 54(100), 22578–83 (May 25, 1989).

18. O. I. Oztunali, W. D. Pon, R. Eng, and G. W. Roles, *Update of Part 61 Impacts Analysis Methodology*, Vol. 2, NUREG/CR-4370 (January 1986).

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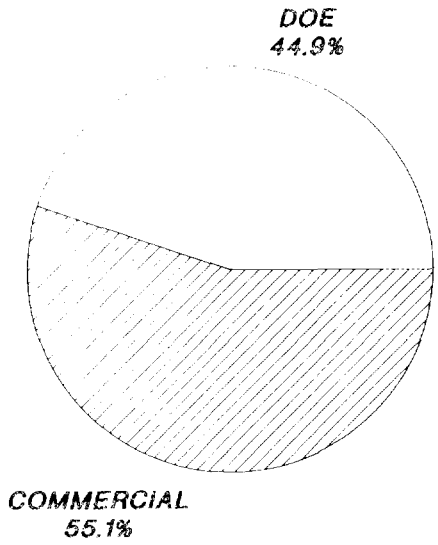
20. U.S. Department of Energy, Office of Environmental Restoration and Waste Management, *Report to Congress in Response to Public Law 99–240, 1992 Annual Report on Low-Level Radioactive Waste Management Progress* (final draft), May 1993.

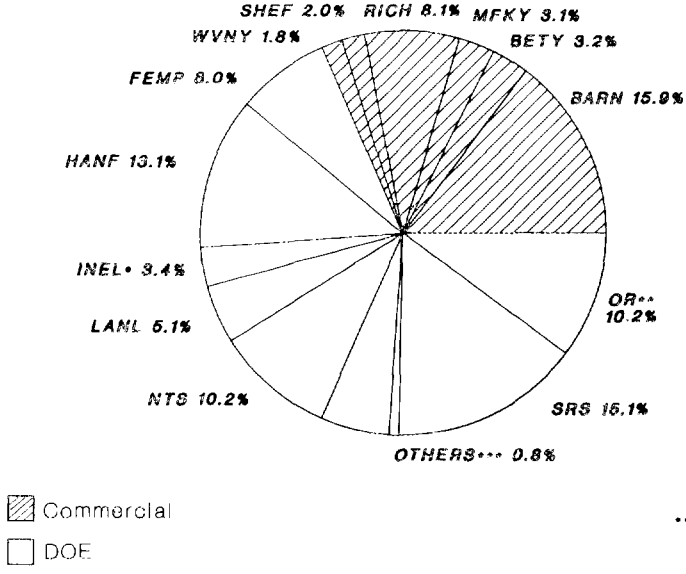
ORNL DWG 93-10805



SOURCE	CUBIC METERS
COMMERCIAL	4.936E+04
DOE	4.030E+04
TOTAL	8.966E+04

Fig. 4.1. Volume of LLW disposed in 1992.

ORNL DWG 93-10806



SITE	CUBIC METERS
BARN	6.842E+05
BETY	1.374E+05
MFKY	1.363E+05
RICH	3.498E+05
SHEF	8.833E+04
WVNY	7.707E+04
FEMP	3.432E+05
HANF	5.645E+05
INEL*	1.454E+05
LANL	2.180E+05
NTS	4.397E+05
OR**	4.408E+05
SRS	6.497E+05
OTHERS***	3.470E+04
TOTAL	4.308E+06

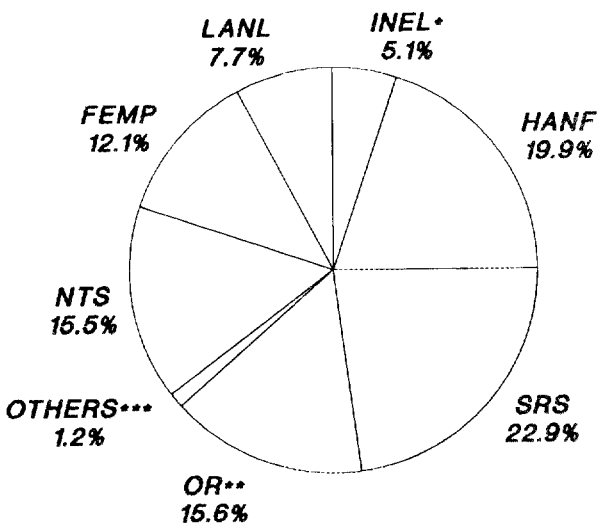
*Excludes LLW buried in 1992.

**Includes contributions from ORNL, K-25 Site, and Y-12 Plant.

***OTHERS - Includes contributions from AMES, BNL, LLNL, PANT, PAD, PORTS, and SNLA.

Fig. 4.2. Total volume of LLW disposed through 1992.

ORNL DWG 93-10807



SITE	CUBIC METERS
FEMP	3.432E+05
HANF	5.645E+05
INEL*	1.454E+05
LANL	2.180E+05
NTS	4.397E+05
OR**	4.408E+05
SRS	6.497E+05
OTHERS***	3.470E+04
TOTAL	2.835E+06

*Excludes LLW buried in 1992.

**Includes contributions from ORNL, K-25 Site, and Y-12 Plant.

***Includes contributions from AMES, BNL, LLNL, PANT, PAD, PORTS, and SNLA.

Fig. 4.3. Total volume of DOE LLW disposed through 1992.

ORNL DWG 93-10808

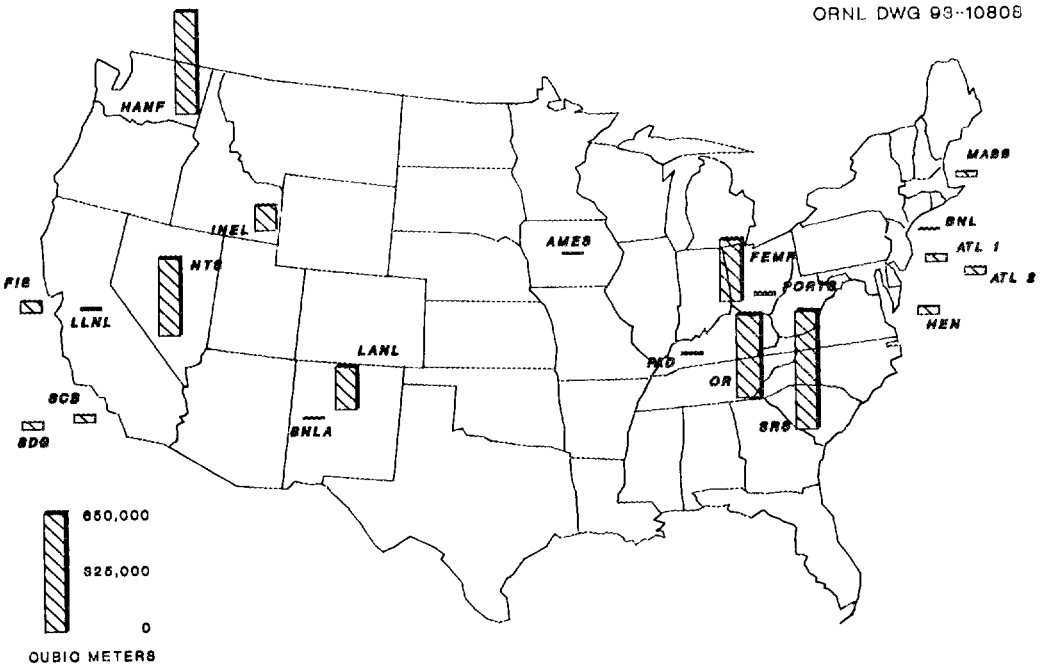
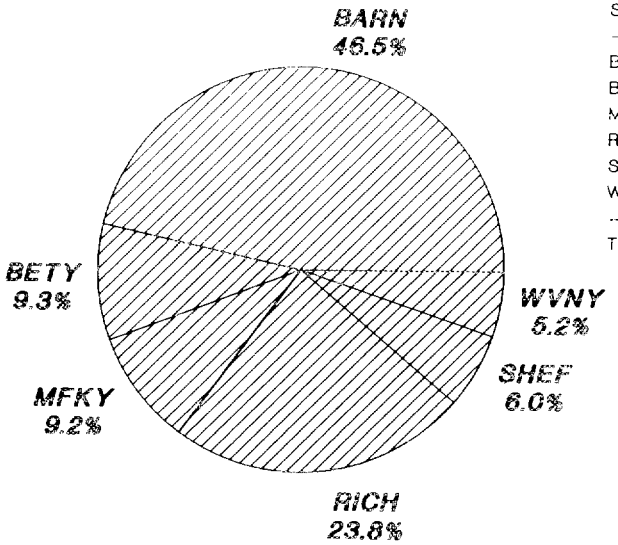


Fig. 4.4. Locations and total volumes of DOE LLW disposed through 1992.

ORNL DWG 93-10809



SITE	CUBIC METERS
BARN	6.842E+05
BETY	1.375E+05
MFKY	1.353E+05
RICH	3.498E+05
SHEF	8.833E+04
WVNY	7.707E+04
TOTAL	1.472E+06

Fig. 4.5. Total volume of commercial LLW disposed through 1992.

ORNL DWG 93-10810

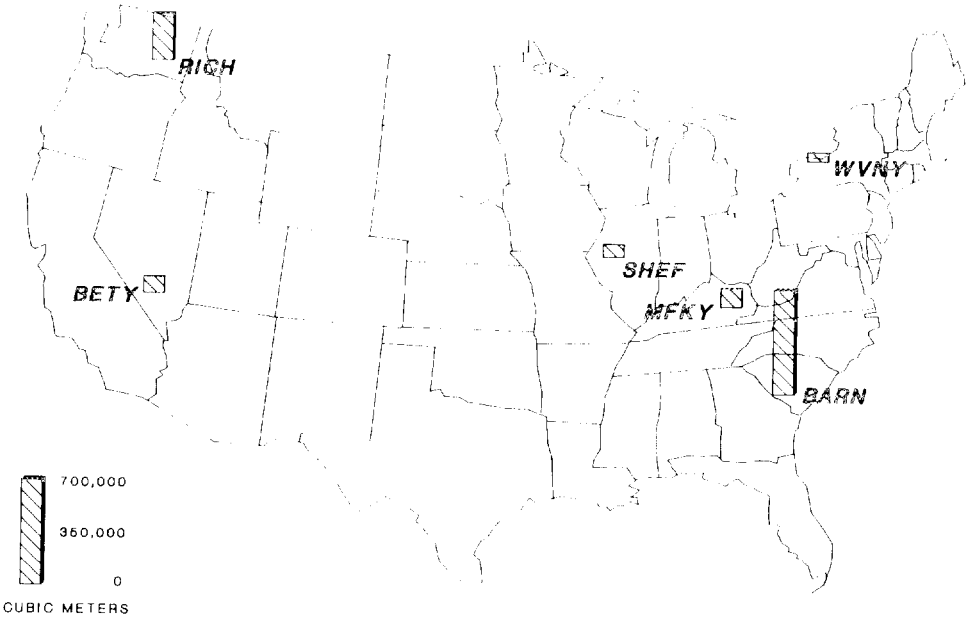


Fig. 4.6. Locations and total volumes of commercial LLW disposed through 1992.

Table 4.1. A summary of characteristics for buried/disposed LLW as of December 31, 1992

Category	Volume (10^3 m^3)		Radioactivity (10^3 Ci)		Thermal power (W)	
	Annual[a]	Cumulative	Annual	Cumulative	Annual	Cumulative
DOE sites[b]	41.6	2,836	631	12,408	3,283	17,419
Commercial sites	49.4	1,472	1,000	5,708	5,057	21,117
Total buried/ disposed LLW	91.0	4,308	1,631	18,116	8,340	38,536

[a]Addition during 1992.

[b]Includes waste estimated to be buried at INEL during 1992 (1,272 m^3; 186,900 Ci) since actual data were not available at time of calculations. However, data were received from INEL (including contributions from ANL-W) at press time and are included in Table C.12 of Appendix C. The volume change and activity change values reported in Table C.12 may be used to update the values reported in Table 4.1. This update results in an annual volume change of -0.96%. Table C.12 data will be integrated into future editions of this report.

Table 4.2. Historical and projected volume, radioactivity, and thermal power of buried DOE LLW[a,b]

End of calendar year	Volume (10^3 m^3)		Radioactivity (10^3 Ci)		Thermal power (W)	
	Annual	Cumulative	Annual	Cumulative[c,d]	Annual	Cumulative[d]
1990	54.6	2,746	339	13,087	1,288	16,443
1991	48.3	2,794	366	12,586	1,555	15,958
1992	41.6	2,836	631	12,408	3,283	17,419
1993	51.3	2,887	1,296	12,643	6,031	20,114
1994	51.3	2,938	1,296	12,499	6,031	20,745
1995	158.3	3,097	1,305	12,307	6,054	21,049
1996	94.9	3,192	1,363	12,158	6,106	21,263
1997	123.8	3,315	1,315	11,961	6,101	21,409
1998	139.6	3,456	1,303	11,758	6,067	21,491
1999	184.3	3,639	1,296	11,558	6,050	21,542
2000	124.3	3,763	1,296	11,361	6,031	21,562
2001	79.5	3,844	1,296	11,174	6,031	21,577
2002	80.3	3,924	1,296	10,999	6,031	21,591
2003	89.1	4,012	1,296	10,834	6,031	21,605
2004	80.3	4,092	1,296	10,677	6,031	21,614
2005	109.3	4,202	1,296	10,530	6,031	21,624
2006	80.3	4,282	1,296	10,391	6,031	21,632
2007	101.0	4,383	1,298	10,264	6,038	21,655
2008	80.3	4,464	1,296	10,142	6,032	21,670
2009	100.7	4,565	1,296	10,027	6,032	21,684
2010	80.3	4,645	1,296	9,916	6,031	21,693
2011	104.5	4,750	1,296	9,812	6,031	21,703
2012	75.3	4,825	1,297	9,716	6,032	21,718
2013	109.3	4,933	1,301	9,628	6,045	21,744
2014	77.9	5,014	1,296	9,541	6,031	21,752
2015	108.1	5,116	1,296	9,458	6,031	21,765
2016	80.3	5,197	1,296	9,380	6,031	21,772
2017	80.3	5,278	1,296	9,305	6,031	21,779
2018	51.3	5,330	1,296	9,235	6,031	21,786
2019	51.3	5,381	1,296	9,168	6,031	21,794
2020	51.3	5,432	1,296	9,105	6,031	21,802
2021	51.3	5,484	1,296	9,046	6,031	21,810
2022	51.3	5,535	1,296	8,990	6,031	21,818
2023	51.3	5,586	1,296	8,937	6,031	21,826
2024	51.3	5,637	1,296	8,886	6,031	21,834
2025	51.3	5,689	1,296	8,839	6,031	21,842
2026	51.3	5,740	1,296	8,794	6,031	21,850
2027	51.3	5,791	1,296	8,752	6,031	21,859
2028	51.3	5,843	1,296	8,712	6,031	21,868
2029	51.3	5,894	1,296	8,674	6,031	21,876
2030	51.3	5,945	1,296	8,639	6,031	21,885

[a]Summation of values in Tables 4.14 (buried DOE LLW, except SRS saltstone) and 4.15 (LLW saltstone at SRS).

[b]Data for INEL for 1992-2030 are based on 1991 data since the actual 1992 data were not available at time of calculations. However, data were received from INEL (including contributions from ANL-W) at press time and are included in Table C.12 of Appendix C. The volume change and activity change values reported in Table C.12 may be used to update the 1992 values reported in Table 4.2. This update results in an annual volume change of -0.96%. Table C.12 data will be integrated into future editions of this report.

[c]The radioactivity added each year for each waste type is decayed as described in the footnotes of Tables 4.14 and 4.15.

[d]Note that the projected cumulative radioactivity decreases while the projected cumulative thermal power increases. This is caused by the decay of relatively short-lived low-energy radionuclides whose daughter (or daughters) have much higher thermal power per curie. This may be shown by comparing the source terms in Table C.3 of Appendix C with the W/Ci values for parents and daughters given in Table B.1 of Appendix B.

Table 4.3. Historical and projected volume, radioactivity, and thermal power of commercial LLW shipped for disposal[a]

End of calendar year	Volume (10^3 m^3)		Radioactivity (10^3 Ci)		Thermal power (W)	
	Annual	Cumulative	Annual	Cumulative[b]	Annual	Cumulative
1990	32.4	1,384	549	4,979	2,774	16,457
1991	38.8	1,423	800	5,272	4,044	18,424
1992	49.4	1,472	1,000	5,708	5,057	21,117
1993[c]	16.8	1,489	268	5,333	1,354	19,729
1994	13.4	1,502	215	5,008	1,088	18,485
1995	9.2	1,511	143	4,672	722	17,114

[a]Includes LLW disposed of at the following commercial sites: Beatty, Nevada; West Valley, New York; Maxey Flats, Kentucky; Richland, Washington; Sheffield, Illinois; and Barnwell, South Carolina.

[b]The radioactivity through 1979 was decayed using a multiple source term methodology (see Tables 4.3 and 4.20-4.25 of ref. 7 for a description of this method). After 1979, the radioactivity is decayed from the year of addition using the representative compositions given in Table C.4 of Appendix C.

[c]Projections were made based on disposal operations at Richland, Washington and Barnwell, South Carolina, as described in Sect. 4.3.5. Projections were made only through 1995 because of large uncertainties in commercial disposal facility operations.

Table 4.4. Historical annual additions and total volume of LLW buried at DOE sites[a]

Year	Volume of waste buried annually, 10^3 m^3										
	FEMP	HANF[b]	INEL	LANL	NTS	ORNL	SRS	Y-12[c]	All other[d]	Total annual addition	Total cumulative volume
1975[e]	309.5	352.0	84.6	131.6	8.3	161.5	269.1	58.4	83.9	1,478.9	1,479
1976	14.4	4.1	6.2	8.8	0.0	3.8	8.1	2.7	0.9	49.0	1,528
1977	2.8	10.7	6.6	3.6	0.5	2.4	14.7	1.5	1.1	43.9	1,572
1978	1.9	9.8	5.9	7.5	10.0	2.0	15.5	1.4	3.2	57.2	1,629
1979	1.6	17.5	5.3	4.9	15.8	2.1	18.2	1.1	1.1	67.6	1,697
1980	1.3	10.4	5.1	4.8	13.3	2.0	19.6	1.4	0.7	58.6	1,755
1981	1.5	12.8	3.1	5.5	21.1	1.4	20.1	1.2	1.6	68.3	1,824
1982	2.8	11.6	3.2	4.5	57.0	1.3	22.4	2.2	2.0	107.0	1,931
1983	3.4	17.9	5.5	3.2	12.1	1.6	26.7	3.4	1.7	75.7	2,006
1984	3.5	18.8	3.9	5.4	36.0	2.2	26.1	7.2	10.6	113.7	2,120
1985	0.7	17.0	3.1	6.7	41.7	2.2	30.5	18.7	2.1	122.7	2,243
1986	0	20.2	3.4	4.5	27.9	1.8	30.1	15.0	1.0	103.9	2,347
1987	0	19.5	3.0	3.7	31.1	0.5	28.2	16.2	1.0	153.2	2,500
1988	0	15.0	2.0	4.3	39.1	0.6	30.2	10.6	1.0	102.8	2,603
1989	0	10.0	1.3	6.4	35.0	1.3	26.8	5.7	2.3	88.8	2,692
1990	0	8.0	1.8	4.5	9.1	0.3	26.6	4.4	0.0	54.7	2,747
1991	0	5.3	1.3	5.8	11.6	0.2	23.8	0.3	0.0	48.3	2,795
1992	0	3.8	f	2.3	20.1	1.1	13.0	0.0	0.0	40.3	2,835
Total	343.4	554.5[g]	145.3	218.0	439.7	238.5	649.7	151.3	114.2	2,835	

[a]No TRU waste included; data from refs. 1 and 7. Slight differences in values shown and those actually reported result from round-off and truncation of numbers.

[b]Updated LLW burial information for Hanford was received at press time and is presented in Tables C.9 and C.10 of Appendix C. This data will be integrated into future updates of this report.

[c]Land disposal of LLW at Y-12 was terminated as of July 1, 1991.

[d]Includes contributions from AMES, BNL, K-25, LLNL, PAD, PANT, PORTS, and SNLA. See Tables 4.5, 4.6, 4.9, and 4.10 for breakdown of 1992 accumulation.

[e]Values for 1975 are cumulative volumes to this date (ref. 3).

[f]INEL data for 1992 were not available at time of calculations for this table. However, data were received from INEL (including contributions from ANL-W) at press time and are included in Table C.12 of Appendix C. The total volume buried at INEL through 1992 may be obtained by adding the total volume from Table C.12 to the total reported for INEL in Table 4.4. This update results in a total volume change for INEL of 0.55%. Table C.12 data will be integrated into future editions of this report.

[g]Does not include 24,969 m^3 of submarine reactor compartments disposed of at Hanford.

Table 4.5. Summary of radionuclide characteristics for LLW at DOE sites[a]

Waste type	Radionuclide characteristic[b]	Volume, m^3			Activity, Ci			
		1992[c]	Cumulative[d]	1993 (projected)	1992[c]	Total undecayed[e]	Total decayed[f]	1993 (projected)
Generated on-site	Uranium/thorium	13,607	g	8,196	308	g	g	273
	Fission product	12,867	g	14,893	19,986	g	g	42,191
	Induced activity	3,242	g	3,244	832,510	g	g	1,134,190
	Tritium	1,309	g	1,428	34,609	g	g	148,388
	Alpha	4,577	g	7,022	480	g	g	1,492
	Other	1,642	g	1,064	222	g	g	317
	Total	37,244	g	35,847	888,115	g	g	1,326,851
Stored	Uranium/thorium	3,837	55,293	3,141	70	2,156	h	113
	Fission product	416	46,399	562	627	545,240	h	218
	Induced activity	342	2,302	186	200,246	200,734	h	100,133
	Tritium	306	396	433	8,239	55,918	h	11,845
	Alpha	2,740	8,643	6,926	14	182	h	62
	Other	929	2,007	844	438	1,052	h	519
	Total	8,570	115,040	12,092	209,634	805,282	h	112,890
Buried[i]	Uranium/thorium	21,508	1,089,794	21,422	302	38,487	49,760	973
	Fission product	12,568	992,140	21,566	19,440	8,713,588	4,002,579	192,098
	Induced activity	1,170	222,718	1,138	410,200	6,653,524	701,923	805,011
	Tritium	1,282	54,459	1,028	14,010	15,471,643	7,244,527	110,008
	Alpha	3,442	325,761	4,714	500	65,360	42,273	1,467
	Other	368	150,006	262	4	12,297,173	367,182	19
	Total	40,338	2,834,878	50,130	444,456	43,239,775	12,408,244	1,109,576

[a]Based on DOE site information provided by the Waste Management Information System (ref. 1). Totals reported in this table may not equal the sum of component entries because of round-off and truncation of numbers.

[b]Radionuclide characteristics: (1) uranium/thorium—those waste materials in which the principal hazard results from naturally occurring uranium and thorium isotopes. The hazard from all other radioactive contaminants should be insignificant. Examples of these wastes include depleted uranium, natural uranium ore, and slightly enriched uranium; (2) fission product—waste materials that are contaminated with beta-gamma-emitting radionuclides which originate as a result of fission processes. Primary examples are ^{137}Cs and ^{90}Sr; (3) induced activity—waste materials that are contaminated with beta-gamma-emitting radioisotopes which are generated through neutron activation. Of major concern is ^{60}Co; (4) tritium—waste materials in which the principal hazard results from tritium (^{3}H); (5) alpha—waste materials contaminated with alpha-emitting radionuclides not listed under U/Th or low levels (<100 nCi/g) of TRU isotopes; and (6) other—unknown or not defined materials.

[c]Does not include buried or generated waste volumes and activity for 1992 for INEL since these data were not available at time of calculations for this table. However, data were received from INEL (including contributions from ANL-W) at press time and are included in Tables C.11 and C.12 of Appendix C. The 1992 volume and activity values in Table 4.5 may be adjusted by adding the volume and activities from Table C.11 and C.12. This update results in total generated volume change of 5.3% and a total buried volume change of 2.1%. Table C.11 and C.12 data will be integrated into future editions of this report.

[d]From beginning of operations through 1992.

Table 4.5 (continued)

[e]Sum of annual additions without decay.

[f]Decayed from time of addition using an isotope generation/depletion code.

[g]Not applicable (i.e., generation is taken to be an intensive quantity (amount/year) and is not additive; whereas stored and buried are extensive quantities (amounts) and are additive).

[h]Information not available.

[i]Total buried decayed activity includes waste projected to be buried at INEL during 1992.

Table 4.6. Summary of physical characteristics for LLW at DOE sites[a]

Waste type	Physical characteristic[b]	Volume, m^3			Activity, Ci		
		1992[c]	Cumulative[d]	1993 (projected)	1992[c]	Total gross[e]	1993 (projected)
Generated on-site	Biological	140	f	176	2	f	1
	Contaminated equipment	4,227	f	4,142	479,780	f	368,346
	Decontamination debris	3,674	f	4,760	1,371	f	1,460
	Dry solids	16,333	f	17,323	405,302	f	832,012
	Solidified sludge	872	f	1,154	470	f	930
	Other	11,998	f	8,292	1,190	f	124,100
	Total	37,244	f	35,847	888,115	f	1,326,851
Stored	Biological	32	200	237	<1	1	1
	Contaminated equipment	1,543	39,400	1,709	202,110	209,000	100,980
	Decontamination debris	1,780	4,690	2,599	202	374	380
	Dry solids	2,204	37,450	6,001	7,276	555,960	11,360
	Solidified sludge	785	25,290	896	5	13	6
	Other	2,224	8,010	650	40	39,934	162
	Total	8,570	115,040	12,092	209,634	805,282	112,890
Buried	Biological	120	g	42	1	g	1
	Contaminated equipment	6,600	g	6,190	250	g	183
	Decontamination debris	7,900	g	7,830	501	g	233
	Dry solids	12,430	g	12,200	390,200	g	770,192
	Solidified sludge	570	g	3,990	504	g	967
	Other	12,718	g	19,880	53,000	g	338,000
	Total	40,338	g	50,130	444,456	g	1,109,576

[a]Based on DOE site information provided by the Waste Management Information System (ref. 1). Totals reported in this table may not equal the sum of component entries because of round-off and truncation of numbers.

[b]Physical characteristics: (a) biological (sewage sludge, animal carcasses, excreta, etc.); (b) contaminated equipment (components, maintenance wastes, etc.); (c) decontamination debris (wastes resulting from decontamination and decommissioning efforts, construction debris, etc.); (d) dry solids (normal plant wastes, blotting paper, combustible materials, etc.); (e) solidified sludge (any wastes solidified from a process sludge such as evaporator bottoms solidification, solidification of precipitated salts, etc.); and (f) other (materials which are outside of the above categories).

[c]Does not include buried or generated waste volumes and activity for 1992 for INEL since these data were not available at time of calculations for this table. However, data were received from INEL (including contributions from ANL-W) at press time and are included in Tables C.11 and C.12 of Appendix C. The 1992 total volume and total activity values in Table 4.6 may be adjusted by adding the volumes and activities from Table C.11 and C.12. This update results in a total generated volume change of 5.3% and a total buried volume change of 2.1%.

[d]From beginning of operations through 1992.

[e]Sum of annual additions without decay.

[f]Not applicable [i.e., generation is taken to be an intensive quantity (amount/year) and is not additive; whereas stored and buried are extensive quantities (amounts) and are additive].

[g]Information not available.

Table 4.7. Breakdown of volumes of LLW generated during 1992 at DOE sites by radionuclide characteristic[a]

DOE site[b]	Volume, m^3						
	Uranium/ thorium	Fission product	Induced activity	Tritium	Alpha	Other[c]	Total
AMES	74	0	0	0	0	0	74
ANL-E	0	0	0	0	0	251	251
ANL-W	d	d	d	d	d	d	d
BNL	5	33	118	20	19	0	196
FEMP	e	e	e	e	e	e	e
FNAL	9	0	117	4	0	0	130
HANF	1,146	1,491	35	0	0	0	2,672
INEL	d	d	d	d	d	d	d
ITRI	6	4	15	9	28	<<1	61
K-25	2,353	0	0	0	0	0	2,353
KCP	0	0	0	0	0	<1	<1
LANL	1,149	64	236	85	762	40	2,336
LBL	0	0	15	3	0	21	39
LLNL	25	0	0	66	96	8	195
MOUND	0	0	0	250	1,800	0	2,050
NR sites[f]	145	141	1,773	0	0	27	2,086
NTS	c	c	c	c	c	c	c
ORISE	<1	<<1	0	2	0	20	22
ORNL	75	1,220	131	9	80	0	1,515
PAD	499	0	0	0	0	462	961
PANT	0	0	0	0	0	627	627
Pinellas	0	0	0	48	0	0	48
PORTS	1,651	0	0	0	0	0	1,651
PPPL	d	d	d	d	d	d	d
RFP	75	0	0	0	693	0	768
RMI	e	e	e	e	e	e	e
SLAC	0	0	0	0	0	0	0
SNLA	4	14	12	1	<<1	6	36
SNLL	1	0	0	12	0	<1	13
SRS	520	9,900	790	800	1,100	180	13,290
Y-12	5,869	0	0	0	0	0	5,869
Total	13,607	12,867	3,242	1,309	4,577	1,642	37,244

[a]Based on DOE site information provided by the Waste Management Information System (ref. 1). Totals reported in this table may not equal the sum of component entries because of round-off and truncation of numbers.

[b]Radionuclide characteristics are described in footnote b of Table 4.5.

[c]Unknown or mixture.

[d]Data for 1992 were not available for this site at time of calculations for this table. However, data were received from INEL (including contributions from ANL-W) at press time and are included in Table C.11 of Appendix C. This update results in a total volume change for DOE of 5.3%. Table C.11 data will be integrated into future editions of this report.

[e]This site is now included in the DOE Environmental Restoration Program. In future updates of this report, information on waste generated from environmental restoration activities at this site will be provided in Chapter 6.

[f]Naval reactors (NR) sites include KAPL, BAPL, and NRF.

Table 4.8. Breakdown of activity of LLW generated during 1992 at DOE sites by radionuclide characteristic[a]

	Activity, Ci						
DOE site[b]	Uranium/ thorium	Fission product	Induced activity	Tritium	Alpha	Other[c]	Total
AMES	<<1	0	0	0	0	0	<<1
ANL-E	c	c	c	c	c	c	c
ANL-W	d	d	d	d	d	d	d
BNL	<<1	<<1	1	1	<1	0	2
FEMP	e	e	e	e	e	e	e
FNAL	<<1	0	3	<<1	0	0	3
HANF	47	17,989	0	0	0	0	18,036
INEL	d	d	d	d	d	d	d
ITRI	<<1	<<1	<<1	<<1	<<1	<<1	<1
K-25	c	0	0	0	0	0	c
KCP	0	0	0	0	0	<1	<1
LANL	<<1	70	385,900	3	467	0	386,400
LBL	0	0	<<1	<1	0	2	2
LLNL	2	0	0	153	<1	<1	155
MOUND	0	0	0	5,000	3	0	5,003
NR sites[f]	0	7	422,077	0	0	<1	422,084
NTS	c	c	c	c	c	c	c
ORISE	<<1	<<1	0	<<1	<<1	<<1	<<1
ORNL	2	1,680	288	5	<1	0	1,975
PAD	<<1	<<1	0	0	<<1	0	<<1
PANT	<<1	0	0	64	0	0	64
Pinellas	0	0	0	13,444	0	0	13,444
PORTS	<<1	0	0	0	0	0	<<1
PPPL	d	d	d	d	d	d	d
RFP	<1	0	0	0	3	0	4
RMI	e	e	e	e	e	e	e
SLAC	0	0	0	0	0	0	0
SNLA	65	130	240	28	5	220	688
SNLL	<<1	0	0	1,910	0	<<1	1,910
SRS	192	110	24,000	14,000	<<1	<<1	38,302
Y-12	c	0	0	0	0	0	c
Total	308	19,986	832,510	34,609	480	222	888,115

[a]Based on DOE site information provided by the Waste Management Information System (ref. 1). Totals reported in this table may not equal the sum of component entries because of round-off and truncation of numbers.

[b]Radionuclide characteristics are described in footnote b of Table 4.5.

[c]Unknown or mixture.

[d]Data for 1992 were not available for this site at time of calculations for this table. However, data were received from INEL (including contributions from ANL-W) at press time and are included in Table C.11 of Appendix C. Table C.11 data will be integrated into future editions of this report.

[e]This site is now included in the DOE Environmental Restoration Program. In future updates of this report, information on waste generated from environmental restoration activities at this site will be provided in Chapter 6.

[f]Naval reactors (NR) sites include KAPL, BAPL, and NRF.

Table 4.9. Breakdown of cumulative volumes of LLW buried at DOE sites by radionuclide characteristic[a]

	Volume, m^3						
DOE site[b]	Uranium/ thorium	Fission product	Induced activity	Tritium	Alpha	Other[c]	Total
AMES	200	0	0	0	0	0	200
ANL-E	0	0	0	0	0	0	0
ANL-W[d]	0	0	0	0	0	0	0
BNL	0	0	5	832	0	3	839
FEMP	337,548	0	0	0	0	5,670	343,218
FNAL	0	0	0	0	0	0	0
HANF[e]	227,734	211,469	121,546	3,789	0	0	564,537
INEL[d]	4,136	25,500	374	1	961	114,400	145,371
ITRI	0	0	0	0	0	0	0
K-25	81,048	0	0	0	0	0	81,048
KCP	0	0	0	0	0	0	0
LANL	63,967	11,552	10,262	3,358	128,814	71	218,024
LBL	0	0	0	0	0	0	0
LLNL[f]	9,102	<<1	<<1	0	0	0	9,102
MOUND	0	0	0	0	0	0	0
NR sites[g]	0	0	0	0	0	0	0
NTS	101,731	216,804	12,853	8,404	90,751	9,282	439,825
ORISE	0	0	0	0	0	0	0
ORNL	19,044	123,427	34,067	3,801	13,042	15,076	208,457
PAD	7,613	0	0	0	0	0	7,613
PANT	121	0	0	13	0	0	134
Pinellas	0	0	0	0	0	0	0
PORTS	12,110	0	0	0	0	0	12,110
PPPL	0	0	0	0	0	0	0
RFP	0	0	0	0	0	0	0
RMI	0	0	0	0	0	0	0
SLAC	0	0	0	0	0	0	0
SNLA	3,178	7	33	<1	<<1	<<1	3,219
SNLL	0	0	0	0	0	0	0
SRS	71,016	403,381	43,579	34,262	92,193	5,504	649,935
Y-12	151,247	0	0	0	0	0	151,247
Total	1,089,794	992,140	222,718	54,459	325,761	150,006	2,834,878

[a]From beginning of operations through 1992. Based on DOE site information provided by the Waste Management Information System (ref. 1). Totals reported in this table may not equal the sum of component entries because of round-off and truncation of numbers.

[b]Radionuclide characteristics are described in footnote b of Table 4.5.

[c]Unknown or mixture.

[d]Data for 1992 were not available for this site at time of calculations for this table. Cumulative values for this site are as of December 31, 1991. However, data were received from INEL (including contributions from ANL-W) at press time and are included in Table C.12 of Appendix C. This update results in a total volume change for INEL of 0.58%. Table C.12 data will be integrated into future editions of this report.

[e]Updated LLW burial information for Hanford was received at press time and is presented in Tables C.9 and C.10 of Appendix C. This data will be integrated into future updates of this report.

[f]No wastes are buried on the LLNL site. The inventory reported is for wastes buried at the Site 300 Area, an explosives disposal area located off, but near, LLNL.

[g]Naval reactors (NR) sites include KAPL, BAPL, and NRF.

Table 4.10. Breakdown of total gross activity of LLW buried at DOE sites by radionuclide characteristic

	Total gross activity, Ci[a]						
DOE site[b]	Uranium/ thorium	Fission product	Induced activity	Tritium	Alpha	Other[c]	Total
AMES	<1	0	0	0	0	0	<1
ANL-E	0	0	0	0	0	0	0
ANL-W[d]	0	0	0	0	0	0	0
BNL	0	0	2	3	0	1	5
FEMP	2,610	0	0	0	0	1,804	4,414
FNAL	0	0	0	0	0	0	0
HANF[e]	507	7,499,242	486,891	454,121	0	0	8,440,761
INEL[d]	45	1,523	36	15	86	11,690,000	11,691,705
ITRI	0	0	0	0	0	0	0
K-25	59	0	0	0	0	0	59
KCP	0	0	0	0	0	0	0
LANL	264	17,902	418,211	1,053,710	4,527	0	1,494,614
LBL	0	0	0	0	0	0	0
LLNL[f]	13	<<1	<<1	0	0	0	13
MOUND	0	0	0	0	0	0	0
NR sites[g]	0	0	0	0	0	0	0
NTS	2,506	90,323	7,095	9,258,999	54,765	361,327	9,775,015
ORISE	0	0	0	0	0	0	0
ORNL	1,349	384,291	853,834	12,239	754	41	1,252,508
PAD	20,396	3	0	0	0	0	20,399
PANT	8	0	<<1	<1	0	<1	8
Pinellas	0	0	0	0	0	0	0
PORTS	26	0	0	0	0	0	26
PPPL	0	0	0	0	0	0	0
RFP	0	0	0	0	0	0	0
RMI	0	0	0	0	0	0	0
SLAC	0	0	0	0	0	0	0
SNLA	12	611	5,493	2,984	3	4	9,107
SNLL	0	0	0	0	0	0	0
SRS	293	719,693	4,881,952	4,689,572	5,225	243,996	10,540,731
Y-12	10,400	0	0	0	0	0	10,400
Total	38,487	8,713,588	6,653,524	15,471,643	65,360	12,297,173	43,239,775

[a]Sum of annual additions without decay, from beginning of operations through 1992. Based on DOE site information provided by the Waste Management Information System (ref. 1). Totals reported in this table may not equal the sum of component entries because of round-off and truncation of numbers.

[b]Radionuclide characteristics are described in footnote b of Table 4.5.

[c]Unknown or mixture.

[d]Data for 1992 were not available for this site at time of calculations for this table. Cumulative values for this site are as of December 31, 1991. However, data were received from INEL (including contributions from ANL-W) at press time and are included in Table C.12 of Appendix C. Table C.12 data will be integrated into future editions of this report.

[e]Updated LLW burial information for Hanford was received at press time and is presented in Tables C.9 and C.10 of Appendix C. This data will be integrated into future updates of this report.

[f]No wastes are buried on the LLNL site. The inventory reported is for wastes buried at the Site 300 Area, an explosives disposal area located off, but near, LLNL.

[g]Naval reactors (NR) sites include KAPL, BAPL, and NRF.

Table 4.11. DOE LLW disposed by methods other than shallow-land burial[a]

Site	Location	Site use (year)	Waste containers buried[b]	Undecayed radioactive content (Ci)
		Atlantic Ocean		
Atlantic	38°30′N 72°06′W	1951-1956; 1959-1962	14,300	74,400[c]
Atlantic	37°50′N 70°35′W	1957-1959	14,500	2,100
Massachusetts Bay	42°25′N 70°35′W	1952-1959	4,008	2,440
Cape Henry	36°56′N 74°23′W	1949-1967	843	87
Central Atlantic	36°20′N/ 43°49′N 45°00′W	1959-1960	432	480
Subtotal			34,083	79,507
		Pacific Ocean		
Farallon Islands (Subsite A)	37°38′N 123°08′W	1951-1953	3,500	1,100
Farallon Islands (Subsite B)	37°37′N 123°17′W	1946-1950; 1954-1956	44,000	13,400
Santa Cruz Basin	33°40′N 119°40′W	1946-1962	3,114	108
Cape Scot	50°56′N 136°03′W 52°25′N 140°12′W	1958-1969	360	124
San Diego	32°00′N 121°30′W	1959-1962	4,415	34
Subtotal (oceans)			55,389	14,766
Total			89,472	94,273
		Hydrofracture facility		
ORNL	Bedded Conasauga shale underlying the ORNL site	1959-1965	Small experimental amounts	
		1966-1980[d]	8.0×10^3 m^3 of grout	600,000
		1982[e]	3.8×10^3 m^3 of grout	200,000
		1983[e]	5.5×10^3 m^3 of grout	500,000
Total			17.3×10^3 m^3	1,300,000

[a]Radioactivity is given at time of burial. Data taken from Table 4.5 of ref. 3.
[b]Estimated number of containers.
[c]Includes approximately 33,000 Ci of induced activity associated with the U.S.S. Seawolf reactor vessel.
[d]Retired after 18 injections.
[e]New facility started up with four injections in 1982 and completed campaign with seven injections in 1983.

Table 4.12. Status of land usage at LLW burial and disposal sites[a]

Site	Site size (ha)	Estimated total usable area[b] (ha)	Estimated area utilized through 1992 (ha)[b]
DOE (burial sites)			
HANF[c]	145,040	385	153
INEL	230,510	35.6	21.2
K-25	607	d	d
LANL	11,137	37.1	17.2
NTS[e]	349,661	820	55
ORNL	1,174	26	7
SNLA	1,141	0.27	0.08
SNLL	167	0.013	d
SRS	84,175	78.9	78.2
Total	823,612	>1,383	>332
Commercial (disposal sites)			
West Valley, NY (Closed Mar. 11, 1975)[f]	8.9	7.2	3.8
Maxey Flats, KY (Closed Dec. 27, 1977)	102	<51	10.4
Sheffield, IL (Closed Apr. 8, 1978)	8.9	8.1	8.1
Barnwell, SC[g]	121	44.5	34.7
Beatty, NV[h]	32	18.6	15.7
Richland, WA	40	29.5	11.9
Total	313	159	84.6
Grand total	823,925	~1,542	>417

[a]Note: 1 acre = 0.4047 ha, and 1 ha = 10,000 m^2.

[b]DOE usable area and area utilized (except where noted) are generally taken from ref. 1. Comparable commercial values (except where noted) are taken from ref. 7.

[c]Utilized land value is for the 200-Area only; in addition, the closed 100- and 300-Area burial grounds include a total of 16.8 ha.

[d]Information not available, or unknown.

[e]This pertains to the radioactive waste management site in Area 5 and Area 3 of the NTS. The availability of land that could be used for shallow-land burial is not clearly defined because of the classified nature of the site and the abundance of land.

[f]WVDP LLW was buried on-site in the noncommercial NRC disposal area from 1982 until late 1986. No waste was buried at West Valley from 1987-1992 (see Table 4.16).

[g]Based on information provided in ref. 6. Anticipated closure date for this site is December 31, 1995.

[h]Based on ref. 8.

Table 4.13. Significant revisions and changes in the current values for LLW compared to the values in the previous year

Burial/ disposal site	DOE/RW-0006, Rev. 8 (1992) Table No.	DOE/RW-0006, Rev. 9 (1993) Table No.	Significant revision or net change	Explanation
DOE/Hanford	4.1, 4.2, 4.4, 4.5, 4.6, 4.9, 4.10, and 4.14	4.1, 4.2, 4.4, 4.5, 4.6, 4.9, 4.10, and 4.14	Hanford buried values for fission product volume and radioactivity for 1986-1991 have decreased	The original values reported were too high due to double-counting of submarine reactor compartments
Commercial	4.20, 4.21, 4.22, 4.23, 4.24, and 4.25	4.21	Reporting of commercial LLW by fuel cycle and I/I categories discontinued	Commercially disposed LLW is now reported by categories consistent with the National Low-Level Waste Management Program

Table 4.14. Historical and projected volume, radioactivity, and thermal power characteristics of buried DOE LLW, except SRS saltstone

End of calendar year	Volume[a,b] (10^3 m^3)		Radioactivity[a,b] (10^3 Ci)		Thermal power (W)	
	Annual	Cumulative	Annual	Cumulative[c]	Annual	Cumulative[c]
1990	54.6	2,746	339	13,087	1,288	16,443
1991	48.3	2,794	366	12,586	1,555	15,958
1992	41.6	2,836	631	12,408	3,283	17,419
1993	51.3	2,887	1,296	12,642	6,031	20,114
1994	51.3	2,938	1,296	12,499	6,031	20,745
1995	51.3	2,990	1,296	12,299	6,031	21,026
1996	51.3	3,041	1,296	12,083	6,031	21,165
1997	51.3	3,092	1,296	11,868	6,031	21,240
1998	51.3	3,144	1,296	11,660	6,031	21,286
1999	51.3	3,195	1,296	11,460	6,031	21,317
2000	51.3	3,246	1,296	11,270	6,031	21,342
2001	51.3	3,298	1,296	11,091	6,031	21,363
2002	51.3	3,349	1,296	10,920	6,031	21,382
2003	51.3	3,400	1,296	10,759	6,031	21,400
2004	51.3	3,451	1,296	10,607	6,031	21,416
2005	51.3	3,503	1,296	10,463	6,031	21,431
2006	51.3	3,554	1,296	10,327	6,031	21,446
2007	51.3	3,605	1,296	10,198	6,031	21,461
2008	51.3	3,657	1,296	10,077	6,031	21,475
2009	51.3	3,708	1,296	9,962	6,031	21,488
2010	51.3	3,759	1,296	9,853	6,031	21,501
2011	51.3	3,811	1,296	9,750	6,031	21,514
2012	51.3	3,862	1,296	9,653	6,031	21,527
2013	51.3	3,913	1,296	9,562	6,031	21,540
2014	51.3	3,964	1,296	9,475	6,031	21,552
2015	51.3	4,016	1,296	9,394	6,031	21,565
2016	51.3	4,067	1,296	9,316	6,031	21,577
2017	51.3	4,118	1,296	9,243	6,031	21,589
2018	51.3	4,170	1,296	9,174	6,031	21,601
2019	51.3	4,221	1,296	9,109	6,031	21,614
2020	51.3	4,272	1,296	9,048	6,031	21,626
2021	51.3	4,324	1,296	8,990	6,031	21,638
2022	51.3	4,375	1,296	8,935	6,031	21,650
2023	51.3	4,426	1,296	8,883	6,031	21,662
2024	51.3	4,477	1,296	8,834	6,031	21,674
2025	51.3	4,529	1,296	8,788	6,031	21,686
2026	51.3	4,580	1,296	8,745	6,031	21,698
2027	51.3	4,631	1,296	8,704	6,031	21,711
2028	51.3	4,683	1,296	8,665	6,031	21,723
2029	51.3	4,734	1,296	8,628	6,031	21,735
2030	51.3	4,785	1,296	8,594	6,031	21,747

[a]Historical (beginning of operations through 1991) annual values of volume and radioactivity (by waste type) for each site are from ref. 7. Similar values for 1992 are from ref. 1. See Tables 4.4, 4.5, 4.9, and 4.10 for more detail. Radioactivity (by waste type) is decayed from the year of addition using the representative compositions given in Table C.3 of Appendix C.

[b]Beginning in 1992, the volume and radioactivity added each year are assumed to remain constant through 2030 at the 1992 values projected (ref. 1) by each site. An exception to this scheme is INEL. Since no 1992 data were available for INEL, the 1992-2030 values for volume and radioactivity were projected based on 1991 data. The radioactivity (by waste type) is decayed from the year of addition using the representative compositions given in Table C.3 of Appendix C. Data were received from INEL (including contributions from ANL-W) at press time and are included in Table C.12 of Appendix C. The volume change and activity change values reported in Table C.12 may be used to update the 1992 values reported in Table 4.14. This update results in an annual volume change of -0.96%. Table C.12 data will be integrated into future editions of this report.

[c]Note that the projected cumulative radioactivity decreases while the projected cumulative thermal power increases. This is caused by the decay of relatively short-lived low-energy radionuclides whose daughter (or daughters) have much higher thermal power per curie. This may be shown by comparing the source terms in Table C.3 of Appendix C with the W/Ci values for parents and daughters given in Table B.1 of Appendix B.

Table 4.15. Projected volume, radioactivity, and thermal power characteristics of DOE LLW saltstone at SRS[a]

End of calendar year	Volume (10^3 m^3)		Radioactivity[b] (10^3 Ci)		Thermal power (W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1993	0.0	0.0	0.0	0.0	0.0	0.0
1994	0.0	0.0	0.0	0.0	0.0	0.0
1995	107.0	107.0	8.1	8.1	23.5	23.5
1996	43.6	151.0	66.1	74.2	75.4	98.9
1997	72.5	223.0	18.2	92.4	70.1	169.0
1998	88.3	312.0	6.0	98.4	36.1	205.0
1999	133.0	444.0	0.0	97.6	19.5	225.0
2000	73.0	517.0	0.0	90.2	0.0	220.0
2001	28.2	546.0	0.0	83.8	0.0	214.0
2002	29.0	575.0	0.0	78.8	0.0	209.0
2003	37.8	612.0	0.0	74.4	0.0	205.0
2004	29.0	641.0	0.0	70.2	0.0	198.0
2005	58.0	699.0	0.0	67.0	0.0	193.0
2006	29.0	728.0	0.0	63.8	0.0	186.0
2007	49.7	778.0	1.6	65.4	7.2	194.0
2008	29.0	807.0	0.0	65.4	1.2	195.0
2009	49.4	857.0	0.0	65.2	1.6	196.0
2010	29.0	886.0	0.0	63.3	0.0	192.0
2011	53.2	939.0	0.0	61.9	0.0	189.0
2012	24.0	963.0	0.4	62.3	1.5	191.0
2013	58.0	1,020.0	4.2	66.5	13.9	204.0
2014	26.6	1,050.0	0.0	65.3	0.0	200.0
2015	56.8	1,100.0	0.0	64.8	0.0	200.0
2016	29.0	1,130.0	0.0	63.4	0.0	195.0
2017	29.0	1,160.0	0.0	61.8	0.0	190.0
2018	0.0	1,160.0	0.0	60.2	0.0	185.0
2019	0.0	1,160.0	0.0	58.7	0.0	180.0
2020	0.0	1,160.0	0.0	57.3	0.0	176.0
2021	0.0	1,160.0	0.0	56.0	0.0	172.0
2022	0.0	1,160.0	0.0	54.6	0.0	168.0
2023	0.0	1,160.0	0.0	53.3	0.0	164.0
2024	0.0	1,160.0	0.0	52.1	0.0	160.0
2025	0.0	1,160.0	0.0	50.9	0.0	156.0
2026	0.0	1,160.0	0.0	49.7	0.0	152.0
2027	0.0	1,160.0	0.0	48.5	0.0	148.0
2028	0.0	1,160.0	0.0	47.4	0.0	145.0
2029	0.0	1,160.0	0.0	46.3	0.0	141.0
2030	0.0	1,160.0	0.0	45.2	0.0	138.0

[a]Taken from ref. 1 of Chapter 2.
[b]Radionuclide composition as a function of time is given in Table C.5 of Appendix C.

Table 4.16. Historical annual additions and total volume of LLW at commercial disposal sites[a]

Year	Volume, m^3							
	Beatty	West Valley[b]	Maxey Flats[c]	Richland	Sheffield[d]	Barnwell	Annual total	Cumulative total
1962	1,861						1,861	1,861
1963	3,512	127	2,206				5,845	7,706
1964	2,836	5,940	3,872				12,648	20,354
1965	1,988	5,192	5,753	668			13,601	33,955
1966	3,533	3,951	5,557	2,402			15,443	49,398
1967	3,206	7,475	7,820	773	2,527		21,801	71,199
1968	3,576	3,490	8,178	1,359	2,713		19,316	90,515
1969	4,526	4,099	10,354	438	2,012		21,429	111,944
1970	5,152	4,906	12,521	423	2,825		25,827	137,771
1971	4,916	7,002	13,173	584	4,430	1,171	31,276	169,047
1972	4,301	9,045	15,578	654	5,956	3,757	39,291	208,338
1973	4,076	7,535	10,074	1,033	8,524	15,839	47,081	255,419
1974	4,103	8,866	8,898	1,411	12,373	18,244	53,895	309,314
1975	4,943	2,243	17,098	1,500	14,116	18,072	57,972	367,286
1976	3,864	427	13,775	2,867	13,480	40,227	74,640	441,926
1977	4,742	351	423	2,718	17,643	45,663	71,540	513,466
1978	8,874	144		7,422	1,735	61,554	79,729	593,195
1979	6,491	138		12,185		63,861	82,675	675,870
1980	12,717	141		24,819		54,723[e]	92,400	768,270
1981	3,351	216		40,732		39,427[e]	83,726	851,996
1982	1,505	632		39,606		34,779	76,522	928,518
1983	1,111	1,284		40,458		35,132	77,985	1,006,503
1984	2,067	966		38,481		34,879	76,393	1,082,896
1985	1,388	809		40,135		34,389	76,721	1,159,617
1986	2,668	2,095		18,833		29,612	53,208	1,212,825
1987	9,414			15,765		27,060	52,239	1,265,064
1988	2,645			11,430		26,391	40,466	1,305,530
1989	3,291			11,562		31,242	46,095	1,351,625
1990	1,684			8,362		22,315	32,361	1,383,986
1991	4,539			11,872		22,368	38,779	1,422,765
1992	14,575			11,271		23,518	49,364	1,472,129
Total	137,455	77,074	135,280	349,763	88,334	684,223		1,472,129

[a]For a summary of historical additions (1962-1984), see Table 4.6 in ref. 3. For operating sites (Beatty, Richland, and Barnwell), the additions for 1985-1991 are from Table 4.16 in ref. 7. Information for 1992 is taken from ref. 9.

[b]West Valley includes a commercial state-licensed facility which opened Nov. 18, 1963, and closed Mar. 11, 1975, and an NRC-licensed facility (for on-site fuel reprocessing wastes) which opened in 1966 and continued to receive only on-site-generated LLW associated with water treatment and site cleanup until late 1986. This license is in abeyance. Disposal operations at the West Valley Demonstration Project (WVDP) have been suspended pending the preparation of an EIS report for the West Valley site closure. The WVDP began in 1982. The LLW volumes reported for 1982 through 1986 are for the WVDP only and are taken from ref. 7. Since the beginning of 1987, LLW generated at the WVDP is stored on-site in engineered facilities pending final disposal (ref. 7).

[c]Closed Dec. 27, 1977. Small perturbations in waste volumes have occurred during site cleanup operations (ref. 11) but are not included here since they are inconsequential.

[d]Closed Apr. 8, 1978. No additional operations have taken place at the site.

[e]These values exclude almost 19,000 m^3 (approximately 14,506 in 1980 and approximately 4,279 in 1981) of very low-level-activity settling pond sludge that was not counted against the annual quota.

Table 4.17. Historical annual additions and total undecayed radioactivity of LLW at commercial disposal sites[a]

	Radioactivity, Ci							
Year	Beatty	West Valley[b]	Maxey Flats[c]	Richland	Sheffield[d]	Barnwell	Annual total	Cumulative total
1962	e						e	e
1963	5,690	100	22,556				28,346	28,346
1964	6,477	10,400	147,218				164,095	192,441
1965	6,377	22,600	63,828	144			92,949	285,390
1966	11,974	35,400	52,737	1,606			101,717	387,107
1967	10,894	123,100	23,273	5,378	3,850		166,495	553,602
1968	6,808	10,600	45,577	64,432	2,381		129,798	683,400
1969	9,761	36,000	31,028	55,964	2,192		134,945	818,345
1970	12,304	91,900	46,969	52,820	5,427		209,420	1,027,765
1971	4,316	436,700	720,146	23,916	7,895	4,151	1,197,124	2,224,889
1972	5,228	131,300	217,351	31,809	4,857	13,575	404,120	2,629,009
1973	5,704	346,000	118,359	57,037	2,834	48,212	578,146	3,207,155
1974	23,904	6,600	143,656	12,773	3,229	13,557	203,719	3,410,874
1975	18,388	11,600	289,570	113,341	6,103	17,428	456,430	3,867,304
1976	4,493	1,200	211,359	104,306	7,744	90,205	419,307	4,286,611
1977	23,811	900	267,063	7,465	11,147	390,121	700,507	4,987,118
1978	5,685	700		235,548	2,547	652,061	896,541	5,883,659
1979	8,897	400		164,787		314,938	489,022	6,372,681
1980	148,312	300		41,031		143,502	333,145	6,705,826
1981	52,214	229		43,905		183,744	280,092	6,985,918
1982	80,929	293		59,007		273,962	414,191	7,400,109
1983	1,356	255		120,534		383,450	505,595	7,905,704
1984	544	25		215,286		385,079	600,934	8,506,638
1985	453	39		287,849		460,571	748,912	9,255,550
1986	672	13		115,591		116,108	232,384	9,487,934
1987	3,353	0		42,734		211,026	257,113	9,745,047
1988	8,690	0		32,067		218,901	259,658	10,004,705
1989	42,678	0		99,056		725,164	866,898	10,871,603
1990	11,323	0		92,985		444,277	548,585	11,420,188
1991	29,679	0		158,784		611,348	799,811	12,219,999
1992	90,206	0		93,923		815,974	1,000,103	13,220,102
Total	641,120	1,266,654	2,400,690	2,334,078	60,206	6,517,354		13,220,102

[a]For a summary of historical additions (1962-1984), see Table 4.6 in ref. 3. For operating sites (Beatty, Richland, and Barnwell), the additions for 1985-1991 are from Table 4.16 in ref. 7. Information for 1992 is taken from ref. 9.

[b]West Valley includes a commercial state-licensed facility which opened Nov. 18, 1963, and closed Mar. 11, 1975, and an NRC-licensed facility (for on-site fuel reprocessing wastes) which opened in 1966 and continued to receive only on-site-generated LLW associated with water treatment and site cleanup until late 1986. This license is in abeyance. Disposal operations at the West Valley Demonstration Project (WVDP) have been suspended pending the preparation of an EIS report for the West Valley site closure. The WVDP began in 1982. The LLW radioactivity values reported for 1982 through 1986 are for the WVDP only and are taken from ref. 7. Since the beginning of 1987, LLW generated at the WVDP is stored on-site in engineered facilities pending final disposal (ref. 7).

[c]Closed Dec. 27, 1977.

[d]Closed Apr. 8, 1978.

[e]Reported as 296 kg of source material (as defined in Title 10, Code of Federal Regulations, Part 40).

Table 4.18. Distribution of total volume and radioactivity, by state, of LLW shipped to commercial disposal sites in 1992[a]

State	Volume (m^3)	Radioactivity (Ci)	State	Volume (m^3)	Radioactivity (Ci)
Alabama	576	53,669	Nebraska	357	101,285
Alaska	4	669	Nevada	4	18
Arizona	539	997	New Hampshire	1	1
Arkansas	184	32,562	New Jersey	1,077	47,959
California	3,199	15,730	New Mexico	99	56
Colorado	959	32,978	New York	1,991	90,377
Connecticut	1,503	29,392	North Carolina	1,750	57,505
Delaware	28	1	North Dakota	3	67
District of Columbia	45	31	Ohio	629	3,440
Florida	666	996	Oklahoma	795	60
Georgia	831	40,312	Oregon	4,183	742
Hawaii	83	3	Pennsylvania	2,636	141,249
Idaho	1	2	Puerto Rico	0	0
Illinois	8,072	103,273	Rhode Island	11	<1
Indiana	77	27	South Carolina	1,297	3,088
Iowa	154	42,085	South Dakota	48	<1
Kansas	232	1,319	Tennessee	2,374	1,595
Kentucky	62	26	Texas	4,612	4,057
Louisiana	701	4,683	Utah	152	108
Maine	249	8,110	Vermont	172	20,513
Maryland	506	8,421	Virgin Islands	0	0
Massachusetts	1,608	76,588	Virginia	2,627	1,154
Michigan	0	0	Washington	2,246	10,663
Minnesota	1,139	59,979	West Virginia	5	31
Mississippi	357	2,669	Wisconsin	195	571
Missouri	320	1,128	Wyoming	<1	5
Montana	4	7	Other[b]	13	5
			Total	49,364[c]	1,000,102[c]

[a]Data provided by EG&G, Idaho (ref. 9), to be published by the Low-Level Waste Management Program.
[b]Wastes generated by U.S. Army bases located inside and outside the United States.
[c]Differences in the 1992 annual totals (i.e., the volume in Table 4.16 and the radioactivity in Table 4.17 and the summations of shipments by state, as shown above) result from round-off and truncation of numbers.

Table 4.19. Historical and projected volume and activity summary of commercial GTCC LLW[a]

Category	Volume (m^3)	Activity (Ci)
Nuclear utility wastes		
• Operations	1,330	23,300,000
• Decommissioning	523	41,700,000
Subtotal	1,853	65,000,000
Sealed sources	6	302,890
DOE-held potential GTCC waste	1,076	538,275
Other generator waste	307	2,924
Total	3,242	65,844,089

[a]Based on the EG&G Idaho, Inc., study of ref. 19. Data reported represent packaged base-case scenario inventories and projections of wastes generated during the period 1985-2035.

Table 4.20. Summary of projected GTCC wastes for LWRs based on packaged waste volume[a]

Vendor[b]/LWR	Reactor component	Estimated packaged waste volume (m^3) by expected cases[c] Low	Base	High	Activity[d] (Ci)
GE/BWR	Cartridge filters	5.80E-02	1.16E+00	2.32E+00	6.62E+00
	Control rod components				
	Bearings	1.42E-04	1.42E-04	1.42E-04	8.93E+00
	Blade	3.53E+02	4.41E+02	8.83E+02	1.62E+05
	Inner drive strainers	2.55E-02	5.09E-01	1.02E+00	6.85E+01
	Outer drive strainers	1.12E+00	2.22E+01	4.55E+01	6.76E+01
	Core shroud	1.80E+02	2.57E+02	3.86E+02	4.93E+06
	Dry tubes	1.31E+01	2.13E+01	4.36E+01	1.08E+05
	Fuel in decontamination resins	1.13E+01	5.66E+01	1.13E+02	2.02E+03
	Local power range monitor	5.80E+01	9.67E+01	1.93E+02	6.65E+04
	Poison curtains	6.78E-03	6.78E-03	6.78E-03	1.55E+02
	Pool filters	1.68E+00	3.36E+01	6.72E+01	2.00E+02
	BWR total	6.18E+02	9.30E+02	1.73E+03	5.27E+06
B&W/PWR	Cartridge filters	1.32E+00	2.64E+01	5.29E+01	3.28E+02
	Control rod drive	3.20E-02	3.20E-02	3.20E-02	6.14E+02
	Core barrel	e	e	4.59E+01	3.64E+05
	Core shroud	1.44E+01	2.06E+01	3.09E+01	1.78E+06
	Crud tank filters	2.32E-01	4.64E+00	9.28E+00	3.47E+01
	Flux wire	4.00E-01	4.00E-01	4.00E-01	1.55E+04
	Fuel in decontamination resins	1.70E+00	8.48E+00	1.70E+01	1.18E+03
	In-core detectors	1.17E+01	1.95E+01	3.90E+01	1.75E+04
	Miscellaneous metals	3.80E-02	3.80E-02	3.80E-02	f
	Primary sources	1.13E-02	1.13E-02	1.13E-02	1.21E+04
	B&W total	2.98E+01	8.01E+01	1.95E+02	2.19E+06
CE/PWR	Cartridge filters	2.30E+00	4.59E+01	9.19E+01	8.33E+01
	Control rod drive	7.40E-01	7.40E-01	7.40E-01	1.45E+03
	Core barrel	e	e	3.69E+02	7.06E+05
	Core shroud	4.63E+01	6.62E+01	9.93E+01	5.54E+06
	Flux wire	6.00E-02	6.00E-02	6.00E-02	f
	Fuel in decontamination resins	9.34E+00	4.66E+01	9.33E+01	4.54E+03
	In-core detectors	2.75E+01	4.59E+01	9.17E+01	2.39E+04
	Primary sources	7.47E-02	7.47E-02	7.47E-02	9.26E+06
	Miscellaneous metals	3.00E-01	3.00E-01	3.00E-01	f
	Thimble plug assemblies	4.00E-01	8.00E-01	1.20E+00	f
	CE total	8.70E+01	2.07E+02	7.48E+02	1.55E+07
WH/PWR	Cartridge filters	8.50E+00	1.70E+02	3.34E+02	3.12E+02
	Control rod drive	1.72E+01	1.72E+01	1.72E+01	6.76E+06
	Core barrel	e	e	5.95E+02	3.94E+06
	Core shroud	1.25E+02	1.79E+02	2.68E+02	2.44E+07
	Fuel in decontamination resins	3.24E+01	1.61E+02	3.22E+02	1.78E+04
	In-core instruments	1.34E+01	2.15E+01	4.47E+01	1.22E+05
	Miscellaneous metals	1.25E+00	1.25E+00	1.25E+00	f
	Source rods	1.15E+00	1.15E+00	1.15E+00	6.73E+06
	Thimble plug assemblies	3.89E+01	7.78E+01	1.17E+02	1.66E+04
	WH total	2.38E+02	6.29E+02	1.70E+03	4.20E+07
	PWR total	3.55E+02	9.16E+02	2.64E+03	5.97E+07
	LWR total	9.73E+02	1.85E+03	4.37E+03	6.50E+07

[a]Based on ref. 19.

[b]GE = General Electric, B&W = Babcock & Wilcox, CE = Combustion Engineering, and WH = Westinghouse.

[c]These projections cover the time frame 1985-2035. The low case corresponds to the lowest volume expected, the base case to the most likely volume, and the high case to the largest volume expected.

[d]The same amount of activity is associated with each volume projection case.

[e]Not included in the low and base cases.

[f]Not reported (information not reported in ref. 19).

Table 4.21. Breakdown of 1992 low-level radioactive waste by type, volume, and activity received by commercial disposal sites[a]

Commercial site	Type of waste	Volume (m^3)	Radioactivity (Ci)
Barnwell	Academic	479	97
	Government	3,283	40,332
	Industrial	8,109	31,232
	Medical	111	10
	Utility	11,536	744,302
		23,518	815,974
Beatty	Academic	454	1,525
	Government	354	381
	Industrial	10,493	50,970
	Medical	344	370
	Utility	2,930	36,960
		14,575	90,206
Richland	Academic	322	102
	Government	842	67
	Industrial	7,123	17,888
	Medical	288	18
	Utility	2,696	75,848
		11,271	93,923

[a]Based on ref. 9.

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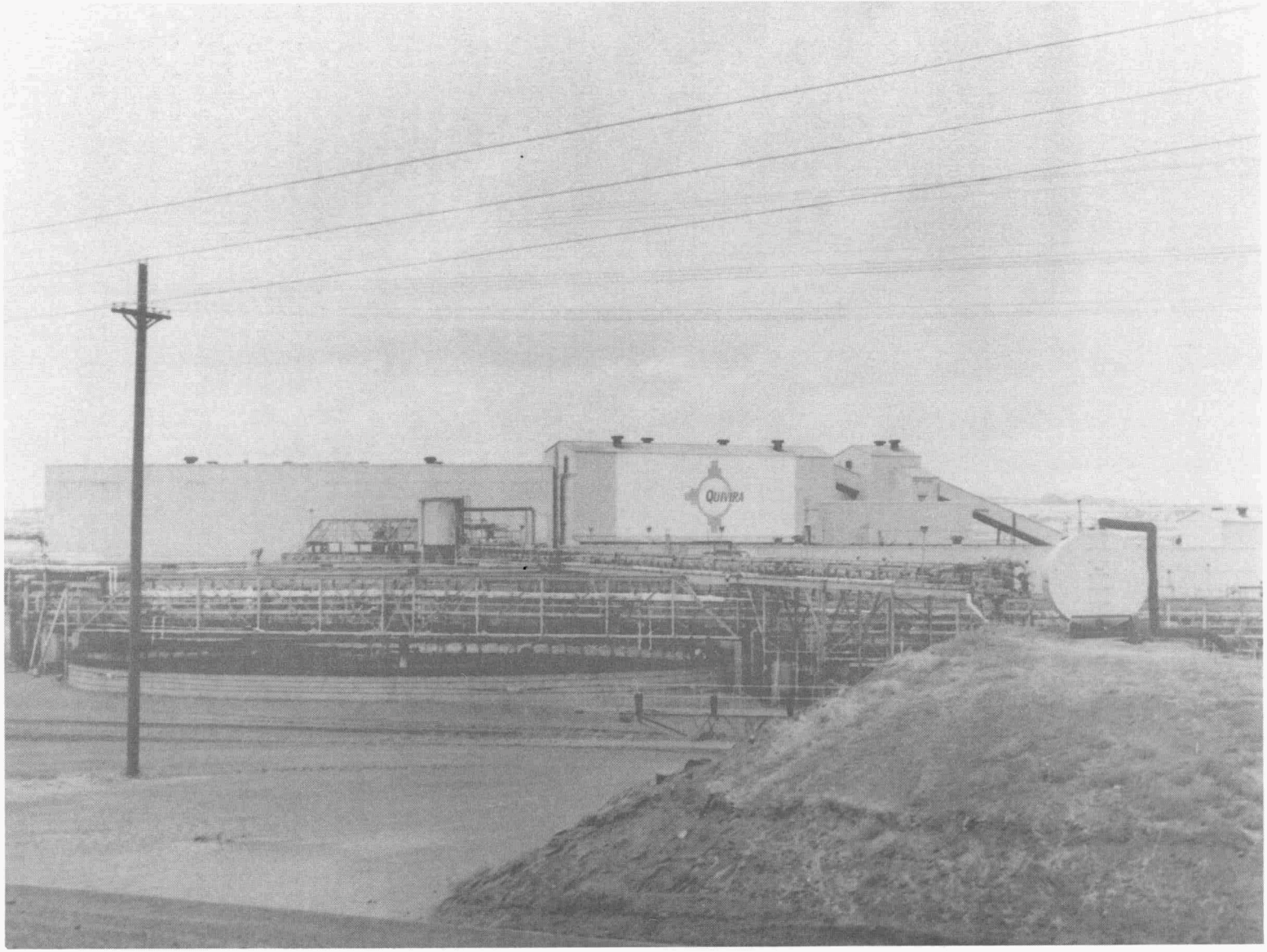

Quivira Mining Company's uranium mill in Grants, New Mexico, showing uranium ore pile, multi-stage thickeners, and mill plant. (Courtesy of the U.S. Department of Energy, Energy Information Administration, Washington, D.C.)

5. URANIUM MILL TAILINGS FROM COMMERCIAL OPERATIONS

5.1 INTRODUCTION

Uranium mill tailings are the residual wastes of milled ore that remain after the uranium values have been recovered. Mill tailings at licensed sites and those that will be produced to meet future uranium requirements are "commercial" mill tailings, the subject of this chapter. Tailings resulting from uranium milled for defense purposes are not included. Existing tailings at sites that are no longer licensed are classified as "inactive" mill tailings. Inactive tailings are administered under the remedial action projects discussed in Chapter 6.

Mill tailings are generated during the process of extracting uranium from the ore fed to the mill. Uranium mills employ either an acid leach or an alkaline leach process to recover uranium, depending on the ore's chemical characteristics. Currently, 97% of the U.S. milling capacity uses the acid leach process. Mill tailings from both processes consist of slurries of sands and clay-like particles called slimes; the tailings slurries are pumped to tailings impoundment ponds for disposal.

U.S. uranium production from conventional milling has declined since 1980; as a consequence, the quantity of mill tailings generated each year has declined (see Table 5.1). During 1992, two mills operated and generated tailings. The location of each of these mills is indicated in the map of Fig. 5.1. While no conventional mills remained operating in the United States[1,2] at the end of 1992, six mills with a total rated capacity of 13,300 t/d of ore were retained on standby status. This small utilization of U.S. capacity can be attributed in large part to nuclear power plant cancellations and deferments. Since the late 1970s, these have led to lower uranium demand which, in turn, has contributed to lower uranium prices and a steady decline in domestic uranium mining. In addition, cost increases for domestic uranium mining and milling have led to increased reliance on imports of lower cost uranium.

In recent years, U.S. uranium concentrate production from conventional milling of ore has declined. The total processing of ore at conventional mills in 1992 was 60% less than in 1991. Concentrate production from conventional mills in 1992 was about 570 t U_3O_8, about 630 t less than 1991 production.[2] Nonconventional concentrate production in 1992 also decreased to about 2,000 t U_3O_8, or 17% below 1991 production.[2] Nonconventional concentrate production includes by-product processing from the mining of phosphate ore as well as the processing of in situ leach mining solutions, heap-leach solutions, mine water, and other solutions from reclamation activities. In situ leaching (ISL) technology has been increasingly applied in recent years in mining operations. Of the total $80/kg-U uranium reserves estimated by the Energy Information Administration (EIA), the amount for which ISL is the proposed mining method has increased from 38% in 1991 to 39% in 1992. Because ISL mining generally is successful at lower costs compared with conventional mining methods, it could gain even wider use in the near future. ISL and by-product production methods do not generate mill tailings. Residual wastes from nonconventional methods are not considered in this chapter.

The volumes of historical and projected cumulative mill tailings through the year 2005 are shown in Fig. 5.2. This graph is based on the data reported in Table 5.1. The estimates of projected domestic tailings are based on U.S. production of uranium found in projections from the DOE/EIA uranium mining and milling viability assessment report (ref. 3), as well as ref. 4.

5.2 INVENTORIES

The status of the licensed mills, including their estimated commercial and government-related tailings inventories at the end of 1992, is shown in Table 5.2 (data based on refs. 1–12). For each mill, the amount of tailings generated depends on the amount of ore processed, the ore-feed grade (U_3O_8 assay), and the percentage of U_3O_8 recovered. Table 5.3 lists the annual milling rate, ore grade, and U_3O_8 recovery. The associated mill tailings generated through 1992 are 189.6×10^6 t (118.6×10^6 m^3). The DOE/EIA estimates[1] that 0.24×10^6 t (1.52×10^5 m^3) of tailings were added to the tailings piles at operating mill sites during 1992.

5.3 WASTE CHARACTERIZATION

Because the amount of uranium (by weight) extracted from the ore during milling is relatively small, the dry weight of the tailings produced is nearly equal to the dry weight of the ore processed. Dry tailings typically are composed of 70 to 80 wt % sand-sized particles and 20 to 30 wt % finer-sized particles. Acid leaching is preferred for ores with low lime content (12% or less). Those with high lime content require excessive quantities of acid for neutralization and, for economic reasons, are best treated by alkaline leaching. In either leach process, most of the uranium is dissolved, together with the other materials present in the ore (e.g., iron, aluminum, and other impurities). After the ore is leached, the uranium-laden leach liquor is removed from the tailings solids by decantation. After thorough washing, the tailings are pumped as a slurry to a tailings pond. The waste liquid accompanying the tailings solids to the disposal pond is approximately 1 to 1.5 times the weight of the processed ore. Typical characteristics of the tailings solids and liquid are outlined in Table 5.4 (ref. 9).

In August 1986, the EPA issued its final rules on ^{222}Rn emissions from tailings piles.[8] Mill owners have 6 years (subject to certain extensions) to phase out the use of large existing tailings piles. New tailings piles must be contained in small [i.e., less than 16 ha (40 acres)] impoundments or disposed of by continuous dewatering and burial with no more than 4 ha (10 acres) uncovered at any one time.

5.4 PROJECTIONS

An average tailings density of 1.6 t/m^3 was used to calculate mill tailings volumes resulting from the milling of uranium ore mined by open-pit and underground operations. The quantity of material produced is based on projections of uranium production as reported in the EIA publication, *Domestic Uranium Mining and Milling Industry 1991—Viability Assessment*, DOE/EIA-0477(91). These projections were based on uranium requirements associated with the DOE/EIA 1991 Lower Reference Case nuclear growth scenario and assumed a 2-year lead time from the mining/milling of uranium to its use as a reactor fuel.

The volumes of tailings generated from 1992 through 2005 are estimated based on revised production schedules for one of the two conventional mill operations expected to be operational in this period. Most of the U.S. production is projected to come from nonconventional extraction operations (in situ, by-product, etc.). Imports and U.S. inventory drawdowns are projected to make up over 80% of U.S. requirements through 2005 and will not add to U.S. tailings buildup.

5.5 REFERENCES

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4. U.S. Department of Energy, Energy Information Administration, *World Nuclear Capacity and Fuel Cycle Requirements 1992*, DOE/EIA-0436(92), Washington, D.C. (October 1992).

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6. U.S. Department of Energy, Grand Junction Office, and Bendix Field Engineering Corporation, *Commingled Uranium Tailings Study*, DOE/DP-0011, Vol. 2, Grand Junction, Colorado (June 1982).

7. W. S. White, *Directory and Profile of Licensed Uranium Recovery Facilities*, NUREG/CR-2869 (ANL/ES-128), Rev. 1, U.S. Nuclear Regulatory Commission, Washington, D.C. (March 1984).

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12. Paul Estey, Exxon Coal and Minerals Company, Houston, Texas, personal communication to L. L. Smith, Energy Information Administration, Washington, D.C. (Aug. 22, 1988).

ORNL DWG 93-10812

Fig. 5.1. Locations of uranium mill tailings sites active during at least part of 1992.

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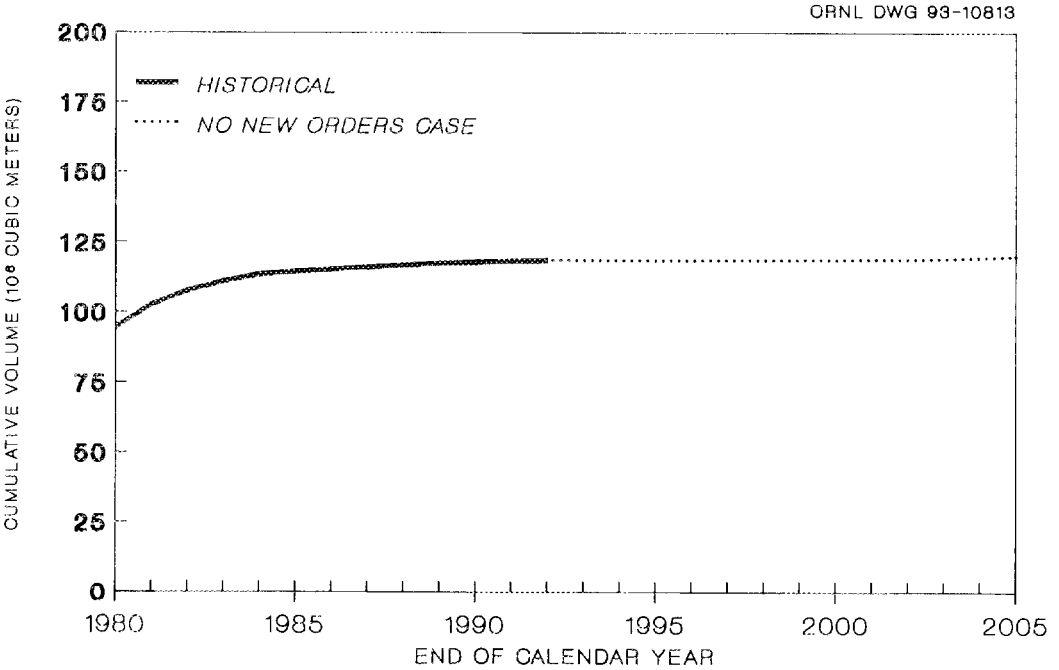


Fig. 5.2. Historical and projected cumulative volume of commercial mill tailings.

Table 5.1. Historical and projected volume of uranium mill tailings[a,b]

End of calendar year	Volume (10^6 m^3) Annual	Cumulative
Prior to 1978		68.0
1978	7.9	75.8
1979	9.1	84.9
1980	9.5	94.4
1981	8.2	102.7
1982	5.0	107.7
1983	3.4	111.1
1984	2.5	113.6
1985	1.0	114.6
1986	0.7	115.4
1987	0.8	116.2
1988	0.7	116.9
1989	0.7	117.6
1990	0.4	118.0
1991	0.4	118.4
1992	0.2	118.6
1993	0.0	118.6
1994	0.0	118.6
1995	0.0	118.6
1996	<0.1	118.6
1997	<0.1	118.7
1998	<0.1	118.7
1999	<0.1	118.8
2000	<0.1	118.8
2001	<0.1	118.9
2002	0.1	118.9
2003	0.3	119.2
2004	0.3	119.5
2005	0.5	120.0

[a]Projections of domestic tailings are generated from estimates of U.S. uranium production under current market conditions described in ref. 3, which is the Lower Reference Case of ref. 4.

[b]Sources: Prior to 1984—U.S. Department of Energy, Grand Junction Project Office data files. 1984-1992—Energy Information Administration, Form EIA-858, "Uranium Industry Annual Survey."

Table 5.2. Status of conventional uranium mill sites at the end of 1992[a]

Location	Operator	Rated capacity[b] (t/d ore)	Status: Operations[b]	Status: Tailings[c]	Tailings storage area (ha)[d]	Total tailings: Volume[e] (10^6 m^3)	Total tailings: Mass (10^6 t)	Total tailings: Government portion[f] (10^6 t)
Colorado								
Canon City	Cotter	1,090	Shut down, 1987	Wood chip covering	81	1.3	2.1	0.3
Uravan	Umetco Minerals	1,180[g]	Decommissioning	Partially stabilized	44	5.9	9.5	5.2
Subtotal		1,090			125	7.2	11.6	5.5
New Mexico								
Ceboilleta	Sohio Western Mining	1,450[g]	Decommissioned, 1986	h	73	1.2	1.9	0
Church Rock	United Nuclear	2,720[g]	Decommissioned, 1986	h	83	2.0	3.2	0
Grants	Anaconda	5,440[g]	Decommissioned, 1987	Partially stabilized	199	13.6	21.7	8.0
Grants	Quivira Mining	6,350	Shut down, 1985	Fenced	142	18.8	30.1	9.1
Grants	Homestake Mining	3,080[g]	Decommissioning	Unstabilized	105	12.7	20.3	10.4
Marquez	Bokum Resources	1,820[g]	New (on standby)	Never operated	0	0	0	0
Subtotal		6,350			602	48.3	77.2	27.5
South Dakota								
Edgemont	Tennessee Valley Authority	680[g]	Decommissioned, 1983	Partially stabilized	50	1.2	1.8	1.5
Subtotal		0			50	1.2	1.8	1.5
Texas								
Falls City	Continental Oil/ Pioneer Nuclear	3,080[g]	Decommissioned, 1981	h	89	6.5	10.5	0
Hobson	Rio Grande Resources	2,720	Decommissioning	h	101	3.9	5.9	0
Ray Point (Felder Facility)	Exxon	1,000[g]	Decommissioned, 1973[i]	Stabilized[j]	18	0.2	0.4[k]	0
Subtotal		2,720			208	10.6	16.8	0
Utah								
Blanding	Umetco/Energy Fuels Nuclear	1,810	Shut down, 1990	Partially stabilized	135	1.9	3.2	0
La Sal	Rio Algom	680	Decommissioned	h	14	2.2	3.5	0
Moab	Atlas	1,270[g]	Decommissioning	Unstabilized	>80	6.0	9.6	5.4
Hanksville	Plateau Resources	910	New (on standby)	Never operated	26	0	0	0
Subtotal		3,400			>257	10.1	16.3	5.4

Table 5.2 (continued)

Location	Operator	Rated capacity[b] (t/d ore)	Status: Operations[b]	Status: Tailings[c]	Tailings storage area (ha)[d]	Total tailings: Volume[e] (10^6 m^3)	Total tailings: Mass (10^6 t)	Total tailings: Government portion[f] (10^6 t)
Washington								
Ford	Dawn Mining	410	Shut down, 1982	Wood chip covering	43	1.8	2.8	1.1
Wellpinit	Western Nuclear	1,810[g]	Decommissioned	h	17	1.6	2.6	0
Subtotal		410			60	3.4	5.4	1.1
Wyoming								
Gas Hills	American Nuclear	860[g]	Decommissioned, 1988	Unstabilized	52	3.3	5.3	1.9
Gas Hills	Pathfinder	2,540[g]	Decommissioned	Unstabilized	55	6.6	10.6	2.4
Jeffrey City	Western Nuclear	1,540[g]	Decommissioned, 1988	Interim stabilization	34	4.4	7.0	3.0
Natrona	Umetco	1,270[g]	Decommissioned, 1987	Unstabilized	70	4.6	7.3	1.9
Powder River	Exxon	2,900[g]	Decommissioned, 1984	Partially stabilized	81	6.4	10.3	0
Powder River	Rocky Mountain Energy	1,810[g]	Decommissioned, 1987	Unstabilized	61	2.7	4.3	0
Shirley Basin	Pathfinder	1,630	Decommissioned	h	94	4.7	7.4	0
Shirley Basin	Petrotomics	1,360[g]	Decommissioned, 1985	Unstabilized	65	3.9	6.3	0.7
Red Desert	Minerals Exploration/ Union Energy Mining	2,720	Shut down, May 1983	Partially stabilized	121	1.3	2.1	0
Subtotal		4,350			633	37.9	60.6	9.9
1990 total for all sites[b,l,m]		18,320[n]			h	118.6	189.6	50.9[o]

[a]Data based on refs. 1-12. Note: subtotals and totals may not equal sum of components because of independent rounding. Ray Point, Texas (Felder Facility), site was stabilized during 1987 by Exxon Corporation. Historical data are revised based on detailed study of milling data from the Grand Junction Project Office and EIA files. The values shown include all tailings.

[b]From refs. 1, 6, and 10. Values rounded to nearest 10 t.

[c]On Aug. 15, 1986, EPA issued its final rules on ^{222}Rn emissions from tailings piles. Mill owners have 6 years (subject to certain extensions) to phase out the use of large existing tailings piles. New tailings piles may be contained in small impoundments (less than 16 ha) or disposed of continuously by dewatering and burial (i.e., no more than 4 ha are uncovered at any one time). See ref. 8.

[d]From ref. 7; 1 ha = 10,000 m^2 or approximately 2.5 acres.

[e]Calculated from reported mass using density = 1.6 t/m^3.

[f]From ref. 6, Table 8.0. These tailings are from government contracts only and are included in the "Total tailings" column.

[g]Estimates provided are not included in the total. See column labeled "Operations" under "Status" for reason.

[h]Not available.

[i]From ref. 10.

[j]From ref. 12.

[k]From ref. 11.

[l]These values are cumulative totals that may not equal sum of components due to independent rounding. For annual totals see Table 5.3.

[m]From ref. 1.

[n]Mills reported as permanently closed on Form EIA-858 for 1992. This is not the same as decommissioned, according to industry contacts.

[o]Total at the end of government-contracted deliveries in 1970 (ref. 6).

Table 5.3. Uranium ore processed, U_3O_8 recovery rate, and tailings generated through 1992[a,b]

End of calendar year	Ore processed		U_3O_8		Tailings generated	
	Mass[c] (10^6 t)	Grade (% U_3O_8)	Recovery from ore (%)	Product[d] (10^3 t)	Mass[e] (10^6 t)	Volume[f] (10^6 m^3)
Prior to 1978	g	g	g	g	108.8	68.0
1978	12.5	0.134	91	15.6	12.6	7.9
1979	14.6	0.113	91	15.3	14.5	9.1
1980	15.3	0.118	93	17.2	15.2	9.5
1981	13.2	0.115	94	14.5	13.2	8.2
1982	7.9	0.119	96	9.9	8.1	5.0
1983	5.4	0.128	97	7.0	5.4	3.4
1984	3.9	0.112	95	4.4	4.0	2.5
1985	1.6	0.161	96	2.8	1.6	1.0
1986	1.2	0.338	97	4.0	1.2	0.7
1987	1.3	0.284	96	3.8	1.3	0.8
1988	1.1	0.288	95	3.2	1.1	0.7
1989	1.1	0.323	95	3.7	1.0	0.7
1990	0.7	0.293	94	2.1	0.7	0.4
1991	0.6	0.188	92	1.2	0.6	0.4
1992	0.2	0.229	96	0.6	0.2	0.2
Total[h]					189.6	118.6

[a]Sources: Prior to 1984–U.S. Department of Energy, Grand Junction Area Office data files. 1984-1992–Energy Information Administration, Form EIA-858, "Uranium Industry Annual Survey."

[b]This table has been revised based on a detailed study of milling data from the Grand Junction Project Office and EIA files. The values shown include all tailings.

[c]Before in-process inventory adjustments.

[d]Conventional U_3O_8 concentrate production.

[e]Includes adjustments to ore-fed amounts for annual mill circuit inventory changes and uranium concentrate production.

[f]Calculated assuming that the average density of tailings is 1.6 t/m^3 (metric tons per cubic meter).

[g]Not available.

[h]Totals may not equal sum of components due to independent rounding.

Table 5.4. Typical characteristics of uranium mill tailings[a]

Tailings component	Particle size (μm)	Chemical composition	Radioactivity characteristics
Sands	75 to 500	SiO_2 with <1% complex silicates of Al, Fe, Mg, Ca, Na, K, Se, Mn, Ni, Mo, Zn, U, and V; also metallic oxides	0.004 to 0.01% U_3O_8[b] Acid leaching:[c] 26 to 100 pCi $^{226}Ra/g$; 70 to 600 pCi $^{230}Th/g$
Slimes	45 to 75	Small amounts of SiO_2 but mostly very complex clay-like silicates of Na, Ca, Mn, Mg, Al, and Fe; also metallic oxides	U_3O_8 and ^{226}Ra are almost twice the concentration present in the sands Acid leaching:[c] 150 to 400 pCi $^{226}Ra/g$; 70 to 600 pCi $^{230}Th/g$
Liquids	d	Acid leaching: pH 1.2 to 2.0; Na^+, NH_4^+, SO_4^{-2}, Cl^-, and PO_4^{-3}; dissolved solids up to 1% Alkaline leaching: pH 10 to 10.5; CO_3^{-2} and HCO_3^-; dissolved solids ~10%	Acid leaching: 0.001 to 0.01% U 20 to 7,500 pCi $^{226}Ra/L$; 2,000 to 22,000 pCi $^{230}Th/L$ Alkaline leaching: 200 pCi $^{226}Ra/L$; essentially no ^{230}Th (insoluble)

[a]Adapted from information in ref. 9.

[b]U_3O_8 content is higher for acid leaching than for alkaline leaching.

[c]Separate analyses of sands and slimes from the alkaline leaching process are not available. However, total ^{226}Ra and ^{230}Th contents of up to 600 pCi/g (of each) have been reported for the combined sands and slimes.

[d]Particle size does not apply. Up to 70% of the liquid may be recycled. Recycle potential is greater in the alkaline process.

ORNL PHOTO 1396-94

Decontamination of a former process building at the Weldon Spring Site Remedial Action Project. (Courtesy of the U.S. Department of Energy, Office of the Deputy Assistant Secretary for Environmental Restoration, Washington, D.C.)

6. ENVIRONMENTAL RESTORATION WASTES

6.1 INTRODUCTION

The fundamental goal of the DOE Office of Environmental Restoration (DOE/EM-40, or simply EM-40) is to ensure that the risks to the environment and human health and safety posed by inactive and surplus facilities and sites are either eliminated or reduced to prescribed, safe levels. These facilities contain radioactive and chemically hazardous contaminants as a result of previous activities conducted by DOE and its predecessor agencies. Although this goal encompasses all requirements prescribed by applicable federal, state, and local environmental statutes and regulatory requirements, it is not limited to regulatory compliance. DOE's paramount concern is maintaining and improving human health and safety and protecting the environment.

The DOE environmental restoration program includes a bias for action to expedite actual cleanup wherever and whenever possible. However, major actions are currently being undertaken at only a limited number of sites because most sites are in the assessment phase to determine the nature and extent of contamination that must be addressed. Closures and interim remedial actions are being undertaken at several sites to address more immediate concerns and bring them into compliance with federal and state environmental laws and regulations. Full remediation will follow assessment efforts, and, after cleanup is completed, these sites will continue to be monitored.

Environmental restoration efforts are proceeding in two major areas: remedial action (RA) and decontamination and decommissioning (D&D). These activities include cleanup of facilities and areas that supported defense-related activities, such as nuclear weapon component fabrication, and nondefense, civilian nuclear power activities, such as the development of heat sources for the space program and the operation of small test reactors.

RA activities are concerned with all aspects of the assessment and cleanup of inactive sites at which releases of radioactive and chemically hazardous substances have occurred. These actions are not only limited to those areas directly impacted by the release but also include additional areas to which contaminants may have migrated (e.g., to ground water). A number of DOE installations are on the EPA National Priorities List. RA tasks include site discovery, preliminary assessment, and site inspection; site characterization, analysis of cleanup alternatives, and selection of remedy; cleanup and site closure; and site compliance monitoring. Although such activities may deal with storage tanks, buildings, and structures, most are concerned with contaminated environmental media such as soil, sediment, and ground water.

The principal regulatory requirements for RA activities are derived from the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Activities may further be subject to requirements associated with compliance with the National Environmental Policy Act (NEPA) as well as to additional regulatory requirements imposed by the states. Other requirements are set forth in various DOE Orders and standards and other guidance documents.

D&D activities are primarily concerned with the safekeeping of surplus nuclear facilities following shutdown and for either their ensuing decontamination for reuse or their complete dismantlement. Such tasks include surveillance and maintenance, assessment and characterization, environmental review, engineering, specific D&D operations, and project closeout. Most D&D activities are concerned with facilities such as reactors, hot cells, processing plants, storage tanks, and other structures from which, in general, few releases to the environment have occurred. Approximately 500 contaminated facilities are currently included in the EM-40 inventory for future action. The objectives of D&D activities are to decontaminate these facilities and to eliminate any potential hazards to public health and the environment.

D&D activities are carried out under the authority of the Atomic Energy Act (AEA) and with requirements set forth in various DOE Orders and standards and other guidance documents. In addition, the provisions of RCRA and CERCLA may apply also to those facilities from which there either has been a release or there is a potential for release to the environment. State requirements may also apply in certain instances. Only those D&D activities at facilities transferred to the Office of Environmental Restoration and Waste Management (EM-1) are addressed in this chapter. Recently, EM-1 was renamed the Office of Environmental Management. This modification will be incorporated in all sections of future updates of this report.

Because many RA and D&D sites are still in the assessment phase, it is very difficult to project the volumes and types of waste that may be generated. Moreover, detailed information on the specific cleanup activities that may be applied to various contamination problems is not yet available; therefore, the quantity of resultant waste that might be generated cannot be reliably determined. In fact, the plans for many sites are not yet to a stage at which even the broad category of response that will be taken is known. For example, the decision whether a given contaminated area, such as a waste pit, is to be excavated or stabilized in place is not typically made until after (1) the nature of the problem has been adequately defined, (2) various response alternatives and related impacts have been evaluated in considerable detail, and (3) other agencies (such as the EPA, the impacted state, and the local community) have had a chance to comment on the preferred alternative. Materials regarded as waste would be generated only if the waste pit were excavated; no waste would be generated if the pit were capped in place.

DOE is currently undertaking several initiatives to determine the volumes and types of waste that may be generated during future environmental restoration activities. These studies have not yet been completed to a point at which realistic waste projections can be made; these results should be available within the next few years. Hence, environmental restoration waste volumes are not provided in this report. However, the volumes of contaminated solid environmental media are known to a reasonable degree at many sites, and these volumes are included in Sect. 6.3.

6.2 THE OFFICE OF ENVIRONMENTAL RESTORATION

Environmental restoration activities under the auspices of the DOE Office of Environmental Restoration (EM-40) are managed by three program offices: Southwestern Area Programs (EM-45), Northwestern Area Programs (EM-44), and Eastern Area Programs (EM-42). Each office manages both RA and D&D activities. Activities are divided into 17 major projects to assist in the planning, oversight, and performance-tracking of environmental restoration activities (see Fig. 6.1).

6.2.1 Southwestern Area Programs

The Southwestern Area Programs include all EM-40 activities managed through the DOE Nevada and Albuquerque operations offices, the Grand Junction Projects Office, and the Rocky Flats Office. Activities managed by the Nevada Operations Office include remediation of a number of locations at the Nevada Test Site (NTS) and at off-site areas where nuclear tests have been conducted. Environmental restoration activities at NTS involve cleanup of areas of contamination from above-ground and underground nuclear weapons testing. Off-site locations include Amchitka Island, Alaska; the Rio Blanco and Rulison Test sites in Colorado; the Gnome and Gasbuggy Test sites in New Mexico; the Salmon Test Site in Mississippi; and the Shoal and Central Nevada Test sites in Nevada.

The Albuquerque Operations Office activities are managed as five separate projects. Environmental restoration activities at the Albuquerque Laboratories project include remedial actions at the South Valley Superfund Site, Sandia National Laboratories–New Mexico (referred to in this report as SNLA), Los Alamos National Laboratory (LANL), and the Inhalation Toxicology Research Institute (ITRI), all of which are located in New Mexico; and at Sandia National Laboratories–California (referred to in this report as SNLL). These laboratories were used for various defense-related R&D activities. Environmental restoration activities at Albuquerque Production Facilities include remedial actions at the Pantex, Kansas City, Pinellas, and Mound plants. These plants, which are located in Texas, Missouri, Florida, and Ohio, respectively, were used in the production of nuclear materials for defense activities.

The Albuquerque Operations Office is responsible also for implementing the Uranium Mill Tailings Remedial Action Project (UMTRAP), which was authorized in 1978, and involves the stabilization and control of (a) 24 inactive uranium-processing sites and associated vicinity properties located in 10 states and 4 Indian reservations and (b) vicinity properties associated with the Edgemont, South Dakota, inactive uranium mill, which is currently owned by the Tennessee Valley Authority (see Fig. 6.2). All of the sites are located in the western United States, except for one in Canonsburg, Pennsylvania. Currently, two Albuquerque projects oversee work for UMTRAP: Uranium Mill Tailing Remedial Action (UMTRA) Surface and UMTRA Ground-Water Assessment and Remediation. Remedial actions have been completed at 10 sites under the UMTRA Surface Project.

The fifth project managed by the Albuquerque Operations Office consists of two sites being remediated by the Grand Junction Projects Office. This projects office is responsible for directing RA activities for tailings remediation and for surface and ground-water cleanup at the Monticello Mill Tailings Site in Utah and the Grand Junction Projects Office Site in Colorado.

The Rocky Flats Plant (RFP) in Colorado was formerly a nuclear weapons manufacturing facility; the mission of this facility is currently environmental restoration and waste management. Storage and disposal of hazardous, radioactive, and mixed wastes occurred on-site in the past when the facility was operational. Off-site areas that may require remediation include two reservoirs and surrounding land areas. These areas may have received

contaminated effluent and sediments originating from the plant.

6.2.2 Northwestern Area Programs

The Northwestern Area Programs include all EM-40 activities managed through the DOE Idaho, Richland, Oakland, and Chicago operations offices. Environmental restoration activities managed by the Idaho Operations Office are limited to cleanup of facilities and areas at the Idaho National Engineering Laboratory (INEL), which was established in 1949 as a site where nuclear reactors, support facilities, and equipment could be safely built, tested, and operated to evaluate various options for the use of nuclear power as a means to generate electricity. INEL is currently one of DOE's principal centers for nuclear energy research and development (R&D). These activities have resulted in the contamination of structures, ground water, and surface water within the site.

The Richland Operations Office manages environmental restoration activities at the Hanford (HANF) Site in the state of Washington. HANF has been involved in a large number of nuclear production activities since the early 1940s. More than 1,000 waste sites have been identified, most of which have resulted from the on-site storage or soil-column disposal of low-level radioactive, hazardous, and mixed wastes. More than 100 surplus facilities contaminated with radioactivity are scheduled for D&D. These facilities include nine former production reactors, as well as chemical process buildings and ancillary structures. Remediation of HANF includes constructing a disposal facility to receive cleanup wastes and closing underground storage tanks and other RCRA closures.

The Oakland Operations Office has been responsible for managing a number of activities associated with nuclear weapons research and other nuclear and energy research. This office oversees a number of installations. Those installations with an ongoing EM-40 program include Lawrence Livermore National Laboratory (LLNL), Lawrence Berkeley Laboratory (LBL), Stanford Linear Accelerator Center (SLAC), General Atomic (GA) Site, Laboratory for Energy-Related Health Research (LEHR), General Electric Vallecitos Nuclear Center, and the DOE portion of the Santa Susana Field Laboratory (SSFL), known as the Energy Technology Engineering Center (ETEC). All of these installations are located in California. Activities at these sites have resulted in the contamination of facilities, soil, and ground water with a wide range of radioactive and chemically hazardous substances.

The Chicago Operations Office manages two EM-40 projects: the Chicago and Battelle Columbus Laboratories. The primary mission of Chicago Laboratories is energy research, development, and demonstration. Environmental restoration activities are being performed under this project at 5 R&D laboratories: Argonne National Laboratory–East (ANL–E), Illinois (including Site A/Plot M, which was formerly a portion of ANL–E); Argonne National Laboratory–West (ANL–W), Idaho; Brookhaven National Laboratory (BNL), New York; Princeton Plasma Physics Laboratory (PPPL), New Jersey; and Ames (AMES) Laboratory, Iowa. RAs at these sites include remediation of soil and ground-water contamination, disposal sites, and underground storage tanks. Environmental restoration activities are also being conducted at the Reactive Metals, Inc. (RMI) Site in Ohio. RA activities at this site involve the cleanup of a former metals-extrusion plant that became contaminated as a result of the processing of radioactive materials (principally uranium). In addition to the activities at these six sites, activities included in the Chicago Laboratories program encompass the D&D of two retired nuclear reactors (at Hallam, Nebraska, and Piqua, Ohio) and processing facilities at the Separations Process Research Unit located at the Knolls Atomic Power Laboratory (KAPL) in the state of New York. Environmental restoration activities at Battelle Columbus Laboratories in Ohio include the D&D of 15 contaminated buildings and surrounding soils that were previously used for government-sponsored nuclear research.

6.2.3 Eastern Area Programs

The Eastern Area Programs include all EM-40 activities managed through the DOE Oak Ridge and Savannah River operations offices and the Fernald Field Office. The Oak Ridge Operations Office manages environmental restoration activities at installations in the vicinity of Oak Ridge, Tennessee, including ORNL, the K-25 Site, and the Y-12 Plant. The Oak Ridge Operations Office is also responsible for environmental restoration activities at the Portsmouth Gaseous Diffusion Plant (PORTS) in Ohio and the Paducah Gaseous Diffusion Plant (PAD) in Kentucky. These facilities provided enriched uranium for use in production reactors for defense purposes. Previous activities at these sites have resulted in contamination of soils, surface water, ground water, and various structures. The primary contaminant at most of these sites is uranium.

The Oak Ridge Operations Office also manages the Formerly Utilized Sites Remedial Action Project (FUSRAP), which is primarily concerned with the cleanup of sites that were formerly used to support the activities of the Manhattan Engineer District, established for the Manhattan Project, and the Atomic Energy Commission (AEC). Private firms and institutions were contracted by the federal government in the 1940s and 1950s to develop processes and perform research on radioactive materials. The storage and processing of uranium and thorium ores, concentrates, and residues were often involved. Although these sites were cleaned up to formerly acceptable levels, FUSRAP was established in 1974 to identify; reevaluate; and, if necessary, remediate these sites. Currently, 44 sites have been identified in 14 states: 12 of these sites have

already been remediated (see Fig. 6.3). Most FUSRAP sites are in the eastern half of the country.

The Oak Ridge Operations Office also manages environmental restoration activities being conducted by the Weldon Spring Site Office. This site office is responsible for the cleanup of a former uranium processing plant in Missouri. Environmental restoration activities at this site include the D&D of the chemical plant processing buildings, remedial action of the raffinate pits and quarry, restoration of contaminated vicinity properties, construction and operation of two water treatment plants and waste-processing facilities, and disposal of all waste generated by site cleanup activities.

The Savannah River Operations Office manages environmental restoration at the Savannah River Site (SRS) in South Carolina. The site's nuclear production reactors have not operated since 1988; much of the site's current mission is environmental restoration and waste management. Its historical mission of producing nuclear materials for defense purposes has resulted in the generation of a significant quantity of radioactive, hazardous, and mixed wastes, which were disposed of on-site. Soil and ground-water contamination has resulted from contaminants migrating from seepage and settling basins, unlined disposal pits, waste piles, burial grounds, and underground storage tanks. D&D activities are currently under way at several reactor areas; remedial action activities are ongoing at burial grounds, tanks, pits, basins, and areas having ground-water contamination.

The Fernald Field Office is responsible for implementing the Fernald Environmental Management Project (FEMP) in Ohio. This site was the location of the former Feed Materials Production Center, whose mission was to produce feed materials (principally uranium) for nuclear reactor fuel as part of the nation's defense program. The mission of this project is now environmental restoration and waste management. Previous activities at this site resulted in the contamination of structures, soil, surface water, and ground water. The major contaminants are generally uranium and radium.

6.3 ENVIRONMENTAL RESTORATION WASTE CHARACTERISTICS

The volumes and types of wastes associated with DOE environmental restoration activities are a direct result of the remedy chosen. Waste associated with remediation of contaminated environmental media would occur only when such media are exhumed. For example, no waste would be produced at a site for which an in situ remedy was selected, such as capping an area containing contaminated soil. If a minimal remedial action were selected (e.g., pumping and treating a small pocket of contaminated ground water followed by construction of lateral barriers to minimize future migration), the site would have relatively small waste volumes. However, if large volumes of contaminated environmental media were removed, treated to provide a more suitable waste form for disposal, and then disposed of in an engineered facility, the site would have very large waste volumes.

Environmental restoration wastes are different from those associated with processing operations in that they generally have much lower concentrations of radioactive and chemically hazardous substances. Much of the material requiring remediation is a consequence of past activities such as spills, waste disposal, and environmental releases such as liquid discharges to drainage basins. In addition, operations within structures resulted in the contamination of equipment, walls, and floors from routine material-handling activities and from off-normal incidents such as spills and equipment failure. D&D of these facilities will result in wastes such as wipes, concrete, metal, personal protective clothing, and decontamination solvents that have generally low concentrations of radioactive and chemical contaminants.

Environmental restoration wastes also differ from those resulting from processing operations in that they are generally highly heterogeneous both in physical form and chemical constituency. For example, remediation of an abandoned waste pit could require the exhumation of all materials previously placed into the pit for disposal. This effort could involve any possible imaginable combination of objects ranging from small pieces of equipment and drums to entire vehicles such as trucks and forklifts. In addition, a full spectrum of contaminants could be associated with these previously disposed materials including those associated with ordnance operations, processing of uranium and thorium ores and concentrates, and the operation of nuclear reactors and associated chemical processing plants. This potential variety is in contrast to waste streams associated with processing activities that have relatively consistent chemical and physical properties.

Because most DOE environmental restoration projects are in the assessment phase of the remedy-selection process, it is not possible to make definitive projections of wastes that will result from these projects. For this reason, such estimates are not included here. Rather, the volumes of radioactively contaminated solid media associated with the various environmental restoration sites are provided. These volumes are based on historical knowledge, monitoring information, and field-characterization results. These volumes are given in Table 6.1 for radioactively contaminated soil (including sediment and sludge) and in Table 6.2 for radioactively contaminated debris such as metal, concrete, brick, and wood. The actual waste volumes that will result from cleanup of some sites may be significantly lower than those given in these two tables, especially for those sites for which minimal remedial actions are selected. Such minimal remedial actions will likely occur at major DOE installations located in remote areas of the country. In addition, decontamination of metallic items such as hot-cell liners, tanks, and processing equipment could allow for unrestricted release of these

items, which would reduce the volume of material requiring disposal.

The volumes of radioactively contaminated media given in Tables 6.1 and 6.2 are limited to solid materials (i.e., contaminated liquids such as surface-water impoundments and ground water are not included). These data are based on currently available information encompassing those projects for which characterization activities have proceeded to a point which allows for preparation of realistic volume estimates. Some projects have not yet initiated field-characterization activities, and historical records are not available in sufficient detail to allow for volume estimates to be made. The volume estimates for such sites will be larger than those shown in these two tables because not all of the potentially contaminated media would have been addressed. These sites are generally limited to the large defense installations in the western part of the country where field characterization activities are just being initiated.

An intensive effort is currently under way to better define waste management requirements for implementing the DOE environmental restoration program. A data collection program was recently initiated to develop "cradle-to-grave" contaminated media/waste information to allow for better planning of waste treatment and disposal capacity needs.[1] This effort includes collecting data on all waste types that may result from future environmental restoration activities including radioactive, sanitary, demolition, hazardous wastes as regulated by RCRA and the Toxic Substances Control Act (TSCA). The results of this data collection program are currently being compiled. Once these data are fully compiled and verified, more complete waste estimates can be made. Such estimates will be included in future revisions of this report.

Previous versions of this report have included more detailed information for two environmental restoration projects that are well into the cleanup phase, UMTRAP and FUSRAP. Such information is not available for most of the other DOE environmental restoration programs because these programs are still largely in the assessment or remedial design phases. The information for UMTRAP and FUSRAP provided in the 1992 IDB report[2] is generally still current. Readers desiring more detailed waste information for these two programs should refer to that report.

Three major radioactive waste classes are associated with environmental restoration activities: LLW, TRU waste, and 11e(2) by-product material. As defined in DOE Order 5820.2A, LLW is waste that contains radioactivity and is not classified as HLW, TRU waste, spent nuclear fuel, or 11e(2) by-product material. Environmental restoration activities will not generate any HLW or spent nuclear fuel. TRU waste is waste contaminated with alpha-emitting transuranium radionuclides with half-lives greater than 20 years and at concentrations greater than 100 nCi/g at the time of assay. As defined in Sect. 11e(2) of the AEA of 1954 (P.L. 83-703, as amended), 11e(2) by-product material is tailings or waste produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content. In addition to radioactive contaminants, these wastes can also be contaminated with hazardous constituents as regulated by RCRA or TSCA; such wastes are considered mixed wastes. All TRU wastes are considered mixed wastes, which is consistent with DOE policy for complying with the Federal Facility Compliance Act (FFCA). Thus, a total of five waste classes are relevant for radioactively contaminated material resulting from environmental restoration activities: LLW, mixed LLW, TRU waste, 11e(2) by-product material, and mixed 11e(2) by-product material.

The relative volumes of these five waste classes for contaminated soil and solid debris for environmental restoration sites are shown in Figs. 6.4 and 6.5, respectively. The two waste classes that constitute the largest volumes of radioactively contaminated soil are LLW and 11e(2) by-product material. The large volume of soil designated as LLW is mainly associated with three sites: NTS, LANL, and HANF. Together, these three sites account for almost 90% of the soil in this waste class. The actual amount of contaminated soil at these three sites that will eventually be handled as waste is highly uncertain because remedy-selection decisions have yet to be made. The large volume of 11e(2) by-product material is mainly the result of the large volume of waste associated with uranium mill tailings being remediated under UMTRAP.

The volume of radioactively contaminated debris is a very small fraction of that associated with soil. The total volume of contaminated debris is approximately 3.2×10^6 m^3; the total volume of contaminated soil is approximately 7.1×10^7 m^3. Most of this debris is classified as LLW (see Fig. 6.5), which accounts for about 81% of the total volume of radioactively contaminated debris. As with the volume estimates provided for soil, the total amount of debris that will be handled as waste could be lower than that given here if a significant fraction of this debris (e.g., metallic items) can be decontaminated to allow for reuse.

Since environmental restoration information is currently in the initial stages of being compiled at a number of sites, much of the information included in Tables 6.1 and 6.2 is preliminary. In addition, these tables include information only for sites currently in the EM-40 program for which data are available. That is, zero volumes may be reported for areas of a site at which characterization activities have not been initiated, resulting in an underestimate of the total volume of radioactively contaminated media. Conversely, overly conservative assumptions may be incorporated into some estimates to ensure adequate sizing of treatment and disposal facilities. These uncertainties will continue to be reduced with time as characterization and engineering studies become available to refine these volume estimates.

The information contained in this chapter is limited to radioactively contaminated environmental media and wastes, consistent with the scope of this report. The volume estimates given in Tables 6.1 and 6.2 are limited to solid materials; liquids, such as contaminated surface water and ground water, as well as liquid wastes currently in storage, are not included. It should not be concluded that sites for which no (or minimal) volumes are given in Tables 6.1 and 6.2 have no waste management concerns. Environmental restoration activities at such sites could generate hazardous wastes as regulated by RCRA and TSCA, as well as large volumes of sanitary and demolition wastes. Also, additional characterization activities at these sites may identify areas of radioactive contamination requiring remediation in the future. As it becomes available, such information will be included in future updates of this report.

The volumes of radioactively contaminated soil and debris given in Tables 6.1 and 6.2 are limited to those sites and facilities currently in the EM-40 program. These data are summed across all elements of a site including environmental media, wastes currently in storage, and radioactively contaminated materials that could result from future D&D activities. At a number of sites, wastes generated as a result of EM-40 RA and D&D activities have been transferred to the Office of Waste Management (EM-30) for treatment, storage, and disposal. These wastes are no longer being managed by EM-40 and are therefore not included in this chapter. In addition, an extensive effort is currently underway by EM-30 and EM-40 to compile mixed waste information to meet FFCA requirements. Environmental restoration information is being provided to EM-30 for inclusion in the Mixed Waste Inventory Report, which will be issued later in 1994.

The DOE Office of Facility Transition (EM-60) is currently preparing a detailed inventory of all facilities that may eventually be transferred to the Office of Environmental Management (EM-1). As facilities are transferred to EM-1, environmental restoration and waste management information will be developed and included in future updates of this report.

6.4 REFERENCES

1. R.P. Whitfield, U.S. Department of Energy, Deputy Assistant Secretary for Environmental Restoration, Washington, D.C., letter to Distribution, "Contaminated Media/Waste Data Call Guidance," dated Oct. 8, 1993.

2. 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, Oak Ridge, Tennessee (October 1992).

ORNL DWG 94-6750R2

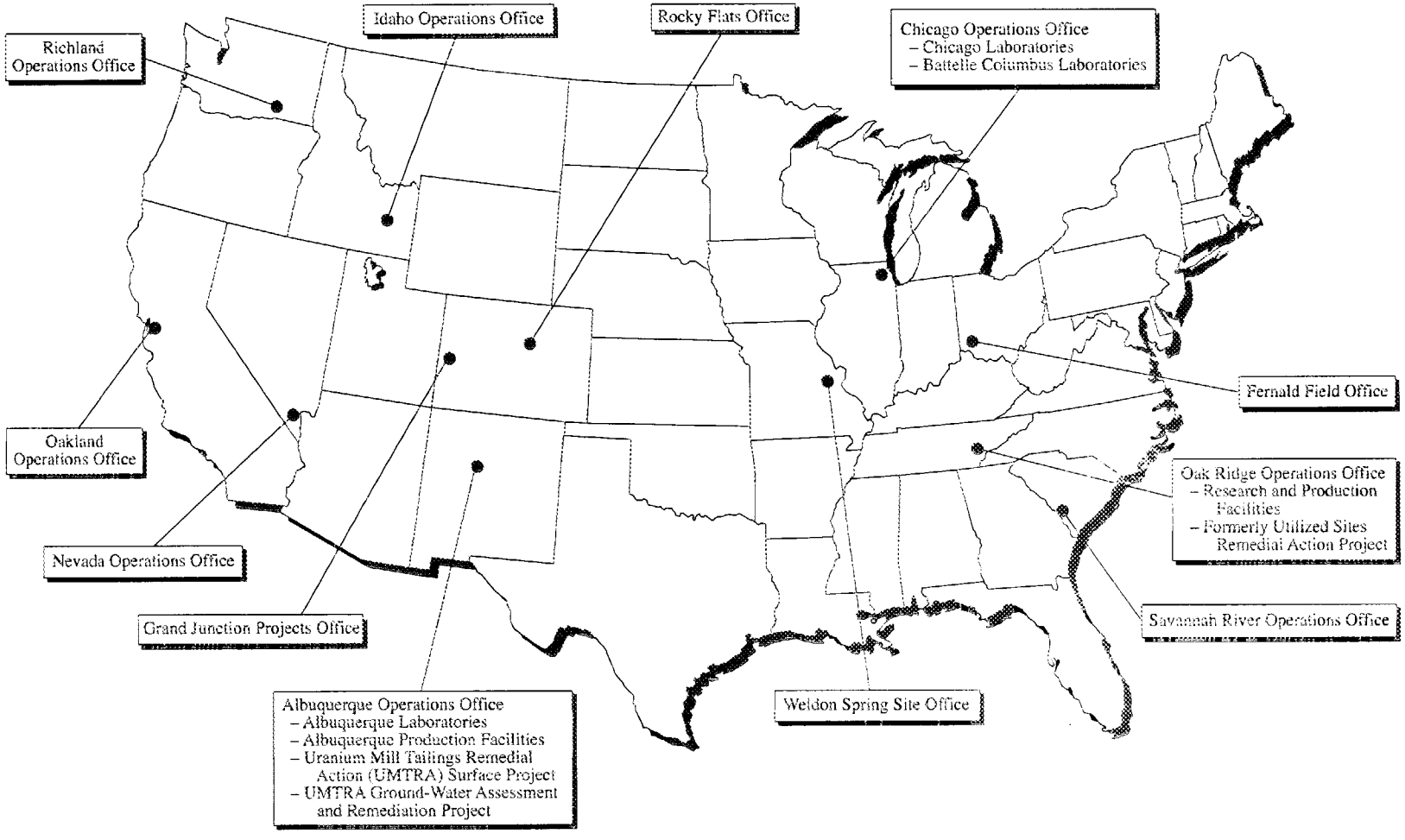
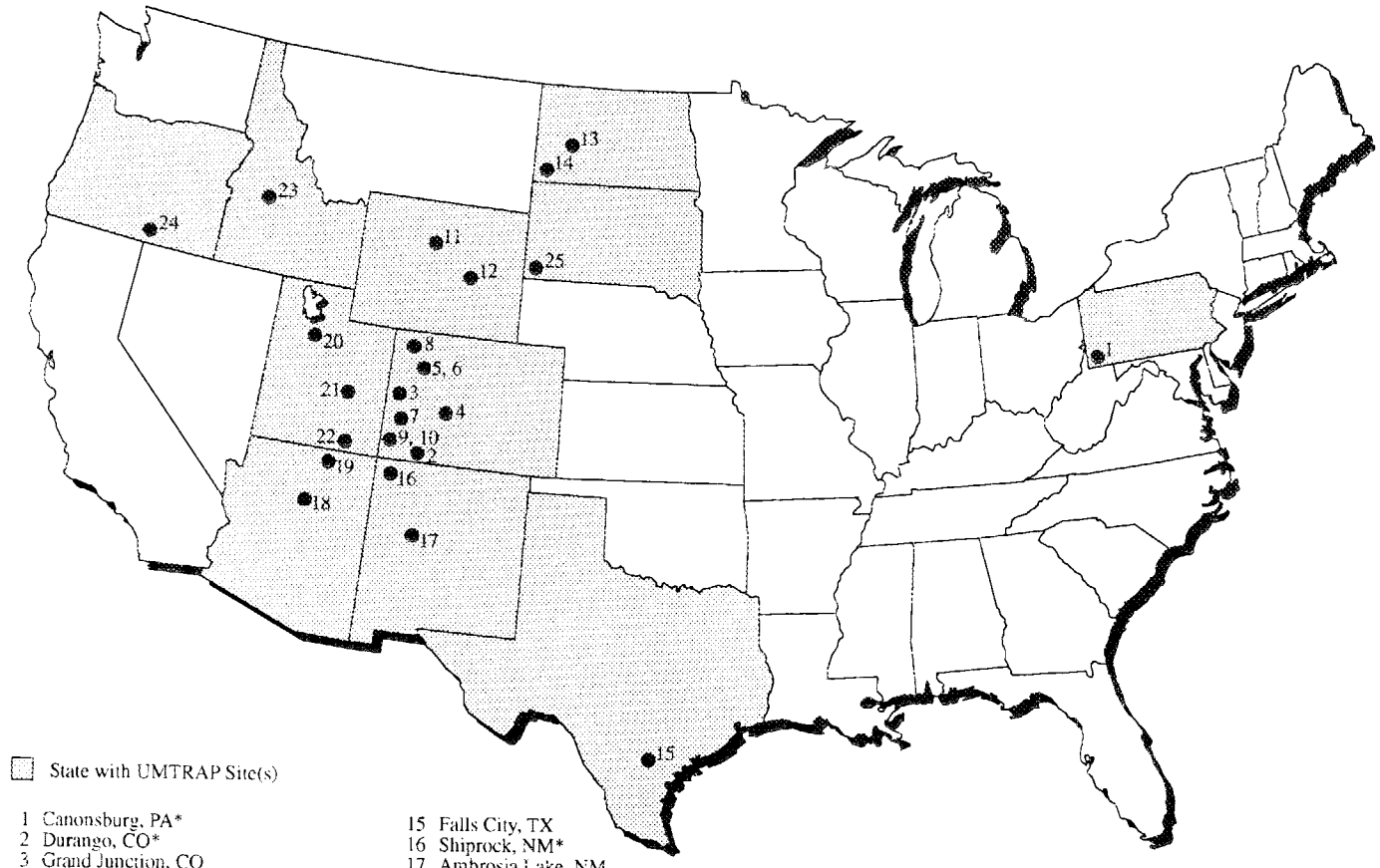


Fig. 6.1. Locations of site offices that manage the 17 major projects of the DOE environmental restoration program.

ORNL DWG 94-6751



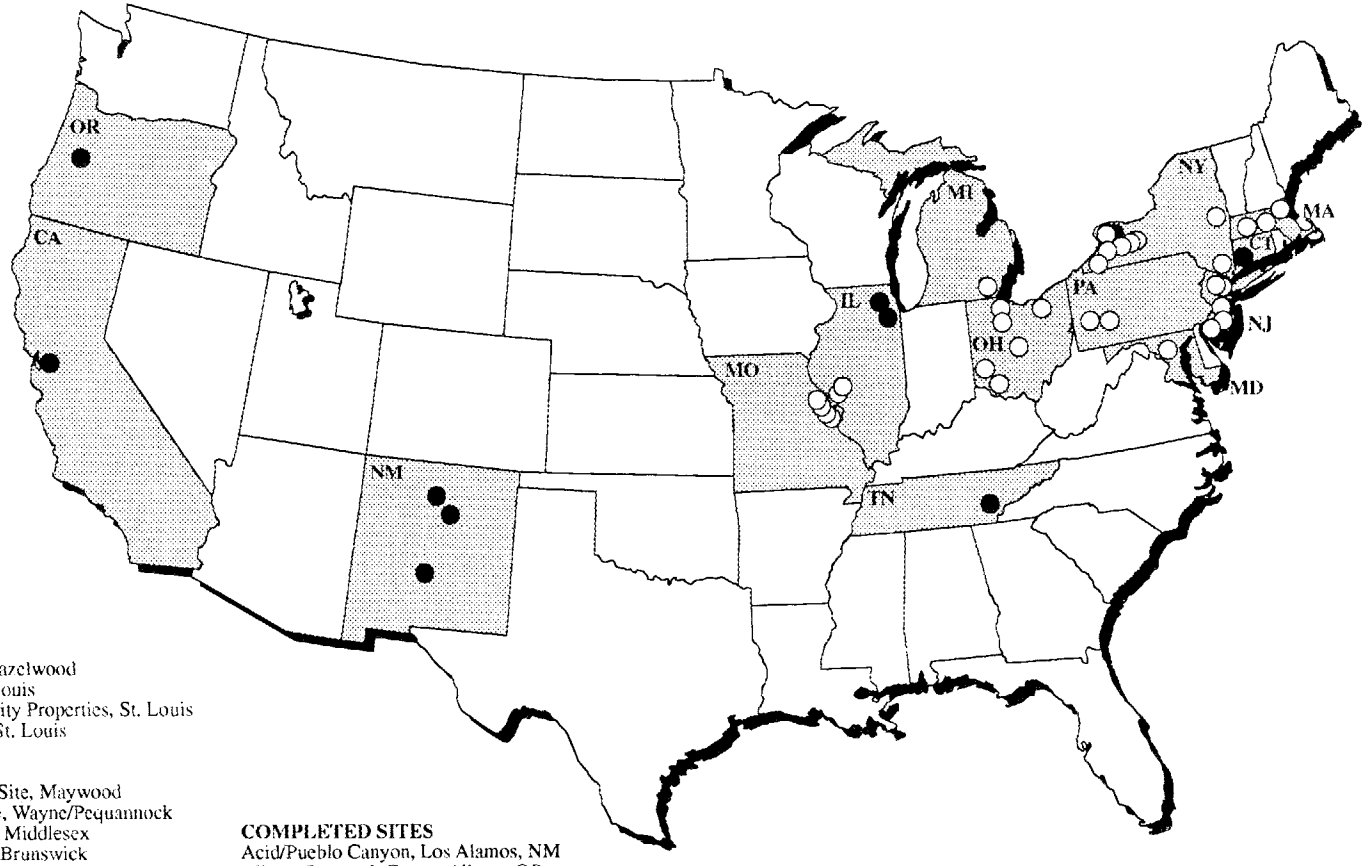
State with UMTRAP Site(s)

1 Canonsburg, PA*
2 Durango, CO*
3 Grand Junction, CO
4 Gunnison, CO
5 New Rifle, CO
6 Old Rifle, CO
7 Naturita, CO
8 Maybell, CO
9 Slick Rock (North Continent Site), CO
10 Slick Rock (Union Carbide Site), CO
11 Riverton, WY*
12 Converse, Co., WY*
13 Belfield, ND
14 Bowman, ND
15 Falls City, TX
16 Shiprock, NM*
17 Ambrosia Lake, NM
18 Tuba City, AZ*
19 Monument Valley, AZ
20 Salt Lake City, UT*
21 Green River, UT*
22 Mexican Hat, UT
23 Lowman, ID*
24 Lakeview, OR*
25 Edgemont, SD*

* Site work completed

Fig. 6.2. Locations of UMTRAP sites.

ORNL DWG 94-6752



MISSOURI SITES
¥*† Latty Avenue Properties, Hazelwood
¥* St. Louis Airport Site, St. Louis
* St. Louis Airport Site Vicinity Properties, St. Louis
St. Louis Downtown Site, St. Louis

NEW JERSEY SITES
¥*† Maywood Interim Storage Site, Maywood
¥*† Wayne Interim Storage Site, Wayne/Pequannock
† Middlesex Sampling Plant, Middlesex
† New Brunswick Site, New Brunswick
DuPont & Company, Deepwater

NEW YORK SITES
† Niagara Falls Storage Site, Lewiston
¥† Colonie Interim Storage Site, Colonie
Ashland 1, Tonawanda
Ashland 2, Tonawanda
Linde Center, Tonawanda
Seaway Industrial Park, Tonawanda
Baker and Williams Warehouses, New York City
B&L Steel, Buffalo

COMPLETED SITES
Acid/Pueblo Canyon, Los Alamos, NM
Albany Research Center, Albany, OR
Bayo Canyon, Los Alamos, NM
Chupadera Mesa, White Sands Missile Range, NM
Elza Gate Site, Oak Ridge, TN
Kellex/Pierpont, Jersey City, NJ
Middlesex Municipal Landfill, Middlesex, NJ
National Guard Armory, Chicago, IL
Niagara Falls Storage Site Vicinity Prop., Lewiston, NY
Seymour Specialty Wire, Seymour, CT
University of California, Berkeley, CA
University of Chicago, Chicago, IL

ADDITIONAL SITES
Aliquippa Forge, Aliquippa, PA
B&T Metals, Columbus, OH
Baker Bros., Toledo, OH
Chapman Valve, Indian Orchard, MA
General Motors, Adrian, MI
Granite City Steel, Granite City, IL
Luckey Site, Luckey, OH
Madison Site, Madison, IL
Oxford Site, Oxford, OH
Painsville Site, Painsville, OH
* Shpack Landfill, Norton, MA
Springdale Site, Springdale, PA
Ventron Corporation, Beverly, MA
W. R. Grace & Company, Curtis Bay, MD
Fairfield Site, Fairfield, OH

○ REMEDIAL ACTION ONGOING OR PLANNED
● REMEDIAL ACTION COMPLETED
† DOE-OWNED OR LEASED SITE
¥ ASSIGNED BY CONGRESS
* NPL SITE
□ STATE WITH FUSRAP SITE(S)

Fig. 6.3. Locations of FUSRAP sites.

ORNL DWG 93-10816

ENVIRONMENTAL RESTORATION WASTES
(RADIOACTIVELY CONTAMINATED SOILS)

WASTE CLASS	CUBIC METERS
11e(2) BY-PRODUCT	3.600E+07
LOW-LEVEL	2.900E+07
MIXED 11e(2) BY-PRODUCT	5.300E+01
MIXED LOW-LEVEL	4.300E+06
TRANSURANIC	1.300E+06
TOTAL	7.100E+07

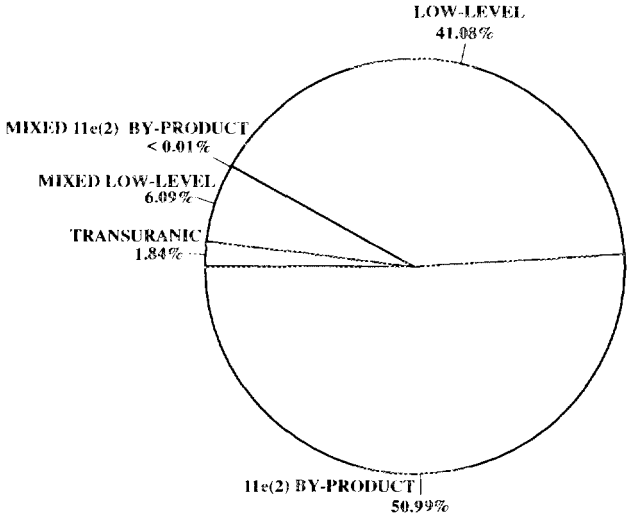


Fig. 6.4. Estimated volumes of radioactively contaminated soils associated with environmental restoration projects.

ORNL DWG 93-10817

ENVIRONMENTAL RESTORATION WASTES
(RADIOACTIVELY CONTAMINATED DEBRIS)

WASTE CLASS	CUBIC METERS
11e(2) BY-PRODUCT	2.600E+05
LOW-LEVEL	2.600E+06
MIXED 11e(2) BY-PRODUCT	1.300E+03
MIXED LOW-LEVEL	3.400E+05
TRANSURANIC	5.400E+02
TOTAL	3.200E+06

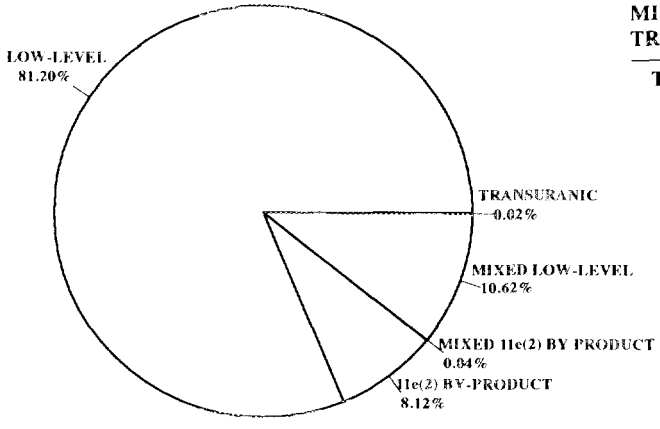


Fig. 6.5. Estimated volumes of radioactively contaminated debris associated with environmental restoration projects.

Table 6.1. Estimated volumes of radioactively contaminated soils associated with environmental restoration projects[a,b]

Environmental restoration program	Waste volume, m^3					
	LLW	Mixed LLW	11e(2) by-product[c]	Mixed 11e(2) by-product	TRU waste[d]	Total
Southwestern Area Programs						
Albuquerque Laboratories						
Inhalation Toxicology Research Institute	9,000					9,000
Los Alamos National Laboratory	8,300,000	1,200,000			93,000	9,600,000
Sandia National Laboratories—Albuquerque	15,000	52,000				67,000
Sandia National Laboratory—Livermore						0
South Valley Superfund Site						0
Albuquerque Production Facilities						
Kansas City Plant						0
Mound Plant	140,000	17,000				150,000
Pantex Plant						0
Pinellas Plant						0
Grand Junction Projects Office						
Grand Junction Projects Office Site			35,000	47		35,000
Monticello Remedial Action Project[e]			2,200,000			2,200,000
Nevada Operations Office						
Nevada Test Site	14,000,000	460				14,000,000
Nevada off-site locations[f]	9,500	21,000				30,000
Rocky Flats Plant	18,000	250,000				270,000
Uranium Mill Tailings Remedial Action Project[g]			32,000,000			32,000,000
Southwestern Area total	22,000,000	1,500,000	34,000,000	47	93,000	58,000,000
Northwestern Area Programs						
Battelle Columbus Laboratories	640				390	1,000
Chicago Laboratories						
Ames Laboratory	360	240				600
Argonne National Laboratory—East	8,700	19,000			21	27,000
Argonne National Laboratory—West	1					1
Brookhaven National Laboratory	23,000	3,400				26,000
Hallam Site						0
Piqua Site						0
Princeton Plasma Physics Laboratory						0
Reactive Metals, Inc., Site	24,000	3,500				27,000
Separations Process Research Unit	14,000					14,000
Site A/Plot M[h]	4,500	500				5,000
Hanford Site[i]	3,100,000	760,000				3,900,000
Idaho National Engineering Laboratory	280,000	200,000			170,000	660,000

Table 6.1 (continued)

Environmental restoration program	Waste volume, m^3					
	LLW	Mixed LLW	11e(2) by-product[c]	Mixed 11e(2) by-product	TRU waste[d]	Total
Oakland Operations Office						
General Atomic Site		0.63				0.63
General Electric Vallecitos Nuclear Center						0
Laboratory for Energy-Related Health Research	620					620
Lawrence Berkeley Laboratory						0
Lawrence Livermore National Laboratory		42				42
Santa Susana Field Laboratory	600					600
Stanford Linear Accelerator Center					64,000	64,000
Northwestern Area total	3,500,000	990,000			230,000	4,700,000
Eastern Area Programs						
Fernald Environmental Management Project	1,500,000	170,000				1,700,000
Formerly Utilized Sites Remedial Action Project						
Missouri sites	210,000		500,000			720,000
New Jersey sites	54,000	24,000	390,000			460,000
New York sites	9,400	12,000	460,000			480,000
Other sites	91,000	7,200	28,000			130,000
Oak Ridge Laboratories and Production Facilities						
K-25 Site	3,300	1,500				4,800
Oak Ridge National Laboratory	43,000	28,000			500	71,000
Oak Ridge Reservation (off-site)[j]	100,000					100,000
Paducah Gaseous Diffusion Plant	1,800	70,000				72,000
Portsmouth Gaseous Diffusion Plant	7,700	2,200				9,900
Y-12 Plant	960	280,000				280,000
Savannah River Site	1,400,000	1,200,000			990,000	3,600,000
Weldon Spring Site Remedial Action Project			490,000	5.3		490,000
Eastern Area total	3,400,000	1,800,000	1,900,000	5.3	990,000	8,100,000
Grand total	29,000,000	4,300,000	36,000,000	53	1,300,000	71,000,000

Table 6.1 (continued)

[a]Estimated as of September 30, 1993. Includes contaminated soil, sediment, and sludge. Blank entries mean there are no radioactively contaminated soils for the indicated waste class.

[b]These volume estimates represent the quantity of in-place contaminated materials; the waste volumes resulting from remedial action activities may be larger or smaller depending on the selected remedy and treatment technology utilized. Waste volumes resulting from minimal remedial actions such as capping, monitoring, and certain in situ remedies will be quite small. All values are preliminary and are being updated as site characterization activities proceed. Values are given to two significant figures unless information was reported to only one significant figure. Some totals may not equal sum of components due to independent rounding.

[c]By-product material as defined in Section 11e(2) of the Atomic Energy Act of 1954 (P.L. 83-703), as amended.

[d]All TRU wastes are considered to be mixed wastes, consistent with the DOE approach for complying with the Federal Facility Compliance Act.

[e]Includes contaminated debris, which will be managed in the same manner as contaminated soil.

[f]Consists of Amchitka Island, Alaska; the Rio Blanco and Rulison Test sites in Colorado; the Gnome and Gasbuggy Test sites in New Mexico; the Salmon Test Site in Mississippi; and the Shoal and Central Nevada Test sites in Nevada.

[g]Estimated as of December 31, 1991.

[h]Estimate is very preliminary and includes contaminated debris.

[i]Does not include contaminated soil at the 200 Area of the Hanford Site, which is currently planned to be capped in place. A small percentage of the radioactively contaminated soil at the Hanford Site may be TRU waste.

[j]Includes contaminated areas in the vicinity of Oak Ridge, Tennessee, beyond the boundaries of the Y-12 Plant, the K-25 Site, and Oak Ridge National Laboratory.

Table 6.2. Estimated volumes of radioactively contaminated debris associated with environmental restoration projects[a,b]

Environmental restoration program	Waste volume, m^3					
	LLW	Mixed LLW	11e(2) by-product[c]	Mixed 11e(2) by-product	TRU waste[d]	Total
Southwestern Area Programs						
Albuquerque Laboratories						
Inhalation Toxicology Research Institute	44					44
Los Alamos National Laboratory	9,800	1,600				11,000
Sandia National Laboratories–Albuquerque	2,600					2,600
Sandia National Laboratories–Livermore						0
South Valley Superfund Site						0
Albuquerque Production Facilities						
Kansas City Plant						0
Mound Plant	28,000					28,000
Pantex Plant						0
Pinellas Plant						0
Grand Junction Projects Office						
Grand Junction Projects Office Site			2,100	38		2,200
Monticello Remedial Action Project[e]						0
Nevada Operations Office						
Nevada Test Site	3,800	290				4,100
Nevada off-site locations[f]						0
Rocky Flats Plant						0
Uranium Mill Tailings Remedial Action Project[g]			110,000			110,000
Southwestern Area total	44,000	1,900	110,000	38		160,000
Northwestern Area Programs						
Battelle Columbus Laboratories	4,200	24				4,300
Chicago Laboratories						
Ames Laboratory	110	3				110
Argonne National Laboratory–East	4,000	120,000			190	130,000
Argonne National Laboratory–West	150					150
Brookhaven National Laboratory	33	360			6.9	400
Hallam Site						0
Piqua Site						0
Princeton Plasma Physics Laboratory						0
Reactive Metals, Inc., Site	5,000	99				5,100
Separations Process Research Unit	1,400	1.6			36	1,500
Site A/Plot M[h]						0
Hanford Site[i]	2,300,000	120,000				2,500,000
Idaho National Engineering Laboratory	23,000	2,700				26,000

Table 6.2 (continued)

Environmental restoration program	Waste volume, m^3					
	LLW	Mixed LLW	11e(2) by-product[c]	Mixed 11e(2) by-product	TRU waste[d]	Total
Oakland Operations Office						
General Atomic Site	730	29				750
General Electric Vallecitos Nuclear Center	24					24
Laboratory for Energy-Related Health Research	390					390
Lawrence Berkeley Laboratory		4.2				4.2
Lawrence Livermore National Laboratory		35				35
Santa Susana Field Laboratory	1,000	20			39	1,100
Stanford Linear Accelerator Center						0
Northwestern Area total	2,400,000	240,000			270	2,600,000
Eastern Area Programs						
Fernald Environmental Management Project	100,000	84,000				190,000
Formerly Utilized Sites Remedial Action Project						
Missouri sites	130		17,000			17,000
New Jersey sites	6		65			71
New York sites	5,100	110	11,000			16,000
Other sites	690					690
Oak Ridge Laboratories and Production Facilities						
K-25 Site	26,000					26,000
Oak Ridge National Laboratory	11,000	1,200			270	12,000
Oak Ridge Reservation (off-site)[j]						0
Paducah Gaseous Diffusion Plant		13,000				13,000
Portsmouth Gaseous Diffusion Plant	34,000					34,000
Y-12 Plant	160	530				690
Savannah River Site	40	670				710
Weldon Spring Site Remedial Action Project			120,000	1,300		120,000
Eastern Area total	180,000	100,000	150,000	1,300	270	430,000
Grand total	2,600,000	340,000	260,000	1,300	540	3,200,000

Table 6.2 (continued)

[a]Estimated as of September 30, 1993. Includes contaminated metal, concrete, brick, wood, and other similar materials. Blank entries mean there are no radioactively contaminated debris for the indicated waste class.

[b]These volume estimates represent the quantity of in-place contaminated materials; the waste volumes resulting from remedial action activities may be larger or smaller depending on the selected remedy and treatment technology utilized. Waste volumes resulting from minimal remedial actions such as capping, monitoring, and certain in situ remedies will be quite small. All values are preliminary and are being updated as site characterization activities proceed. All values are given to two significant figures unless information was reported to only one significant figure. Some totals may not equal sum of components due to independent rounding.

[c]By-product material as defined in Section 11e(2) of the Atomic Energy Act of 1954 (P.L. 83-703), as amended.

[d]All TRU wastes are considered to be mixed wastes, consistent with the DOE approach for complying with the Federal Facility Compliance Act.

[e]Contaminated debris will be managed in the same manner as contaminated soil. The volume of debris associated with remediation of the Monticello Uranium Mill Tailings Site and vicinity properties is included with the contaminated soil volume given in Table 6.1.

[f]Consists of Amchitka Island, Alaska; the Rio Blanco and Rulison Test sites in Colorado; the Gnome and Gasbuggy Test sites in New Mexico; the Salmon Test Site in Mississippi; and the Shoal and Central Nevada Test sites in Nevada.

[g]Estimated as of December 31, 1991.

[h]Contaminated debris volume is included with the contaminated soil volume given in Table 6.1.

[i]A small percentage of the radioactively contaminated debris at the Hanford Site may be TRU waste.

[j]Includes contaminated areas in the vicinity of Oak Ridge, Tennessee, beyond the boundaries of the Y-12 Plant, the K-25 Site, and Oak Ridge National Laboratory.

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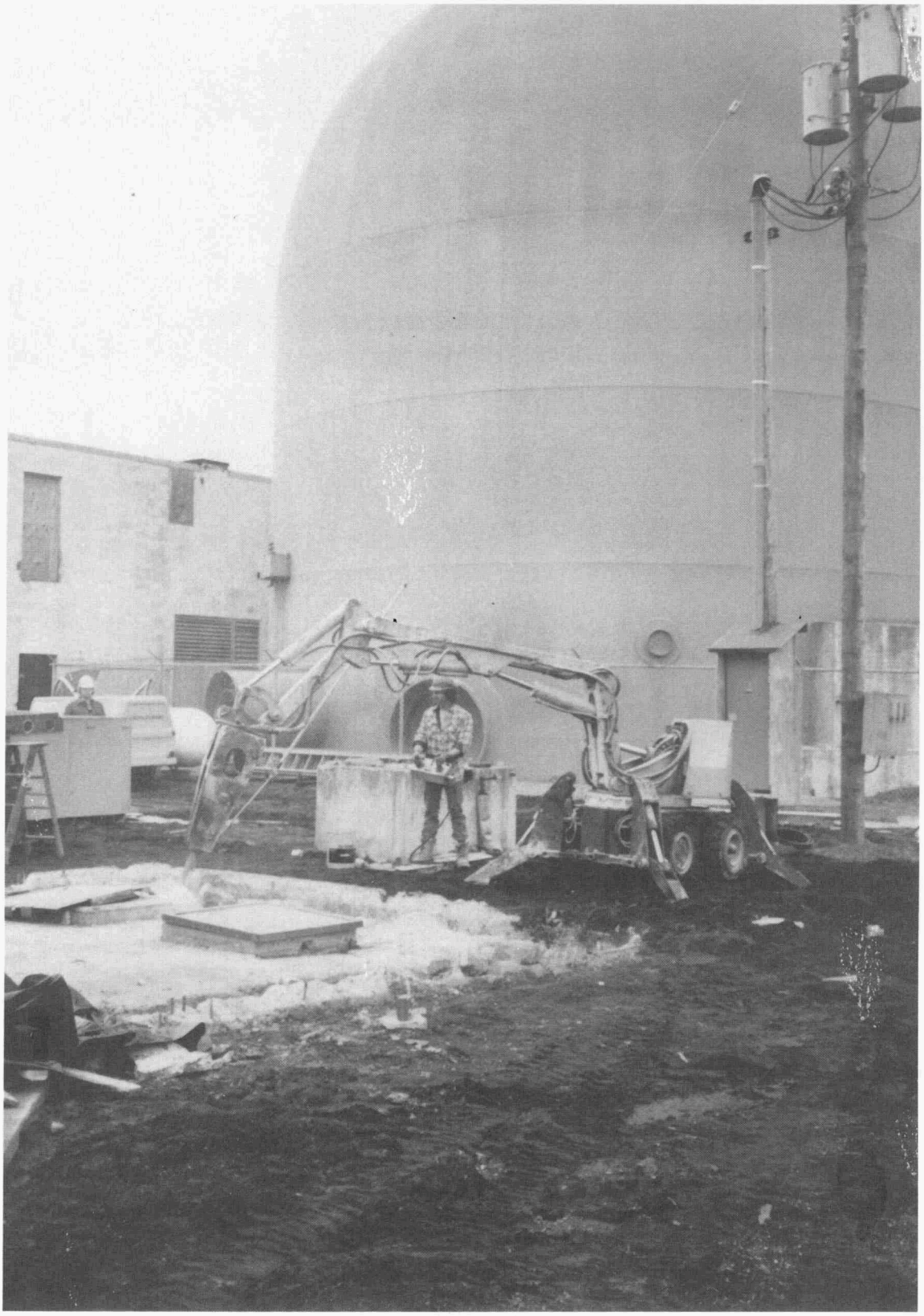

A hydraulic chisel being used in decontamination and decommissioning activities at the Saxton reactor site. (Courtesy of GPU Nuclear Corporation, Harrisburg, Pennsylvania.)

7. COMMERCIAL DECOMMISSIONING WASTES

7.1 INTRODUCTION

At the end of their useful life, commercial nuclear facilities must be shut down and decommissioned. A schedule of historical and projected commercial LWR shutdowns, based on refs. 1 and 2, is given in Table 7.1. The projected volume, radioactivity, and thermal power of various types of waste generated from future commercial power LWR decommissioning activities are reported in Table 7.2. These waste projections are in addition to those previously reported in Chapter 4 (for LLW) and in Chapter 6 (for environmental restoration activities). This approach is taken mainly because the timing associated with future decontamination and decommissioning (D&D) activities at commercial power reactor sites is uncertain. The projected waste data shown in Table 7.2 are based on the projected LWR shutdown schedule given in Table 7.1 and decommissioning waste source terms developed from refs. 3–9. These projections also assume a 4-year period for decommissioning, beginning 2 years after reactor shutdown to allow sufficient preparation time for D&D operations. It is further assumed that the D&D wastes will be sent to disposal sites in four equal volumes during the 4 years of facility decommissioning. The power reactor shutdown schedule presented in Table 7.1 is based on utility estimates of reactor lifetimes. Actual decommissioning schedules may be significantly different from those indicated in this report if any of the following are implemented:

- reactors are upgraded to extend their operating lifetimes,
- significant radioactivity decay time is allowed before decommissioning operations begin, or
- the last core of spent fuel is required to remain on site for a minimum period (possibly several years) prior to shipment.

Estimates of wastes from decommissioning reference commercial LWRs and supporting fuel cycle facilities (viz., uranium conversion, enrichment, and fuel fabrication) are given in Table 7.3 (data from refs. 3–12). Most of these estimates assume a 40-year facility-operating life. (In practice, the operating lifetime can vary significantly, depending on the extent to which facility equipment is periodically upgraded or retrofitted.) Not shown in this table are the radioactive wastes that will result from the decommissioning of research, training, and test reactors.[13,14] However, the total volumes of these wastes are not expected to be significant because such reactors are much smaller than commercial power reactors.

7.2 WASTE CHARACTERIZATION

The LWR decommissioning radioactive wastes can be grouped into three major categories:[4,7] (1) neutron-activated wastes, (2) contaminated wastes, and (3) miscellaneous radioactive wastes.

Neutron-activated materials generally include the reactor vessel and its internal components (e.g., core support assemblies and control-rod guide tubes) and the inner portion of the biological shield. Contaminated materials include much of the piping and equipment in the reactor containment, fuel-handling, and auxiliary control buildings. In addition, some of the concrete surfaces of these buildings are expected to be radioactive and will require removal. The miscellaneous radioactive waste category consists of a small, but significant, group of materials that includes both "wet" and "dry" solid wastes. Wet radioactive wastes result from the processing of chemical decontamination solutions and contaminated water. These wastes include spent ion-exchange resins, cartridge filters, and evaporator and concentrator bottoms. Dry radioactive wastes include discarded contaminated items, such as rags and wipes, tools, and protective clothing. Many reactor items with surface contamination can be decontaminated,[15] rendering most of the material nonradioactive and producing a smaller, more concentrated volume of waste containing the radioactivity. Waste decontamination requires the appropriate technology and a defined level of radioactivity which the contamination level is acceptable. Establishing such criteria is complicated because there are varying levels of natural radioactivity. Minimum regulatory levels have already been defined in Europe;[16] the EPA, which has responsibility for defining such levels in the United States, began a review of criteria in 1984. Currently, the NRC handles requests to declare a waste below regulatory concern on a case-by-case basis.

Depending on the level of technology and the minimum regulatory level definition, actual decommissioning waste volumes could vary considerably from the estimates reported in Table 7.3. However, the actual total radioactivity in the D&D waste from a particular facility is not expected to vary significantly from that projected.

A list of the larger commercial power reactors that have undergone some mode of decommissioning to date is provided in Table 7.4 (data from refs. 1 and 17). (A comprehensive listing of all types of domestic reactors that have been shut down or dismantled is given in ref. 1.) As described in ref. 18, the NRC has defined the three major alternative classifications for decommissioning of nuclear facilities:

- DECON—"... the alternative in which the equipment, structures and portions of a facility and site containing radioactive contaminants are removed or decontaminated to a level that permits the property to be released for unrestricted use shortly after cessation of operations."

- SAFSTOR—"... the alternative in which the nuclear facility is placed and maintained in such condition that the nuclear facility can be safely stored and subsequently decontaminated (deferred decontamination) to levels that permit release for unrestricted use."

- ENTOMB—"... the alternative in which radioactive contaminants are encased in a structurally long-lived material, such as concrete. The entombment structure is appropriately maintained, and continued surveillance is carried out until the radioactivity decays to a level permitting unrestricted release of the property." (This alternative would be allowable for nuclear facilities contaminated with relatively short-lived radionuclides such that all contaminants would decay to levels permissible for unrestricted use within a period on the order of 100 years.)

Decommissioning operations collect LLW plus a small volume of high-activity wastes from the internal parts of certain reactor cores. These high-activity wastes are often referred to as "high-activity activation wastes." Under NRC rules, many of these wastes would be classified as greater-than-Class C (GTCC) LLW. Some GTCC wastes contain significant concentrations of long-lived, nontransuranic radioisotopes, such as ^{59}Ni, ^{63}Ni, and ^{94}Nb. These isotopes are generated by long-term irradiation of stainless steel and some other alloys used for reactor core structural components. Because the method of waste disposal for these reactor internals is different from LLW disposal, GTCC wastes are reported separately. Under current NRC regulations,[19-20] these wastes are considered not generally acceptable for shallow-land disposal. Such wastes must be put into a federal geologic repository unless the NRC approves an alternative disposal in a licensed site. High-activity activation wastes from the immediate decommissioning of LWRs are estimated to make up less than 1% of the total waste volume, but they contain more than 95% of the radioactivity.[4,7] Such reactor wastes are comprised of many long-lived radionuclides. Most of this radioactivity is in a single reactor component, the stainless steel core shroud that surrounds the reactor fuel.

As reported in ref. 21, a study of reactor decommissioning wastes is being made by Pacific Northwest Laboratory (PNL) for the NRC. This study includes an analysis of wastes from the Shippingport Station decommissioning and an analysis of neutron-activated metal components (GTCC materials) from the internals of other reactors. Thus far, the waste characterization assessments from this study have indicated the following:

- All reactor decommissioning materials, except the pressure vessel internals, have the potential for being disposed of as Class-A LLW;
- Fission products and TRU radionuclides are absent; and
- Most radioactivity results from neutron-activation products, of which ^{60}Co is the principal contributor.

Additional updated information on the radioactive characteristics of commercial reactor D&D wastes (in particular, spent LWR control rod assemblies) will be documented in future supplements to ref. 21.

7.3 INVENTORIES AND PROJECTIONS

Of the reactors listed in Table 7.4, only three, the Elk River station, the sodium reactor experiment at Santa Susana, California, and the Shippingport station (discussed later), have been completely dismantled. A summary of the wastes from decommissioning the Elk River station is provided in Table 7.5 (data from refs. 22–24). Types and volumes of wastes from decommissioning the sodium reactor experiment are reported in Table 7.6 (data from ref. 25).

For the projections listed in Table 7.2, a 6-year period for decommissioning activities is assumed: 2 years for planning and preparation and 4 years for actual decommissioning, with wastes generated equally over the final 4 years. The option does exist, however, to delay decommissioning for 10 to 60 years after reactor shutdown to allow significant radioactive decay to occur.[18] For example, radioactivity levels in PWR piping have been estimated to decrease, in 10 years, to 8.7% and, in 30 years, to 0.63% of the radioactivity levels at the time of reactor shutdown. At PWR shutdown and for about 4 years thereafter, ^{55}Fe and ^{60}Co control the radiation levels; from 4 to about 100 years, ^{60}Co and ^{63}Ni control radiation levels; and well beyond 100 years, ^{59}Ni and ^{94}Nb control radiation levels.[7] The choice between immediate or

delayed decommissioning involves cost trade-offs between the costs of storage with delayed decommissioning versus the higher costs resulting from the higher radiation levels associated with rapid decommissioning.[26] Therefore, the start of actual decommissioning may be much later than the shutdown date to allow plant radiation levels to decay to lower levels. Another consideration is that the last core of discharged spent fuel may need to remain at the reactor site for at least 5 years prior to shipment. Table 7.7 shows the effects of various decommissioning alternatives on the volumes and radioactivities of D&D wastes from a reference BWR[3-5] and a reference PWR.[6-8] For cases involving deferred D&D activities, it is evident that both the volumes and activities of wastes significantly decline after a safe storage period of 50 years.

PNL is updating its earlier analysis of LWR decommissioning costs and waste projections (documented in refs. 3–8). This updated analysis is being performed for the NRC and will be completed early next year. Information garnered from the updated LWR D&D study will be used to develop new decommissioning waste source terms and to revise Tables 7.2 and 7.7 in future editions of this report.

Inventories and projections of wastes from three major DOE decommissioning programs are summarized in Tables 7.8, 7.9, and 7.10 (data from refs. 27–29). Table 7.8 lists waste inventory and projection data for completed decommissioning activities at the Shippingport Station Decommissioning Project, site of the first domestic commercial power reactor. The facility was shut down in 1982, and physical dismantling began in September 1985. During April 1989, the decommissioned reactor pressure vessel from the Shippingport Station was received for disposal at the Hanford Site after an 8000-mile water journey. The pressure vessel was the last major reactor component to be shipped from the facility. Shippingport decommissioning activities were completed in 1990.[27]

Table 7.9 (data from ref. 28) presents a summary of the West Valley Demonstration Project (WVDP), formerly a commercial fuel reprocessing facility. Since startup of the project in 1982, more than 70% of the cell surface areas of the original process building have been decontaminated and released for project reuse.

Inventories and projections of wastes from decontamination activities at the damaged Three Mile Island–Unit 2 (TMI–2) reactor are summarized in Table 7.10. Removal of core debris from the damaged reactor was begun in January 1986 and was completed in April 1990. This resulted in the shipment of 155.9 t of core debris to INEL for R&D testing and storage. TMI–2 is currently scheduled to have Post Defueling Monitored Storage (PDMS) preparation activities completed by the end of 1993. Implementation of PDMS activities will require NRC approval of a submitted licensing change request.[29]

Decommissioning waste projections are being compiled on several other reactors and a fuel fabrication plant. The reactors include Dresden–Unit 1, La Crosse, Saxton, Humboldt Bay–Unit 3, Rancho Seco, Fort St. Vrain, Pathfinder, Shoreham, Indian Point–Unit 1, Yankee Rowe, and San Onofre–Unit 1.

The Commonwealth Edison Company has issued a decommissioning plan and environmental report[30] for the Dresden–Unit 1 nuclear power station. Commonwealth Edison plans to decommission this reactor by first placing the facility in a SAFSTOR condition until Dresden–Units 2 and 3 are ready for decommissioning. If an extended-life program for Units 2 and 3 is not initiated, all three Dresden units will be decommissioned by dismantling, beginning in 2017. A summary of projected radioactive materials from the SAFSTOR decommissioning of the Dresden–Unit 1 station is given in Table 7.11 (data from refs. 30 and 31).

The La Crosse BWR was shut down in 1987 and placed in SAFSTOR in 1988. Current plans are to dismantle the reactor after a SAFSTOR period of 25 years. Projected volumes and associated activities of annual waste shipments from this reactor during this period are given in Table 7.12 (data from ref. 32).

The Saxton Nuclear Experimental Reactor is a 3-MW(e) PWR that was placed in SAFSTOR following its shutdown in 1972. Work on dismantling the reactor site (DECON) started in 1986. To date, decontamination of the control room and radwaste building has been completed. The reactor containment building is not scheduled for dismantling until the mid-1990s. A summary of projected waste characteristics from dismantling the Saxton site is provided in Table 7.13 (data from ref. 33).

Projections of wastes from decommissioning the 65-MW(e) Humboldt Bay–Unit 3 BWR are reported in Table 7.14 (data from ref. 34). Projections for the Humboldt Bay BWR include wastes from completely dismantling the reactor following a SAFSTOR period of 30 years (i.e., SAFSTOR with delayed DECON).

The Rancho Seco reactor is a 918-MW(e) PWR that was shut down in 1989. Table 7.15 (data from ref. 35) lists projected volumes of wastes from the dismantlement of this reactor following a SAFSTOR period of about 20 years.

In August 1989, the 330-MW(e) Fort St. Vrain HTGR was shut down to replace an inoperable control rod. During this forced outage, stress cracking of the feed-water ring headers to the steam generators was noted and thus resulted in a decision to permanently cease reactor operations. The DECON option was selected as the mode of decommissioning. During 1991 and 1992, early dismantling of certain systems and components and defueling of the reactor were performed pending issuance of the decommissioning order. In August 1992, a team headed by Westinghouse was selected to perform decommissioning and assume early dismantlement responsibilities. Later that year, the NRC issued the Fort St. Vrain Decommissioning Order, which became effective on December 7, 1992. Projections of wastes from

DECON of the Fort St. Vrain reactor are reported in Table 7.16 (data from refs. 36 and 37). Actual inventories of wastes disposed from D&D activities through 1992 are reported in Table 7.17 (data from ref. 38).

The 40-MW(e) Peach Bottom–Unit 1 HTGR was shut down in 1974 and placed in SAFSTOR. To put the reactor in this mode of decommissioning, 490 containers of solid radioactive waste were packaged and shipped. This solid waste represented a total volume of nearly 400 m^3 and an activity level of 380 Ci. In addition, about 1.14 m^3 (300 gal) of liquid waste, consisting of contaminated oil, were processed or solidified.[39]

The 66-MW(e) Pathfinder BWR was placed in the SAFSTOR mode following its shutdown in 1967. Work on dismantling the reactor (DECON) began in July 1990. The scope of this phase of decommissioning includes the reactor building, the fuel-handling building, the fuel transfer tube and vault, and the surrounding areas. By May 1991, most of the piping, pumps, tanks, wiring, ventilation, and miscellaneous systems were removed and disposed of. The reactor vessel was lifted out of containment in May 1991. Later that year, the decommissioning team shipped the vessel via rail to a commercial LLW disposal site near Richland, Washington. Upon completion of this phase of decommissioning, only trace amounts of residual contamination will remain in the operating, converted fossil plant. Waste inventories and projections from D&D activities at the Pathfinder reactor site are given in Table 7.18 (data from ref. 40).

The 820-MW(e) Shoreham BWR underwent low-power tests until 1989, when the plant's owner, Long Island Lighting Company, agreed to sell the plant to the state of New York for decommissioning. A proposed decommissioning plan (ref. 41) for the Shoreham plant was reviewed and approved by the NRC (ref. 42). Prompt decontamination and dismantling (DECON) of the Shoreham plant began in 1992, and they are proceeding. Projections of wastes from decommissioning the Shoreham BWR are reported in Table 7.19 (information based on ref. 43).

Table 7.20 (data from ref. 44) reports projections of wastes from decommissioning the Indian Point–Unit 1 reactor. This 265-MW(e) PWR was shut down in 1974 and later placed in SAFSTOR. The projections of Table 7.20 pertain to a case of complete dismantlement (DECON) of the Unit 1 station upon completion of its SAFSTOR phase, which will occur when the Unit 2 (PWR) station is finally shut down.

The 167-MW(e) Yankee Rowe PWR was shut down in 1992, and projections of wastes from its decommissioning are reported in Table 7.21 (data from ref. 45). These projections are reported for two major phases of project decommissioning: component removal (1993–1994), which includes the reactor core components and steam generator; and balance of decommissioning (1999–2002), which includes the remainder of the reactor's components and general plant inventories.[45]

Projections of wastes from decommissioning the recently shut down San Onofre–Unit 1 PWR are reported in Table 7.22 (data from ref. 46). These projections are reported for a case involving SAFSTOR.

Inventories and projections of wastes from decommissioning activities at the Cimarron (Oklahoma) Fuel Fabrication Facility are provided in Table 7.23 (data from ref. 47). During 1992, 46 shipments of low-specific-activity (LSA) waste were made from the Cimarron Facility to Barnwell, South Carolina. These shipments totaled about 488 m^3 in volume and 0.23 Ci of activity. Decontamination work at this fabrication plant is scheduled to be completed during 1993.

Currently, the total impact of wastes from D&D activities at commercial reactor and fuel cycle sites has been small. However, the impact will become more significant after the year 2000, when more of the older reactors complete their campaign of operation.

In addition to wastes from the decommissioning of commercial reactor and fuel cycle facilities, some other wastes will result from U.S. Department of Defense (DOD) power plant decommissioning operations. During a period spanning 20 to 30 years, about 100 nuclear-powered submarines of the U.S. Navy may be removed from service and consigned to permanent disposal after removal of spent fuel. Current plans are to dispose of the submarine reactor compartments by land burial at the Hanford Site. Each reactor compartment contains about 1000 t of metal, and it is estimated that 100 reactor compartments can be buried on 4 ha (10 acres) of land.[48] As of the end of 1992, 56 submarines had been taken out of active service. In 28 of these submarines, the reactor compartment was first defueled, then later removed, and disposed of at Hanford. (LLW disposed from these activities is included in the DOE site inventories reported in Chapter 4.) The remaining 28 submarines with reactor compartments were being held in protective storage.[1]

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Table 7.1. Schedule of actual and projected final shutdown dates for commercial light-water reactors[a,b]

Calendar year of shutdown	BWR		PWR		Total LWR	
	No.	MW(e)	No.	MW(e)	No.	MW(e)
1963	1	5			1	5
1967	1	66	1	17	2	83
1968	2	39			2	39
1972			1	3	1	3
1974			1	265	1	265
1976	1	65			1	65
1978	1	200			1	200
1979			1	926[c]	1	926
1982			1	72	1	72
1987	1	48			1	48
1989	1	820	1	918	2	1,738
1991			1	167	1	167
1992			2	1,566	2	1,566
Actual totals through 1992	8	1,243	9	3,934	17	5,177
2000	1	67			1	67
2004	1	610			1	610
2005	1	605			1	605
2007			3	1,892	3	1,892
2008	2	2,086	2	1,346	4	3,432
2009			1	470	1	470
2010	3	1,956	2	1,178	5	3,134
2011			1	755	1	755
2012	2	1,159	1	781	3	1,940
2013	4	3,376	9	7,596	13	10,972
2014	5	3,856	8	6,377	13	10,233
2015	1	800	2	1,843	3	2,643
2016	2	1,832	5	4,400	7	6,232
2017			2	1,872	2	1,872
2018	1	762	2	1,769	3	2,531
2020			3	3,137	3	3,137
2021			3	3,075	3	3,075
2022	2	2,183			2	2,183
2023	1	1,100	2	1,968	3	3,068
2024	4	4,195	3	3,470	7	7,665
2025	2	1,996	6	6,860	8	8,856
2026	4	4,210	4	3,909	8	8,119
2027			4	4,745	4	4,745
2028			3	3,430	3	3,430
2029	1	1,055	1	1,103	2	2,158
2030			4	4,620	4	4,620
Projected totals (1993-2030)	37	31,848	71	66,596	108	98,444

[a]Data from refs. 1 and 2. Historical data (prior to 1993) are based on ref. 1. Projected shutdown dates are based on utility-projected dates for reactor retirement reported in Table 4 of ref. 2.

[b]Years in which no reactor shutdown is expected are eliminated.

[c]Shutdown of Three Mile Island-Unit 2 nuclear power plant due to an accident. Upon completion of the present cleanup campaign, the plant will be placed in a monitored storage mode and will be decommissioned when TMI-Unit 1 is dismantled.

Table 7.2. Projections of cumulative volume, radioactivity, and thermal power of wastes from decommissioning commercial light-water reactors shut down during 1993-2030[a,b,c]

Waste type	Volume (m^3)	Activity (Ci)	Thermal power (W)
Boiling-water reactors			
Class-A LLW	510,450	42,970	327
Class-B LLW	10,282	133,525	1,024
Class-C LLW	1,460	443,816	1,634
Subtotals	522,192	620,311	2,985
Greater-than-Class-C LLW[d]	273	4,466,342	27,350
Totals for D&D of BWRs	522,465	5,086,653	30,335
Pressurized-water reactors			
Class-A LLW	1,017,984	221,865	1,145
Class-B LLW	12,128	299,606	2,593
Class-C LLW	964	252,429	1,887
Subtotals	1,031,076	773,900	5,625
Greater-than-Class-C LLW[d]	258	45,587,422	267,112
Totals for D&D of PWRs	1,031,334	46,361,322	272,737
Total light-water reactors			
Total LLW	1,553,268	1,394,211	8,610
Greater-than-Class-C LLW	531	50,053,764	294,462
Totals for D&D of LWRs	1,553,799	51,447,975	303,072

[a]The projections of this table are based on a decommissioning scenario which assumes that upon reactor shutdown, there will be a 2-year planning period followed by a 4-year decontamination campaign, with wastes being collected equally over each of the 4 years. In terms of numerical significance, the number of digits used to report these projections are greater than justified. However, this procedure is used for bookkeeping purposes to ensure consistency in the numerical totals reported. Since these projections are based on the reactor shutdown dates reported in ref. 1 and the source terms developed from refs. 3-9 (see Appendix C), each reported number is significant to no more than three figures.

[b]This table refers only to reactors yet to be decommissioned. Historical reactor D&D wastes are included in the institutional/industrial (I/I) waste inventories reported in Chapter 4.

[c]The projections reported for volume, activity, and thermal power are the cumulative levels of wastes from reactor D&D activities during the period 1993-2036. For the scenario described in footnote a, the year 2036 is the last year in which wastes are collected from reactors shut down in the year 2030.

[d]Contribution from the core shroud (see ref. 9).

Table 7.3. Projections of radioactive wastes from decommissioning reference commercial power reactors and fuel cycle facilities[a]

Fuel cycle facility	Capacity	Operation		Decommissioning alternative	Waste volume, m^3	
		Period	Lifetime (years)		LLW[b]	GTCC[c]
Boiling-water reactor	1,155 MW(e)		40[d]	DECON	18,938	10[e]
Pressurized-water reactor	1,175 MW(e)		40[d]	DECON	18,192	5[e]
Uranium conversion plant (solvent extraction process)	10,000 MTIHM/year		40	DECON	1,260	0
Uranium enrichment plants (gaseous diffusion plants)						
• K-25 site	7,700,000 kg SWU/year	1945-1985	40	DECON	910,112	0
• Paducah site	11,300,000 kg SWU/year	1954-2005	51	DECON	662,414	0
• Portsmouth site	8,300,000 kg SWU/year	1956-2005	49	DECON	630,093	0
Fuel fabrication plant	1,000 MTIHM/year		40	DECON	1,090	0

[a]Based on information reported in refs. 3-12.
[b]Class-A, Class-B, and Class-C LLW.
[c]Greater-than-Class-C LLW.
[d]Reactor operations assume a 75%-capacity factor.
[e]Assumes contributions only from the core shroud. Estimated from information provided in the report DOE/LLW-114 (ref. 9).

Table 7.4. List of U.S. civilian reactors shut down or dismantled as of December 31, 1992[a]

[Reactors of 10-MW(th) capacity or greater]

Reactor facility	Location	Reactor type	Capacity rating		Year of shutdown	Decommissioning alternative selected	Present status of decommissioning alternative
			MW(e)	MW(th)			
Boiling Nuclear Superheater Power Station (BONUS)	Punta Higuera, PR	Boiling-water	17	50	1968	ENTOMB	ENTOMB
Carolinas-Virginia Tube Reactor (CVTR)	Parr, SC	Pressure-tube, heavy-water	17	64	1967	SAFSTOR	SAFSTOR
Dresden Nuclear Power Station—Unit 1	Morris, IL	Boiling-water	200	700	1978	SAFSTOR	SAFSTOR preparation[b]
Elk River Power Station	Elk River, MN	Boiling-water	22	58	1968	DECON	DECON completed[c]
Enrico Fermi—Unit 1	Lagoona Beach, MI	Sodium-cooled, fast	61	200	1972	SAFSTOR	SAFSTOR
ESADA/GE Vallecitos Experimental Superheat Reactor (Empire States Atomic Development Associates and General Electric Company)	Pleasanton, CA	Light-water, moderated	NE[d]	17	1967	SAFSTOR	SAFSTOR
Fort St. Vrain Reactor	Platteville, CO	High-temperature, gas-cooled	330	842	1989	DECON	DECON in progess[e]
General Electric Testing Reactor	Pleasanton, CA	Tank	NE	50	1977	SAFSTOR	SAFSTOR
Hallam Nuclear Power Facility	Hallam, NE	Sodium-cooled, graphite-moderated	75	240	1964	ENTOMB	ENTOMB
Humboldt Bay Power Plant—Unit 3	Eureka, CA	Boiling-water	65	242	1976	SAFSTOR	SAFSTOR[f]
Indian Point Station—Unit 1	Buchanan, NY	Pressurized-water	265	615	1974	SAFSTOR[g]	SAFSTOR
La Crosse Nuclear Generating Station	Genoa, WI	Boiling-water	48	165	1987	SAFSTOR	SAFSTOR[h]
Pathfinder Atomic Plant	Sioux Falls, SD	Boiling-water	66	192	1967	DECON	DECON[i]
Peach Bottom Power Station—Unit 1	Peach Bottom, PA	High-temperature, gas-cooled	40	115	1974	SAFSTOR	SAFSTOR

Table 7.4 (continued)

Reactor facility	Location	Reactor type	Capacity rating MW(e)	Capacity rating MW(th)	Year of shutdown	Decommissioning alternative selected	Present status of decommissioning alternative
Piqua Nuclear Power Facility	Piqua, OH	Organic-cooled and moderated	11	46	1966	ENTOMB	ENTOMB
Plum Brook Reactor	Sandusky, OH	Tank	NE	60	1974	SAFSTOR	SAFSTOR
Rancho Seco	Clay Station, CA	Pressurized-water	918	2,915	1989	SAFSTOR	SAFSTOR preparation[j]
San Onofre-Unit 1	San Clemente, CA	Pressurized-water	436	1,347	1992	SAFSTOR	SAFSTOR preparation[k]
Saxton Nuclear Experimental Reactor Project	Saxton, PA	Pressurized-water	3	24	1972	SAFSTOR	DECON in progress[l]
Shippingport Power Station	Shippingport, PA	Pressurized-water	72	236	1982	DECON	DECON completed[m]
Shoreham Reactor	Brookhaven, NY	Boiling-water	820	2,436	1989	DECON	DECON in progress[n]
Sodium Reactor Experiment	Santa Susana, CA	Sodium-cooled, graphite-moderated	10	30	1964	DECON	DECON completed[o]
Southwest Experimental Fast Oxide Reactor (SEFOR)	Strickler, AR	Sodium-cooled, fast	NE	20	1972	SAFSTOR	SAFSTOR
Three Mile Island-Unit 2 Reactor	Londonderry Township, PA	Pressurized-water	926	2,770	1979	p	p
Trojan-Unit 1	Prescott, OR	Pressurized-water	1,130	3,411	1992	TBD	TBD
Vallecitos Boiling-Water Reactor (VBWR)	Pleasanton, CA	Boiling-water	5	33	1963	SAFSTOR	SAFSTOR
Westinghouse Testing Reactor (WTR)	Waltz Mill, PA	Tank	NE	60	1962	SAFSTOR	SAFSTOR
Yankee Rowe-Unit 1	Rowe, MA	Pressurized-water	167	600	1991	SAFSTOR	SAFSTOR preparation

[a]Based on refs. 1 and 17.
[b]Estimates of decommissioning wastes are reported in Table 7.11.
[c]Decommissioning wastes are reported in Table 7.5.
[d]NE = no electricity generated by reactor before it was shut down.
[e]Estimates of decommissioning wastes are reported in Table 7.16. Actual inventories are reported in Table 7.17.
[f]Estimates of decommissioning wastes are reported in Table 7.14.
[g]Estimates of decommissioning wastes are reported in Table 7.20.
[h]Estimates of decommissioning wastes are reported in Table 7.12.

Table 7.4 (continued)

[i]Estimates of decommissioning wastes are reported in Table 7.18.
[j]Decommissioning wastes are reported in Table 7.15.
[k]Decommissioning wastes are reported in Table 7.22.
[l]DECON of the Saxton facility started in 1986. Estimates of decommissioning wastes are given in Table 7.13.
[m]Decommissioning wastes are reported in Table 7.8.
[n]DECON of the Shoreham plant started in 1992. Estimates of decommissioning wastes are reported in Table 7.19.
[o]Decommissioning wastes are reported in Table 7.6.
[p]TMI-Unit 2 has completed defueling and decontamination in selected areas. The plant will be placed in a long-term monitored storage mode and will be decommissioned when TMI-Unit 1 is dismantled. Inventories of decontamination wastes are reported in Table 7.10.

Table 7.5. Types and quantities of wastes from decommissioning the Elk River reactor site[a,b]

Reactor component or waste type[c]	Volume (m^3)	Mass (t)	Radioactivity[d] (Ci)
Reactor pressure vessel	4.6	36.0	1,110
Reactor internals			
Upper shroud	e	e	770
Lower shroud	e	e	35
Core and shroud plate	e	e	2,370
Core support stand	e	e	100
Inner thermal shield	e	e	3,090
Shadow shields	e	e	2,330
Feedwater distribution ring	e	e	75
Subtotals (internals)	1.1	8.1	8,770
Externals	5.3	54.0	440[f]
Biological shield	5.9	39.0	5.8
Miscellaneous radioactive contaminated materials (excluding concrete)	1,350	1,090	e
Contaminated concrete	2,010	2,680	e
Totals	3,377	3,907	>10,325

[a]Based on information reported in COO-651-93 (ref. 22), BNL-NUREG-29244R (ref. 23), and ref. 24.

[b]The Elk River BWR operated from 1963 to 1968 and generated 58.29 MW(e)-years of (gross) electrical energy. The plant was decommissioned from 1971 to 1974. During this time, the reactor was completely dismantled.

[c]All decommissioning wastes were shipped to Sheffield, Illinois.

[d]Estimated at the start of decommissioning.

[e]Information not available.

[f]Includes 75 Ci estimated for the outer thermal shield of the reactor.

Table 7.6. Types and volumes of wastes from decommissioning the Santa Susana Sodium Reactor Experiment site[a,b]

Type of waste[c]	Shipping container volume, m^3					
	King-Pac[d]	Boxes[e]	Casks	Drums	Unboxed	Totals
Activated vessel components		301	20		18	339
Contaminated components		1,458	49	29	17	1,553
Contaminated soil and concrete	1,752			42		1,794
Absorbed alcohol and other solidified liquids				141		141
Disposed liquid				36		36
Totals	1,752	1,759	69	248	35	3,863

[a]Based on information reported in ESG-DOE-13403 (ref. 25). Activity data were not available.

[b]This sodium-cooled, graphite-moderated reactor operated from 1957 to 1964 and generated 4.244 MW(e)-years of (gross) electrical energy. The plant was decommissioned from 1974 to 1983. During this time, the reactor was completely dismantled.

[c]Initially, these wastes were shipped to Beatty, Nevada. Later in the decommissioning program, shipments were made to Hanford, Washington.

[d]This is a registered trademark for tri-walled cardboard containers used for packaging low-specific-activity nonmetallic wastes (e.g., contaminated soil, bedrock, and concrete rubble).

[e]Wooden boxes used for packaging low-specific-activity wood or steel.

Table 7.7. Estimated volumes and activities of wastes from decommissioning alternatives considered for reference LWRs[a,b,c]

Decommissioning alternative	Totals		Class-A LLW		Class-B LLW		Class-C LLW	
	Volume (m^3)	Activity (10^3 Ci)	Volume (m^3)	Activity (10^3 Ci)	Volume (m^3)	Activity (10^3 Ci)	Volume (m^3)	Activity (10^3 Ci)
Reference boiling-water reactor [1,155 MW(e)]								
Immediate decontamination following shutdown	18,938	295.8	18,512	13.9	373	42.8	53	239.1
Deferred decontamination after a safe storage period of:								
30 years[d]	18,938	9.0	18,652	1.4	233	1.1	53	6.5
50 years[d]	1,736	5.9	1,450	0.2	247	1.0	39	4.7
100 years[d]	1,626	4.0	1,340	0.1	247	0.6	39	3.3
Entombment[e]	8,031	286.6	7,605	4.7	373	42.8	53	239.1
Reference pressurized-water reactor [1,175 MW(e)]								
Immediate decontamination following shutdown	18,192	124.7	17,961	37.3	214	53.1	17	34.3
Deferred decontamination after a safe storage period of:								
30 years[d]	18,195	3.6	18,055	1.5	123	0.6	17	1.5
50 years[d]	1,700	1.6	1,568	0.3	115	0.2	17	1.1
100 years[d]	1,650	1.0	1,533	0.2	100	<0.1	17	0.8
Entombment[e]	3,367	126.5	3,136	39.1	214	53.1	17	34.3

[a]From refs. 3-8. Activities were calculated from data reported in refs. 3-8. Data for each reactor are based on 40 years of operation and a capacity factor of 0.75.

[b]Based on the limiting concentrations of long- and short-lived radionuclides given in Tables 1 and 2 of 10 CFR 61.55.

[c]Estimates for GTCC wastes from LWR decommissioning (DECON) were recently developed by EG&G Idaho, Inc. and are reported in ref. 9. A summary of all GTCC wastes estimated in ref. 9 for LWR operations and decommissioning activities is presented in Chapter 4.

[d]Includes radioactive wastes from both preparations for safe storage and deferred decontamination.

[e]Involves the removal of reactor spent fuel (shipped to repository) followed by the encasement of the rest of the radioactive portion of the reactor facility.

Table 7.8. Characteristics of wastes from decommissioning activities at the Shippingport Station Decommissioning Project[a,b]

Type of waste	Total waste removed from the Shippingport reactor facility		
	Volume (m^3)	Mass (kg)	Activity (Ci)
Liquid	2,187	c	0.64
Solid[d]			
Reactor pressure vessel package	283	815,560	16,467
Spent resins	101	56,429	40.82
Asbestos	1,072	138,205	2.49
Compacted trash	24	12,412	0.04
Metallic waste	1,801	1,117,113	41.59
Large, one-piece components	326	455,230	24.27
Concrete	52	52,470	0.08
Lead	57	62,302	0.17
Soil	53	31,493	1.44
Solidified sludge	164	198,066	4.30
Other solids	2,123	833,976	26.54
Total solid waste	6,056	3,773,256	16,608.75

[a]Based on ref. 27.

[b]The Shippingport reactor operated from 1957 to 1982, generating 841.8 MW(e)-years of (gross) electrical energy. During its history, the reactor operated with three different cores. Two of these were light-water cooled, seed-blanket, PWR-type cores. The third and last core in the reactor was a seed-blanket LWBR-type. Physical dismantling began in September 1985 and was completed in July 1989.

[c]Information not available.

[d]Solid waste volume and mass include total volume and total mass as packaged.

Table 7.9. Inventories and projections of wastes from various activities at the West Valley Demonstration Project[a,b]

Waste description	Total wastes as of December 31, 1992	Projected total wastes upon completion of the project[c]
Spent fuel remaining[d]		
Mass, MTIHM	27	27
Number of fuel assemblies	125	125
High-level waste generated from reprocessing operations (1966-1972)[e]		
Volume, m^3 (waste form)	1,231 (liquid, sludge, and zeolite)	210 (glass)
Activity, Ci[f]	27,250,000	23,590,000[g]
Transuranic waste generated from presolidification activities and HLW vitrification[h]		
Volume, m^3	43	300
Activity, Ci[f]	54	350
Low-level waste generated from presolidification activities and HLW vitrification		
Buried waste (1982-86) volume, m^3	5,786	15,000
Buried waste (1982-86) activity, Ci[f]	625	58,600
Stored waste volume, m^3	13,290	
Stored waste activity, Ci[f]	i	
Low-level waste incorporated in cement by radwaste treatment system[j]		
Stored waste volume, m^3	3,417	5,560
Stored waste activity, Ci[f]	336	547
Low-level waste from postsolidification D&D after HLW vitrification		
Volume, m^3	0	4,300
Activity, Ci[f]	0	1,400
Total low-level summary (buried and stored wastes)		
Volume, m^3	22,493	
Activity, Ci[f]	>961	

[a]Based on data reported in ref. 28.

[b]At the West Valley Demonstration Project (WVDP) site, Nuclear Fuel Services, Inc., operated a reprocessing plant with a rated capacity of 300 MTIHM/year. During its operation from 1966 to 1972, 640 t of spent fuel were reprocessed.

[c]Wastes generated after 1987 are regarded as stored, not buried or disposed.

[d]At the end of 1992, 125 fuel assemblies (representing 27 t of spent fuel) still remained in storage at the WVDP. These assemblies are owned by DOE. The return shipment of all commercially owned spent fuel (625 fuel assemblies) to the owner utilities was completed by the end of 1986.

[e]Currently, about 2,031 m^3 of HLW is stored at the WVDP site in two underground steel tanks. Eventually, this waste will be vitrified and about 300 canisters of glass will be produced. This assumes each canister contains 0.70 m^3 of glass.

[f]Principal nuclides include ^{241}Am, ^{241}Pu, ^{137}Cs, ^{99}Tc, ^{90}Sr, and ^{63}Ni.

[g]Decayed activity for 1997.

[h]Excludes remote-handled TRU waste.

[i]Information currently unavailable. This information will be updated in future updates of this report to include estimated total activity for containerized wastes after they become characterized.

[j]Comprised of Class A and Class C LLW. See Table C.10 of Appendix C.

Table 7.10. Characteristics of wastes from decontamination activities at the Three Mile Island-Unit 2 reactor site[a,b]

Type of waste	Mass shipped (t)	Total waste shipped from TMI (August 1979 through December 1992)	
		Packaged volume (m^3)	Shipment activity[c] (Ci)
Spent fuel/core debris[d]	155.9	123.9	6,911,513
Low-level and other wastes[e]			
Dry activated waste (DAW)[f]		6,894.7	718.7
Wet and solidified waste[g]		312.6	7,464.2
Submerged demineralizer system (SDS)[h]		58.2	673,877.7
EPICOR II system liners[i]			
First generation		125.7	77,750
Second generation		947.3	5,066.9
Defueling water cleanup system (DWCS)[j]		8.45	5,886.3
Off-site deconable scrap		138.9	4
Totals	155.9	8,609.75	7,582,280.8

[a]Three Mile Island (TMI)-Unit 2 is a PWR reactor with the following characteristics: rated capacity-926 MW(e); mass of fuel in core before accident-82 MTIHM; and number of fuel assemblies before accident-177. The reactor began operation in 1978 and generated 231.6 MW(e)-years of (gross) electrical energy before being permanently shut down by an accident in March 1979.

[b]Based on information reported in ref. 29.

[c]These activities represent the cumulative sum of curies reported at the time of waste shipment. The values reported are not corrected for decay after the time of shipment.

[d]Defueling of the reactor started in January 1986. Fuel-debris shipments were completed in April 1990.

[e]Other wastes include those regarded as "abnormal" because their classification is presently uncertain.

[f]Dry activated wastes are dry wastes packaged in drums, boxes, and high-integrity containers.

[g]Includes solidified miscellaneous liquids and miscellaneous resin liners and filters from TMI-Unit 2 systems.

[h]Resin liners and filters from the SDS (for water treatment).

[i]Resin liners and filters from the EPICOR II system that use organic ion-exchange resins and inorganic zeolite media. These include processing high-integrity containers (HICs). The EPICOR II system is a special type of filtering system used at the TMI-Unit 2 site in the final stages of decontaminating large volumes of contaminated water.

[j]Resin liners and filters from the DWCS that use inorganic zeolite media. These are primarily processing HICs.

Table 7.11. Projected characteristics of radioactive wastes from Dresden-Unit 1 decommissioning activities[a,b,c]

Waste category	Reactor component(s)	Volume (m^3)
Radioactive materials	Reactor vessel and internals:[d]	
	Reactor vessel	11
	Bioshield sand and concrete	239
	Thermal shield	2
	Instrumentation support tubes	1
	Bottom core support structure	1
	Other[e]	5
	Subtotal	259
	Solidified decontamination solvents	655
	Reactor station components and materials[f]	6,214
	Total	7,128
Radioactive hazardous materials	Asbestos insulation on contaminated piping and components	409
	Grand total	7,537

[a]Based on refs. 30 and 31.

[b]The 200-MW(e) Dresden BWR began operation in 1960 and generated about 1,800 MW(e)-years of (gross) electrical energy before it was shut down in 1978. The projections of this table pertain to wastes from the dismantlement of the reactor following a SAFSTOR period of about 30 years.

[c]These projections do not include 32 m^3 of LLW from SAFSTOR preparation activities (e.g., materials from cleaning spent fuel pool surfaces, miscellaneous sumps, and other contaminated areas; filters from chemical cleaning system; and miscellaneous dry active trash).

[d]The greatest source of radioactivity in the Dresden containment building is in the reactor vessel and internals. This activity results from neutron activation products in the vessel and shield materials. Reference 28 reports an estimated activity of 4,029,000 Ci for the vessel and internals when the reactor was shut down in 1978. By the year 2017, when dismantling of the reactor is to begin, this activity is projected to drop to a level of about 16,000 Ci.

[e]Other reactor internal components include steam deflector support, top grid assembly, bottom support grid, control rod guide tubes, and reactor vessel cladding.

[f]Reactor station components and materials include piping, valves, pumps, heat exchangers, building concrete, and structural steel.

Table 7.12. Inventories and projections of low-level radioactive wastes from La Crosse BWR decommissioning activities[a,b]

Calendar year(s)	Decommissioning mode	Average annual quantity of waste shipped to burial site[c,d]	
		Volume (m^3/year)	Activity (Ci/year)
1988	SAFSTOR	4.62	70.3
1989[e]	SAFSTOR	6.74	32.12
1990[e]	SAFSTOR	4.59	0.74
1991[e]	SAFSTOR	5.46	0.32
1992[e]	SAFSTOR	3.72	0.44
Totals (through 1992)	SAFSTOR	25.13	103.92[f]
1993	SAFSTOR	5.0	0.4
1994	SAFSTOR	5.0	0.4
1995-1998	SAFSTOR	0.0	0.0
1999-2003	SAFSTOR	6.5	13
2004-2008	SAFSTOR	4.9	7
2009-2013	SAFSTOR	3.6	5
2014-2018	DECON	103.0	>280
Projected totals (1993-2018)	SAFSTOR/DECON	600.0	>1,525.8[f]
Historical and projected totals (1988-2018)	SAFSTOR/DECON	625.1	1,629.7[f]

[a]Based on the information reported in ref. 32.

[b]The 48-MW(e) La Crosse BWR began operation in 1968 and generated 462 MW(e)-years of (gross) electrical energy until it was shut down in April 1987. The reactor was placed in SAFSTOR in 1988. The data in this table are based on a SAFSTOR period of 25 years.

[c]During the SAFSTOR period, the principal types of radioactive solid waste which will be processed and shipped to a suitable disposal facility will be low-level radioactive wastes principally with radioactivity content less than Class C (10 CFR 61) wastes. These wastes will include (1) dry active wastes (DAW), normally Class A, unstable; (2) dewatered spent demineralizer resins and filtration media, normally Class A or B, stable; and (3) contaminated or irradiated plant system components, normally Class B or C, stable.

[d]Contributions from activated core components and structural materials are not included. Volume estimates of these materials are currently not available; however, a preliminary activity estimate of 12,620 Ci has been made for these activated materials for year 2014, when the reactor will be ready for dismantlement.

[e]Volume of waste for this year reflects significant reductions due to treatment. Waste shipments for this year contained DAW and contaminated metal, which were either decontaminated, supercompacted, or both by two Oak Ridge waste treatment companies (Quadrex Recycle Center and SEG).

[f]Undecayed activity.

Table 7.13. Projected volumes of wastes from Saxton PWR decommissioning activities[a,b,c]

Reactor component(s)/waste	Volume (m^3)
Reactor vessel, head, and internals	39.64
Pressurizer	3.12
Primary coolant pump	2.83
Steam generator	24.07
Demineralizers	4.25
Shutdown cooling pumps	0.85
Relief valve discharge tank	4.25
Purification system surge tank	9.91
Safety injection pumps	1.42
Cooling heat exchanger	16.99
Containment vessel sump pumps	0.85
Discharge tank drain pumps	0.85
Containment ventilation equipment	16.99
Primary piping	5.66
Auxiliary system piping and valves	28.32
Contaminated and activated concrete of containment vessel	229.37
General valves, controllers, and instrumentation	42.48
Low-level waste from disposal operations	33.98
Westinghouse supercritical test loop	42.48
Total volume	508.31

[a]Based on the information reported in ref. 33.

[b]The 3-MW(e) Saxton PWR was shut down in 1972 and placed in SAFSTOR. Work on dismantling the reactor site started in 1986. This facility operated from 1962 until 1971, generating 10.4 MW(e)-years of (gross) electrical energy.

[c]Activity data are unknown at this time. Saxton reactor decommissioning waste characteristics are still being reviewed, and additional information will be provided in this table in future reports.

Table 7.14. Projected burial volumes of radioactive wastes from SAFSTOR (mothballing/delayed dismantling) of Humboldt Bay-Unit 3[a,b,c]

D&D activity/reactor component	Volume (m^3)
Spent fuel racks	63
Nuclear steam supply system removal	
Reactor vessel	71[d]
Reactor vessel internals	24[e]
Other components	17
Removal of major equipment	
Main turbine/generator	353
Main condenser	164
Disposal of contaminated plant systems	
Turbine system	425
Electrical system	153
High-pressure steam and feedwater systems	190
Condensate system	155
Radwaste collection and treatment systems	200
Other systems	248
Decontamination of site buildings	
Refueling	434
Yard piping and soil	160
Other	30
Disposal of contaminated solid waste	152
Process liquid waste[f]	63
Disposal of modified plant and off-gas systems as a result of 1986-1991 capital improvements	100
Total	3,002

[a]Based on the information reported in ref. 34.

[b]The 65-MW(e) Humboldt Bay-Unit 3 BWR operated from 1963 until 1976, generating 545 MW(e)-years of (net) electrical energy. The plant was placed in a SAFSTOR mode in 1988. The projections in this table and in ref. 34 assume delayed dismantling (DECON) of the reactor begins in 2015. At this time, the SAFSTOR period will end and the current inventory of spent fuel at the site will have been shipped to a federal repository when the latter is available.

[c]Except where noted, the volumes reported represent estimates for packaged Class A LLW.

[d]Includes 53 m^3 of Class C LLW.

[e]Includes 22 m^3 of Class C LLW and 2 m^3 of GTCC waste.

[f]Class B LLW.

Table 7.15. Projected volumes of wastes from Rancho Seco PWR decommissioning activities[a,b,c]

Reactor component(s)/waste	Volume (m^3)
Spent fuel racks	359
Reactor vessel	212
Reactor vessel internals	156
Primary system components and piping	1,336
Total for reactor vessel and components	2,063
Secondary and radwaste systems	2,625
Contaminated structures	468
Processed liquid waste	98
Dry active waste	397
Grand total	5,651

[a]Based on ref. 35 (extracted from a 1991 decommissioning cost study prepared by TLG Engineering, Inc.).

[b]The 918-MW(e) Rancho Seco-Unit 1 PWR was shut down in 1989. The reactor operated from 1974 until 1989, generating 5,277.3 MW(e)-years of (gross) electrical energy.

[c]The projections in this table pertain to wastes from dismantlement of the reactor following a SAFSTOR period of about 20 years.

Table 7.16. Projected characteristics of wastes from DECON (dismantling) of the Fort St. Vrain HTGR[a,b]

Reactor component(s)/waste	Burial volume (m^3)	Activity (Ci)	Projected LLW class
Prestressed concrete reactor vessel (PCRV) system			
PCRV concrete	1,174.94	c	A
Control rod drives (CRDs)	97.81	c	A
CRD absorber strings	18.81	c	C
CRD metal clad reflector	4.04	c	C
Boronated stainless steel rods	845.27	c	B
Top cover plates	1.59	c	A
Top head kaowool[d] and liner	13.32	c	A
Core barrel	21.97	c	A
Core support blocks	41.09	c	A
Core support floor kaowool, plates, and liner	6.94	c	A
Metal clad reflector blocks (non-CRD)	28.67	c	C
Dummy fuel blocks	168.28	c	A
Graphite reflector blocks	237.65	c	A, B
Silica insulation blocks	14.27	c	A
Large permeable reflectors	709.32	c	B
Reflector keys	0.57	c	A
Metal shell for large side reflector	0.58	c	A
Radial cover plate, kaowool, and PCRV liner	55.57	c	A
Region constraint devices	1.42	c	C
Helium purification and regeneration system	30.87	c	A
Helium circulators	4.01	c	A
Steam generators	269.02	c	A, B
PCRV system total	3,746.01	1.30E+6	
Material handling, treatment, and storage (MHTS) systems			
Fuel handling machine	63.33	c	A
Fuel storage wells	28.48	c	A
Equipment storage wells	2.98	c	A
Auxiliary transfer cask	19.52	c	A
Hot service facility	10.98	c	A
MHTS systems total	125.29	3.88E-2	
Decontamination and waste (DW) systems			
Decontamination system	9.57	c	A
Radioactive liquid waste	9.15	c	A
Radioactive gas waste	32.93	c	A
Dry activated and other wastes	153.34	c	A
DW systems total	204.99	1.33E-4	
Fort St. Vrain HTGR total	4,076.29	1.30E+6	

[a]Based on refs. 36 and 37. The case considered involves complete dismantlement of all radioactive systems at the reactor site after defueling of the reactor has been completed.

[b]The 330-MW(e) Fort St. Vrain HTGR operated from 1979 until 1989, generating about 490 MW(e)-years of (gross) electrical energy.

[c]Information is not available.

[d]Kaowool is an insulation material.

Table 7.17. Actual radioactive waste disposal from the decommissioning of the Fort St. Vrain reactor[a,b]

Year	Irradiated hardware			Dry active waste		
	No. of shipments	Volume[c] (m^3)	Activity (Ci)	No. of shipments	Volume[c] (m^3)	Activity (Ci)
1991	6	29.1	8,083.80	20	13.3	1.81
1992[d]	64	365.8	32,678.49	6	13.4	7.88
Total	70	394.9	40,762.29	26	26.7	9.69

[a]Based on ref. 38. Includes shipments made by Public Service Company of Colorado and decommissioning contractor and waste processors subsequent to volume reduction.

[b]Tracking of volume by individual components and/or system is not performed due to mixing of components from various waste streams, void spaces, etc.

[c]Actual disposal volume which therefore includes void space, filler volume, package volume, etc.

[d]Prior to December 8, 1992, preliminary dismantlement activities were performed. Decommissioning order for Fort St. Vrain became effective on December 7, 1992.

Table 7.18. Characteristics of radioactive wastes associated with decommissioning the Pathfinder reactor[a,b]

Reactor component(s)/waste	Volume[c] (m^3)	Mass (t)	Activity (Ci)
Reactor vessel[d]	113	280.5	560.92
Bioshield	78	179	0.26
Recirculation pumps and motors (3)	71	56	0.018
Contaminated concrete	50	40	0.065
Dry active waste[e]	567	635.5	0.557
Liquids	0	0	0
Asbestos	97[f]	17	0.0001
Total	976	1,208	561.82

[a]Based on ref. 40. All material is low-specific-activity LLW.

[b]The 66-MW(e) Pathfinder BWR began operation in 1964 and had generated about 140,000 MW(e)-hours of electrical energy when it was shut down in 1967.

[c]These numbers represent the volume of radioactive waste shipped to processors; the final disposal volumes have not yet been determined.

[d]Includes reactor pressure vessel, internal components, control rod drive blades, gravel, grout, and routine shipping (Type A) packaging components.

[e]Includes piping, valves, conduit, cable, sand, wire, steel, shield blocks, grating, lights, filters, plastic, paper, and wood.

[f]This is the volume of asbestos removed during D&D. Later this material was reduced in volume to 20 m^3.

Table 7.19. Projected characteristics of wastes from Shoreham BWR decommissioning activities[a,b]

(Unless otherwise indicated, all wastes are projected to be LLW Class A)

Reactor component(s)/waste	Burial volume (m^3)	Activity (Ci)
Reactor pressure vessel (RPV)	c	c
Reactor internals[d]	50.1	403
Reactor recirculation system	c	c
Control rod blades	27.8	462
Control rod drive system[e]	c	c
Residual heat removal system	c	c
Core spray system	c	c
Reactor water cleanup system	c	c
Fuel pool cleanup system	c	c
Condensate and demineralizer system	c	c
Process sampling system	c	c
Spent fuel rack and accessories	c	c
Process and dry activated wastes	c	c
Demineralizer system and resins/filters	c	c
Liquid radwaste system	c	c
Mirror insulation	c	c
Totals	93.1	865

[a]Based on ref. 43.

[b]The 820-MW(e) Shoreham BWR underwent low-power tests until 1989, when the Long Island Lighting Company agreed to sell the plant to the state of New York for decommissioning. A total of 865 MW(e)-hours of (gross) electrical energy were generated during the low power tests.

[c]All items noted have been sent to volume reduction facilities (VRFs) for processing prior to burial. As of June 1993, about 2600 m^3 have been sent to VRFs. Of this pre-processed volume, 15.2 m^3 (representing less than 0.3 Ci of activity) will be buried as waste.

[d]Includes about 0.4 m^3 (198 Ci) of incore instruments (local power range monitor tubes), which are projected to be Class B LLW.

[e]Excludes control blades and control rod drives.

Table 7.20. Projected volumes of wastes from Indian Point-Unit 1 PWR decommissioning activities[a,b]

Reactor component(s)	Container (type and number)		
	LSA boxes	Cask liners	Total
Contaminated piping, valves, equipment, and concrete	1,269	0	1,269
Spent fuel racks	9	0	9
Reactor internals	7	13	20
Reactor vessel	52	0	52
Total containers	1,337	13	1,350
External volume (m^3) of each container (box or liner)	4.694	3.341	
Total container volume (m^3)	6,275	43	6,318

[a]Based on ref. 44.

[b]The 265-MW(e) Indian Point-Unit 1 PWR began operation in 1962 and generated about 1,440 MW(e)-years of (gross) electrical energy before it was shut down in 1974. The projections in this table pertain to wastes from the dismantlement of the reactor following a SAFSTOR period of about 35 years.

Table 7.21. Projected characteristics of wastes from Yankee Rowe PWR decommissioning activities[a,b]

Reactor component	Volume (m^3)	Activity (Ci)
Component Removal Project (1993-1994)		
Reactor vessel internals	59.7	290,000
Reactor core baffle[c]	1.4	1,020,000
Steam generator	200.1	1,760
Pressurizer	19.3	5
Dry activated waste	137.6	<50
Filters	17.0	120
Drums	15.7	<80
Demineralizer resin	3.4	60
Total (1993-1994)	454.2	1,312,075
Balance of decommissioning (1999-2002)		
Reactor vessel	156.5	6,940
Main coolant pumps	26.6	20
General plant inventory	1,499.6	<500
Building inventory	178.8	<60
Spent fuel racks	240.1	<30
Drums	178.1	<50
Total (1999-2002)	2,279.7	7,600
Total (1993-2002)	2,733.9	1,319,675

[a]Based on ref. 45. The values reported in this table are preliminary and will be finalized in the decommissioning plan that will be submitted to the NRC.

[b]The 167-MW(e) Yankee Rowe-Unit 1 PWR began operation in 1960 and generated about 4,030 MW(e)-years of (gross) electrical energy before it was shut down in 1992.

[c]The reactor core baffle, the component directly adjacent to the reactor core, exceeds the Class C limits in accordance with 10 CFR 61.55 and will be handled as HLW.

Table 7.22. Projected volumes of wastes from San Onofre-Unit 1 PWR decommissioning activities[a,b]

Activity/reactor facility component or type of waste	Waste volume, m^3				
	Class A	Class B	Class C	GTCC	Total
Annual SAFSTOR maintenance					
Dry activated waste[c]	121.12				121.12
Spent fuel racks	14.39				14.39
Nuclear steam supply system (NSSS) removal					
Reactor coolant piping	86.04				86.04
Pressurizer quench tank	12.94				12.94
Reactor coolant system pumps and motors	49.28				49.28
Pressurizer	56.64				56.64
Steam generators	367.54				367.54
Control rod drive mechanism and incore instrumentation	48.20				48.20
Vessel internals	22.26	13.06	30.81	20.25	86.38
Reactor vessel	147.15	51.94			199.09
NSSS total	790.05	65.00	30.81	20.25	906.11
Plant systems					
Auxiliary feedwater	92.12				92.12
Containment ventilation	42.45				42.45
Contaminated electrical equipment	79.27				79.27
Feedwater sampling	90.28				90.28
Feedwater	338.48				338.48
Gaseous radwaste	54.46				54.46
Letdown demineralizer	3.82				3.82
Letdown and residual heat removal	42.48				42.48
Liquid radwaste	37.72				37.72
Post-accident sampling	5.35				5.35
Pressurizer and relief tank	0.20				0.20
Radwaste drain system	5.21				5.21
Reactor coolant pump seal water system	13.71				13.71
Reactor cool system	3.12				3.12
Reactor cool system sampling system	13.06				13.06
Safety injection	85.70				85.70
Spent fuel cooling	11.98				11.98
Chemical volume and control system	23.93				23.93
Plant systems total	943.34				943.34
Site buildings					
Reactor sphere and enclosure	249.27				249.27
Auxiliary additions	2.04				2.04
Contaminated soil	724.96				724.96
Fuel storage	21.69				21.69
Miscellaneous contaminated buildings	18.49				18.49
Radwaste	13.45				13.45
Reactor auxiliary	5.89				5.89
Storage building	1.42				1.42
Site buildings total	1,037.21				1,037.21
Final waste liquid processing		40.24			40.24
Mixed waste	16.68				16.68
Totals	2,922.79	105.24	30.81	20.25	3,079.09

[a]Based on ref. 46.

[b]The 436-MW(e) San Onofre-Unit 1 PWR began operation in 1967 and generated about 6,045 MW(e)-years of (gross) electrical energy before it was shut down in 1992.

[c]Includes 83.94 m^3 of dry activated waste (including protective worker clothing) generated during the latter phase of decommissioning.

Table 7.23. Characteristics of wastes from decommissioning activities at the Cimarron Fuel Fabrication Facility[a]

Project area	Type of waste	Total waste removed from Cimarron through December 1992[b] Volume (m^3)	Activity (Ci)	Projected waste volume remaining[c] (m^3)
Burial ground	LLW (LSA)[d]	1,833.10	5.37	0
Mixed-oxide fuel plant	TRU	255.89	10.87	0
	LLW (LSA)	463.88	3.25	0
Uranium fuel plant areas				
a. Uranium fuel plant	LLW (LSA)	2,198.76	3.65	12-24
b. North Field	LLW (LSA)	630.19	0.33	0
Liquid process waste evaporation ponds				
a. Mixed-oxide plant pond	LLW (LSA)	104.30	0.000009	0
b. Uranium plant pond	LLW (LSA)	183.73	0.23	0
Sanitary lagoon piping and manholes	LLW (LSA)	1,565.63	2.93	0
Project totals	TRU	255.89	10.87	0
	LLW (LSA)	6,979.59	15.76	12-24
Total waste		7,235.48	26.63	12-24

[a]Based on the information provided in ref. 47.
[b]The LLW inventories are included in the commercial disposal site inventories of Chapter 4.
[c]Decontamination work is scheduled to be completed during 1993. More than 95% of the estimated decontamination requirement has been completed.
[d]LSA = low-specific-activity waste.

ORNL PHOTO 6945-93

Mixed low-level waste in storage at the Hanford Site Central Waste Complex. (Courtesy of the Westinghouse Hanford Company, Richland, Washington, and the Hazardous Waste Remedial Actions Program, Oliver Springs, Tennessee.)

8. MIXED LOW-LEVEL WASTE

8.1 INTRODUCTION

This chapter reports estimated inventories and generation rates of mixed LLW from DOE-site and commercial operations. Mixed LLW includes mixtures of low-level radioactive materials and (chemically and/or physically) hazardous wastes. Typically, mixed LLW at DOE sites includes a variety of contaminated materials, including air filters, cleaning materials, engine oils and grease, paint residues, photographic materials, soils, building materials, and plant equipment being decommissioned. Mixed high-level and TRU wastes are not included in this chapter, but they are included in the HLW and TRU waste inventories and projections of Chapters 2 and 3, respectively.

The radioactive components of mixed wastes are subject to the Atomic Energy Act (AEA), as amended,[1] which, for government sources, is administered by DOE, and, for commercial sources, by NRC (unless a state has obtained agreement-state status). In general, the hazardous components of most mixed wastes are subject to either of two federal statutes that are administered by the U.S. Environmental Protection Agency (EPA) (unless a state has obtained an authorization status): (1) the Resource Conservation and Recovery Act (RCRA), as amended,[2] and (2) the Toxic Substances Control Act (TSCA).[3] Some mixed wastes, particularly spent engine oils, are regulated by state laws. The treatment, handling, and disposal of RCRA- and TSCA-regulated mixed wastes are subject to the regulations of the EPA[4,5] and NRC (or the authorized and agreement states), or DOE. Table 8.1 (data from ref. 6) lists those states and territories designated by EPA as having mixed waste authorization.

In this report, mixed LLW is considered separately from the purely radioactive LLW, which is discussed in Chapter 4. This section reports mixed LLW inventories and projections for two major groups of mixed LLW. The first comprises wastes whose hazardous components are RCRA and/or state regulated. The summary information reported for these RCRA/state-regulated wastes are based on the 1993 DOE Interim Mixed Waste Inventory Report (IMWIR),[7] which is required by the Federal Facility Compliance Act (FFCA).[8] DOE is currently refining and updating the site information and data in the IMWIR. Wastes whose hazardous components are regulated by TSCA comprise the second group of mixed LLW; inventories and projections of this group are reported in this chapter. Information for the TSCA-regulated wastes was provided by the Waste Management Information System (WMIS),[9] a data base of treatment, storage, and disposal (T/S/D) facility capabilities and DOE site waste stream characteristics. The WMIS was established to support the DOE Office of Environmental Restoration and Waste Management and is maintained by the Hazardous Waste Remedial Actions Program (HAZWRAP).

Unless otherwise noted, the inventories and projections reported for mixed LLW are separate from those reported for strictly radioactive LLW in Chapter 4. Inventories of mixed LLW currently stored at DOE sites are being thoroughly characterized. As a result, the waste at some sites could require reclassification, thereby causing significant changes in the inventories that reflect current data.

8.2 WASTE CHARACTERIZATION

Currently, generic characterization of mixed wastes is difficult for several reasons: (1) such wastes have different blends of hazardous (chemical and/or physical) and radioactive components that dictate precautionary measures; (2) several processes may be involved in generating these wastes; (3) various methods are used to prepare these wastes for storage; and (4) in recent years, EPA has adopted new toxicity-characteristic leaching procedures (TCLPs). Representative data on the chemical and radionuclide compositions of mixed wastes will be reported as more detailed site information is available.

In this chapter, inventories and annual generation rates of mixed LLW are expressed in terms of physical and hazardous categories. Physical properties are classified in four categories: solid, liquid, gas, and sludge. Hazardous properties are classified according to waste categories identified in the IMWIR and TSCA.

8.3 SUMMARY OF DOE MIXED LLW

Cumulative mass inventories and generation rates are reported in this chapter for most of the DOE sites listed in

Table D.3, Appendix D. The rates are based on (a) RCRA-/state-regulated waste information reported in the IMWIR[7] and (b) information on TSCA-regulated wastes from WMIS.[9] Some generation rates may vary from current inventory additions because the generation levels reported do not reflect treatment that may take place before the waste is placed in interim storage. DOE site inventories and generation rates are given in both mass [kilograms (kg)] and volume [cubic meters (m^3)] units. Until recently, many DOE sites tracked and reported their mixed waste streams in mass units. However, for disposal considerations, DOE is requiring these sites to report their mixed waste inventories and generation rates in units of disposal volume. In cases where the site reported waste volumes but not masses (or vice versa), a reasonable set of material densities was used to estimate waste masses (or volumes). These densities are indicated in either the footnotes of the tables reporting this information or in the discussion of specific site information given under Sect. 8.4.

A breakdown of the mixed LLW volume inventory by site is graphically described in Fig. 8.1, and a breakdown of the volume-generation level by site is shown in Fig. 8.2. The current total volume inventory of mixed LLW at DOE sites is about 183,400 m^3. About 60,000 m^3 of additional mixed LLW are estimated to be generated during the period 1993–1997.

Summary 1992 cumulative inventories and projected 5-year (1993–1997) cumulative generation for mixed LLW from DOE site operations are reported in Tables 8.2–8.5. For each site, information is reported for RCRA-/state-regulated wastes based on the IMWIR[7] and for TSCA-regulated wastes based on DOE site information submitted to WMIS.[9] Cumulative 1992 inventories of mixed LLW in interim storage are reported on a mass and volume basis in Tables 8.2 and 8.3, respectively. The additional mass generation and volume generation of these wastes projected to result from DOE site operations over the next 5 years are given in Tables 8.4 and 8.5, respectively.

Detailed characteristics of RCRA-/state-regulated wastes from site operations are described in Tables 8.6–8.8 (adapted from ref. 7). The IMWIR documents inventories and generation levels for a wide range of categories of RCRA-/state-regulated wastes. These categories are based on various physical and chemical groupings and are described in detail in Table 8.6. Cumulative 1992 mass and volume inventories for these physical/chemical groups are given in Table 8.7. Projected cumulative generation levels for each category over the next 5 years (1993–1997) are given in Table 8.8.

Detailed characteristics of TSCA-regulated mixed LLW from DOE site operations are reported by physical category (solid, liquid, gas, and sludge) in Tables 8.9–8.12 and by TSCA hazard category [polychlorinated biphenyls (PCBs), asbestos, and other specified materials] in Tables 8.13–8.16.

Cumulative 1992 mass inventories and volume inventories are given in the physical category tables for the TSCA-regulated wastes (Tables 8.9 and 8.10, respectively). Annual mass generation and volume generation of these wastes for 1992 are reported in Tables 8.11 and 8.12, respectively.

The hazardous category tables for TSCA-regulated wastes include information on PCB wastes and asbestos. Other mixed LLW regulated by TSCA at each site are also indicated. PCBs are a group of synthetic organic chemicals once widely used in electrical equipment, special hydraulic systems, heat-transfer systems, and other industrial products. They are currently considered a possible carcinogen. Asbestos is a group of magnesium silicate compounds that are mixed with varying amounts of calcium and iron silicates. They are fibrous, noncombustible minerals that have been previously used in the manufacture of many fireproofing and insulating materials. However, such compounds have been found to produce long-term carcinogenic effects; consequently, their use is being phased out.

Cumulative 1992 mass and volume inventories are reported in the hazardous category tables for TSCA-regulated wastes (Tables 8.13 and 8.14, respectively). Annual mass generation and volume generation of these wastes for 1992 are reported in Tables 8.15 and 8.16, respectively.

Historical and annual projections of DOE-site mixed LLW are reported in Tables 8.17–8.19. Historical and projected annual volume generation reported in the IMWIR for RCRA-/state-regulated mixed LLW from DOE-site environmental restoration activities are given in Table 8.17. Corresponding information on generated TSCA-regulated mixed LLW from DOE site operations, based on ref. 9, are reported in Tables 8.18 (annual mass data) and 8.19 (annual volume data).

8.4 SPECIFIC DOE SITE MIXED LLW

This section highlights the major ground rules and assumptions associated with the DOE site TSCA mixed LLW information reported in Tables 8.2–8.5 and Tables 8.7–8.19. Most of the information reported in the subsections that follow describes the TSCA mixed LLW inventory, generation, and projection ground rules and assumptions documented in the specific DOE site submittals of ref. 9. Corresponding information associated with the RCRA-/state-regulated wastes reported in the IMWIR are generally given in ref. 7.

8.4.1 Ames Laboratory (AMES)

At Ames, the only waste that is both LLW and TSCA-regulated is asbestos-containing material. Small quantities

of such waste are projected for AMES in Tables 8.4, 8.5, 8.18, and 8.19 to reflect the completion of D&D activities at the site. Waste estimates for the period 1995–2030 are unknown.

8.4.2 Argonne National Laboratory–East (ANL–E)

Projections reported in Tables 8.4, 8.5, 8.18, and 8.19 for ANL–E are rough estimates based on preliminary forecasts of remediation projects. Full waste characterization for these site remediation projects must still be performed. No current inventories of TSCA-regulated wastes are reported. ANL–E handles and reports radioactively contaminated asbestos as LLW because this material is shipped to HANF, where it is accepted as LLW. The quantities of reported projected wastes are based on an assumed density for solids of 3,000 kg/m^3.

8.4.3 Brookhaven National Laboratory (BNL)

Mixed TSCA LLW inventories reported for BNL in Tables 8.2, 8.3, 8.9, 8.10, 8.13, and 8.14 represent cumulative levels from 1986. Projected annual generation rates reported in Tables 8.18 and 8.19 for BNL assume that TSCA-contaminated materials are removed and substituted where possible. This assumption results in a projected generation rate that is constant for a while but eventually declines over the long term.

8.4.4 Fermi National Accelerator Laboratory (FNAL)

FNAL mixed TSCA LLW inventories reported in Tables 8.2, 8.3, 8.9, 8.10, 8.13, and 8.14 represent cumulative levels from 1989. Tables 8.18 and 8.19 show that annual TSCA waste generation is projected to remain constant over the next 5 years but that it will sharply decline over the three decades that follow.

8.4.5 Hanford Site (HANF)

Reported quantities of RCRA/state mixed LLW for HANF in Tables 8.2–8.5 include only contributions from newly generated solid wastes, which include sludges, metal debris, lab packs, soils, and a variety of other materials. HANF RCRA/state mixed LLW inventories and projections reported in the IMWIR also include contributions from double-shell tank waste, which consists of aqueous liquids and organic liquids. These liquids, although comprising mixed LLW, are managed as HLW. For this reason, contributions from the double-shell tank waste are not included in this chapter, but in the HLW inventories and projections of Chapter 2.

Mixed TSCA LLW inventories reported for HANF in Tables 8.2, 8.3, 8.9, 8.10, 8.13, and 8.14 represent cumulative levels from 1987. Inventories and generation levels reported for 1992 are based on an assumed average density of 1,000 kg/m^3 for liquids and debris and 1,500 kg/m^3 for soils. Generation projections are based on an average annual generation between mid-1987 and 1992 (5.5 years).

8.4.6 Los Alamos National Laboratory (LANL)

Inventories of TSCA-regulated mixed LLW at LANL reported in Tables 8.2, 8.3, 8.9, 8.10, 8.13, and 8.14 represent cumulative levels from 1971. These reported inventories are based on the limited records kept of asbestos and PCB wastes in the early operating years.

8.4.7 Lawrence Berkeley Laboratory (LBL)

For the most part, only TSCA LLW volume information was reported by LBL in ref. 9. TSCA LLW mass estimates for LBL are based on the densities cited in the footnotes of Tables 8.2, 8.4, 8.9, 8.11, and 8.13. The mass generation projections of Tables 8.18 were estimated from the volume generation projections of Table 8.19 using a density of 1,000 kg/m^3. Inventories of LBL TSCA LLW reported in Tables 8.2, 8.3, 8.9, 8.10, 8.13, and 8.14 represent cumulative levels from 1988. In addition to asbestos and PCBs, inventories of TSCA LLW at LBL include pump oils contaminated with tritium. The projections reported for LBL reflect several assumptions. After 1992, there will be no generation of contaminated oil. In addition, future generation of asbestos and PCB wastes will be sporadic—dependent upon laboratory decommissioning schedules.

8.4.8 Lawrence Livermore National Laboratory (LLNL)

Inventories of TSCA-regulated LLW at LLNL are reported in Tables 8.2, 8.3, 8.9, 8.10, 8.13, and 8.14. No TSCA wastes were generated in 1992 nor are any projected for the future partly because the site no longer purchases equipment which uses PCBs. In recent years, the only generation of TSCA wastes at LLNL occurred when capacitors containing PCBs were removed from service, and when asbestos was removed from building demolition or renovation.

8.4.9 Mound Plant (MOUND)

Mound Plant TSCA LLWs are PCB wastes. Inventories for these wastes reported in Tables 8.2, 8.3, 8.9, 8.10, 8.13, and 8.14 represent cumulative levels from 1985.

8.4.10 Naval Reactors (NR) Program Sites

Generation levels reported for NR Program sites in Tables 8.4, 8.5, 8.18, and 8.19 represent contributions from

the Knolls Atomic Power Laboratory (KAPL). The projections reported in Tables 8.18 and 8.19 assume a generation rate for asbestos wastes consistent with maintenance and plant D&D activities.

8.4.11 Oak Ridge National Laboratory (ORNL)

Inventories of TSCA LLW at ORNL reported in Tables 8.2, 8.3, 8.9, 8.10, 8.13, and 8.14 are cumulative levels from 1968. Site generation projections reported in Tables 8.18 and 8.19 pertain to radioactivity-contaminated asbestos. Some ORNL wastes containing PCBs are included in the RCRA waste inventories reported in ref. 7.

8.4.12 Paducah Gaseous Diffusion Plant (PAD)

The PAD site TSCA LLW inventories reported in Tables 8.2, 8.3, 8.9, 8.10, 8.13, and 8.14 are cumulative levels from 1980. Projections reported for generated TSCA wastes in Tables 8.18 and 8.19 are based on the following assumptions:

- a routine waste generation of 608 m^3/year;
- the mass of a 55-gal (0.21 m^3) drum is 159 kg;
- generation levels resulting from routine site activities, environmental restoration activities, and engineering project activities;
- reported quantities for only waste solids and liquids, no sludges; and
- all future PCB wastes to be regarded as hazardous.

8.4.13 Portsmouth Gaseous Diffusion Plant (PORTS)

At PORTS, TSCA-regulated mixed LLW is comprised of both PCBs and asbestos. Inventories of these wastes are reported in Tables 8.2, 8.3, 8.9, 8.10, 8.13, and 8.14. Current generation rates are reported in Tables 8.11, 8.12, 8.15, and 8.16. Projections of TSCA wastes from PORTS site activities are currently not available.

8.4.14 Remedial Action Program (RAP) Sites

Mixed LLW inventories, generation, and projections reported in this chapter for remedial action program (RAP) sites include contributions from the Battelle Columbus Laboratory Decommissioning Project (BCLDP) and the Santa Susana Field Laboratory (SSFL) of the Energy Technology Engineering Center (ETEC).

Projections for BCLDP waste generation pertain only from 1993 to the year 2000, at which time the project is scheduled to be completed. The generation level reported for 1998–2030 is an annual average based on total contributions from 1998–2000. Mass quantities were estimated from reported volume projections using an assumed waste density of 1,000 kg/m^3.

TSCA waste inventories for SSFL include contributions from the years 1991 and 1992. SSFL TSCA waste is primarily asbestos-containing floor tiles removed during D&D operations.

8.4.15 Rocky Flats Plant (RFP)

Projections reported in Tables 8.18 and 8.19 for TSCA LLW generated at RFP pertain to both asbestos and PCB wastes. Assumptions associated with projected asbestos generation include:

- funding support to continue for asbestos removal projects,
- regulations not to be modified to require the removal of all damaged asbestos, and
- no removal of asbestos required by site transition activities (i.e., changes in the uses of site facilities).

Assumptions associated with projected PCB generation rates at RFP include:

- funding support to continue for PCB remediation,
- PCB materials removed to contain some amounts of LLW contamination, and
- a transformer containing PCBs to be removed from service in 1994.

8.4.16 Sandia National Laboratory–Albuquerque (SNLA)

Inventories of TSCA LLW (asbestos) reported for SNLA in Tables 8.2, 8.3, 8.9, 8.10, 8.13, and 8.14 represent cumulative levels from 1989, when disposal of LLW in SNLA landfills ceased. Estimates for future TSCA LLWs are currently unknown. Future generation is expected to be mostly radioactively contaminated asbestos from D&D activities. Some older buildings on the site have been designated for D&D and are known to contain radioactively contaminated asbestos. However, no funding is yet available for cleanup of these facilities and no sampling and analysis has occurred.

8.4.17 Savannah River Site (SRS)

SRS mixed TSCA LLW inventories reported in Tables 8.2, 8.3, 8.9, 8.10, 8.13, and 8.14 represent cumulative levels from 1986. Most of the SRS TSCA wastes are asbestos materials whose mass was estimated from site-reported volume data using an assumed density of 200 kg/m^3. This density was also used to estimate the projected TSCA LLW mass generation rates reported in Tables 8.4, 8.11, 8.15, and 8.18.

8.4.18 West Valley Demonstration Project (WVDP)

At the WVDP site, TSCA-regulated mixed LLW is comprised of both asbestos and PCB wastes. The waste projections reported for WVDP in Table 8.18 and 8.19 are based on the following assumptions:

- wastes estimated for 1993 include both asbestos and PCB wastes, the latter of which is associated with two capacitors and two light ballasts scheduled for removal;
- the average generation level reported for 1998–2030 excludes 1,024 kg (1.15 m^3) of PCB waste to be removed from this work scheduled to begin in the year 2000; and
- asbestos removal already begun is to be completed by the year 2030.

8.4.19 Y-12 Plant (Y-12)

Y-12 Plant TSCA mixed LLW inventories reported in Tables 8.2, 8.3, 8.9, 8.10, 8.13, and 8.14 represent cumulative levels from 1982. These wastes are PCBs. Contributions from asbestos are not reported because it is considered to be a sanitary waste at the Y-12 Plant. Waste volumes reported were estimated from site-reported waste mass information using an assumed density of 1,500 kg/m^3 for solids and 1,000 kg/m^3 for liquids. In Tables 8.9–8.12, the quantity of generated sludge cannot be broken out and therefore is included in the solid or liquid data given in these tables. In Table 8.9, a large portion of the cumulative inventory (5,341,225 kg) consists of disposal area remedial action soils from the Oil Land Farm Soil Storage Facility.

Projected TSCA mixed LLW generation rates for the Y-12 Plant are unavailable due to three factors: (1) the changing Y-12 Plant mission; (2) the unknown amount of environmental restoration work to be done; and (3) the unknown amount of D&D work to be done.

8.5 COMMERCIAL MIXED LOW-LEVEL WASTES

Recently, the NRC and EPA co-sponsored a survey study to compile a national profile of the volumes, characteristics, and treatability of commercially generated mixed LLW. Such a profile was designed to provide the following:

- states and compacts with information to assist in planning and developing adequate disposal capacity for low-level radioactive waste, including mixed waste, as mandated by the Low-Level Radioactive Waste Policy Amendments Act;
- private developers with a clearer idea of the characteristics and volumes of mixed waste and the technical capability and capacity needed to treat this waste; and
- a reliable national data base on the volumes, characteristics, and treatability of commercial mixed waste.

In addition, the data were collected to provide a basis for possible federal actions that would effectively manage and regulate the treatment and disposal of mixed waste. Results from this investigation are documented in ref. 10 and summarized in this report.

The study identified the types and volumes of mixed LLW generated from five groups of facilities: nuclear utilities, medical facilities, academic institutions, industrial facilities, and NRC-licensed government facilities. The study selected a random sample of 1,323 facilities out of a total target population of 2,936 facilities. Data from the 1,016 completed mixed waste survey questionnaires (77% response rate) received and the use of appropriate weighting factors indicate that approximately 3,950 m^3 of low-level radioactive mixed waste—of which 72% was liquid scintillation fluids—were generated in the United States in 1990.

The study divided the low-level radioactive mixed waste into several hazardous stream categories, including the following:

- Liquid scintillation fluids from laboratory counting activities.
- Waste oil from various pumps, equipment, and maintenance activities.
- Chlorinated or fluorinated organics and chlorinated fluorocarbons, including sludges and contaminated filters from dry cleaning, refrigeration, degreasing, and decontamination operations. Chloroform and a number of pesticides are also included.
- Other organics, including miscellaneous solvents, reagents, expired products, and other organic compounds (or materials like rags, wipes, etc., contaminated with such) from research and manufacturing activities, experimental procedures, and laboratory and process equipment cleaning.
- Lead wastes, including lead shielding and lead solutions for research and industrial facilities.
- Mercury wastes, including equipment and debris contaminated with mercury.
- Chromate wastes, including chromium-contaminated solutions for research, maintenance, and waste treatment (ion exchange) operations.
- Cadmium wastes from decontamination activities.
- Aqueous corrosive wastes, including inorganic acids, or, in some instances, bases from cleanup and decontamination activities.
- Other hazardous materials, including materials either not readily assignable to any one of the previous categories or containing a number of different hazardous materials.

Summaries of estimated generation rates, amounts in storage, and amounts treated for each of the five facility categories and each of the hazardous waste stream categories are shown in Tables 8.20 and 8.21, respectively (data from ref. 10). Upper and lower bounds were also set on the volume of mixed waste that is untreatable under current technologies by making the simplifying assumption

that liquid scintillation fluids, oil, nonhalogenated organics, and corrosive wastes are treatable. Deducting their total contribution from the estimated total mixed waste generation rate leaves residues of about 524 m^3. This upper bound for untreatable mixed waste is approximately 13% of the estimated 1990 national generation rate of 3,950 m^3. However, it was noted that the capacity to treat *all* of the so-called treatable mixed waste may not be available.

8.6 REFERENCES

1. U.S. Congress, Atomic Energy Act of 1954, Pub. L. 83-703, Aug. 15, 1954.

2. U.S. Congress, Resource Conservation and Recovery Act of 1976, Pub. L. 94-580, Oct. 21, 1976, as amended by the Hazardous and Solid Waste Amendments Acts of 1984, Pub. L. 98-616, Nov. 9, 1984.

3. U.S. Congress, Toxic Substances Control Act of 1976, Pub. L. 94-469, Oct. 11, 1976.

4. U.S. Environmental Protection Agency, "Identification and Listing of Hazardous Waste," *Code of Federal Regulations*, 40 CFR Parts 260-271 (1986).

5. U.S. Environmental Protection Agency, "Subchapter R--Toxic Substances Control Act," *Code of Federal Regulations*, 40 CFR Parts 700-799 (1988).

6. Betsy Owen, Science Applications International Corporation, Germantown, Maryland, facsimiles to S. N. Storch, Oak Ridge National Laboratory, Oak Ridge, Tennessee, dated June 4 and 10, 1993, containing the updated respective EPA mixed waste authorization statuses for states and U.S. territories as of April 30, 1993.

7. U.S. Department of Energy, *Interim Mixed Waste Inventory Report: Waste Streams, Treatment Capacities, and Technologies*, DOE/NBM-1100, Washington, D.C. (April 1993).

8. U.S. Congress, Federal Facility Compliance Act of 1992, Pub. L. 102-386, Oct. 6, 1992.

9. U.S. Department of Energy, Waste Management Information System (WMIS), DOE site TSCA-regulated mixed LLW data submittals (Attachment 5) issued, received, and maintained by the Hazardous Waste Remedial Actions Program (HAZWRAP), Martin Marietta Energy Systems, Inc., submitted to the IDB Program during August-December 1993. The following TSCA mixed LLW submittals were received and reviewed by HAZWRAP and its support contractors before being submitted to the IDB Program for analysis and integration. Preceding each submittal is the site (in parentheses) to which it refers.

   a. (AMES) Kay M. Hannasch, Ames Laboratory, Ames, Iowa, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, submitting Ames Laboratory TSCA mixed LLW information, dated Aug. 11, 1993.

   b. (ANL-E) R. Max Schletter, Argonne National Laboratory, Argonne, Illinois, memorandum to A. L. Taboas, DOE Argonne Area Office, Argonne, Illinois, "Request for Office of Waste Management, Waste Data Information Update," dated Aug. 26, 1993.

   c. (ANL-W) No submittal.

   d. (BNL) Carson L. Nealy, U.S. Department of Energy, Brookhaven Area Office, Upton, New York, memorandum to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Brookhaven National Laboratory--1993 Waste Management Information System (WMIS) Update," dated Aug. 12, 1993.

   e. (FNAL) J. Donald Cossairt, Fermi National Accelerator Laboratory, Batavia, Illinois, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Request for Office of Waste Management, Waste Data Information Update," dated Aug. 9, 1993.

f. (HANF) R. D. Wojtasek, Westinghouse Hanford Company, Hanford Site, Richland, Washington, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Request for Office of Waste Management, Waste Data Information Update," 9305688B R1, dated Aug. 30, 1993.

g. (INEL) Virginia C. Randall, EG&G Idaho Inc., Idaho National Engineering Laboratory, Idaho Falls, Idaho, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Integrated Data Base for 1993," VCR-11-94, dated Feb. 14, 1994.

h. (ITRI) Susan Umshler, U.S. Department of Energy, Kansas City Area Office, Kansas City, Missouri, memorandum to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, detailing TSCA mixed LLW information for the Inhalation Toxicology Research Institute, dated Aug. 6, 1993.

i. (K-25) Jeff Wilson, Martin Marietta Energy Systems, Inc., Oak Ridge K-25 Site, Oak Ridge, Tennessee, facsimile to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, dated Sept. 15, 1993.

j. (LANL) Thomas C. Gunderson, Los Alamos National Laboratory, Los Alamos, New Mexico, memorandum to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "WMIS Data Call," EM-DO: 93-941, dated Aug. 17, 1993.

k. (LBL) Hannibal Joma, U.S. Department of Energy, San Francisco Operations Office, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, submitting Lawrence Berkeley Laboratory TSCA mixed LLW waste information, 93W-332/5484.1.A.13, dated Aug. 23, 1993.

l. (LLNL) Kevin Hartnett, U.S. Department of Energy, San Francisco Operations Office, facsimile to Millie Jeffers, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, providing LLNL LLW information, dated Nov. 18, 1993.

m. (MOUND) Mary E. Sizemore, EG&G Mound Applied Technologies, Miamisburg, Ohio, memorandum to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Request for DOE Waste Date (sic) Information Update," dated Aug. 20, 1993.

n. (NR sites) J. J. Mangeno, U.S. Department of Energy, Naval Reactors Programs Office (NE-60), Crystal City, Virginia, memorandum to J. Coleman, DOE/EM Office of Technical Support (DOE/EM-35), Washington, D.C., "Update of Radioactive Waste Data on Waste Streams and Treatment, Storage, and Disposal Units for NE-60 Cognizant Facilities," dated Aug. 9, 1993.

o. (NTS) Layton J. O'Neill, U.S. Department of Energy, Nevada Operations Office, Las Vegas, Nevada, memorandum to Joseph A. Coleman, DOE/EM Office of Technical Support (DOE/EM-35), Washington, D.C., "Request for Office of Waste Management, Waste Data Information Update," dated Sept. 2, 1993.

p. (ORISE) Lynda H. McLaren, U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tennessee, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Waste Management Information System: Integrated Data Base—Oak Ridge Institute for Science and Education (ORISE) Submission," dated Sept. 21, 1993.

q. (ORNL) Site data received, but no letter of transmittal.

r. (PAD) Jimmy C. Massey, Martin Marietta Energy Systems, Inc., Paducah, Kentucky, letter to Donald C. Booher, DOE Paducah Site Office, Paducah, Kentucky, "Update of Department of Energy Low-Level Radioactive and Low-Level Mixed Waste Data for the 1993 Integrated Data Base Annual Report," dated Aug. 20, 1993.

s. (PANT) R. M. Loghry, Mason & Hanger—Silas Mason Company, Inc., Amarillo, Texas, letter to Lise J. Wachter, Martin Marietta Energy Systems Inc., HAZWRAP, Oliver Springs, Tennessee, "Request for Office of Waste Management—Waste Data Information Update," dated Aug. 20, 1993.

t. (PINELLAS) Gary C. Schmidtke, DOE Pinellas Area Office, Largo, Florida, memorandum to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, detailing Pinellas Plant TSCA mixed LLW information, dated July 30, 1993.

u. (PORTS) Eugene W. Gillespie, DOE Portsmouth Site Office, Piketon, Ohio, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Request for Office of Waste Management, Waste Data Information Update," EO-23-5379, dated Aug. 10, 1993.

v. (PPPL) No submittal.

w. (RFP) W. T. Prymak, DOE Rocky Flats Office, Golden, Colorado, memorandum to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Submission of Waste Data Information to Support the Integrated Data Base," dated Aug. 27, 1993.

x. (SLAC) Matthew A. Allen, Stanford Linear Accelerator Center, Palo Alto, California, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Waste Data Information Update," dated Aug. 16, 1993.

y. (SNLA) Steve Ward, Sandia National Laboratories, Albuquerque, New Mexico, letter to George K. Laskar, DOE Albuquerque Operations, "Transmittal of Waste Management Information System (WMIS) Update Information," dated Aug. 5, 1993.

z. (SNLL) K. K. Shepodd, Sandia National Laboratories, Livermore, California, memorandum to S. E. Umshler, DOE Kansas City Area Office, Kansas City, Missouri, "Updated Data for the Waste Management Information System," dated Aug. 9, 1993.

aa. (SRS) Michael G. O'Rear, U.S. Department of Energy, Savannah River Operations Office, memorandum to the DOE/EM Director of the Office of Technical Support (DOE/EM-35), Washington, D.C., "Department of Energy Waste Inventory Data Systems," dated Nov. 3, 1993.

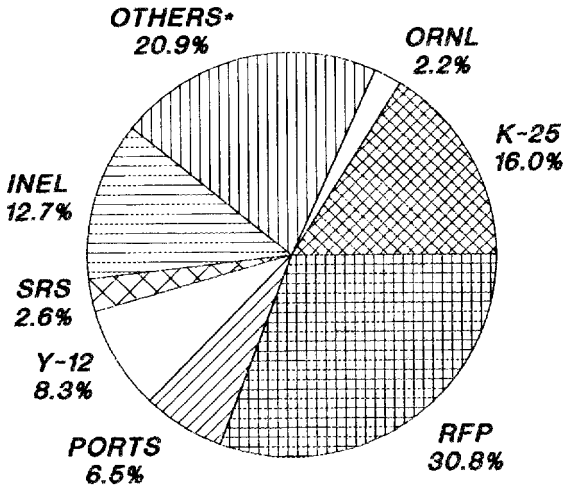
ab. (Y-12) Site data received, but no letter of transmittal.

ac. (WIPP) No submittal.

ad. (WVDP) J. P. Jackson, West Valley Nuclear Services Company, Inc., West Valley, New York, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Waste Information Update for Calendar Year 1992," dated Aug. 20, 1993.

10. J. A. Klein, et al., *National Profile on Commercially Generated Low-Level Radioactive Mixed Waste*, prepared by Oak Ridge National Laboratory, Oak Ridge, Tennessee, for U.S. Nuclear Regulatory Commission and U.S. Environmental Protection Agency, NUREG/CR-5938, ORNL-6731 (December 1992).

ORNL DWG 93-10819

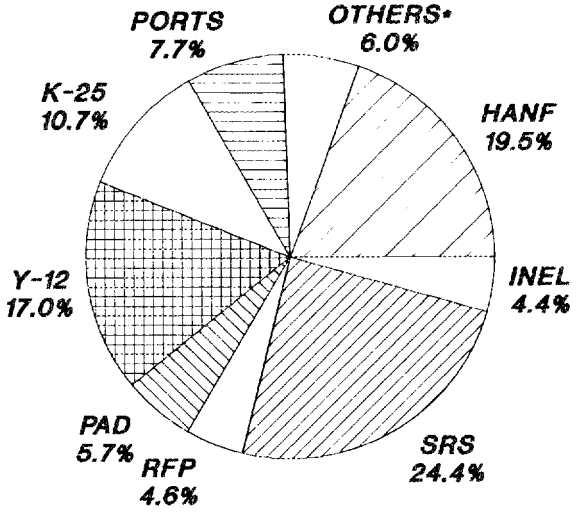


SITE	CUBIC METERS
INEL	2.322E+04
K-25	2.910E+04
ORNL	4.022E+03
PORTS	1.193E+04
RFP	5.608E+04
SRS	4.740E+03
Y-12	1.513E+04
OTHERS*	3.816E+04
TOTAL	1.824E+05

*Reported contributions from 35 sites.

Fig. 8.1. Total volume inventory of all DOE mixed LLW through 1992.

ORNL DWG 93-10820



SITE	CUBIC METERS
HANF	1.168E+04
INEL	2.620E+03
K-25	6.401E+03
PAD	3.422E+03
PORTS	4.611E+03
RFP	2.764E+03
SRS	1.467E+04
Y-12	1.023E+04
OTHERS*	3.604E+03
TOTAL	6.001E+04

*Reported contributions from 34 sites.

Fig. 8.2. Projected cumulative volume generation of all DOE mixed LLW during 1993–1997.

Table 8.1. Thirty-four states and territories with EPA mixed waste authorization[a]

State/territory	Effective date	State/territory	Effective date
Arizona	01/22/93	Missouri	03/12/93
Arkansas	05/29/90	Nebraska	12/03/88
California	08/01/92	Nevada	06/29/92
Colorado	11/07/86	New Mexico	07/25/90
Connecticut	12/31/90	New York	05/07/90
Florida	02/12/91	North Carolina	11/21/89
Georgia	09/26/88	North Dakota	08/24/90
Guam	10/10/89	Ohio	06/30/89
Idaho	04/09/90	Oklahoma	11/27/90
Illinois	04/30/90	Oregon	05/29/90
Indiana	09/30/91	South Carolina	09/13/87
Kansas	06/25/90	South Dakota	06/17/91
Kentucky	12/19/88	Tennessee	08/11/87
Louisiana	10/26/91	Texas	03/15/90
Michigan	12/26/89	Utah	03/07/89
Minnesota	06/23/89	Washington	11/23/87
Mississippi	05/28/91	Wisconsin	04/24/92

[a]Based on ref. 6. Information as of April 30, 1993.

Table 8.2. Cumulative mass (kg) inventories of DOE site operations mixed LLW through 1992[a,b]

Site	RCRA/state[c]	TSCA[d]	Total
AMES	692	2,400	3,092
ANL-E	156,496	0	156,496
ANL-W	19,223	e	19,223
BNL	78,305	262	78,567
FEMP	3,524,491	e	3,524,491
FNAL	e	98	98
HANF[f]	2,946,863[g,h]	101,815	3,048,678
INEL	11,958,814	i	11,958,814
ITRI	960	e	960
K-25	38,661,192[g]	e	38,661,192
KCP	4,260	0	4,260
LANL	938,787	379,858	1,318,645
LBL	13,439	4,190	17,629
LLNL	204,189	252	204,441
MOUND	20,370	3,489	23,859
NR sites[j]	17,161	0	17,161
NTS	0	e	e
ORISE	e	e	e
ORNL	2,894,562[g]	199,289	3,093,851
PAD	186,105[g]	2,529,125	2,715,230
PANT	126,011	e	126,011
PINELLAS	29	0	29
PORTS	5,530,643[k]	1,431,630	6,962,273
PPPL	0	e	e
RAP sites[l]	1,349,212	900	1,350,112
RFP	61,240,145	25,120	61,265,265
RMI	9,098	e	9,098
SLAC	e	0	0
SNLA	98,285	68	98,353
SNLL	3,577	0	3,577
SRS	2,373,342[g]	18,656	2,391,998
WVDP	16,790	12,251	29,041
Y-12	16,503,573[g]	5,872,900	22,376,473
Others[m]	44,129,016	e	44,129,016
Total	193,005,630	10,582,303	203,587,933

[a]Materials may be in interim storage awaiting treatment. Specific site information is provided in Sect. 8.4.

[b]In general, densities of 500 kg/m^3 for compressed gases, 1,000 kg/m^3 for liquids, and 1,500 kg/m^3 for solids and sludges were assumed to estimate masses when site did not report mass data.

[c]Based on the IMWIR, ref. 7.

[d]Based on the DOE site data submittals of ref. 9.

[e]Information not available or unknown.

[f]Includes contributions from PNL.

[g]Reported inventory as of the end of 1991.

[h]Consists of contributions from newly generated solid waste.

[i]Contributions are included in the RCRA/state category.

[j]Includes contributions (if any) from Bettis (BAPL), Knolls (KAPL), and NRF (INEL).

[k]Reported inventory as of the end of February 1993.

[l]Includes contributions from Santa Susana (ETEC/SSFL), Colonie (CISS), Grand Junction (GJPO), and Weldon Spring (WSSRAP).

[m]Includes contributions from the Middlesex Sampling Plant in New Jersey (44,043,936 kg), the Laboratory for Energy-Related Health Research in California, and 4 naval shipyards (Mare Island, California; Pearl Harbor, Hawaii; Portsmouth, Maine; and Puget Sound, Washington).

Table 8.3. Cumulative volume (m^3) inventories of DOE site operations mixed LLW through 1992[a]

Site	RCRA/state[b]	TSCA[c]	Total
AMES	0.2	2.4	2.6
ANL-E	95.9	0	95.9
ANL-W	9.5	d	9.5
BNL	84.5	0.7	85.2
FEMP	3,108.1	d	3,108.1
FNAL	d	0.1	0.1
HANF[e]	2,930.7[f,g]	87.4	3,018.1
INEL	23,215.4	h	23,215.4
ITRI	1.3	d	1.3
K-25	29,100.4[f]	d	29,100.4
KCP	5.4	0	5.4
LANL	680.5	1,859.6	2,540.1
LBL	22.2	3.3	25.5
LLNL	212.0	0.2	212.2
MOUND	50.7	3.4	54.1
NR sites[i]	30.9	0	30.9
NTS	0.0	d	d
ORISE	d	d	d
ORNL	2,665.2[f]	1,357.0	4,022.2
PAD	185.8[f]	3,293.3	3,479.1
PANT	87.9	d	87.9
PINELLAS	0.0	0	0
PORTS	5,527.7[j]	6,403.0	11,930.7
PPPL	0.0	d	d
RAP sites[k]	715.6	5.7	721.3
RFP	56,026.0	52.0	56,078.0
RMI	15.9	d	15.9
SLAC	d	0	0
SNLA	65.5	0.4	65.9
SNLL	9.6	0	9.6
SRS	4,648.0[f]	92.1	4,740.1
WVDP	12.2	32.6	44.8
Y-12	11,112.1[f]	4,014.0	15,126.1
Others[l]	24,545.2	d	24,545.2
Total	165,164.4	17,207.2	182,371.6

[a]Materials may be in interim storage awaiting treatment. Specific site information is provided in Sect. 8.4.

[b]Based on the IMWIR, ref. 7.

[c]Based on the DOE site data submittals of ref. 9.

[d]Information not available or unknown.

[e]Includes contributions from PNL.

[f]Reported inventory as of the end of 1991.

[g]Consists of contributions from newly generated solid waste.

[h]Contributions are included in the RCRA/state category.

[i]Includes contributions (if any) from Bettis (BAPL), Knolls (KAPL), and NRF (INEL).

[j]Reported inventory as of the end of February 1993.

[k]Includes contributions from Santa Susana (ETEC/SSFL), Colonie (CISS), Grand Junction (GJPO), and Weldon Spring (WSSRAP).

[l]Includes contributions from the Middlesex Sampling Plant in New Jersey (24,468 m^3), the Laboratory for Energy-Related Health Research in California, and 4 naval shipyards (Mare Island, California; Pearl Harbor, Hawaii; Portsmouth, Maine; and Puget Sound, Washington).

Table 8.4. Projected 5-year (1993-1997) cumulative mass (kg) generation of DOE site operations mixed LLW[a,b]

Site	RCRA/state[c]	TSCA[d]	Total
AMES	0	100	100
ANL-E	61,973	251,486	313,459
ANL-W	4,550	e	4,550
BNL	27,243	214	27,457
FEMP	66,796	e	66,796
FNAL	e	150	150
HANF[f]	11,750,832[g]	92,500	11,843,332
INEL	2,569,971	0	2,569,971
ITRI	16,290	e	16,290
K-25	6,637,185[h]	e	6,637,185
KCP	0	0	0
LANL	545,950	164,000	709,950
LBL	17,874	70,000	87,874
LLNL	404,417	0	404,417
MOUND	1,559	0	1,559
NR sites[i]	35,820	49,466	85,286
NTS	0	e	e
ORISE	e	e	e
ORNL	652,192[h]	64,935	717,127
PAD	380,598[h]	2,305,225	2,685,823
PANT	276,400	e	276,400
PINELLAS	0	0	0
PORTS	4,456,147	e	4,456,147
PPPL	395	e	395
RAP sites[j]	9,216	84,250	93,466
RFP	3,908,995	128,480	4,037,475
RMI	440	e	440
SLAC	e	0	0
SNLA	1,564	e	1,564
SNLL	4,175	0	4,175
SRS	18,538,150[h]	26,600	18,564,750
WVDP	8,009	23,217	31,226
Y-12	13,101,716[h]	e	13,101,716
Others[k]	42,940	e	42,940
Total	63,521,397	3,260,623	66,782,020

[a]Specific site information is provided in Sect. 8.4.

[b]In general, densities of 500 kg/m^3 for compressed gases, 1,000 kg/m^3 for liquids, and 1,500 kg/m^3 for solids and sludges were assumed to estimate masses when site did not report mass data.

[c]Based on the IMWIR, ref. 7.

[d]Based on the DOE site data submittals of ref. 9.

[e]Information not available or unknown.

[f]Includes contributions from PNL.

[g]Cumulative generation for the period 1992-1997. Consists of contributions from newly generated solid waste.

[h]Cumulative generation for the period 1992-1996.

[i]Includes contributions (if any) from Bettis (BAPL), Knolls (KAPL), and NRF (INEL).

[j]Includes contributions from Battelle (BCLDP) and Santa Susana (ETEC/SSFL).

[k]Includes contributions from 6 naval shipyards (Charleston, South Carolina; Mare Island, California; Norfolk, Virginia; Pearl Harbor, Hawaii; Portsmouth, Maine; and Puget Sound, Washington).

Table 8.5. Projected 5-year (1993-1997) cumulative volume (m^3) generation of DOE site operations mixed LLW[a]

Site	RCRA/state[b]	TSCA[c]	Total
AMES	0.0	<0.1	<0.1
ANL-E	29.8	628.1	657.9
ANL-W	3.9	d	3.9
BNL	27.4	1.6	29.0
FEMP	151.1	d	151.1
FNAL	d	0.2	0.2
HANF[e]	11,603.2[f]	79.5	11,682.7
INEL	2,619.5	0	2,619.5
ITRI	4.3	d	4.3
K-25	6,401.0[g]	d	6,401.0
KCP	0.0	0.0	0.0
LANL	524.7	265.0	789.7
LBL	31.1	7.0	38.1
LLNL	430.5	0.0	430.5
MOUND	1.5	0.0	1.5
NR sites[h]	38.9	93.2	132.1
NTS	0.0	d	d
ORISE	d	d	d
ORNL	599.4[g]	262.8	862.2
PAD	380.1[g]	3,041.4	3,421.5
PANT	195.7	d	195.7
PINELLAS	0.0	0.0	0.0
PORTS	4,610.9	d	4,610.9
PPPL	0.5	d	0.5
RAP sites[i]	20.4	88.3	108.7
RFP	2,640.5	123.1	2,763.6
RMI	0.9	d	0.9
SLAC	d	0.0	0.0
SNLA	0.8	d	0.8
SNLL	15.8	0.0	15.8
SRS	14,537.7[g]	133.0	14,670.7
WVDP	7.3	96.0	103.3
Y-12	10,233.0[g]	d	10,233.0
Others[j]	79.9	d	79.9
Total	55,189.8	4,819.3	60,009.1

[a]Specific site information is provided in Sect. 8.4.
[b]Based on the IMWIR, ref. 7.
[c]Based on the DOE site data submittals of ref. 9.
[d]Information not available or unknown.
[e]Includes contributions from PNL.
[f]Cumulative generation for the period 1992-1997. Consists of contributions from newly generated solid waste.
[g]Cumulative generation for the period 1992-1996.
[h]Includes contributions (if any) from Bettis (BAPL), Knolls (KAPL), and NRF (INEL).
[i]Includes contributions from Battelle (BCLDP) and Santa Susana (SSFL/ETEC).
[j]Includes contributions from 6 naval shipyards (Charleston, South Carolina; Mare Island, California; Norfolk, Virginia; Pearl Harbor, Hawaii; Portsmouth, Maine; and Puget Sound, Washington).

Table 8.6. Physical/chemical groups and categories used to characterize RCRA- and state-regulated mixed LLW from DOE site operations[a]

Waste group/category	Description
Liquids	Consist of solutions and slurries
Aqueous	Consist mainly of water, have <1% (by mass) total organic carbon (TOC) content, and <35-40% (by mass) settled or suspended solids. Some are commonly referred to as wastewaters. Exclude lab packs
Organic	Comprised mainly of hydrocarbons such as petroleum distillates and halogenated solvents. Include any pumpable fluids, liquids, and slurries with a TOC of at least 1% and <35-40% (by mass) of suspended or settled solids. Exclude lab packs
Sludges and solids	Solid or semisolid materials other than soil or debris. Include highly viscous, nonpumpable materials
Inorganic	Comprised of solid or semisolid inorganic or mineralogical materials other than soil or debris. These wastes are generally homogeneous and include sludges from chemical wastewater treatment plants and dusts from air pollution control devices. Contain less than 50% heterogeneous debris (by volume)
Organic	Comprised of solid or semisolid organic materials other than debris. Semisolids include highly viscous liquids and sludges. These wastes are generally homogeneous and include sludges from biological wastewater treatment plants, activated carbon, and organic resins. Contain less than 50% heterogeneous debris (by volume)
Cemented solids	Liquids, sludges, or miscellaneous solids that have been solidified/stabilized with portland cement or other solidifying agents but do not meet land disposal restriction (LDR) treatment standards. These are a separate subcategory of homogeneous inorganic solids that require special handling and treatment
Solids	Contaminated soils are geologic materials less than 60 mm in diameter that have radioactive and hazardous contaminants. Such soils are stored in waste containers for special handling and treatment. Exclude in-situ soils. Include mixtures of soils and debris containing less than 50% debris (by volume)
Debris	Solid material, which is either discarded or intended to be discarded, exceeding 60 mm particle size that is either (1) a manufactured object, (2) plant or animal matter, or (3) natural or geological material (e.g., boulders and cobblestones). Excludes lead acid batteries and process residuals (e.g., smelter slag and residual ash) for which special treatment standards have been established. Mixtures of debris and other materials are considered debris if the mixture is comprised of >50% debris by volume
Inorganic	Include discarded metallic and ceramic construction materials, equipment, and structures. Some of these contain metal piping, metal turnings, glass, concrete, rocks, and asphalt
Organic	Include animal carcasses, discarded paper, plastic products, wood, rubber, and fabrics such as clothing, gloves, and rags
Heterogeneous	Composed of both inorganic and organic debris or debris with soils or process solids that occupy up to 50% of the total waste volume
Labpacks	Wastes with one or more small containers of free liquids or solids surrounded by a solid absorbent material in a large container. Include used scintillation vials and relatively small amounts of discarded laboratory equipment and laboratory chemicals

Table 8.6 (continued)

Waste group/category	Description
Labpacks (continued)	
With metals	Contain one or more RCRA toxic characteristic (TC) metals
Without metals	Not contaminated with TC metals
Reactive/dangerous wastes	Wastes that are chemically reactive and dangerous thereby posing an acute physical hazard. Wastes with reactive contaminants (e.g., cyanides) are not considered in this group unless the overall waste matrix material itself is reactive
Compressed gases	Include discarded aerosol cans and pressurized gas cylinders
Explosives	Waste materials that may explode during normal or extreme handling. Includes discarded high-explosive materials and nitrated celluloses
Reactive metals	Bulk reactive metals that, when mixed with water, generate toxic or flammable gases. Include sodium, alkaline metal alloys, aluminum fines, and other pyrophoric materials
Inherently hazardous wastes	Wastes whose primary components are toxic or hazardous
Batteries	Primarily lead acid and cadmium batteries
Beryllium dust	Waste containing bulk quantities of beryllium dust
Elemental lead	Includes both surface-contaminated and activated lead. Surface-contaminated lead includes bricks, counterweights, shipping casks, and other shielding containers. Activated lead includes material activated by neutron or accelerated particle absorption
Liquid mercury	Any waste containing bulk quantities of liquid mercury
Multiple wastes	Wastes comprised of mixtures of some of the waste forms described above and, therefore, may require sorting or separating prior to treatment
Other wastes	Wastes that do not fit into any of the above categories or are not yet characterized well enough to determine their physical and chemical properties. Includes mixtures of wastes not previously defined

[a]Based on the IMWIR, ref. 7.

Table 8.7. Cumulative mass and volume inventories through 1992, by physical/chemical matrix category, of RCRA- and state-regulated mixed LLW from DOE site operations[a]

Category[b]	Mass (kg)	Volume (m^3)
Liquids		
Aqueous	49,648,415	49,073.3
Organic	2,081,754	2,148.3
Sludges and solids		
Inorganic	56,608,672	42,381.7
Organic	2,888,740	2,881.7
Cemented solids	242,054	169.1
Soils	12,916,684	9,930.0
Debris		
Inorganic	46,090,689	26,495.7
Organic	1,097,946	3,472.0
Heterogeneous	3,589,414	9,742.5
Labpacks		
With metals	131,174	167.7
Without metals	99,685	99.3
Reactive/dangerous wastes		
Compressed gases	2,558	4.2
Explosives	830	0.8
Reactive metals	47,021	66.0
Inherently hazardous wastes		
Batteries	16,505	16.8
Beryllium dust	2,205	1.5
Elemental lead	4,290,984	8,249.5
Liquid mercury	270,954	31.8
Multiple wastes	10,628,584	7,309.6
Other wastes	2,350,762	2,922.9
Grand total (DOE complex)	193,005,630	165,164.4

[a]Based on the IMWIR, ref. 7. Detailed site data for these categories are also reported in this reference.

[b]As described in Table 8.6 and ref. 7.

Table 8.8. Projected 5-year (1993-1997) cumulative mass and volume generation, by physical/chemical matrix category, of RCRA- and state-regulated mixed LLW from DOE site operations[a]

Category[b]	Mass (kg)	Volume (m^3)
Liquids		
Aqueous	8,342,923	8,324.0
Organic	8,621,826	9,074.1
Sludges and solids		
Inorganic	7,712,018	5,451.9
Organic	2,014,960	2,054.1
Cemented solids	7,820,412	4,906.9
Soils	654,418	502.8
Debris		
Inorganic	1,322,256	993.1
Organic	2,193,790	2,266.1
Heterogeneous	5,201,567	5,800.8
Labpacks		
With metals	2,826,764	2,742.2
Without metals	3,421,754	3,429.8
Reactive/dangerous wastes		
Compressed gases	11,503	14.5
Explosives	3,100	3.1
Reactive metals	13,936	10.3
Inherently hazardous wastes		
Batteries	131,704	130.2
Beryllium dust	1,050	0.7
Elemental lead	777,622	311.2
Liquid mercury	96,671	91.3
Multiple wastes	11,889,962	8,429.1
Other wastes	463,161	653.6
Grand total (DOE complex)	63,521,397	55,189.8

[a]Based on the IMWIR, ref. 7. Detailed site data for these categories are also reported in this reference.

[b]As described in Table 8.6 and ref. 7.

Table 8.9. Cumulative mass (kg) inventories through 1992, by physical category, of TSCA-regulated mixed LLW from DOE site operations[a,b]

Site	Solid	Liquid	Gas[c]	Sludge	Total
AMES	2,400	0	0	0	2,400
ANL-E	0	0	0	0	0
ANL-W					
BNL	262	0	0	0	262
FEMP					
FNAL	98	0	0	0	98
HANF[d]	94,255	7,560	0	0	101,815
INEL	e	e	0	e	e
ITRI					
K-25					
KCP	0	0	0	0	0
LANL	376,220	3,638	0	0	379,858
LBL	2,790	1,400	0	0	4,190
LLNL	247	5	0	0	252
MOUND	2,490	999	0	0	3,489
NR sites[f]	0	0	0	0	0
NTS					
ORISE					
ORNL	199,289	0	0	0	199,289
PAD	2,379,587	149,538	0	0	2,529,125
PANT					
PINELLAS	0	0	0	0	0
PORTS	1,245,900	95,294	0	90,436	1,431,630
PPPL					
RAP sites[g]	900	0	0	0	900
RFP	21,100	4,020	0	0	25,120
RMI					
SLAC	0	0	0	0	0
SNLA	68	0	0	0	68
SNLL	0	0	0	0	0
SRS	18,656	0	0	0	18,656
WVDP	12,251	0	0	0	12,251
Y-12	5,578,000	294,900	0	h	5,872,900
Total	9,934,513	557,354	0	90,436	10,582,303

[a]Based on the DOE site data submittals of ref. 9. Material may be in interim storage awaiting treatment. Specific site information is provided in Sect. 8.4.

[b]In general, densities of 500 kg/m^3 for compressed gases, 1,000 kg/m^3 for liquids, and 1,500 kg/m^3 for solids and sludges were assumed to calculate masses when the site did not report mass data.

[c]Stored in cylinders.

[d]Includes contributions from PNL.

[e]For INEL, ref. 9(g) reports the following 1992 physical category cumulative mass inventories: solid, 8,600,000 kg; liquid, 179,000 kg; no gas; and sludge, 3,080,000 kg. These inventories are not included in the totals reported in this table because they are included in the INEL RCRA/state waste inventories of the IMWIR (ref. 7).

[f]Includes contributions (if any) from Bettis (BAPL), Knolls (KAPL), and NRF (INEL).

[g]Includes contributions from Battelle (BCLDP) and Santa Susana (SSFL/ETEC).

[h]Unknown.

Table 8.10. Cumulative volume (m^3) inventories through 1992, by physical category, of TSCA-regulated mixed LLW from DOE site operations[a,b]

Site	Solid	Liquid	Gas[c]	Sludge	Total
AMES	2.4	0	0	0	2.4
ANL-E	0	0	0	0	0
ANL-W					
BNL	0.7	0	0	0	0.7
FEMP					
FNAL	0.1	0	0	0	0.1
HANF[d]	79.8	7.6	0	0	87.4
INEL	e	e	0	e	e
IIRI					
K-25					
KCP	0	0	0	0	0
LANL	1,855.1	4.5	0	0	1,859.6
LBL	1.9	1.4	0	0	3.3
LLNL	0.2	<<.1	0	0	0.2
MOUND	2.5	0.9	0	0	3.4
NR sites[f]	0	0	0	0	0
NTS					
ORISE					
ORNL	1,357.0	0	0	0	1,357.0
PAD	3,128.0	165.3	0	0	3,293.3
PANT					
PINELLAS	0	0	0	0	0
PORTS	6,186.0	65.0	0	152.0	6,403.0
PPPL					
RAP sites[g]	5.7	0	0	0	5.7
RFP	46.5	5.5	0	0	52.0
RMI					
SLAC	0	0	0	0	0
SNLA	0.4	0	0	0	0.4
SNLL	0	0	0	0	0
SRS	92.1	0	0	0	92.1
WVDP	32.6	0	0	0	32.6
Y-12	3,719.0	295.0	0	h	4,014.0
Total	16,510.0	545.2	0	152.0	17,207.2

[a]Based on the DOE site data submittals of ref. 9. Material may be in interim storage awaiting treatment. Specific site information is provided in Sect. 8.4.

[b]In general, densities of 500 kg/m^3 for compressed gases, 1,000 kg/m^3 for liquids, and 1,500 kg/m^3 for solids and sludges were assumed to calculate masses when the site did not report mass data.

[c]Stored in cylinders.

[d]Includes contributions from PNL.

[e]For INEL, ref. 9(g) reports the following 1992 physical category cumulative volume inventories: solid, 19,000 m^3; liquid, 178 m^3; no gas; and sludge, 3,100 m^3. These inventories are not reported in this table because they are included in the INEL RCRA/state waste inventories of the IMWIR (ref. 7).

[f]Includes contributions (if any) from Bettis (BAPL), Knolls (KAPL), and NRF (INEL).

[g]Includes contributions from Battelle (BCLDP) and Santa Susana (SSFL/ETEC).

[h]Unknown.

Table 8.11. 1992 mass (kg) generation, by physical category, of TSCA-regulated mixed LLW from DOE site operations[a,b]

Site	Solid	Liquid	Gas[c]	Sludge	Total
AMES	200	0	0	0	200
ANL-E	0	0	0	0	0
ANL-W					
BNL	34	0	0	0	34
FEMP					
FNAL	29	0	0	0	29
HANF[d]	56,245	0	0	0	56,245
INEL	e	0	0	0	e
ITRI					
K-25					
KCP	0	0	0	0	0
LANL	73,822	431	0	0	74,253
LBL[b]	1,560	26	0	0	1,586
LLNL	0	0	0	0	0
MOUND	0	0	0	0	0
NR sites[f]	9,611	0	0	0	9,611
NTS					
ORISE					
ORNL	35,229	0	0	0	35,229
PAD	102,867	69,753	0	0	172,620
PANT					
PINELLAS	0	0	0	0	0
PORTS	297,470	71,950	0	4,360	373,780
PPPL					
RAP sites[g]	900	0	0	0	900
RFP	18,884	0	0	0	18,884
RMI					
SLAC	0	0	0	0	0
SNLA	0	0	0	0	0
SNLL	0	0	0	0	0
SRS	6,740	0	0	0	6,740
WVDP	2,808	0	0	0	2,808
Y-12	50,420	2,134,000	0	h	2,184,420
Total	656,819	2,276,160	0	4,360	2,937,339

[a]Based on the DOE site data submittals of ref. 9. Material may be in interim storage awaiting treatment. Specific site information is provided in Sect. 8.4.

[b]In general, densities of 500 kg/m^3 for compressed gases, 1,000 kg/m^3 for liquids, and 1,500 kg/m^3 for solids and sludges were assumed to calculate masses when the site did not report mass data.

[c]Stored in cylinders.

[d]Includes contributions from PNL.

[e]For INEL, ref. 9(g) reports 760,000 kg of TSCA mixed LLW (solids) generated during 1992. These wastes are not reported in this table, however, because they are part of the INEL RCRA/state waste inventories of the IMWIR (ref. 7).

[f]Includes contributions (if any) from Bettis (BAPL), Knolls (KAPL), and NRF (INEL).

[g]Includes contributions from Battelle (BCLDP) and Santa Susana (SSFL/ETEC).

[h]Unknown.

Table 8.12. 1992 volume (m^3) generation, by physical category, of TSCA-regulated mixed LLW from DOE site operations[a,b]

Site	Solid	Liquid	Gas[c]	Sludge	Total
AMES	1.0	0	0	0	1.0
ANL-E	0	0	0	0	0
ANL-W					
BNL	0.2	0	0	0	0.2
FEMP					
FNAL	<0.1	0	0	0	<0.1
HANF[d]	41.8	0	0	0	41.8
INEL	e	0	0	0	e
ITRI					
K-25					
KCP	0	0	0	0	0
LANL	82.7	0.4	0	0	83.1
LBL	1.0	0.4	0	0	1.4
LLNL	0	0	0	0	0
MOUND	0	0	0	0	0
NR sites[f]	18.9	0	0	0	18.9
NTS					
ORISE					
ORNL	106.0	0	0	0	106.0
PAD	250.3	72.0	0	0	322.3
PANT					
PINELLAS	0	0	0	0	0
PORTS	828.0	20.0	0	30.0	878.0
PPPL					
RAP sites[g]	5.7	0	0	0	5.7
RFP	32.3	0	0	0	32.3
RMI					
SLAC	0	0	0	0	0
SNLA	0	0	0	0	0
SNLL	0	0	0	0	0
SRS	33.7	0	0	0	33.7
WVDP	6.8	0	0	0	6.8
Y-12	34.0	2,134.0	0	h	2,168.0
Total	1,442.5	2,226.8	0	30.0	3,699.3

[a]Based on the DOE site data submittals of ref. 9. Material may be in interim storage awaiting treatment. Specific site information is provided in Sect. 8.4.

[b]Densities of 500 kg/m^3 for compressed gases, 1,000 kg/m^3 for liquids, and 1,500 kg/m^3 for solids and sludges were assumed to calculate masses when the site did not report mass data.

[c]Stored in cylinders.

[d]Includes contributions from PNL.

[e]For INEL, ref. 9(g) reports 1,260 m^3 of TSCA mixed LLW (solids) generated during 1992. These wastes are not reported in this table, however, because they are included in the INEL RCRA/state waste inventories of the IMWIR (ref. 7).

[f]Includes contributions (if any) from Bettis (BAPL), Knolls (KAPL), and NRF (INEL).

[g]Includes contributions from Battelle (BCLDP) and Santa Susana (SSFL/ETEC).

[h]Unknown.

Table 8.13. Cumulative mass (kg) inventories through 1992, by hazard category, of TSCA-regulated mixed LLW from DOE site operations[a]

Site	PCB	Asbestos	Other	Total
AMES	0	2,400	0	2,400
ANL-E	0	0	0	0
ANL-W				
BNL	228	34	0	262
FEMP				
FNAL	98	0	0	98
HANF[b]	101,815	c	0	101,815
INEL	d	0	d	d
ITRI				
K-25				
KCP	0	0	0	0
LANL	19,837	360,021	0	379,858
LBL	410	2,175	1,605[e]	4,190
LLNL	5	247	0	252
MOUND	3,489	0	0	3,489
NR sites[f]	0	0	0	0
NTS				
ORISE				
ORNL	0	199,289	0	199,289
PAD	2,485,418	43,707	0	2,529,125
PANT				
PINELLAS	0	0	0	0
PORTS	1,033,900	397,730	0	1,431,630
PPPL				
RAP sites[g]	0	900	0	900
RFP	9,860	15,260	0	25,120
RMI				
SLAC	0	0	0	0
SNLA	0	68	0	68
SNLL	0	0	0	0
SRS	636	18,020[h]	0	18,656
WVDP	4,196	8,055	0	12,251
Y-12	5,872,900	0	0	5,872,900
Total	9,532,792	1,047,906	1,605	10,582,303

[a]Based on the DOE site data submittals of ref. 9. Material may be in interim storage awaiting treatment. Specific site information is provided in Sect. 8.4.

[b]Includes contributions from PNL.

[c]Unknown.

[d]For INEL, ref. 9(g) reports no asbestos and 230 kg of PCB wastes. These are part of a 1992 cumulative TSCA-regulated waste inventory of 11,859,000 kg. These inventories are not included in this table, however, because they are part of the INEL RCRA/state waste inventories of the IMWIR (ref. 7).

[e]Pump oil contaminated with tritium.

[f]Includes contributions (if any) from Bettis (BAPL), Knolls (KAPL), and NRF (INEL).

[g]Includes contributions from Battelle (BCLDP) and Santa Susana (SSFL/ETEC).

[h]Estimated from volume data assuming a density of 200 kg/m^3.

Table 8.14. Cumulative volume (m^3) inventories through 1992, by hazard category, of TSCA-regulated mixed LLW from DOE site operations[a]

Site	PCB	Asbestos	Other	Total
AMES	0	2.4	0	2.4
ANL-E	0	0	0	0
ANL-W				
BNL	0.5	0.2	0	0.7
FEMP				
FNAL	0.1	0	0	0.1
HANF[b]	87.4	c	0	87.4
INEL	d	0	d	d
ITRI				
K-25				
KCP	0	0	0	0
LANL	56.8	1,802.8	0	1,859.6
LBL	0.4	1.5	1.4[e]	3.3
LLNL	<<.1	0.2	0	0.2
MOUND	3.4	0	0	3.4
NR sites[f]	0	0	0	0
NTS				
ORISE				
ORNL	0	1,357.0	0	1,357.0
PAD	3,121.5	171.8	0	3,293.3
PANT				
PINELLAS	0	0	0	0
PORTS	2,901.0	3,502.0	0	6,403.0
PPPL				
RAP sites[g]	0	5.7	0	5.7
RFP	26.8	25.2	0	52.0
RMI				
SLAC	0	0	0	0
SNLA	0	0.4	0	0.4
SNLL	0	0	0	0
SRS	2.0	90.1	0	92.1
WVDP	5.1	27.5	0	32.6
Y-12	4,014.0	0	0	4,014.0
Total	10,219.0	6,986.8	1.4	17,207.2

[a]Based on the DOE site data submittals of ref. 9. Material may be in interim storage awaiting treatment. Specific site information is provided in Sect. 8.4.

[b]Includes contributions from PNL.

[c]Unknown.

[d]For INEL, ref. 9(g) reports no asbestos and 0.2 m^3 of PCB wastes. These are part of a 1992 cumulative TSCA-regulated waste inventory of 22,278 m^3. These inventories are not included in this table, however, because they are part of the INEL RCRA/state waste inventories of the IMWIR (ref. 7).

[e]Pump oil contaminated with tritium.

[f]Includes contributions (if any) from Bettis (BAPL), Knolls (KAPL), and NRF (INEL).

[g]Includes contributions from Battelle (BCLDP) and Santa Susana (SSFL/ETEC).

Table 8.15. 1992 mass (kg) generation, by hazard category, of TSCA-regulated mixed LLW from DOE site operations[a]

Site	PCB	Asbestos	Other	Total
AMES	0	200	0	200
ANL-E	0	0	0	0
ANL-W				
BNL	0	34	0	34
FEMP				
FNAL	29	0	0	29
HANF[b]	56,245	c	0	56,245
INEL	d	d	0	d
ITRI				
K-25				
KCP	0	0	0	0
LANL	68,948	5,305	0	74,253
LBL	40	1,500	46[e]	1,586
LLNL	0	0	0	0
MOUND	0	0	0	0
NR sites[f]	0	9,611	0	9,611
NTS				
ORISE				
ORNL	0	35,229	0	35,229
PAD	151,369	21,251	0	172,620
PANT				
PINELLAS	0	0	0	0
PORTS	184,600	189,180	0	373,780
PPPL				
RAP sites[g]	0	900	0	900
RFP	284	18,600	0	18,884
RMI				
SLAC	0	0	0	0
SNLA	0	0	0	0
SNLL	0	0	0	0
SRS	0	6,740[h]	0	6,740
WVDP	0	2,808	0	2,808
Y-12	2,184,420	0	0	2,184,420
Total	2,645,935	291,358	46	2,937,339

[a]Based on the DOE site data submittals of ref. 9. Material may be in interim storage awaiting treatment. Specific site information is provided in Sect. 8.4.

[b]Includes contributions from PNL.

[c]Unknown.

[d]For INEL, ref. 9(g) reports a 1992 generation of 760,000 kg, comprised of 680,000 kg of PCBs and 80,000 kg of asbestos. These contributions are not included in this table, however, because these wastes are part of the INEL RCRA/state waste inventories of the IMWIR (ref. 7).

[e]Pump oil contaminated with tritium.

[f]Includes contributions (if any) from Bettis (BAPL), Knolls (KAPL), and NRF (INEL).

[g]Includes contributions from Battelle (BCLDP) and Santa Susana (SSFL/ETEC).

[h]Estimated from volume data assuming a density of 200 kg/m^3.

Table 8.16. 1992 volume (m^3) generation, by hazard category, of TSCA-regulated mixed LLW from DOE site operations[a]

Site	PCB	Asbestos	Other	Total
AMES	0	1.0	0	1.0
ANL-E	0	0	0	0
ANL-W				
BNL	0	0.2	0	0.2
FEMP				
FNAL	<0.1	0	0	<0.1
HANF[b]	41.8	c	0	41.8
INEL	d	d	0	d
ITRI				
K-25				
KCP	0	0	0	0
LANL	46.0	37.1	0	83.1
LBL	<<0.1	1.0	0.4[e]	1.4
LLNL	0	0	0	0
MOUND	0	0	0	0
NR sites[f]	0	18.9	0	18.9
NTS				
ORISE				
ORNL	0	106.0	0	106.0
PAD	230.0	92.3	0	322.3
PANT				
PINELLAS	0	0	0	0
PORTS	411.0	467.0	0	878.0
PPPL				
RAP sites[g]	0	5.7	0	5.7
RFP	1.5	30.8	0	32.3
RMI				
SLAC	0	0	0	0
SNLA	0	0	0	0
SNLL	0	0	0	0
SRS	0	33.7	0	33.7
WVDP	0	6.8	0	6.8
Y-12	2,168.0	0	0	2,168.0
Total	2,898.4	800.5	0.4	3,699.3

[a]Based on the DOE site data submittals of ref. 9. Material may be in interim storage awaiting treatment. Specific site information is provided in Sect. 8.4.

[b]Includes contributions from PNL.

[c]Unknown.

[d]For INEL, ref. 9(g) reports a 1992 generation of 1,260 m^3, comprised of 580 m^3 of PCBs and 680 m^3 of asbestos. These contributions are not included in this table, however, because these wastes are part of the INEL RCRA/state waste inentories of the IMWIR (ref. 7).

[e]Pump oil contaminated with tritium.

[f]Includes contributions (if any) from Bettis (BAPL), Knolls (KAPL), and NRF (INEL).

[g]Includes contributions from Battelle (BCLDP) and Santa Susana (SSFL/ETEC).

Table 8.17. Historical and projected annual volume (m^3) generation rates for RCRA- and state-regulated mixed LLW from DOE site environmental restoration activities[a]

Site	1992 and prior[b]	1993	1994	1995	1996	1997	Projected total[c]
AMES	0		1,000				1,000
ANL-E	0	9.9	10	9.5	9.5	9.4	48.3
ANL-W	0						
BNL	0		8.6			85	93.6
FEMP	2,500	230	34,000	34,000	34,000	63,000	165,230
FNAL	0						
HANF[d]	6.9	14	59	130	350	500	1,053
INEL	11	180	46	5,300	8,500	48	14,074
ITRI	0						
K-25	1[e]	70	220	65	24	220	599
KCP	0						
LANL	0						
LBL	0						
LLNL	0					8,100	8,100
MOUND	1.8		28	57	57	57	199
NR sites[f]	0						
NTS	0			10	120,000	83,000	203,010
ORISE	0						
ORNL	0	1	5	6	6	8	26
PAD	7[e]	1,400	4,500	6,200	3,500	9,000	24,600
PANT	0	720	120				840
PINELLAS	0						
PORTS	18[e]	550	360	1,100	1,100	620	3,730
PPPL	0						
RAP sites[g]	110.6	101	1,601	1,601	101	101	3,505
RFP	43	77	11,000	41,000	41,000	55,000	148,077
RMI	15.9	3.2	3.2	3.2	3.2	3.2	16.0
SLAC	0						
SNLA	0	70	110	140	8,800	9,400	18,520
SNLL	0						
SRS	0	7.8	7.8	7.8	7.8	7.8	39.0
WVDP	0						
Y-12	29[e]	140	59	34	160	33	426
Others[h]	24,476.1	8.5	20				28.5
Total	27,220.3	3,582.4	53,157.6	89,663.5	217,618.5	229,192.4	593,214.4

[a]Based on the IMWIR, ref. 7.
[b]Actual data.
[c]Totals for the period 1993-1997.
[d]Includes contributions from PNL.
[e]Does not include contributions from years prior to 1992.
[f]Includes contributions (if any) from Bettis (BAPL), Knolls (KAPL), and NRF (INEL).
[g]Includes contributions (if any) from Battelle (BCLDP), Colonie (CISS), Grand Junction (GJPO), Santa Susana (SSFL/ETEC), and Weldon Spring (WSSRAP).
[h]Includes contributions (if any) from General Atomic (California), Laboratory for Energy-Related Health Research (California), Middlesex Sampling Plant (New Jersey), and Palo Forest Reserve (Illinois).

Table 8.18. Historical and projected annual mass (kg) generation rates for TSCA-regulated mixed LLW from DOE site operations[a]

Site	1992[b]	1993	1994	1995	1996	1997	1998-2030[c]
AMES	200	50	50	d	d	d	d
ANL-E	0	0	188,528	31,467	31,467	24	24
ANL-W							
BNL	34	40	42	44	44	44	40
FEMP							
FNAL	29	30	30	30	30	30	10
HANF[e]	56,245	18,500	18,500	18,500	18,500	18,500	18,500
INEL	f	0	0	0	0	0	0
ITRI							
K-25							
KCP	0	0	0	0	0	0	0
LANL	74,253	28,000	31,000	37,000	37,000	31,000	28,000
LBL	1,586	1,400	1,400	1,400	1,400	1,400	1,400
LLNL	0	0	0	0	0	0	0
MOUND	0	0	0	0	0	0	0
NR sites[g]	9,611	9,918	10,318	10,190	9,605	9,435	9,275
NTS							
ORISE							
ORNL	35,229	4,827	15,027	15,027	15,027	15,027	15,027
PAD	172,620	461,605	461,190	460,810	460,810	460,810	460,810
PANT							
PINELLAS	0	0	0	0	0	0	0
PORTS	373,780	d	d	d	d	d	d
PPPL							
RAP sites[h]	900	16,950	17,800	16,500	16,500	16,500	1,500
RFP	18,884	84,000	3,180	19,400	2,500	19,400	18,800
RMI							
SLAC	0	0	0	0	0	0	0
SNLA	0	d	d	d	d	d	d
SNLL	0	0	0	0	0	0	0
SRS	6,740	5,320	5,320	5,320	5,320	5,320	5,320
WVDP	2,808	4,689	4,632	4,632	4,632	4,632	4,663
Y-12	2,184,420	d	d	d	d	d	d
Total	2,937,339	635,329	757,017	620,320	602,835	582,122	563,369

[a]Based on the DOE site data submittals of ref. 9. Specific site information is provided in Sect. 8.4.

[b]Actual data.

[c]Average annual generation rate anticipated for this period.

[d]Information not available.

[e]Includes contributions from PNL.

[f]For INEL, ref. 9(g) reports a 1992 generation of 760,000 kg of TSCA-regulated wastes, which are included in the site's RCRA/state waste inventories reported in the IMWIR (ref. 7).

[g]Includes contributions (if any) from Bettis (BAPL), Knolls (KAPL), and NRF (INEL).

[h]Includes contributions from Battelle (BCLDP) and Santa Susana (SSFL/ETEC).

Table 8.19. Historical and projected annual volume (m^3) generation rates for TSCA-regulated mixed LLW from DOE site operations[a]

Site	1992[b]	1993	1994	1995	1996	1997	1998-2030[c]
AMES	1.0	<0.1	<0.1	d	d	d	d
ANL-E	0	0	470.8	78.6	78.6	<0.1	<0.1
ANL-W							
BNL	0.2	0.3	0.3	0.3	0.3	0.3	0.3
FEMP							
FNAL	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<<0.1
HANF[e]	41.8	15.9	15.9	15.9	15.9	15.9	15.9
INEL	f	0	0	0	0	0	0
ITRI							
K-25							
KCP	0	0	0	0	0	0	0
LANL	83.1	45.0	50.0	60.0	60.0	50.0	45.0
LBL	1.4	1.4	1.4	1.4	1.4	1.4	1.4
LLNL	0	0	0	0	0	0	0
MOUND	0	0	0	0	0	0	0
NR sites[g]	18.9	20.5	20.5	20.2	17.2	16.8	16.5
NTS							
ORISE							
ORNL	106.0	36.4	56.6	56.6	56.6	56.6	56.6
PAD	322.3	609.0	608.5	608.0	608.0	608.0	608.0
PANT							
PINELLAS	0	0	0	0	0	0	0
PORTS	878.0	d	d	d	d	d	d
PPPL							
RAP sites[h]	5.7	18.0	20.8	16.5	16.5	16.5	1.5
RFP	32.3	6.3	21.8	37.0	21.0	37.0	32.0
RMI							
SLAC	0	0	0	0	0	0	0
SNLA	0	d	d	d	d	d	d
SNLL	0	0	0	0	0	0	0
SRS	33.7	26.6	26.6	26.6	26.6	26.6	26.6
WVDP	6.8	19.2	19.2	19.2	19.2	19.2	19.2
Y-12	2,168.0	d	d	d	d	d	d
Total	3,699.3	798.7	1,312.5	940.4	921.4	848.4	823.1

[a]Based on the DOE site data submittals of ref. 9. Specific site information is provided in Sect. 8.4.

[b]Actual data.

[c]Average annual generation rate anticipated for this period.

[d]Information not available.

[e]Includes contributions from PNL.

[f]For INEL, ref. 9(g) reports a 1992 generation of 1,260 m^3 of TSCA-regulated watses, which are included in the site's RCRA/state waste inventories reported in the IMWIR (ref. 7).

[g]Includes contributions (if any) from Bettis (BAPL), Knolls (KAPL), and NRF (INEL).

[h]Includes contributions from Battelle (BCLDP) and Santa Susana (SSFL/ETEC).

Table 8.20. National commercially generated mixed LLW profile volume summary, by facility category[a]

Facility category	Waste volume, m^3		
	Generated in 1990	Stored as of Dec. 31, 1990[b]	Treated in 1990[c]
Academic	820.7	154.2	1,581.9
Government	750.4	78.9	612.5
Industrial	1,428.0	1,197.3	1,115.1
Medical	563.6	63.1	466.3
Nuclear power plants	385.8	622.5	216.9
Total[d]	3,948.5	2,116.0	3,992.6

[a]Based on ref. 10.
[b]This is not the amount of mixed waste requiring disposal. Some of this waste was being accumulated for treatment.
[c]Treated wastes may include mixed wastes generated in years prior to 1990.
[d]Total reported in this table may not equal the sum of component entries because of round-off and truncation of numbers.

Table 8.21. National commercially generated mixed LLW profile volume summary, by hazardous waste stream[a]

Hazardous stream	Waste volume, m^3		
	Generated in 1990	Stored as of Dec. 31, 1990[b]	Treated in 1990[c]
Organics			
Liquid scintillation fluids	2,837.2	363.4	3,371.8
Waste oil	148.9	178.1	139.4
Chlorinated organics	70.9	27.0	23.2
Fluorinated organics	0	3.5	0
Chlorinated fluorocarbons (CFCs)	113.2	254.7	3.7
Other organics	274.6	117.9	258.9
Total organics[d]	3,444.8	944.6	3,797.0
Metals			
Lead	81.6	138.7	6.1
Mercury	12.5	81.1	1.5
Chromium	28.4	53.3	3.9
Cadmium	0.3	745.2	0.1
Total metals[d]	122.8	1,018.3	11.6
Aqueous corrosives	80.4	12.2	2.6
Other hazardous materials	300.5	141.0	181.4
Grand totals[d]	3,948.5	2,116.0	3,992.6

[a]Based on ref. 10.
[b]This is not the amount of mixed waste requiring disposal. Some of this waste was being accumulated for treatment.
[c]Treated wastes may include mixed wastes generated in years prior to 1990.
[d]Totals reported in this table may not equal the sum of component entries because of round-off and truncation of numbers.

APPENDIX A. MISCELLANEOUS RADIOACTIVE MATERIALS

APPENDIX A. MISCELLANEOUS RADIOACTIVE MATERIALS

A.1 INTRODUCTION

This appendix lists year-end 1992 inventories of miscellaneous radioactive materials (MRM) at seven major DOE sites and one commercial site, the Babcock & Wilcox (B&W) Nuclear Environmental Services Lynchburg Technology Center site at Lynchburg, Virginia. Information on inventories at the end of calendar-year 1992 was collected by direct contact with these sites.

The types of materials covered in this appendix represent principally wastes that will probably require repository disposal but that are not covered specifically in the preceding chapters of this report. However, there may be some overlap with materials covered elsewhere in this report (particularly in Chapter 1) because much of the miscellaneous material reported by the sites consists of whole or sectioned fuel rods or assemblies that originated in commercial reactors and were used in various DOE-related experimental programs.

Damaged fuel assemblies and core debris from the TMI-Unit 2 reactor are included in this appendix as part of the inventory at INEL.

This appendix does not include spent fuels from naval reactors and defense production reactors, which are discussed briefly in Chapter 1. Also, it does not include greater-than-Class-C low-level waste (GTCC LLW), which is covered in Chapter 4.

The map of Fig. A.1 shows the current locations of MRM, and Fig. A.2 compares the masses of MRM now stored at the various sites.

A.2 INVENTORIES AND PROJECTIONS

Table A.1 summarizes the current inventories of MRM at the eight major sites. Tables A.2 through A.9 describe the separate materials at each site in more detail. The data presented in Tables A.1 through A.9 (derived from refs. 1–9) will be useful in planning for final disposal of these materials in a repository. As previously noted, some quantities of the commercially generated spent fuels reported in Tables A.2–A.9 may already be covered in Chapter 1 of this report. The spent-fuel inventories reported in Tables A.2–A.9 will be reviewed to identify clearly any possible overlaps between the inventories in these tables and those reported in Chapter 1. Any spent-fuel inventory overlaps identified from this investigation will be clarified in subsequent editions of this report.

Last year's IDB report listed miscellaneous materials inventoried at the Hanford 200-Area burial grounds. As noted in Table A.5, these materials have been reclassified as TRU waste and, therefore, are no longer classified in the MRM category.

Inventories of special radioactive materials stored at INEL are given in Table A.6. These include materials stored at the Idaho Chemical Processing Plant (ICPP) and the Naval Reactors Facility (NRF). The spent fuels that are included in these inventories are scheduled to be stored indefinitely.[10–11] If required, future special campaigns could reprocess many of these spent fuels.

The spent fuels now inventoried at the SRS (Table A.9) are not currently regarded as reprocessible because of the lack of defined reprocessing schemes or required facilities. Therefore, this fuel is considered by SRS to be in indefinite storage.[12]

Recently, DOE made the decision to phase out the reprocessing of spent fuel from defense production reactors. INEL and the SRS are preparing phase-out plans. A summary of DOE spent fuel no longer scheduled for reprocessing is given in Sect. 1.4 of this report.

A recent submittal from INEL[13] contains data that supersedes and augments some of the information in ref. 5; however, the recent submittal was received too late to be incorporated in this year's IDB. After updating as necessary, it will be incorporated in next year's IDB.

A.3 REFERENCES

1. G. C. Marshall, Argonne National Laboratory-West, Idaho Falls, Idaho, letter to R. Salmon, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Update of Argonne National Laboratory-West Miscellaneous Radioactive Materials Data for the 1993 Integrated Data Base Report," dated June 10, 1993.

2. K. D. Long, Babcock & Wilcox Nuclear Environmental Services, Lynchburg, Virginia, letter to R. Salmon, Oak Ridge National Laboratory, Oak Ridge, Tennessee, dated Apr. 19, 1993.

3. D. A. Dickman, Battelle Pacific Northwest Laboratory, Richland, Washington, letter to R. Salmon, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Update of PNL Miscellaneous Radioactive Materials Inventory for the 1993 Integrated Data Base Report," dated Apr. 26, 1993.

4. R. D. Wojtasek, Westinghouse Hanford Company, Richland, Washington, letter to R. Salmon, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Update of Westinghouse Hanford Miscellaneous Radioactive Materials Data for the 1993 Integrated Data Base Report," dated Apr. 30, 1993.

5. A. P. Hoskins, Westinghouse Idaho Nuclear Company, Inc., Idaho Falls, Idaho, letter to M. J. Bonkoski, DOE/ID, Idaho Falls, Idaho, APH-33-93, dated Apr. 28, 1993.

6. D. R. Connors, Westinghouse Electric Corporation, Bettis Atomic Power Laboratory, West Mifflin, Pennsylvania, letter to R. Salmon, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Update of Idaho Naval Reactors Facility Miscellaneous Radioactive Materials for the 1993 Integrated Data Base Report," dated Apr. 28, 1993.

7. A. Martinez, Los Alamos National Laboratory, Los Alamos, New Mexico, letter to R. Salmon, Oak Ridge National Laboratory, Oak Ridge, Tennessee, dated June 24, 1993.

8. A. M. Krichinsky, Oak Ridge National Laboratory, Oak Ridge, Tennessee, personal communication to S. N. Storch, Oak Ridge National Laboratory, Oak Ridge, Tennessee, dated Apr. 14, 1993.

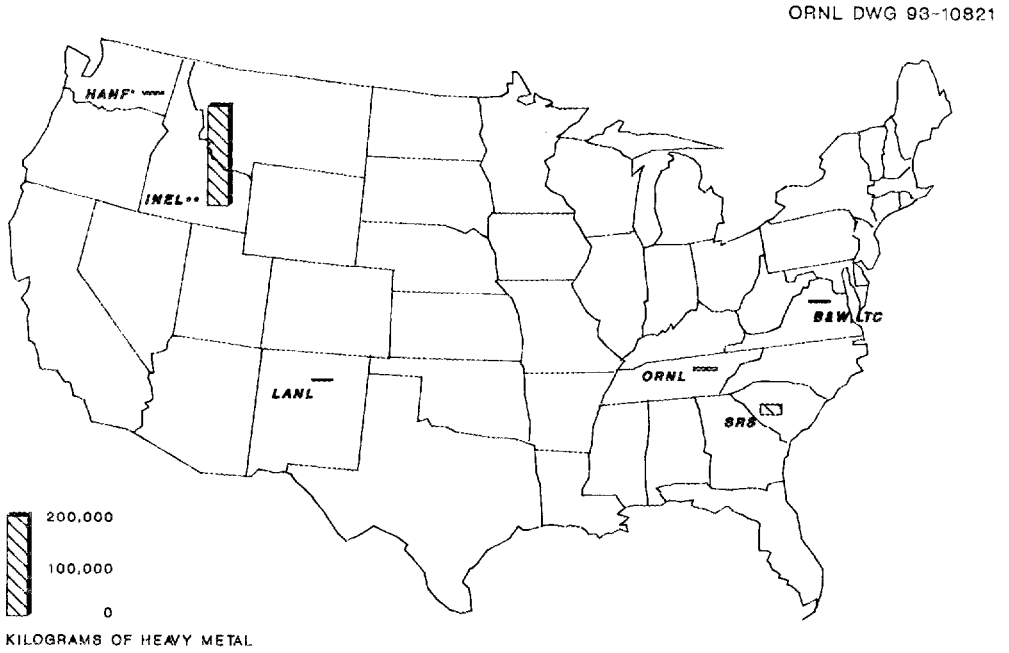
9. S. W. McAlhany, DOE Field Office, Savannah River, Aiken, South Carolina, letter to R. Salmon, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Update of Savannah River Site Spent Fuel Inventory," dated Apr. 12, 1993.

10. D. A. Knecht, Westinghouse Idaho Nuclear Company, Inc., Idaho Falls, Idaho, letter to M. J. Bonkoski, DOE/ID, Idaho Falls, Idaho, "CY-91 Integrated Data Base Information," DAK-23-92, dated Mar. 17, 1992.

11. D. R. Connors, Westinghouse Electric Corporation, Bettis Atomic Power Laboratory, West Mifflin, Pennsylvania, letter to R. L. Pearson, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Update of Idaho Naval Reactors Facilities Miscellaneous Waste Inventory for the 1992 Integrated Data Base Report," dated May 5, 1992.

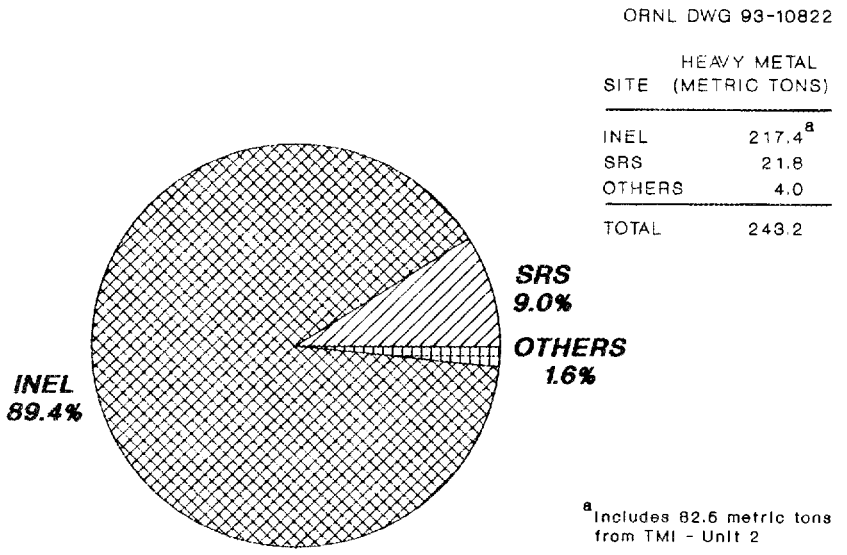
12. W. C. Dennis, Jr., DOE Field Office, Savannah River, Aiken, South Carolina, letter to R. L. Pearson, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Update of Savannah River Site (SRS) Miscellaneous Spent Fuel for the 1992 Integrated Data Base Report," dated May 4, 1992.

13. J. H. Clark, EG&G Idaho, Inc., Idaho Falls, Idaho, letter to J. A. Klein, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "The Integrated Data Base (IDB), Revision 8-JHC-32-94," dated Feb. 16, 1994.



*Includes contribution from both PNL and 200 Area burial grounds.
**Includes contributions from ANL-W, ICPP, NRF, and other facilities.

Fig. A.1. Locations and total masses of miscellaneous radioactive materials through 1992.



SITE	HEAVY METAL (METRIC TONS)
INEL	217.4[a]
SRS	21.8
OTHERS	4.0
TOTAL	243.2

[a]Includes 82.6 metric tons from TMI - Unit 2

Fig. A.2. Mass and locations of miscellaneous radioactive materials as of December 31, 1992.

Table A.1. Inventory of miscellaneous radioactive materials as of December 31, 1992, that may require geologic disposal

Storage site and location	Total candidate materials (kg)	Uranium content, kg			Total plutonium content (kg)	Total thorium content (kg)
		Total	^{235}U	^{233}U[a]		
Reported potential miscellaneous materials inventory						
Argonne National Laboratory–West, Idaho Falls, ID	341.21	332.20	41.440		9.012	
Babcock & Wilcox, Lynchburg Technology Center, Lynchburg, VA	102.33	101.50	1.317		<0.833	
Battelle Pacific Northwest Laboratory, Richland, WA	2,309.9	2,273.3	20.9		29.7	6.9
Hanford 200-Area burial grounds, Richland, WA	0.0	0.0	0.0		0.0	
Idaho National Engineering Laboratory, Idaho Falls, ID[b]	217,360.1	164,026.0	6,837.6	962.53	470.1	52,864
Los Alamos National Laboratory, Los Alamos, NM	19.44	18.13	14.67	0.058	1.31	
Oak Ridge National Laboratory, Oak Ridge, TN	1,253.29	1,252.49	798.7	280.29	0.801	
Savannah River Site, Aiken, SC	21,783.74	13,092.33	762.46	31.16	43.21	8,648.2
Total reported	243,190.0	181,095.95	8,477.09	1,274.04	554.96	61,539.1

[a]Some of the ^{233}U waste may be certifiable as TRU waste and would therefore be reported in Chapter 3 in the future.

[b]Many of the fuels at ICPP have a lower uranium enrichment than that of fuels normally processed. These fuels could be reprocessed in a special campaign, if required.

Table A.2. Miscellaneous radioactive materials inventory at Argonne National Laboratory-West, as of December 31, 1992[a]

Source of material	Composition	Description[b]	U content, kg		Total Pu content (kg)
			Total	^{235}U	
Radioactive Waste and Scrap Facility[c]					
Basic research-ANL	Scrap	In canister[d]	182.00	12.980	5.052
EBR-2 blanket subassembly	Scrap	In canister[d]	134.35	21.62	0.242
LMFBR test fuel	Scrap	In canister[d]	13.33	5.253	3.026
Postirradiation test on NUMEC[e] LMFBR	Scrap	In canister[d]	0.72	0.345	0.123
Sodium Loop Safety Facility	Scrap	In canister[d]	1.80	1.242	0.569
Total			332.20	41.44	9.012

[a]See ref. 1.

[b]Information regarding the burnup of this scrap may be available.

[c]Radioactive Scrap and Waste Facility is located approximately 0.5 miles north of ANL-W site.

[d]Canisters are retrievable and constructed of stainless steel with minimum dimensions of 8-in. OD and 5-ft length. The canister lid is gasketed and tightly screwed on, welded closed, or screwed into a canister fitted with pipe threads.

[e]Nuclear Uranium Materials Equipment Corporation.

Table A.3. Miscellaneous radioactive materials inventory at B&W Nuclear Environmental Services, Inc., Lynchburg Technology Center, as of December 31, 1992[a]

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM)	U content, kg		Total Pu content (kg)
				Total	^{235}U	
Arkansas I	UO_2, Zr-clad	Three full-length rods; three sectioned rods in four 4.25-in.-diam × 33-in. Al canisters	47,000	11.762	0.046	0.133
B&W Test Reactor	UO_2, Zr-clad	In fourteen 4.25-in.-diam × 33-in. Al canisters	Unknown[c]	0.015	0.005	<0.0005
Consolidated Edison	UO_2, Zr-clad	Four sectioned rods in 4.25-in.-diam × 33-in. Al canisters	29,523	10.849	0.060	0.088
Hot-cell solid waste	Miscellaneous[d]	In forty-four 80-gal drums, thirty-six 55-gal drums, and ninety-two 30-gal drums		e	e	<0.082[f]
Oconee I	UO_2, Zr-clad	Twenty-three sectioned rods in twenty-six 4.25-in.-diam × 33-in. Al canisters	18,686	0.531	0.004	0.003
			24,080	2.159	0.028	0.017
			26,480	6.482	0.033	0.056
			31,160	4.275	0.041	0.037
			39,180	11.000	0.057	0.101
			50,000	8.517	0.030	0.094
	UO_2, Zr-clad	One full-length rod (archive fuel rod No. 15181)	50,000	2.062	0.007	
	UO_2, Zr-clad	Five full-length rods; three sectioned rods	59,300	14.543	0.047	
	UO_2-Gd_2O_3, Zr-clad	In four 4.25-in.-diam × 33-in. Al canisters	15,000	7.911	0.103	0.048
Oconee II	UO_2, Zr-clad	Eight sectioned rods in seven 4.25-in.-diam × 33-in. Al canisters	27,500	10.711	0.105	0.095
			31,000	6.432	0.057	0.056
			36,000	1.999	0.015	0.020
TMI-Unit 2	UO_2 debris	In one 4.25-in.-diam × 33-in. Al canister	Unknown[c]	0.047	0.0307	<0.0005

Table A.3 (continued)

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM)	U content, kg		Total Pu content (kg)
				Total	^{235}U	
Various fuel scrap samples	UO_2, Zr-clad	In one 4.25-in.-diam × 33-in. Al canister	Unknown[c]	2.202	0.702	<0.0005
Total				101.497	1.371	<0.833

[a]See ref. 2.
[b]Zr-clad = Zircaloy-clad.
[c]Currently in underground storage tubes.
[d]Miscellaneous materials from periodic hot-cell cleanup.
[e]Negligible.
[f]Calculated assuming a contamination level of <0.5 g of plutonium per drum.

Table A.4. Miscellaneous radioactive materials inventory at Battelle Pacific Northwest Laboratory, as of December 31, 1992[a]

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM)	U content, kg		Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U		
Calvert Cliffs	UO_2, Zr-clad	Fuel rods 0.440-in. diam × 147 in. (full-length rods)					
		175 intact rods, 1 cut rod[c]	30,000	370.5	2.6	5.3	
		154 intact rods, 1 cut rod[c]	45,000	293.5	1.7	7.7	
Cooper	UO_2, Zr-clad	98 rods[c]	28,000	365.9	2.5	3.1	
H. B. Robinson	UO_2, Zr-clad	19 cut fuel rod sections[c]	28,000	35.1	0.3	0.3	
Miscellaneous scrap and fuel	Cut pieces, scrap	In hot cells	Unknown	31.7	3.4	2.6	0.2
PNL Lot Numbers:							
ATM-5		Glass mix		0.1	d	d	
ATM-6		Glass mix		0.1	d	d	
Point Beach-1	UO_2, Zr-clad	3 intact fuel assemblies, miscellaneous cut samples	33,000	1,164.5	10.3	10.6	6.7
Shippingport			24,000	3.6	d	d	
VBWR[e]	UO_2, Zr-clad	6 rodlets and 160-in. fuel rod segments	7,500-33,000	8.3	0.1	0.1	
Total				2,273.3	20.9	29.7	6.9

[a]See ref. 3.
[b]Zr-clad = Zircaloy-clad.
[c]Rods are in a hot cell.
[d]Negligible.
[e]Vallecitos boiling-water reactor.

Table A.5. Miscellaneous radioactive materials inventory at the Hanford 200-Area burial grounds, as of December 31, 1992

Source of material	Composition	Description	U content, kg		Total Pu content (kg)
			Total	^{235}U	
This material is no longer in the miscellaneous radioactive materials category[a]					

[a]In accordance with ref. 4, this material has been reclassified as remote-handled TRU waste. Its characteristics are reported in Table C.13 of Appendix C.

Table A.6. Miscellaneous radioactive materials inventory at the Idaho National Engineering Laboratory, as of December 31, 1992[a]

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM or % of initial loading)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
DOE/Defense plus other government agency materials inventory at Idaho Chemical Processing Plant (ICPP)								
Advanced test reactor (ATR)	UAl_x fuel, Al-clad	808 assemblies 5.4 × 49.5 in.	41% (avg.)	666.7	543.4		1.82	
Gas-cooled reactor experiment (GCRE)	UO_2-MgO, some in pellets and some Hastelloy-clad	Two cans, one SS and one Al	NA	0.984	0.918			
Miscellaneous Al-clad fuel (ARMF, HFBR, ORR)	UAl_x fuel, Al-clad	15 plates 3.1 × 0.065 × 25.2 in.; 240 elements 2.9 × 3.2 × 24.5 in.; 17 elements 3 × 3 × 25.6 in.	NA	66.80	53.42			
Miscellaneous SS-clad fuel (APPR, BMI, GETR, SPSS, and SPEC)	UO_2 and U metal with SS in the fuel, all SS-clad	APPR — one SS can 5 × 36 in.; BMI — three Al or SS cans 6 × 12 in.; GETR — ten SS cans 5.5 × 3.64 in.; SPEC — one Al can 4 × 24 in.	NA	9.459	6.16			
Shippingport light-water breeder reactor (LWBR)	UO_2 ceramic fuel pellets with Th, Zr, and Ca oxides, Zr-clad; Th blanket	48 elements 10 × 103 in. in 24 SS cans 25.5 × 158 in.	NA	656.64	10.56	523.68	0.177	41,933
Shippingport LWBR (unirradiated)	UO_2 ceramic fuel pellets with Th, Zr, and Ca oxides, Zr-clad	40 elements, Zr-clad, contained in SS cans	None	323.6		302.4		14.4
Stationary media (SM-1A)	UO_2 in SS powder fuel, SS-clad	93 assemblies 2.9 × 2.9 × 33.6 in. in 93 SS cans 4.9 × 39 in.	5,124 (avg.)	65.759	56.648			
TORY-IIA	UO_2-BeO with Ca cermet	146 Al cans 4.5 × 22 in.	0.9%	48.645	45.325			

Table A.6 (continued)

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM or % of initial loading)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
DOE/Defense plus other government agency materials inventory at ICPP (continued)								
TORY-IIC	UO_2-Y_2O_3-ZrO_2-BeO ceramic pellets crushed to 0.25 × 0.06 in.	655 Al tubes 2.75 × 54 in. in 23 canisters	1.5%	58.95	55.86			
Subtotal				1,897.5	777.3	826.08	1.997	41,947
DOE/Civilian Development Programs materials inventory at ICPP								
Boiling reactor experiment No. 5 (BORAX-V)	UO_2 with SS and 2.5% Si, SS-clad	36 assemblies 3.6 × 3.9 × 36 in.	NA	20.8	19.4			
Experimental breeder reactor-2 (EBR-2)	Fuel is U metal with 5% fissium,[c] metallic sodium bonding, SS-clad	41,951 elements 0.174 × 23.8 in. in 3,688 SS cans 2 × 25.5 in.	25,000-30,000	1,967.5	1,224.97		5.2	
Fermi reactor core-1 & 2	U-Mo alloy fuel, metallic sodium bonding, Zr-clad, some declad	214 assemblies canned in 214 Al cans 3.1 × 43 in.	2%	3,911.06	997.45		2.0	
Fermi reactor core-1 blanket	U-Mo alloy fuel, metallic sodium bonding, SS-clad	510 assemblies canned in 14 SS cans 25.5 × 156.5 in.	<1%	34,165	120		6.63	
Fort St. Vrain Reactor (FSVR)	U-Th carbide and Th carbide, pyrolytic carbon-coated particles in graphite matrix	744 assemblies 14 × 16 × 31 in.	6,000-26,000	308.33	167.648	90.139	0.752	8,316.6
Miscellaneous Al-clad (University of Washington)	UAl_x in an Al matrix	26 bundles 2.9 × 2.4 × 27 in.	0.44%	4.056	3.80			
Miscellaneous unirradiated SS-clad (ANL-W, EBR-II scrap)	U-5% fissium,[c] SS-clad	56 SS cans	None	55.7	21.64			

Table A.6 (continued)

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM or % of initial loading)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
DOE/Civilian Development Programs materials inventory at ICPP (continued)								
Miscellaneous unirradiated (ANL foils, VYCOR glass)	U-metal foils and U-metal mixed with glass	13 drums	None	38.171	34.435			
Missouri University Research Reactor (MURR)	UAl_x with SS rollers and Al in the matrix, Al-clad	56 assemblies 4 × 4.5 × 32.5 in.	20-24%	38.02	33.21			
Pathfinder	UO_2-B_4C and SS in the matrix. Some thermocouples, SS-clad	417 rods 0.9 × 79.5 in.	NA	53.406	49.242			
Peach Bottom	U-Th carbide, pyrolytic carbon-coated particles in graphite matrix with Rh and B	1,603 graphite elements 3.5 × 144 in. in 90 Al cans 4.5 × 153 in.	<1%	332.42	233.54	46.31	0.97	2,620
Pulstar (State University of New York at Buffalo)	UO_2 pellets with Be, Zr-clad	504 fuel pins 0.474 × 26.125 in. in 24 SS cans	8,000-12,000	251.431	12.1		0.793	
Shippingport PWR-Core 1	UO_2-ZrO_2 fuel with boron, Zr-clad	4 subassemblies 5.6 × 5.6 × 84.5 in.	42.6%	2.02	1.63			
Shippingport PWR-Core 2	UO_2-ZrO_2 fuel with boron and some with CaO, Zr-clad	19 clusters 7.4 × 7.4 × 104.5 in.	47%	519.68	394.34		1.95	
SNAP (AI, S8DR, S8ER, S2DR, STF, SER)	U-Zr-hydride fuel, clad removed	19 Al cans 3.8 × 36 in.; 12 Al cans 2.5 × 43 in.	NA	28.8	26.8			
TRIGA (Training Reactor, Isotopes, General Atomic) stainless steel-clad	U-Zr-hydride fuel, some containing graphite, erbium, SS-clad	21 elements 3 × 3 × 37 in. in Al and SS cans; 7 rods 1.4 × 30 in. in Al cans; 263 elements 1.5 × 29 in., not canned	Varies	60.82	14.18		0.03	

Table A.6 (continued)

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM or % of initial loading)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
DOE/Civilian Development Programs materials inventory at ICPP (continued)								
TRIGA aluminum-clad	U-Zr-hydride fuel with Mo and graphite, Al-clad	570 rods 1.4 × 29 in., not canned	Varies	103.17	20.24			
Unirradiated graphite (Parka, LANL)	U-carbide fuel with ZrC, contained in graphite blocks	2,168 rods 3/4 × 52 in. and also 390 cans	None	403.26	371.97			
Unirradiated metal	U metal or U metal with Al	9 drums	None	17.34	15.85			
Vallecitos Boiling-Water Reactor (VBWR) (Geneva)	UO_2 or UO_2-TiO_2 fuel with SS, Zr, and TiO_2 in the matrix, SS- or Al-clad	142 rods in four 6 × 36 in. Al cans	8%	12.38	2.61			
Subtotal				42,293	3,765.2	136.45	18.33	10,937
DOE materials inventory at the Naval Reactors Facility (NRF)								
Shippingport PWR-Core 1	UO_2 pellets, Zr-clad	Miscellaneous test specimens from blanket fuel assemblies	11,100	568	<0.5		3.4	
Shippingport PWR-Core 2	UO_2 wafers, Zr-clad	Three modules and module sections from blanket fuel assemblies	14,273	1,028	2		8.9	
Shippingport PWR-Core 2 seed	UO_2 wafers, Zr-clad	One seed module		11.09	7.45			
Subtotal				1,607.09	9.45		12.3	

Table A.5 (continued)

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM or % of initial loading)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
DOE/Civilian Development Programs materials inventory at Power Burst Facility (PBF)								
PBF irradiated driver core	UO_2-ZrO_2-CaO ternary fuel pellets, SS-clad	2,425 rods 0.75 × 47.5 in. in 72 canisters	1,849	561.63	102.82			
PBF unirradiated driver core	UO_2-ZrO_2-CaO ternary fuel pellets, SS-clad	595 rods 0.75 × 47.5 in.	None	140.3	25.34			
Subtotal				701.93	128.16			
DOE/Civilian Development Program materials inventory at Test Area North (TAN)								
Connecticut Yankee (BCD)	UO_2, SS-clad	One 15 × 15 PWR assembly with 4 rods replaced with SS rods contained in one canister	32,151	378.485	5.204		3.775	
Dresden	UO_2-Dy_2O_3 fuel, Zr-clad	One complete 6 × 6 BWR assembly 5.5 × 5.5 × 134.25 in. of 36 rods and 1 partial assembly of 19 rods	NA	165.0	d		1.064	
Dry-rod consolidation technology[e] (DRCT)	UO_2 fuel, Zr-clad	24 canisters 8.3 × 7.9 × 155 in. (408 fuel rods per canister)	28,124 (avg.)	21,002.7	147.36		183.29	
Engine maintenance assembly and disassembly[f] (EMAD)	UO_2, Zr-clad	Five 15 × 15 PWR assemblies that were not consolidated in the DRCT program	27,525	2,303.32	17.09		19.19	
H.B. Robinson	UO_2 fuel, Zr-clad	113 rods	20,000	257.43	1.84		2.09	
Loose fuel-rod shipping basket (LFRSB) (LEU)	Variety of many different types of fuel rods	106 SS rods filled with cut-up pieces of fuel, some not canned and some clad	NA	309.354	1.759		2.627	

Table A.6 (continued)

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM or % of initial loading)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
DOE/Civilian Development Program materials inventory at TAN (continued)								
Loss-of-fluid test (LOFT)	UO_2-ZrO_2 fuel, Zr-clad	14 assemblies and 5 one-quart SS cans of fines	500-6,400	2,201.69	89.371		2.029	
Peach Bottom	UO_2 fuel, Zr-clad. One assembly is depleted U	2 partial assemblies, 1 with 47 rods and 1 with 46. Assemblies are 5.4 × 5.4 × 176 in.	NA	354.64	2.39		1.87	
TMI-Unit 2	UO_2 fuel, Zr-clad fuel assemblies reduced to large pieces of core debris, partial assemblies, and rubble	342 SS canisters	3,176	82,399	1,820		151	
Turkey Point-3 (BCD)	UO_2, Zr-clad	One 15 × 15 PWR assembly with 11 rods replaced with SS rods contained in one canister	25,665	408.57	3.52		3.24	
Virginia Electric Power Company (VEPCO) (Surry)	UO_2 fuel, Zr-clad	12 assemblies, typical 15 × 15 PWR	30,521	7,551.28	52.36		66.59	
Subtotal				117,332	2,140.89		436.765	
DOE/Civilian Development Program materials inventory at Test Reactors Area (TRA)								
Canadian Deuterium Uranium Reactor (CANDU)	UO_2 pellets, Zr-clad	8 pins	5,000	2.66	0.261			
Gap conductance (GAP CON)	UO_2 pellets, Zr-clad	20 pins	41-115	12.838	1.285			
General Electric[g] (GE)	UO_2 pellets, Zr-clad	5 rods	NA	18.644	0.394		0.071	

Table A.6 (continued)

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM or % of initial loading)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
DOE/Civilian Development Program materials inventory at TRA (continued)								
Halden assemblies	UO_2 pellets, Zr-clad	5 pins	4,000	2.313	0.233		0.005	
Halden Pu-U mixed oxide fuel assemblies	UO_2-PuO_2 pellets, Zr-clad	13 rods of various sizes in 4 Al canisters	41,000	4.55	d		0.324	
Irradiation effects (IE)	UO_2 pellets, Zr-clad	Pins	27-17,600	7.833	0.677		0.012	
LOFT lead rod (LLR)	UO_2 pellets, Zr-clad	7 pins	36-510	3.51	0.327			
Loss of coolant (LOC)	UO_2 pellets, Zr-clad	60 pins	16-150	7.777	0.816		0.01	
Mitsubishi Atomic Power Industries (MAPI)	UO_2 pellets, Zr-clad	49 rods 0.4 × 39 in., 36 enriched and 13 depleted, in 12 canisters	5,140	22.300	0.976[h]			
Operational Transient (OPTRAN)	UO_2 pellets, Zr-clad	Pins	0-15,000	19.669	0.472		0.09	
Power coolant mismatch (PCM)	UO_2 pellets, Zr-clad	30 pins	<70	18.628	6.557			
Reactivity initiated accident (RIA)	UO_2 pellets, Zr-clad	23 pins	0-6,090	8.989	0.504		0.013	
Saxton	UO_2 pellets, Zr-clad	21 pins	10,400-18,253	7.607	0.66		0.025	
Severe fuel damage (SFD)	UO_2 pellets, Zr-clad	143 pins	NA	50.867	2.711		0.15	

Table A.6 (continued)

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM or % of initial loading)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
DOE/Civilian Development Program materials inventory at TRA (continued)								
Thermocouple (TC)	UO_2 pellets, Zr-clad	Pins	0-<20	6.186	0.683			
Subtotal				194.57	16.56		0.7	
Total at INEL				164,026	6,837.6	962.53	470.1	52,884

[a]Information is based on the INEL Spent Fuel Data Base. See refs. 5 and 6.
[b]Fuel composition and cladding material where applicable. Zr = Zircaloy; SS = stainless steel.
[c]Fissium is a mixture of nonradioactive isotopes of typical fission product elements that is added to the EBR fuel prior to irradiation.
[d]Depleted.
[e]Mixture of EMAD and surry fuel.
[f]EMAD is a project that used Turkey Point fuel. There is also some EMAD fuel under DRCT.
[g]Most likely five Peach Bottom rods from fuels stored at TAN.
[h]In enriched rods only.

Table A.7. Miscellaneous radioactive materials inventory at the Los Alamos National Laboratory, as of December 31, 1992[a]

Source of material	Composition	Container description	U content, kg			Total Pu content (kg)	Total Th content (kg)
			Total	^{235}U	^{233}U		
Enriched uranium (hot-cell waste)[b]	Noncombustible material	Same as for ^{233}U items	3.092	1.81			
Omega West Reactor	Reactor fuel rods; SS-clad	0.3 in. diam × 13.5 in. length	7.772	6.84			
Plutonium-239 (hot-cell waste)[b]	Noncombustible material; 48 items are cemented items	Same as for ^{233}U items				1.31	
Reactor	U_3O_8 in fuel rods; SS-clad	~0.3 in. diam × ~13.5 in. length. Stored in a lead-lined cask that weighs ~17,000 kg	7.174	5.988			
Thorium (hot-cell waste)[b]	Noncombustible material	Same as for ^{233}U items					0
UMTREX rods	U_3O_8 fuel pins	Lead-shielded container ~10 in. diam × 2.5 ft in height	0.032	0.03			
Uranium enriched in ^{233}U (hot-cell waste)[b]	Noncombustible material	Material stored in a three-layered configuration; the innermost container is a metal container ~8 in. in diam and 12 in. high. This container is within a plastic container with a plastic lid. The final layer of containment is steel with a welded lid. This container is ~8.5 in. in diam × 11 in. high	0.06		0.058		
Total			18.130	14.668	0.058	1.31	0

[a]See ref. 7.
[b]199 g of ^{239}Pu, 92 g (45 g iso) enriched uranium, and 6 g of ^{233}U are buried as TRU waste in six canisters. Containers are shielded canisters with a diameter of ~26 in. and 10 ft in length. Canisters range in weight from 2600 to 3640 lb.

Table A.8. Miscellaneous radioactive materials inventory at the Oak Ridge National Laboratory, as of December 31, 1992[a]

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM)	U content, kg			Total Pu content (kg)
				Total	^{235}U	^{233}U	
Belgium Reactor-3 (BR-3)	UO_2, Zr-clad	3/8-in.-diam × 6-in. fuel rod lengths	42,000	0.837	0.020		0.006
Consolidated Edison Uranium (CEU)	U_3O_8-CdO solid cake	In 401 3.5-in.-OD × 24-in. SS cans	c	1,044.38	797.70	101.32	
Dresden-1	UO_2, Zr-clad	Sheared fuel pins in two 1-qt paint cans	~24,000	5.00	0.024		0.020
		9/16-in.-diam × 8-in. fuel rod sections plus short lengths	20,000	0.930	0.005		0.006
General Electric Test Reactor (GETR)	UO_2, Zr-clad	9/16-in.-diam × 8-in. fuel test capsules	1,000-2,000	0.399	0.022		
H. B. Robinson	UO_2, Zr-clad	1/2-in.-diam × 12-in. fuel rod sections plus short lengths	30,000	1.00	0.005		0.004
Molten Salt Reactor Experiment[d] (MSRE)	$LiF-BeF_2-ZrF_4-UF_4$	See ref. 13	~5 × 10^4 Ci total (see ref. 13)	36.95	0.940	31.01	0.743
Monticello	UO_2, Zr-clad	1/2-in.-diam × 6-in. fuel rod sections plus short lengths	40,000	1.00	0.004		0.008
Oconee-1	UO_2, Zr-clad	1/2-in.-diam × 6-in. fuel rod sections plus short lengths	38,000	1.00	0.005		0.005
ORNL Inventory Item Nos. AUA-67/AUA-70 from LANL	U metal chunks	In two 3.75-in.-OD × 18-in. SS cans	c	6.02		5.89	
CZA-91 from ANL	UO_x powder	In one 3.5-in.-OD × 13-in. SS can	c	0.881		0.856	
HUA-2A from HEDL	UO_x powder	In five 3.75-in.-OD × 7-in. SS cans	c	0.317		0.307	
LAE-03 from Atomics International (AI)	Metal	In one 3-in.-OD × 10-in. SS can	c	0.01		0.01	

Table A.8 (continued)

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM)	U content, kg			Total Pu content (kg)
				Total	^{235}U	^{233}U	
ORNL Inventory Item Nos. (contd.)							
RCP-02 from SRS	UO_2 powder	In thirty-two 3.5-in.-OD × 24-in. SS cans	c	11.14		10.72	
RCP-03 from SRS	UO_2 powder	In 140 3.88-in.-OD × 10-in. SS cans	c	67.41		61.61	
RCP-04 from SRS	UF_4-LiF powder converted from UO_2	In four 3.5-in.-OD × 24-in. SS cans	c	3.19		2.92	
RCP-06	U_3O_8-CdO solid cake	In twenty-seven 3.5-in.-OD × 24-in. SS cans	c	65.55		60.50	
RCP-20/JZBL from LANL	U metal chunks	In six 3.5-in.-OD × 24-in. SS cans	c	5.15		5.05	
Peach Bottom-2	UO_2, Zr-clad	9/16-in.-diam × 8-in. fuel rod sections plus short lengths	10,000	0.324	0.001		0.001
Quad City-1	UO_2, Zr-clad	1/2-in.-diam × 6-in. fuel rod sections plus short lengths	40,000	1.00	0.004		0.008
Total				1,252.488	798.7	280.29	0.801

[a]See ref. 8.
[b]Zr-clad = Zircaloy-clad.
[c]No information regarding the burnup of this fuel is available.
[d]The Molten Salt Reactor Experiment was concluded in 1969, and the fuel has never been removed from the facility. A surveillance and monitoring program has been in force since shutdown. Decommissioning of the MSRE facility is an environmental restoration activity discussed earlier in Chapter 6.

Table A.9. Miscellaneous radioactive materials inventory at the Savannah River Site, as of December 31, 1992[a]

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
DOE/Civilian Development Programs materials inventory at SRS								
Canadian Deuterium Uranium Reactor (CANDU)	UO_2, Zr-clad	Rods in three 5.0-in.-diam × 14-ft cans; pieces in three 3.5-in.-diam × 1-ft cans	6,500	50.07	0.231			
Carolinas-Virginia Tube Reactor	UO_2-Zr or SS-clad	One bundle of 34 rods in a 5.0-in.-diam × 14-ft can	Unknown	67.27	0.640		0.200	
Dresden	UO_2-ThO_2, SS-clad	Intact assemblies in 4.4-in. × 4.4-in. × 135-in. cans	4,000-10,000	684.00	37.545	15.391	1.879	1,857.0
Elk River Reactor (ERR)	UO_2-ThO_2, SS-clad	Assemblies 3.5 in. × 3.5 in. × 81.62 in.	Max. 50,000	224.29	186.159	14.722		4,818.6
H. B. Robinson	UO_2-PuO_2, Zr-clad, SS casing	Four 6- to 8-in.-long fragments in 4.5-in.-diam × 32-in.-long can	6,800-30,000	0.51	0.004		0.003	
Light-water reactor (LWR) samples	UO_2-PuO_2, SS- and Zr-clad	Fuel rod pieces in five 3.75-in.-diam × 32.5-in.-long cans	Unknown	12.631	0.192		0.109	
Nereide (a French experiment using DOE fuel)	UAl-Si_x, Al-clad	Materials Test Reactor plate-type fuel assembly 34.37 in. × 2.98 in. × 3.14 in.	600	35.42	7.015			
Saxton	UO_2-PuO_2, Zr- or SS-clad	567 rods in eight 5.0-in.-diam × 14-ft cans and 64 rods in one 3.75-in.-diam × 50-in. can	1,000	280.21	1.411		15.408	
	UO_2, Zr-clad	Multiple pins in four 5.0-in.-diam × 14-ft cans and one bundle in one 12-in.-diam × 14-ft can	1,600	89.19	6.866		0.233	

Table A.9 (continued)

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
DOE/Civilian Development Programs materials inventory at SRS (continued)								
Vallecitos boiling-water reactor (VBWR)	UO_2, Zr-clad	In four 3.5-in.-diam × 12-in. cans	1,500	11.93	1.243		0.003	
Subtotal				1,455.521	241.306	30.113	17.835	6,675.6
DOE plus other government agencies materials inventory at SRS								
B&W scrap	UO_2-PuO_2, SS-clad	In 3.5-in.-diam × 32-in. cans	6-54	0.025	0.013		0.048	
Experimental boiling-water reactor (EBWR)	UO_2, SS-clad	Assemblies 3.75 in. × 3.75 in. × 62.5 in.	1,600	1.73	1.612			
	UO_2, Zr-clad	Assemblies 3.75 in. × 3.75 in. × 62.5 in.	1,600	1,600.32	95.456			
	UO_2-Zr, Zr-clad	Assemblies 3.75 in. × 3.75 in. × 62.5 in.	1,600	7,482.73	73.967		9.092	
	UO_2-ZrO_2-CaO, Zr-clad	Assemblies 3.75 in. × 3.75 in. × 62.5 in.	1,600	28.93	26.651			
	UO_2-PuO_2, Zr-clad	Assemblies 3.75 in. × 3.75 in. × 62.5 in.	1,600	917.72	2.087		13.940	
Experimental breeder reactor-2 (EBR-2)	UO_2-PuO_2, SS-clad (from ANL)	Eight rods in a 3.5-in.-diam × 30-in. can	120 kW total in 1975	0.44	0.376		0.114	
	UO_2-PuO_2, SS-clad (from HEDL)	Rod segments in 0.5-in.-diam × 42-in. cans	10,000-34,000	2.04	1.624		0.680	
Experimental power reactor-1 (EPR-1)	PuO_2, SS-clad	Pieces in 4.5-in.-diam × 32-in. cans	Unknown				0.022	
Gas-cooled reactor experiment (GCRE)	UO_2 or UO_2-BeO, Hastelloy-clad	Four 2-in.-diam × 32-in. Al cans of scrap pieces; two 1.5-in.-diam Al cans of plates; 66 pin-type assemblies		61.290	56.559			

Table A.9 (continued)

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
DOE plus other government agencies materials inventory at SRS (continued)								
Heavy-water components test reactor (HWCTR)	U and UO_2, Zr-clad	Intact assemblies 3 in. diam × 132 in. Pieces of assemblies in 3.5-in.-diam × 12-in. cans	6,200	1,051.376	9.470		0.565	
	U-Zr, Zr-clad			37.165	31.590			
High-temperature reactor experiment (HTRE)	UO_2-BeO, Nichrome-clad	Segments and pieces of fuel assemblies and test pieces in thirteen 4-in.-diam × 36-in. Al cans		4.039	3.423			
Mobile Low Power Plant No. 1 (ML-1)	UO_2 and PuO_2-BeO, SS-clad	Sixty-eight 19-pin assemblies		58.575	54.478			
Oak Ridge National Laboratory (ORNL) SIW-1 rods	U, Zr-clad	Rods in three 4.5-in.-diam × 9.25-in. Al cans	Unknown but low	0.184	0.171			
Oak Ridge Reactor-low enriched uranium (ORR-LEU)	U_3Si_2, Al-clad	In fourteen 3.5-in. × 3.5-in. × 168-in. Al cans	15,600	95.006	14.960		0.537	
ORNL mixed oxide	UO_2-PuO_2, Zr- or SS-clad	One 3.5-in.-diam × 15.12-in. can	Unknown but low	0.376	0.030		0.094	
Savannah River Site (SRS)	UO_2-PuO_2, Zr-clad	In one 12.0-in.-diam × 14-ft can	Unknown	69.87	0.304		0.161	
Shippingport	UO_2, Zr-clad	One 10.5-in.-diam × 15-in. container	18,000	16.000	0.023		0.108	
Sodium Reactor Experiment (SRE)	U, Th rods, SS-clad	3.5-in.-diam × 110.25-in. cans	10,000	154.934	143.410	1.045		1,972.6
	UC, SS-clad			44.324	4.344		0.016	

Table A.9 (continued)

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
DOE plus other government agencies materials inventory at SRS (continued)								
Special Power Excursion Reactor Test (SPERT-3)	UO_2, Zr-clad	Three 4.0-in.-diam × 12-ft cans	Unknown	9.739	0.603			
Subtotal				11,636.813	521.151	1.045	25.377	1,972.6
Total				13,092.334	762.457	31.158	43.212	8,648.2

[a]See refs. 9 and 12. The spent fuels listed in this table are not reprocessible in existing facilities.
[b]Zr-clad = Zircaloy-clad.

APPENDIX B. CHARACTERISTICS OF IMPORTANT RADIONUCLIDES

APPENDIX B. CHARACTERISTICS OF IMPORTANT RADIONUCLIDES

B.1 DISCUSSION

The following Table B.1 lists radionuclides whose characteristics are most often referenced in the variety of studies and evaluations discussed in Chapters 1–7. It includes isotopes for HLW, TRU waste, LLW, and uranium mill tailings as defined by EPA,[1] NRC,[2,3] and DOE.[4,5] The data in Table B.1 were obtained from refs. 6–9.

B.2 REFERENCES

1. U.S. Environmental Protection Agency, "Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," *Code of Federal Regulations*, 40 CFR Part 191 (1992).

2. U.S. Nuclear Regulatory Commission, "Licensing Requirements for Land Disposal of Radioactive Waste," *Code of Federal Regulations*, 10 CFR Part 61 (1992).

3. U.S. Nuclear Regulatory Commission, "Biomedical Waste Disposal," *Fed. Regist.* 46(47), 16230-16234 (Mar. 11, 1981).

4. U.S. Department of Energy, DOE Order 5820.2A, *Radioactive Waste Management*, Washington, D.C., Sept. 26, 1988.

5. U.S. Department of Energy, Energy Information Administration, *Domestic Uranium Mining and Milling Industry 1990—Viability Assessment*, DOE/EIA-0477(90), Washington, D.C. (December 1991).

6. D. C. Kocher, *Radioactive Decay Data Tables*, DOE/TIC-11026, Washington, D.C. (1981).

7. D. C. Kocher, *A Radionuclide Decay Data Base—Index and Summary Table*, NUREG/CR-1413, ORNL/NUREG-70, Oak Ridge National Laboratory, Oak Ridge, Tennessee (May 1980).

8. E. Browne and R. B. Firestone, *Table of Radioactive Isotopes*, John Wiley and Sons, Inc., ed. V. S. Shirley, New York (1986).

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Table B.1. Characteristics of important radionuclides[a]

Nuclide	Atomic number	Half-life[b]	Principal mode(s) of decay[c]	Major radiation energies[d] (MeV/dis)			"Q" value[e]		Specific activity (Ci/g)	Daughter(s)
				α	ϵ	γ(X)	(MeV/dis)	(W/Ci)		
^{3}H	1	1.233E+01 y	β		0.00568		5.68E-03	3.37E-05	9.650E+03	^{3}He
^{14}C	6	5.730E+03 y	β		0.0495		4.95E-02	2.93E-04	4.457	^{14}N
^{26}Al	13	7.2E+05 y	EC		0.4451	2.6758	3.079	1.825E-02	1.91E-02	^{26}Mg
^{32}Si	14	650 y	β		0.0647		2.10E-01	1.245E-03	1.719E+01	^{32}P
^{32}P	15	14.282 d	β		0.6947		6.95E-01	4.12E-03	2.853E+05	^{32}S
^{35}S	16	87.51 d	β		0.0486		4.86E-02	2.88E-04	4.263E+04	^{35}Cl
^{36}Cl	17	3.01E+05 y	β (98.1%); EC (1.9%)		0.2460		2.460E-01	1.458E-03	3.299E-02	^{36}Ar; ^{36}S
^{40}K	19	1.277E+09 y	β (89.33%): EC (10.67%)		0.4545	0.1559	6.104E-01	3.62E-03	6.983E-06	^{40}Ca ^{40}Ar
^{45}Ca	20	163.8 d	β		0.0770		7.70E-02	4.56E-04	1.780E+04	^{45}Sc
^{46}Sc	21	83.83 d	β	0.1120	2.0095		2.122	1.257E-02	3.381E+04	^{46}Ti
^{51}Cr	24	27.704 d	EC		0.0031	0.0325	3.56E-02	2.11E-04	9.240E+04	^{51}V
^{54}Mn	25	312.20 d	EC		0.0034	0.8360	8.394E-01	4.975E-03	7.738E+03	^{54}Cr
^{55}Fe	26	2.73 y	EC		0.0038	0.0016	5.4E-03	3.2E-05	2.500E+03	^{55}Mn
^{59}Fe	26	44.496 d	β		0.1174	1.1882	1.3056	7.741E-03	4.918E+04	^{59}Co
^{57}Co	27	271.77 d	EC		0.0176	0.1252	1.428E-01	8.464E-01	8.456E+03	^{57}Fe
^{58}Co	27	70.92 d	EC		0.0336	0.9758	1.0094	5.99E-03	3.181E+04	^{58}Fe
^{60}Co	27	5.271 y	β		0.0958	2.5058	2.6016	1.541E-02	1.131E+03	^{60}Ni
^{60m}Co	27	10.47 min	IT (99.75%); β (0.25%)		0.0536	0.0066	6.02E-02	3.57E-04	2.993E+08	^{60}Co; ^{60}Ni
^{59}Ni	28	7.5E+04 y	EC		0.0043	0.0024	6.72E-03	3.98E-05	8.079E-02	^{59}Co
^{63}Ni	28	1.001E+02 y	β		0.0171		1.71E-02	1.01E-04	6.168E+01	^{63}Cu
^{65}Zn	30	244.1 d	EC		0.0066	0.5838	5.90E-01	3.51E-03	8.237E+03	^{65}Cu
^{67}Ga	31	3.261 d	EC		0.0333	0.1549	1.882E-01	1.115E-03	5.975E+05	^{67}Zn
^{75}Se	34	119.77 d	EC		0.0134	0.3924	4.06E-01	2.41E-03	1.453E+04	^{75}As

Table B.1 (continued)

Nuclide	Atomic number	Half-life[b]	Principal mode(s) of decay[c]	Major radiation energies[d] (MeV/dis)			"Q" value[e]		Specific activity (Ci/g)	Daughter(s)
				α	ε	γ(X)	(MeV/dis)	(W/Ci)		
^{79}Se	34	<6.5E+04 y			0.0529		5.29E-02	3.13E-04	6.966E-02	^{79}Br
^{85}Kr	36	1.072E+01 y	β		0.2505	0.0022	2.53E-01	1.50E-03	3.923E+02	^{85}Rb
^{86}Rb	37	18.66 d	β		0.6670	0.0945	7.62E-01	4.52E-03	8.138E+04	^{86}Sr
^{89}Sr	38	50.55 d	β		0.5829	0.0001	5.83E-01	3.46E-03	2.905E+04	^{89}Y
^{90}Sr	38	2.85E+01 y	β		0.1958		1.96E-01	1.16E-03	1.364E+02	^{90}Y
^{90}Y	39	2.671 d	β		0.9332		9.33E-01	5.54E-03	5.441E+05	^{90}Zr
^{91}Y	39	58.51 d	β		0.6039	0.0036	6.07E-01	3.60E-03	2.452E+04	^{91}Zr
^{93}Zr	40	1.53E+06 y	β		0.0471	0.0018	4.89E-02	2.90E-04	2.513E-03	^{93}Nb
^{95}Zr	40	64.02 d	β		0.1200	0.7337	8.54E-01	5.06E-03	2.148E+04	^{95}Nb
^{93m}Nb	41	1.36E+01 y	IT		0.0281	0.0018	2.99E-02	1.77E-04	2.826E+02	^{93}Nb
^{94}Nb	41	2.03E+04 y	β		0.1454	1.5715	1.7169	1.018E-02	1.873E-01	^{94}Mo
^{95}Nb	41	34.97 d	β		0.0435	0.7643	8.078E-01	4.788E-03	3.910E+04	^{95}Mo
^{93}Mo	42	3500 y	EC		0.0051	0.0107	1.58E-02	9.37E-05	1.10	^{93}Nb
^{99}Mo	42	2.748 d	β		0.4076	0.2723	6.799E-01	4.028E-03	4.796E+05	^{99}Tc
^{99}Tc	43	2.13E+05 y	β		0.0846		8.46E-02	5.01E-04	1.695E-02	^{99}Ru
^{99m}Tc	43	6.006 h	IT		0.0142	0.1240	1.382E-01	8.186E-04	5.271E+06	^{99}Tc
^{103}Ru	44	39.254 d	β		0.1105	0.4851	5.96E-01	3.53E-03	3.227E+04	^{103}Rh
^{106}Ru	44	1.020 y	β		0.1004		1.004E-01	5.951E-04	3.346E+03	^{106}Rh
^{103m}Rh	45	56.12 min	IT		0.0375	0.0017	3.92E-02	2.32E-04	3.253E+07	^{103}Rh
^{106}Rh	45	2.17 h	β		0.3144	2.8826	3.197	1.894E-02	3.560E+09	^{106}Pd
^{107}Pd	46	6.5E+06 y	β			0.0093	9.3E-03	5.5E-05	5.143E-04	^{107}Ag
^{110}Ag	47	24.6 s	β (99.70%); EC (0.30%)		1.1842	0.0316	1.216	7.208E-03	4.169E+09	^{110}Cd; ^{110}Pd
^{110m}Ag	47	249.76 d	β (98.64%); IT (1.36%)		0.0755	2.7392	2.815	1.669E-02	4.750E+03	^{110}Cd; ^{110}Ag
^{113}Cd	48	9.3E+15 y	β		0.0933		9.13E-02	5.412E-04	3.402E-13	^{113}In
^{113m}Cd	48	1.37E+01 y	β (99.9%); IT (0.1%)			0.1834	1.83E-01	1.08E-03	2.168E+02	^{113}In; ^{113}Cd
^{115m}Cd	48	44.6 d	β		0.6029	0.0329	6.36E-01	3.76E-03	2.546E+04	^{115}In

Table B.1 (continued)

Nuclide	Atomic number	Half-life[b]	Principal mode(s) of decay[c]	Major radiation energies[d] (MeV/dis) α	ε	γ(X)	"Q" value[e] (MeV/dis)	(W/Ci)	Specific activity (Ci/g)	Daughter(s)
^{111}In	49	2.807 d	EC		0.0340	0.4053	4.393E-01	2.604E-03	4.157E+05	^{111}Cd
^{113m}In	49	1.658 h	IT		0.1340	0.2555	3.89E-01	2.31E-03	1.673E+07	^{113}In
^{114m}In	49	49.51 d	IT (95.7%); EC (4.3%)		0.1431	0.0943	2.37E-01	1.40E-03	2.313E+04	^{114}In; ^{114}Cd
^{113}Sn	50	115.09 d	EC		0.1394	0.2808	4.20E-01	2.48E-03	1.004E+04	^{113}In
^{117m}Sn	50	13.61 d	IT		0.1613	0.1580	3.19E-01	1.89E-03	7.969E+04	^{117}Sn
^{119m}Sn	50	293.0 d	IT		0.0783	0.0114	8.97E-02	5.32E-04	4.478E+03	^{119}Sn
^{121m}Sn	50	5.5E+01 y	IT (77.6%); β (22.4%)		0.0352	0.0050	4.02E-02	2.43E-04	5.912E+01	^{121}Sn; ^{121}Sb
^{123}Sn	50	129.2 d	β		0.5222	0.0069	5.29E-01	3.14E-03	8.219E+03	^{123}Sb
^{125}Sn	50	9.64 d	β		0.8110	0.3124	1.123	6.656E-03	1.084E+05	^{125}Sb
^{126}Sn	50	~1E+05 y	β		0.1249	0.0573	1.82E-01	1.08E-03	2.837E-02	^{126}Sb
^{124}Sb	51	60.20 d	β		0.3897	1.8523	2.242	1.329E-02	1.749E+04	^{124}Te
^{125}Sb	51	2.73 y	β		0.1257	0.4434	5.69E-01	3.37E-03	1.032E+03	^{125}Te
^{126}Sb	51	12.4 d	β		0.3527	2.7496	3.102	1.839E-02	8.360E+04	^{126}Te
^{126m}Sb	51	19.0 min	β (86%); IT (14%)		0.6323	1.5484	2.181	1.292E-02	7.854E+07	^{126}Te; ^{126}Sb
^{123m}Te	52	119.7 d	IT		0.1020	0.1482	2.502E-01	1.482E-03	8.870E+03	^{123}Te
^{125m}Te	52	58 d	IT		0.1106	0.0361	1.467E-01	8.690E-04	1.801E+04	^{125}Te
^{127}Te	52	9.35 h	β		0.2248	0.0048	2.30E-01	1.36E-03	2.639E+06	^{127}I
^{127m}Te	52	109 d	IT (97.6%); β (2.4%)		0.0821	0.0111	9.32E-02	5.52E-04	9.432E+03	^{127}Te; ^{127}I
^{129}Te	52	1.160 h	β		0.5422	0.0624	6.05E-01	3.58E-03	2.094E+07	^{129}I
^{129m}Te	52	33.6 d	IT (64%); β (36%)		0.2663	0.0370	3.03E-01	1.80E-03	3.013E+04	^{129}Te; ^{129}I
^{123}I	53	13.2 h	EC		0.0276	0.1729	2.005E-01	1.188E-03	1.940E+06	^{123}Te
^{125}I	53	60.14 d	EC		0.0179	0.0423	6.02E-02	3.57E-04	1.737E+04	^{125}Te
^{129}I	53	1.57E+07 y	β		0.0556	0.0246	8.04E-02	4.77E-04	1.765E-04	^{129}Xe
^{131}I	53	8.040 d	β		0.1913	0.3626	5.74E-01	3.40E-03	1.240E+05	^{131}Xe
^{133}Xe	54	5.245 d	β		0.1363	0.0459	1.82E-01	1.08E-03	1.872E+05	^{133}Cs
^{134}Cs	55	2.062 y	β		0.1639	1.5555	1.719	1.019E-02	1.294E+03	^{134}Ba
^{135}Cs	55	3.0E+06 y	β		0.0563		5.63E-02	3.32E-04	1.151E-03	^{135}Ba
^{137}Cs	55	3.017E+01 y	β (94.6%); β (5.4%)			0.1708	1.71E-01	1.01E-03	8.698E+01	^{137m}Ba; ^{137}Ba
^{133}Ba	56	1.054E+01 y	EC		0.0547	0.4045	4.592E-01	2.722E-03	2.500E+02	^{133}Cs
^{137m}Ba	56	2.552 min	IT		0.0652	0.5991	6.64E-02	3.94E-03	5.379E+08	^{137}Ba

Table B.1 (continued)

Nuclide	Atomic number	Half-life[b]	Principal mode(s) of decay[c]	Major radiation energies[d] (MeV/dis)			"Q" value[e]		Specific activity (Ci/g)	Daughter(s)
				α	ϵ	γ(X)	(MeV/dis)	(W/Ci)		
^{141}Ce	58	32.50 d	β		0.1707	0.0770	2.48E-01	1.47E-03	2.848E+04	^{141}Pr
^{144}Ce	58	284.9 d	β		0.0918	0.0192	1.11E-01	6.58E-04	3.190E+03	^{144}Pr
^{143}Pr	59	13.58 d	β		0.3156		3.16E-01	1.87E-03	6.731E+04	^{143}Nd
^{144}Pr	59	17.28 min	β		1.2091	0.0289	1.238	7.338E-03	7.555E+07	^{144}Nd
^{144m}Pr	59	7.2 min	IT (99.96%); β (0.04%)		0.0464	0.0121	5.85E-02	3.43E-04	1.814E+08	^{144}Pr; ^{144}Nd
^{146}Pm	61	5.53 y	EC (66.1%); β (33.9%)		0.0928	0.7542	8.47E-01	5.02E-03	4.428E+02	^{146}Nd; ^{146}Sm
^{147}Pm	61	2.6234 y	β		0.6196		6.20E-02	3.67E-04	9.270E+02	^{147}Sm
^{148}Pm	61	5.370 d	β		0.7235	0.5747	1.298	7.691E-03	1.643E+05	^{148}Sm
^{148m}Pm	61	41.29 d	β (95.4%); IT (4.6%)		0.1695	1.9861	2.156	1.278E-02	2.136E+04	^{148}Sm; ^{148}Pm
^{151}Sm	62	9.0E+01 y	β		0.1251		1.25E-01	7.41E-04	2.631E+01	^{151}Eu
^{152}Eu	63	1.333E+01 y	EC (72.08%); β (27.92%)		0.1275	1.1628	1.290	7.646E-03	1.729E+02	^{152}Sm; ^{152}Gd
^{154}Eu	63	8.8 y	β		0.2794	1.2531	1.532	9.081E-03	2.699E+02	^{154}Gd
^{155}Eu	63	4.96 y	β		0.0650	0.0633	1.28E-01	7.59E-04	4.651E+02	^{155}Gd
^{153}Gd	64	241.6 d	EC		0.0399	0.1015	1.414E-01	8.381E-04	3.526E+03	^{153}Eu
^{157}Tb	65	150 y	EC		0.0031	0.0050	8.10E-03	4.802E-05	1.519E+01	^{157}Gd
^{158}Tb	65	150 y	EC (82%) β (18%)				9.02E-01	5.347E-03	1.508E+01	^{158}Gd ^{158}Dy
^{160}Tb	65	72.3 d	β		0.2535	1.1271	1.381	8.186E-03	1.129E+04	^{160}Dy
^{169}Yb	70	32.02 d	EC		0.1117	0.3121	4.238E-01	2.512E-03	2.414E+04	^{169}Tm
^{175}Hf	72	70.0 d	EC		0.0439	0.3646	4.085E-01	2.422E-03	1.066E+04	^{175}Lu
^{181}Hf	72	42.39 d	β		0.1943	0.5441	7.54E-01	4.47E-03	1.702E+04	^{181}Ta
^{182}Ta	73	115.0 d	β		0.2073	1.3011	1.508	8.940E-03	6.253E+03	^{182}W
^{187}Re	75	4.6E+10 y	β		0.0007		2.59	1.535E-02	3.823E-08	^{187}Os
^{192}Ir	77	73.831 d	β (95.4%); EC (4.6%)		0.2162	0.8137	1.030	6.105E-03	9.211E+03	^{192}Pt; ^{192}Os
^{201}Tl	81	3.046 d	EC		0.0481	0.0924	1.40E-01	8.30E-04	2.132E+05	^{201}Hg
^{207}Tl	81	4.77 min	β		0.4931	0.0022	4.95E-01	2.93E-03	1.904E+08	^{207}Pb

Table B.1 (continued)

Nuclide	Atomic number	Half-life[b]	Principal mode(s) of decay[c]	Major radiation energies[d] (MeV/dis)			"Q" value[e]		Specific activity (Ci/g)	Daughter(s)
				α	ε	γ(X)	(MeV/dis)	(W/Ci)		
^{208}Tl	81	3.053 min	β		0.5979	3.3742	3.972	2.354E-02	2.945E+08	^{208}Pb
^{209}Pb	82	3.253 h	β		0.1980		1.98E-01	1.17E-03	4.544E+06	^{209}Bi
^{211}Pb	82	36.1 min	β		0.4523	0.0678	5.20E-01	3.083E-03	2.468E+07	^{211}Bi
^{212}Pb	82	10.64 h	β		0.1752	0.1453	3.20E-01	1.90E-03	1.389E+06	^{212}Bi
^{211}Bi	83	2.14 min	α (99.727%); β (0.273%)	6.5505	0.0099	0.0467	6.607	3.916E-02	4.164E+08	^{207}Tl; ^{211}Po
^{212}Bi	83	1.0092 h	α (35.94%); β (64.06%)	2.1740	0.5025	0.1061	2.783	1.649E-02	1.465E+07	^{208}Tl; ^{212}Po
^{213}Bi	83	45.59 min	α (2.16%); β (97.84%)	0.1268	0.4563	0.0825	6.66E-01	3.95E-03	1.934E+07	^{209}Tl; ^{213}Po
^{209}Po	84	102 y	α (99.74%) EC (0.26%)				4.9645	2.943E-01	1.68E+01	^{205}Pb ^{209}Bi
^{212}Po	84	2.98E-07 s	α	8.7844			8.784	5.207E-02	1.774E+17	^{208}Pb
^{213}Po	84	4.2E-06 s	α	8.3757			8.375	4.964E-02	1.261E+16	^{209}Pb
^{215}Po	84	1.780E-03 s	α	7.3864			7.386	4.378E-02	2.948E+13	^{211}Pb
^{216}Po	84	1.50E-02 s	α	6.7785			6.779	4.018E-02	3.482E+11	^{212}Pb
^{217}At	85	3.23E-02 s	α	7.0557		0.0002	7.066	4.189E-02	1.610E+12	^{213}Bi
^{219}Rn	86	3.96 s	α	6.8122	0.0064	0.0560	6.875	4.076E-02	1.301E+10	^{215}Po
^{220}Rn	86	55.6 s	α	6.2878		0.0005	6.288	3.727E-02	9.223E+08	^{216}Po
^{222}Rn	86	3.825 d	α	5.4892		0.0004	5.490	3.255E-02	1.538E+05	^{218}Po
^{221}Fr	87	4.9 min	α	6.3571	0.0084	0.0277	6.393	3.789E-02	1.772E+08	^{217}At
^{223}Fr	87	21.8 min	β		0.3805	0.0542	4.35E-01	2.85E-03	3.868E+07	^{223}Ra
^{223}Ra	88	11.43 d	α	5.6972	0.0731	0.1348	5.905	3.500E-02	5.121E+04	^{219}Rn
^{224}Ra	88	3.66 d	α	5.6751	0.0022	0.0103	5.688	3.372E-02	1.593E+05	^{220}Rn
^{225}Ra	88	14.2 d	β		0.1057	0.0137	1.19E-01	7.08E-04	3.920E+04	^{225}Ac
^{226}Ra	88	1.600E+03 y	α	4.7741	0.0035	0.0057	4.784	2.836E-02	9.887E-01	^{222}Rn
^{228}Ra	88	5.75 y	β		0.0116		1.16E-02	6.88E-05	2.340E+02	^{228}Ac
^{225}Ac	89	10.0 d	α	5.7501	0.0257	0.0176	5.793	3.434E-02	5.803E+04	^{221}Fr
^{227}Ac	89	2.177E+01 y	β (98.62%); α (1.38%)	0.0673	0.0125	0.0002	8.00E-02	4.74E-04	7.233E+01	^{227}Th; ^{223}Fr
^{228}Ac	89	6.13 h	β		0.4292	0.9269	1.356	8.036E-03	2.242E+06	^{228}Th
^{227}Th	90	18.718 d	α	5.9022	0.0543	0.1113	6.068	3.597E-02	3.073E+04	^{223}Ra
^{228}Th	90	1.913 y	α	5.3992	0.0201	0.0034	5.423	3.214E-02	8.196E+02	^{224}Ra
^{229}Th	90	7.340E+03 y	α	4.8620		0.0343	4.896	2.902E-02	2.127E-01	^{225}Ra

Table B.1 (continued)

Nuclide	Atomic number	Half-life[b]	Principal mode(s) of decay[c]	Major radiation energies[d] (MeV/dis)			"Q" value[e]		Specific activity	Daughter(s)
				α	ε	γ(X)	(MeV/dis)	(W/Ci)	(Ci/g)	
^{230}Th	90	7.54E+04 y	α	4.6651		0.0004	4.665	2.765E-02	2.109E-02	^{226}Ra
^{231}Th	90	1.0633 d	β	0.1732		0.0295	2.03E-01	1.21E-03	5.316E+05	^{231}Pa
^{232}Th	90	1.405E+10 y	α	4.0056		0.0002	4.006	2.375E-02	1.097E-07	^{228}Ra
^{234}Th	90	24.10 d	β		0.0158	0.0094	2.52E-02	1.49E-04	2.316E+04	^{234}Pa
^{231}Pa	91	3.276E+04 y	α	4.9230	0.0483	0.0399	5.011	2.970E-02	4.723E-02	^{227}Ac
^{233}Pa	91	27.0 d	β		0.1941	0.2042	3.98E-01	2.36E-03	2.075E+04	^{233}U
^{234m}Pa	91	1.17 min	β (99.87%); IT (0.13%)		0.8227	0.0121	8.35E-01	4.95E-03	6.868E+08	^{234}U; ^{234}Pa
^{232}U	92	6.89E+01 y	α	5.3055		0.0002	5.307	3.146E-02	2.140E+01	^{228}Th
^{233}U	92	1.592E+05 y	α	4.8141	0.0055	0.0013	4.821	2.857E-02	9.680E-03	^{229}Th
^{234}U	92	2.454E+05 y	α	4.7732		0.0001	4.773	2.829E-02	6.246E-03	^{230}Th
^{235}U	92	7.037E+08 y	α	4.3785	0.0426	0.1561	4.577	2.713E-02	2.161E-06	^{231}Th
^{236}U	92	2.342E+07 y	α	4.4793	0.0106	0.0015	4.492	2.662E-02	6.469E-05	^{232}Th
^{238}U	92	4.468E+09 y	α	4.1945	0.0085	0.0013	4.205	2.492E-02	3.362E-07	^{234}Th
^{236}Np	93	1.550E+05 y	EC (91%); β (8.9%); α (0.20%)		0.1967	0.1411	3.38E-01	2.00E-03	1.317E-02	^{236}U; ^{236}Pu; ^{232}Pa
^{237}Np	93	2.140E+06 y	α	4.7604	0.0640	0.0327	4.857	2.879E-02	7.049E-04	^{233}Pa
^{239}Np	93	2.355 d	β		0.2521	0.1740	4.26E-01	2.53E-03	2.320E+05	^{239}Pu
^{236}Pu	94	2.851 y	α	5.7521	0.0126	0.0020	5.767	3.418E-02	5.313E+02	^{232}U
^{238}Pu	94	8.774E+01 y	α	5.4871	0.0099	0.0018	5.499	3.2593E-02	1.712E+01	^{234}U
^{239}Pu	94	2.411E+04 y	α	5.1011		0.0001	5.101	3.024E-02	6.216E-02	^{235}U
^{240}Pu	94	6.563E+03 y	α	5.1549			5.155	3.056E-02	2.279E-01	^{236}U
^{241}Pu	94	1.44E+01 y	β	0.0001		0.0052	5.3E-03	3.2E-05	1.030E+02	^{241}Am
^{242}Pu	94	3.763E+05 y	α	4.8901	0.0081	0.0014	4.900	2.904E-02	3.818E-03	^{238}U
^{244}Pu	94	5.26E+07 y	α (99.875%); SPF (0.125%)	4.5751	0.0007	0.0001	4.576	2.712E-02	1.774E-05	^{240}U; (fission products)
^{241}Am	95	4.327E+02 y	α	5.4801	0.0304	0.0287	5.539	3.283E-02	3.432	^{237}Np
^{242}Am	95	16.01 h	β (82.7%); EC (17.3%)		0.1781	0.0180	1.96E-01	1.16E-03	8.084E+05	^{242}Cm; ^{242}Pu
^{242m}Am	95	1.41E+02 y	IT (99.55%); α (0.45%)	0.0232	0.0403	0.0049	6.84E-02	4.05E-04	9.718	^{242}Am; ^{238}Np
^{243}Am	95	7.380E+03 y	α	5.2856		0.0461	5.3137	3.1496E-02	1.993E-01	^{239}Np
^{242}Cm	96	162.94 d	α	6.0434	0.0090	0.0018	6.0542	3.5886E-02	3.306E+03	^{238}Pu
^{243}Cm	96	2.85E+01 y	α (99.76%); EC (0.24%)	5.8380	0.1129	0.1316	6.083	3.605E-02	5.162E+01	^{239}Pu; ^{243}Am

Table B.1 (continued)

Nuclide	Atomic number	Half-life[b]	Principal mode(s) of decay[c]	Major radiation energies[d] (MeV/dis)			"Q" value[e]		Specific activity	Daughter(s)
				α	ε	γ(X)	(MeV/dis)	(W/Ci)	(Ci/g)	
^{244}Cm	96	1.811E+01 y	α	5.7965		0.0016	5.798	3.437E-02	8.090E+01	^{240}Pu
^{245}Cm	96	8.5E+03 y	α	5.3631	0.1342	0.1178	5.615	3.329E-02	1.717E-01	^{241}Pu
^{246}Cm	96	4.73E+03 y	α	5.3764	0.0072	0.0014	5.385	3.192E-02	3.072E-01	^{242}Pu
^{247}Cm	96	1.56E+07 y	α	4.9475		0.3152	5.263	3.119E-02	9.278E-05	^{243}Pu
^{248}Cm	96	3.40E+05 y	α (91.74%); SPF (8.26%)	4.6524			4.6524	2.7577E-02	4.251E-03	^{244}Pu; (fission products)
^{252}Cf	98	2.645 y	α (96.908%); SPF (3.092%)	5.9308	0.0051	0.0011	5.9370	3.5191E-02	5.378E+02	^{248}Cm; (fission products)

[a]Based on refs. 5-9.

[b]y – years; d – days; h – hours; min – minutes; and s – seconds.

[c]α – alpha decay; β – negative beta decay; EC – electron capture; IT – isomeric transition (radioactive transition from one nuclear isomer to another of lower energy); and SPF – spontaneous fission.

[d]α – alpha decay; ε – total electron emissions; and γ(X) – gamma and X-ray photons.

[e]The sum of the average energies for different radiation types in MeV/disintegration or W/Ci (includes alpha and beta particles, discrete electrons, and photons). The "Q" value indicates the amount of energy (heat) that could be deposited in a radioactive material from each decay event if none of the radiation escaped from the material. Neutrinos are not included.

APPENDIX C. WASTE FLOWSHEETS, SOURCE TERMS, AND CHARACTERISTICS

APPENDIX C. WASTE FLOWSHEETS, SOURCE TERMS, AND CHARACTERISTICS

C.1 DISCUSSION

In this report, a number of engineering estimates, assumptions, and ground rules are used to determine radioactive waste and spent fuel projections through the year 2030. Many of these involve parameters that characterize certain types of waste (e.g., see Table C.1). In other instances, estimates were made of the waste volume generated per unit of product throughput for each step in the fuel cycle. This appendix is a compilation of generic flowsheets and source terms used for making waste projections. Source terms are used to describe quantitative and qualitative characteristics of radioactive wastes. In general, the source term for a particular waste is comprised of two components unique to that waste: (1) the number of curies of radioactivity expressed either per unit of facility production or per unit of waste volume or mass and (2) a listing of the relative radioactivity contributions of component radioisotopes.

The source terms used in the analysis of this report are based on reported historical data, engineering estimates, calculations, and/or experimental data. Documentation of the source terms and key waste-modeling parameters is provided in the following sets of figures and tables (based primarily on refs. 1 through 10). Detailed information on how these source terms and modeling parameters were derived is available, mainly in ref. 1 and its update (ref. 2). Figures C.1 and C.2 were adapted from refs. 1 and 2. Figure C.3 was adapted from information presented in ref. 3. The mass, radioactivity, and thermal power of the nuclides contained in all stored domestic commercial LWR spent fuel as of December 31, 1992, are listed in Table C.2.

Representative DOE LLW radionuclide compositions are described in Table C.3 (based on ref. 1). Average concentrations for representative radionuclides in LLW disposed of at commercial sites are given in Table C.4. Table C.5, which gives the radionuclide composition of saltstone at SRS, summarizes information obtained from ref. 3. LWR energy generation values are reported in Table C.6; the values are based on refs. 4–7. Table C.7 gives a summary of major sources and estimated characteristics of commercial greater-than-Class-C LLW (data from refs. 8 and 9). Information on the LLW to be incorporated in cement as a result of future operations by the West Valley Demonstration Project Radwaste Treatment System is presented in Table C.8, which is taken from ref. 10.

Additional HANF and INEL waste information and data recently provided for this report at press time are given in Tables C.9–C.13. The information and data in these tables will be integrated into future editions of this report. Historical HANF buried LLW volume and radioactivity inventories and characteristics are reported in Tables C.9 and C.10, respectively. Table C.11 reports and compares recently reported INEL generated LLW volume and activity for 1992 with the estimates used in this report. The same type of comparison is made with estimated and recently reported actual 1992 INEL buried LLW characteristics in Table C.12. Table C.13 summarizes various remote-handled TRU wastes at HANF that are not included in the inventories shown in Chapter 3. These wastes are stored at the HANF 200-Area burial grounds and were previously identified as miscellaneous radioactive materials. They represent an additional TRU waste inventory that will be integrated into the TRU waste chapter in future updates of this report.

C.2 REFERENCES

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ORNL DWG 93-10829

DECOMMISSIONING OF 1-MW(e) CAPACITY OF BOILING-WATER REACTOR (IMMEDIATE DECOMMISSIONING)

LOW-LEVEL WASTE

PACKAGED WASTE VOLUME = 1.64E+1 m^3/MW(e)

TOTAL ACTIVITY = 2.63E+2 Ci/MW(e)

	WASTE CLASS		
	A	B	C
Volume, m^3/MW(e)	1.60E+1	3.23E-1	4.59E-2
Activity, Ci/MW(e)	1.23E+1	3.88E+1	2.12E+2
Specific Activity, Ci/m^3			
^{14}C	3.97E-6	1.03E-3	1.68E-1
^{59}Ni	1.40E-5	6.31E-3	1.00E+0
^{94}Nb	2.15E-8	1.44E-5	2.39E-3
^{99}Tc	9.34E-8	3.15E-7	5.02E-5
^{60}Co	2.70E-1	4.29E+1	5.37E+2
^{63}Ni	1.97E-3	8.73E-1	1.37E+2
^{90}Sr	5.48E-4	5.07E-2	0.00E+0
^{90}Y	5.48E-4	5.07E-2	0.00E+0
^{137}Cs	2.54E-2	3.44E+0	0.00E+0
^{137m}Ba	2.40E-2	3.25E+0	0.00E+0
Half-Life <5 yr	4.47E-1	6.90E+1	3.93E+3
Total	7.69E-1	1.20E+2	4.61E+3

GREATER THAN CLASS C LOW-LEVEL WASTE

PACKAGED WASTE VOLUME = 8.55E-3 m^3/MW(e)

TOTAL ACTIVITY = 1.11E+3 Ci/MW(e)

	GREATER THAN CLASS C
Volume, m^3/MW(e)	8.55E-3
Activity, Ci/MW(e)	1.11E+3
Specific Activity, Ci/m^3	
^{14}C	1.20E+1
^{54}Mn	1.77E+3
^{55}Fe	7.04E+4
^{60}Co	4.83E+4
^{59}Ni	6.41E+1
^{63}Ni	8.91E+3
^{94}Nb	1.30E-1
Total	1.29E+5

Fig. C.1. Boiling-water reactor decommissioning wastes per 1-MW(e) capacity.

ORNL DWG 93-10830

DECOMMISSIONING OF 1-MW(e) CAPACITY OF PRESSURIZED WATER REACTOR (IMMEDIATE DECOMMISSIONING)

LOW-LEVEL WASTE

PACKAGED WASTE VOLUME = 1.55E+1 m^3/MW(e)

TOTAL ACTIVITY = 1.06E+2 Ci/MW(e)

	WASTE CLASS		
	A	B	C
Volume, m^3/MW(e)	1.53E+1	1.82E-1	1.45E-2
Activity, Ci/MW(e)	3.28E+1	4.40E+1	2.91E+1
Specific Activity, Ci/m^3			
^{14}C	0.00E+0	0.00E+0	0.00E+0
^{59}Ni	4.75E-5	7.23E-3	5.51E-1
^{94}Nb	2.41E-8	5.22E-5	4.06E-3
^{99}Tc	0.00E+0	0.00E+0	0.00E+0
^{60}Co	3.57E-1	7.83E+1	7.39E+2
^{63}Ni	5.86E-3	1.16E+0	8.99E+1
^{90}Sr	4.88E-5	1.73E-3	0.00E+0
^{90}Y	4.88E-5	1.73E-3	0.00E+0
^{137}Cs	5.39E-2	2.06E+0	0.00E+0
^{137m}Ba	5.10E-2	1.95E+0	0.00E+0
Half-Life <5 yr	1.68E+0	1.59E+2	1.18E+3
Total	2.15E+0	2.42E+2	2.01E+3

GREATER THAN CLASS C LOW-LEVEL WASTE

PACKAGED WASTE VOLUME = 3.87E-3 m^3/MW(e)

TOTAL ACTIVITY = 5.05E+3 Ci/MW(e)

	GREATER THAN CLASS C
Volume, m^3/MW(e)	3.87E-3
Activity, Ci/MW(e)	5.05E+3
Specific Activity, Ci/m^3	
^{14}C	1.33E+2
^{54}Mn	7.73E+4
^{55}Fe	7.56E+5
^{60}Co	3.89E+5
^{59}Ni	4.31E+2
^{63}Ni	8.26E+4
^{94}Nb	2.24E+0
Total	1.31E+6

Fig. C.2. Pressurized-water reactor decommissioning wastes per 1-MW(e) capacity.

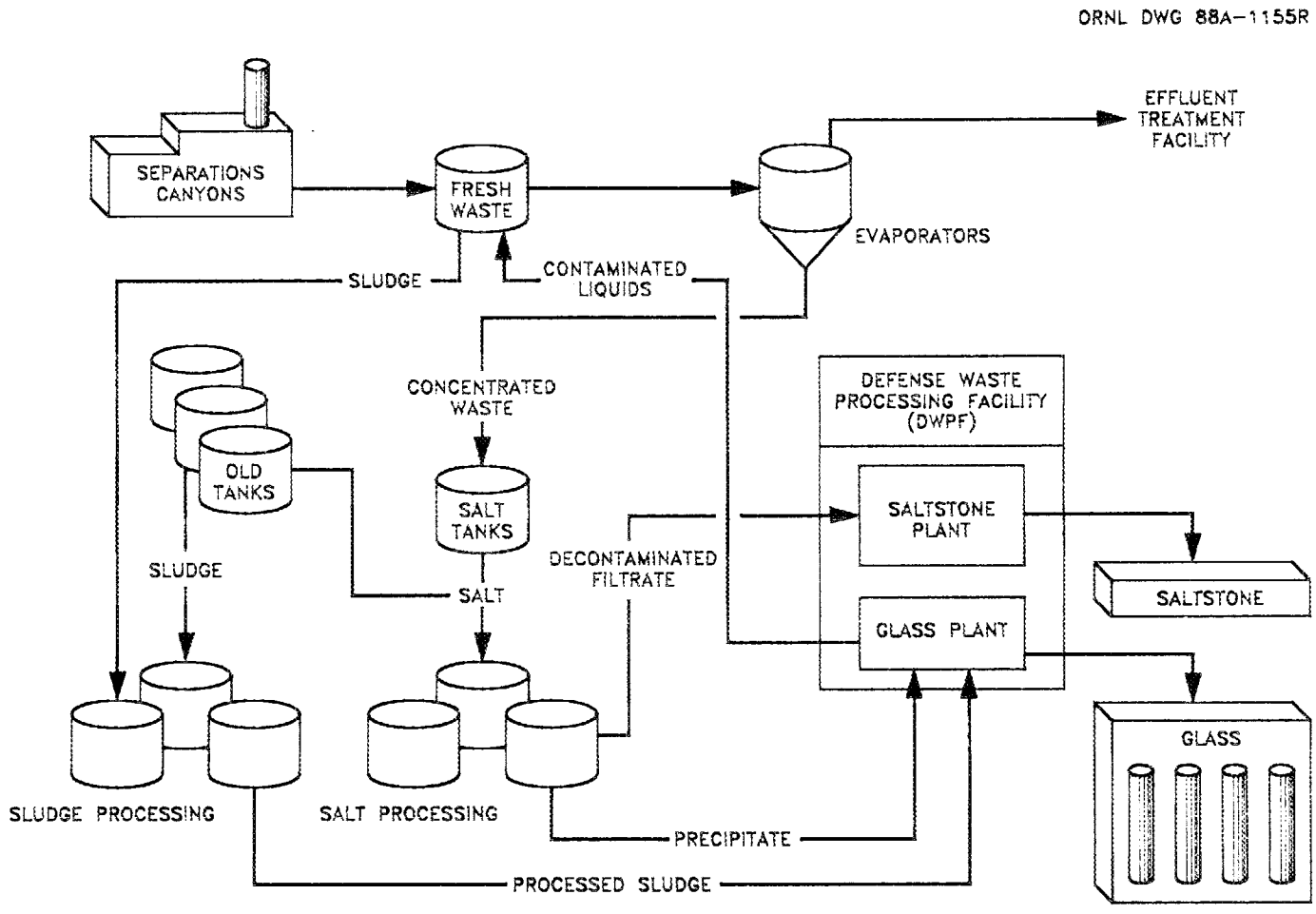

Fig. C.3. Waste flow diagram for the SRS Defense Waste Processing Facility.

Table C.1. Estimated representative unit activity and thermal power characteristics of various types of radioactive materials and wastes

Radioactive material/ waste type	Unit activity (Ci/m^3)	Unit thermal power (W/m^3)
Spent fuel[a]		
BWR	1,000,000-10,000,000	3,500-40,000
PWR	2,000,000-20,000,000	7,500-65,000
High-level waste	1,500-15,000	5-50
Transuranic waste		
Remote handled, stored	1,000	1-2
Contact handled, stored	25-50	0.5-1.5
Buried	0.25-0.50	0.005-0.010
Low-level waste[b]		
DOE sites	9-27	0.012-0.054
Commercial sites[c]	4.6-6.4	0.30-1.60
Class A	0.5-0.7	0.03-0.10
Class B	55-60	14-15
Class C	0.1->7,000[d]	0.003-115[d]
GTCC[e]	>0.1-No limit	>0.003-No limit
Uranium mill tailings	0.010	0.00020

[a]Lower-bound levels are based on cumulative spent fuel discharged; upper-bound levels are based on annual discharges.

[b]Based on 1986-1988 Solid Waste Information Management System (SWIMS) and the national Low-Level Waste Management Program (LLWMP) data access system, both of which were maintained by EG&G, Idaho, Inc., Idaho Falls, Idaho.

[c]Waste classification is defined by the NRC in 10 CFR 61.55 on the basis of concentration of certain long- and short-lived radionuclides. The classification system is designed to minimize potential exposures in both the short and long term. The gross Ci/m^3 shown above are representative of typical LLW shipped to commercial disposal sites. Nuclear power plant wastes account for most of the radioactivity (~96%) and include Class A, B, and C. Essentially all medical wastes are Class A. Industrial wastes are largely Class A, but they contain some Class B and C.

[d]Maximum for ^{63}Ni in activated metal or ^{90}Sr. There is no limit on concentration of ^{3}H, ^{60}Co, or nuclides with half-lives <5 years. The maximum thermal power shown is based on the highest reported gross Ci/m^3 analysis for irradiated core components (1986-1988) and assumes all the activity is due to ^{60}Co, which would yield the greatest heat output. If the activity is due to activation products, such as ^{54}Mn, ^{58}Co, etc., the Ci/m^3 could be much higher for individual shipments, and the total W/m^3 could exceed the value shown.

[e]In temporary storage. The concentration of actinides and ^{129}I determine the lower activity boundary. There is no limit on concentrations of ^{3}H, ^{60}Co, or nuclides with half-lives <5 years.

Table C.2. Mass, radioactivity, and thermal power of nuclides in domestic commercial LWR spent fuel at the end of calendar year 1992[a]

Atomic number	Element	Mass number of nuclide	Mass, g		Radioactivity, Ci		Thermal power, W	
			Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1	Hydrogen	Stable[b]	1.06E+04	1.24E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Hydrogen	3	1.96E+02	1.35E+03	1.89E+06	1.30E+07	6.37E+01	4.38E+02
2	Helium	Stable	6.43E+03	5.96E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3	Lithium	Stable	2.54E+03	2.84E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	Beryllium	Stable	2.47E+00	2.32E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5	Boron	Stable	2.34E+03	2.59E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6	Carbon	Stable	4.15E+05	4.65E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Carbon	14	1.05E+03	9.85E+03	4.70E+03	4.39E+04	1.38E+00	1.29E+01
7	Nitrogen	Stable	2.84E+05	3.20E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
8	Oxygen	Stable	3.14E+08	3.49E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00
9	Fluorine	Stable	2.49E+04	2.77E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
10	Neon	Stable	1.02E+00	9.77E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
11	Sodium	Stable	3.48E+04	3.88E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Sodium	24	2.06E-04	2.06E-04	1.80E+03	1.80E+03	4.98E+01	4.98E+01
12	Magnesium	Stable	4.75E+03	5.27E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
13	Aluminum	Stable	1.96E+05	2.11E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
14	Silicon	Stable	1.11E+06	1.24E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
15	Phosphorus	Stable	5.56E+05	5.81E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Phosphorus	32	3.81E-01	3.81E-01	1.09E+05	1.09E+05	1.10E+03	1.10E+03
16	Sulfur	Stable	6.08E+04	6.94E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
17	Chlorine	Stable	1.15E+04	1.29E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
18	Argon	Stable	9.74E+02	9.39E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
19	Potassium	Stable	4.21E+00	4.03E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
20	Calcium	Stable	4.65E+03	5.18E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
21	Scandium	Stable	2.75E-01	2.63E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
22	Titanium	Stable	2.02E+05	2.15E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
23	Vanadium	Stable	4.22E+04	4.36E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Vanadium	50	1.35E+02	1.35E+03	2.42E-11	2.42E-10	2.67E-13	2.67E-12
24	Chromium	Stable	2.55E+07	2.83E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Chromium	51	9.44E+01	9.44E+01	8.72E+06	8.72E+06	1.87E+03	1.87E+03
25	Manganese	Stable	2.11E+06	2.37E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Manganese	54	2.08E+02	3.43E+02	1.61E+06	2.65E+06	8.02E+03	1.32E+04
26	Iron	Stable	7.70E+07	8.63E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Iron	55	5.68E+03	1.83E+04	1.42E+07	4.58E+07	4.80E+02	1.55E+03
	Iron	59	3.54E+00	3.55E+00	1.74E+05	1.75E+05	1.35E+03	1.35E+03
27	Cobalt	Stable	1.85E+05	2.05E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Cobalt	58	1.09E+02	1.11E+02	3.46E+06	3.54E+06	2.07E+04	2.12E+04
	Cobalt	60	1.63E+04	7.73E+04	1.84E+07	8.75E+07	2.84E+05	1.35E+06
28	Nickel	Stable	2.43E+07	2.62E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Nickel	59	1.52E+05	1.36E+06	1.15E+04	1.03E+05	4.57E-01	4.10E+00
	Nickel	63	2.65E+04	2.23E+05	1.64E+06	1.38E+07	1.65E+02	1.39E+03
29	Copper	Stable	4.16E+04	4.57E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
30	Zinc	Stable	9.38E+04	1.04E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Zinc	65	2.46E+01	3.59E+01	2.03E+05	2.96E+05	7.11E+02	1.04E+03

Table C.2 (continued)

Atomic number	Element	Mass number of nuclide	Mass, g		Radioactivity, Ci		Thermal power, W	
			Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
31	Gallium	Stable	8.06E+01	7.73E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
32	Germanium	Stable	1.50E+03	1.38E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
33	Arsenic	Stable	4.70E+02	4.33E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
34	Selenium	Stable	1.17E+05	1.06E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Selenium	79	1.40E+04	1.27E+05	9.76E+02	8.89E+03	2.43E-01	2.21E+00
35	Bromine	Stable	5.09E+04	4.65E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
36	Krypton	Stable	8.02E+05	7.26E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Krypton	81	5.60E-02	4.89E-01	1.18E-03	1.03E-02	1.45E-07	1.27E-06
	Krypton	85	5.50E+04	3.48E+05	2.16E+07	1.37E+08	3.23E+04	2.05E+05
37	Rubidium	Stable	2.34E+05	2.11E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Rubidium	86	3.94E+00	3.94E+00	3.21E+05	3.21E+05	1.45E+03	1.45E+03
	Rubidium	87	5.81E+05	5.25E+06	5.08E-02	4.60E-01	4.25E-05	3.84E-04
38	Strontium	Stable	8.32E+05	7.52E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Strontium	89	1.19E+04	1.20E+04	3.46E+08	3.48E+08	1.20E+06	1.20E+06
	Strontium	90	1.26E+06	9.85E+06	1.71E+08	1.34E+09	1.99E+05	1.56E+06
39	Yttrium	Stable	1.03E+06	9.14E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Yttrium	90	3.19E+02	2.47E+03	1.73E+08	1.35E+09	9.61E+05	7.46E+06
	Yttrium	91	2.16E+04	2.18E+04	5.30E+08	5.36E+08	1.90E+06	1.92E+06
40	Zirconium	Stable	7.76E+08	9.08E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Zirconium	93	1.97E+06	1.80E+07	4.94E+03	4.52E+04	5.74E-01	5.25E+00
	Zirconium	95	4.06E+04	4.12E+04	8.72E+08	8.85E+08	4.42E+06	4.48E+06
41	Niobium	Stable	1.25E+06	1.92E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Niobium	93m	1.61E+00	4.92E+01	4.54E+02	1.39E+04	8.05E-02	2.47E+00
	Niobium	94	1.58E+04	1.40E+05	2.97E+03	2.63E+04	3.03E+01	2.68E+02
	Niobium	95	3.45E+04	3.53E+04	1.35E+09	1.38E+09	6.48E+06	6.62E+06
	Niobium	95m	1.76E+01	1.79E+01	6.71E+06	6.81E+06	9.32E+03	9.46E+03
42	Molybdenum	Stable	8.56E+06	7.84E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
43	Technetium	99	1.84E+06	1.69E+07	3.13E+04	2.87E+05	1.57E+01	1.44E+02
44	Ruthenium	Stable	5.21E+06	4.71E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Ruthenium	103	1.62E+04	1.62E+04	5.23E+08	5.23E+08	1.75E+06	1.75E+06
	Ruthenium	106	2.84E+05	5.13E+05	9.49E+08	1.72E+09	5.64E+04	1.02E+05
45	Rhodium	Stable	9.93E+05	9.38E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Rhodium	103m	1.45E+01	1.45E+01	4.71E+08	4.72E+08	1.09E+05	1.09E+05
	Rhodium	106	2.67E-01	4.82E-01	9.49E+08	1.72E+09	9.10E+06	1.65E+07
46	Palladium	Stable	2.46E+06	2.17E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Palladium	107	5.34E+05	4.88E+06	2.75E+02	2.51E+03	1.63E-02	1.49E-01
47	Silver	Stable	1.83E+05	1.71E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Silver	108	2.49E-09	1.87E-08	1.83E+00	1.38E+01	6.81E-03	5.12E-02
	Silver	108m	7.88E-01	5.93E+00	2.05E+01	1.55E+02	1.99E-01	1.50E+00
	Silver	110	2.11E-05	3.05E-05	8.78E+04	1.27E+05	6.31E+02	9.14E+02
	Silver	110m	1.39E+03	2.01E+03	6.60E+06	9.56E+06	1.10E+05	1.60E+05
	Silver	111	3.07E+01	3.07E+01	4.85E+06	4.85E+06	1.09E+04	1.09E+04
48	Cadmium	Stable	3.20E+05	2.99E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Cadmium	109	8.61E-01	1.82E+00	2.22E+03	4.70E+03	2.58E-01	5.46E-01

Table C.2 (continued)

Atomic number	Element	Mass number of nuclide	Mass, g		Radioactivity, Ci		Thermal power, W	
			Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
	Cadmium	113m	6.09E+02	4.20E+03	1.32E+05	9.11E+05	2.22E+02	1.53E+03
	Cadmium	115m	2.75E+01	2.76E+01	7.00E+05	7.02E+05	2.61E+03	2.62E+03
49	Indium	Stable	2.76E+03	2.74E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Indium	114	8.45E-05	8.49E-05	1.16E+05	1.17E+05	5.54E+02	5.57E+02
	Indium	114m	5.25E+00	5.28E+00	1.22E+05	1.22E+05	1.71E+02	1.72E+02
	Indium	115	5.40E+03	5.82E+04	3.36E-08	3.62E-07	4.82E-11	5.20E-10
	Indium	115m	5.45E-02	5.45E-02	3.45E+05	3.45E+05	6.89E+02	6.89E+02
50	Tin	Stable	1.27E+07	1.49E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Tin	117m	1.76E+01	1.76E+01	1.40E+06	1.40E+06	2.60E+03	2.60E+03
	Tin	119m	3.57E+03	5.18E+03	1.60E+07	2.32E+07	8.26E+03	1.20E+04
	Tin	121m	5.47E+01	4.77E+02	3.24E+03	2.82E+04	6.49E+00	5.65E+01
	Tin	123	4.96E+02	5.64E+02	4.08E+06	4.63E+06	1.27E+04	1.45E+04
	Tin	125	1.30E+01	1.30E+01	1.41E+06	1.41E+06	9.32E+03	9.32E+03
	Tin	126	6.50E+04	6.00E+05	1.85E+03	1.70E+04	2.30E+00	2.12E+01
51	Antimony	Stable	4.97E+04	4.66E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Antimony	124	4.25E+01	4.31E+01	7.45E+05	7.53E+05	9.89E+03	1.00E+04
	Antimony	125	3.52E+04	1.20E+05	3.64E+07	1.24E+08	1.14E+05	3.87E+05
	Antimony	126	1.61E+00	1.61E+00	1.35E+05	1.35E+05	2.49E+03	2.49E+03
	Antimony	127	1.35E+01	1.35E+01	3.61E+06	3.61E+06	2.14E+04	2.14E+04
52	Tellurium	Stable	1.12E+06	1.02E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Tellurium	123	2.80E+01	2.42E+02	8.14E-09	7.04E-08	8.25E-13	7.13E-12
	Tellurium	123m	2.72E+00	3.00E+00	2.41E+04	2.66E+04	3.51E+01	3.88E+01
	Tellurium	125m	4.76E+02	1.66E+03	8.58E+06	2.99E+07	7.21E+03	2.51E+04
	Tellurium	127	6.09E+00	6.51E+00	1.61E+07	1.72E+07	2.17E+04	2.32E+04
	Tellurium	127m	1.36E+03	1.49E+03	1.29E+07	1.40E+07	6.93E+03	7.54E+03
	Tellurium	129	4.36E-01	4.37E-01	9.14E+06	9.15E+06	3.27E+04	3.27E+04
	Tellurium	129m	4.49E+02	4.49E+02	1.35E+07	1.35E+07	2.37E+04	2.37E+04
	Tellurium	132	1.22E+02	1.22E+02	3.71E+07	3.71E+07	7.35E+04	7.35E+04
53	Iodine	Stable	1.28E+05	1.18E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Iodine	129	4.28E+05	3.95E+06	7.56E+01	6.97E+02	3.50E-02	3.22E-01
	Iodine	131	5.40E+02	5.40E+02	6.69E+07	6.69E+07	2.27E+05	2.27E+05
54	Xenon	Stable	1.24E+07	1.13E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Xenon	129m	4.01E-03	4.01E-03	5.07E+02	5.07E+02	7.09E-01	7.09E-01
	Xenon	131m	2.17E+01	2.17E+01	1.82E+06	1.82E+06	1.75E+03	1.75E+03
	Xenon	133	5.34E+02	5.34E+02	1.00E+08	1.00E+08	1.07E+05	1.07E+05
55	Cesium	Stable	2.65E+06	2.45E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Cesium	134	2.47E+05	6.62E+05	3.19E+08	8.57E+08	3.25E+06	8.72E+06
	Cesium	135	7.85E+05	6.84E+06	9.04E+02	7.88E+03	3.02E-01	2.63E+00
	Cesium	136	7.85E+01	7.85E+01	5.75E+06	5.75E+06	7.84E+04	7.84E+04
	Cesium	137	2.83E+06	2.24E+07	2.47E+08	1.95E+09	2.73E+05	2.16E+06
56	Barium	Stable	3.28E+06	2.94E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Barium	136m	3.52E-06	3.52E-06	9.48E+05	9.48E+05	1.15E+04	1.15E+04
	Barium	137m	4.33E-01	3.43E+00	2.33E+08	1.84E+09	9.16E+05	7.24E+06
	Barium	140	2.40E+03	2.40E+03	1.75E+08	1.75E+08	4.89E+05	4.89E+05

Table C.2 (continued)

Atomic number	Element	Mass number of nuclide	Mass, g		Radioactivity, Ci		Thermal power, W	
			Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
57	Lanthanum	Stable	2.91E+06	2.64E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Lanthanum	138	1.32E+01	1.24E+02	2.53E-07	2.37E-06	1.86E-09	1.74E-08
	Lanthanum	140	3.65E+02	3.65E+02	2.03E+08	2.03E+08	3.40E+06	3.40E+06
58	Cerium	Stable	2.90E+06	2.62E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Cerium	141	1.50E+04	1.50E+04	4.28E+08	4.28E+08	6.27E+05	6.27E+05
	Cerium	142	2.70E+06	2.45E+07	6.48E-02	5.87E-01	0.00E+00	0.00E+00
	Cerium	144	5.58E+05	8.77E+05	1.78E+09	2.80E+09	1.18E+06	1.86E+06
59	Praseodymium	Stable	2.58E+06	2.33E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Praseodymium	143	2.61E+03	2.61E+03	1.76E+08	1.76E+08	3.28E+05	3.28E+05
	Praseodymium	144	2.36E+01	3.70E+01	1.78E+09	2.80E+09	1.31E+07	2.06E+07
	Praseodymium	144m	1.18E-01	1.85E-01	2.14E+07	3.36E+07	7.31E+03	1.15E+04
60	Neodymium	Stable	6.37E+06	5.83E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Neodymium	144	2.65E+06	2.75E+07	3.13E-06	3.25E-05	0.00E+00	0.00E+00
	Neodymium	147	7.20E+02	7.20E+02	5.78E+07	5.78E+07	1.40E+05	1.40E+05
61	Promethium	147	2.91E+05	9.84E+05	2.70E+08	9.13E+08	9.69E+04	3.27E+05
	Promethium	148	7.73E+01	7.73E+01	1.27E+07	1.27E+07	9.78E+04	9.78E+04
	Promethium	148m	4.86E+02	4.86E+02	1.04E+07	1.04E+07	1.32E+05	1.32E+05
62	Samarium	Stable	1.02E+06	9.49E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Samarium	147	1.83E+05	3.68E+06	4.16E-03	8.38E-02	5.70E-05	1.15E-03
	Samarium	148	4.17E+05	3.52E+06	1.26E-07	1.06E-06	1.50E-09	1.27E-08
	Samarium	149	6.55E+03	7.13E+04	1.57E-09	1.71E-08	0.00E+00	0.00E+00
	Samarium	151	3.00E+04	2.90E+05	7.91E+05	7.63E+06	9.27E+01	8.95E+02
63	Europium	Stable	2.58E+05	2.33E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Europium	152	7.72E+01	5.43E+02	1.34E+04	9.39E+04	1.01E+02	7.10E+02
	Europium	154	9.29E+04	5.20E+05	2.51E+07	1.40E+08	2.24E+05	1.25E+06
	Europium	155	3.23E+04	1.45E+05	1.50E+07	6.74E+07	1.09E+04	4.90E+04
	Europium	156	5.33E+02	5.33E+02	2.94E+07	2.94E+07	3.03E+05	3.03E+05
64	Gadolinium	Stable	1.34E+06	1.66E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Gadolinium	152	7.54E+01	2.38E+03	1.64E-09	5.19E-08	2.14E-11	6.76E-10
	Gadolinium	153	1.93E+02	2.95E+02	6.80E+05	1.04E+06	6.15E+02	9.41E+02
65	Terbium	Stable	2.36E+04	2.44E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Terbium	160	1.98E+02	2.03E+02	2.24E+06	2.29E+06	1.82E+04	1.87E+04
	Terbium	161	1.57E+00	1.57E+00	1.84E+05	1.84E+05	3.70E+02	3.70E+02
81	Thallium	Stable	2.42E-09	2.03E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Thallium	206	6.07E-22	6.07E-22	1.32E-13	1.32E-13	1.20E-15	1.20E-15
	Thallium	207	6.69E-12	3.41E-10	1.28E-03	6.50E-02	3.74E-06	1.91E-04
	Thallium	208	1.00E-08	4.05E-07	2.96E+00	1.19E+02	6.96E-02	2.80E+00
	Thallium	209	1.91E-14	1.18E-13	7.80E-06	4.83E-05	1.30E-07	8.03E-07
82	Lead	Stable	2.30E+03	2.56E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Lead	204	3.20E+01	3.56E+02	4.01E-13	4.46E-12	6.18E-15	6.88E-14
	Lead	205	7.89E-02	7.55E-01	4.59E-06	4.39E-05	1.33E-10	1.28E-09
	Lead	209	2.27E-10	6.39E-10	1.03E-03	2.91E-03	1.19E-06	3.34E-06
	Lead	210	9.96E-08	1.19E-05	7.60E-06	9.12E-04	1.76E-09	2.11E-07
	Lead	211	5.18E-11	2.64E-09	1.28E-03	6.52E-02	3.83E-06	1.95E-04

Table C.2 (continued)

Atomic number	Element	Mass number of nuclide	Mass, g		Radioactivity, Ci		Thermal power, W	
			Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
	Lead	212	5.92E-06	2.39E-04	8.23E+00	3.32E+02	1.57E-02	6.32E-01
	Lead	214	1.71E-12	1.98E-10	5.62E-05	6.50E-03	1.79E-07	2.07E-05
83	Bismuth	Stable	9.32E+02	1.04E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Bismuth	208	1.28E-02	1.21E-01	5.96E-05	5.66E-04	9.38E-07	8.91E-06
	Bismuth	210	1.62E-05	1.62E-05	2.01E+00	2.01E+00	4.64E-03	4.64E-03
	Bismuth	210m	7.49E-02	7.18E-01	4.25E-05	4.08E-04	1.34E-06	1.28E-05
	Bismuth	211	3.06E-12	1.56E-10	1.28E-03	6.52E-02	5.10E-05	2.60E-03
	Bismuth	212	5.61E-07	2.26E-05	8.23E+00	3.32E+02	1.40E-01	5.64E+00
	Bismuth	213	1.87E-11	1.16E-10	3.61E-04	2.24E-03	1.52E-06	9.40E-06
	Bismuth	214	1.27E-12	1.47E-10	5.62E-05	6.50E-03	7.20E-07	8.33E-05
84	Polonium	210	1.02E-02	1.19E-02	4.60E+01	5.33E+01	1.48E+00	1.71E+00
	Polonium	211	3.75E-17	1.91E-15	3.58E-06	1.83E-04	1.61E-07	8.22E-06
	Polonium	212	2.97E-17	1.20E-15	5.27E+00	2.13E+02	2.79E-01	1.13E+01
	Polonium	213	2.80E-20	1.73E-19	3.53E-04	2.19E-03	1.79E-05	1.11E-04
	Polonium	214	2.29E-19	2.03E-17	7.36E-05	6.52E-03	3.42E-06	3.03E-04
	Polonium	215	4.34E-17	2.21E-15	1.28E-03	6.52E-02	5.71E-05	2.91E-03
	Polonium	216	2.36E-11	9.52E-10	8.22E+00	3.32E+02	3.36E-01	1.36E+01
	Polonium	218	1.99E-13	2.30E-11	5.62E-05	6.50E-03	2.04E-06	2.36E-04
85	Astatine	217	2.24E-16	1.39E-15	3.61E-04	2.24E-03	1.54E-05	9.55E-05
86	Radon	218	1.18E-17	1.18E-17	1.74E-05	1.74E-05	7.49E-07	7.49E-07
	Radon	219	9.83E-14	5.01E-12	1.28E-03	6.52E-02	5.31E-05	2.71E-03
	Radon	220	8.91E-09	3.59E-07	8.22E+00	3.32E+02	3.12E-01	1.26E+01
	Radon	222	3.65E-10	4.23E-08	5.62E-05	6.50E-03	1.86E-06	2.15E-04
87	Francium	221	2.04E-12	1.26E-11	3.61E-04	2.24E-03	1.39E-05	8.63E-05
	Francium	223	4.95E-13	2.36E-11	1.91E-05	9.14E-04	4.97E-08	2.37E-06
88	Radium	222	1.30E-14	1.30E-14	1.74E-05	1.74E-05	6.90E-07	6.90E-07
	Radium	223	2.50E-08	1.27E-06	1.28E-03	6.52E-02	4.55E-05	2.32E-03
	Radium	224	5.16E-05	2.08E-03	8.22E+00	3.32E+02	2.82E-01	1.14E+01
	Radium	225	8.41E-09	5.63E-08	3.30E-04	2.21E-03	2.31E-07	1.55E-06
	Radium	226	5.73E-05	6.59E-03	5.67E-05	6.52E-03	1.64E-06	1.88E-04
	Radium	228	3.25E-11	3.87E-09	7.61E-09	9.07E-07	5.87E-13	6.99E-11
89	Actinium	225	6.22E-09	3.85E-08	3.61E-04	2.24E-03	1.26E-05	7.81E-05
	Actinium	227	1.92E-05	9.15E-04	1.39E-03	6.62E-02	6.72E-07	3.21E-05
	Actinium	228	5.63E-12	6.03E-12	1.26E-05	1.35E-05	1.09E-07	1.17E-07
90	Thorium	226	6.49E-13	6.49E-13	1.74E-05	1.74E-05	6.66E-07	6.66E-07
	Thorium	227	4.23E-08	2.10E-06	1.30E-03	6.47E-02	4.75E-05	2.36E-03
	Thorium	228	9.89E-03	4.02E-01	8.11E+00	3.30E+02	2.65E-01	1.08E+01
	Thorium	229	1.34E-03	1.02E-02	2.84E-04	2.16E-03	8.70E-06	6.62E-05
	Thorium	230	3.55E+00	1.19E+02	7.17E-02	2.39E+00	2.03E-03	6.77E-02
	Thorium	231	8.53E-05	8.92E-04	4.54E+01	4.75E+02	2.55E-02	2.66E-01
	Thorium	232	5.89E-01	2.09E+01	6.46E-08	2.29E-06	1.56E-09	5.55E-08
	Thorium	233	1.14E-11	1.14E-11	4.16E-04	4.16E-04	1.05E-06	1.05E-06
	Thorium	234	3.19E-02	3.58E-01	7.39E+02	8.29E+03	3.00E-01	3.36E+00
91	Protactinium	231	7.05E-01	7.34E+00	3.33E-02	3.47E-01	1.00E-03	1.05E-02
	Protactinium	232	1.30E-05	1.30E-05	5.57E+00	5.57E+00	3.64E-02	3.64E-02

Table C.2 (continued)

Atomic number	Element	Mass number of nuclide	Mass, g		Radioactivity, Ci		Thermal power, W	
			Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
	Protactinium	233	3.63E-02	3.12E-01	7.54E+02	6.49E+03	1.71E+00	1.47E+01
	Protactinium	234	4.86E-07	5.39E-06	9.73E-01	1.08E+01	1.40E-02	1.55E-01
	Protactinium	234m	1.08E-06	1.21E-05	7.39E+02	8.29E+03	3.65E+00	4.10E+01
	Protactinium	235	5.76E-17	5.76E-17	1.91E-09	1.91E-09	5.34E-12	5.34E-12
92	Uranium	230	6.37E-10	6.37E-10	1.74E-05	1.74E-05	6.18E-07	6.18E-07
	Uranium	231	5.98E-09	5.98E-09	8.05E-04	8.05E-04	6.65E-07	6.65E-07
	Uranium	232	1.34E+00	2.06E+01	2.88E+01	4.42E+02	9.24E-01	1.42E+01
	Uranium	233	3.17E+00	4.73E+01	3.07E-02	4.58E-01	8.92E-04	1.33E-02
	Uranium	234	4.12E+05	4.41E+06	2.58E+03	2.76E+04	7.42E+01	7.94E+02
	Uranium	235	1.78E+07	2.16E+08	3.84E+01	4.68E+02	1.01E+00	1.22E+01
	Uranium	236	9.33E+06	8.50E+07	6.04E+02	5.50E+03	1.64E+01	1.49E+02
	Uranium	237	6.15E+02	6.16E+02	5.03E+07	5.03E+07	9.51E+04	9.52E+04
	Uranium	238	2.20E+09	2.46E+10	7.39E+02	8.29E+03	1.87E+01	2.10E+02
	Uranium	239	1.99E-02	1.99E-02	6.64E+05	6.64E+05	1.79E+03	1.79E+03
	Uranium	240	2.78E-04	2.78E-04	2.58E+02	2.58E+02	2.12E-01	2.12E-01
93	Neptunium	235	7.54E-03	1.38E-02	1.06E+01	1.93E+01	6.15E-04	1.12E-03
	Neptunium	236	9.46E-01	7.74E+00	1.25E-02	1.02E-01	2.52E-05	2.06E-04
	Neptunium	236m	1.12E-04	1.12E-04	6.62E+01	6.62E+01	5.23E-02	5.23E-02
	Neptunium	237	1.07E+06	9.20E+06	7.55E+02	6.49E+03	2.31E+01	1.98E+02
	Neptunium	238	2.54E+01	2.54E+01	6.59E+06	6.59E+06	3.16E+04	3.16E+04
	Neptunium	239	1.79E+03	1.79E+03	4.16E+08	4.16E+08	1.01E+06	1.01E+06
	Neptunium	240	4.41E-04	4.41E-04	5.32E+03	5.32E+03	5.64E+01	5.64E+01
	Neptunium	240m	2.48E-06	2.48E-06	2.63E+02	2.63E+02	1.52E+00	1.52E+00
	Neptunium	241	1.70E-13	1.70E-13	8.29E-06	8.29E-06	2.32E-08	2.32E-08
94	Plutonium	236	2.48E+00	7.85E+00	1.32E+03	4.17E+03	4.59E+01	1.45E+02
	Plutonium	237	2.15E-02	2.16E-02	2.60E+02	2.61E+02	9.60E-02	9.63E-02
	Plutonium	238	3.48E+05	2.73E+06	5.96E+06	4.68E+07	1.97E+05	1.55E+06
	Plutonium	239	1.16E+07	1.25E+08	7.22E+05	7.78E+06	2.22E+04	2.40E+05
	Plutonium	240	5.35E+06	5.19E+07	1.22E+06	1.18E+07	3.80E+04	3.68E+05
	Plutonium	241	2.87E+06	2.11E+07	2.95E+08	2.18E+09	9.16E+03	6.74E+04
	Plutonium	242	1.15E+06	1.01E+07	4.39E+03	3.85E+04	1.30E+02	1.14E+03
	Plutonium	243	2.33E-01	2.33E-01	6.06E+05	6.06E+05	6.99E+02	6.99E+02
	Plutonium	244	6.73E+01	5.29E+02	1.19E-03	9.39E-03	3.46E-05	2.72E-04
	Plutonium	245	2.59E-06	2.59E-06	3.13E+00	3.13E+00	7.42E-03	7.42E-03
	Plutonium	246	5.73E-07	5.73E-07	2.80E-02	2.80E-02	2.36E-05	2.36E-05
95	Americium	239	4.23E-09	4.23E-09	4.66E-03	4.66E-03	1.13E-05	1.13E-05
	Americium	240	1.83E-05	1.83E-05	4.72E+00	4.72E+00	3.09E-02	3.09E-02
	Americium	241	1.48E+05	8.46E+06	5.07E+05	2.90E+07	1.69E+04	9.64E+05
	Americium	242	6.17E-01	7.70E-01	4.99E+05	6.23E+05	5.67E+02	7.07E+02
	Americium	242m	1.70E+03	1.45E+04	1.65E+04	1.41E+05	6.52E+00	5.56E+01
	Americium	243	2.34E+05	1.91E+06	4.67E+04	3.81E+05	1.50E+03	1.23E+04
	Americium	244	1.68E-02	1.68E-02	2.14E+04	2.14E+04	1.12E+02	1.12E+02
	Americium	244m	1.65E-04	1.65E-04	4.91E+03	4.91E+03	1.48E+01	1.48E+01
	Americium	245	6.10E-07	6.10E-07	3.77E+00	3.77E+00	6.99E-03	6.99E-03
	Americium	246	9.18E-10	9.18E-10	2.81E-02	2.81E-02	2.27E-04	2.27E-04

Table C.2 (continued)

Atomic number	Element	Mass number of nuclide	Mass, g		Radioactivity, Ci		Thermal power, W	
			Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
96	Curium	242	1.59E+04	1.93E+04	5.27E+07	6.39E+07	1.94E+06	2.36E+06
	Curium	243	9.11E+02	6.25E+03	4.70E+04	3.23E+05	1.73E+03	1.18E+04
	Curium	244	7.13E+04	4.40E+05	5.77E+06	3.56E+07	2.02E+05	1.25E+06
	Curium	245	2.78E+03	2.03E+04	4.78E+02	3.48E+03	1.59E+01	1.15E+02
	Curium	246	3.90E+02	2.61E+03	1.20E+02	8.03E+02	3.92E+00	2.63E+01
	Curium	247	4.08E+00	2.55E+01	3.79E-04	2.37E-03	1.21E-05	7.56E-05
	Curium	248	2.42E-01	1.39E+00	1.03E-03	5.92E-03	1.28E-04	7.37E-04
	Totals		3.56E+09	4.01E+10	1.34E+10	2.64E+10	5.56E+07	1.00E+08

[a]Includes contributions from nuclides in the fuel, cladding, and fuel assembly structural material.
[b]The term "stable" represents a group of nonradioactive nuclides of a particular element.

Table C.3. Representative DOE LLW radionuclide composition by percent activity[a]

Uranium/thorium		Fission product		Induced activity		Alpha, <100 nCi/g		"Other"	
Nuclide	Composition	Nuclide	Composition	Nuclide	Composition	Nuclide	Composition	Nuclide	Composition
^{208}Tl	0.0017	^{60}Co	0.08	^{51}Cr	4.95	^{238}Pu	2.62	^{3}H	1.22
^{212}Pb	0.0045	^{90}Sr	7.77	^{54}Mn	38.10	^{239}Pu	0.20	^{14}C	0.06
^{212}Bi	0.0045	^{90}Y	7.77	^{58}Co	55.40	^{240}Pu	0.70	^{54}Mn	6.76
^{212}Po	0.0029	^{95}Zr	1.27	^{59}Fe	0.49	^{241}Pu	96.4	^{58}Co	6.24
^{216}Po	0.0045	^{95}Nb	2.83	^{60}Co	0.87	^{241}Am	0.004	^{60}Co	18.03
^{224}Ra	0.0045	^{99}Tc	0.02	^{65}Zn	0.19	^{242}Cm	0.056	^{90}Sr	8.48
^{228}Ra	0.0269	^{125}Sb	2.93			^{244}Cm	0.020	^{90}Y	8.48
^{228}Ac	0.0269	^{125m}Te	0.73		100.00			^{99}Tc	0.12
^{228}Th	0.0045	^{106}Ru	6.39				100.000	^{134}Cs	13.98
^{231}Th	0.0259	^{106}Rh	6.39					^{137}Cs	18.45
^{232}Th	0.273	^{134}Cs	0.38					^{137m}Ba	17.45
^{234}Th	33.197	^{137}Cs	17.31					^{238}U	0.73
^{234m}Pa	33.197	^{137m}Ba	16.38						
^{234}Pa	0.0034	^{144}Ce	14.67						100.00
^{235}U	0.0258	^{144}Pr	14.67						
^{238}U	33.197	^{147}Pm	0.06						
		^{151}Sm	0.11						
	100.0000	^{152}Eu	0.09						
		^{154}Eu	0.09						
		^{155}Eu	0.06						
			100.00						

[a]Based on ref. 1.

Table C.4. Average concentrations for representative radionuclides in LLW at commercial disposal sites[a]

Radionuclide	Half-life[b]	Concentration (Ci/m^3)
^{3}H	1.228E+01 y	1.083E+00
^{14}C	5.730E+03 y	5.079E-03
^{26}Al	7.300E+05 y	2.980E-10
^{32}Si	1.000E+02 y	3.725E-11
^{32}P	1.428E+01 d	9.292E-04
^{35}S	8.751E+01 d	2.208E-03
^{36}Cl	3.010E+05 y	6.143E-06
^{40}K	1.280E+09 y	1.766E-07
^{51}Cr	2.770E+01 d	7.137E-02
^{54}Mn	3.122E+02 d	3.895E-01
^{55}Fe	2.730E+00 y	3.112E+00
^{59}Fe	4.445E+01 d	5.081E-03
^{58}Co	7.092E+01 d	2.047E-01
^{60}Co	5.271E+00 y	2.242E+00
^{59}Ni	7.500E+04 y	1.364E-03
^{63}Ni	1.001E+02 y	2.692E-01
^{65}Zn	2.441E+02 d	1.174E-01
^{85}Kr	1.072E+01 y	8.147E-04
^{89}Sr	5.055E+01 d	6.032E-03
^{90}Sr	2.850E+01 y	6.987E-02
^{90}Y	2.671E+01 d	6.987E-02
^{91}Y	5.851E+01 d	8.859E-03
^{95}Zr	6.402E+01 d	1.036E-02
^{94}Nb	2.030E+04 y	1.659E-05
^{95}Nb	3.497E+01 d	1.916E-02
^{93}Mo	3.500E+03 y	9.273E-12
^{99}Tc	2.130E+05 y	1.949E-04
^{103}Ru	3.925E+01 d	5.900E-04
^{108m}Ag	1.300E+02 y	5.534E-06
^{110m}Ag	2.498E+02 d	3.600E-02
^{113}Cd	9.000E+15 y	4.223E-12
^{124}Sb	6.020E+00 d	2.621E-03
^{125}Sb	2.730E+00 y	1.901E-02
^{123}Te	1.300E+13 y	5.710E-07
^{125}I	6.014E+00 d	4.570E-04
^{129}I	1.570E+07 y	2.101E-05
^{131}I	8.040E+00 d	5.299E-03
^{134}Cs	2.062E+00 y	8.661E-02
^{135}Cs	3.000E+06 y	1.105E-05
^{137}Cs	3.017E+01 y	2.431E-01
^{137m}Ba	2.552E+00 min	2.300E-01
^{141}Ce	3.250E+01 d	1.649E-03
^{144}Ce	2.849E+02 d	1.463E-02
^{144}Pr	1.728E+01 min	1.463E-02
^{144}Nd	2.100E+15 y	1.689E-10
^{147}Pm	2.623E+00 y	1.317E-02
^{157}Tb	1.100E+02 y	1.012E-10
^{158}Tb	1.800E+02 y	3.768E-10
^{175}Hf	7.000E+01 d	1.427E-03
^{181}Hf	4.240E+01 d	3.235E-03
^{187}Re	4.100E+10 y	1.772E-11

Table C.4 (continued)

Radionuclide	Half-life[b]	Concentration (Ci/m^3)
^{209}Po	3.253E+00 h	1.284E-10
^{226}Ra	1.600E+03 y	2.852E-04
^{229}Th	7.340E+03 y	1.310E-10
^{230}Th	7.540E+04 y	1.721E-08
^{232}Th	1.405E+10 y	8.482E-03
^{231}Pa	3.276E+04 y	1.016E-10
^{233}U	1.592E+05 y	2.308E-07
^{234}U	2.454E+05 y	5.368E-05
^{235}U	7.037E+08 y	3.179E-05
^{236}U	2.432E+07 y	7.886E-07
^{238}U	4.468E+09 y	9.970E-03
^{237}Np	2.140E+06 y	2.210E-07
^{239}Pu	2.413E+04 y	1.021E-05[c]
^{240}Pu	6.563E+03 y	2.504E-06[c]
^{242}Pu	3.763E+05 y	6.148E-07[c]
^{241}Am	4.322E+02 y	4.053E-05
^{243}Am	7.380E+03 y	1.398E-08
^{248}Cm	3.400E+05 y	6.220E-07
Total		8.380E+00

[a]Taken from the report by G. W. Roles, Characteristics of Low-Level Radioactive Waste Disposed During 1987 Through 1989, NUREG-1418, December 1990.

[b]y = years; d = days; h = hours; min = minutes; and s = seconds.

[c]Isotopes of plutonium are omitted when this list is applied to waste disposed at Barnwell, South Carolina, because this site has not permitted disposal of plutonium (even though traces of plutonium could have entered with other wastes).

Table C.5. Projected composition of LLW saltstone at SRS[a,b]

End of calendar year	Radioactivity fraction of radionuclide[c]																
	^{3}H	^{89}Sr	^{90}Sr	^{90}Y	^{91}Y	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{106}Rh	^{125}Sb	^{137}Cs	^{137m}Ba	^{144}Ce	^{144}Pr	^{147}Pm	Total[d]
1995	0.12	0.00	0.34	0.34	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.05	0.05	0.00	0.00	0.08	1.00
1996	0.02	0.00	0.11	0.11	0.00	0.00	0.00	0.01	0.01	0.01	0.06	0.02	0.02	0.00	0.00	0.65	1.00
1997	0.02	0.00	0.20	0.20	0.00	0.00	0.00	0.01	0.00	0.00	0.03	0.03	0.03	0.00	0.00	0.47	1.00
1998	0.03	0.00	0.24	0.24	0.00	0.00	0.00	0.01	0.00	0.00	0.03	0.04	0.03	0.00	0.00	0.38	1.00
1999	0.04	0.00	0.27	0.27	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.04	0.04	0.00	0.00	0.30	1.00
2000	0.05	0.00	0.29	0.29	0.00	0.00	0.00	0.02	0.00	0.00	0.02	0.05	0.04	0.00	0.00	0.24	1.00
2001	0.06	0.00	0.31	0.31	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.05	0.05	0.00	0.00	0.20	1.00
2002	0.06	0.00	0.32	0.32	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.05	0.05	0.00	0.00	0.16	1.00
2003	0.07	0.00	0.33	0.33	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.05	0.05	0.00	0.00	0.13	1.00
2004	0.07	0.00	0.34	0.34	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.06	0.05	0.00	0.00	0.11	1.00
2005	0.08	0.00	0.35	0.35	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.06	0.05	0.00	0.00	0.09	1.00
2006	0.09	0.00	0.35	0.35	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.06	0.05	0.00	0.00	0.07	1.00
2007	0.09	0.00	0.36	0.35	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.06	0.05	0.00	0.00	0.06	1.00
2008	0.09	0.00	0.36	0.36	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.06	0.05	0.00	0.00	0.05	1.00
2009	0.09	0.00	0.36	0.36	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.06	0.05	0.00	0.00	0.04	1.00
2010	0.10	0.00	0.37	0.36	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.03	1.00
2011	0.11	0.00	0.36	0.36	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.02	1.00
2012	0.11	0.00	0.37	0.36	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.02	1.00
2013	0.11	0.00	0.37	0.36	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.02	1.00
2014	0.11	0.00	0.37	0.36	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.01	1.00
2015	0.11	0.00	0.37	0.36	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.01	1.00
2016	0.12	0.00	0.37	0.36	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.01	1.00
2017	0.12	0.00	0.37	0.36	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.01	1.00
2018	0.12	0.00	0.37	0.36	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00
2019	0.12	0.00	0.37	0.36	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00
2020	0.12	0.00	0.37	0.36	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00
2021	0.12	0.00	0.37	0.36	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00
2022	0.12	0.00	0.36	0.36	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00
2023	0.12	0.00	0.36	0.36	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00
2024	0.12	0.00	0.36	0.36	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00
2025	0.12	0.00	0.36	0.36	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00
2026	0.12	0.00	0.36	0.35	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00
2027	0.12	0.00	0.36	0.35	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00
2028	0.12	0.00	0.36	0.35	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00
2029	0.12	0.00	0.36	0.35	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00
2030	0.12	0.00	0.36	0.35	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00

[a]Taken from ref. 3.

[b]Chemical composition (wt %): fly ash, 46.0; water, 30.2; cement, 11.5; $NaNO_3$, 6.0; NaOH, 1.9; $NaNO_2$, 1.5; $NaAl(OH)_4$, 1.3; Na_2SO_4, 0.7; and other, 0.9.

[c]The radionuclide composition at the end of a year is expressed in terms of the fraction of each significant nuclide making up an average unit of radioactivity in all saltstone collected from the beginning of the operation of the saltstone plant to the end of the year indicated.

[d]For some years the total may not equal the sum of components because of independent rounding.

Table C.6. Historical and projected DOE/EIA No New Orders Case commercial LWR net annual electrical generation[a,b]

End of calendar year	Historical generation [MW(e)-years]			End of calendar year	No New Orders Case projected generation[c] [MW(e)-years]		
	BWR	PWR	Total		BWR	PWR	Total
1960	29	4	33	1993	20,632	48,339	68,970
1961	60	97	157	1994	20,632	48,914	69,546
1962	137	96	233	1995	20,632	49,032	69,664
1963	136	208	344	1996	20,632	50,150	70,782
1964	164	198	362	1997	20,632	50,401	71,033
1965	164	212	376	1998	20,632	50,555	71,186
1966	221	334	556	1999	20,632	50,795	71,426
1967	184	419	603	2000	20,606	50,795	71,400
1968	205	781	986	2001	20,587	51,521	72,109
1969	238	1,049	1,287	2002	20,587	51,494	72,081
1970	1,011	1,192	2,203	2003	20,587	51,703	72,290
1971	1,969	2,103	4,075	2004	20,439	51,703	72,142
1972	3,188	2,450	5,641	2005	20,185	51,703	71,888
1973	4,446	4,620	9,073	2006	19,769	51,703	71,472
1974	5,298	6,650	11,955	2007	19,769	50,953	70,721
1975	6,309	12,089	17,395	2008	19,444	49,447	68,891
1976	8,044	13,113	21,343	2009	18,277	47,576	65,853
1977	9,636	17,737	27,388	2010	17,380	46,249	63,629
1978	11,353	19,596	31,142	2011	17,029	45,354	62,383
1979	11,390	17,332	28,662	2012	16,489	45,036	61,525
1980	10,416	17,848	28,343	2013	15,247	42,134	57,380
1981	10,187	20,310	30,517	2014	13,523	36,663	50,186
1982	10,201	20,716	30,938	2015	11,849	34,365	46,214
1983	9,363	22,494	31,883	2016	11,649	32,547	44,197
1984	9,766	26,427	35,072	2017	11,010	30,031	41,040
1985	12,151	30,413	41,382	2018	10,707	28,438	39,146
1986	12,737	33,726	46,495	2019	10,438	27,550	37,989
1987	14,810	36,465	51,275	2020	10,438	26,609	37,048
1988	16,722	41,639	58,361	2021	10,438	24,134	34,572
1989	16,845	43,489	60,334	2022	9,969	22,880	32,849
1990	20,417	45,407	65,808	2023	6,866	21,321	28,187
1991	20,573	49,310	69,883	2024	5,816	17,905	23,720
1992	19,761	50,833	70,594	2025	4,592	14,625	19,217
				2026	2,584	10,508	13,092
				2027	854	7,844	8,698
				2028	854	5,305	6,159
				2029	500	4,437	4,937
				2030	0	3,715	3,715

[a]Historical data for 1960-1989 are based on refs. 5 and 6.

[b]Historical data for 1990-1992 and projected data for 1993-2030 were obtained from DOE/EIA and are based on ref. 7.

[c]The projections contained in this table show minor differences from those found in the publication World Nuclear Capacity and Fuel Cycle Requirements 1993 (ref. 7). The differences are attributable to the use of a later version of input data to compute the projections found here.

Table C.7. Estimated sources and characteristics of commercial Greater-Than-Class-C LLW[a]

Waste source	Physical form	Primary isotopes of concern for disposal
Utilities		
Operations	Activated metals, instruments, filters, ion-exchange resins, sludges	^{59}Ni, ^{63}Ni, ^{94}Nb, and TRU isotopes
Decommissioning	Activated metals	^{59}Ni, ^{63}Ni, and ^{94}Nb
Fuel testing labs		
Burnup lab operation	Solidified liquids, metal cuttings, glassware, equipment, ion-exchange resins	^{90}Sr and TRU isotopes
Burnup lab decommissioning	Solidified liquids, metals, glassware, equipment	^{90}Sr and TRU isotopes
Sealed sources		
Manufacturer operations	Trash, metal, foils	^{14}C, ^{90}Sr, ^{137}Cs, ^{241}Am, and Pu isotopes
Manufacturer decommissioning	Trash, metal, foils	^{14}C, ^{90}Sr, ^{137}Cs, ^{241}Am, and Pu isotopes
Sources designated as waste	Sealed sources	^{137}Cs, ^{238}Pu, ^{239}Pu, and ^{241}Am
Other		
^{14}C users	Solidified process liquids	^{14}C
Test and research reactors	Activated metals	^{59}Ni, ^{94}Nb, and TRU isotopes
Other	Soil, trash	^{241}Am

[a]Gleaned from information given in refs. 8 and 9.

Table C.8. Projected number and volume of drums and classes of LLW incorporated in cement to be generated in the WVDP Low-Level Radwaste Treatment System[a,b,c,d]

End of calendar year	Number of drums			Total volume of drums (m^3)
	Class A[e]	Class B	Class C[f]	
1987	726	g	-	196
1988	-	g	2,009	542
1989	-	g	4,523	1,221
1990[h]	-	g	3,862	1,043
1991	-	g	0	0
1992	1,237	g	300	415
1993	3,197	g	1,987	1,400
Total number	5,160	g	12,681	
Total volume, m^3	1,393	g	3,424	4,817

[a]The so-called square drums used are parallelepipeds of square cross section (~0.6 m × 0.6 m × 0.8 m) with a volume of 71 gal (0.27 m^3).

[b]The classes are in accordance with the Classes (A, B, or C) as set by requirements of the NRC in 10 CFR 61.55.

[c]Taken from ref. 10.

[d]Alkaline HLW liquid is processed (see Chapter 2) to yield a loaded ion-exchange material (zeolite), which is HLW, and an effluent, which is LLW. This effluent is solidified with cement.

[e]Generated in 1987 during equipment testing campaigns.

[f]Stored in a shielded drum cell.

[g]No Class B waste is expected to be generated with the effluent mentioned in footnote d.

[h]Processing of alkaline HLW liquid was completed in November 1990, leaving a 1,090-m^3 heel of liquid in the alkaline HLW waste (liquid plus sludge) storage tank.

Table C.9. Volume (m^3) of LLW annually buried at Hanford, by radionuclide characteristic[a]

Calendar year	Uranium/ thorium[b]	Fission products	Induced activity	Tritium	Total
1945[c]	1,339.39				1,339.39
1946	1,339.39				1,339.39
1947	2,613.66				2,613.66
1948	2,613.66				2,613.66
1949	2,613.66		2.55		2,616.21
1950	3,123.36				3,123.36
1951	2,981.78				2,981.78
1952	3,015.76		223.70		3,239.46
1953	3,550.95		120.34		3,671.29
1954	3,137.52	1,958.12	10.19		5,105.83
1955	5,351.91	1,557.44			6,909.35
1956	4,556.20		45.31		4,601.51
1957	2,775.07		1,529.12		4,304.19
1958	3,229.55				3,229.55
1959	3,256.46				3,256.46
1960	2,997.36	1,159.58	2,463.58		6,620.52
1961	2,350.31				2,350.31
1962	2,347.48	254.85			2,602.33
1963	2,321.99	421.92			2,743.92
1964	3,175.75		240.69		3,416.44
1965	5,431.20		17,567.87		22,999.07
1966	3,421.83				3,421.83
1967	4,416.04		11,336.99		15,753.03
1968		835.32	39.64		874.96
1969	137,903.79	21,614.28	5,097.06		164,615.13
1970	180.73	2,529.42	3,964.41		6,674.56
1971	175.98	2,888.90	7.52		3,072.40
1972	262.22	2,900.28	41,626.34	3.04	44,791.88
1973	3,178.51	3,289.03	2,335.57	6.06	8,809.17
1974	209.23	4,087.95	1,469.38		5,766.56
1975	100.65	4,604.88	1,856.39		6,561.91
1976	77.20	3,073.75	919.33	2.93	4,073.21
1977	180.73	9,266.22	1,274.39		10,721.33
1978	541.07	8,296.62	972.26		9,809.96
1979	322.99	14,717.53	2,428.78		17,469.30
1980	216.10	9,193.70	970.80	14.40	10,395.90
1981	299.77	10,359.16	2,166.93	0.64	12,826.49
1982	453.41	9,640.80	1,415.73	145.14	11,655.07
1983	1,257.20	14,579.31	1,994.25	117.53	17,948.28
1984	727.52	13,926.02	4,089.01	35.23	18,777.77
1985	1,002.81	11,128.62	4,869.46	45.79	17,046.68
1986	1,463.71	15,666.42	3,961.12		21,091.26
1987	3,131.01	13,682.00	3,489.83	9.56	20,312.40
1988	1,335.95	13,658.71	1,678.25	105.59	16,778.30
1989	663.94	12,041.49	748.48	246.55	13,700.45
1990	261.10	11,399.72	475.31	1,237.53	13,374.56
1991	517.61	8,518.30	120.03	1,420.32	10,576.26
1992	1,377.07	9,187.34	35.12	329.79	10,929.32
Total	227,802.38	236,437.68	121,545.73	3,720.08	589,505.87

[a]Revised data received at press time. Note from Mike Coony, Westinghouse Hanford, to Laverne Cash, HAZWRAP, dated Jan. 19, 1994.

[b]The uranium/thorium category includes 904.45 m^3 of waste that is actually a mixture of uranium/thorium and tritium nuclides.

[c]First year of recorded burial operations.

Table C.10. Activity (Ci) of LLW annually buried at Hanford, by radionuclide characteristic[a]

Calendar year	Uranium/ thorium	Fission products	Induced activity	Tritium	Total
1945[b]	0.04	1,020.00	0.00	0.00	1,020.04
1946	0.03	2,025.00	0.00	0.00	2,025.03
1947	0.07	4,150.00	0.00	0.00	4,150.07
1948	0.06	6,200.00	0.00	0.00	6,200.06
1949	0.07	8,225.00	1.00	0.00	8,226.07
1950	0.06	9,250.00	0.00	0.00	9,250.06
1951	0.07	10,250.00	0.00	0.00	10,250.07
1952	0.21	14,280.00	40.00	0.00	14,320.21
1953	0.21	19,210.00	40.00	0.00	19,250.21
1954	0.16	49,530.10	5.00	0.00	49,535.26
1955	0.16	45,000.00	0.00	0.00	45,000.16
1956	0.30	31,640.00	25.00	0.00	31,665.30
1957	0.19	21,060.00	650.00	0.00	21,710.19
1958	0.19	19,015.00	0.00	0.00	19,015.19
1959	0.19	18,965.00	0.00	0.00	18,965.19
1960	0.26	13,300.10	1,220.00	0.00	14,520.36
1961	0.26	7,060.00	0.00	0.00	7,060.26
1962	0.13	4,220.00	0.00	0.00	4,220.13
1963	0.13	2,285.00	0.00	0.00	2,285.13
1964	0.20	10,355.00	4,500.00	0.00	14,855.20
1965	0.20	28,990.00	4,705.00	0.00	33,695.20
1966	0.20	9,485.00	0.00	0.00	9,485.20
1967	0.11	13,700.00	2,065.00	0.00	15,765.11
1968	0.00	71,202.00	20.00	0.00	71,222.00
1969	36.76	75,549.00	1,800.00	0.00	77,385.76
1970	13.81	38,281.18	1,880.00	0.00	40,174.98
1971	4.79	6,161.65	300.00	964.00	7,430.44
1972	11.87	54,070.41	20,485.00	131,800.00	206,367.28
1973	7.76	14,527.43	1,151.90	273,300.00	288,987.09
1974	7.37	5,233.59	1,001.22	0.00	6,242.18
1975	15.50	237,679.51	1,134.08	0.00	238,829.09
1976	5.58	417,228.23	557.88	482.00	418,273.70
1977	8.40	901,947.86	3,301.33	0.00	905,257.59
1978	18.55	1,029,517.58	5,952.11	0.00	1,035,488.24
1979	3.74	864,908.96	14,380.07	0.00	879,292.77
1980	13.50	136,036.98	1,418.06	1,542.12	139,010.66
1981	17.58	792,903.21	4,238.20	43.99	797,202.98
1982	28.02	708,044.51	656.88	1,622.00	710,351.41
1983	58.11	858,805.07	2,621.23	148.73	861,633.14
1984	11.42	259,081.90	959.38	2.83	260,055.53
1985	11.86	268,347.36	2,235.27	5.08	270,599.57
1986	52.40	203,136.89	183.51	0.00	203,372.80
1987	19.59	67,104.67	258.18	946.10	68,328.54
1988	55.12	141,680.56	1,506.90	14.23	143,256.82
1989	33.87	158,711.16	16.76	0.09	158,761.88
1990	8.75	251,353.57	489.19	42,985.37	294,836.88
1991	8.53	495,315.70	1,993.27	263.81	497,581.31
1992	46.63	507,976.92	0.00	0.42	508,023.96
Total[c]	503.01	8,914,021.12	81,791.44	454,120.77	9,450,436.33

[a]Revised data received at press time. Note from Mike Coony, Westinghouse Hanford, to Laverne Cash, HAZWRAP, dated January 19, 1994.

[b]First year of recorded site burial operations.

[c]Total sum without decay.

Table C.11. INEL-generated LLW breakdown by radionuclide characteristic[a]

Radionuclide characteristic	Volume, m^3		Volume change[b] (m^3)	Activity, Ci		Activity change[b] (Ci)
	Estimated 1992	1992		Estimated 1992	1992	
Uranium/thorium	2.052E+02	8.844E+01	-1.168E+02	2.710E-01	6.833E-03	-2.642E-01
Fission product	0	0	0	0	0	0
Induced activity	0	0	0	0	0	0
Tritium	0	0	0	0	0	0
Alpha	0	0	0	0	0	0
Other[c]	2.721E+03	1.895E+03	-8.260E+02	1.052E+05	1.439E+05	3.870E+04
Total	2.926E+03	1.983E+03	-9.430E+02	1.052E+05	1.439E+05	3.870E+04

[a]Virginia C. Randall, Idaho National Engineering Laboratory, Idaho Falls, Idaho, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Integrated Data Base Data for 1993-VCR-11-94," dated February 14, 1994. Estimated 1992 values based on 1991 reported values.

[b]Volume change = 1992 volume − estimated 1992 volume; activity change = 1992 activity − estimated 1992 activity.

[c]Unknown or mixture.

Table C.12. INEL buried LLW breakdown by radionuclide characteristic[a]

Radionuclide characteristic	Volume, m^3		Volume change[b] (m^3)	Cumulative volume (m^3)	Activity, Ci		Activity change[b] (Ci)	Total gross activity[c,d] (Ci)
	Estimated 1992	1992			Estimated 1992	1992		
Uranium/thorium	2.831E+01	8.844E+01	6.013E+01	4.224E+03	2.474E-01	6.833E-03	-2.406E-01	4.503E+01
Fission product	0	0	0	2.550E+04	5.921E+03	0	-5.921E+03	1.523E+03
Induced activity	0	0	0	3.741E+02	1.809E+05	0	-1.809E+05	3.623E+01
Tritium	0	0	0	6.230E-01	0	0	0	1.531E+01
Alpha	0	0	0	9.605E+02	0	0	0	8.550E+01
Other[e]	1.244E+03	7.556E+02	-4.884E+02	1.152E+05	0	1.439E+05	1.439E+05	1.183E+07
Total	1.272E+03	8.441E+02	-4.279E+02	1.463E+05	1.869E+05	1.439E+05	-4.292E+04	1.183E+07

[a]Virginia C. Randall, Idaho National Engineering Laboratory, Idaho Falls, Idaho, letter to Lise J. Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Integrated Data Base Data for 1993-VCR-11-94," dated February 14, 1994. Estimated 1992 values based on 1991 reported values. The estimated 1992 values were used in the decay calculations as indicated in the tables of Chapter 4.

[b]Volume change = 1992 volume – estimated 1992 volume; activity change = 1992 activity – estimated 1992 activity.

[c]Beginning of operations through 1992.

[d]Sum annual additions without decay.

[e]Unknown or mixture.

Table C.13. Summary characteristics of additional remote-handled TRU wastes at the Hanford Site[a]

Characteristic and unit of measure	Amount
Volume, m^3	140.13
Uranium content, kg	279.49
Plutonium content, kg	47.24
Fission product radioactivity,[b] Ci	520,405

[a]These wastes are stored at the Hanford 200-Area burial grounds and were previously identified as miscellaneous radioactive materials. They are not included in the inventories of TRU waste reported in Chapter 3. They represent an additional TRU waste inventory that will be integrated into the TRU waste chapter in future updates of this report.

[b]Undecayed.

APPENDIX D. REFERENCE SITES AND FACILITIES

APPENDIX D. REFERENCE SITES AND FACILITIES

This appendix provides information on the major DOE and commercial sites and facilities discussed in this report. The DOE operations and special site offices are identified in Table D.1, along with the sites for which they have responsibility. This is followed by Table D.2, which lists DOE Naval Reactors Program (NE-60) offices and sites. Table D.3 lists major DOE sites and facilities referred to in this report, and major commercial radioactive waste disposal sites are given in Table D.4. For each site or facility listed in Tables D.3 and D.4, additional information is provided, including reference symbol or label, location, operations contractor, and, for DOE sites, the supervisory DOE operations and area office.

Table D.1. DOE operations and special site offices

DOE office	Symbol/label	General mailing address (Phone number)[a]	Radioactive waste sites for which DOE office has responsibility
Albuquerque Operations Office[b]	DOE/AL	P.O. Box 5400 Albuquerque, NM 87115-5400 (505/845-4154)	Grand Junction Projects Office sites Inhalation Toxicology Research Institute Kansas City Plant Los Alamos National Laboratory Mound Plant Pantex Plant Pinellas Plant Sandia National Laboratories—Albuquerque Sandia National Laboratories—Livermore Uranium Mill Tailings Remedial Action Program sites Waste Isolation Pilot Plant
Chicago Operations Office[c]	DOE/CH	Building 201 9800 South Cass Avenue Argonne, IL 60439 (708/252-2001)	Ames Laboratory Argonne National Laboratory—East Argonne National Laboratory—West Battelle Columbus Laboratories Brookhaven National Laboratory Fermi National Accelerator Laboratory Princeton Plasma Physics Laboratory
Fernald Field Office	DOE/FN	P.O. Box 398705 7400 Wiley Road Cincinnati, OH 45239-8705 (513/738-6319)	Fernald Environmental Management Project Reactive Metals, Inc. Extrusion Plant
Idaho Operations Office	DOE/ID	785 DOE Place Idaho Falls, ID 83402 (208/526-0111)	Argonne National Laboratory—West Idaho National Engineering Laboratory West Valley Demonstration Project
Nevada Operations Office	DOE/NV	P.O. Box 98518 Las Vegas, Nevada 89193-8518 (702/295-1212)	Nevada Test Site
Oak Ridge Operations Office[d]	DOE/OR	P.O. Box 2001 Oak Ridge, TN 37831 (615/576-5454)	Formerly Utilized Sites Remedial Action Program (FUSRAP) sites Oak Ridge Institute for Science and Education Oak Ridge K-25 Site Oak Ridge National Laboratory Oak Ridge Y-12 Plant Paducah Gaseous Diffusion Plant Portsmouth Gaseous Diffusion Plant Weldon Spring Site Remedial Action Project

Table D.1 (continued)

DOE office	Symbol/label	General mailing address (Phone number)[a]	Radioactive waste sites for which DOE office has responsibility
Richland Operations Office	DOE/RL	P.O. Box 550 825 Jadwin Avenue Richland, WA 99352 (509/376-7411)	Hanford Site Pacific Northwest Laboratory
Rocky Flats Office	DOE/RF	P.O. Box 928 Golden, CO 80401-0928 (303/966-7000)	Rocky Flats Plant
San Francisco Operations Office	DOE/SAN	1333 Broadway Oakland, CA 94612 (510/273-6383)	Energy-Related Health Research Laboratory Lawrence Berkeley Laboratory Lawrence Livermore National Laboratory Santa Susana Field Laboratory Stanford Linear Accelerator Center
Savannah River Operations Office	DOE/SR	P.O. Box A Aiken, SC 29802 (803/725-6211)	Savannah River Site

[a]Access to main organizations.

[b]The Albuquerque Operations Office also has the following area offices (monitoring activities of the sites indicated) under its purview: Amarillo (Pantex Plant), Dayton (Mound Plant), Grand Junction (Grand Junction Projects Office), Kansas City (Kansas City Plant), Los Alamos (Los Alamos National Laboratory), and Pinellas (Pinellas Plant).

[c]The Chicago Operations Office has the following area offices (monitoring activities of the sites indicated) under its purview: Argonne (Argonne National Laboratory—East), Batavia (Fermi National Accelerator Laboratory), Upton (Brookhaven National Laboratory), and Princeton (Princeton Plasma Physics Laboratory).

[d]The Oak Ridge Operations Office has a separate site office located at the following: Oak Ridge K-25 Site, Oak Ridge National Laboratory, Oak Ridge Y-12 Plant, Paducah, Portsmouth, and Weldon Spring.

Table D.2. DOE Naval Reactors Program offices and sites

DOE office	Symbol/label	General mailing address (Phone number)[a]	Radioactive waste sites for which DOE office has responsibility
DOE/HQ, Office of Naval Reactors	DOE/HQ/NE-60	Route Symbol NE-60 2521 Jefferson Davis Highway Arlington, VA 22202 (703/603-7321)	(Oversees Pittsburgh and Schenectady area offices and their sites)
Pittsburgh Naval Reactors Offices	DOE/PNRO	P.O. Box 109 West Mifflin, PA 15122-0109 (412/476-5000)	Bettis Atomic Power Laboratory Naval Reactors Facility (Idaho Falls, ID)
Schenectady Naval Reactors Office	DOE/SNRO	P.O. Box 1069 Schenectady, NY 12301-1069 (518/395-4000)	Knolls Atomic Power Laboratory

[a]Access to main organizations.

Table D.3. Major DOE sites and facilities referred to in this report

Site/facility	Symbol/label	Principal contractor(s) for site operations and mailing address (Phone number)[a]	DOE operations office (Phone number)[a]
Ames Laboratory	AMES	Iowa State University Spedding Hall Pammel Drive Ames, IA 50011-3020 (515/294-2680)	Chicago (708/252-2001)
Argonne National Laboratory–East	ANL–E	University of Chicago 9700 South Cass Avenue Argonne, IL 60439 (708/252-2000)	Chicago Argonne Area Office (708/252-2001)
Argonne National Laboratory–West[b]	ANL–W	University of Chicago Idaho Site P.O. Box 2528 Idaho Falls, ID 83403-2528 (208/533-7000)	Idaho (208/526-0111)
Battelle Columbus Laboratories Decommissioning Project	BCLDP	Battelle Memorial Institute 505 King Avenue Columbus, OH 43201-2693 (614/424-3989)	Chicago (708/252-2001)
Brookhaven National Laboratory	BNL	Associated Universities, Inc. 16 South Railroad Street Upton, NY 11973-2310 (516/282-2123)	Chicago Brookhaven Area Office (516/282-3427)
Colonie Interim Storage Site	CISS	Bechtel National, Inc. P.O. Box 5169 Albany, NY 12205 (518/482-0237)	Oak Ridge (615/576-5454)
Fermi National Accelerator Laboratory	FNAL	University Research Association P.O. Box 500 Batavia, IL 60510 (708/840-3000)	Chicago Batavia Area Office (708/840-3281)

Table D.3 (continued)

Site/facility	Symbol/label	Principal contractor(s) for site operations and mailing address (Phone number)[a]	DOE operations office (Phone number)[a]
Fernald Environmental Management Project	FEMP	Fluor Daniels Fernald Environmental Restoration Management Corporation P.O. Box 398704 7400 Wiley Road Cincinnati, OH 45239-8704 (513/738-6200)	Fernald (513/738-6319)
Grand Junction Projects Office	GJPO	Chem-Nuclear Geotech, Inc. P.O. Box 14000 Grand Junction, CO 81502-5504 (303/248-6200)	Albuquerque (505/845-4154)
Hanford Site	HANF	Westinghouse Hanford Company, Inc. P.O. Box 1970 Richland, WA 99352 (509/376-7511)	Richland (509/376-7411)
Idaho National Engineering Laboratory	INEL	EG&G Idaho, Inc. P.O. Box 1625 Idaho Falls, ID 83415-4201 (208/526-0111)	Idaho (208/526-0111)
Inhalation Toxicology Research Institute	ITRI	Lovelace Biomedical and Environmental Research Institute, Inc. P.O. Box 5890 Albuquerque, NM 87185 (505/845-1037)	Albuquerque (505/845-4154)
Kansas City Plant	KCP	Allied-Signal Aerospace Company Kansas City Division Bannister Federal Complex Kansas City, MO 64141 (816/997-2000)	Albuquerque Kansas City Area Office (816/997-3348)

Table D.3 (continued)

Site/facility	Symbol/label	Principal contractor(s) for site operations and mailing address (Phone number)[a]	DOE operations office (Phone number)[a]
Lawrence Berkeley Laboratory	LBL	University of California One Cyclotron Road Berkeley, CA 94720 (510/486-4000)	San Francisco Lawrence Berkeley Laboratory Site Office (510/486-4363)
Lawrence Livermore National Laboratory	LLNL	University of California 7000 East Avenue P.O. Box 808, L-1 Livermore, CA 94550 (510/422-1100)	San Francisco (510/273-6383)
Los Alamos National Laboratory	LANL	University of California P.O. Box 1663 Los Alamos, NM 87545 (505/667-5061)	Albuquerque Los Alamos Area Office (505/667-5061)
Mound Plant	MOUND	EG&G Mound Applied Technologies P.O. Box 3000 Miamisburg, OH 45343-0987 (513/865-4020)	Albuquerque Dayton Area Office (513/865-3271)
Naval Reactors Program Facilities			
Bettis Atomic Power Laboratory	BAPL	Westinghouse Electric Corporation P.O. Box 79 West Mifflin, PA 15122-0079 (412/476-5000)	DOE/HQ Office of Naval Reactors (NE-60) Pittsburgh Naval Reactors Office (412/476-5000)
Knolls Atomic Power Laboratory	KAPL	General Electric Company P.O. Box 1072 Schenectady, NY 12301-1072 (518/395-4000)	DOE/HQ Office of Naval Reactors (NE-60) Schenectady Naval Reactors Office (518/395-4000)
Naval Reactors Facility (INEL)	NRF	Westinghouse Electric Corporation P.O. Box 2068 Idaho Falls, ID 83403-2068 (208/526-5526)	DOE/HQ Office of Naval Reactors (NE-60) Pittsburgh Naval Reactors Office (412/476-5000)

Table D.3 (continued)

Site/facility	Symbol/label	Principal contractor(s) for site operations and mailing address (Phone number)[a]	DOE operations office (Phone number)[a]
Nevada Test Site	NTS	Reynolds Electrical & Engineering Company, Inc. P.O. Box 98521 Mail Stop 738 Las Vegas, NV 89193-8521 (702/295-9060)	Nevada (702/295-1212)
Oak Ridge Institute for Science and Education	ORISE	Oak Ridge Associated Universities 246 Laboratory Road P.O. Box 117 Oak Ridge, TN 37831-0117 (615/576-3000)	Oak Ridge (615/576-5454)
Oak Ridge K-25 Site	K-25	Martin Marietta Energy Systems, Inc. P.O. Box 2003 Oak Ridge, TN 37831-7358 (615/576-5454)	Oak Ridge (615/576-5454)
Oak Ridge National Laboratory	ORNL	Martin Marietta Energy Systems, Inc. P.O. Box 2008 Oak Ridge, TN 37831-6235 (615/576-5454)	Oak Ridge (615/576-5454)
Oak Ridge Y-12 Plant	Y-12	Martin Marietta Energy Systems, Inc. P.O. Box 2009 Oak Ridge, TN 37831-8010 (615/576-5454)	Oak Ridge (615/576-5454)
Pacific Northwest Laboratory[c]	PNL	Battelle Memorial Institute Battelle Boulevard P.O. Box 999 Richland, WA 99352 (509/375-2121)	Richland (509/376-7411)

Table D.3 (continued)

Site/facility	Symbol/label	Principal contractor(s) for site operations and mailing address (Phone number)[a]	DOE operations office (Phone number)[a]
Paducah Gaseous Diffusion Plant	PAD	Martin Marietta Energy Systems, Inc. P.O. Box 1410 Paducah, KY 42001 (502/441-6000)	Oak Ridge Paducah Site Office (502/441-6800)
Pantex Plant	PANT	Mason & Hanger–Silas Mason Company, Inc. P.O. Box 30020 Amarillo, TX 79177 (806/477-3000)	Albuquerque Amarillo Area Office (806/477-3000)
Pinellas Plant	PINELLAS	Martin Marietta Specialty Components, Inc. P.O. Box 2908 Largo, FL 34649-2908 (813/541-8001)	Albuquerque Pinellas Area Office (813/541-8196)
Portsmouth Gaseous Diffusion Plant	PORTS	Martin Marietta Energy Systems, Inc. P.O. Box 628 Piketon, OH 45661 (614/897-2331)	Oak Ridge Portsmouth Site Office (614/897-2331)
Princeton Plasma Physics Laboratory	PPPL	Princeton University P.O. Box 451 Princeton, NJ 08543 (609/243-2000)	Chicago Princeton Area Office (609/243-3700)
Reactive Metals, Inc. Extrusion Plant	RMI	RMI Titanium Company P.O. Box 579 Ashtabula, OH 44004 (216/992-7442)	Fernald Ashtabula Area Office (216/992-7442)
Rocky Flats Plant	RFP	EG&G Rocky Flats, Inc. P.O. Box 464 Golden, CO 80401-0464 (303/966-7000)	Rocky Flats Office (303/966-7000)

Table D.3 (continued)

Site/facility	Symbol/label	Principal contractor(s) for site operations and mailing address (Phone number)[a]	DOE operations office (Phone number)[a]
Sandia National Laboratories			
Albuquerque	SNLA	Martin Marietta Sandia Corporation P.O. Box 5800 Albuquerque, NM 87185-5800 (505/844-5678)	Albuquerque (505/845-4154)
Livermore	SNLL	Martin Marietta Sandia Corporation P.O. Box 969 Livermore, CA 94551-0969 (510/294-3000)	Albuquerque (505/845-4154)
Santa Susana Field Laboratory (Energy Technology Engineering Center)	SSFL (ETEC)	Rockwell International Rocketdyne Division 6633 Canoga Avenue P.O. Box 1449 Canoga Park, CA 91304 (818/586-5326)	San Francisco (510/273-6383)
Savannah River Site	SRS	Westinghouse Savannah River Company P.O. Box 616 Aiken, SC 29802 (803/725-6211)	Savannah River (803/725-6211)
Stanford Linear Accelerator Center	SLAC	Stanford University P.O. Box 4349 Palo Alto, CA 94309 (415/926-3300)	San Francisco Stanford Site Office (415/926-3208)
Three Mile Island—Unit 2 Reactor	TMI—Unit 2	General Public Utilities P.O. Box 480 Middletown, PA 17057 (717/944-7621)	Idaho Three Mile Island Site Office (717/944-7621)

Table D.3 (continued)

Site/facility	Symbol/label	Principal contractor(s) for site operations and mailing address (Phone number)[a]	DOE operations office (Phone number)[a]
Waste Isolation Pilot Plant	WIPP	Westinghouse Electric Corporation WIPP Project Office P.O. Box 2078 Carlsbad, NM 88221 (505/885-7500)	Albuquerque WIPP Project Office (505/887-8115)
Weldon Spring Site Remedial Action Project	WSSRAP	Jacobs Engineering Group, Inc. MK-Ferguson Company 7295 Highway 94 South St. Charles, MO 63304 (314/441-8978)	Oak Ridge Weldon Spring Site Office (314/441-8978)
West Valley Demonstration Project	WVDP	Westinghouse Electric Corporation West Valley Nuclear Services Company, Inc. 10300 Rock Springs Road P.O. Box 191 West Valley, NY 14171-0191 (716/942-3235)	Idaho West Valley Project Office (716/942-4313)

[a]Phone number for access to main organization.
[b]Part of the Idaho National Engineering Laboratory.
[c]Part of the Hanford Site.

Table D.4. Major commercial radioactive waste disposal sites included in this report[a]

Site	Symbol/label	Principal contractor(s) for site operations and mailing address (Phone number)[b]
Barnwell	BARN	Chem-Nuclear Systems, Inc. 140 Stoneridge Drive Columbia, SC 29210 (803/256-0450)
Beatty	BETY	U.S. Ecology, Nuclear P.O. Box 578 Beatty, NV 89003 (702/553-2203)
Maxey Flats	MFKY	Commonwealth of Kentucky[c] Department of Environmental Protection/Superfund Branch Maxey Flats Project 14 Reilly Road Frankfort, KY 40601-1190 (502/564-6716) Site address: Maxey Flats Project Route 2 P.O. Box 238A Hillsboro, KY 41049 (606/784-6612)
Richland	RICH	U.S. Ecology, Nuclear P.O. Box 638 Richland, WA 99352 (509/377-2411)
Sheffield	SHEF	U.S. Ecology, Nuclear P.O. Box 158 Sheffield, IL 61361 (815/454-2342)
West Valley	WVNY	Westinghouse Electric Corporation West Valley Nuclear Services Company, Inc. 10300 Rock Springs Road P.O. Box 191 West Valley, NY 14171-0191 (716/942-3235) New York State Energy Research and Development Authority 2 Rockefeller Plaza Albany, NY 12223 (518/465-6251)

[a]Does not include uranium mill tailings sites. See Table 5.2.
[b]Phone number for access to main organizations.
[c]The Commonwealth of Kentucky assumed operating contractor responsibilities for the Maxey Flats site in 1992.

APPENDIX E. INTEGRATED DATA BASE READER COMMENT FORM

APPENDIX E. INTEGRATED DATA BASE READER COMMENT FORM

To maintain an updated distribution list for this report, the Integrated Data Base (IDB) is asking its readership to supply the information requested on the Reader Comment Form provided at the end of this report. When filling out this form, please respond to the questions in Items 1–11 (note that some require two answers). Item 12 requests some personal information (please type or print your complete name and mailing address). To be eligible for future updates of this report, please fold, attach stamp, and mail the completed Reader Comment Form to the Integrated Data Base Program at the mailing address given on the back of the form (and listed below) by September 1, 1994. Also, please notify the IDB Program of any corrections or future changes in your mailing address. Your cooperation and assistance are greatly appreciated.

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GLOSSARY OF TERMS

This glossary gives definitions of some terms commonly used in the main body of this report. A more detailed glossary of waste terms,[a] applicable to the DOE complex, is being developed by the DOE Office of Environmental Restoration and Waste Management and will be issued for use by DOE and its contractors in early 1994.

Actinides: Elements with atomic numbers from 90 to 103 inclusive. (Note that actinium is not part of this group.)

Activation product: A radioactive material produced by bombardment with neutrons, protons, or other nuclear particles.

Agreement State: A state that has entered into an agreement with the U.S. Nuclear Regulatory Commission (as specified by the Atomic Energy Act of 1954) and has authority to regulate the disposal of low-level radioactive waste under such an agreement. This term is used in the Low-Level Radioactive Waste Policy Act (Public Law 99-240).

Alpha decay: Radioactive decay in which an alpha particle (^{4}He nucleus) is emitted.

Beta decay: Radioactive decay in which a beta particle (negative electron) is emitted.

Borosilicate glass: A type of glass containing at least 5% boric oxide. It is used in glassware that resists heat and is a leading candidate for use in high-level waste immobilization and disposal.

Branching ratio: In branching radioactive decay, the fraction of nuclei that disintegrates in a specific way. (It is usually expressed as a percentage.)

Burnup, specific: The total energy released per initial unit mass of reactor fuel as a result of the fission process occurring. The unit commonly used for specific burnup is megawatt-days per metric ton of initial heavy metal, MWd/MTIHM.

By-product material: (1) Any radioactive material (except special nuclear material) yielded in, or made radioactive by, exposure to the radiation incident or to the process of producing or utilizing special nuclear material. For purposes of determining the applicability of the Resource Conservation and Recovery Act to any radioactive waste, the term "any radioactive material" refers only to the actual radionuclides dispersed or suspended in the waste substance. The nonradioactive hazardous waste component of the waste substance will be subject to regulation under the Resource Conservation and Recovery Act; (2) the tailings or waste produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content. Ore bodies depleted by uranium solution extraction operations and which remain underground do not constitute "by-product material."

Calcine: A form of high-level waste produced from defense reactor fuel reprocessing waste (at the Idaho Chemical Processing Plant) by heating to a temperature below the melting point to bring about loss of moisture and oxidation to a chemically stable granular powder.

Canister: A metal container used for the storage or disposal of heat-producing solid high-level radioactive waste.

Capacity factor, plant: The ratio of the electrical energy actually supplied by a power plant in a given time interval to the electrical energy that could have been produced at continuous full-power operation during the same time period.

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[a]U.S. Department of Energy, Office of Environmental Restoration and Waste Management, *Glossary of Terms*, working draft, July 1993.

Capsules: Encapsulated strontium and cesium high-level wastes produced from defense reactor fuel reprocessing at the Hanford site.

Cladding: A corrosion-resistant tube, commonly made of zirconium alloy or stainless steel, surrounding the reactor fuel pellets which provides protection from a chemically reactive environment and containment of fission products.

Code of Federal Regulations: A documentation of the general rules by the executive departments of the federal government. The code is divided into 50 titles that represent broad areas subject to federal regulation. Each title is divided into chapters that usually bear the name of the issuing agency. Each chapter is further subdivided into parts covering specific regulatory areas.

Control rod: A movable part of the reactor core that is adjusted to regulate the degree of fuel fissioning in the core.

Conversion, fuel: Chemical treatment of yellowcake (U_3O_8) to uranium hexafluoride (UF_6) in preparation for enrichment.

Core, nuclear reactor: That part of the reactor which contains the nuclear fuel and in which most or all of the nuclear fissions occur.

Daughter product(s): The nuclide(s) formed by the radioactive decay of the parent radionuclide.

Decay, radioactive: The transition of a nucleus from one energy state to a lower one, usually involving the emission of a photon, electron, neutron, or alpha particle.

Decay chain, radioactive: A series of nuclides in which each member decays to the next member of the chain through radioactive decay until a stable nuclide has been formed.

Decommissioning: Activities taken to reduce the potential health and safety impacts of commercial and DOE-contaminated facilities, including removing a unit from operation and/or decontamination, entombment, dismantlement, or conversion of the site to another use.

Decommissioning wastes: Wastes (generally low-level) collected or resulting from facility decommissioning activities.

Decontamination: Activities taken to remove unwanted (typically radioactive) material from facilities, soils, or equipment by washing, chemical action, mechanical cleaning, or other (treatment) techniques.

Deep bed plant: A boiling-water reactor facility using a demineralizer vessel for water purification which contains an ion-exchange resin that is 3 or more ft deep.

Disintegration energy (Q-value): The amount of energy released in a particular nuclear disintegration. This is usually expressed in MeV/disintegration.

DOE waste: Radioactive waste produced from activities supported by the Department of Energy and/or U.S. government defense programs.

Double-shell tank wastes: High-level wastes, generated from defense reactor fuel reprocessing at Hanford, which are stored in double-shelled tanks. These wastes consist of a mixture of liquid and suspended solids referred to as slurry. See also "single-shell tank wastes."

Electron capture: Radioactive decay in which an orbital electron is captured by the nucleus of the radionuclide.

Enrichment, fuel: A nuclear fuel cycle process which increases the concentration of fissionable uranium (i.e., ^{235}U) in uranium ore above its natural level of 0.71%. (The method currently utilized in the United States is gaseous diffusion.)

Environmental Impact Statement: A report that documents the information required to evaluate the environmental impact of a project. Such a report informs decision-makers and the public of the reasonable alternatives which would avoid or minimize adverse impacts or enhance the quality of the environment.

Environmental restoration: Cleanup and restoration of sites contaminated with radioactive and/or hazardous substances during past production, accidental releases, or disposal activities.

Equilibrium cycle: An assumed nuclear fuel cycle in which the feed and waste materials of a facility have constant compositions. In a reactor this condition typically results after the third or fourth fuel-loading schedule.

Fabrication, fuel: Conversion of enriched UF_6 into pellets of ceramic uranium dioxide (UO_2). These pellets are then sealed into corrosion-resistant tubes of zirconium alloy or stainless steel. The loaded tubes, called fuel elements or rods, are then mounted into special assemblies for loading into the reactor core.

Fertile nuclide: A nuclide capable of being transformed into a fissile nuclide by neutron capture.

Filter/demineralizer plant: A facility that combines filtration and ion-exchange processing using nonregenerable powered resins.

Fissile nuclide: A nuclide capable of undergoing nuclear fission with neutrons.

Fission, nuclear: The division of a heavy atomic nucleus into two or more isotopes, usually accompanied by the emission of neutrons and gamma radiation.

Fission products: Nuclides produced either by fission or by the subsequent decay of the nuclides thus formed.

Fission, spontaneous: Nuclear fission that occurs without the addition of particles or energy to the nucleus.

Formerly utilized site: A site contaminated with radioactive wastes which was previously used for supporting nuclear activities of the DOE's predecessor agencies, the Manhattan Engineer District (Manhattan Project) and the Atomic Energy Commission.

Fuel assembly: A grouping of nuclear fuel rods that remains integral during the charging and discharging of a reactor core.

Fuel cycle, nuclear: The complete series of steps involved in supplying fuel for nuclear reactors. It includes mining, refining, UF_6 conversion, enrichment, fabrication of fuel elements, use in a reactor, and management of radioactive waste. It may also involve chemical processing to recover the fissionable material remaining in the spent fuel, reenrichment of the fuel material, refabrication of new fuel elements.

Generation (electricity): The process of producing electric energy from other forms of energy; also, the amount of electric energy produced, commonly expressed in kilowatt-hours (kWh) or megawatt-years [MW(e)-years].

Generation (gross): The total amount of electric energy produced by the generating units in a generating station or stations, measured at the generator terminals.

Generation (net): Gross generation less the electric energy consumed at the generating station for station use.

Generation (waste): The origination of new wastes from various facility operations (including production, rework, decontamination and decommissioning, and environmental restoration), including the recovery of pre-1970 transuranic-produced wastes, should their recovery be determined necessary.

Glass frit: A fusible ceramic mixture used to make glass for use in the immobilization and disposal of high-level wastes.

Greater-than-Class-C low-level waste: Waste from commercial sources containing radionuclide concentrations that exceed U.S. Nuclear Regulatory Commission limits for Class C low-level radioactive waste as defined in 10 CFR Part 61.55.

Grout: A mortar or cement mixture used to immobilize radioactive wastes.

Half-life, radioactive: For a single radioactive decay process, the time required for the activity to decrease to one-half of its initial value by that process.

Hazardous waste: Nonradioactive waste containing concentrations of either toxic, corrosive, flammable, or reactive chemicals above maximum permissible levels as defined by the U.S. Environmental Protection Agency (EPA) in 40 CFR Part 261 or polychlorinated biphenyls (PCBs) above maximum permissible levels as defined by the EPA in 40 CFR Parts 702–799.

High-level waste: As defined by the Nuclear Waste Policy Act, high-level waste is (1) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including the liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations and (2) other highly radioactive material that the U.S. Nuclear Regulatory Commission, consistent with existing law, determines by rule to require permanent isolation.

Hydrofracture: A process formerly used for permanent disposal of low-level (approximately 0.25 Ci/L) liquid waste at the Oak Ridge National Laboratory. The process involved mixing the waste with a blend of cement and other additives with the resulting grout being injected into shale at a depth of 200 to 300 m. The injected grout hardened into thin, horizontal sheets several hundred meters wide.

Industrial waste: Commercial low-level waste resulting from nonnuclear fuel cycle sources. These include the commercial producers of radiochemicals and radiopharmaceuticals, luminous dial manufacturers, and instruments that incorporate sealed source components (e.g., smoke detectors).

Institutional waste: Commercial low-level waste resulting from bioresearch, medical, and certain nonbioresearch sources. Bioresearch wastes include wastes from animal

studies at universities. Medical wastes include those generated from diagnostic and therapeutic procedures on humans at hospitals. Nonbioresearch wastes include research reactor wastes; small-volume, sealed radiation sources; and accelerator targets.

Leaching: The process of removal or separation of soluble components from a solid by percolating water or other liquids through the solid.

Low-level waste: As specified in the Low-Level Radioactive Waste Policy Amendments Act of 1985 (Public Law 99-240), radioactive waste not classified as high-level waste, spent nuclear fuel, or by-product material specified as uranium or thorium tailings and waste.

Mill tailings, uranium: Earthen residues that remain after the extraction of uranium from ores. Tailings may also contain other minerals or metals not extracted in the process.

Mixed low-level waste: Waste that satisfies the definition of low-level radioactive waste (LLW) in the Low-Level Radioactive Waste Policy Amendments Act of 1985 and that contains hazardous waste that has at least one of the following characteristics: (1) is listed as a hazardous waste in Subpart D of 40 CFR Part 261, (2) exhibits any of the hazardous waste characteristics identified in Subpart C of 40 CFR Part 261, or (3) contains PCB-containing wastes subject to regulation under the Toxic Substances Control Act and 40 CFR Parts 702–799.

Mixed waste: Waste that includes concentrations of both radionuclides and hazardous chemicals.

Moderator: A material used to reduce neutron energy (for fissioning if in a reactor) by elastic scattering.

MRS facility: A proposed facility for the monitored retrievable storage of spent fuel from commercial power plants. Such a facility would permit continuous monitoring, management, and maintenance of these wastes and provide for their ready retrieval for further processing or disposal.

Naturally occurring and accelerator-produced radioactive material: Any radioactive material that can be considered naturally occurring and is not source, special nuclear, or by-product material or that is produced in a charged particle accelerator.

Neutron activation: The process of irradiating a material with neutrons so that the material itself is transformed into a radioactive nuclide.

Nonfuel components: Nuclear reactor core parts and hardware, excluding the nuclear fuel itself. Such components include shrouds, control rods, fuel channels, in-core chambers, support tubes, and dummy fuel rods.

Parent: A radionuclide that upon decay yields a specified nuclide (the daughter) either directly or as a later member of a radioactive decay series.

Pressure vessel, reactor: A strong-walled container housing the core of most types of power reactors. It usually also contains other core components such as the moderator and control rods.

PUREX™ process: A solvent extraction process that may be employed in the reprocessing of uranium/plutonium-based nuclear fuels.

Radioactivity: The number of spontaneous nuclear disintegrations occurring in a given quantity of material during a suitably small period of time. A unit of activity commonly used is the curie (Ci), which is 3.7×10^{10} disintegrations/s.

Reactor, boiling-water: A light-water reactor in which water, used as both coolant and moderator, is allowed to boil in the core. The resulting steam is used directly to drive a turbine.

Reactor, breeder: A reactor that produces more fissionable fuel than it consumes. The new fissionable material is created by a process (breeding) in which fission neutrons are captured in fertile materials.

Reactor, fast flux: A reactor in which fission is induced predominantly by fast neutrons.

Reactor, high-temperature, gas-cooled: A nuclear reactor that uses an inert gas (helium) as the primary coolant and graphite as the moderator.

Reactor, light-water: A nuclear reactor that uses light water (H_2O) as the primary coolant and moderator, with slightly enriched uranium as the fuel. There are two types of commercial light-water reactors: boiling-water and pressurized-water.

Reactor, naval propulsion: A reactor used to power a vessel or submarine of the U.S. Navy.

Reactor, pressurized-water: A light-water reactor in which heat is transferred from the core to a heat exchanger via water kept under high pressure, so that high temperatures can be maintained in the primary coolant system without boiling the water. Steam is generated in a secondary circuit.

Reactor, production: A reactor whose primary purpose is to produce fissile or other materials or to perform irradiations on an industrial scale. Unless otherwise specified, the term usually refers to either a tritium- or plutonium-production facility used to produce materials for nuclear weapons.

Reactor, research: A reactor whose nuclear radiations are used primarily as a tool for basic or applied research. Typically, it has a thermal power of 10 MW(t) or less and may include facilities for testing reactor materials.

Reactor, test: A reactor associated with an engineering-scale test program conducted to develop basic design information or demonstrate safety characteristics of nuclear reactor systems.

Reinserted fuel: Irradiated reactor fuel that is discharged in one cycle and inserted into the same reactor during a subsequent refueling. In a few cases, fuel discharged from one reactor has been used to fuel a different reactor.

Repository, geologic: A facility that has an excavated subsurface system for the permanent disposal of spent fuel and high-level waste.

Reprocessing, fuel: The chemical/mechanical processing of irradiated nuclear reactor fuel to remove fission products and recover fissile and fertile material.

Salt cake: A salt form of high-level waste stored in tanks, which is produced from neutralizing acidic liquid waste from defense reactor fuel reprocessing with an alkaline agent (caustic soda).

Saltstone: A low-level waste by-product from the solidification of high-level waste at the Savannah River Site. Saltstone is retained in trenches at the Savannah River Site.

Sea-bed disposal: Placement of waste packages in deep ocean sediments.

Sea dumping (disposal): The practice of periodically dumping shiploads of drummed, solidified waste into the ocean at specified locations. (No longer performed.)

Separative work unit: The standard measure of enrichment services. The separative work unit (SWU) is expressed as a unit of mass. For example, 1 kilogram of separative work is expressed as 1 kg SWU.

Single-shell tank wastes: High-level wastes, generated from defense reactor fuel reprocessing at Hanford, which are stored in single-shelled tanks. These tanks contain inventories of liquid, sludge, and salt cake. See also "double-shell tank wastes."

Slurry, high-level waste: A watery mixture of highly radioactive, insoluble matter.

Solvent extraction: The separation of materials of different chemical types and solubilities by selective solvent action; used to recover and separate uranium and plutonium in reprocessing spent nuclear fuel.

Source term (IDB Program usage): A set of qualitative and quantitative features used to describe the origin and concentration of radioactive waste. The qualitative features include a flowchart of waste streams generated by a facility or an activity. Quantitative features include (1) the number of curies of radioactivity expressed either per unit of facility production or per unit of waste volume or mass and (2) a listing of the relative concentrations of component radioisotopes per curie of waste activity.

Special nuclear material: Plutonium, or uranium enriched to a higher-than-natural assay.

Spent fuel: Nuclear fuel that has been permanently discharged from a reactor after it has been irradiated. Typically, spent fuel is measured in terms of either the number of discharged fuel assemblies or the quantity of discharged fuel mass. The latter is measured either in metric tons of heavy metal (i.e., only the heavy-metal content of the spent fuel is considered) or in metric tons of initial heavy metal (essentially, the initial heavy-metal mass of the fuel before irradiation). The difference between these two quantities is the weight of the fission products produced during irradiation.

Thermal power: A measure of the rate of heat-energy emission that results from the radioactive decay of a material. A unit of thermal power commonly used is the watt (W).

THOREX process: A solvent extraction process developed for the reprocessing of thorium-based nuclear fuels.

Transuranic waste: As defined and used by the U.S. Department of Energy (DOE Order 5820.2A), radioactive waste that, at the time of assay, contains more than 100 nCi/g of alpha-emitting isotopes with atomic numbers greater than 92 and half-lives greater than 20 years.

Transuranic waste acceptance criteria: A set of conditions established for permitting transuranic wastes to be disposed at the Waste Isolation Pilot Plant.

Transuranic waste certification: The process for verifying that a suspect radioactive waste is transuranic.

Transuranic waste, contact-handled: Transuranic waste with a surface dose rate of less than 200 mrem/h and minimal heat generation to permit handling by contact methods.

Transuranic waste nondestructive assay/nondestructive examination: Nondestructive test procedures performed on suspect transuranic wastes to determine their transuranic isotope concentration. From these tests such wastes can be properly classified (certified) as transuranic or low-level.

Transuranic waste, remote-handled: Transuranic waste with a surface dose rate of greater than 200 mrem/h and/or heat generation to require remote handling and/or shielding.

Vitrification: The conversion of high-level waste materials into a glassy or noncrystalline solid for subsequent disposal.

Waste Isolation Pilot Plant: A facility, located near Carlsbad, New Mexico, to be used for demonstrating the safe disposal of transuranic wastes from DOE activities.

Yellowcake: A uranium oxide concentrate that results from milling (concentrating) uranium ore. It typically contains 80 to 90% U_3O_8.

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