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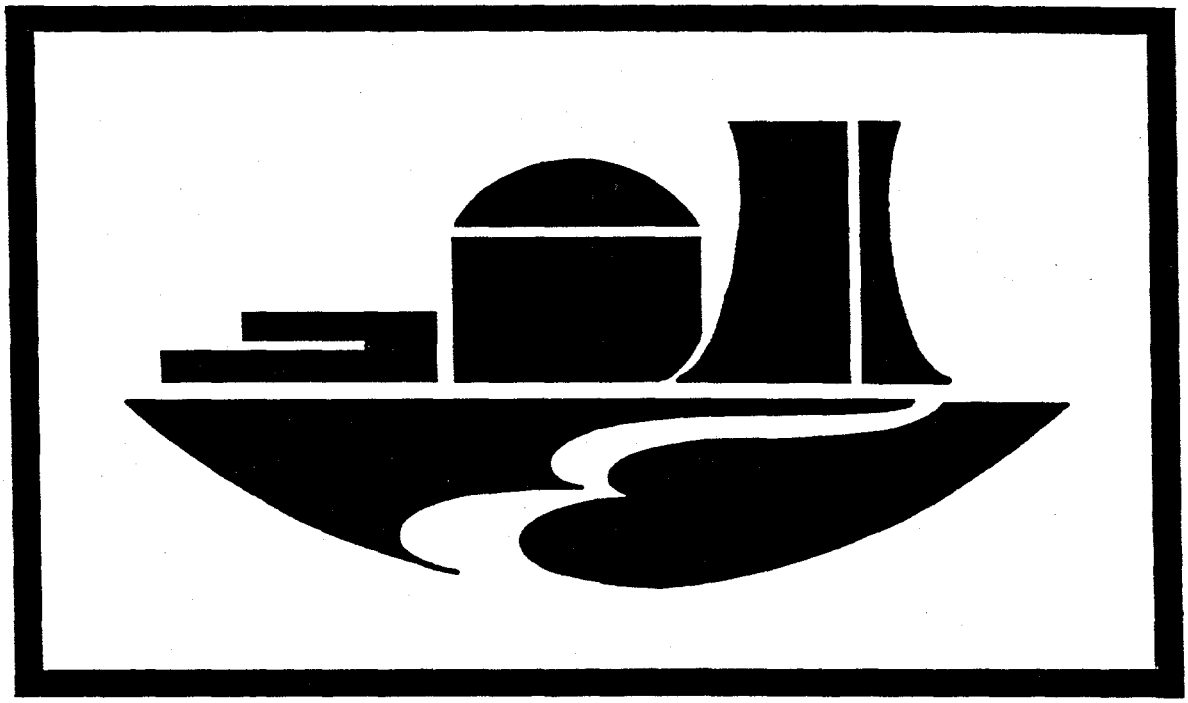
Integrated Data Base Report—1996: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics



Prepared for

U.S. Department of Energy
Office of Environmental Management
Washington, D.C. 20585

ph

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Managed by Lockheed Martin Energy Research Corp. for the
U.S. Department of Energy under contract DE-AC05-96OR22464

NOTICE

Annual Integrated Data Base (IDB) Program Report Format Change and Access on the Internet

Previously, printed hard-copy issues of the annual IDB Program radioactive waste inventory report have been made available. However, beginning with the 1997 report issue (DOE/RW-0006, Rev. 13) distribution of printed copies outside the DOE community will be discontinued.

A copy of *Integrated Data Base Report—1996: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics* (DOE/RW-0006, Rev. 13) will be accessible via the Internet on the DOE Office of Environmental Management (EM) world wide web (WWW) server at the uniform resource locator (URL)

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The EM WWW server provides a collection of documents and other information and data relating to DOE/EM's mission. It was established as an EM-wide information resource available to DOE employees, other federal agencies, Congress, state and tribal governments, and the general public. The EM WWW Server is updated and maintained to provide historical and current DOE/EM information.

In the event that access to this data through the WWW is not an option for you, you may contact the IDB Program at 423/576-7575 or send E-mail to

sns@ornl.gov

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 the government and commercial sectors. Baseline information is provided for DOE program planning purposes and to support DOE 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 some 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 DOE's Office of Environmental Management at either of the following:

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19901 Germantown Road
Germantown, MD 20874-1290

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This report was prepared by the Integrated Data Base Program, which is sponsored by the DOE Office of Environmental 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 nuclear 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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[a]With support from DOE/EIA and DOE Office of Spent Fuel Management.
[b]Carlsbad Technical Assistance Contractor (CTAC).
[c]Waste Isolation Pilot Plant Technical Assistance Contractor (WTAC).
[d]With support from DOE LLW Management Program (ATL International) and National Low-Level Waste Management Program.

Major DOE data sources supporting the Integrated Data Base Program report

Name of data source	Waste type information provided	Supporting DOE program office	Principal contractor and mailing address (Phone number)
DOE Office of Civilian Radioactive Waste Management	Commercial spent nuclear fuel inventories	DOE/RW Office of Storage and Transportation (RW-40)	DOE/RW Waste Acceptance Division (DOE/RW-44) Forrestal Building 1000 Independence Avenue, S.W. Washington, D.C. 20585-0001 (202/586-4153)
Integrated Spent Nuclear Fuel Database System	DOE spent nuclear fuel	Office of Spent Fuel Management (EM-67)	Lockheed Martin Idaho Technologies Company National Spent Fuel Program P.O. Box 1625 Idaho Falls, ID 83415 (208/526-8909)
Environmental Restoration Core Database	DOE/EM-40 contaminated media/waste	Office of Environmental Restoration (EM-40)	DOE/EM Office of Program Integration (DOE/EM-43) Cloverleaf Building U.S. Department of Energy 20400 Century Boulevard Germantown, MD 20874 (301/903-8121)
International Nuclear Model, Personal Computer Version (PCINM)	Commercial spent nuclear fuel projections	Energy Information Administration (DOE/EIA)	DOE/EIA Analysis and Systems Division Nuclear Fuel Cycle Branch Route Symbol EI-531 950 L'Enfant Plaza Washington, D.C. 20024 (202/426-1129)

Major DOE data sources supporting the Integrated Data Base Program report (continued)

Name of data source	Waste type information provided	Supporting DOE program office	Principal contractor and mailing address (Phone number)
Manifest Information Management System (MIMS)	Commercial low-level waste	Office of Waste Management (EM-30)	Lockheed Martin Idaho Technologies Company National Low-Level Waste Management Program P.O. Box 1625 Idaho Falls, ID 83415 (208/526-9717)
Uranium Reserve Assessment Program	Commercial uranium mill tailings	Energy Information Administration (DOE/EIA)	DOE/EIA Analysis and Systems Division Nuclear Fuel Cycle Branch Route Symbol EI-531 950 L'Enfant Plaza Washington, D.C. 20024 (202/426-1128)
Transuranic Waste Baseline Inventory Database and Report (TWBID and TWBIR)	DOE transuranic waste	DOE Carlsbad Area Office National Transuranic Program Office (NTPO)	Drez Environmental Associates 8816 Cherry Hills Road, N.E. Albuquerque, NM 87111 (505/828-9857)
DOE/EM Technical Waste Information Database	DOE low-level waste, DOE special-case waste, and RCRA-regulated and TSCA-regulated DOE mixed wastes	Office of Waste Management (EM-30)	DOE/EM Office of Waste Management Office of Planning and Analysis Route Symbol EM-35 Trevion II Building U.S. Department of Energy 19901 Germantown Road Germantown, MD 20874-1290 (301/903-7126)

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GLOSSARY OF ABBREVIATIONS, ACRONYMS, AND INITIALISMS

In this report, all abbreviations, acronyms, and initialisms are defined in the text before they are used. In some cases, they are redefined in the text for the reader's convenience.

ACRR	Annular Core Research Reactor (at SNL/NM)
AEA	Atomic Energy Act of 1954
AEC	Atomic Energy Commission
Ames	Ames Laboratory, Ames, Iowa
ANC	American Nuclear Corporation
ANL–E	Argonne National Laboratory–East, Argonne, Illinois
ANL–W	Argonne National Laboratory–West, INEEL, Idaho
ARCO	Atlantic Richfield (Medical Products) Company, Reading, Pennsylvania
ARRR	Aerotest Radiography and Research Reactor, San Ramon, California
ASI	Advanced Sciences, Inc.
ATL	Advanced Technologies and Laboratories International, Inc.
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 (at INEEL ICPP)
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 Federal, Inc., Germantown, Maryland
BEMR	Baseline Environmental Management Report
BETY	Beatty, Nevada (commercial waste site)
BMI	Battelle Memorial Institute, Columbus, Ohio
BMRR	Brookhaven Medical Research Reactor (at BNL)
BNI	Bechtel National, Inc., Oak Ridge, Tennessee
BNL	Brookhaven National Laboratory, Upton, New York
BR	Belgium reactor
BSR	Bulk Shielding Reactor (at ORNL)
B&W–LTC	Babcock and Wilcox–Lynchburg Technology Center, Lynchburg, Virginia
BWR	Boiling-water reactor
CADMUS	The Cadmus Group, Inc.
CANDU	Canadian Deuterium Reactor
CCMV	Converse County Mining Venture, Converse County, Wyoming
CE	Combustion Engineering Site (FUSRAP site), Windsor, Connecticut
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CEU	Consolidated Edison Uranium (at ORNL)
CFC	Chlorinated fluorocarbon

CH	Contact-handled (transuranic waste)
CISS	Colonie Interim Storage Site, Colonie, New York
CRCPD	Conference of Radiation Control Program Directors, Inc., Frankfort, Kentucky
CRWMS-M&O	Civilian Radioactive Waste Management System—Management and Operating (contractor)
CTAC	Carlsbad Technical Assistance 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/CAO	DOE Carlsbad Area Office, Carlsbad, 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 Management (Headquarters), Germantown, Maryland
DOE/FN	DOE Fernald Area 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/OAK	DOE Oakland Operations Office, Oakland, California
DOE/OH	DOE Ohio Field Office, Miamisburg, Ohio
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/SR	DOE Savannah River Operations Office, Aiken, South Carolina
DOE/WIPP	DOE WIPP Project Office, Carlsbad, New Mexico
DOE/WVAO	DOE West Valley Area Office, West Valley, New York
DOT	Department of Transportation, U.S.
DRCT	Dry rod consolidation technology
DST	Double-shell tank
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 (at ANL–E)
EC	Electron capture
ECF	Extended Core Facility (at INEEL NRF)
EG&G/ID	EG&G Idaho, Inc., Idaho Falls, Idaho (former management and operating contractor for Idaho National Engineering Laboratory)
EIA	Energy Information Administration (DOE)
EIS	Environmental impact statement
EMAD	Engine maintenance assembly and disassembly (at NTS)
EOCY	End of calendar year
EOFY	End of fiscal year
EPA	Environmental Protection Agency, U.S.
ETEC	Energy Technology Engineering Center, Canoga Park, California [also referred to as the Santa Susana Field Laboratory (SSFL)]

ETTP	East Tennessee Technology Park, Oak Ridge, Tennessee (formerly called the Oak Ridge K-25 Site)
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
FRR	Foreign Research Reactor
FSVR	Fort St. Vrain Reactor, Platteville, Colorado
FUSRAP	Formerly Utilized Sites Remedial Action Program
FY	Fiscal year
GA	General Atomics, San Diego, California
GAP CON	Gap conductance
GDP	Gaseous diffusion plant
GE	General Electric
GETR	General Electric Test Reactor, Pleasanton, California
GJPO	(DOE) Grand Junction Projects Office, Grand Junction, Colorado
GJRAP	Grand Junction Remedial Action Project
GTCC	Greater-than-Class-C (low-level waste)
Hanford	Hanford Site, Richland, Washington
HAW	High-activity waste
HAZWRAP	Hazardous Waste Remedial Actions Program
HCF	Hot Cell Facility (at SNL/NM)
HEDL	Hanford Engineering Development Laboratory (at Hanford)
HEN	Cape Henry (Atlantic Ocean off Virginia)
HFBR	High-Flux Beam Reactor (at BNL)
HFEF	Hot Fuel Examination Facility (at ANL–W)
HIC	High-integrity container
HLW	High-level waste
HTGR	High-temperature, gas-cooled reactor
HWVP	Hanford Waste Vitrification Plant (at Hanford)
ICPP	Idaho Chemical Processing Plant, Idaho National Engineering Laboratory
IDB	Integrated Data Base (Program)
IE	Irradiation effects
IFSF	Irradiated Fuel Storage Facility (at INEEL)
I/I	Industrial and institutional (waste)
ILAW	Immobilized low-activity waste
INEEL	Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho
ISA	Interim Storage Area (at Hanford)
ISFSI	Independent Spent Fuel Storage Installation
ISL	In situ leaching
IT	Isomeric transition
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

KAPL	Knolls Atomic Power Laboratory, Schenectady, New York
KCP	Kansas City Plant, Kansas City, Missouri
KESS	Kesselring Site (at KAPL)
LANL	Los Alamos National Laboratory, Los Alamos, New Mexico
LAW	Low-activity waste
LBNL	Lawrence Berkeley National Laboratory, Berkeley, California
LDR	Land disposal restriction
LEHR	Laboratory for Energy-Related Health Research, Davis, California
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
LMER	Lockheed Martin Energy Research (Corporation), Oak Ridge, Tennessee
LMES	Lockheed Martin Energy Systems, Inc., Oak Ridge, Tennessee
LMFBR	Liquid Metal Fast Breeder Reactor
LMITCO	Lockheed Martin Idaho Technologies Company, Idaho Falls, Idaho
LOC	Loss of coolant
LOFT	Loss-of-fluid test
LSA	Low specific activity
LWBR	Light-water breeder reactor
LWR	Light-water reactor
MACTEC	MAC Technical Services Company
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
MLLW	Mixed low-level waste
Mound	Mound Plant, Miamisburg, Ohio
MPC	Matrix parameter category
MRM	Miscellaneous radioactive material
MSR	Molten Salt Reactor (at ORNL)
MSRE	Molten Salt Reactor Experiment
MTIHM	Metric tons initial heavy metal
MTR	Materials Test Reactor (at INEEL)
MTRUW	Mixed transuranic waste
MTU	Metric tons uranium
MURR	Missouri (University of) Research Reactor, Columbia, Missouri
MWIR	Mixed Waste Inventory Report
NA	Not applicable
NARM	Naturally occurring and accelerator-produced radioactive materials
NBSR	National Bureau of Standards Reactor, Gaithersburg, Maryland
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, U.S.
NRF	Naval Reactors Facility (at INEEL)
NTIS	National Technical Information Service, Springfield, Virginia
NTPO	National Transuranic Waste Program Office
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, East Tennessee Technology Park, and Oak Ridge 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 Reservation, Oak Ridge, Tennessee
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
PCB	Polychlorinated biphenyl
PER	(Special) Power Excursion Reactor (test) (at INEEL)
PFP	Plutonium Finishing Plant (at Hanford)
Pinellas	Pinellas Plant, Largo, Florida
PNNL	Pacific Northwest National 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
RASB	Radioactive asbestos
RBOF	Receiving Basin for Off-Site Fuels (at SRS)
RCF	RCRA (see below) facility assessment
RCRA	Resource Conservation and Recovery Act of 1976
REECO	Reynolds Electrical and Engineering Co., Inc., Mercury, Nevada
RFETS	Rocky Flats Environmental Technology Site, Golden, Colorado
RH	Remote-handled (transuranic 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

RPCB	Radioactive polychlorinated biphenyl
RSWF	Radioactive Scrap and Waste Facility (at ANL–W)
SAIC	Science Applications International Corporation
SBW	Sodium-bearing waste
SCB	Santa Cruz Basin (Pacific Ocean off Santa Cruz, California)
SCW	Special case waste
SDG	San Diego (Pacific Ocean off San Diego, California)
SDS	Submerged demineralizer system
SEG	Scientific Ecology Group, Inc., Oak Ridge, Tennessee
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
SNF	Spent nuclear fuel
SNL/CA	Sandia National Laboratories/California, Livermore, California
SNL/NM	Sandia National Laboratories/New Mexico, Albuquerque, New Mexico
SNM	Special nuclear material
SNRO	DOE Schenectady Naval Reactors Office, Schenectady, New York
SNRS	Stationary Neutron Radiography System, Sacramento, California
SPF	Spontaneous fission
SRS	Savannah River Site, Aiken, South Carolina
SRTC	Savannah River Technical Center (at SRS)
SS	Stainless steel
SSFL	Santa Susana Field Laboratory, Canoga Park, California [also referred to as the Energy Technology Engineering Center (ETEC)]
SST	Single-shell tank
SWIMS	Solid Waste Information Management System
SWU	Separative work unit
TAN	Test Area North (at INEEL)
TBD	To be determined
TBE	Teledyne Brown Engineering, Westwood, New Jersey
TC	Thermocouple
TCLP	Toxicity characteristic leaching procedure
TENR	Technologically enhanced natural radioactive material
TESS	TRW Environmental Safety Systems, Inc.
THOREX	Thorium extraction
TMI	Three Mile Island reactor site, Middletown, Pennsylvania
TRA	Test Reactor Area (at INEEL)
TREAT	Transient Reactor Test Facility (at ANL–W)
TRIGA	Training Reactor, Isotopes, General Atomic
TRU	Transuranic
TRUW	Transuranic waste
TSCA	Toxic Substances Control Act of 1976
TSR	Tower Shielding Reactor (at ORNL)
T/S/D	Treatment, storage, and disposal
TVA	Tennessee Valley Authority, Knoxville, Tennessee
TWBID	Transuranic Waste Baseline Inventory Database
TWBIR	Transuranic Waste Baseline Inventory Report
TYP	Ten-year plan

UMT	Uranium mill tailings
UMTRAP	Uranium Mill Tailings Remedial Action Project
USAMC	U.S. Army Material Command, Rock Island, Illinois
USGS	U.S. Geological Survey
VA	Veterans Administration, U.S.
VEPCO	Virginia Electric Power Company, Richmond, Virginia
WAC	Waste acceptance criteria
WEC	Westinghouse Electric Corporation, Pittsburgh, Pennsylvania
WHC	Westinghouse Hanford Company, Richland, Washington
WHPP	(Transuranic) Waste Handling and Packaging Plant, Oak Ridge National Laboratory
WIND	Windsor Site (at KAPL)
WIPP	Waste Isolation Pilot Plant, Carlsbad, New Mexico
WMin	Waste minimization
WPIO	Waste Isolation Pilot Plant Project Integration Office, Albuquerque, New Mexico
WSSRAP	Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri
WTAC	Waste Isolation Pilot Plant Technical Assistance Contractor
WTWBIR	Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report
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
11e(2)	By-product material as defined in Sect. 11e(2) of the Atomic Energy Act of 1954
M11e(2)	Mixed 11e(2) by-product material

INTEGRATED DATA BASE REPORT—1996: U.S. SPENT NUCLEAR FUEL AND RADIOACTIVE WASTE INVENTORIES, PROJECTIONS, AND CHARACTERISTICS

ABSTRACT

The Integrated Data Base Program has compiled historic data on inventories and characteristics of both commercial and U.S. Department of Energy (DOE) spent nuclear fuel (SNF) and commercial and U.S. government-owned radioactive wastes. Inventories of most of these materials are reported as of the end of fiscal year (FY) 1996, which is September 30, 1996. Commercial SNF and commercial uranium mill tailings inventories are reported on an end-of-calendar year (CY) basis. All SNF and radioactive waste data reported 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 DOE/Energy Information Administration (EIA) projections of U.S. commercial nuclear power growth and the expected DOE-related and private industrial and institutional activities.

The radioactive materials considered, on a chapter-by-chapter basis, are SNF, high-level waste, transuranic waste, low-level waste, uranium mill tailings, DOE Environmental Restoration Program contaminated environmental media, naturally occurring and accelerator-produced radioactive material, and mixed (hazardous and radioactive) low-level waste. For most of these categories, current and projected inventories are given through FY 2030, and the radioactivity and thermal power are calculated based on reported or estimated isotopic compositions.

0. OVERVIEW

0.1 INTRODUCTION

This report is an update of the previous document[1] on spent nuclear fuel (SNF) and radioactive waste inventories and projections that was prepared for use in the planning and analysis of various SNF and waste management functions. Quantities of SNF and radioactive wastes produced from both commercial and U.S. Department of Energy (DOE)-sponsored activities are reported.

Previous issues of this report had reported SNF and waste information on a calendar-year (CY) basis. However, this report documents DOE site waste quantities on a fiscal-year (FY) basis in order to provide a consistent format with the information associated with the DOE Office of Environmental Management (DOE/EM) Ten Year Plan (TYP). In general, total radioactive waste inventories for DOE sites are reported as of the end-of-fiscal-year (EOFY) 1996 (i.e., as of September 30, 1996). Information on annual commercial SNF and commercial uranium mill tailings inventories, provided by the DOE Energy Information Administration (DOE/EIA), are reported on an end-of-calendar-year (EOCY) basis.

Projections of future SNF and radioactive wastes are generally reported for the FY period 1997–2030. Such projections may change in future revisions of this report as waste minimization (WMin), environmental restoration, and decontamination and decommissioning (D&D) programs and activities at various government and commercial sites are defined and become operative. In general, the tables of this document use a horizontal line to mark the point in time when past history ends and future projections begin. Because historical radioactive waste inventories are generally reported as EOFY 1996, the line is drawn between the data entries for FY 1996 and FY 1997. Data reported for either FY or CY 1997 in this document are regarded as projected numerical information.

This document contains information that has been assembled as a part of the Integrated Data Base (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 SNF and radioactive wastes. While this report documents inventories and projections of radioactive wastes from commercial and DOE site activities, estimates for certain other waste categories are not fully reported because of the current unavailability of data. These categories include naturally occurring and accelerator-produced radioactive material (NARM), discussed in Sect. 0.2, and wastes from U.S. Department of Defense (DOD) activities, particularly those resulting from the cleanup of military sites contaminated with significant amounts of radioactive waste. A study[2] by the U.S. General Accounting Office indicates that as many as 420 DOD locations could be contaminated with radioactive wastes. Future updates of this report will report information and data on NARM and DOD site radioactive wastes as they become available.

This report also does not report inventories of nonradioactive materials. These include hazardous wastes, sanitary wastes, and materials not categorized as waste (MNCAW), such as uncontaminated scrap metal. Preliminary estimates of inventories of MNCAW are reported in ref. 3.

Except for some NARMs, most 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 SNF, high-level waste (HLW), transuranic waste (TRUW), low-level waste (LLW), and uranium mill tailings (UMTs). Large quantities of radioactive waste also result from DOE site

environmental restoration activities and the D&D programs of DOE and commercial nuclear facilities. This report also documents inventories and projections of mixed low-level waste (MLLW), which is both hazardous and radioactive.

The primary purpose of this document is to report U.S. SNF 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 SNFs. In addition, the recent literature was reviewed to aid in selecting the data that are presented herein and to help establish a basis for many of the calculated radioactivity levels and heat-generation rates that are included. In this report, SNF 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 DOE 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 SNF storage facilities. Discussion of the data is minimized to explain mainly what the data represent. Major DOE data sources providing information and data for this report are identified in a table following the preface. Likewise, discussions of packaging details, shielding and transportation requirements, health and environmental effects, and costs are purposely avoided. Questions regarding the information and data presented may be addressed to the IDB Program.

The DOE waste information and data contained in this report are furnished by the DOE contractor sites listed in Table 0.1. This table indicates also the types of radioactive waste managed at each site. 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 DOE site waste data reported were received from DOE contractors through DOE operations offices. DOE-HQ assigns to selected organizations major responsibilities for providing information on particular topics involving SNF and radioactive waste management. Further detailed information is generally available from data bases maintained at the specific DOE and commercial sites. Additional information on the reference sites and facilities referred to in this report is provided in Appendix C.

0.2 CHARACTERIZATION OF WASTE FORMS

The major characteristics of radioactive materials and wastes are described in the following:

- **Spent Nuclear Fuel (SNF)**

  SNF consists of irradiated fuel discharged from a nuclear reactor. Unless otherwise identified, all SNFs discussed in this report are assumed to be permanently discharged and eligible for repository disposal. Three categories of permanently discharged SNF 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 SNFs 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 SNF.

  Currently, most LWR SNF 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 and Environmental Laboratory (INEEL) at Idaho Falls, Idaho; and the Midwest Fuel Recovery Plant (MFRP) at Morris, Illinois. The WVDP facility is currently being decommissioned. All utility-owned SNF assemblies previously stored there have been returned to the

utilities, and the fuel remaining is DOE-owned material.

SNFs discharged from a variety of reactors are currently stored at the Hanford Site (Hanford) and INEEL. Hanford 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 SNF from the Fort St. Vrain high-temperature, gas-cooled reactor (HTGR), are stored at INEEL. Some special SNFs are stored at the Savannah River Site (SRS) and at INEEL. These special fuels are government owned and are not scheduled for reprocessing in support of DOE activities.

- **High-Level Waste (HLW)**

For this report, HLW means the highly radioactive material resulting from the reprocessing of SNF. This material 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.[4] 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.

- **Transuranic Waste (TRUW)**

TRUW refers to radioactive waste that contains more than 100 nCi/g of alpha-emitting isotopes with atomic numbers greater than 92 and half-lives greater than 20 years.[5,6] Such waste results 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" (CH) TRUW], but energetic gamma and neutron emissions from certain transuranic (TRU) nuclides and fission-product contaminants may require shielding or remote handling ["remote-handled" (RH) TRUW].

- **Low-Level Waste (LLW)**

Several statutes (refs. 4, 6, and 7) define LLW not by what it is, but by what it is not. In general, LLW is radioactive waste not classified as SNF, HLW, TRUW, nor by-product materials such as UMT 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,[6] which specifies DOE's policy for radioactive waste management. According to this order, LLW includes all radioactive waste not classified as either HLW, TRUW, SNF, or the bulk of the by-product tailings containing uranium or thorium and their decay products 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 of 1954 (AEA)][8] or NARM to be managed as LLW. Any LLW that also contains hazardous chemicals covered by either the Resource Conservation and Recovery Act (RCRA)[9] or the Toxic Substances Control Act (TSCA)[10] requires management as a "mixed waste."

The definition of commercial LLW is based on two statutes, the Nuclear Waste Policy Act (NWPA)[4] and the Low-Level Radioactive Waste Policy Amendments Act (LLRWPAA).[7] According to both the NWPA and the LLRWPAA, commercial LLW is radioactive material that (a) is not HLW, SNF, TRUW, or by-product material as defined in Sect. 11e(2) of the AEA, and (b) is consistent with existing law, is classified by the U.S. Nuclear Regulatory Commission (NRC) as LLW.

The radiation level from LLW may sometimes be high enough such as to require shielding for handling and transport. For commercial LLWs, the NRC has defined, in ref. 11, 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 inventories of solid LLW either destined for disposal or awaiting treatment prior to its disposal. It includes no liquid or gas waste in storage.

- **Uranium Mill Tailings (UMT)**

  Uranium mill tailings (UMT) 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.

- **Naturally Occurring and Accelerator-Produced Radioactive Material (NARM)**

  NARM wastes include both accelerator wastes (LLW) and naturally occurring radioactive material (NORM) that contain radionuclides (e.g., ^{226}Ra, ^{222}Rn, ^{232}Th, ^{238}U) existing throughout the earth's crust. Accelerator wastes include accelerator targets, wastes from accelerator maintenance or D&D, and wastes from radiopharmaceutical manufacture. NORM wastes are classified according to their specific activity as either discrete or diffuse. Discrete NORM wastes have a relatively small volume but large radioactivity and include industrial gauges, old radium watch and industrial dials, radium needles in medical equipment, resins (filters) that remove radioactive radium from public drinking water, and some radiopharmaceutical waste. Diffuse NORM wastes are characterized by a relatively large volume with small radioactivity. These materials result from industrial processes and include:

  - coal ash and slag from utility electrical generation;
  - solid wastes from geothermal energy production;
  - slag, leachate, and tailings from the mining and processing of metals other than uranium or thorium (e.g., copper);
  - sludge from drinking water treatment;
  - scale, sludge, produced water, and equipment from oil and natural-gas production containing NORM; and
  - wastes (phosphogypsum and slag) from mining phosphate ores for fertilizer (ammonium phosphate) production.[12,13]

  Current inventories of total domestic NARM wastes are not known. Future updates of this document will include additional information on NARM waste inventories, projections, and characteristics as they become available.

- **Mixed Low-Level Waste (MLLW)**

  MLLW 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;[9] the TSCA;[10] and state regulations. Typically, MLLW 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 updated information and data from the DOE Office of Waste Management Technical Information Collection Database.[14]

- **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 fiscal 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 and for which there is 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 among 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. Of the latter, 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 0.2. These include the projected time frame and specific assumptions used for estimating commercial and government (DOE) waste projections. The commercial SNF projections reported in this document assume a reference projection of nuclear power growth and no SNF reprocessing. The reference nuclear power electrical growth projection (and associated discharged SNF schedule) used throughout this report is the 1997 DOE/Energy Information Administration (EIA) Reference Case.[15] Throughout this report, this case will be referred to as the Reference Case. The Reference Case SNF and power-capacity projection cases are based on a 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. 15. In particular, the Reference Case assumes that no new advanced LWRs will become operational before the year 2015 and that all current nuclear units are retired on the dates when their initial license-terms expire.

Detailed information about reactors already built, being built, or planned in the United States for domestic use or export as of December 31, 1995, is provided in report DOE/OSTI-8200-R59 (ref. 16), which contains a comprehensive listing of all domestic reactors categorized by primary function or purpose: 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 September 30, 1996—some as recently as November 1997. 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 SNF 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 some wastes by an abridged version of the ORIGEN2 code (ref. 17). Annual levels of radioactivity (Ci) reported in this document include contributions from both parent and daughter decay products.

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 SNF and HLW, is an important concern. Thermal energy generation rates are highest for SNF, HLW, and RH TRUW. 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 (J) 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 SNF and TRUW, mass is reported to provide better assurances of accountability. SNF 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 TRUWs.

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 fiscal 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 SNF, TRUW, LLW, and MLLW. No HLW from SNF reprocessing was generated during FY 1996. In previous issues of this document, annual generation rates have not been reported for HLW in part because there are problems in accurately estimating HLW generation levels. One major difficulty is accounting for net waste-quantity changes caused by 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 SNF inventories and projections can be expressed in terms of the number of permanently discharged boiling-water reactor (BWR) and PWR fuel assemblies. HLW will be immobilized in either borosilicate glass or a glass/ceramic matrix solidified in stainless steel canisters. Quantities of LLW and stored TRUW 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 radioactivity (Ci %).

0.5 CHAPTER OVERVIEWS

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

0.5.1 Spent Nuclear Fuel (SNF)

Chapter 1 of this report presents national data on the quantities of permanently discharged SNF from commercial nuclear power reactors. Historical data on commercial SNF inventories are reported along with 1997 DOE/EIA projections for the Reference Case.[15] The Reference Case is the baseline commercial scenario used throughout this report to make waste projections. For the projection period considered in this report (CYs 1997–2030), the Reference Case assumes that no new reactors will be ordered.

DOE SNF inventories are also reported in Chapter 1. These include various types of research reactor SNFs which are stored at the SRS and the INEEL.

In this report, the mass of discharged SNF is generally 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 High-Level Waste (HLW)

The inventories of HLW in storage at the end of FY 1996 and projected through FY 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. Inventories and projections of vitrified defense HLW are reported for Hanford, INEEL, and the Defense Waste Processing Facility (DWPF) at SRS. In addition, inventories 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 Hanford and the INEEL 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 SNFs. 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 SNFs, little additional HLW is expected to be generated at DOE sites in the future.

0.5.3 Transuranic Waste (TRUW)

The locations, inventories, and projections of TRUW buried and stored at DOE sites are presented in Chapter 3. Inventories of TRUW are reported as of September 30, 1996, and 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 TRUW volumes through FY 2022 were also requested from the sites, but the sites were not able to make such estimates in all cases. Projections are reported through FY 2022 for those sites that provided estimates.

In 1984, DOE (with input from other federal agencies) revised the minimum radioactivity concentration level for defining TRUW from greater than 10 nCi/g to greater than 100 nCi/g.[18] Consequently, some waste currently in the inventory may contain wastes stored under both criteria. This redefinition, as well as the development of instrumentation to detect these low levels of radioactivity, may reduce the volume of TRUW. 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 Low-Level Waste (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 industrial and institutional (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 FY 1996, approximately 66% of the total cumulative volume of disposed LLW resulted from various DOE activities. The remaining 34% resulted from domestic commercial activities. About 29% of the volume of LLW disposed during FY 1996 resulted from commercial activities.

0.5.5 Uranium Mill Tailings (UMT)

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. During CY 1996, only one NRC-licensed mill was operational. 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. Tailings from the now inactive mills that produced uranium only for government operations are being stabilized under DOE's Environmental Restoration Program (see Chapter 6).

0.5.6 Environmental Restoration Program

The mission of the DOE Office of Environmental Restoration (EM-40) is to protect human health and the environment from risks posed by inactive and surplus facilities and contaminated areas by remediating sites and facilities in the most cost-efficient and responsible manner possible in order to provide for future beneficial use. An overview of the Environmental Restoration Program 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 Environmental Restoration Program includes a bias for action to expedite actual cleanup wherever and whenever possible. Activities are prioritized based on factors such as the need to eliminate risks at sites not controlled by the federal government, the goal of reducing risks at all sites, and compliance with various laws, regulations, and agreements. Most actions are designed to either remove or contain contamination in the environment or to decommission contaminated structures. Related activities include treatment of contaminated materials and wastes, transportation of these materials and wastes to storage and disposal facilities, and disposal of wastes in permitted facilities.

The total volume of solid radioactively contaminated material being addressed by the Environmental Restoration Program is approximately 57 million m^3. About 70% of this volume is expected to be managed in-situ using remedies such as capping, monitoring, and retention of land-use controls. The total volume of radioactive waste resulting from ex-situ remedies is approximately 17 million m^3. About one-half of this volume is LLW and most of the remainder is mill tailings and debris being managed under the Uranium Mill Tailings Remedial Action Program (UMTRAP). An additional 27 million m^3 of mill tailings and debris has already been disposed of in engineered containment cells under UMTRAP. Strategies for managing the radioactive wastes associated with the Environmental Restoration Program are presented in Chapter 6.

0.5.7 Naturally Occurring and Accelerator-Produced Radioactive Material (NARM)

Chapter 7 describes the characteristics of NARM (and NORM). Some inventories and projections of these materials, based on information currently available, are also reported.

0.5.8 Mixed Low-Level Waste (MLLW)

Current inventories and generation rates of MLLW 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 AEA,[8] while the hazardous components are defined by the RCRA,[9] the TSCA,[10] and pertinent state regulations. As of the end of FY 1996, inventories of MLLW at DOE sites totaled about 76,240 m^3.

0.5.9 Appendixes

Several appendixes are included in this report. Appendix A is a compilation of 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. A tabulation of the

properties of important radionuclides is given in Appendix B. Appendix C lists the sites and facilities referred to in this report.

0.6 SUMMARY DATA

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 decayed radioactivities of commercial and DOE wastes and SNF accumulated through both CY and FY 1996.

Summaries of SNF and radioactive waste inventories and projections are provided in Tables 0.3 and 0.4. In general, material to be sent to R&D facilities or to the proposed national geologic repository for SNF and HLW is still listed in each individual site's inventory.

DOE waste volume summaries for specific sites are given in Tables 0.5–0.7. Waste generation for FY 1996 is presented in Table 0.5, and total FY 1996 inventories for stored and buried wastes are provided in Tables 0.6 and 0.7, respectively.

0.7 REFERENCES

1. U.S. Department of Energy, *Integrated Data Base Report—1995: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, DOE/RW-0006, Rev. 12, Oak Ridge National Laboratory, Oak Ridge, Tennessee (December 1996).

2. U.S. General Accounting Office, *Environmental Cleanup—Better Data Needed for Radioactively Contaminated Defense Sites*, GAO/NSIAD-94-168, Washington, D.C. (August 1994).

3. Coreen Casey and Beth A. Heath, EG&G Idaho, Inc., Radioactive Waste Technical Support Program, *Material Not Categorized as Waste (MNCAW) Data Report*, DOE/LLW-93, predecisional draft, Idaho National Engineering Laboratory, Idaho Falls, Idaho (November 1993).

4. 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.

5. U.S. Environmental Protection Agency, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," *Code of Federal Regulations*, 40 CFR Part 191 (July 1, 1996).

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

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

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

9. 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.

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

11. 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 (Jan. 1, 1996).

12. The League of Women Voters Education Fund, *The Nuclear Waste Primer*, Lyons & Burford, New York, 1993.

13. K. P. Smith, *An Overview of Naturally Occurring Radioactive Materials (NORM) in the Petroleum Industry*, ANL/EAIS-7, Argonne National Laboratory, Argonne, Illinois (December 1992).

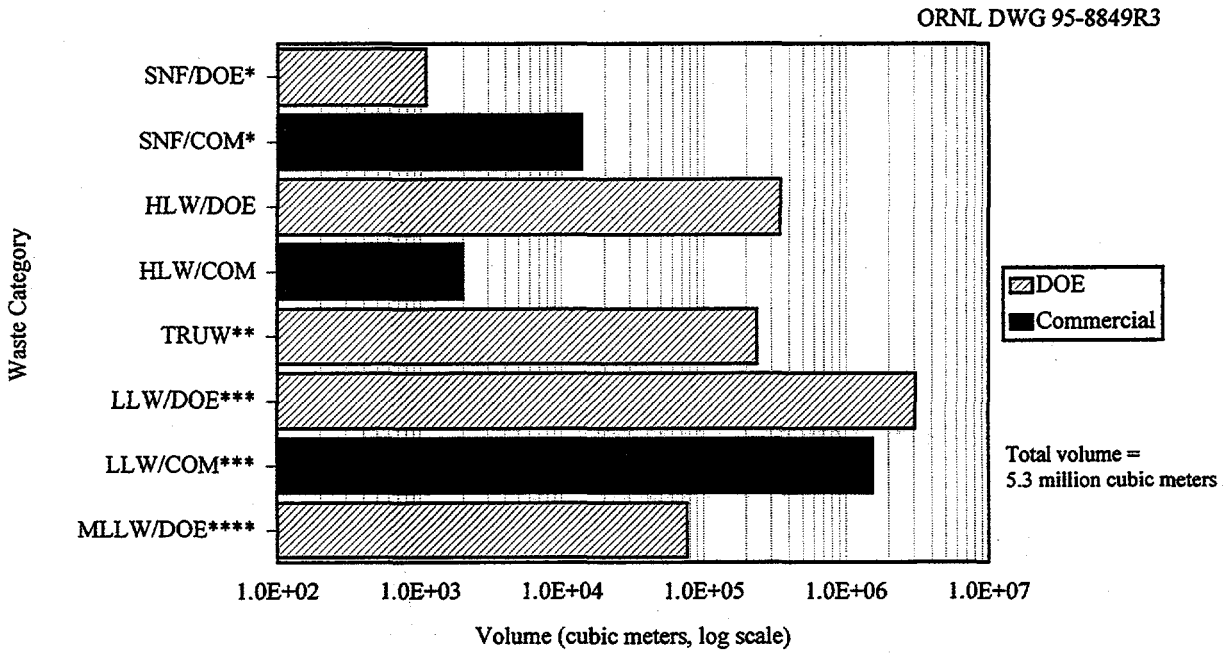
14. U.S. Department of Energy, Office of Environmental Restoration, Office of Waste Management, *Technical Information Collection Database*, updated through Oct. 30, 1997.

15. U.S. Department of Energy, Energy Information Administration, *Nuclear Power Generation and Fuel Cycle Report 1997*, DOE/EIA-0436(97), Washington, D.C. (September 1997).

16. U.S. Department of Energy, Office of Scientific and Technical Information, *Nuclear Reactors Built, Being Built, or Planned: 1996*, DOE/OSTI-8200-R60, Oak Ridge, Tennessee (August 1997).

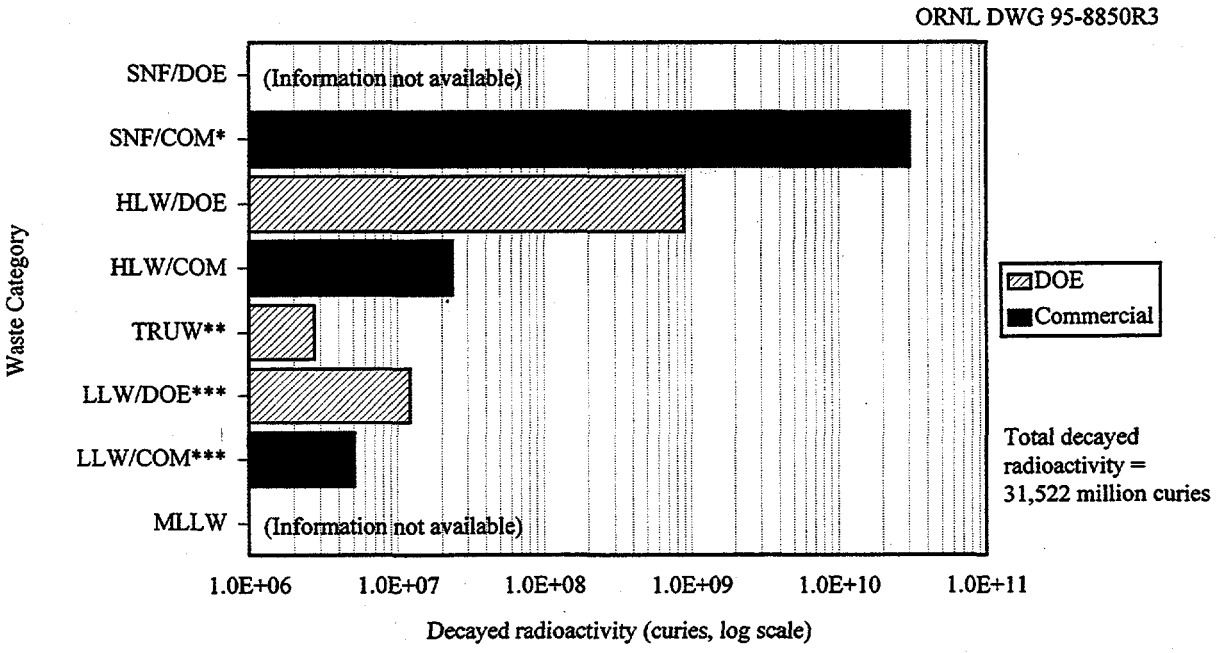
17. A. G. Croff, *ORIGEN2—A Revised and Updated Version of the Oak Ridge Isotope Generation and Depletion Code*, ORNL-5621, Oak Ridge National Laboratory, Oak Ridge, Tennessee (July 1980).

18. 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. 6)].



*Permanently discharged reactor fuel. Includes spacing between fuel assembly rods.
**DOE wastes include both retrievably stored and buried materials.
***Includes contributions from disposed wastes only.
****Includes retrievably stored RCRA and TSCA materials only.

Fig. 0.1. Total volumes of DOE and commercial radioactive wastes and SNF through 1996.



*Estimate of commercial LWR fuel permanently discharged.
**DOE wastes include both retrievably stored and buried materials.
***Includes contributions from disposed wastes only.

Fig. 0.2. Total decayed radioactivities of DOE and commercial radioactive wastes and SNF through 1996.

Table 0.1. Types of radioactive wastes managed at DOE sites referenced in this report[a]

Site(s)	Symbol/label	SNF	HLW	TRUW	LLW	MLLW	UMT
Ames Laboratory	Ames			X[a]	X	X	
Argonne National Laboratory–East	ANL–E	X		X	X	X	
Argonne National Laboratory–West	ANL–W	X		X	X	X	
Atlantic Richfield (Medical Products) Company	ARCO			X			
Battelle Columbus Laboratories	BCL			X	X		
Brookhaven National Laboratory	BNL	X			X	X	
East Tennessee Technology Park	ETTP				X	X	
Energy Technology Engineering Center	ETEC			X	X	X	
Fermi National Accelerator Laboratory	FNAL				X		
Fernald Environmental Management Project	FEMP				X	X	
Hanford Site[b]	Hanford	X	X	X	X	X	
Idaho National Engineering and Environmental Laboratory[c]	INEEL	X	X	X	X	X	
Inhalation Toxicology Research Institute[d]	ITRI				X	X	
Kansas City Plant	KCP				X	X	
Laboratory for Energy-Related Health Research	LEHR					X	
Lawrence Berkeley National Laboratory	LBNL			X	X	X	
Lawrence Livermore National Laboratory	LLNL			X	X	X	
Los Alamos National Laboratory	LANL	X		X	X	X	
Missouri (Univ. of) Research Reactor	MURR			X			
Mound Plant	Mound			X	X	X	
Naval Reactors Facilities and Shipyards[e]	NR Sites			X	X	X	
Nevada Test Site	NTS			X	X	X	
Oak Ridge Institute of Science and Education	ORISE				X		
Oak Ridge National Laboratory	ORNL	X		X	X	X	
Paducah Gaseous Diffusion Plant	PAD			X	X	X	
Pantex Plant	PANT			X	X	X	
Pinellas Plant	Pinellas				X	X	
Portsmouth Gaseous Diffusion Plant	PORTS				X	X	
Princeton Plasma Physics Laboratory	PPPL				X	X	
Reactive Metals, Inc. Site	RMI				X	X	
Rocky Flats Environmental Technology Site	RFETS			X	X	X	
Sandia National Laboratory/California	SNL/CA				X	X	
Sandia National Laboratory/New Mexico	SNL/NM	X		X	X	X	
Savannah River Site	SRS	X	X	X	X	X	
Stanford Linear Accelerator Center	SLAC				X		
Teledyne Brown Engineering	TBE			X			
Uranium Mill Tailings Remedial Action Project Sites[f]	UMTRAP						X
U.S. Army Material Command	USAMC			X			
West Valley Demonstration Project	WVDP	X	X	X	X	X	
Y-12 Plant (Oak Ridge)	Y-12				X	X	

[a]An "X" entry in this table indicates that the listed site manages waste of the category indicated. General site information is given in Appendix C.

[b]Includes Pacific Northwest National Laboratory (PNNL).

[c]Includes the Idaho Chemical Processing Plant (ICPP); excludes ANL–W.

[d]Also referred to as the Lovelace Biomedical and Environmental Research Institute.

[e]These sites are listed in Table C.2 of Appendix C.

[f]These sites are listed in Chapter 6.

Table 0.2. Major assumptions used in this report

Inventory/projection basis

- Inventories (except where indicated) are reported as of the end of FY 1996 (September 30, 1996)
- Projections are generally reported for the FYs 1997–2030

HLW solidification activities

- For Hanford, HLW solidification (borosilicate glass production) starts in 2002 and concludes in 2028
- For INEEL, HLW solidification (immobilization) starts in 2019 and continues through 2034
- For SRS, HLW solidification (glass production) at the Defense Waste Processing Facility (DWPF) started in 1996 and continues through 2019
- For WVDP, HLW solidification (glass production) started in 1996 and will be completed in 2001

Commercial activities

- DOE/EIA projections of installed net LWR electrical capacity for the Reference Case[a] of ref. 15:

Reference Case

CY	1997	2000	2005	2010	2015	2020	2025	2030
GW(e)	101	99	95	89	63	49	22	2

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

LWR fuel	CY fuel is loaded	Fuel enrichment (% ^{235}U)	Design burnup (MWd/MTIHM)
BWR	1993	3.14	36,000
	1996	3.12	40,000
	2000	3.47	43,000
	2010	3.58	46,000
PWR	1993	3.84	42,000
	1997	4.11	46,000
	2001	4.38	50,000
	2008	4.74	55,000

- SNF 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 0.3. Total SNF and radioactive waste inventories[a]

Waste category	Mass (MTIHM)	Volume (m^3)	Radioactivity[b] (10^6 Ci)	Thermal power (10^3 W)
SNF				
Commercial				
BWRs	12,105	4,880[c]	d	d
PWRs	22,148	8,928[c]	d	d
DOE	2,483	1,091	d	d
HLW[e]				
Hanford (DOE)[f]		207,300	332.1	954.1
Idaho (DOE)		10,550	48.4	143.6
Savannah River (DOE)		127,500	498.0	1,402.7
West Valley (commercial)		2,000	23.6	70.5
TRUW (DOE)[g]				
Buried		141,400	>0.14	d
Stored (site operations)[h]		96,600	2.60	d
Stored (environmental restoration activities)		42	d	d
LLW				
DOE sites				
Generated		30,764	d	d
Stored (site operations)		d	d	d
Stored (environmental restoration activities)		290,000	d	d
Disposed[i]		3,068,000	12.1	22.0
Commercial sites				
Major disposal facilities		1,551,000	5.1	19.9
Other disposal facilities		199,988	d	d
UMT (commercial licensed mill sites)[j]		118,700,000	d	d
11e(2) by-product material (from DOE environmental restoration)[k]	d	28,000,000	d	d
MLLW				
DOE sites				
Stored (site operations)	d	76,240	d	d
Stored (environmental restoration activities)	d	40,000	d	d
Commercial generator sites	d	d	d	d
Commercial disposal facilities	d	31,014	d	d

[a]Commercial inventories are reported as of December 31, 1996 (EOCY 1996); and DOE site inventories are reported as of September 30, 1996 (EOFY 1996).

[b]Except for TRUWs, radioactivity data are calculated decayed values as of September 30, 1996.

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

[d]Information not available.

[e]Includes contributions (if any) from both tank waste and canister material.

[f]Hanford tank wastes consist of HLW, TRUW, 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.

[g]Data as of September 30, 1996.

[h]As-generated wastes, mixed and nonmixed.

[i]Includes contributions of LLW from HLW immobilization activities.

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

[k]Includes contributions from mixed as well as radioactive wastes.

Table 0.4. Current and projected total quantities of radioactive waste and SNF

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

Source and type of material	End of FY				
	1996	2000	2010	2020	2030
DOE sites					
SNF, mass, MTHM[a]	2,483	b	b	b	b
HLW					
Interim storage	347.3	310	244	96	3
Glass or glass/ceramic[c]	0.06	0.7	2.9	11.1	18.5
TRUW					
Buried	141[d]	141	141	141	141
Stored (as generated from site operations)	96.6[d]	b	b	b	b
Stored (environmental restoration activities)	0.042	b	b	b	b
LLW					
Buried[e]	3,068	3,277	3,791	4,361	4,577
Stored (site operations)	b	b	b	b	b
Stored (environmental restoration activities)	290	b	b	b	b
MLLW					
Stored (site operations)	76.2	b	b	b	214
Stored (environmental restoration activities)	40	b	b	b	b
11e(2) by-product material					
Stored (environmental restoration activities)	28,000	b	b	b	b
Commercial sites					
LWR SNF, mass, MTIHM[a,f,g] (no reprocessing)					
Reference Case	34,252	43,300	63,400	78,500	86,700
HLW (WVDP)					
Interim storage	2.0	0.2	0.0	0.0	0.0
Glass	0.02	0.22	0.24	0.24	0.24
LLW buried[e] (no reprocessing)	1,551	1,588	b	b	b
UMT[g]	118,700	b	b	b	b
MLLW	b	b	b	b	b
Other commercial disposal facilities[h]					
LLW	200.0	b	b	b	b
MLLW	31.0	b	b	b	b
NARM	296.7	b	b	b	b
11e(2) by-product	168.6	b	b	b	b

[a]Historically, spent nuclear fuel has been measured in units of mass rather than units of volume.

[b]Information not available.

[c]Includes projections for glass at SRS and glass/ceramic at INEEL.

[d]Includes mixed and nonmixed wastes.

[e]Projections include contributions of LLW from HLW immobilization activities.

[f]The 1996 discharged spent nuclear 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 nuclear fuel inventories and projections reported in this document and those reported by DOE/EIA.

[g]End of CY data.

[h]Includes wastes from DOE-, commercial-, DOD-, and EPA-sponsored activities.

Table 0.5. Volume (m^3) of DOE site wastes generated during FY 1996

Site(s)	HLW	TRUW		LLW[b]	MLLW		Total (site)
		CH[a]	RH[a]		RCRA	TSCA	
Ames		0	0		2		2
ANL-E		8	0	211	c	70	289
ANL-W		0	0	270	c		270
BNL				416	2		418
ETEC		0	0	925	9		934
ETTP					d	d	c
FEMP				c	c	c	c
FNAL				30	c	c	30
Hanford		34	0	3,922	318		4,274
INEEL				6,791	c		6,791
ITRI					c		c
KCP							
LANL		138	0	4,022	54		4,214
LBNL		0	0	23	1		24
LEHR				308			308
LLNL		16		279	116		411
Mound		0	0	749			749
NR sites[e]		0	0	789	16	3	808
NTS		0	0	6	c		6
ORISE							
ORNL		16	12		d	d	28
PAD		0	0				0
PANT		0	0	174	28		202
Pinellas							
PORTS							
PPPL				34	<1		35
RFETS		37	0		c		37
SLAC							
SNL/CA				1	c		1
SNL/NM		2	0		c	c	2
SRS		171	0.6	8,195	61	<<1	8,428
WVDP		0	0	444	2		446
Y-12					d	d	c
Others		<<1		3,173[f]	881[g]		4,054
Total	0[h]	422	13	30,764	1,489	73	32,761

[a]Projected annual addition to as-generated waste stored inventory during FY 1996. Information for FY 1996 was not available. Includes contributions from both mixed and nonmixed wastes.

[b]Excludes wastes from DOE environmental restoration activities.

[c]Information unavailable or unknown.

[d]Included in 880 m^3 reported as RCRA and non-RCRA PCB MLLW for the Oak Ridge Reservation (ORR).

[e]Includes contributions from Bettis Atomic Power Laboratory, Knolls Atomic Power Laboratory, and naval shipyards.

[f]Includes 3,159 m^3 from ORR.

[g]Includes 880 m^3 reported as both RCRA and TSCA wastes for the ORR.

[h]From SNF reprocessing. (No SNF was reprocessed during FY 1996.)

Table 0.6. Volume (m^3) inventory of stored DOE site SNF and radioactive wastes as of EOFY 1996

Site(s)	SNF	HLW	TRUW[a]		LLW[b]	MLLW[c]		Total (site)
			CH	RH		RCRA	TSCA	
Ames					18			18
ANL-E	0.1		81		564	51	70	766
ANL-W	9		7	22		390		428
BNL	7				297	4	<<1	308
ETEC			2	5	425	39		471
ETTP					13,638	22,237	4,001	40,876
FEMP					140,000			140,000
FNAL					91			91
Hanford	260	207,300	11,008	203		8,018	102	226,891
INEEL	469	10,550	64,760	62	18,634	846		95,321
ITRI					50			50
KCP					<<1			<<1
LANL			8,610	93		765		9,468
LBNL			<<1		35	7		42
LLNL			240		644	493		1,377
Mound			236		3,392	37	<1	3,666
NR sites[d]	80			3	3	68	19	173
NTS			618		301	25		944
ORISE					<<1			<<1
ORNL	17		921	1,283	1,842	2,843	9	6,915
PAD			4		110,000	147		110,151
PANT			<1		208			208
Pinellas					124			124
PORTS					13,000			13,000
PPPL								
RFETS			1,889		5,463	19,730		27,082
SLAC					174			174
SNL/CA					26	e		26
SNL/NM	6		8		360	e		374
SRS	89	127,500	6,034	1	1,616	7,717	3	142,960
WVDP	11	2,000	37	484	14,936	27		17,495
Y-12					2,934	7,262	325	10,521
Others	143		4		27,000	4		27,151
Total	1,091	347,350	94,459	2,156	355,775	71,710	4,530	877,071

[a]Includes both mixed and nonmixed as-generated wastes.

[b]Inventory as of the end of CY 1995 for EM-30 sites. Does not apply to FEMP, PAD, PORTS, and sites included in "Others" (FUSRAP sites, GA, GJPO Site, and RMI).

[c]Excludes about 40,000 m^3 of MLLW from environmental restoration activities (see Table 6.8 in Chapter 6).

[d]Includes contributions from Bettis Atomic Power Laboratory, Knolls Atomic Power Laboratory, and naval shipyards.

[e]Information unavailable or unknown.

Table 0.7. Volume (m^3) inventory of buried DOE site wastes as of EOFY 1996[a,b,c]

Site(s)	TRUW	LLW[d]	Total (site)
Ames		e	e
ANL-E			
ANL-W			
BNL		839	839
ETEC			
ETTP		81,048	81,048
FEMP		343,220	343,220
FNAL			
GJPO			
Hanford	63,600	639,948	703,548
INEEL	57,000	150,234	207,234
ITRI			
KCP			
LANL	14,000	228,220	242,220
LBNL			
LLNL		9,102	9,102
Mound			
NR sites			
NTS		514,055	514,055
ORISE			
ORNL	572	210,360	210,932
PAD		7,613	7,613
PANT		134	134
Pinellas			
PORTS		12,110	12,110
PPPL			
RFETS			
SLAC			
SNL/CA			
SNL/NM	1	3,218	3,219
SRS	4,870	693,487	698,357
WVDP	1,350	f	1,350
Y-12		151,343	151,343
Total	141,393	3,044,931	3,186,324

[a]Excludes 89,472 containers (94,273 Ci, undecayed) of LLW in 50- and 80-gal drums disposed of by sea dumping.

[b]Excludes 17,300 m^3 (1,300,000 Ci, undecayed) of LLW grout injected into shale underlying the ORNL site.

[c]Excludes wastes from environmental restoration activities.

[d]The data listed for LLW represent disposed inventories and include materials that are not buried.

[e]Wastes from the Chemical Disposal Site at Ames were excavated and shipped to a commercial disposal facility in 1995.

[f]Only commercial LLW is buried at WVDP.

1. SPENT NUCLEAR FUEL

1.1 INTRODUCTION

This chapter reports both the quantities and characteristics of spent nuclear fuel (SNF) that has been permanently discharged from commercial light-water reactors (LWRs) and one-of-a-kind reactors. In addition, this chapter contains a mass summary report of U.S. Department of Energy (DOE) SNF (see Sect. 1.4). Though currently in storage at numerous commercial and DOE sites, this fuel will ultimately require geologic disposal.

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

Historical inventories of commercial LWR SNF have been updated through December 31, 1995.[1] The data reported in this chapter include the inventories of SNF stored at the West Valley Demonstration Project (WVDP), the Midwest Fuel Recovery Plant (MFRP), the Idaho National Engineering and Environmental Laboratory (INEEL), and other DOE sites in addition to those stored at the various reactor sites. The current locations of existing and planned power reactor sites and commercial LWR SNF storage facilities are given in report DOE/OSTI-8200-R60 (ref. 2).

Projections of nuclear capacity and SNF discharges are given for the calendar years (CYs) 1997–2030 for the DOE/Energy Information Administration (EIA) Reference Case forecast schedule reported in ref. 3. Starting with an estimate for 1997 of 100.7 GW(e), the Reference Case forecast projects installed commercial nuclear electric capacity to start declining in the year 1999, ultimately decreasing to 2.3 GW(e) by 2030.

The Reference Case scenario for projecting accumulated SNF assumes a nuclear fuel cycle that does not have any fuel reprocessing. SNF discharge projections, in terms of cumulative mass discharged, are graphically illustrated in Fig. 1.1.

DOE/EIA projections for the Reference Case assume that current average equilibrium burnup levels of discharged SNF will be 33,000 and 41,000 megawatt day (MWd)/metric tons of initial heavy metal (MTIHM) for boiling-water reactor (BWR) and pressurized-water reactor (PWR) fuel, respectively.[3]

1.2 COMMERCIAL SPENT NUCLEAR FUEL

1.2.1 Inventories and projections

The total inventory of commercial LWR SNF in storage at the WVDP site, the MFRP, DOE sites, and the reactor sites as of December 31, 1996, is estimated to be over 34,000 MTIHM. Of this total amount, 26 MTIHM are stored at the WVDP site,[4] 674 MTIHM are stored at the MFRP,[1] 171 MTIHM are stored at INEEL,[4] and about 25 MTIHM are stored at other DOE sites. The remainder is stored at the reactor sites. These inventories do not include the SNF reprocessed at the WVDP site when the facility was operated as a fuel reprocessing plant. The WVDP SNF inventories include 125 LWR fuel assemblies (representing 26 MTIHM), which are owned by DOE.

A BWR/PWR breakdown of the electric power generating capacity for the Reference Case forecast, along with historical reactor capacity data, is given in Table 1.1. The buildups of permanently discharged LWR SNF mass are given on a historical basis in Table 1.2 and for the projected DOE/EIA Reference Case in Table 1.3.

1.2.2 Characterization

Reference characteristics of BWR and PWR fuel assemblies, obtained from refs. 5 and 6, are summarized in Table 1.4. More detailed information on SNF characteristics may be found in ref. 7.

1.3 DISPOSAL

The DOE Office of Civilian Radioactive Waste Management (OCRWM) has been focused on characterization of the Yucca Mountain site to address suitability of the site. The approach has been refined to structure a multi-staged process for arriving at a site suitability determination. This process calls for an assessment to be made in 1998 of the viability of siting a repository at Yucca Mountain and an updating of the regulatory framework for siting a repository. Excavation of the main tunnel of the Exploratory Shaft Facility was completed in April 1997. Extensive surface-based and underground testing are still being conducted.

OCRWM is developing an approach for the performance of its waste acceptance, storage, and transportation responsibilities, as set forth in the Nuclear Waste Policy Act (NWPA), as amended, and in the Standard Contract for disposal of SNF and HLW (see Glossary of Terms). A presolicitation conference was held July 9, 1996, to discuss technical and contractual issues related to the potential acquisition of transportation services. At the presolicitation conference, OCRWM made available a draft Statement of Work and a draft Concept of Operations for the waste acceptance and transportation services acquisition. A draft request for proposals (RFP) was issued for public review and comment in December 1996, followed by another presolicitation conference in March 1997.

OCRWM is pursuing an acquisition process that is market-driven, relying on private industry (contractors) to provide all necessary services and equipment to fulfill OCRWM's mission at competitive fixed prices and fixed rates. The contractors would accept SNF from its owners and generators (purchasers) and supply casks and equipment for transporting SNF to (and possibly storage at) a designated federal facility. Contractors would work with purchasers to determine the best way to service a site and would recommend to the NRC preferred transportation routes to a federal facility.

OCRWM may award up to four contracts, covering four regions of the United States. The intent is to develop a market infrastructure to foster competition and innovative approaches to waste acceptance and transportation.

1.4 DOE SPENT NUCLEAR FUEL

Summary inventory characteristics of DOE SNF as of June 1997 are given in Table 1.5 (based on ref. 4). Projected site inventories for CY 2035 are also included. Figure 1.2 shows the major locations and masses of current DOE SNF inventories.

For clarification, the quantities of SNF reported in Table 1.5 include contributions from other nuclear fuels besides those permanently discharged from production reactors. SNFs reported in this table 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 SNF and are eligible for inclusion in Table 1.5. This table also lists some commercially generated nuclear fuels and nuclear fuels from foreign research reactors (FRRs) and university research reactors which are stored at DOE sites. More detailed information on these special nuclear fuels will be included in future updates of this report.

Major changes in the DOE SNF inventories reported in Table 1.5 that have occurred since the last publication of this document are attributed to the following:

- SNF at LANL has been moved to SRS;
- SRS has also received shipments of SNF from several universities, non-DOE-owned research reactors, and FRRs;
- Inventories of naval SNF at INEEL have increased, and most SNF that was previously stored at the INEEL ICPP-603 facility has been removed;
- At McClellan Air Force Base, inventories of Training Reactor, Isotopes, General Atomics (TRIGA) fuel have increased; and
- About 167 MTIHM of SNF has been processed at SRS and Argonne National Laboratory–West (ANL–W), and the resulting waste is now listed as high-level waste (HLW).

1.5 REFERENCES

1. U.S. Department of Energy, Energy Information Administration, Nuclear Fuel Data Form RW-859, Washington, D.C. (historical data as of December 31, 1995).

2. U.S. Department of Energy, Office of Scientific and Technical Information, *Nuclear Reactors Built, Being Built, or Planned: 1996*, DOE/OSTI-8200-R60, Oak Ridge, Tennessee (August 1997).

3. U.S. Department of Energy, Energy Information Administration, *Nuclear Power Generation and Fuel Cycle Report 1997*, DOE/EIA-0436(97), Washington, D.C. (September 1997).

4. Elwood P. Stroupe, National Spent Nuclear Fuel Program, Idaho National Engineering Laboratory, Idaho Falls, Idaho, correspondence to Stephen N. Storch, IDB Program, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Spent Fuel Data for the Integrated Data Base," EPS-36-97, dated July 14, 1997.

5. General Electric Company, *General Electric Standard Safety Analysis Report*, BWR/6, Docket STN 50-447, San Jose, California (1973).

6. Westinghouse Nuclear Energy Systems, *Reference Safety Analysis Report*, RESAR-3, Docket STN 50-480, Pittsburgh, Pennsylvania (1972).

7. U.S. Department of Energy, *Characteristics of Potential Repository Wastes*, Vols. 1–4, DOE/RW-0184-R1, Oak Ridge National Laboratory, Oak Ridge, Tennessee (July 1992).

ORNL DWG 96-3532R

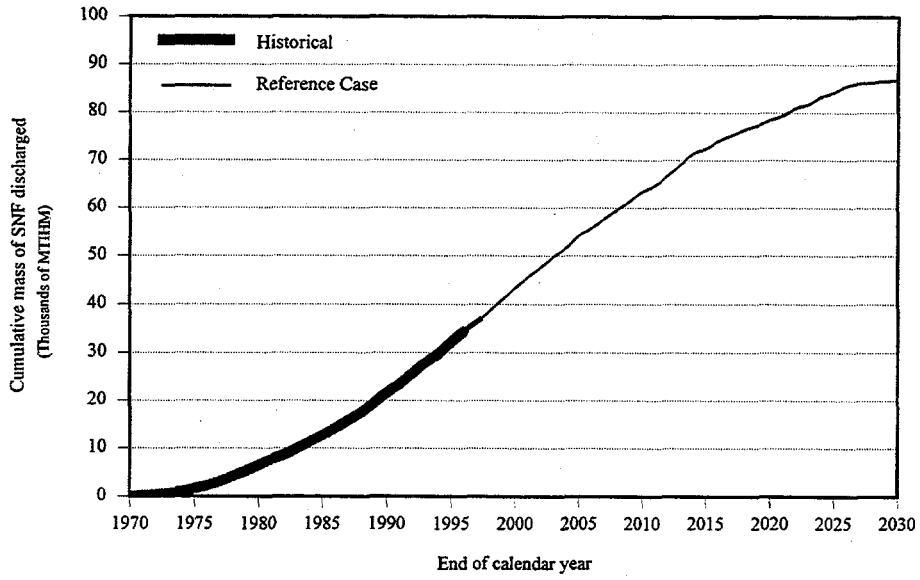
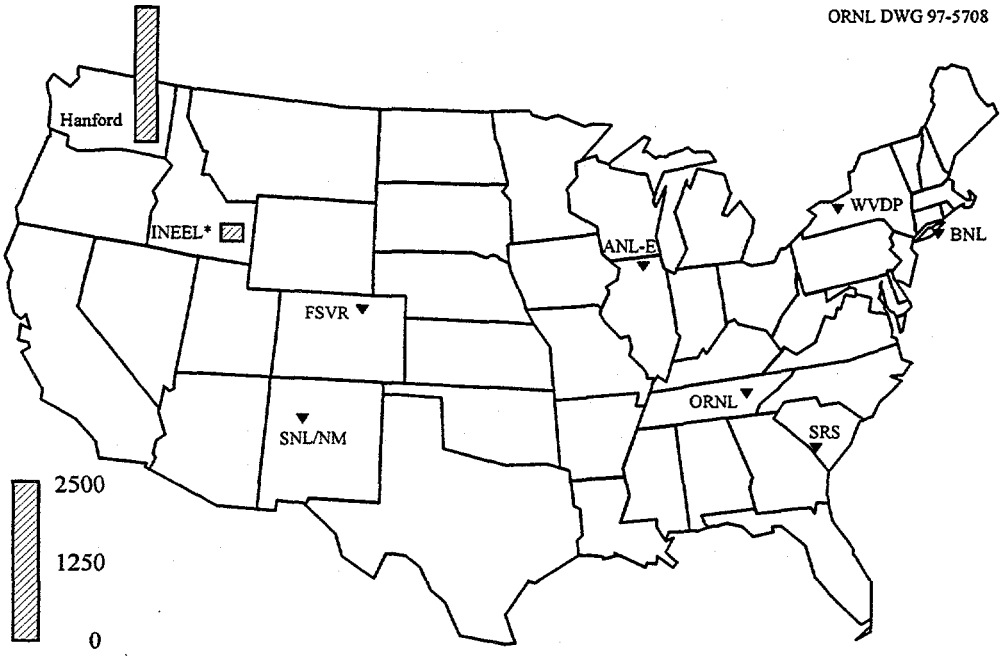


Fig. 1.1. Historical and projected mass (MTIHM) of cumulative commercial SNF discharged for the DOE/EIA Reference Case.

ORNL DWG 97-5708



*Includes contributions from ANL-W and NRF.
Note. Only locations are shown for sites whose DOE SNF inventories are less than 50 MTHM. Excludes fuel at universities and non-DOE-owned domestic reactors.

Fig. 1.2. Major locations and masses of current DOE SNF inventories.

Table 1.1. Historical and projected installed LWR electric power generating capacity for the DOE/EIA Reference Case

End of CY	Historical capacity[a] [GW(e)]			End of CY	Reference Case projected capacity[b] [GW(e)]		
	BWR	PWR	Total		BWR	PWR	Total
1960	0.1	0.2	0.3	1997	33.6	67.1	100.7
1961	0.1	0.2	0.3	1998	33.6	67.1	100.7
1962	0.1	0.2	0.4	1999	33.1	66.3	99.4
1963	0.1	0.2	0.4	2000	33.1	66.3	99.4
1964	0.1	0.2	0.4	2001	33.1	66.3	99.4
1965	0.1	0.2	0.4	2002	32.7	65.3	98.0
1966	0.1	0.2	0.4	2003	32.7	65.3	98.0
1967	0.1	1.3	1.4	2004	31.9	63.9	95.8
1968	0.2	1.2	1.4	2005	31.7	63.3	95.0
1969	0.8	1.7	2.6	2006	31.1	62.3	93.4
1970	2.9	2.9	5.8	2007	30.9	61.9	92.8
1971	4.3	3.7	8.0	2008	30.7	61.3	92.0
1972	7.0	6.5	13.5	2009	30.5	61.0	91.5
1973	8.1	14.1	22.1	2010	29.7	59.4	89.1
1974	13.3	19.4	32.7	2011	29.4	58.9	88.3
1975	15.0	23.3	38.3	2012	28.3	56.5	84.8
1976	16.8	27.9	44.7	2013	24.5	49.0	73.5
1977	16.8	30.4	47.2	2014	21.6	43.2	64.8
1978	17.6	32.2	49.8	2015	21.0	42.0	63.0
1979	17.6	32.2	49.8	2016	19.2	38.3	57.5
1980	17.6	34.3	51.9	2017	18.3	36.5	54.8
1981	17.6	38.6	56.2	2018	17.4	34.8	52.2
1982	18.7	40.5	59.2	2019	17.4	34.8	52.2
1983	19.7	43.6	63.3	2020	16.4	32.7	49.1
1984	24.2	45.8	70.0	2021	15.0	30.0	45.0
1985	26.8	51.7	78.5	2022	13.6	27.2	40.8
1986	28.9	55.2	84.1	2023	12.2	24.5	36.7
1987	31.8	60.8	92.6	2024	9.6	19.2	28.8
1988	31.8	63.1	94.9	2025	7.4	14.7	22.1
1989	33.8	64.1	97.9	2026	4.2	8.4	12.6
1990	32.9	66.7	99.6	2027	2.3	4.7	7.0
1991	32.0	67.7	99.6	2028	1.1	4.6	5.7
1992	31.8	67.1	98.9	2029	0.0	3.5	3.5
1993	31.8	67.2	99.0	2030	0.0	2.3	2.3
1994	31.9	67.2	99.1				
1995	32.2	67.2	99.4				
1996	32.2	68.5	100.7				

[a]Based on ref. 1.

[b]Data from ref. 3. Assumes that no new reactors will be ordered. Projections assume that one-third of the total capacity will be provided by BWRs and the remainder by PWRs.

Table 1.2. Historical mass (MTIHM) of permanently discharged commercial SNF by reactor type[a]

End of CY	BWR[b]		PWR[c]		Total LWR[d]	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1968–1970		16		39		55
1971	65	81	44	83	109	164
1972	146	226	100	183	246	410
1973	94	320	67	250	161	570
1974	242	562	208	458	449	1,020
1975	226	787	322	780	548	1,567
1976	298	1,085	401	1,181	699	2,266
1977	383	1,469	467	1,648	850	3,116
1978	384	1,852	699	2,346	1,082	4,199
1979	400	2,252	721	3,068	1,121	5,320
1980	620	2,872	618	3,686	1,238	6,558
1981	459	3,331	676	4,362	1,135	7,692
1982	357	3,688	640	5,002	998	8,690
1983	491	4,179	771	5,773	1,263	9,952
1984	498	4,677	841	6,614	1,339	11,291
1985	532	5,209	861	7,475	1,393	12,684
1986	458	5,667	996	8,472	1,454	14,139
1987	597	6,264	1,109	9,581	1,706	15,844
1988	536	6,799	1,117	10,697	1,652	17,497
1989	698	7,497	1,215	11,913	1,913	19,410
1990	633	8,130	1,504	13,417	2,137	21,547
1991	588	8,718	1,271	14,688	1,859	23,406
1992	695	9,413	1,596	16,284	2,291	25,697
1993	700	10,113	1,532	17,816	2,232	27,929
1994	675	10,788	1,207	19,024	1,882	29,811
1995	627	11,415	1,514	20,538	2,141	31,952[e]
1996[f]	690	12,105	1,610	22,148	2,300	34,252

[a]Based on refs. 1 and 3.
[b]BWR = boiling-water reactor.
[c]PWR = pressurized-water reactor.
[d]LWR = light-water reactor.
[e]Excludes 70 MTIHM of discharged fuel assemblies that are expected to be reinserted.
[f]Data reported are based on last year's projection for CY 1996.

Table 1.3. Current and projected mass (MTIHM) of permanently discharged commercial LWR SNF for the DOE/EIA Reference Case[a]

End of CY	Annual	Cumulative
1996[b]	2,300	34,252
1997	2,100	36,300
1998	2,300	38,600
1999	2,400	41,000
2000	2,300	43,300
2001	2,100	45,500
2002	2,200	47,600
2003	2,200	49,800
2004	1,900	51,700
2005	2,500	54,200
2006	1,600	55,800
2007	2,000	57,800
2008	1,800	59,600
2009	1,800	61,400
2010	2,000	63,400
2011	1,300	64,700
2012	2,100	66,800
2013	2,200	69,000
2014	2,400	71,400
2015	1,000	72,400
2016	1,800	74,100
2017	1,100	75,200
2018	1,200	76,400
2019	900	77,300
2020	1,100	78,500
2021	1,100	79,500
2022	1,400	81,000
2023	900	81,800
2024	1,500	83,300
2025	1,000	84,200
2026	1,300	85,500
2027	600	86,100
2028	200	86,300
2029	300	86,600
2030	100	86,700

[a]Assumes no future fuel reprocessing. Note that cumulative levels reported may not equal sum of annual additions because of independent rounding.

[b]Data reported as based on last year's projection for CY 1996.

Table 1.4. IDB reference characteristics of LWR nuclear 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. 5.
[b]Ref. 6.
[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 1.5. Summary inventory of DOE SNF for years 1997 and 2035[a]

Site/category	Facility[b]	1997 total mass (kg)	1997 volume (m^3)	Discharged heavy metal (MTHM)	
				1997	2035
ANL-E	Alpha-gamma hot cell	257.10	0.10	0.08	0.08
	Chicago Pile-5	12.80	0.01	0.00	0.00
	Subtotal	269.90	0.12	0.08	0.08
ANL-W	FCF	543.81	0.09	0.18	0.18
	HFEF	6,598.23	1.02	1.94	1.94
	RSWF	33,469.78	3.04	26.05	26.05
	TREAT	206.81	4.95	0.02	0.02
	Subtotal	40,818.63	9.11	28.20	28.20
BNL	BMRR	165.46	0.13	0.00	0.01
	HFBR	3,650.21	7.24	0.22	1.35
	Subtotal	3,815.67	7.37	0.23	1.36
FRR	FRR				16.15
FSVR	ISFSI	187,392.00	130.27	14.73	14.73
Hanford	Area 200 (burial)	808.78	4.41	0.32	0.32
	Area 400 (ISA)	350.60	0.08	0.02	0.02
	Area 618 (burial)	0.00	0.00	0.00	0.00
	Bldg. 324	4,077.50	1.19	2.28	2.28
	Bldg. 325	50.00	0.01	0.01	0.01
	Bldg. 327	39.00	0.01	0.02	0.02
	FFTF	130,223.38	40.67	10.99	10.99
	PFP	1,023.40	0.02	0.01	0.01
	T-plant	38,500.00	9.45	15.82	15.82
	105-K East Basin	1,723,772.00	99.94	1,146.43	1,146.43
	105-K West Basin	1,806,522.00	104.56	957.16	957.16
	Subtotal	3,705,366.66	260.34	2,133.06	2,133.06
INEEL	ICPP-603	11,115.48	6.57	1.81	1.81
	ICPP-666	394,143.02	174.53	15.94	15.94
	ICPP-749	204,181.88	47.90	78.59	78.59
	ICPP-IFSF	131,390.79	86.11	10.02	10.02
	MTR canal	1,990.70	0.75	0.26	0.26
	PER-620	5,580.50	0.84	0.56	0.56
	TAN-607	333,480.56	131.85	85.29	85.29
	TAN-791	55,275.81	10.67	38.37	38.37
	TRA-660	577.62	0.46	0.23	0.23
	TRA-670	8,240.00	9.73	0.73	2.47
	Subtotal	1,145,976.36	469.39	231.80	233.54
INEEL/NRF	ECF	347,784.67	80.34	5.61	5.61

Table 1.5 (continued)

Site/category	Facility[b]	1997 total mass (kg)	1997 volume (m^3)	Discharged heavy metal (MTHM)	
				1997	2035
ORNL	Bldg. 7827	1,978.90	4.01	0.15	0.15
	Bldg. 7829	782.40	0.48	0.03	0.03
	Bldg. 7920	204.30	0.10	0.00	0.00
	Bldg. 7900 pools	9,373.30	7.98	0.47	1.14
	BSR	327.04	0.40	0.06	0.06
	MSR	8,940.00	3.88	0.04	0.04
	TSR	182.00	0.10	0.01	0.01
	Subtotal	21,787.94	16.94	0.76	1.42
SNL/NM	ACRR	100.00	0.09	0.00	2.36
	Dense pack	900.00	1.12	0.10	0.10
	Manzano storage	12,800.00	5.20	0.00	0.00
	Subtotal	13,800.00	6.40	0.10	2.46
SRS	RBOF	217,285.03	89.11	40.02	40.02
U.S. Navy	U.S. Navy Shipyards				49.35
WVDP	Fuel Receiving and Storage Facility	42,780.00	11.34	26.31	26.31
Other	Non-DOE-owned domestic reactors				
	Armed Forces Radiobiological Facility	323.00	0.08	0.02	0.02
	ARRR	263.90	0.07	0.01	0.01
	DOW TRIGA Reactor	265.20	0.06	0.01	0.01
	GA TRIGA Reactor Facility	884.60	0.22	0.06	0.06
	GE Pleasanton	80.00	0.05	0.01	0.01
	Hot cell facility (GA)	28.90	0.08	0.01	0.01
	Lynchburg Technology Center	77.05	0.03	0.04	0.04
	MNRC	570.80	0.13	0.04	0.04
	NBSR	830.98	2.16	0.02	0.11
	Omaha VA Medical Center	162.40	0.04	0.01	0.01
	USGS Facility of Denver, Colorado	547.40	0.13	0.03	0.04
	Subtotal	4,057.43	3.05	0.27	0.37
	University				
	Cornell University	418.20	0.10	0.02	0.03
	Georgia Institute of Technology	0.00	0.00	0.00	0.15
	Iowa State University Reactor	38.55	0.19	0.02	0.02
	Kansas State University	377.40	0.09	0.02	0.03
	Massachusetts Institute of Technology	304.00	0.20	0.03	0.12
	North Carolina State University	880.00	0.24	0.53	0.53
	Ohio State University	200.00	2.14	0.03	0.03
	Oregon State University	336.80	0.08	0.02	0.03
	Pennsylvania State University	615.40	0.15	0.04	0.04
	Purdue University	3.72	0.01	0.00	0.03

Table 1.5 (continued)

Site/category	Facility[b]	1997 total mass (kg)	1997 volume (m^3)	Discharged heavy metal (MTHM)	
				1997	2035
Other (contd.)	University (contd.)				
	Reed Reactor Facility	227.80	0.06	0.01	0.01
	Rhode Island Nuclear Science Center	99.00	0.10	0.02	0.17
	State University of New York–Buffalo	1,000.00	0.13	0.66	0.66
	Texas A&M	632.40	0.15	0.03	0.08
	University of California–Irvine	384.20	0.09	0.02	0.02
	University of Massachusetts–Lowell	230.00	0.15	0.00	0.05
	University of Texas–Austin	533.80	0.13	0.03	0.03
	University of Arizona	333.20	0.08	0.02	0.02
	University of Florida	313.00	0.66	0.01	0.03
	University of Illinois	698.90	0.17	0.04	0.05
	University of Maryland	316.20	0.08	0.02	0.03
	University of Michigan	598.00	0.71	0.10	0.47
	University of Missouri[c]	806.00	0.97	0.09	0.59
	University of Utah	425.40	0.12	0.03	0.04
	University of Virginia	191.40	0.19	0.04	0.09
	University of Wisconsin	775.20	0.19	0.04	0.09
	Washington State University	731.00	0.18	0.04	0.09
	Worcester Institute of Technology	150.80	0.16	0.02	0.02
	Subtotal	11,620.37	7.52	1.92	3.56
	Grand total	5,742,754.67	1,091.30	2,483.09	2,556.21

[a]Based on ref. 4. Inventories for 1997 are reported as of June 1997.

[b]Abbreviations used in this table: ACRR—Annular Core Research Reactor, ARRR—Aerotest Radiography and Research Reactor, BMRR–Brookhaven Medical Research Reactor, BSR—Bulk Shielding Reactor, CMR—Chemistry and Metallurgical Research, ECF—Extended Core Facility, FCF—Fuel Conditioning Facility, FFTF—Fast Flux Test Facility, FRR—Foreign Research Reactor, FSVR—Fort St. Vrain Reactor, GA—General Atomics, GE—General Electric, HCF—Hot Cell Facility, HFBR—(Brookhaven) High Flux Beam (Research) Reactor, HFEF—Hot Fuel Examination Facility, ICPP—Idaho Chemical Processing Plant, IFSF—Irradiated Fuel Storage Facility, ISA—Interim Storage Area, ISFSI—Independent Spent Fuel Storage Installation, MNRC—McClellan Nuclear Radiation Center, MSR—Molten Salt Reactor, MTR—Materials Test Reactor, NBSR—National Bureau of Standards Reactor, PER—(Special) Power Excursion Reactor (Test), PFP—plutonium finishing plant, RBOF—Receiving Basin for Off-Site Fuels, RSWF—Radioactive Scrap and Waste Facility, SRTC—Savannah River Technical Center, TAN—Test Area North, TRA—Test Reactor Area, TREAT—Transient Reactor Test Facility, TRIGA—Training Reactor, Isotopes, General Atomic, TSR—Tower Shielding Reactor, USGS—U.S. Geological Survey, and VA—Veterans Administration.

[c]Includes reactors at both Columbia and Rolla.

2. HIGH-LEVEL WASTE

2.1 INTRODUCTION

High-level waste (HLW) is generated by the chemical reprocessing of spent reactor fuel, irradiated targets, and naval propulsion fuel. HLW generally contains more than 99 wt % of the nonvolatile fission products produced during reactor operation. HLW from a facility that recovers both uranium and plutonium contains a residual amount of about 0.5 wt % of those elements, while HLW from a facility that recovers only uranium contains a residual 0.5 wt % of the uranium and essentially all of the plutonium. Most fission products have short half-lives and therefore quickly decay. HLW older than 10 years contains primarily the fission product radionuclides ^{137}Cs and ^{90}Sr and very small amounts of transuranic (TRU) nuclides, which typically have very long half-lives.

In 1992, DOE decided to phase out the domestic reprocessing of irradiated nuclear fuel for the recovery of enriched uranium or plutonium in support of defense activities. Only limited quantities of HLW from the reprocessing of deteriorating SNF are expected to be generated for the immediate future. Future D&D activities of HLW facilities, including the flushing of residual wastes found in reprocessing facilities, must be managed as either mixed low-level waste (MLLW) or as mixed transuranic waste (MTRUW).

When first generated, HLW is a highly radioactive, acidic liquid. This liquid generates heat and must be handled remotely behind heavy shielding in corrosion-resistant vessels. At the Hanford Site (Hanford), HLW was neutralized with caustic soda (sodium hydroxide), and sodium nitrite was then added for corrosion control so that the HLW could be stored in carbon-steel tanks. This practice continued at Hanford, the Savannah River Site (SRS), and the West Valley Demonstration Project (WVDP) because of cost considerations relating to using stainless steel. Neutralization with caustic soda forms sodium nitrate (which remains in solution) and hydrated oxides of certain radionuclides and nonradioactive chemicals (which precipitate and collect as a sludge on the floor of the tank). In addition, the ^{137}Cs remains largely in solution. At the Idaho National Engineering and Environmental Laboratory (INEEL), however, the waste has always been stored at the Idaho Chemical Processing Plant (ICPP) as an acidic liquid in stainless steel tanks and then converted into a granular solid (calcine) by thermal processing, which drives off water and decomposes nitrate and fluoride salts to stable oxides and calcium fluoride. The calcine is stored in stainless steel bins enclosed in concrete vaults.

The supernatant liquid resulting from neutralization may become concentrated by evaporation, either by self-boiling or in evaporators. If enough water is removed from the waste, sodium nitrate and sodium nitrite will crystallize from the solution. The crystals then will settle to the bottom of the tank liquid and on top of the sludge. If there are many crystals, a salt cake will form.

To reduce heat generation in tanks, large quantities of ^{137}Cs and ^{90}Sr were removed from some Hanford HLW and encapsulated in concentrated form as halide salts. Some of these capsules were subsequently leased to non-DOE organizations for beneficial use. All of the leased capsules have now been returned to Hanford.

A new nonaqueous form of HLW will be generated through the operation of an electrometallurgical process for treatment of limited amounts of sodium-bonded fuel at the Argonne National Laboratory–West (ANL–W) facility located on the INEEL site.

In summary, HLW exists in a variety of physical or chemical forms (alkaline or acidic, supernatant liquid, sludge, salt cake, calcine solid, etc.), all of which must be stored to safely protect the environment and the health of workers and of the public.

Most of the current U.S. inventory of HLW has resulted from DOE activities. HLW is stored at SRS (Aiken, South Carolina), INEEL (Idaho Falls, Idaho), and Hanford (Richland, Washington). A small amount of HLW was generated by commercial operations and reprocessing of some DOE SNF at the Nuclear Fuel Services (NFS) plant, near West Valley, New York, between 1966 and 1972, at a site owned by the New

York State Energy Research and Development Authority (NYSERDA). After 1972, fuel reprocessing operations at this plant were discontinued. In 1980, Congress passed the West Valley Demonstration Project Act (Pub. L. 96–368), which authorizes DOE to conduct, jointly with NYSERDA (90% DOE, 10% NYSERDA), a demonstration of solidification of HLW for disposal and the decontamination and decommissioning (D&D) of facilities used in the demonstration. The HLW data presented in this chapter are based on separate submittals provided by Hanford, INEEL, SRS, and WVDP in ref. 1.

2.2 AGREEMENTS AND INTERFACES

HLW is considered to be a mixed waste (i.e., waste containing both radioactivity and hazardous substances) unless demonstrated to the contrary. The hazardous substances of HLW are defined by the Resource Conservation and Recovery Act (RCRA).[2] Liquid HLW is *characteristic* mixed waste (i.e., as stored, it exhibits the characteristic of corrosivity because of its acidity, alkalinity, or toxicity because of the presence of heavy metals). Some HLW may also be *listed* mixed waste (i.e., it contains substances managed as hazardous under RCRA because of its source). Mixed wastes must be managed according to RCRA[2] and Atomic Energy Act (AEA)[3] requirements.

The Federal Facility Compliance Act (FFCA)[4] of 1992 amends the Solid Waste Disposal Act to require (among other things) that DOE prepare a Site Treatment Plan (STP) for each site which generates, stores, or treats mixed waste. In effect, these STPs constitute a legally enforceable agreement between DOE and the host state that DOE must comply with certain requirements for mixed waste management. STPs must be approved by the host state for the site. The FFCA exempts the STP requirement if a site already has an enforceable agreement with the host state and EPA that covers the treatment of mixed waste.

Two similar triparty agreements existed before approval of the STPs. One (for Hanford) is among DOE, the U.S. Environmental Protection Agency (EPA), and the state of Washington Department of Ecology. This triparty agreement[5] serves as an STP, is legally enforceable, and requires DOE to undertake specific actions at Hanford on a prescriptive timetable. The other triparty agreement (for SRS) involves DOE, EPA, and the state of South Carolina. However, this Federal Facilities Agreement applies only to those waste storage tanks that do not meet current DOE and regulatory criteria for secondary containment and leak detection. Consequently, an STP is being prepared for SRS HLWs.

At INEEL, an STP has been executed with the state of Idaho for the treatment of all mixed wastes, including HLW. This STP was published on October 31, 1995; reissued on November 30, 1995; and then subsequently updated on March 20, 1997. The Idaho STP incorporates regulations established in the Settlement Agreement Court Order of 1995,[6] which delineates specific actions and schedules for treating and removing SNF, HLW, and TRUW currently stored at INEEL. The Settlement Agreement was completed on October 17, 1995, among the state of Idaho, DOE, and the U.S. Department of the Navy to resolve issues arising from previous cases in the U.S. District Court.

The state of New York recently approved an STP for HLW at WVDP.

2.3 WASTE CHARACTERIZATION

Characterization of HLW at some sites has been hampered over the years by the use of several different flow sheets for the processes that generated the waste or prepared the wastes for storage (e.g., nuclide separation, precipitation, and evaporation). In some instances, wastes have been blended. Information for all sites is based on historic records of reprocessing feeds and, for Hanford, INEEL, SRS, and WVDP, extensive sampling of stored HLW.

In previous versions of this report, HLW data were presented by physical form in some detail (e.g., liquid, sludge, slurry, salt cake, and precipitate). Starting with Rev. 11 and continuing in this year's revision, the data are more simply categorized as solid, liquid, or process-generated (canistered) material. Each of these three waste categories requires different storage and processing methods. As HLW pretreatment and vitrification processes proceed, inventories of liquid and solid waste will generally decrease, and canistered material will increase.

Radionuclide compositions and inventories are given for the current and projected HLW at Hanford (Table 2.11), INEEL (Tables 2.12 and 2.22), SRS (Table 2.13); and WVDP (Table 2.14). In addition, chemical compositions are presented for projected HLW final waste form at each site in Tables 2.16–2.19.

2.4 INVENTORIES AND PROJECTIONS

Tables 2.1–2.3, respectively, present historical and projected volumes, radioactivity, and thermal power

inventories of HLW currently in storage. The radioactivity and resultant thermal power of HLW decay, over time, in a manner characteristic of the constituent radionuclides, but, as previously mentioned, the volume depends significantly on the specific treatment history of the waste. When one takes into account all radionuclides in HLW, total radioactivity and thermal power each typically decrease about 2 to 4% per year within storage units to which no new waste has been added.

Locations of the four HLW sites and the relative volumes of HLW are represented in Fig. 2.1. The total volume and radioactivity for the HLW (solid and liquid) stored at the four sites are shown graphically in Fig. 2.2. Historical and projected cumulative volumes of HLW stored or produced at each site are graphically illustrated in Fig. 2.3. The number of waste canisters projected to be produced by each site are depicted in Fig. 2.4.

Current DOE plans are to immobilize and package HLW for disposal in a NRC-licensed, underground geologic repository. Figures 2.5–2.8 show, for each of the four sites, the general treatment processes by which the HLW will be immobilized to a form acceptable to the DOE Office of Civilian Radioactive Waste Management (DOE/RW), which has responsibility for accepting the waste for ultimate emplacement in a repository. Tables 2.4–2.6, respectively, give the projected volume, radioactivity, and thermal power for HLW immobilized as borosilicate glass. Table 2.7 gives estimates, year by year and by site, of the number of HLW canisters to be produced based on reference flowsheets. Projected volume, radioactivity, and number of HLW canisters from the new ANL–W process are given separately in Tables 2.21 and 2.22. Canister estimates for SRS [Defense Waste Processing Facility (DWPF)] and WVDP are fairly well established (both projects began radioactive operations in FY 1996), while canister estimates for INEEL and Hanford are less certain because pretreatment and immobilization processes have not yet been finalized. Tables 2.8–2.10 give the volume, radioactivity, and thermal power, respectively, of stored HLW by site and by physical form. Currently available summary information about the radionuclide distribution for stored and projected HLW and associated other wastes for each site is given in Tables 2.11–2.14. Significant changes in any of these tables from the previous IDB report (Rev. 12)[7] are presented in Table 2.15. It should be noted that the radioactivity reported in Tables 2.2, 2.5, and 2.9 include contributions from both parent and daughter products.

Projected inventories (volume, radioactivity, and thermal power) for HLW presented in Tables 2.1–2.6 have been generated by each site based on certain assumptions and therefore should be considered only as current best estimates. As treatment methods or waste forms are modified, current baseline projections for Hanford or INEEL HLW may be superceded. All HLW sites have essentially ceased reprocessing operations, and very little additional HLW will be generated. Major HLW activities will be (a) continued safe storage, (b) pretreatment (c) immobilization, and (d) interim storage pending shipment to a national repository. Thus, the inventory of liquid HLW in storage generally will decrease, and the inventory of solidified HLW in interim storage, pending shipment to a national repository, will increase. The current projected number of HLW canisters for Hanford, INEEL, and SRS is reported in Tables 2.7 and 2.21. For INEEL, the new projections reflect the state of Idaho, Department of the Navy, and DOE Settlement Agreements completed in 1995.

Summary flowsheets of the reference immobilization processes are given for Hanford (Fig. 2.5), INEEL (Fig. 2.6), SRS (Fig. 2.7), and WVDP (Fig. 2.8). Overall, these flowsheets are very similar; process differences reflect differences among sites in waste characteristics.

2.4.1 Hanford

Hanford HLW is stored in underground carbon-steel tanks. The HLW inventory (as of EOFY 1996) consists of 118,800 m^3 considered to be "solid" HLW (salt cake and sludge in single- and double-shell tanks) and 88,460 m^3 of "liquid" HLW (supernatant in single- and double-shell tanks and drainable interstitial liquid in single- and double-shell tanks), for a total of 207,300 m^3. This volume of Hanford solid waste represents a reduction of 24,900 m^3 from the EOCY 1995 value reported in the previous edition of this report (IDB Rev. 12).[7] While part of this reduction is the result of waste evaporation, the majority is an artifact of redefining the reported volume of single-shell tank salt cake to avoid the double accounting of waste interstitial volume.

A total of 2,217 capsules have been manufactured at Hanford, some of which have been leased off-site for beneficial purposes. Of the total 1,577 cesium and 640 strontium capsules, 249 cesium capsules and 35 strontium capsules have been dismantled. The inventory of capsules that have been dismantled is not expected to be returned to Hanford for interim storage and future processing. This leaves 1,328 cesium capsules and 605 strontium capsules to be processed (overpacked) and disposed of as HLW.

The HLW projections for Hanford are based on the assumptions that (1) fuel reprocessing is not resumed,

(2) double-shell tanks will continue to receive limited D&D-generated waste, and (3) volume reduction of stored wastes through evaporation will continue.

2.4.2 INEEL

INEEL HLW at the Idaho Chemical Processing Plant (ICPP) is currently being stored as both acidic liquid and calcined solids (calcine). Underground, high-integrity, stainless-steel tanks contain about 6,700 m^3 of acidic liquid waste. [Of this waste, only 1,100 m^3 is actual HLW; the rest is sodium-bearing waste (SBW), which is either MLLW or MTRUW. While it has been managed in the same way as is HLW because of site practice, options described in the ICPP environmental impact statement (EIS) would allow for other management practices.] Underground stainless-steel bins currently store about 3,800 m^3 of calcine, an interim solid waste form. More than 90% of the total radioactivity is in the calcine.

For INEEL, the HLW projections at ICPP include streams associated with the intermediate calcining of liquid waste, followed by separation of HLW and LLW fractions in the remaining liquid waste and redissolved calcine. No new HLW from reprocessing activities was produced after FY 1992; SNF reprocessing facilities are being placed into cold standby pending D&D. Liquid SBW continues to be generated by fuel storage, waste treatment, and D&D activities. The current reference waste form at the ICPP is a glass. According to the October 17, 1995, Settlement Agreement, the ICPP is to calcine all of the liquid waste currently stored in the tanks by December 31, 2012. All of the HLW must be treated to be converted to the final waste form and be "road ready" by December 31, 2035. It is assumed that radioactive operations and canister production will start in 2020 and continue through 2035 (see Fig. 2.6). The projections reported in Tables 2.1–2.7 reflect this assumption.

In addition to the current INEEL HLW at ICPP described above, Argonne National Laboratory (ANL) has developed an electrometallurgical treatment method for SNFs that are not amendable for direct disposal in a geological repository. This treatment method, which generates small quantities of HLWs, is being demonstrated at the ANL–W facility for SNF from the Experimental Breeder Reactor-II. The reactor fuel contains sodium, a reactive metal, as a thermal bond. The demonstration, which runs through June 1999, is being performed under an environmental assessment (ref. 8). If the demonstration is successful, an environmental impact statement (EIS) will be prepared for applying the technology to other problem fuels. The present demonstration and future operations make use of existing equipment and hot cells, the ANL–W Fuel Conditioning Facility, and the Hot Fuel Examination Facility. The electrometallurgical process is a nonaqueous method using molten salts and liquid metals. It results in two solid HLW products, a zeolite-based ceramic, and a stainless-steel-based metallic waste form. Projected characteristics of the HLW from the treatment of sodium-bonded SNF are provided in Table 2.21. Major radionuclides comprising final HLW forms from the treatment of sodium-bonded SNF are listed in Table 2.22. These values have not been incorporated in Tables 2.4–2.7.

2.4.3 SRS

SRS HLW is stored as alkaline liquid, sludge, salt cake, and precipitate. The current untreated HLW inventory of about 126,500 m^3 is stored in underground, single- and double-shelled carbon-steel tanks. Although reprocessing operations are being phased out, the HLW tank farms are continuing to receive HLW from the canyons as part of cleanout operations and stabilization of damaged fuel elements. Pretreatment of silicate and supernatant portions of HLW is performed in the In-Tank Precipitation Facility, while pretreatment (washing) of the sludge is performed by extended sludge processing. Characterization data for SRS HLW are based on sampling and process knowledge. Allowable facility design variability of feed composition is limited; therefore, the data reported in Tables 2.1–2.6 assume a uniform feed rate and minor changes in composition.

2.4.4 WVDP

Reprocessing at the West Valley NFS plant was terminated in 1972, after which no additional HLW has been generated. HLW at WVDP is stored in two underground tanks. The current HLW inventory of 2,000 m^3 consists of liquid alkaline waste and solid waste (composed of both alkaline sludge and inorganic zeolite ion-exchange material contaminated with ^{90}Sr and ^{137}Cs). The cesium-loaded zeolite was transferred and blended with the sludge and alkaline waste in 1995. A small amount of acidic waste remaining from reprocessing of a thorium fuel was also blended with the alkaline waste in 1995. Immobilization of readily retrievable HLW is expected to be complete in FY 1998, with immobilization of tank heels and other residues expected to be completed by 2002.

2.5 SOLIDIFICATION FOR PERMANENT DISPOSAL

HLW will be processed and immobilized to a form acceptable for permanent disposal in a geologic repository.[9–13] Borosilicate glass has been selected as the reference waste form for all sites.[14] Projections are based on current funding guidance provided to the sites by DOE.

2.5.1 Hanford

The current technical baseline for Hanford is to retrieve and process all (≥99 vol %) of the tank wastes using a two-phase approach which will depend on private contractors to design, construct, operate, and finance most of the required processing capability. The demonstration phase (Phase I) facilities for supernatant (liquid) pretreatment and LLW and some HLW immobilization are scheduled to begin operation in June 2002 and may process waste through 2011. HLW sludges will be pretreated in-tank using water washing and caustic leaching as appropriate. Up to 13 vol % of the supernatant and 6 vol % of the sludges will be processed during Phase I. Full-scale production facilities, including out-of-tank sludge pretreatment, are scheduled to begin operating in 2012. These facilities will be sized to complete immobilization of LLW by 2024 and HLW by 2028 in order to meet current triparty agreement milestones.

The pretreatment processes separate the majority of the radioactivity contained in the tank waste into a high-activity stream, which is treated by vitrification and disposed of as HLW, and a low-activity stream, which the NRC has determined can be managed as LLW. The low-activity waste will also be vitrified but disposed of as LLW. The current technical baseline uses settle/decant to separate solids from the liquids, primarily ion exchange to reduce the radioactivity in the supernatants, and caustic leaching to reduce the volume of HLW sludges requiring vitrification. The projected radioactivity and thermal power of the LLW final form, shown in Table 2.11, were derived in support of a performance assessment for LLW disposal at Hanford, which, in turn, provides the basis for classification of the low-activity waste fraction from Hanford site tanks. As such, these values should be considered as bounding. As waste pretreatment processing plans become better defined, these values may be adjusted downward.

An interim storage facility will be built at Hanford with sufficient capacity to store the entire HLW volume of glass produced by the HLW vitrification facility. Storage will continue until the HLW canisters are shipped to a geologic repository. It is assumed for planning purposes that shipment to the repository will commence no sooner than 2035. Thus values for glass volume, curies, watts and number of canisters given in Tables 2.4 through 2.7, respectively, represent the total accumulation of Hanford's HLW canisters.

2.5.2 INEEL

Currently, an EIS is under development to evaluate the HLW processing options for the ICPP at INEEL. The EIS will be issued in 1999 and will result in a Record of Decision made for the preferred option.

The ICPP baseline[15] assumed the New Waste Calcining Facility will operate through 2012 and complete calcining the liquid SBW inventory as required by the Settlement Agreement. A new separations-vitrification facility is planned to be on line by 2020. Newly generated liquid waste and calcine will be processed to separate the high-activity radionuclides from the low-activity waste. In addition, the land disposal restriction (LDR) treatments for the RCRA constituents in the waste will then be made as required. The high-activity waste will be vitrified in a new facility and stored until final disposition after 2035. The separated low-activity waste will be grouted and disposed. All HLW is projected to be processed by December 31, 2035, to meet the Settlement Agreement.

As described in Sect. 2.4.2, treatment of problem SNFs using the electrometallurgical technique at ANL–W is projected to run from 2000–2011 and will result in two HLW forms: a zeolite-based ceramic and a stainless-steel-based metallic waste form (see Table 2.21). Most of the fission products and transuranics, which form chlorides during treatment operations, are stabilized in zeolite, which is then combined with glass frit and processed into a ceramic using a hot isostatic press. The metallic waste form includes noble metal fission products and cladding material after dissolution of the fuel matrix. It is converted into a solid ingot by melting. Both waste forms will be produced using irradiated materials as part of a demonstration of a technology that offers promise in preparing materials for permanent disposal in a geological repository.

2.5.3 SRS

The plan to process SRS HLW into glass is detailed in *High Level Waste System Plan Revision 7(U)*,[16] which was transmitted to DOE November 11, 1996. Briefly, Rev. 7 depicts the completion of the immobilization of the current inventory of HLW in FY 2018.

For SRS, canyon cleanout operations are scheduled to be completed by FY 2002. Additional HLW from canyon cleanout activities until then will represent a maximum increase of about 14.5% of current inventory. Pretreatment (sludge-washing) of liquid HLW has been started, and the DWPF began producing canisters of solidified HLW in FY 1996. The HLW glass waste forms will be stored at SRS until a national repository is ready to accept them (see Fig. 2.7).

2.5.4 WVDP

Pretreatment at the WVDP is complete. In May 1988, the pretreatment of liquid HLW was initiated. The alkaline liquid HLW 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 that is operated in a batch mode is used to remove cesium from the alkaline liquid waste (see 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 solution. Both sludge-wash processing cycles were completed in 1994. The wash solutions are also treated in the STS before they are incorporated in cement. The washed sludge, the acidic waste, and the loaded zeolite will be combined and incorporated into a glass. The primary vitrification campaign began in July 1996 and will be completed by FY 1998. Tank heels and residual material will then continue to be vitrified through mid-FY 2001. The glass will either be stored on-site until it is transferred to a federal repository or transferred off-site to facilitate accelerated site cleanup activity.

2.5.5 Low-Activity Waste from HLW Immobilization

The HLW immobilization processes described at each of the sites also generate low-activity wastes (LAWs), which contain low concentrations of radioactivity. Table 2.20 gives the historical and projected annual volumes of LAW generated from final HLW form production at each site.

2.6 REFERENCES

1. DOE site HLW data submittal attachments, submitted to the IDB Program during July–October 1997. The following HLW submittals were received and reviewed by the IDB Program before analysis and integration. Preceding each submittal is the site (in parentheses) to which it refers.

   a. (Hanford) William J. Taylor, DOE Richland Operations Office, Richland, Washington, correspondence to Kenneth J. Picha, Jr., High-Level Waste Program Manager, DOE-HQ, copy to Steve Loghry, IDB Program, ORNL, Oak Ridge, Tennessee, "High-Level Waste (HLW) Information Request for the 1997 Integrated Data Base Report," 97-WDD-115, dated July 11, 1997.

   b. (INEEL) Clark B. Millet, Lockheed Martin Idaho Technologies Company, Idaho Falls, Idaho, correspondence to Steve Loghry, IDB Program, ORNL, Oak Ridge, Tennessee, "IDB Data Spreadsheet," dated Sept. 2, 1997.

   c. (SRS) J. R. Hester, Westinghouse Savannah River Company, Aiken, South Carolina, correspondence to Steve Loghry, IDB Program, ORNL, Oak Ridge, Tennessee, "DOE Integrated Database," dated Sept. 2, 1997.

   d. (WVDP) J. J. Hollinden, West Valley Nuclear Services Company, Inc., West Valley, New York, correspondence to Steve Loghry, IDB Program, ORNL, Oak Ridge, Tennessee, "Submittal of High-Level Waste Information for the 1997 Integrated Data Base Report," WZ:97:0052, dated July 23, 1997.

2. U.S. Congress, Resource Conservation and Recovery Act of 1976, Pub. L. 94–580, 1976, as amended.

3. U.S. Congress, Atomic Energy Act of 1954, Pub. L. 83–703, Aug. 15, 1994.

4. U.S. Congress, The Federal Facility Compliance Act of 1992, Pub. L. 102–386, Oct. 6, 1992.

5. 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).

6. State of Idaho, "Settlement Agreement," U.S. District Court of Idaho, Civil No. 91-0054-S-EJL (Oct. 16, 1995).

7. U.S. Department of Energy, *Integrated Data Base Report—1995: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, DOE/RW-0006, Rev. 12, Oak Ridge National Laboratory, Oak Ridge, Tennessee (December 1996).

8. U.S. Department of Energy, *Environmental Assessment Electrometallurgical Treatment Research and Demonstration Project in the Fuel Conditioning Facility at Argonne National Laboratory–West*, DOE/EIA-1148 (May 1996).

9. 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).

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

11. 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.

12. 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).

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

14. 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).

15. U.S. Department of Energy, *The INEEL Environmental Management Accelerated Cleanup: Focus on 2006*, PLN-177 (draft), Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho (June 1997).

16. U.S. Department of Energy, *High-Level Waste System Plan Revision 7(U)*, HLW-OVP-96-0083, Savannah River Site, Aiken, South Carolina (Nov. 11, 1996).

ORNL DWG 95-8248R2

Fig. 2.1. Locations and total volumes of HLW through FY 1996.

ORNL DWG 95-9223R2

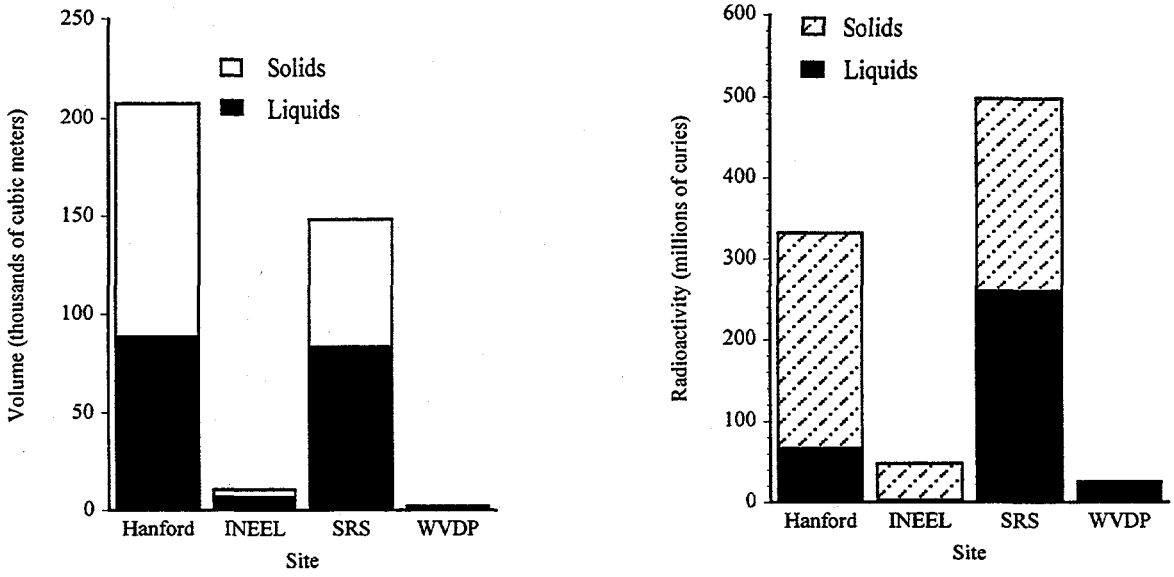


Fig. 2.2. Total volume and radioactivity of solid and liquid HLW through FY 1996.

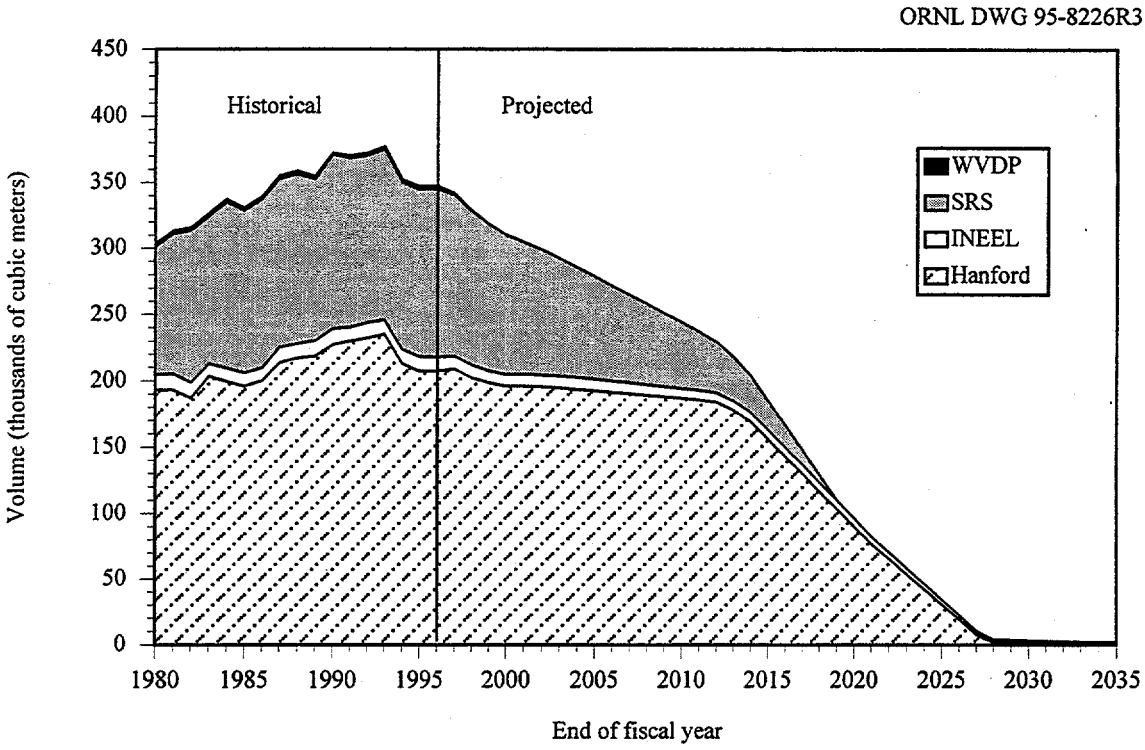


Fig. 2.3. Historical and projected cumulative volumes of untreated HLW in storage.

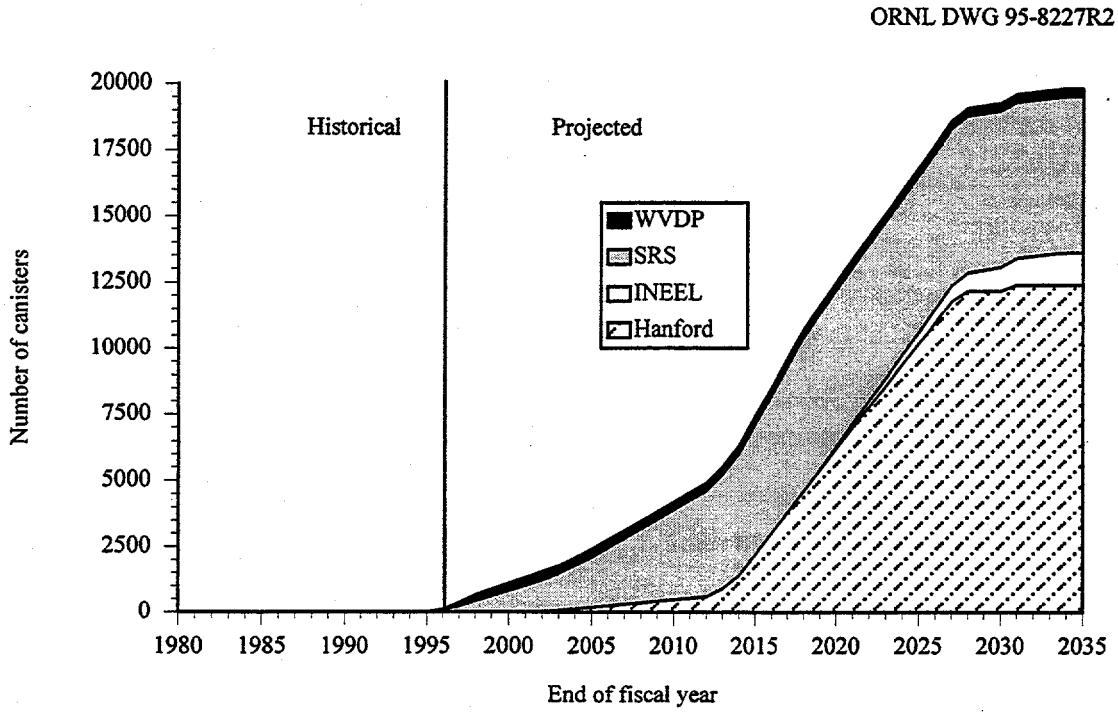


Fig. 2.4. Historical and projected cumulative number of HLW canisters.

ORNL DWG 96-7942R

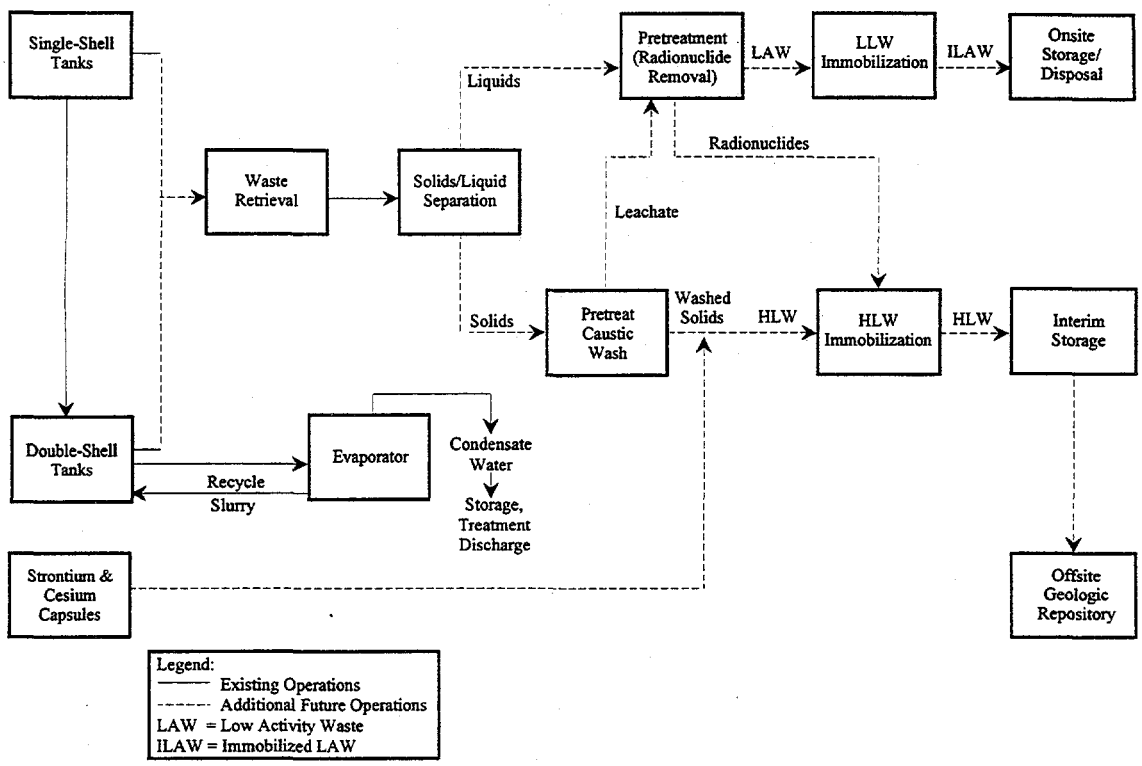


Fig. 2.5. Treatment methods for tank waste and capsules at Hanford.

ORNL DWG 96-7943R

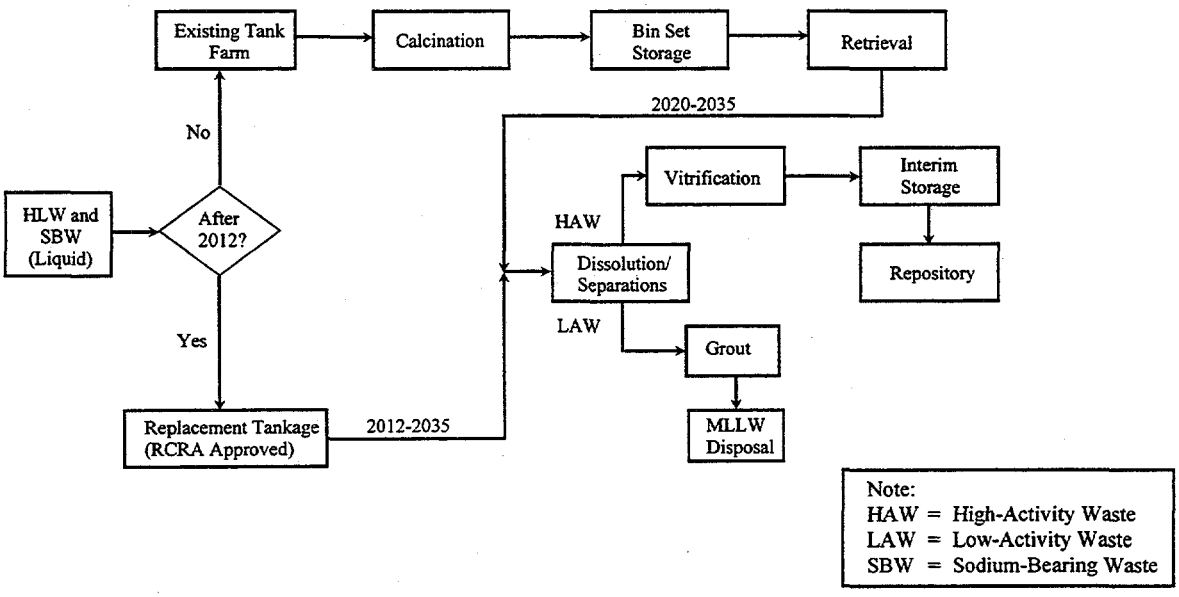
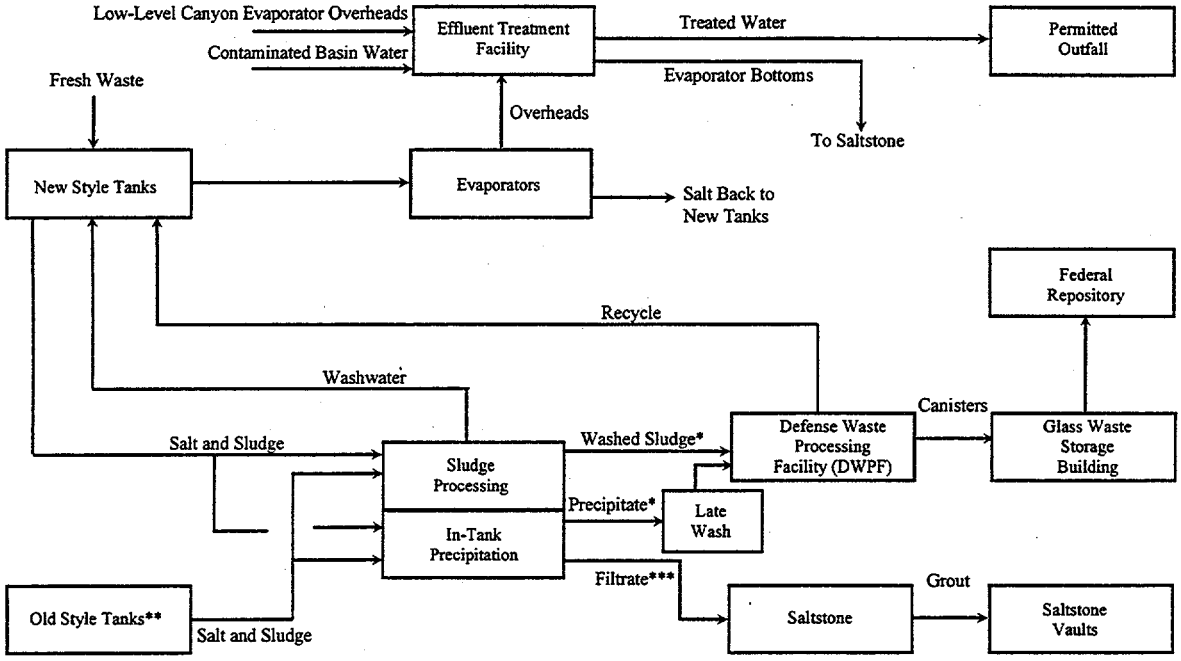


Fig. 2.6. Treatment methods for HLW in tanks and bins at ICPP.

ORNL DWG 96-7145R



*High-activity waste stream
**Do not meet current DOE and regulatory criteria for secondary containment.
***Low-activity waste stream.

Fig. 2.7. Treatment methods for HLW in tanks and canisters at SRS.

ORNL DWG 91A-332R3

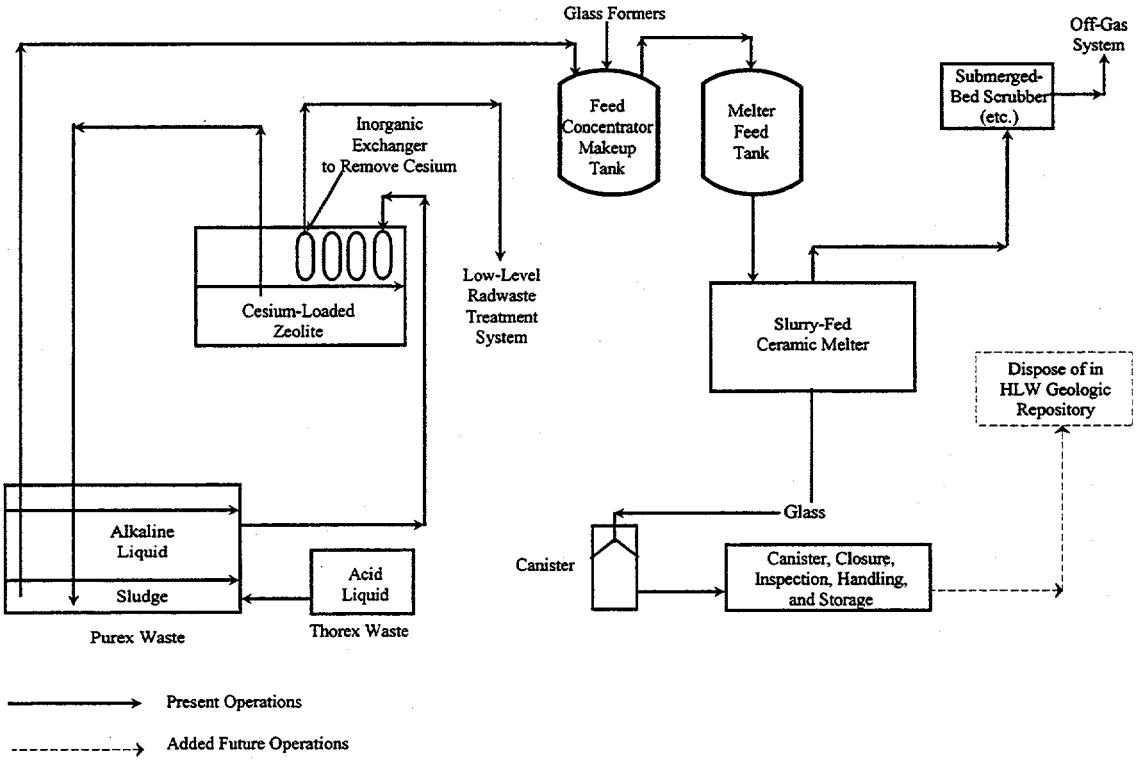


Fig 2.8. Treatment methods for HLW in tanks and canisters at WVDP.

Table 2.1. Historical and projected cumulative volume (10^3 m^3) of HLW stored in tanks, bins, and capsules, by site[a,b]

End of year[c]	Hanford	INEEL	SRS	WVDP	Total
1990	227.4	12.0	131.7	1.2	372.3
1991	230.6	10.4	127.9	1.7	370.7
1992	231.1	11.2	126.9	1.6	370.7
1993	233.6	10.5	129.3	2.0	375.4
1994	215.3	11.0	126.3	2.2	354.8
1995	209.6	11.2	126.5	2.2	349.5
1996	207.3	10.5	127.5	2.0	347.3
1997	208.9	9.8	121.9	1.1	341.7
1998	202.1	9.7	116.4	0.5	328.7
1999	198.7	8.8	110.8	0.4	318.7
2000	196.0	8.8	105.3	0.2	310.2
2001	196.1	8.9	99.8		304.7
2002	195.5	8.9	94.2		298.7
2003	194.7	8.9	88.7		292.2
2004	193.6	8.9	83.1		285.6
2005	192.5	8.8	77.6		278.9
2006	191.4	8.6	72.0		272.1
2007	190.3	8.3	66.5		265.2
2008	189.2	8.1	61.0		258.3
2009	188.1	7.6	55.4		251.0
2010	187.0	7.4	49.9		244.2
2011	185.9	7.1	44.3		237.3
2012	184.0	7.1	38.8		229.9
2013	178.0	7.1	33.3		218.3
2014	169.2	7.1	27.7		204.0
2015	156.0	7.1	22.2		185.3
2016	142.9	7.1	16.6		166.6
2017	129.7	7.1	11.1		147.9
2018	116.5	7.1	5.5		129.1
2019	103.3	6.7			110.0
2020	90.2	6.2			96.4
2021	77.0	5.7			82.7
2022	65.5	5.2			70.7
2023	53.9	4.7			58.6
2024	42.4	4.2			46.6
2025	30.8	3.7			34.5
2026	19.3	3.2			22.5
2027	7.8	2.8			10.6
2028	2.0	2.3			4.3
2029	2.0	1.8			3.8
2030	2.0	1.4			3.4
2031	2.0[d]	1.0			3.0
2032	2.0[d]	0.6			2.6
2033	2.0[d]	0.3			2.3
2034	2.0[d]	0.0			2.0
2035	2.0[d]	0.0			2.0

[a]Historical inventories for HLW volume are taken from the previous edition of this report [i.e., DOE/RW-0006, Rev. 12 (December 1996)]. The inventories for 1996 and the projections through 2035 are taken from ref. 1.

[b]Numbers shown as 0.0 are less than 50 m^3. Values of 0.0 or blank do not imply tank cleanout will be 100%.

[c]Data for 1990 through 1995 are on EOCY basis; data for 1996 through 2035 are on an EOFY basis.

[d]These volumes (2,000 m^3) represent the residual amount (<1.0%) of HLW which will remain in tanks until 2035 or later, as per agreement among DOE, the Washington State Department of Ecology, and the EPA (see ref. 5).

Table 2.2. Historical and projected cumulative decayed radioactivity (10^6 Ci) of HLW stored in tanks, bins, and capsules, by site[a,b]

End of year[c]	Hanford	INEEL	SRS	WVDP	Total
1990	399.3	63.2	561.6	26.7	1,050.8
1991	384.2	59.4	537.6	26.2	1,007.4
1992	372.1	50.8	632.4	25.9	1,081.2
1993	361.4	52.5	606.0	25.3	1,045.3
1994	348.0	51.6	534.5	24.7	958.8
1995	339.9	49.3	502.2	24.1	915.4
1996	332.1	48.4	492.6	21.7	894.8
1997	324.4	47.6	466.1	9.7	847.8
1998	316.9	46.4	448.2	4.2	815.7
1999	309.6	45.4	422.1	2.9	779.9
2000	302.4	44.3	396.9	1.4	745.0
2001	295.4	43.2	372.7		711.4
2002	288.2	42.2	349.4		679.8
2003	280.8	41.3	327.0		649.1
2004	273.5	40.3	301.9		615.6
2005	266.3	39.3	277.7		583.3
2006	259.3	38.4	251.1		548.8
2007	252.5	37.5	225.4		515.4
2008	245.8	36.7	200.8		483.4
2009	239.4	35.9	177.2		452.5
2010	233.1	35.1	154.5		422.7
2011	226.9	34.2	132.7		393.9
2012	220.4	33.4	111.8		365.6
2013	187.4	32.7	91.8		311.9
2014	153.9	31.9	72.5		258.4
2015	119.2	31.2	54.0		204.5
2016	86.1	30.5	36.3		152.9
2017	76.2	29.8	19.3		125.3
2018	66.8	29.1	3.0		98.9
2019	57.7	28.2			86.0
2020	49.1	22.9			72.0
2021	40.8	19.2			60.0
2022	33.7	15.5			49.3
2023	27.0	12.4			39.4
2024	20.5	9.4			29.9
2025	14.4	6.5			20.8
2026	8.5	4.6			13.0
2027	2.8	2.8			5.6
2028	0.1	1.5			1.6
2029	0.1	1.1			1.2
2030	0.1	0.6			0.7
2031	0.1	0.2			0.3
2032	0.1	0.2			0.3
2033	0.1	0.1			0.2
2034	0.1	0.0			0.1
2035	0.1	0.0			0.1

[a]Historical inventories for HLW radioactivity are taken from the previous edition of this report [i.e., DOE/RW-0006, Rev. 12 (December 1996)]. The inventories for 1995 and the projections through 2035 are taken from ref. 1.

[b]Numbers shown as 0.0 are less than 50,000 Ci. Values of 0.0 or blank do not imply tank cleanout will be 100%.

[c]Data for 1990 through 1995 are on an EOCY basis; data for 1996 through 2035 are on an EOFY basis.

Table 2.3. Historical and projected cumulative decayed thermal power (10^3 W) of HLW stored in tanks, bins, and capsules, by site[a,b]

End of year[c]	Hanford	INEEL	SRS	WVDP	Total
1990	1,150.3	184.4	1,566.7	76.9	2,978.3
1991	1,106.5	172.0	1,509.3	75.9	2,863.7
1992	1,073.1	147.3	1,724.3	79.1	3,023.8
1993	1,043.1	153.7	1,615.3	74.1	2,886.3
1994	999.8	150.8	1,497.3	78.1	2,726.0
1995	976.7	142.8	1,406.0	69.7	2,595.2
1996	954.1	143.6	1,387.7	64.8	2,550.2
1997	932.1	141.3	1,318.0	29.3	2,420.6
1998	910.5	137.6	1,275.5	12.7	2,336.3
1999	889.5	134.5	1,207.7	8.9	2,240.6
2000	868.9	131.0	1,141.3	4.3	2,145.6
2001	848.9	128.8	1,076.4		2,054.1
2002	828.0	125.8	1,013.0		1,966.8
2003	806.9	122.7	951.4		1,880.9
2004	785.6	119.6	881.0		1,786.2
2005	764.9	117.5	812.8		1,695.2
2006	744.7	114.2	736.8		1,595.8
2007	725.0	112.2	663.4		1,500.6
2008	705.9	108.8	592.5		1,407.1
2009	687.3	106.4	524.0		1,317.7
2010	669.1	104.2	458.0		1,231.2
2011	651.4	101.7	394.3		1,147.4
2012	632.6	99.8	332.9		1,065.4
2013	541.5	97.6	273.8		912.9
2014	448.7	95.4	216.8		760.8
2015	351.7	93.2	161.9		606.7
2016	258.9	91.1	109.0		459.0
2017	229.5	89.0	58.1		376.6
2018	201.2	87.0	9.0		297.2
2019	174.1	84.5			258.6
2020	148.2	68.7			216.8
2021	123.3	57.4			180.8
2022	102.0	46.6			148.7
2023	81.6	37.2			118.8
2024	62.1	28.1			90.2
2025	43.4	19.5			63.0
2026	25.6	13.8			39.4
2027	8.5	8.5			17.0
2028	0.3	4.7			5.0
2029	0.3	3.3			3.5
2030	0.3	1.9			2.1
2031	0.3	0.8			1.0
2032	0.3	0.5			0.8
2033	0.3	0.2			0.5
2034	0.3	0.0			0.3
2035	0.3	0.0			0.3

[a]Historical inventories for HLW thermal power are taken from the previous edition of this report [i.e., DOE/RW-0006, Rev. 12 (December 1996)]. The inventories for 1995 and the projections through 2035 are taken from ref. 1.

[b]Numbers shown as 0.0 are less than 50 W. Values of 0.0 or blank do not imply tank cleanout will be 100%.

[c]Data for 1990 through 1995 are on an EOCY basis; data for 1996 through 2035 are on an EOFY basis.

Table 2.4. Historical and projected annual and cumulative volume (10^3 m^3) of HLW glass stored in canisters, by site[a,b]

End of FY	Hanford[c]		INEEL–ICPP[d]		SRS[e]		WVDP[f]		Total	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1996					0.040	0.040	0.019	0.019	0.059	0.059
1997					0.094	0.134	0.095	0.114	0.189	0.248
1998					0.125	0.259	0.071	0.185	0.196	0.444
1999					0.125	0.384	0.016	0.201	0.141	0.585
2000					0.125	0.509	0.020	0.221	0.145	0.730
2001					0.125	0.635	0.020	0.241	0.145	0.876
2002	0.023	0.023			0.125	0.760		0.241	0.148	1.024
2003	0.046	0.069			0.125	0.885		0.241	0.171	1.195
2004	0.069	0.138			0.156	1.041		0.241	0.225	1.420
2005	0.069	0.207			0.156	1.198		0.241	0.225	1.645
2006	0.069	0.275			0.188	1.386		0.241	0.257	1.902
2007	0.069	0.344			0.188	1.573		0.241	0.257	2.159
2008	0.069	0.413			0.188	1.761		0.241	0.257	2.415
2009	0.069	0.482			0.188	1.949		0.241	0.257	2.672
2010	0.069	0.551			0.188	2.137		0.241	0.257	2.929
2011	0.069	0.620			0.188	2.324		0.241	0.257	3.185
2012	0.069	0.689			0.188	2.512		0.241	0.257	3.442
2013	0.344	1.033			0.188	2.700		0.241	0.532	3.974
2014	0.574	1.607			0.188	2.888		0.241	0.762	4.735
2015	0.918	2.525			0.188	3.076		0.241	1.106	5.841
2016	0.918	3.443			0.188	3.263		0.241	1.106	6.947
2017	0.918	4.361			0.188	3.451		0.241	1.106	8.053
2018	0.918	5.279			0.188	3.639		0.241	1.106	9.158
2019	0.918	6.197	0.004	0.004	0.063	3.702		0.241	0.985	10.143
2020	0.918	7.115	0.054	0.058		3.702		0.241	0.972	11.115
2021	0.918	8.033	0.043	0.101		3.702		0.241	0.961	12.076
2022	0.918	8.951	0.043	0.143		3.702		0.241	0.961	13.037
2023	0.918	9.869	0.043	0.187		3.702		0.241	0.961	13.998
2024	0.918	10.787	0.044	0.230		3.702		0.241	0.962	14.960
2025	0.918	11.705	0.044	0.274		3.702		0.241	0.962	15.921
2026	0.918	12.623	0.049	0.323		3.702		0.241	0.967	16.889
2027	0.918	13.541	0.049	0.373		3.702		0.241	0.967	17.856
2028	0.459	14.000	0.055	0.427		3.702		0.241	0.514	18.370
2029		14.000	0.062	0.490		3.702		0.241	0.062	18.432
2030		14.000	0.062	0.552		3.702		0.241	0.062	18.494

Table 2.4 (continued)

End of FY	Hanford[c]		INEEL–ICPP[d]		SRS[e]		WVDP[f]		Total	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
2031			0.059	0.611					0.059	0.611
2032			0.047	0.657					0.047	0.657
2033			0.046	0.704					0.046	0.704
2034			0.040	0.743					0.040	0.743
2035				0.743						0.743

[a]Taken from data given in ref. 1. Glass may be in storage at the site, in transit to a repository, or in a repository.

[b]See Table 2.7 for the projected number of canisters.

[c]Hanford's reference canister has a diameter of 61 cm and is 450 cm long (about 2 ft in diam by about 15 ft in length). The nominal glass volume is expected to be 1.1 m^3 with a minimum waste oxide loading of 25 vol % (excluding sodium and silicon). Hanford HLW glass volume projections are based on cesium and strontium from capsules being blended with tank wastes during the period 2013 through 2016, assuming that the capsule materials will be declared waste and treated as HLW.

[d]INEEL's canister projections assume the use of a canister containing 0.625 m^3 of glass. For ANL–W projected waste volumes, see Table 2.21.

[e]At SRS, the DWPF canisters are 0.6 m in diam by 3 m in length (about 2 ft in diam by about 10 ft in length). Each canister is assumed to contain 0.625 m^3 of glass [i.e., 85% of the usable capacity (0.735 m^3)] made with HLW from the reprocessing of SNF at SRS. The glass incorporates 36 wt % oxides from waste (28 wt % from SNF 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.

[f]For WVDP, it is assumed that 276 canisters 0.6 m in diam by 3 m in length (2 ft in diam by 10 ft in length) are filled with waste glass during 1996–1999 and that each canister contains 0.8 m^3 of glass at the filling temperature. Tank heels and residual materials will continue to be vitrified through mid-FY 2001.

Table 2.5. Historical and projected annual and cumulative decayed radioactivity (10^6 Ci) of HLW glass stored in canisters, by site[a,b]

End of FY	Hanford[c]		INEEL–ICPP[d]		SRS		WVDP		Total	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1996					5.35	5.35	1.90	1.900	7.25	7.25
1997					12.53	17.76	11.50	13.400	24.03	31.16
1998					16.33	33.68	5.30	18.400	21.63	52.08
1999					15.96	48.88	1.20	19.100	17.16	67.98
2000					15.61	63.38	1.40	20.100	17.01	83.48
2001					15.26	77.22	1.40	21.100	16.66	98.32
2002	0.24	0.24			14.93	90.42		20.600	15.17	111.26
2003	0.48	0.72			14.60	103.00		20.100	15.08	123.81
2004	0.70	1.40			17.85	118.56		19.600	18.55	139.56
2005	0.68	2.05			17.47	133.40		19.200	18.15	154.64
2006	0.67	2.67			20.51	150.95		18.700	21.17	172.32
2007	0.65	3.26			20.07	167.68		18.300	20.72	189.24
2008	0.64	3.82			19.64	183.63		17.900	20.27	205.35
2009	0.62	4.35			19.22	198.81		17.500	19.84	220.66
2010	0.61	4.86			18.81	213.26		17.100	19.41	235.22
2011	0.59	5.34			18.41	227.00		16.700	19.00	249.04
2012	0.58	5.80			18.02	240.06		16.300	18.60	262.16
2013	26.84	32.50			17.64	252.47		15.900	44.48	300.87
2014	28.06	59.81			17.27	264.26		15.500	45.33	339.57
2015	30.12	88.55			16.91	275.43		15.200	47.02	379.18
2016	29.42	115.93			16.56	286.03		14.800	45.98	416.76
2017	6.87	120.13			16.21	296.06		14.500	23.09	430.69
2018	6.71	124.08			15.88	305.56		14.200	22.59	443.83
2019	6.56	127.77	0.19	0.19	5.24	304.22		13.800	11.81	445.98
2020	6.41	131.23	4.65	4.83		297.69		13.500	11.05	447.25
2021	6.26	134.47	3.22	7.97		291.31		13.200	9.48	446.95
2022	6.12	137.48	3.14	11.00		285.08		12.900	9.26	446.46
2023	5.97	140.28	2.79	13.50		279.00		12.600	8.76	445.38
2024	5.84	142.88	2.73	15.90		273.07		12.300	8.57	444.15
2025	5.70	145.28	2.67	18.30		267.27		12.000	8.37	442.85
2026	5.57	147.50	1.83	19.60		261.60		11.700	7.40	440.40
2027	5.44	149.54	1.68	20.80		256.07		11.500	7.12	437.91
2028	2.66	148.75	1.31	21.50		250.67		11.200	3.97	432.12
2029		145.32	0.45	21.50		245.39		11.000	0.45	423.21
2030		141.96	0.44	21.40		240.24		10.700	0.44	414.31

Table 2.5 (continued)

End of FY	Hanford[c]		INEEL–ICPP[d]		SRS		WVDP		Total	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
2031		e	0.39	21.30		e		e		e
2032		e	0.07	20.80		e		e		e
2033		e	0.07	20.40		e		e		e
2034		e	0.07	20.00		e		e		e
2035		e	0.07	19.60		e		e		e

[a]Taken from data given in ref. 1.

[b]Radioactive decay is taken into account by each site by means of radioisotope generation and depletion codes.

[c]The significant increase in annual radioactivity for the years 2013–2016 reflects the accelerated processing schedule for the strontium and cesium capsules at Hanford (see Sect. 2.5.1). Hanford HLW glass radioactivity projections are based on ^{90}Sr and ^{137}Cs from capsules being blended with tank wastes during the period 2013 through 2016, assuming that the capsule materials will be declared waste and treated as HLW.

[d]For ANL–W radioactivity at FY 2000, see Table 2.22.

[e]Not available.

Table 2.6. Historical and projected annual and cumulative decayed thermal power (10^3 W) of HLW glass stored in canisters, by site[a,b]

End of FY	Hanford[c]		INEEL–ICPP[d]		SRS		WVDP		Total	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1996					15.02	15.02	5.70	5.70	20.72	20.72
1997					35.44	50.21	34.00	39.50	69.44	89.71
1998					46.47	95.85	15.90	54.60	62.37	150.45
1999					45.68	139.87	3.50	56.90	49.18	196.77
2000					44.89	182.27	4.30	59.90	49.19	242.17
2001					44.08	223.02	4.20	62.80	48.28	285.82
2002	0.74	0.74			43.28	262.14		61.40	44.02	324.28
2003	1.44	2.16			42.48	299.66		60.00	43.92	361.82
2004	2.11	4.22			52.11	346.02		58.70	54.22	408.94
2005	2.06	6.18			51.13	390.45		57.30	53.19	453.94
2006	2.01	8.05			60.19	443.04		56.10	62.20	507.20
2007	1.97	9.84			59.04	493.42		54.80	61.01	558.06
2008	1.92	11.53			57.92	541.67		53.60	59.84	606.80
2009	1.88	13.14			56.82	587.85		52.40	58.69	653.39
2010	1.83	14.67			55.74	632.03		51.20	57.57	697.91
2011	1.79	16.13			54.68	674.30		50.00	56.47	740.42
2012	1.75	17.50			53.64	714.71		48.90	55.39	781.11
2013	73.51	90.61			52.63	753.34		47.80	126.14	891.75
2014	77.38	165.90			51.64	790.25		46.80	129.02	1,002.95
2015	83.76	245.83			50.67	825.51		45.70	134.43	1,117.04
2016	81.83	321.99			49.73	859.17		44.70	131.56	1,225.86
2017	20.77	335.33			48.81	891.32		43.70	69.58	1,270.34
2018	20.29	347.88			47.91	921.99		42.70	68.21	1,312.57
2019	19.83	359.68	0.56	0.56	15.84	920.05		41.80	36.22	1,322.08
2020	19.37	370.76	13.95	14.50		902.37		40.80	33.31	1,328.43
2021	18.92	381.14	9.27	23.90		885.09		39.90	28.19	1,330.02
2022	18.49	390.84	9.05	32.80		868.20		39.00	27.54	1,330.84
2023	18.06	399.90	8.05	40.40		851.70		38.20	26.11	1,330.20
2024	17.65	408.33	7.89	47.70		835.58		37.30	25.54	1,328.91
2025	17.24	416.17	7.72	54.70		819.82		36.50	24.96	1,327.19
2026	16.85	423.43	5.28	58.70		804.43		35.70	22.13	1,322.26
2027	16.46	430.14	4.85	62.50		789.38		34.90	21.31	1,316.93
2028	8.04	428.29	3.77	64.60		774.69		34.10	11.81	1,301.67
2029		418.43	1.29	64.50		760.33		33.40	1.29	1,276.66
2030		408.81	1.26	64.40		746.29		32.70	1.26	1,252.20

Table 2.6 (continued)

End of FY	Hanford[c]		INEEL–ICPP[d]		SRS		WVDP		Total	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
2031		e	1.13	64.00		e		e		e
2032		e	0.02	54.30		e		e		e
2033		e	0.21	61.70		e		e		e
2034		e	0.20	60.50		e		e		e
2035		e	0.20	59.10		e		e		e

[a]Taken from data given in ref. 1.

[b]Thermal power is taken into account by each site by means of radioisotope generation and depletion codes.

[c]The significant increase in annual thermal power for the years 2013–2016 reflects the accelerated processing schedule for the strontium and cesium capsules at Hanford (see Sect. 2.5.1). Hanford HLW thermal power projections are based on ^{90}Sr and ^{137}Cs from capsules being blended with tank wastes during the period 2013 through 2016, assuming that the capsule materials will be declared waste and treated as HLW.

[d]ANL–W thermal power values are not included here. See Table 2.22 for radioactivity values.

[e]Not available.

Table 2.7. Historical and projected number of HLW canisters, by site[a]

End of FY	Hanford[b]		INEEL–ICPP[c]		SRS[d]		WVDP[e]		Total	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1996					64	64	26	26	90	90
1997					150	214	118	144	268	358
1998					200	414	88	232	288	646
1999					200	614	20	252	220	866
2000					200	814	25	277	225	1,091
2001					200	1,014	25	302	225	1,316
2002	20	20			200	1,214		302	220	1,536
2003	40	60			200	1,414		302	240	1,776
2004	60	120			250	1,664		302	310	2,086
2005	60	180			250	1,914		302	310	2,396
2006	60	240			300	2,214		302	360	2,756
2007	60	300			300	2,514		302	360	3,116
2008	60	360			300	2,814		302	360	3,476
2009	60	420			300	3,114		302	360	3,836
2010	60	480			300	3,414		302	360	4,196
2011	60	540			300	3,714		302	360	4,556
2012	60	600			300	4,014		302	360	4,916
2013	300	900			300	4,314		302	600	5,516
2014	500	1,400			300	4,614		302	800	6,316
2015	800	2,200			300	4,914		302	1100	7,416
2016	800	3,000			300	5,214		302	1100	8,516
2017	800	3,800			300	5,514		302	1100	9,616
2018	800	4,600			300	5,814		302	1100	10,716
2019	800	5,400	6	6	101	5,915		302	907	11,623
2020	800	6,200	87	93		5,915		302	887	12,510
2021	800	7,000	68	161		5,915		302	868	13,378
2022	800	7,800	68	229		5,915		302	868	14,246
2023	800	8,600	69	298		5,915		302	869	15,115
2024	800	9,400	70	368		5,915		302	870	15,985
2025	800	10,200	70	438		5,915		302	870	16,855
2026	800	11,000	79	517		5,915		302	879	17,734
2027	800	11,800	79	596		5,915		302	879	18,613
2028	400	12,200	88	684		5,915		302	488	19,101
2029		12,200	99	783		5,915		302	100	19,200
2030		12,200	100	883		5,915		302	100	19,300

Table 2.7 (continued)

End of FY	Hanford[b]		INEEL–ICPP[c]		SRS[d]		WVDP[e]		Total	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
2031		12,200	94	977		5,944		302	94	19,423
2032		12,200	75	1,052		5,944		302	75	19,498
2033		12,200	74	1,126		5,944		302	74	19,572
2034		12,200	63	1,189		5,944		302	63	19,635
2035		12,200		1,189		5,944		302		19,635

[a]Taken from ref. 1. The projected waste volume, radioactivity, and thermal power values (Tables 2.4–2.6) are consistent with the number of canisters reported. Canister projections may not be calculated by the site in whole numbers, as presented here. Due to round-off, numbers may not add exactly. The projections reported for Hanford and INEEL reflect major changes in the HLW solidification schedule. These changes are mainly caused by current DOE funding guidance.

[b]Hanford's reference canister has a diameter of 61 cm and is 450 cm long (about 2 ft in diam by about 15 ft in length). The nominal glass volume is expected to be 1.1 m^3 with a minimum waste oxide loading of 25 vol % (excluding sodium and silicon).

[c]INEEL canister projections assume the use of a canister containing 0.625 m^3 of glass. For projected ANL–W canisters, see Table 2.21.

[d]Canisters are 0.6 m in diam by 3 m in length (about 2 ft in diam by about 10 ft in length). Each canister is assumed to contain 0.625 m^3 of glass made with HLW from the reprocessing of SNF at SRS. The glass incorporates 36 wt % oxides from waste (28 wt % from SNF and 8 wt % from processing chemicals) and 64 wt % oxides from nonradioactive glass frit.

[e]Canisters are 0.6 m in diam by 3 m in length (about 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 2.8. Current volume (10^3 m^3) of HLW in storage by site through FY 1996[a]

Site	Tank waste		Capsules		Canister material	Total
	Liquid[b]	Solid[c]	Sr	Cs		
Hanford	88.46	118.8	0.0011	0.0024		207.3
INEEL	6.74	3.80				10.5
SRS	83.3[d]	65.0			0.040	148.3
WVDP[e]	2.0				0.019	2.0
Total	180.5	187.6	0.0011	0.0024	0.059	368.1

[a]Taken from ref. 1.

[b]Liquid tank waste consists of free tank supernatant and drainable interstitial liquid.

[c]Solid tank waste consists of sludge, salt cake, zeolite, calcine, and precipitate. Hanford salt cake volume has been adjusted to exclude the pore volume occupied by drainable interstitial liquid, which is reported as part of the liquid waste volume.

[d]SRS liquid tank waste consists of free supernate and drainable interstitial liquid. The actual physical volume of all tank waste at SRS is 127,500 m^3, which is reported in Table 2.1.

[e]WVDP liquid waste includes sludge and zeolite.

Table 2.9. Current radioactivity (10^6 Ci) of HLW in storage by site through FY 1996[a]

Site	Tank waste		Capsules		Canister material	Total
	Liquid[b]	Solid[c]	Sr	Cs		
Hanford	66.9	122.4	43.9	98.9		332.1
INEEL	2.6	45.8				48.4
SRS	260.8	231.8			5.4	498.0
WVDP[d]	21.7				1.9	23.6
Total	352.0	400.0	43.9	98.9	7.3	902.1

[a]Taken from ref. 1.

[b]Liquid tank waste consists of free tank supernatant and drainable interstitial liquid.

[c]Solid tank waste consists of sludge, salt cake, zeolite, calcine, and precipitate. Hanford salt cake volume has been adjusted to exclude the pore volume occupied by drainable interstitial liquid, which is reported as part of the liquid waste volume.

[d]WVDP liquid waste includes sludge and zeolite.

Table 2.10. Current thermal power (10^3 W) of HLW in storage by site through FY 1996[a]

Site	Tank waste		Capsules		Canister material	Total
	Liquid[b]	Solid[c]	Sr	Cs		
Hanford	162.9	404.6	146.8	239.8		954.1
INEEL	7.6	136.0				143.6
SRS	550.6	837.1			15.0	1,402.7
WVDP[d]	64.8				5.7	70.5
Total	785.9	1,377.7	146.8	239.8	20.7	2,570.9

[a]Taken from ref. 1.

[b]Liquid tank waste consists of free tank supernatant and drainable interstitial liquid.

[c]Solid tank waste consists of sludge, salt cake, zeolite, calcine, and precipitate. Hanford salt cake volume has been adjusted to exclude the pore volume occupied by drainable interstitial liquid, which is reported as part of the liquid waste volume.

[d]WVDP liquid waste includes sludge and zeolite.

Table 2.11. Major radionuclides comprising HLW and associated wastes at Hanford[a]

Radionuclides	Radioactivity, Ci, by waste category				
	Interim forms[b]		Final forms[c]		
	Tank waste	Other (capsules)	HLW glass canisters	LLW form (glass)[d]	Cumulative emissions
^{3}H[e]					
^{14}C	4.573E+03		9.110E-02	4.420E+00	4.507E+03
^{90}Sr	5.812E+07	2.194E+07	2.543E+07	1.693E+06	
^{90}Y	5.812E+07	2.194E+07	2.543E+07	1.693E+06	
^{99}Tc	3.210E+04		2.247E+03	2.955E+04	
^{129}I	2.980E-01		5.959E-06	2.891E-04	2.948E-01
^{137}Cs	3.686E+07	5.078E+07	1.504E+07	2.532E+06	
^{137m}Ba	3.491E+07	4.809E+07	1.424E+07	2.398E+06	
^{151}Sm	1.050E+06		7.713E+05	4.875E+04	
^{238}Pu	1.404E+03		9.913E+02	9.823E+01	
^{239}Pu	2.635E+04		2.393E+04	2.371E+03	
^{240}Pu	6.691E+03		6.061E+03	6.005E+02	
^{241}Pu	8.878E+04		1.730E+04	1.714E+03	
^{242}Pu	2.802E-01		2.547E-01	2.523E-02	
^{241}Am	1.037E+05		9.358E+04	7.032E+03	
^{242}Am	6.218E+01		4.997E+01	3.724E+00	
Total	1.893E+08	1.427E+08	8.105E+07	8.405E+06	4.507E+03

[a]Data taken from ref. 1(a).

[b]As of Sept. 30, 1996.

[c]As of Sept. 30, 2028.

[d]Radionuclide distribution and decay power in LLW glass and emissions out of system are undefined, pending flowsheet development and regulatory decisions.

[e]Estimate of the EOFY 1996 inventory for ^{3}H is currently unavailable.

Table 2.12. Major radionuclides comprising HLW and associated wastes at INEEL–ICPP[a]

Radionuclides	Radioactivity, Ci, by waste category			
	Interim forms[b]		Final forms[c]	
	Liquid	Calcine	Glass	Grout
^{3}H	d	d	d	d
^{14}C	d	d	d	d
^{60}Co	d	d	d	d
^{63}Ni	d	d	d	d
^{90}Sr	6.09E+05	1.07E+07	4.52E+06	4.52E+02
^{90}Y	6.09E+05	1.07E+07	4.52E+06	4.52E+02
^{99}Tc	d	d	d	d
^{106}Ru	1.51E+02	9.34E+02	1.03E-09	1.03E-09
^{106}Rh	1.51E+02	9.34E+02	1.03E-09	1.03E-09
^{125}Sb	4.43E+02	5.00E+02	4.26E-02	4.26E-06
^{129}I	d	d	d	d
^{134}Cs	3.21E+03	2.71E+04	6.66E-02	6.66E-06
^{137}Cs	7.17E+05	1.23E+07	5.35E+06	5.35E+02
^{137m}Ba	6.80E+05	1.16E+07	5.07E+06	5.07E+02
^{144}Ce	6.52E+02	2.95E+03	3.49E-12	3.49E-16
^{144}Pr	6.52E+02	2.95E+03	3.49E-12	3.49E-16
^{147}Pm	d	4.73E+04	1.70E+00	1.70E-04
^{154}Eu	3.83E+03	4.40E+04	2.09E+03	2.09E-01
^{155}Eu	1.50E+03	2.44E+03	1.79E+01	1.79E+01
^{232}Th	d	d	d	d
^{233}U	d	2.06E-06	2.06E-06	2.06E-10
^{234}U	4.99E+00	5.55E+01	1.16E+02	1.16E-02
^{235}U	3.33E-01	3.80E-01	8.02E-01	8.02E-05
^{236}U	3.41E-01	9.01E-01	1.87E+00	1.87E-04
^{238}U	1.39E-01	2.15E-02	4.55E-02	4.55E-06
^{237}Np	4.30E+00	5.61E+00	1.43E+01	1.43E-03
^{238}Pu	7.06E+03	1.11E+05	9.04E+04	9.04E+00
^{239}Pu	5.20E+02	1.09E+03	8.33E+02	8.33E-02
^{240}Pu	3.71E+02	7.69E+02	1.71E+02	1.71E-02
^{241}Pu	4.44E+03	1.73E+05	2.65E+04	2.65E+00
^{242}Pu	1.22E-01	3.10E+00	3.10E+00	3.10E-04
^{241}Am	3.00E+03	1.54E+03	2.24E+03	2.24E-01
^{243}Am	d	1.43E+01	1.42E+01	1.42E-03
^{242}Cm	d	3.01E-01	1.57E-27	1.57E-31
^{244}Cm	d	6.16E+02	1.39E+02	1.39E-02
Total	2.64E+06	4.58E+07	1.96E+07	1.96E+03

[a]Data taken from ref. 1(b). See Table 2.22 for projected radionuclides in ANL–W HLW at FY 2000.

[b]As of Sept. 30, 1996.

[c]As of Sept. 30, 2035.

[d]Unknown.

Table 2.13. Major radionuclides comprising HLW and associated wastes at SRS[a]

Radionuclides	Radioactivity, Ci, by waste category			
	Interim form[b]	Final forms[b]		
	Tank waste	Canister material	Saltstone (LLW)	Outfall
^{3}H	9.62E+04	1.04E+03	4.02E-02	c
^{14}C	2.00E+01	2.16E-01	8.36E-06	c
^{90}Sr	1.06E+08	1.15E+06	4.42E+01	c
^{90}Y	1.06E+08	1.15E+06	4.42E+01	c
^{99}Tc	2.57E+04	2.78E+02	1.07E-02	c
^{129}I	4.16E+01	4.50E-01	1.74E-05	c
^{137}Cs	1.34E+08	1.45E+06	5.59E+01	c
^{137m}Ba	1.27E+08	1.37E+06	5.29E+01	c
^{238}Pu	1.73E+06	1.87E+04	7.21E-01	c
^{239}Pu	3.64E+04	3.94E+02	1.52E-02	c
^{240}Pu	1.66E+04	1.79E+02	6.92E-03	c
^{241}Pu	7.52E+05	8.14E+03	3.14E-01	c
^{242}Pu	2.84E+01	3.07E-01	1.19E-05	c
^{241}Am	9.61E+05	1.04E+04	4.01E-01	c
^{242m}Am	7.24E+01	7.83E-01	3.02E-05	c
^{232}Th	1.47E+00	1.59E-02	6.15E-07	c
^{233}U	1.08E+02	1.17E+00	4.53E-05	c
^{234}U	3.01E+01	3.25E-01	1.26E-05	c
^{237}Np	7.04E+01	7.62E-01	2.94E-05	c
^{244}Cm	2.60E+03	2.81E+01	1.09E-03	c
Total[d]	4.76E+08	5.15E+06	1.99E+02	c

[a]Data taken from ref. 1(c).
[b]As of Sept. 30, 1996.
[c]Negligible contribution.
[d]Totals listed pertain only to the contributions from the radionuclides listed and do not indicate the total radioactivity of the particular waste category.

Table 2.14. Major radionuclides comprising HLW and associated wastes at WVDP[a]

Radionuclides	Radioactivity, Ci, by waste category	
	Interim form[b]	Final form[b]
	Tank waste	Canister material
^{63}Ni	7.6E+03	5.8E+02
^{90}Sr	5.3E+06	4.4E+05
^{90}Y	5.3E+06	4.4E+05
^{93}Zr	2.6E+02	2.0E+01
^{93m}Nb	1.9E+02	1.4E+01
^{99}Tc	1.6E+03	1.2E+02
^{137}Cs	5.7E+06	5.2E+05
^{135}Cs	1.5E+02	1.4E+01
^{137m}Ba	5.4E+06	5.0E+05
^{151}Sm	7.5E+04	5.7E+03
^{238}Pu	7.4E+03	5.7E+02
^{239}Pu	1.5E+03	1.2E+02
^{240}Pu	1.1E+03	8.7E+01
^{241}Pu	5.5E+04	4.2E+03
^{242}Pu	1.5E+00	1.2E+01
^{241}Am	5.0E+04	3.8E+03
^{242}Am	2.6E+02	2.0E+01
^{243}Am	3.2E+02	2.5E+01
^{244}Cm	5.5E+03	4.2E+02
Total	2.2E+07	1.9E+06

[a]Data taken from ref. 1(d).
[b]As of Sept. 30, 1996.

Table 2.15. Significant revisions and changes in the current values for HLW compared to the values in the previous year[a,b]

Waste characteristics	Previous report values[a]	Significant revisions and changes	Updated values[b]	Explanation
		Hanford Site		
Number of canisters	See Table 2.7	Canister production schedule updated	See Table 2.7	
Tank waste volume	See Table 2.8	Tank waste volume adjustment	See Table 2.8	The single-shell tank salt cake component of solid waste volume is adjusted ("compressed") to account for interstitial liquid being reported separately as part of the liquid category
		Idaho National Engineering and Environmental Laboratory		
Number of canisters	See Table 2.7	Canister volume changed to be consistent with SRS. Data added for HLW generated from stabilization of sodium-bonded fuel at ANL–W	See Table 2.7	Based on current funding guidance from DOE and the INEEL Focus on 2006 draft report (see ref. 15)
		Savannah River Site		
Number of canisters	See Table 2.7	Canister production schedule updated	See Table 2.7	Based on current funding guidance from DOE and the SRS *High-Level Waste System Plan Revision 7(U)* (see ref. 16)
		West Valley Demonstration Project		
Volume, radioactivity, and thermal power	See Tables 2.8–2.10	Values reported are for liquid, sludge, and zeolite	See Tables 2.8–2.10	Wastes have been blended prior to vitrification

[a]Data are for Dec. 31, 1995. See tables and text cited in Chapter 2 of ref. 6 (DOE/RW-0006, Rev. 12).
[b]Data are for Sept. 30, 1996, as reported in this document (DOE/RW-0006, Rev. 13).

Table 2.16. Proposed representative chemical composition of future HLW glass to be generated at Hanford[a]

Component	Wt %	Component	Wt %
Al_2O_3	9.31	Na_2O	11.79
B_2O_3	7.02	Na_2SO_4	0.10
Bi_2O_3	1.15	NiO	1.08
CaO	0.83	P_2O_5	1.56
Ce_2O_3	1.13	PbO_2	0.14
Cr_2O_3	0.36	SiO_2	46.11
Fe_2O_3	4.49	SrO	0.18
K_2O	0.17	ThO_2	0.01
La_2O_3	0.11	UO_3	6.69
Li_2O	2.01	ZrO_2	3.79
MnO_2	1.17	Other	0.17
NaF	0.63		
		Total	100.00

[a]Data taken from ref. 1(a).

Table 2.17. Proposed representative chemical composition of future HLW glass to be generated at INEEL[a]

Chemical compound	Glass, wt %, formed from high-activity fraction from		
	Dissolved Zr calcine	Dissolved Al calcine	Na-bearing-waste
Al_2O_3	0.5	12.7	17.2
AMP[b]	0.8	6.6	
B_2O_3	12.2	8.1	11.3
CaF_2	14.5		
CaO	0.4		
Cs_2O		0.1	
Fe_2O_3		0.1	0.1
Na_2O	12.9	18.0	13.8
P_2O_5	0.1		
SiO_2	56.8	54.4	57.6
ZrO_2	1.8		
Total	100.0	100.0	100.0

[a]Data taken from ref. 1(b); flowsheet estimate, not verified by laboratory tests. Compositions are not available of future ceramic and metal waste forms generated by treatment of sodium-bonded fuel at ANL–W.

[b]Ammoniummolybdophosphate.

Table 2.18. Proposed representative chemical composition of future HLW glass to be generated at SRS[a]

Component	Wt %	Component	Wt %
Al_2O_3	3.9	MgO	2.0
B_2O_3	7.3	MnO	1.2
CaO	0.6	Na_2O	8.7
$Ca_3(PO_4)_2$	1.1	NiO	0.1
Cr_2O_3	0.2	SiO_2	53.4
CuO	0.4	TiO_2	0.3
FeO	1.1	U_3O_8	0.9
Fe_2O_3	11.1	ZnO	0.1
K_2O	2.4	Other	0.4
Li_2O	4.8		
		Total	100.0

[a]Data taken from ref. 1(c).

Table 2.19. Proposed representative chemical composition of future HLW glass to be generated at WVDP[a]

Component	Wt %	Composition	Wt %
Al_2O_3	6.00	Nd_2O_3	0.14
B_2O_3	12.89	NiO	0.25
BaO	0.16	P_2O_5	1.20
CaO	0.48	PdO	0.03
Ce_2O_3	0.31	Pr_6O_{11}	0.04
CoO	0.02	Rh_2O_3	0.02
Cr_2O_3	0.14	RuO_2	0.08
Cs_2O	0.08	SO_3	0.23
CuO	0.03	SiO_2	40.98
Fe_2O_3	12.02	Sm_2O_3	0.03
K_2O	5.00	SrO	0.02
La_2O_3	0.04	ThO_2	3.56
Li_2O	3.71	TiO_2	0.80
MgO	0.89	UO_3	0.63
MnO	0.82	Y_2O_3	0.02
MoO_3	0.04	ZnO	0.02
Na_2O	8.00	ZrO_2	1.32
		Total	100.00

[a]Data taken from ref. 1(d).

Table 2.20. Historical and projected annual and cumulative volume (10^3 m^3) of LAW generated from final HLW waste form production at each site[a]

End of FY	Hanford		INEEL[b]		SRS[c]		WVDP		Total	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1996					0.5	22.8	d	d	0.5	22.8
1997					2.0	24.8	d	d	2.0	24.8
1998					26.9	51.7	d	d	26.9	51.7
1999					40.3	92.0	d	d	40.3	92.0
2000					29.9	121.9	d	d	29.9	121.9
2001					25.8	147.7			25.8	147.7
2002	3.088	3.088			25.3	173.0			28.4	176.1
2003	3.088	6.176			26.1	199.1			29.2	205.3
2004	3.088	9.264			24.6	223.7			27.7	233.0
2005	3.088	12.352			27.0	250.7			30.1	263.1
2006	3.088	15.440			26.0	276.7			29.1	292.2
2007	3.088	18.528			27.2	303.9			30.3	322.5
2008	3.088	21.616			25.9	329.8			29.0	351.4
2009	3.088	24.704			27.4	357.2			30.5	381.9
2010	3.088	27.792			25.2	382.4			28.3	410.2
2011	3.088	30.880			25.4	407.8			28.5	438.7
2012	14.330	45.210			27.0	434.8			41.3	480.0
2013	21.740	66.950			25.0	459.8			46.7	526.8
2014	21.740	88.690			25.2	485.0			46.9	573.7
2015	21.740	110.430			26.4	511.4			48.1	621.9
2016	21.740	132.170			24.1	535.5			45.8	667.7
2017	21.740	153.910			24.9	560.4			46.6	714.3
2018	21.740	175.650			24.4	584.8			46.1	760.5
2019	21.740	197.390	0.25	0.25	0.1	584.8			22.1	782.6
2020	21.740	219.130	2.32	2.57		584.8			24.1	806.6
2021	21.740	240.870	1.64	4.21		584.8			23.4	830.0
2022		240.870	1.64	5.85		584.8			1.6	831.6
2023		240.870	1.69	7.54		584.8			1.7	833.3
2024		240.870	1.70	9.24		584.8			1.7	835.0
2025		240.870	1.71	10.95		584.8			1.7	836.7

Table 2.20 (continued)

End of FY	Hanford		INEEL[b]		SRS[c]		WVDP		Total	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
2026		240.870	2.06	13.01		584.8			2.1	838.8
2027		240.870	2.07	15.08		584.8			2.1	840.9
2028		240.870	2.40	17.48		584.8			2.4	843.3
2029		240.870	2.87	20.34		584.8			2.9	846.2
2030		240.870	2.87	23.21		584.8			2.9	849.1
2031		240.870	2.71	25.92		584.8			2.7	851.8
2032		240.870	2.14	28.07		584.8			2.1	853.9
2033		240.870	2.13	30.20		584.8			2.1	856.0
2034		240.870	1.82	32.02		584.8			1.8	857.8
2035		240.870		32.02		584.8				857.8

[a]Based on refs. 1a–1d.
[b]LLW grout.
[c]LLW saltstone.
[d]Negligible quantity.

Table 2.21. Projected characteristics of HLW generated at ANL–W from the treatment of sodium-bonded SNF[a]

End of FY	Volume, m^3		Number of canisters[b]	
	Ceramic waste	Metal waste	Annual	Total
1996	0	0	0	0
1997	0	0	0	0
1998	0	0	0	0
1999	0	0	0	0
2000	3.6	0.08	5	5
2001	3.6	0.08	6	11
2002	3.6	0.08	6	17
2003	3.6	0.08	6	23
2004	3.6	0.08	6	29
2005	3.6	0.08	6	35
2006	3.6	0.08	6	41
2007	3.6	0.08	6	47
2008	3.6	0.08	6	53
2009	3.6	0.08	6	59
2010	3.6	0.08	6	65
2011	3.6	0.08	6	71
2012–2030	0	0	0	0
Total	43.2	0.96		

[a]Based on ref. 1(b).

[b]Based on the SRS Reference Canister, which is assumed to contain 0.625 m^3 of glass.

Table 2.22. Major radionuclides comprising final HLW forms at ANL–W from the treatment of sodium-bonded SNF

Radionuclide	Radioactivity, [a] Ci		Radionuclide	Radioactivity, [a] Ci	
	Ceramic waste	Metal waste		Ceramic waste	Metal waste
^{14}C		4.3E+00	^{233}U	2.0E-04	5.8E-05
^{60}Co		3.2E+03	^{234}U	2.8E+00	7.7E-01
^{63}Ni		4.1E+02	^{235}U	8.8E-02	2.5E-02
^{90}Sr	7.1E+05		^{236}U	6.3E-02	1.8E-02
^{90}Y	7.1E+05		^{238}U	2.8E-01	9.7E-02
^{99}Tc		1.3E+02	^{237}Np	1.3E+00	2.4E-05
^{106}Rh		2.1E+04	^{238}Pu	1.0E+03	1.8E-02
^{106}Ru		2.1E+04	^{239}Pu	4.7E+04	9.3E-01
^{126}Sn		2.8E+00	^{240}Pu	4.2E+03	8.1E-02
^{125}Sb		1.4E+04	^{241}Pu	3.0E+04	5.4E-01
^{129}I	3.4E-01		^{242}Pu	3.4E-01	5.6E-06
^{134}Cs	7.9E+03		^{241}Am	1.6E+03	3.1E-02
^{135}Cs	1.6E+01		^{242}Am	1.4E+01	2.7E-04
^{137}Cs	8.5E+05		^{243}Am	2.8E-01	4.8E-06
^{137m}Ba	8.0E+05		^{242}Cm	1.2E+01	2.3E-04
^{144}Ce	4.9E+04		^{243}Cm	1.6E-01	3.0E-06
^{144}Pr	4.9E+04		^{244}Cm	1.9E+00	3.1E-05
^{147}Pm	4.5E+05		^{245}Cm	6.8E-05	1.1E-09
^{154}Eu	2.1E+03		^{246}Cm	4.2E-07	7.1E-12
^{155}Eu	1.9E+04		^{247}Cm	2.4E-13	4.0E-18
^{226}Ra	3.0E-05		^{248}Cm	2.6E-14	4.4E-19
^{232}U	2.6E-03	1.2E-04			
			Total	3.7E+06	6.0E+04

[a]Based on ref. 1(b). Radioactivity levels reported are decayed to FY 2000 and reflect totals for the treatment of all sodium-bonded fuel.

3. TRANSURANIC WASTE

3.1 INTRODUCTION

This chapter presents information on the inventories and characteristics of transuranic (TRU) waste (TRUW) at various DOE TRUW sites in the United States. TRUW is a waste category specific to DOE; it does not apply to wastes regulated by the U.S. Nuclear Regulatory Commission. DOE Order 5820.2A, *Radioactive Waste Management*, defines TRUW as waste that (1) is contaminated with alpha-emitting TRU radionuclides (i.e., those with atomic numbers greater than 92) with half-lives greater than 20 years and (2) contains a total concentration of such radionuclides in excess of 100 nCi/g of waste at the time of assay.[1]

DOE Order 5820.2A also states that heads of field elements can determine that other alpha-contaminated waste at the site(s) may be managed as TRUW.[1] As a consequence of this provision, wastes containing radionuclides, such as ^{233}U, ^{241}Pu, and ^{244}Cm, which do not meet the strict definition of TRU radionuclides because of their respective atomic numbers or half-lives, may be managed as TRUW at some sites.

Most TRUW exists in solid form (e.g., items such as protective clothing, paper, rags, glass, miscellaneous tools, and equipment that have become contaminated with TRU radionuclides).[2] Some TRUW is in the form of sludges or liquids resulting from chemical processing for recovery of plutonium or other TRU elements.[2] Some of the liquids have been solidified, and some sludges have been dewatered. All sludge and liquid wastes scheduled for disposal in the Waste Isolation Pilot Plant (WIPP) will be solidified (before the wastes are shipped) to meet the current WIPP waste acceptance criteria (WAC).[3]

Before 1970, TRUW was disposed of on-site in shallow, landfill-type, DOE-owned burial sites. TRUW disposed of in this manner is referred to as "buried" TRUW. In 1970, DOE's predecessor agency, the U.S. Atomic Energy Commission, concluded that waste containing long-lived alpha-emitting radionuclides should have greater confinement from the environment. Thus, TRUW 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.[4] This waste is referred to as "retrievably stored" TRUW.

Retrievably stored waste is contained in a variety of packagings (e.g., metal drums and wooden and metal boxes) and is stored in various facilities such as earth-mounded berms, concrete culverts, and buildings and on outdoor pads. Many of these facilities have been upgraded and now comply with applicable hazardous waste storage regulations.

TRUW 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 equals or exceeds 200 mrem/h, the package is classified as RH TRUW.

CH TRUW contains relatively small quantities of fission and activation products that produce highly penetrating radiation; typically, TRUW emissions consist mostly of alpha particles and some neutrons and primarily low-energy gamma and X-rays. RH TRUW typically contains a greater amount of fission and activation products that produce highly penetrating radiation and produce a higher level of radiation at the surface of the package.

TRUW which contains, in addition to radioactive constituents, hazardous constituents defined and regulated according to the Resource Conservation and Recovery Act (RCRA) is defined as mixed TRUW. Examples of mixed TRUW are radionuclide-contaminated sludges from plutonium recovery, discarded materials contaminated with both solvents and radioactive materials, scintillation fluids, and discarded contaminated lead shielding. Mixed TRUW must be managed to comply with both the applicable hazardous waste regulations (e.g., RCRA) and the regulations applying only to radioactive TRUW.

Some TRUW may also be contaminated with hazardous materials defined by regulations other than RCRA (e.g., Toxic Substances Control Act and state regulations). Once identified, DOE continues to manage these wastes appropriately to meet all other

hazardous waste regulations in addition to RCRA (if applicable).

Under existing arrangements, retrievably stored TRUW is the responsibility of the DOE Office of Waste Management (EM-30). It is planned that the retrievably stored TRUW and newly generated TRUW from routine site operational activities will be shipped to WIPP for disposal; whereas, buried TRUW and TRUW generated from site remediation activities and decontamination and decommissioning (D&D) activities are the responsibility of the Office of Environmental Restoration (EM-40). (See Chapter 6 of this document for a discussion of environmental restoration wastes.)

3.2 TRUW INVENTORIES

3.2.1 Sources of Data

The vast majority of the quantitative information contained in this chapter is either derived or summarized from data furnished by the DOE sites in response to a data call in January 1996 and subsequently updated in May 1997.[5] The update in May 1997 requested the sites to provide the actual amounts of TRUW generated during fiscal year (FY) 1996, and this new information was added to the end of calendar year (EOCY) 1995 stored waste volumes provided by the sites in response to the January 1996 data call. The radionuclide data for the stored waste inventory have not been updated since the data were received in response to the January 1996 data call. Therefore, as discussed later, the radionuclide inventory is based on the stored TRUW inventory at EOCY 1995 that was provided in response to the January 1996 data call. In addition, the May 1997 data update request also required the sites to update the information for TRU-contaminated soil volumes stored at the sites based on the most recent estimates available at the site. As programs and plans evolve or are changed, modifications or additions will be made to the data and other information presented in this chapter. It is expected that the quality and accuracy of the data will continue to improve with each annual revision of this document, thus improving the usefulness of the data for program planning and decision-making.

Early TRUW inventory practices were not as stringent as are current practices regarding requirements for waste identification, categorization, and segregation. Consequently, early inventory data are based largely on process knowledge and on various studies and summaries related to site-specific practices.[6] As these efforts continue and TRUW is further characterized, there will be revisions in the estimated overall quantities of TRUW.

3.2.2 Site Locations—Summarized Volumes and Radioactivity

TRUW management activities (generation, retrievable storage, etc.) are performed at 10 major sites and 17 small-quantity sites (SQS). Figure 3.1 shows the locations of the DOE's TRUW sites. Tables 3.1–3.14, which are discussed later in this chapter, summarize the distribution of TRUW, TRU-contaminated soils, and their associated radioactivities at various DOE TRUW sites. The volumes reported in this document reflect two waste conditions: as-generated and final form. For stored waste, the as-generated volumes reflect the waste volumes currently in storage at the site; whereas, for projected waste, the as-generated volumes reflect the expected waste volumes at the time of generation. The final-form volumes reflect the expected volume of the waste following site processing, treatment, and repackaging of the as-generated waste for disposal at WIPP.

3.2.3 Site Data Submittal Process

The data reported in this document are based on both as-generated and final-form volumes of TRUW and, as mentioned previously, are summarized from data furnished by the DOE sites in response to a data call in January 1996 and subsequently updated in May 1997.[5] The data received from the sites in 1997 included actual volumes of waste generation for FY 1996, and these volumes were used to update the EOCY 1995 waste volumes reported by the sites in response to the January 1996 data call. It should be noted that not all sites provided updated information in 1997. For all sites that did not report any information by the deadline of June 30, 1997, it has been assumed that the data reported in response to the January 1996 are still valid.

To meet the needs of the Transuranic Waste Baseline Inventory Report (TWBIR), the data in January 1996 were collected at the waste-stream level in both their as-generated and final forms. The data were grouped by similar physical and chemical properties and aggregated to produce estimated total volumes of the waste.

The data reported in the tables in this chapter include both the as-generated and final-form volumes at the end of FY 1996, and the projected increase in these respective volumes from FY 1997 through FY 2033.

3.2.4 Volumes and Radioactivities of TRUW at DOE Sites

3.2.4.1 As-generated TRUW volumes

Table 3.1 shows the total estimated *as-generated* TRUW volumes in storage at the end of FY 1996 and projected through FY 2033 for each DOE site, and Tables 3.2–3.3 show the breakup of this total *as-generated* inventory into mixed and nonmixed CH TRUW (Table 3.2) and mixed and nonmixed RH TRUW (Table 3.3).

3.2.4.2 Final-form TRUW volumes

Table 3.4 shows the *expected final-form volumes* of the stored and projected TRUW reported earlier in Table 3.1 *after the waste is processed to its final form.* Tables 3.5–3.6 show the breakup of this expected final-form volume into mixed and nonmixed CH TRUW (Table 3.5), and mixed and nonmixed RH TRUW (Table 3.6).

Tables 3.7 and 3.8 show the expected total final-form volumes of TRUW at each site distributed among each final waste form (e.g., combustible waste). Table 3.7 shows the final waste form distribution for the major sites, whereas Table 3.8 presents the same for the SQS.

3.2.4.3 Decayed radioactivities for retrievably stored TRUW

The yearly undecayed activity reported for each radionuclide by each TRUW site for CH TRUW and RH TRUW generated from 1970 through 1995 was decayed to the EOCY 1996 using the ORNL computer code ORIGEN2.[7] This code converts the annual as-stored radioactivities to annual decayed radioactivities and accumulates these quantities to produce tables showing cumulative decayed activity for each radionuclide at each site. Once the decayed activities were calculated, the decayed mass was estimated using standard values of the specific activity of each radionuclide as reported in Appendix B of Rev. 12 of the IDB document. Waste volumes are assumed to be unaffected by radioactive decay.

Tables 3.9–3.12 show the distribution of the primary TRUW radionuclides for all the DOE sites (decayed to the EOCY 1996) for retrievably stored CH TRUW and RH TRUW both by radioactivity and by mass. As shown in these tables, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, and ^{241}Am cumulatively contribute more than 99% of the total activity for retrievably stored CH TRUW (Table 3.9), whereas ^{232}Th, ^{235}U, ^{238}U, ^{239}Pu, and ^{240}Pu contribute more than 98% of the total radionuclide mass for retrievably stored CH TRUW (Table 3.10). Similar information on RH TRUW and on the relative distribution of both the radioactivity and mass of the primary radionuclides for the various DOE sites can be derived from Tables 3.11 and 3.12.

In this report, primary radionuclides are those that cumulatively contribute 98% of either the total radionuclide activity or mass.

3.2.4.4 Buried TRUW volumes and radioactivities

Table 3.13 summarizes the buried TRUW volumes and associated radioactivity, both as-stored and as-decayed. Buried TRUW volumes and radioactivities shown in Table 3.13 are unchanged from Rev. 12 of the IDB report because, as discussed above, no further wastes are being buried. Table 3.13 shows both cumulative as-stored and as-decayed radioactivities for all nuclides, as well as for TRU nuclides only.

3.2.4.5 Contaminated soil volumes and radioactivities

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 the contaminated soil. The data shown in Table 3.14 are based on previous data and the updates received from the sites in 1997. Additional characterization efforts will be required to reduce the uncertainties of this data.

3.3 PROJECTED FUTURE QUANTITIES OF TRUW

Tables 3.1–3.6 show the estimated future volumes of TRUW generation. Tables 3.1–3.3 give projections for as-generated waste forms and Tables 3.4–3.6 give projections for final waste forms. The sites were not requested to estimate the radioactivities or isotopic compositions of these wastes because it was believed that there would, in most instances, be little basis for such estimates. The estimated volumes are given as the

total cumulative volume expected to be generated from the start of FY 1997 to the end of the FY 2033.

3.4 TRUW DISPOSAL

The goals of the DOE TRUW Program are to terminate interim storage and achieve permanent disposal of DOE TRUW.[8] As stated in Pub. L. 96-164,[9] WIPP 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 complete, and WIPP is now the only facility specifically designed for isolation of TRUW.

In 1992, the WIPP Legislative Land Withdrawal Act[10] was passed, confirming congressional intent to have DOE continue with development and permitting of the facility. Since then, DOE has stated its intent to accelerate processes leading to the start of waste disposal operations at the WIPP. As specified in the WIPP Land Withdrawal Act, the facility will contain about 175,000 m^3 (6.2 million ft^3) of TRUW 650 m below ground in a mined salt formation. Waste received at WIPP will meet the WIPP Waste Acceptance Criteria[3] and its associated quality assurance requirements.

Also, certification and permit requirements are being completed before DOE begins disposal operations of mixed TRUW at the facility. DOE is committed to demonstrating compliance with all applicable regulations before the permanent disposal of TRUW in the WIPP repository. Therefore, compliance with the requirements contained in the environmental standards for management and disposal of mixed TRUW, as mandated in 40 CFR Part 191[11] and the RCRA regulations, are being documented. Following the criteria for compliance with 40 CFR 191 contained in 40 CFR 194,[12] the DOE has prepared and submitted to the EPA an application, titled 40 CFR Part 191, *Compliance Certification Application for the Waste Isolation Pilot Plant.*[13] This application requests certification from the EPA for the WIPP facility. In addition, the DOE has also submitted a RCRA Part B Permit Application[14] to the state of New Mexico to acquire a permit for the disposal of TRUW containing RCRA-regulated wastes at the WIPP facility. Upon receipt of the EPA certification and the RCRA Part B permit, the WIPP facility will begin disposal of TRUW in May 1998.

3.5 REFERENCES

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

2. U.S. Department of Energy, *Transuranic Waste Baseline Inventory Report*, CAO-95-1121, Revision 3, Carlsbad, New Mexico (June 1996).

3. U.S. Department of Energy, *Waste Acceptance Criteria for the Waste Isolation Pilot Plant*, DOE/WIPP-069, Rev. 5, Carlsbad, New Mexico (April 1996).

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

5. U.S. Department of Energy, Carlsbad Area Office, *Transuranic Waste Data Update for Revision 13 of the Integrated Data Base*, CAO:NTP:RAS 97-1151, Carlsbad, New Mexico (May 23, 1997).

6. 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).

7. Croff, A.G., 1983, "ORIGEN2: A Versatile Computer Code for Calculating the Nuclide Compositions and Characteristics of Nuclear Materials," *Nuclear Technology*, **62**, 335–352 (November 1983).

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

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

10. U.S. Congress, *Waste Isolation Pilot Plant Land Withdrawal Act*, Pub. L. 102-579 (1992).

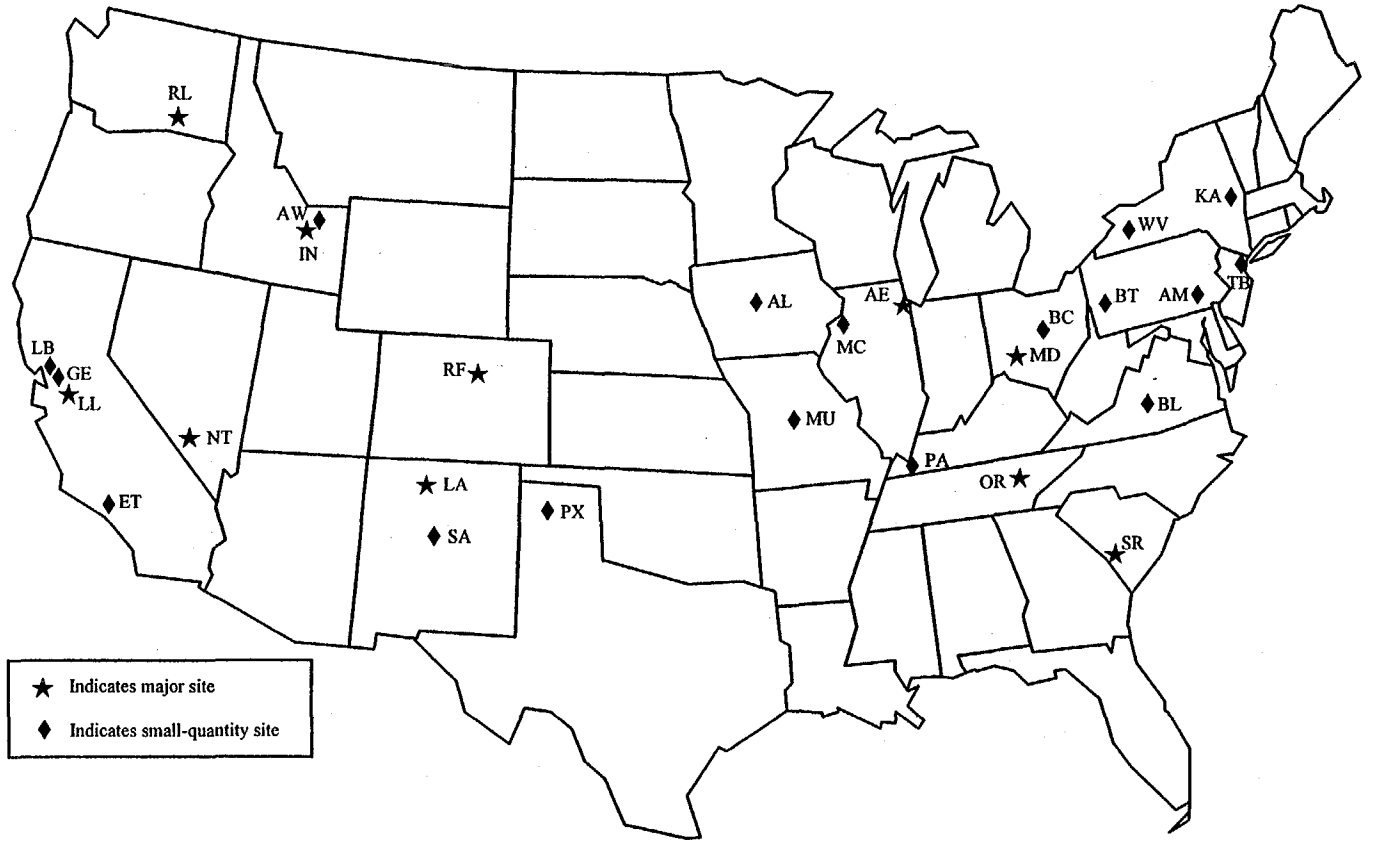
11. U.S. Environmental Protection Agency, *Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes, Final Rule*, 40 CFR Part 191, *Fed. Regist.* **58**, 66398 (Dec. 20, 1993).

12. U.S. Environmental Protection Agency, *Criteria for Certification and Re-Certification of the Waste Isolation Pilot Plant's Compliance with 40 CFR 191 Disposal Regulations, Final Rule*, 40 CFR Part 194, *Fed. Regist.* **61**, 5224 (Feb. 9, 1996).

13. U.S. Department of Energy, *Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot Plant*, DOE/CAO-96-2184 (October 1996).

14. U.S. Department of Energy, *Resource Conservation and Recovery Act Part B Permit Application for the Waste Isolation Pilot Plant, Carlsbad, New Mexico*, DOE/WIPP-91-005, Rev. 6 (October 1996).

ORNL DWG 96-7944R



AE	Argonne National Laboratory-East	IN	Idaho National Engineering & Environmental Laboratory	OR	Oak Ridge National Laboratory
AL	Ames Laboratory	KA	Knolls Atomic Power Laboratory	PA	Paducah Gaseous Diffusion Plant
AM	ARCO Medical Products Company	LA	Los Alamos National Laboratory	PX	Pantex Plant
AW	Argonne National Laboratory-West	LB	Lawrence Berkeley National Laboratory	RF	Rocky Flats Environmental Technology Site
BC	Battelle Columbus Decommissioning Project	LL	Lawrence Livermore National Laboratory	RL	Hanford (Richland) Site
BL	Babcock & Wilcox-Lynchburg	MC	U.S. Army Material Command	SA	Sandia National Laboratories/New Mexico
BT	Bettis Atomic Power Laboratory	MD	Mound Plant	SR	Savannah River Site
ET	Energy Technology Engineering Center	MU	University of Missouri Research Reactor	TB	Teledyne Brown Engineering
GE	General Electric Vallecitos Nuclear Center	NT	Nevada Test Site	WV	West Valley Demonstration Project

Fig. 3.1. U.S. Department of Energy transuranic waste generator and storage sites.

Table 3.1. Summary of as-generated waste-form volumes (m^3) of retrievably stored and projected TRUW (mixed and nonmixed CH and RH TRUW)

Sites	CH TRUW			RH TRUW			Grand total at end of FY 2033
	Stored at end of FY 1996	Projected waste during FY 1997–2033	Total at end of FY 2033	Stored at end of FY 1996	Projected waste during FY 1997–2033	Total at end of FY 2033	
Major sites							
ANL–E	80.6	166.9	247.5	0.0	0.0	0.0	247.5
Hanford	11,008.0	6,270.0	17,278.0	203.0	1,660.0	1,863.0	19,140.9
INEEL	64,760.2	550.0	65,310.2	62.0	0.0	62.0	65,372.2
LANL	8,610.1	6,218.6	14,828.7	93.2	33.8	127.0	14,955.7
LLNL	239.6	645.6	885.1	0.0	0.0	0.0	885.1
Mound	235.8	18.0	253.8	0.0	0.0	0.0	253.8
NTS	618.2	8.0	626.2	0.0	0.0	0.0	626.2
ORNL	921.1	370.0	1,291.1	1,283.0	200.0	1,483.0	2,774.1
RFETS	1,889.2	3,218.1	5,107.2	0.0	0.0	0.0	5,107.2
SRS	6,033.5	8,348.7	14,382.3	0.57	0.0	0.57	14,382.8
Subtotal	94,396.2	25,813.9	120,210.0	1,641.7	1,893.8	3,535.5	123,745.6
Small-quantity sites							
Ames	0.00	1.25	1.25	0.00	0.00	0.00	1.25
ANL–W	6.99	40.69	47.68	22.09	21.69	43.78	91.46
ARCO	0.04	0.03	0.07	0.00	0.00	0.00	0.07
BAPL	0.00	123.06	123.06	0.00	1.56	1.56	124.62
BCL	0.00	0.00	0.00	0.00	368.75	368.75	368.75
ETEC	1.68	0.00	1.68	5.40	0.50	5.90	7.58
KAPL	0.00	0.00	0.00	3.14	1.00	4.14	4.14
LBNL	0.87	1.04	1.91	0.00	0.00	0.00	1.91
MURR	0.21	0.62	0.83	0.00	0.00	0.00	0.83
PAD	4.08	0.00	4.08	0.00	0.00	0.00	4.08
PANT	0.62	0.00	0.62	0.00	0.00	0.00	0.62
SNL/NM	8.23	3.75	11.98	0.00	0.00	0.00	11.98
TBE	0.21	0.00	0.21	0.00	0.00	0.00	0.21
USAMC	2.50	0.00	2.50	0.00	0.00	0.00	2.50
Subtotal	25.43	170.44	195.87	30.63	393.50	424.13	620.00
Commercial site							
WVDP	37.41	143.64	181.05	483.63	28.56	512.19	693.27
Grand total	94,459.0	26,128.0	120,586.9	2,156.0	2,315.9	4,471.8	125,058.9

Table 3.2. Summary of as-generated waste-form volumes (m^3) of retrievably stored and projected CH TRUW (mixed and nonmixed CH TRUW)

Sites	Mixed CH TRUW			Nonmixed CH TRUW			Grand total at end of FY 2033
	Stored at end of FY 1996	Projected waste during FY 1997–2033	Total at end of FY 2033	Stored at end of FY 1996	Projected waste during FY 1997–2033	Total at end of FY 2033	
Major sites							
ANL-E	1.1	1.6	2.6	79.6	165.4	244.9	247.5
Hanford	216.1	2,064.8	2,280.9	10,791.9	4,205.2	14,997.1	17,278.0
INEEL	63,291.0	550.0	63,841.0	1,469.2	0.0	1,469.2	65,310.2
LANL	8,178.8	3,295.5	11,474.2	431.3	2,923.1	3,354.5	14,828.7
LLNL	9.4	66.7	76.1	230.2	578.9	809.1	885.1
Mound	2.1	0.0	2.1	233.7	18.0	251.7	253.8
NTS	609.1	8.0	617.1	9.1	0.0	9.1	626.2
ORNL	602.9	296.0	898.9	318.2	74.0	392.2	1,291.1
RFETS	932.4	188.3	1,120.7	956.8	3,029.8	3,986.5	5,107.2
SRS	3,441.6	1,151.1	4,592.8	2,591.9	7,197.6	9,789.5	14,382.3
Subtotal	77,284.4	7,621.9	84,906.3	17,111.8	18,191.9	35,303.6	120,210.0
Small-quantity sites							
Ames	0.00	1.25	1.25	0.00	0.00	0.00	1.25
ANL-W	4.70	0.94	5.64	2.29	39.75	42.04	47.68
ARCO	0.00	0.00	0.00	0.04	0.03	0.07	0.07
BAPL	0.00	0.00	0.00	0.00	123.06	123.06	123.06
BCL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ETEC	0.84	0.00	0.84	0.84	0.00	0.84	1.68
KAPL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LBNL	0.00	0.00	0.00	0.87	1.04	1.91	1.91
MURR	0.21	0.62	0.83	0.00	0.00	0.00	0.83
PAD	4.08	0.00	4.08	0.00	0.00	0.00	4.08
PANT	0.00	0.00	0.00	0.62	0.00	0.62	0.62
SNL/NM	0.00	0.00	0.00	8.23	3.75	11.98	11.98
TBE	0.00	0.00	0.00	0.21	0.00	0.21	0.21
USAMC	0.00	0.00	0.00	2.50	0.00	2.50	2.50
Subtotal	9.83	2.81	12.64	15.60	167.63	183.23	195.87
Commercial site							
WVDP	5.54	0.00	5.54	31.87	143.64	175.51	181.05
Grand total	77,299.8	7,624.7	84,924.5	17,159.3	18,503.2	35,662.3	120,586.8

Table 3.3. Summary of as-generated waste-form volumes (m^3) of retrievably stored and projected RH TRUW (mixed and nonmixed RH TRUW)

Sites	Mixed RH TRUW			Nonmixed RH TRUW			Grand total at end of FY 2033
	Stored at end of FY 1996	Projected waste during FY 1997–2033	Total at end of FY 2033	Stored at end of FY 1996	Projected waste during FY 1997–2033	Total at end of FY 2033	
Major sites							
ANL–E	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hanford	2.6	1,545.0	1,547.6	200.3	115.0	315.3	1,863.0
INEEL	13.3	0.0	13.3	48.7	0.0	48.7	62.0
LANL	93.2	33.8	127.0	0.0	0.0	0.0	127.0
LLNL	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mound	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NTS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ORNL	883.2	55.7	938.9	399.8	144.3	544.1	1,483.0
RFETS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SRS	0.0	0.0	0.0	0.6	0.0	0.6	0.6
Subtotal	992.4	1,634.5	2,626.9	649.4	259.3	908.7	3,535.6
Small-quantity sites							
Ames	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ANL–W	15.87	11.79	27.66	6.22	9.90	16.12	43.78
ARCO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BAPL	0.00	0.00	0.00	0.00	1.56	1.56	1.56
BCL	0.00	0.00	0.00	0.00	368.75	368.75	368.75
ETEC	5.40	0.50	5.90	0.00	0.00	0.00	5.90
KAPL	0.00	0.18	0.18	3.14	0.82	3.96	4.14
LBNL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MURR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PAD	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PANT	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SNL/NM	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TBE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
USAMC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotal	21.27	12.47	33.74	9.36	381.03	390.39	424.13
Commercial site							
WVDP	17.76	0.0	17.76	465.87	28.56	494.43	512.19
Grand total	1,031.4	1,647.0	2,678.4	1,124.6	668.9	1,793.5	4,471.9

Table 3.4. Summary of final waste-form volumes (m^3) of retrievably stored and projected TRUW (mixed and nonmixed CH and RH TRUW)

Sites	CH TRUW			RH TRUW			Grand total at end of FY 2033
	Stored at end of FY 1996	Projected waste during FY 1997–2033	Total at end of FY 2033	Stored at end of FY 1996	Projected waste during FY 1997–2033	Total at end of FY 2033	
Major sites							
ANL–E	80.6	166.9	247.5	0.0	0.0	0.0	247.5
Hanford	11,007.8	6,270.0	17,277.8	203.0	1,660.0	1,863.0	19,140.7
INEEL	35,979.7	550.0	36,529.7	159.6	0.0	159.6	36,689.3
LANL	8,610.1	6,218.6	14,828.7	93.2	33.8	127.0	14,955.7
LLNL	239.6	645.6	885.1	0.0	0.0	0.0	885.1
Mound	235.8	22.7	258.4	0.0	0.0	0.0	258.4
NTS	618.2	8.0	626.2	0.0	0.0	0.0	626.2
ORNL	460.6	185.0	645.6	1,385.4	115.0	1,500.4	2,146.0
RFETS	6,060.5	3,218.1	9,278.6	0.0	0.0	0.0	9,278.6
SRS	2,220.3	2,640.4	4,860.6	0.9	0.0	0.9	4,861.5
Subtotal	65,513.1	19,925.2	85,438.3	1,842.0	1,808.8	3,650.9	89,089.2
Small-quantity sites							
Ames	0.00	1.25	1.25	0.00	0.00	0.0	1.25
ANL–W	6.99	45.50	52.49	22.09	22.10	44.19	96.68
ARCO	0.21	0.42	0.63	0.00	0.00	0.00	0.63
BAPL	0.00	123.06	123.06	0.00	2.22	2.22	125.28
BCL	0.00	0.00	0.00	0.00	368.75	368.75	368.75
ETEC	1.68	0.00	1.68	5.40	0.50	5.90	7.58
KAPL	23.90	10.40	34.30	0.00	0.00	0.00	34.30
LBNL	0.87	1.04	1.91	0.00	0.00	0.00	1.91
MURR	0.21	0.62	0.83	0.00	0.00	0.00	0.83
PAD	4.08	0.00	4.08	0.00	0.00	0.00	4.08
PANT	0.62	0.00	0.62	0.00	0.00	0.00	0.62
SNL/NM	8.23	3.75	11.98	0.00	0.00	0.00	11.98
TBE	0.21	0.00	0.21	0.00	0.00	0.00	0.21
USAMC	2.50	0.00	2.50	0.00	0.00	0.00	2.50
Subtotal	49.50	186.04	235.54	27.49	393.57	421.06	656.60
Commercial site							
WVDP	37.41	143.64	181.05	483.63	28.56	512.19	693.27
Grand total	65,600.0	20,254.9	85,854.9	2,353.1	2,230.9	4,584.2	90,439.1

Table 3.5. Summary of final waste-form volumes (m^3) of retrievably stored and projected CH TRUW (mixed and nonmixed CH TRUW)

Sites	Mixed CH TRUW			Nonmixed CH TRUW			Grand total at end of FY 2033
	Stored at end of FY 1996	Projected waste during FY 1997–2033	Total at end of FY 2033	Stored at end of FY 1996	Projected waste during FY 1997–2033	Total at end of FY 2033	
Major sites							
ANL–E	1.1	1.6	2.6	79.6	165.4	244.9	247.5
Hanford	215.9	2,064.8	2,280.7	10,791.9	4,205.2	14,997.1	17,277.8
INEEL	35,123.2	550.0	35,673.2	856.5	0.0	856.5	36,529.7
LANL	8,178.8	3,295.5	11,474.2	431.3	2,923.1	3,354.5	14,828.7
LLNL	9.4	66.7	76.1	230.2	578.9	809.1	885.1
Mound	2.1	0.0	2.1	233.7	22.7	256.4	258.4
NTS	609.1	8.0	617.1	9.1	0.0	9.1	626.2
ORNL	301.5	148.0	449.5	159.1	37.0	196.1	645.6
RFETS	3,139.7	188.3	3,328.0	2,920.9	3,029.8	5,950.6	9,278.6
SRS	1,567.6	506.7	2,074.2	652.7	2,133.7	2,786.4	4,860.6
Subtotal	49,148.2	6,829.4	55,977.6	16,364.9	13,095.7	29,460.5	85,438.3
Small-quantity sites							
Ames	0.00	1.25	1.25	0.00	0.00	0.00	1.25
ANL–W	4.70	1.04	5.74	2.29	44.46	46.75	52.49
ARCO	0.00	0.00	0.00	0.21	0.42	0.63	0.63
BAPL	0.00	0.00	0.00	0.00	123.06	123.06	123.06
BCL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ETEC	0.84	0.00	0.84	0.84	0.00	0.84	1.68
KAPL	0.00	1.87	1.87	23.90	8.53	32.43	34.30
LBNL	0.00	0.00	0.00	0.87	1.04	1.91	1.91
MURR	0.21	0.62	0.83	0.00	0.00	0.00	0.83
PAD	4.08	0.00	4.08	0.00	0.00	0.00	4.08
PANT	0.00	0.00	0.00	0.62	0.00	0.62	0.62
SNL/NM	0.00	0.00	0.00	8.23	3.75	11.98	11.98
TBE	0.00	0.00	0.00	0.21	0.00	0.21	0.21
USAMC	0.00	0.00	0.00	2.50	0.00	2.50	2.50
Subtotal	9.83	4.78	14.61	39.67	181.26	220.93	235.54
Commercial site							
WVDP	5.54	0.00	5.54	31.87	143.64	175.51	181.05
Grand total	49,163.6	6,834.2	55,997.8	16,436.4	13,420.6	29,857.0	85,854.9

Table 3.6. Summary of final waste-form volumes (m^3) of retrievably stored and projected RH TRUW (mixed and nonmixed RH TRUW)

Sites	Mixed RH TRUW			Nonmixed RH TRUW			Grand total at end of FY 2033
	Stored at end of FY 1996	Projected waste during FY 1997–2033	Total at end of FY 2033	Stored at end of FY 1996	Projected waste during FY 1997–2033	Total at end of FY 2033	
Major sites							
ANL–E	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hanford	2.6	1,545.0	1,547.6	200.3	115.0	315.3	1,863.0
INEEL	30.3	0.0	30.3	129.4	0.0	129.4	159.6
LANL	93.2	33.8	127.0	0.0	0.0	0.0	127.0
LLNL	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mound	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NTS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ORNL	1,185.5	42.9	1,228.4	199.9	72.2	272.1	1,500.4
RFETS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SRS	0.0	0.0	0.0	0.9	0.0	0.9	0.9
Subtotal	1,311.6	1,621.7	2,933.3	530.5	187.2	717.7	3,650.9
Small-quantity sites							
Ames	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ANL–W	15.87	12.07	27.94	6.22	10.03	16.25	44.19
ARCO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BAPL	0.00	0.00	0.00	0.00	2.22	2.22	2.22
BCL	0.00	0.00	0.00	0.00	368.75	368.75	368.75
ETEC	5.40	0.50	5.90	0.00	0.00	0.00	5.90
KAPL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LBNL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MURR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PAD	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PANT	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SNL/NM	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TBE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
USAMC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotal	21.27	12.57	33.84	6.22	381.00	387.22	421.06
Commercial site							
WVDP	17.76	0.00	17.76	465.87	28.56	494.43	512.19
Grand total	1,350.6	1,634.3	2,984.9	1,002.6	596.8	1,599.4	4,584.3

Table 3.7. Estimated final waste-form volume (m^3) composition of retrievably stored and projected TRUW for major sites

Major sites	Category	Contact-handled			Remote-handled		
		Stored	Projected	Total	Stored	Projected	Total
ANL-E	Heterogeneous	64.38	165.15	229.53	0.00	0.00	0.00
	Lead/cadmium metal waste[a]	0.63	0.21	0.84	0.00	0.00	0.00
	Solidified inorganics	15.19	1.28	16.47	0.00	0.00	0.00
	Solidified organics	0.21	0.07	0.28	0.00	0.00	0.00
	Uncategorized metal	0.21	0.21	0.42	0.00	0.00	0.00
	Subtotal	80.62	166.92	247.54	0.00	0.00	0.00
Hanford	Combustible	268.14	1,567.50	1,835.64	0.35	0.00	0.35
	Heterogeneous	10,472.15	3,762.60	14,234.75	200.31	829.00	1,029.31
	Inorganic nonmetal	25.92	0.00	25.92	0.00	0.00	0.00
	Lead/cadmium metal waste[a]	2.94	0.00	2.94	2.32	831.00	833.32
	Soils	83.95	0.00	83.95	0.00	0.00	0.00
	Solidified inorganics	0.41	0.00	0.41	0.00	0.00	0.00
	Solidified organics	2.40	0.00	2.40	0.00	0.00	0.00
	Uncategorized metal	134.49	939.90	1,074.39	0.00	0.00	0.00
	Unknown	17.35	0.00	17.35	0.00	0.00	0.00
	Subtotal	11,007.75	6,270.00	17,277.75	202.98	1,660.00	1,862.98
INEEL	Combustible	90.52	0.00	90.52	0.00	0.00	0.00
	Filter	260.97	0.00	260.97	0.00	0.00	0.00
	Graphite	204.16	0.00	204.16	0.00	0.00	0.00
	Heterogeneous	57.45	0.00	57.45	83.36	0.00	83.36
	Inorganic nonmetal	163.88	0.00	163.88	0.30	0.00	0.30
	Lead/cadmium metal waste[a]	3,105.50	0.00	3,105.50	0.00	0.00	0.00
	Salt waste	4.66	0.00	4.66	0.00	0.00	0.00
	Solidified inorganics	2,252.71	0.00	2,252.71	7.12	0.00	7.12
	Solidified organics	12.93	0.00	12.93	0.00	0.00	0.00
	Uncategorized metal	248.01	0.00	248.01	0.00	0.00	0.00
	Vitrified	29,578.91	550.00	30,128.91	0.00	0.00	0.00
	Unknown	0.00	0.00	0.00	68.83	0.00	68.83
	Subtotal	35,979.70	550.00	36,529.70	159.61	0.00	159.61
LANL	Combustible	1,997.28	3,404.18	5,401.46	0.00	0.00	0.00
	Filter	0.00	166.28	166.28	0.00	0.00	0.00
	Heterogeneous	1,615.37	20.64	1,636.01	93.20	33.82	127.02
	Inorganic nonmetal	100.01	125.20	225.21	0.00	0.00	0.00
	Salt	119.16	38.92	158.08	0.00	0.00	0.00
	Soils	107.89	0.00	107.89	0.00	0.00	0.00
	Solidified inorganics	2,184.40	304.80	2,489.20	0.00	0.00	0.00
	Solidified organics	6.14	662.87	669.01	0.00	0.00	0.00
	Uncategorized metals	2,479.84	1,495.70	3,975.54	0.00	0.00	0.00
	Subtotal	8,610.09	6,218.59	14,828.68	93.20	33.82	127.02

Table 3.7 (continued)

Major sites	Category	Contact-handled			Remote-handled		
		Stored	Projected	Total	Stored	Projected	Total
LLNL	Combustible	56.79	407.89	464.67	0.00	0.00	0.00
	Filter	17.58	42.66	60.24	0.00	0.00	0.00
	Salt waste	0.73	3.85	4.58	0.00	0.00	0.00
	Solidified inorganics	14.56	7.70	22.26	0.00	0.00	0.00
	Solidified organics	1.46	7.70	9.15	0.00	0.00	0.00
	Uncategorized metal	148.47	175.77	324.24	0.00	0.00	0.00
	Subtotal	239.58	645.56	885.14	0.00	0.00	0.00
Mound	Combustible	7.49	0.00	7.49	0.00	0.00	0.00
	Filter	0.83	0.00	0.83	0.00	0.00	0.00
	Heterogeneous	0.62	0.00	0.62	0.00	0.00	0.00
	Soils	106.88	0.00	106.88	0.00	0.00	0.00
	Solidified inorganics	1.25	0.00	1.25	0.00	0.00	0.00
	Uncategorized metal	63.74	22.68	86.42	0.00	0.00	0.00
	Unknown	54.95	0.00	54.95	0.00	0.00	0.00
	Subtotal	235.76	22.68	258.44	0.00	0.00	0.00
NTS	Heterogeneous	617.35	8.00	625.35	0.00	0.00	0.00
	Unknown	0.83	0.00	0.83	0.00	0.00	0.00
	Subtotal	618.18	8.00	626.18	0.00	0.00	0.00
ORNL	Heterogeneous	460.55	185.00	645.55	269.55	92.50	362.05
	Solidified inorganics	0.00	0.00	0.00	1,115.85	22.50	1,138.35
	Subtotal	460.55	185.00	645.55	1,385.40	115.00	1,500.40
RFETS	Combustible	1,336.65	1,878.12	3,214.77	0.00	0.00	0.00
	Filter	691.38	26.55	717.93	0.00	0.00	0.00
	Graphite	378.86	0.00	378.86	0.00	0.00	0.00
	Heterogeneous	4.58	0.00	4.58	0.00	0.00	0.00
	Inorganic nonmetal	1,868.20	4.20	1,872.40	0.00	0.00	0.00
	Lead/cadmium metal waste[a]	5.63	23.38	29.01	0.00	0.00	0.00
	Salt waste	1,190.90	0.00	1,190.90	0.00	0.00	0.00
	Solidified inorganics	169.31	0.00	169.31	0.00	0.00	0.00
	Solidified organics	114.46	21.00	135.46	0.00	0.00	0.00
	Uncategorized metal	300.57	1,264.80	1,565.37	0.00	0.00	0.00
	Subtotal	6,060.54	3,218.05	9,278.59	0.00	0.00	0.00
SRS	Heterogeneous	1,714.87	1,838.17	3,553.04	0.89	0.00	0.89
	Inorganic nonmetal	0.10	0.00	0.10	0.00	0.00	0.00
	Uncategorized metal	112.92	473.57	586.49	0.00	0.00	0.00
	Vitrified	392.38	328.63	721.01	0.00	0.00	0.00
	Subtotal	2,220.27	2,640.37	4,860.64	0.89	0.00	0.89
	Total (major sites)	65,513.03	19,925.17	85,438.20	1,842.08	1,808.82	3,650.90

[a]Lead/cadmium metal wastes include materials that contain either lead or cadmium or both.

Table 3.8. Estimated final waste-form volume (m^3) composition of retrievably stored and projected TRUW for small-quantity and commercial sites

Major sites	Category	Contact-handled			Remote-handled		
		Stored	Projected	Total	Stored	Projected	Total
		Small-quantity sites (SQS)					
Ames	Solidified inorganics	0.00	1.25	1.25	0.00	0.00	0.00
ANL–W	Combustible	0.00	6.80	6.80	0.00	0.00	0.00
	Heterogeneous	6.99	22.20	29.19	1.60	21.25	22.85
	Uncategorized metal	0.00	16.50	16.50	20.49	0.85	21.34
	Subtotal	6.99	45.50	52.49	22.09	22.10	44.19
ARCO	Heterogeneous	0.21	0.42	0.63	0.00	0.00	0.00
BAPL	Heterogeneous	0.00	0.00	0.00	0.00	2.22	2.22
	Inorganic nonmetal	0.00	0.21	0.21	0.00	0.00	0.00
	Uncategorized metal	0.00	122.85	122.85	0.00	0.00	0.00
	Subtotal	0.00	123.06	123.06	0.00	2.22	2.22
BCL	Heterogeneous	0.00	0.00	0.00	0.00	368.75	368.75
ETEC	Heterogeneous	1.68	0.00	1.68	0.00	0.00	0.00
	Lead/cadmium metal waste[a]	0.00	0.00	0.00	5.40	0.50	5.90
	Subtotal	1.68	0.00	1.68	5.40	0.50	5.90
KAPL	Heterogeneous	23.90	10.40	34.30	0.00	0.00	0.00
LBNL	Heterogeneous	0.87	1.04	1.91	0.00	0.00	0.00
MURR	Heterogeneous	0.21	0.62	0.83	0.00	0.00	0.00
PAD	Solidified inorganics	4.08	0.00	4.08	0.00	0.00	0.00
PANT	Heterogeneous	0.62	0.00	0.62	0.00	0.00	0.00
SNL/NM	Heterogeneous	8.23	3.75	11.98	0.00	0.00	0.00
TBE	Inorganic nonmetal	0.21	0.00	0.21	0.00	0.00	0.00
USAMC	Heterogeneous	2.50	0.00	2.50	0.00	0.00	0.00
	SQS subtotal	49.50	186.04	235.54	27.49	393.57	421.06

Table 3.8 (continued)

Major sites	Category	Contact-handled			Remote-handled		
		Stored	Projected	Total	Stored	Projected	Total
		Commercial site					
WVDP	Filter	0.00	0.00	0.00	48.71	28.56	77.27
	Heterogeneous	18.36	143.64	162.00	18.42	0.00	18.42
	Lead/cadmium metal waste[a]	3.03	0.00	3.03	0.00	0.00	0.00
	Solidified inorganics	5.20	0.00	5.20	0.00	0.00	0.00
	Uncategorized metal	0.42	0.00	0.42	416.50	0.00	416.50
	Unknown	10.40	0.00	10.40	0.00	0.00	0.00
	Commercial site subtotal	37.41	143.64	181.05	483.63	28.56	512.19
	Grand total	86.91	329.68	416.59	511.12	422.13	933.25

[a]Lead/cadmium metal wastes include materials that contain either lead or cadmium or both.

Table 3.9. Summary of decayed radioactivity (Ci) isotopic content of retrievably stored CH TRUW[a]

Site	^{238}Pu	^{239}Pu	^{240}Pu	^{241}Pu	^{241}Am	Total curies	Curies (%)
			Major sites				
ANL-E	2.14E+00	3.28E+01	9.42E+00	5.98E+01	5.73E+00	1.10E+02	0.00
Hanford	8.03E+04	2.76E+04	6.27E+03	9.18E+04	3.54E+03	2.10E+05	8.31
INEEL	5.93E+04	4.01E+04	9.82E+03	1.38E+05	9.01E+04	3.37E+05	13.39
LANL	1.27E+05	3.47E+04	8.62E+03	9.72E+04	1.71E+04	2.85E+05	11.29
LLNL	1.06E+02	1.80E+02	7.17E+01	1.74E+03	1.68E+02	2.27E+03	0.09
Mound	1.53E+03	2.98E+01	0.00E+00	0.00E+00	0.00E+00	1.56E+03	0.06
NTS	1.14E+02	2.59E+03	1.88E+01	2.26E+02	2.82E+02	3.23E+03	0.13
ORNL	1.62E+03	9.39E+02	9.60E+02	4.57E+04	1.59E+03	5.08E+04	2.02
RFETS	8.42E+03	1.95E+05	4.97E+04	7.43E+05	1.32E+05	1.13E+06	44.75
SRS	4.28E+05	8.21E+03	2.02E+03	4.85E+04	2.93E+03	4.90E+05	19.43
Subtotal	7.06E+05	3.09E+05	7.74E+04	1.17E+06	2.48E+05	2.51E+06	99.47
			Small-quantity sites (SQS)				
Ames	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
ANL-W	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
ARCO	0.00E+00	4.13E-03	0.00E+00	3.70E+02	0.00E+00	3.70E+02	0.01
BCL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
BAPL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
ETEC	7.20E-03	4.70E-02	2.20E-02	6.11E-01	3.19E-02	7.19E-01	0.00
KAPL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
LBNL	4.70E-05	4.10E-03	1.07E-03	1.13E-07	2.31E-02	2.83E-02	0.00
MURR	0.00E+00	2.48E-02	0.00E+00	0.00E+00	3.32E-01	3.57E-01	0.00
PAD	0.00E+00	2.06E-01	0.00E+00	0.00E+00	8.30E-02	2.89E-01	0.00
PANT	0.00E+00	5.55E-02	0.00E+00	0.00E+00	0.00E+00	5.55E-02	0.00
SNL/NM	2.77E-01	3.96E+00	9.11E-04	0.00E+00	1.17E+00	5.41E+00	0.00
TBE	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
USAMC	0.00E+00	1.80E+01	0.00E+00	0.00E+00	0.00E+00	1.80E+01	0.00
Subtotal	2.84E-01	2.23E+01	2.40E-02	3.71E+02	1.64E+00	3.95E+02	0.02

Table 3.9 (continued)

Site	^{238}Pu	^{239}Pu	^{240}Pu	^{241}Pu	^{241}Am	Total curies	Curies (%)
			Commercial site				
WVDP	0.00E+00	0.00E+00	0.00E+00	3.43E+01	2.15E+00	3.65E+01	0.00
Total (all sites)	7.06E+05	3.09E+05	7.74E+04	1.17E+06	2.48E+05	2.51E+06	99.49
Total curies, %	28.03	12.27	3.07	46.28	9.83		
Cumulative, %	28.03	40.30	43.37	89.65	99.49		

[a]Decayed to the end of CY 1996.

Table 3.10. Summary of decayed mass (g) isotopic content of retrievably stored CH TRUW[a]

Site	^{232}Th	^{235}U	^{238}U	^{239}Pu	^{240}Pu	Total grams	Grams (%)
			Major sites				
ANL-E	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
Hanford	5.59E+05	1.61E+05	1.43E+07	4.46E+05	2.76E+04	1.55E+07	56.14
INEEL	3.01E+06	2.88E+04	3.44E+05	6.47E+05	4.33E+04	4.07E+06	14.76
LANL	2.12E+04	4.08E+05	3.09E+06	5.59E+05	3.80E+04	3.75E+06	13.58
LLNL	1.33E-08	2.95E+02	9.67E+04	2.91E+03	3.16E+02	1.00E+05	0.36
Mound	0.00E+00	1.24E-01	0.00E+00	4.81E+02	0.00E+00	4.81E+02	0.00
NTS	9.47E-09	2.62E+01	4.88E+02	4.18E+04	8.28E+01	4.24E+04	0.15
ORNL	7.07E+03	2.90E+03	1.29E+05	1.51E+04	4.23E+03	1.58E+05	0.57
RFETS	2.99E-05	8.36E+02	2.37E-02	3.15E+06	2.19E+05	3.37E+06	12.21
SRS	1.05E+05	1.06E+03	2.73E+03	1.33E+05	8.91E+03	2.50E+05	0.91
Subtotal	3.70E+06	2.36E+05	1.80E+07	4.99E+06	3.41E+05	2.72E+07	98.69
			Small-quantity sites (SQS)				
Ames	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
ANL-W	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
ARCO	0.00E+00	3.76E-06	3.47E-01	6.65E-02	0.00E+00	4.14E-01	0.00
BCL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
BAPL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
ETEC	7.18E-12	1.50E-04	2.91E-08	7.58E-01	9.69E-02	8.55E-01	0.00
KAPL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
LBNL	1.19E-12	1.87E-06	6.45E-06	6.61E-02	4.70E-03	7.82E-02	0.00
MURR	0.00E+00	3.18E-05	3.60E-01	3.99E-01	0.00E+00	7.59E-01	0.00
PAD	0.00E+00	6.16E-04	0.00E+00	3.32E+00	0.00E+00	3.32E+00	0.00
PANT	0.00E+00	7.59E-05	0.00E+00	8.95E-01	0.00E+00	8.95E-01	0.00
SNL/NM	2.04E-15	1.81E-03	0.00E+00	6.39E+01	4.01E-03	6.39E+01	0.00
TBE	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
USAMC	0.00E+00	0.00E+00	0.00E+00	2.90E+02	0.00E+00	2.90E+02	0.00
Subtotal	8.37E-12	2.69E-03	7.07E-01	3.59E+02	1.06E-01	3.60E+02	0.00

Table 3.10 (continued)

Site	^{232}Th	^{235}U	^{238}U	^{239}Pu	^{240}Pu	Total grams	Grams (%)
			Commercial site				
WVDP	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
Total (all sites)	3.70E+06	2.36E+05	1.80E+07	5.00E+06	3.41E+05	2.72E+07	98.69
Total grams, %	13.41	0.85	65.08	18.10	1.24		
Cumulative, %	13.41	14.26	79.34	97.44	98.69		

[a]Decayed to the end of CY 1996.

Table 3.11. Summary of decayed radioactivity (Ci) isotopic content of retrievably stored RH TRUW[a]

Site	^{60}Co	^{90}Sr	^{90}Y	^{137}Cs	^{137m}Ba	^{152}Eu	^{154}Eu	^{241}Pu	^{244}Cm	Total curies	Curies (%)
					Major sites						
ANL-E	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
Hanford	2.97E+02	6.62E+03	6.62E+03	7.68E+03	7.27E+03	0.00E+00	0.00E+00	7.56E+03	0.00E+00	3.60E+04	39.57
INEEL	1.82E+01	1.50E+03	1.50E+03	1.69E+03	1.60E+03	1.87E-02	3.16E-01	5.25E+01	5.56E-02	6.36E+03	6.98
LANL	3.65E+00	2.56E+03	2.56E+03	2.81E+03	2.66E+03	2.75E-04	1.79E-02	6.02E+01	0.00E+00	1.07E+04	11.69
LLNL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
Mound	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
NTS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.29E-05	1.49E+02	1.49E+02	0.16
ORNL	2.81E+02	1.31E+04	1.31E+04	2.62E+03	2.48E+03	2.00E+03	9.59E+02	3.26E+01	5.20E+02	3.51E+04	38.52
RFETS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
SRS	0.00E+00	6.69E+00	6.69E+00	6.70E+00	6.34E+00	0.00E+00	0.00E+00	0.00E+00	4.51E+00	3.09E+01	0.03
Subtotal	6.00E+02	2.38E+04	2.38E+04	1.48E+04	1.40E+04	2.00E+03	9.59E+02	7.71E+03	6.74E+02	8.83E+04	96.96
					Small-quantity sites (SQS)						
Ames	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
ANL-W	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
ARCO	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
BCL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
BAPL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
ETEC	2.02E+00	2.65E+00	2.65E+00	2.82E+00	2.66E+00	0.00E+00	0.00E+00	4.58E+00	0.00E+00	1.74E+01	0.02
KAPL	1.16E-01	2.97E+01	2.97E+01	2.98E+01	2.81E+01	0.00E+00	6.61E-01	3.68E-01	0.00E+00	1.18E+02	0.13
LBNL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
MURR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
PAD	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
PANT	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
SNL/NM	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
TBE	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
USAMC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
Subtotal	2.14E+00	3.24E+01	3.24E+01	3.26E+01	3.08E+01	0.00E+00	6.61E-01	4.95E+00	0.00E+00	1.36E+02	0.15

Table 3.11 (continued)

Site	^{60}Co	^{90}Sr	^{90}Y	^{137}Cs	^{137m}Ba	^{152}Eu	^{154}Eu	^{241}Pu	^{244}Cm	Total curies	Curies (%)
					Commercial site						
WVDP	0.00E+00	1.91E+01	1.91E+01	5.23E+01	4.95E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.40E+02	0.15
Total (all sites)	6.02E+02	2.38E+04	2.38E+04	1.49E+04	1.41E+04	2.00E+03	9.60E+02	7.71E+03	6.74E+02	8.86E+04	97.27
Total curies, %	0.66	26.17	26.17	16.35	15.47	2.20	1.05	8.46	0.74		
Cumulative, %	0.66	26.83	53.00	69.35	84.82	87.02	88.07	96.53	97.27		

[a]Decayed to the end of CY 1996.

Table 3.12. Summary of decayed mass (g) isotopic content of retrievably stored RH TRUW[a]

Site	^{232}Th	^{233}U	^{235}U	^{238}U	^{239}Pu	Total grams	Grams (%)
			Major sites				
ANL-E	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
Hanford	1.81E+04	4.72E+01	5.99E+04	3.42E+04	6.61E+03	1.19E+05	2.23
INEEL	6.80E+02	2.52E+01	2.36E+03	4.01E+03	4.98E+02	7.57E+03	0.14
LANL	3.15E-08	2.32E-09	3.84E+03	6.82E+00	3.97E+03	7.82E+03	0.15
LLNL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
Mound	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
NTS	1.38E-10	1.59E-08	1.82E-02	9.71E-12	3.80E+01	3.80E+01	0.00
ORNL	2.08E+06	3.08E+03	8.08E+03	3.10E+06	4.27E+02	5.19E+06	97.40
RFETS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
SRS	8.96E-15	1.30E-08	5.84E-01	0.00E+00	1.71E-01	7.55E-01	0.00
Subtotal	2.10E+06	3.15E+03	7.42E+04	3.14E+06	1.15E+04	5.33E+06	99.92
			Small-quantity sites (SQS)				
Ames	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
ANL-W	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
ARCO	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
BCL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
BAPL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
ETEC	2.51E-11	3.66E-10	1.07E-03	1.29E-08	9.89E+00	9.89E+ 00	0.00
KAPL	7.11E-14	1.39E-11	2.02E-06	9.22E-05	2.66E-02	2.67E-02	0.00
LBL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
MURR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
PAD	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
PANT	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
SNL/NM	0.00E+00	3.17E-10	5.47E-09	0.00E+00	3.23E-05	3.23E-05	0.00
TBE	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
USAMC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
Subtotal	2.52E-11	6.97E-10	1.07E-03	9.22E-05	9.92E+00	9.92E+00	0.00
			Commercial site				
WVDP	0.00E+00	3.57E-09	0.00E+00	0.00E+00	0.00E+00	1.98E+01	0.00
Total (all sites)	2.10E+06	3.15E+03	7.42E+04	3.14E+06	1.16E+04	5.33E+06	99.92
Total grams, %	39.38	0.06	1.39	58.88	0.22		
Cumulative, %	39.38	39.44	40.83	97.71	99.92		

[a]Decayed to the end of CY 1996.

Table 3.13. Summary of buried TRUW volume and radioactivity as of EOCY 1996[a]

Site	Cumulative volume (m^3)	Cumulative as-stored radioactivity		Decayed radioactivity	
		All nuclides (10^3 Ci)	TRU only (10^3 Ci)	All nuclides (10^3 Ci)	TRU only (10^3 Ci)
Major sites					
ANL-E	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hanford[b]	6.36E+04	5.13E+02	2.45E+01	1.07E+02	2.79E+01
INEEL	5.70E+04	2.49E+02	c	c	c
LANL	1.40E+04	d	e	d	d
LLNL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mound	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NTS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ORNL	5.72E+02	f	f	f	f
RFETS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SRS	4.87E+03	3.37E+01	3.37E+01	3.05E+01	3.05E+01
Subtotal	1.40E+05	7.96E+02	5.82E+01	1.38E+02	5.84E+01
Small-quantity sites (SQS)					
Ames	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ANL-W	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ARCO	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BCL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BAPL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETEC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
KAPL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LBNL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MURR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PAD	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PANT	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SNL/NM	1.33E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TBE	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
USAMC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Subtotal	1.33E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Commercial site					
WVDP	1.35E+03	6.52E+02	6.52E+02	0.00E+00	0.00E+00
Total	1.41E+05	1.45E+03	7.10E+02	1.38E+02	5.84E+01

[a]Decayed to the end of CY 1996.

[b]Radioactivity data reported by Hanford is decayed to EOCY 1993.

[c]INEEL data did not include any isotopic compositions, so no TRU radionuclide or decay calculations could be made.

[d]Information not available.

[e]An estimate of 9230 Ci was reported for LANL as-stored TRU alpha radioactivity (as of the end of CY 1991) in *Integrated Data Base for 1992: U.S. Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, DOE/RW-0006, Rev. 8 (October 1992).

[f]The volume represents only the post-1969 disposal volume. Pre-1970 volumes, associated cumulative activities, and radionuclide compositions are not currently available.

Table 3.14. Volumes and radioactivities of TRU-contaminated soils[a]

Site	Soil contaminated with TRUW			
	Solid		Liquid	
	Volume (m^3)	Radioactivity (Ci)	Volume (m^3)	Radioactivity (Ci)
	Major sites			
ANL-E	0	0	0	0
Hanford	b	b	32,000	b
INEEL	c	c	c	c
LANL	108	257	0	0
LLNL	0	0	0	0
Mound	c	c	c	c
NTS	c	c	c	c
ORNL	c	c	c	c
RFETS	2	40	c	c
SRS	0	0	0	0
	Small-quantity sites (SQS)			
Ames	0	0	0	0
ANL-W	0	0	0	0
ARCO	0	0	0	0
BCL	0	0	0	0
BAPL	0	0	0	0
ETEC	0	0	0	0
KAPL	0	0	0	0
LBNL	0	0	0	0
MURR	c	c	c	c
PAD	c	c	c	c
PANT	0	0	0	0
SNL/NM	c	c	c	c
TBE	0	0	0	0
USAMC	c	c	c	c
	Commercial site			
WVDP	c	c	c	c

[a]See ref. 6.

[b]Hanford volumes included in buried TRUW. Previous total radioactivity content estimated at about 81,000 Ci. Current TRU radioactivity reported at about 17,000 Ci.

[c]Information either not provided or available.

4. LOW-LEVEL WASTE

4.1 INTRODUCTION

As used in this chapter, low-level waste (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 (HLW), transuranic waste (TRUW), spent nuclear fuel (SNF), or by-product material specified as uranium or thorium tailings and waste. Tailings (viz., mill tailings) are considered in Chapters 5 and 6. Another waste classification not delineated in this chapter is "mixed" low-level waste (MLLW), which contains both chemically hazardous and radioactive constituents (Chapter 8). Specific definitions of these waste types (as defined by DOE Order 5820.2A) are given in the glossary of this report. DOE generates LLW through its defense activities, naval nuclear propulsion program, and various research and development (R&D) activities. The data for DOE sites represent a summary of information obtained from each site.[1]

Disposal of LLW at commercial sites accounted for about 32 vol % of all LLW disposed at end of fiscal year (EOFY) 1996. Commercially disposed LLW is generally divided into five categories: academic, government, industrial, medical, and utility.[2] The academic category includes university hospitals and university medical and nonmedical research facilities. The government category includes state and non-DOE federal agencies. The industrial category is comprised of private entities such as R&D companies, manufacturers, nondestructive-testing operations, mining works, fuel fabrication facilities, and radiopharmaceutical manufacturers. The medical category includes hospitals and clinics, research facilities, and private medical offices. The utility category includes commercial nuclear reactors. In earlier revisions of the IDB report, 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 categories previously described were used, starting with Rev. 9 of the IDB report.

Some LLW is also generated by DOE environmental restoration programs (see Chapter 6). Other LLW will be generated by nonroutine D&D operations. Waste from past commercial D&D operations is included in the disposed commercial waste inventories reported in this chapter.

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 disposal are given in Table 4.1. Historical and projected annual data for disposed DOE LLW are presented in Table 4.2. Similar data are shown for disposed commercial LLW in Table 4.3.

4.2 DOE LLW

4.2.1 Inventories of LLW at DOE Sites

An abridged picture of DOE LLW inventories, projections, and characteristics through EOFY 1996 is given in Figs. 4.1–4.4, as well as Tables 4.1, 4.2, and 4.4–4.16. The data in these tables are derived from DOE site responses to the DOE Office of Environmental Management (DOE/EM) Technical Information Collection Database.[1] As reflected in the tables, DOE LLW data can be grouped into three major areas: generation, storage, and disposal. Summaries of DOE site-generated LLW volumes are presented in Tables 4.6, 4.8, and 4.9. Table 4.10 provides summary volumes of LLW-contaminated media in storage at DOE sites.

A summary of DOE LLW disposed volume is presented in Tables 4.1, 4.2, 4.4, 4.7, 4.11, and 4.13. Before October 1979, some LLW generated by DOE contractors was shipped to commercial disposal sites. The volume and radioactivity data for DOE LLW that were shipped to commercial disposal sites are contained in the commercial LLW tables of this chapter.

Currently, LLW generated by DOE activities is generally disposed of at DOE sites (see Figs. 4.3 and 4.4).

Small quantities of DOE LLW have been disposed of by dumping the LLW into the sea or by hydrofracture.[3] Table 4.12 shows the estimated quantity and radioactivity of LLW disposed of by these methods. Dumping of LLW into the sea was halted by the United States in 1970, and hydrofracture was terminated in 1983.

4.2.2 Characterization of LLW at DOE Sites

Based on information reported in ref. 1, summaries of the characteristics of DOE LLW by matrix parameter category (MPC) are reported in Tables 4.6–4.9 and 4.11. Table 4.5 provides definitions of each of the MPC codes used in the tables. For DOE site activities sponsored by the Office of Waste Management (EM-30), this breakdown provides a detailed description of the LLW that has been generated or disposed. However, the DOE Environmental Restoration Program (EM-40) has large volumes of LLW currently in storage (such as unsolidified sludges and residues) which do not fit into the categories described in Table 4.5. A breakdown of this data, by DOE site, is provided in Table 4.10.

In addition to shallow-land burial, DOE LLW has been disposed by dumping wastes into the sea and hydrofracture (Table 4.12). Most of the DOE wastes that were dumped into the sea 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.[4] Waste was mixed with a blend of cement and other additives, and the resulting grout was injected into shale at depths of 200 to 300 m. The injected grout hardened into thin, horizontal sheets several hundred meters wide.

4.2.3 DOE LLW Projections

LLW generation and disposal projections reported by DOE sites are presented in Tables 4.6 and 4.7, respectively, for three fiscal-year (FY) time periods: 1997, 1998–2006, and 2007–2030. The data presented in Tables 4.6 and 4.7 represent the total LLW generation or disposal, respectively, during each of the three periods.

The projected disposal data (Table 4.7), combined with actual 1996 (Table 4.7) and historical (ref. 5) disposal data, were used to calculate historical and projected volume, radioactivity, and thermal power of DOE-disposed LLW. LLW data were collected by a different breakdown in previous revisions of the IDB report (Revs. 1–10). Historical disposal data through 1993 were decayed from the year of addition through the year 2030 using the representative radionuclide compositions[6] given in Table A.2 of Appendix A. Beginning with 1994, disposal data were decayed from the year of addition through 2030 using radionuclide compositions provided by each disposal site in the data call for Rev. 11 of this report. Disposed radioactivity data for 1996–2030 were not available.[1] Consequently, radioactivity values based on historical disposals were estimated for this time period.

Projected volume, radioactivity, and thermal power for disposed DOE LLW are presented in Tables 4.2 and 4.13–4.16. Table 4.2 reports projections of total disposed DOE LLW (summarizing Tables 4.13–4.16), while Table 4.13 summarizes all disposed DOE LLW except LLW that results from final HLW form production. Contributions from the latter are reported separately for each of three DOE sites in Tables 4.14–16. Projections of the characteristics of low-activity waste (LAW) generated from Hanford tank HLW immobilization activities are provided in Table 4.14. Corresponding projections for LLW grout produced from INEEL HLW immobilization activities are reported in Table 4.15, which is followed by Table 4.16, which summarizes projections of saltstone, a LLW by-product from the solidification of HLW at SRS. As shown in Fig. 2.7 in Chapter 2, saltstone is to be stored in concrete vaults at SRS. HLW immobilization is also taking place at the West Valley Demonstration Project (WVDP), but the quantity of LLW being generated from the immobilization is not significant.

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: Barnwell, South Carolina, and Richland, Washington. Commercial operations at the Maxey Flats, Kentucky; West Valley, New York; Sheffield, Illinois; and Beatty, Nevada, sites have been halted. 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 EOFY 1996 are listed in Tables 4.17 and 4.18, respectively (compiled from refs. 5 and 7). 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 those through 1994 are given in ref. 5. Quantities of LLW shipped to disposal sites during 1996 (Jan. 1–Sept. 30) are listed in Table 4.19 on a state-by-state basis.[7] Table 4.20 provides a breakdown of waste received at Barnwell and Richland in 1996 (Jan. 1—Sept. 30) by category (i.e., academic, government, industrial, medical, or utility LLW).

Table 4.3 is a summary of historical and projected volumes, radioactivity (decayed), and thermal power for commercial LLW. Projections are made only through 2005 because of large uncertainties in commercial disposal facility operations. Included in Table 4.3 are contributions from the drums of cemented LLW (totaling over 5,000 m^3) generated by the WVDP as a result of the vitrification of HLW.

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.[8] 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 A.3 of Appendix A. 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 (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.[9] In 10 CFR Part 61 (ref. 8), 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)[10] 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 limited information on the sources, volumes, and characteristics of GTCC LLW.[11]

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."[12] 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 of NRC licensing. A generic description of estimated sources and forms of GTCC LLW is presented in Table A.4 of Appendix A.

In 1994, DOE revised an earlier study to provide information about estimates of current and future GTCC LLW to the year 2035 (2055 in some instances). Information garnered during the study[13] includes identification of generators, waste form characteristics, volumes, and radionuclide activities. The study categorizes GTCC LLW as (1) nuclear utilities waste, (2) sealed-sources waste, (3) DOE-held potential GTCC LLW, and (4) other generator waste. Various scenarios for data projection were 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 concentration values applied to the packaged volumes. Each of the three scenarios is treated for three cases: low, base, and high.

Based on base-case projections of after-concentration-averaged-packaged waste to the year 2035, the study determined that the largest volume of GTCC wastes (approximately 53%) is generated by nuclear power plants. The "other" generator waste category contributes approximately 31% of the total GTCC LLW volume projected to the year 2035. Sealed sources are about 16% of the total projected volume of GTCC LLW. A summary of historical and projected cumulative volume and radioactivity for GTCC LLW is presented in Table 4.21.

4.3.4 Commercial LLW Disposal Sites

Of the six commercial LLW disposal sites, only two remain open: Barnwell and Richland. Historical information regarding commercial LLW facilities can be found in previous editions of the IDB report. Closure dates for the four closed facilities are presented in the footnotes of Tables 4.17 and 4.18.

The Barnwell, South Carolina, disposal site is operated by Chem-Nuclear Systems, Inc. During the first 9 months of CY 1996, Barnwell received 73 vol % of the total volume of commercial LLW shipped for disposal. Barnwell was scheduled to restrict access to Southeast compact members starting July 1, 1995; however, the state of South Carolina withdrew from the Southeast compact. As a result, Barnwell is open for disposal to all states with the exception of North Carolina.

The Richland, Washington, disposal site is operated by U.S. Ecology, Inc. During the first 9 months of CY 1996, Richland received about 27 vol % of the total volume of commercial LLW shipped for disposal. Richland accepted wastes only from member states of the Northwest and Rocky Mountain compacts (Alaska, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Washington, and Wyoming).

4.3.5 Commercial LLW Projections

This report presents summary information for disposed commercial waste. Historical volume, radioactivity, and thermal power data through 1979 are taken from an earlier version of this report (DOE/RW-0006, Rev. 8). After 1979, the source term for commercial LLW in Table A.3 of Appendix A is used to decay the annual waste additions to the commercial sites.

Projections for disposed commercial LLW are made only through 2005 because of uncertainties in current facility operations and the availability of future sites. Neither Barnwell nor Richland have a published closure date.[7] As a result, for projections, the disposal rates for 1997–2005 are assumed to be the same. Historical and projected volume, radioactivity, and thermal power for disposed commercial LLW are presented in Table 4.3.

4.4 REFERENCES

1. U.S. Department of Energy, Office of Environmental Restoration, Office of Waste Management, *Technical Information Collection Database*, updated through Oct. 30, 1997.

2. R. L. Fuchs, *1996 State-by-State Assessment of Low-Level Radioactive Wastes Received at Commercial Disposal Sites*, DOE/LLW-243, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho (September 1997).

3. U.S. Department of Energy, *Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, DOE/RW-0006, Rev. 1, Oak Ridge National Laboratory, Oak Ridge, Tennessee (December 1985).

4. U.S. Energy Research and Development Administration, Environmental Impact Statement, *Radioactive Waste Facilities*, WASH-1532 (Draft), Oak Ridge National Laboratory, Oak Ridge, Tennessee (January 1974).

5. U.S. Department of Energy, *Integrated Data Base Report—1995: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, DOE/RW-0006, Rev. 12, Oak Ridge National Laboratory, Oak Ridge, Tennessee (December 1996).

6. 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).

7. Ronald L. Fuchs, Lockheed Martin Idaho Technologies Company, National Low-Level Waste Management Program, Idaho Falls, Idaho, correspondence to A. S. Icenhour, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "IDB Submittal Document–RLF-64-97," dated July 10, 1997.

8. U.S. Nuclear Regulatory Commission, "Licensing Requirements for Land Disposal of Radioactive Wastes," *Code of Federal Regulations*, 10 CFR Part 61, Jan. 1, 1997.

9. U.S. Congress, The Low-Level Radioactive Waste Policy Act, Pub. L. 95–573, Dec. 22, 1980.

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

11. U.S. Department of Energy, *Recommendations for Management of Greater-than-Class-C Low-Level Radioactive Waste*, DOE/NE-0077, Washington, D.C. (February 1987).

12. 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).

13. Lockheed Idaho Technologies Company, *Greater-Than-Class-C Low-Level Radioactive Waste Characterization: Estimated Volumes, Radionuclide Activities, and Other Characteristics*, DOE/LLW-114, Rev. 1, Idaho Falls, Idaho (September 1994).

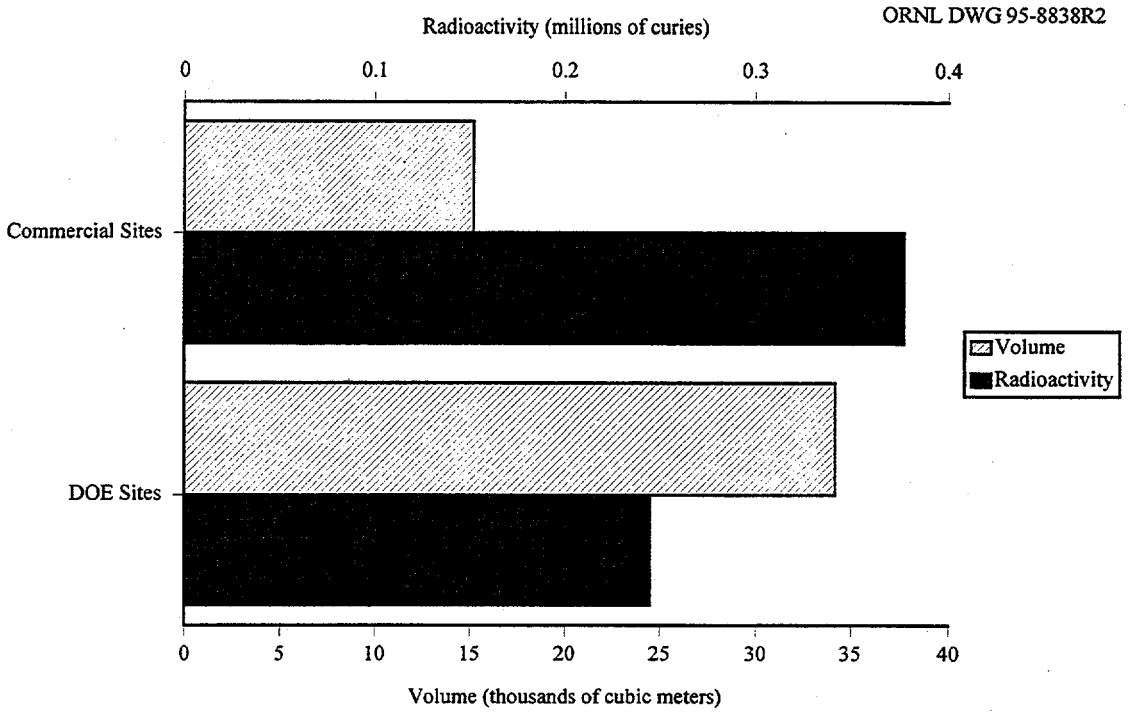
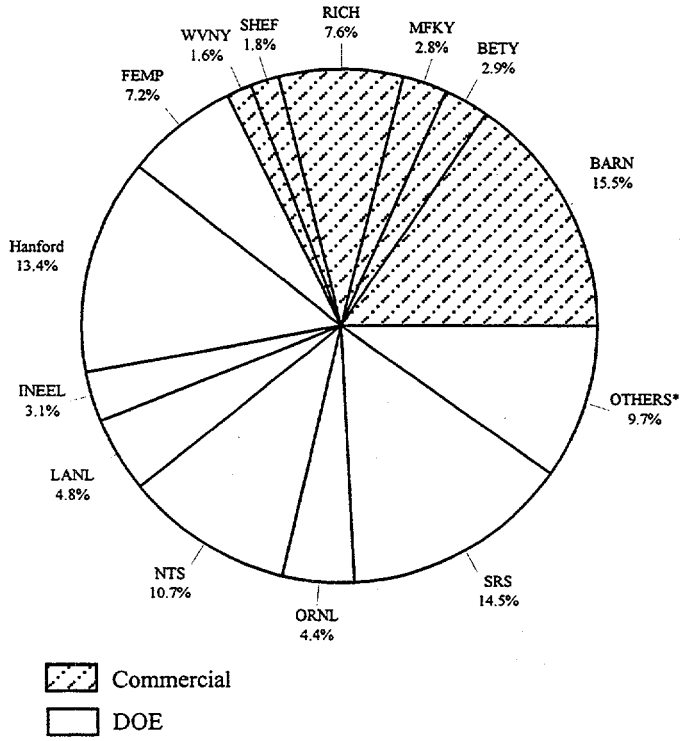


Fig. 4.1. Comparison of volume and radioactivity of LLW disposed of at commercial and DOE facilities during FY 1996.



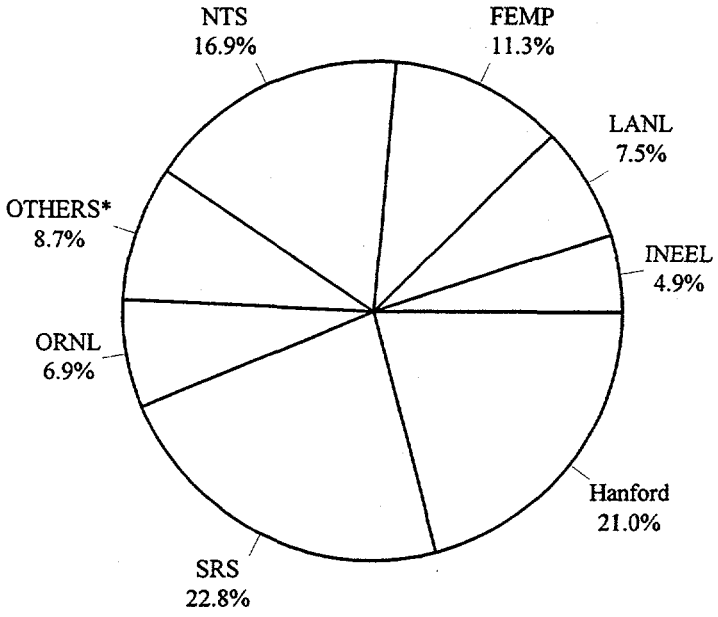
ORNL DWG 95-8839R2

SITE	CUBIC METERS
BARN	7.410E+05
BETY	1.375E+05
MFKY	1.353E+05
RICH	3.663E+05
SHEF	8.833E+04
WVNY	7.707E+04
FEMP	3.432E+05
Hanford	6.399E+05
INEEL	1.502E+05
LANL	2.282E+05
NTS	5.141E+05
ORNL	2.104E+05
SRS	6.935E+05
OTHERS*	4.655E+05
TOTAL	4.791E+06

*Includes contributions from BNL, ETTP, LLNL, PAD, PANT, PORTS, SNL/NM, and Y-12.

Fig. 4.2. Total volume of LLW disposed of by EOFY 1996.

ORNL DWG 95-8845R2

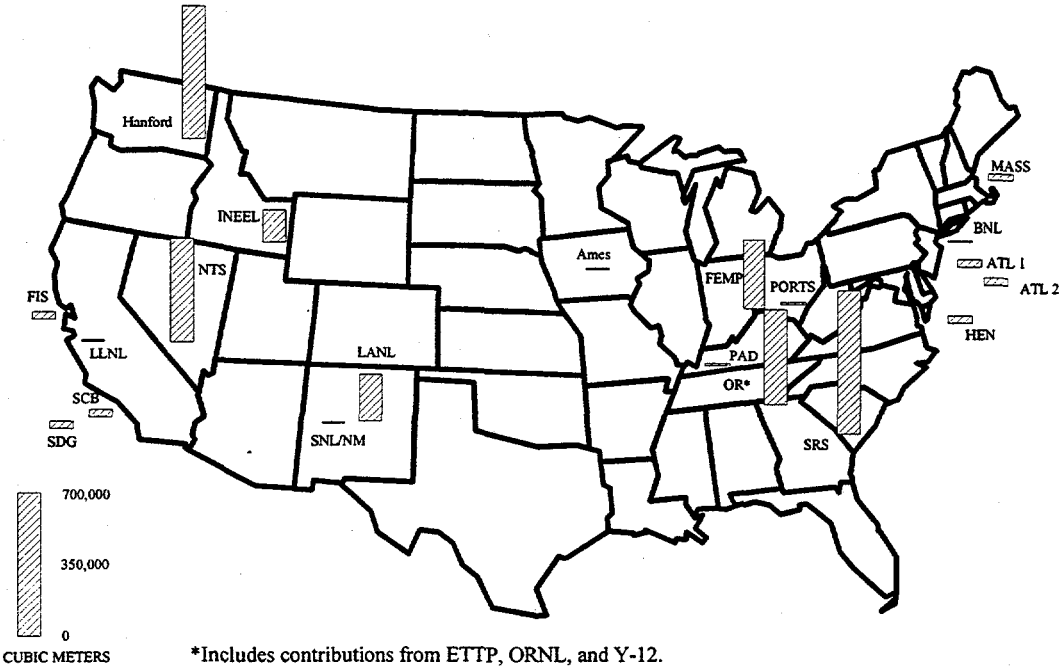


SITE	CUBIC METERS
FEMP	3.432E+05
Hanford	6.399E+05
INEEL	1.502E+05
LANL	2.282E+05
NTS	5.141E+05
ORNL	2.104E+05
SRS	6.935E+05
OTHERS*	2.655E+05
TOTAL	3.045E+06

*Includes contributions from BNL, ETTP, LLNL, PAD, PANT, PORTS, SNL/NM, and Y-12.

Fig. 4.3. Total volume of DOE LLW disposed of by EOFY 1996.

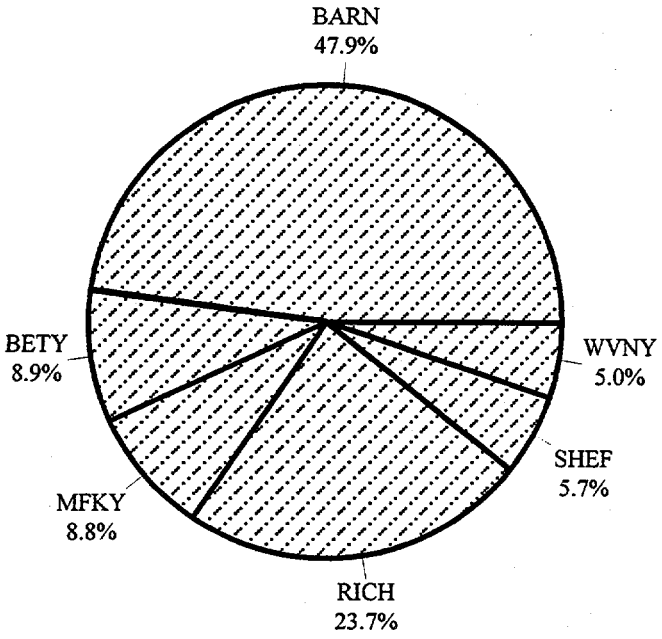
ORNL DWG 95-8846



*Includes contributions from ETTP, ORNL, and Y-12.

Fig. 4.4. Locations and total volumes of DOE LLW disposed of by EOFY 1996.

ORNL DWG 95-8129R2



SITE	CUBIC METERS
BARN	7.410E+05
BETY	1.375E+05
MFKY	1.353E+05
RICH	3.663E+05
SHEF	8.833E+04
WVNY	7.707E+04
TOTAL	1.545E+06

Fig. 4.5. Total volume of commercial LLW disposed of by EOFY 1996.

ORNL DWG 95-8130R2

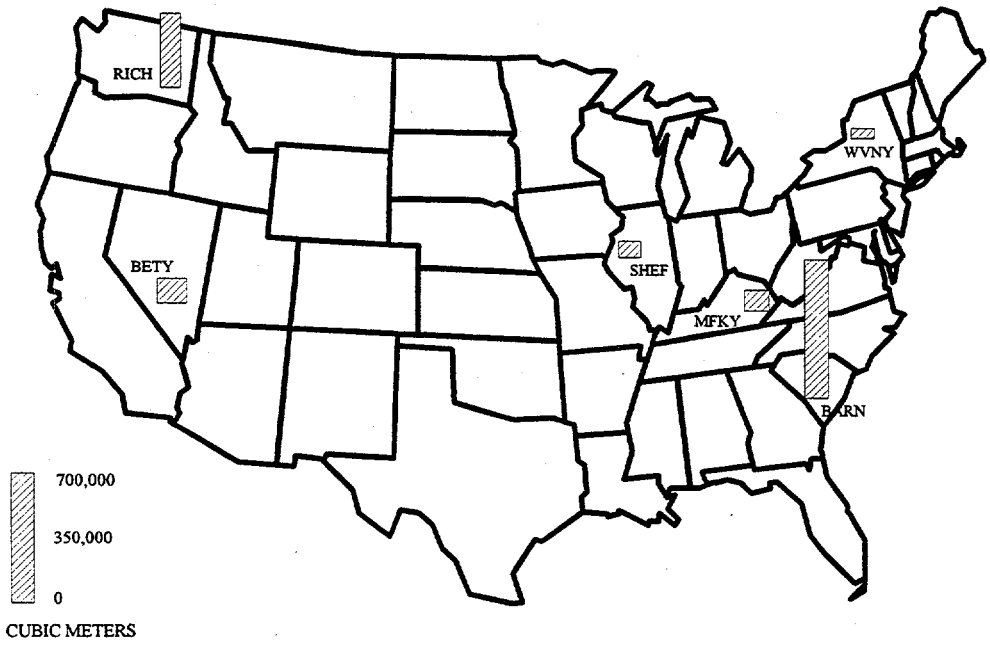


Fig. 4.6. Locations and total volumes of commercial LLW disposed of by EOFY 1996.

Table 4.1. Summary of characteristics for disposed LLW as of EOFY 1996

Category	Volume (10^3 m^3)		Radioactivity (10^3 Ci)		Thermal power (W)	
	Annual[a]	Cumulative	Annual	Cumulative	Annual	Cumulative
DOE sites[b]	33.7	3,045	245	12,148	1,331	22,022
Major commercial sites[c]	15.2	1,545	377	5,136	1,905	19,917
Other commercial sites[d]	44.3[e]	200	f	f	f	f
Total	93.2	4,790	622	17,284	3,236	41,939

[a]Addition during FY 1996.

[b]Excludes contributions of LLW from final HLW form production.

[c]Includes contributions from Beatty, West Valley, Maxey Flats, Richland, Sheffield, and Barnwell sites.

[d]Commercially operated facilities that dispose of LLW, MLLW, NARM, and 11e(2) by-product material for both federal and private customers.

[e]Contribution during the period Jan. 1–Sept. 30, 1996.

[f]Unavailable.

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

End of year[b]	Volume (10^3 m^3)		Radioactivity (10^3 Ci)		Thermal power (W)	
	Annual	Cumulative	Annual	Cumulative[c]	Annual	Cumulative
1990	60.0	2,759	545	13,516	2,013	17,844
1991	53.6	2,812	717	13,277	2,788	18,220
1992	48.3	2,860	1,078	13,401	4,947	20,741
1993	50.5	2,911	894	13,147	3,263	20,398
1994	52.1	2,963	621	12,858	3,463	21,534
1995	48.5	3,011	422	12,550	2,378	22,195
1996	34.2	3,068	245	12,148	1,333	22,024
1997	35.0	3,103	472	12,032	2,602	23,253
1998	52.7	3,156	373	11,827	2,162	23,914
1999	66.1	3,222	374	11,635	2,159	24,487
2000	55.7	3,277	374	11,453	2,155	24,973
2001	51.6	3,329	374	11,280	2,150	25,373
2002	54.2	3,384	571	11,313	2,697	26,251
2003	55.0	3,439	567	11,346	2,679	27,041
2004	53.5	3,492	562	11,377	2,663	27,760
2005	55.9	3,548	558	11,408	2,650	28,416
2006	54.9	3,603	554	11,438	2,637	29,016
2007	47.7	3,651	432	11,352	1,899	28,837
2008	46.4	3,697	428	11,283	1,888	28,720
2009	47.9	3,745	424	11,228	1,878	28,635
2010	45.7	3,791	420	11,184	1,867	28,578
2011	45.9	3,836	416	11,148	1,856	28,542
2012	58.7	3,895	981	11,687	3,444	30,121
2013	64.1	3,959	1,331	12,574	4,426	32,668
2014	64.3	4,024	1,306	13,421	4,358	35,110
2015	65.5	4,089	1,281	14,233	4,290	37,450
2016	63.2	4,152	1,258	15,009	4,225	39,685
2017	64.0	4,216	1,235	15,749	4,162	41,820
2018	63.5	4,280	1,212	16,456	4,099	43,850
2019	39.5	4,319	1,190	17,128	4,038	45,791
2020	41.5	4,361	1,161	17,760	3,926	47,588
2021	40.8	4,402	1,140	18,364	3,867	49,287
2022	19.0	4,421	247	18,063	1,360	48,438
2023	19.1	4,440	247	17,773	1,360	47,629
2024	19.1	4,459	247	17,494	1,360	46,851
2025	19.1	4,478	247	17,222	1,360	46,080
2026	19.5	4,497	247	16,962	1,360	45,338
2027	19.5	4,517	247	16,710	1,360	44,613
2028	19.8	4,537	247	16,466	1,360	43,915
2029	20.3	4,557	247	16,232	1,360	43,233
2030	20.3	4,577	247	16,004	1,360	42,567

[a]Summation of values in Tables 4.13 (buried DOE LLW, except LLW from final HLW form production) and 4.14–4.16 (LLW from final HLW form production).

[b]Historical data prior to 1996 are expressed on an EOCY basis.

[c]The radioactivity added each year for each waste type is decayed as described in the footnotes of Tables 4.13.

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

End of year	Volume (10^3 m^3)		Radioactivity (10^3 Ci)		Thermal power (W)	
	Annual	Cumulative	Annual	Cumulative[b]	Annual	Cumulative
1990	33.5	1,387	549	4,979	2,774	16,457
1991	38.8	1,426	800	5,272	4,044	18,424
1992	49.8	1,476	1,000	5,708	5,057	21,117
1993	23.4	1,499	643	5,709	3,252	21,627
1994	25.0	1,524	751	5,841	3,799	22,746
1995	19.9	1,544	172	5,376	869	20,815
1996[c]	7.0	1,551	288	5,136	1,455	19,917
1997[d]	9.4	1,560	384	5,030	1,940	19,643
1998	9.4	1,570	384	4,936	1,940	19,401
1999	9.4	1,579	384	4,856	1,940	19,206
2000	9.4	1,588	384	4,787	1,940	19,053
2001	9.4	1,598	384	4,727	1,940	18,937
2002	9.4	1,607	384	4,677	1,940	18,853
2003	9.4	1,617	384	4,633	1,940	18,798
2004	9.4	1,626	384	4,595	1,940	18,767
2005	9.4	1,635	384	4,562	1,940	18,757

[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. Contributions for West Valley include over 5,000 m^3 generated during CY 1987 through CY 1995 as a result of preparation activities for HLW vitrification.

[b]The radioactivity through 1979 was decayed using a multiple source term methodology (see Tables 4.3 and 4.20–4.25 of Rev. 8 of this report for a description of this method). After 1979, the radioactivity is decayed from the year of addition using the representative compositions given in Table A.3 of Appendix A.

[c]Data presented are for Jan. 1, 1996, to Sept. 30, 1996, to adjust to a FY basis. Years prior to 1996 are calendar years.

[d]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 2005 because of large uncertainties in commercial disposal facility operations.

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

End of year[c]	Volume of waste disposed annually, 10^3 m^3										
	FEMP	Hanford	INEEL	LANL	NTS	ORNL	SRS	Y-12[d]	All others[e]	Total annual addition	Total rounded off volume
1975[f]	309.3	352.0	84.6	131.6	8.3	181.5	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	11.7	3.2	4.5	57.0	1.3	22.4	2.2	2.0	107.1	1,931
1983	3.4	17.9	5.5	3.2	12.1	1.8	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	0.0	21.1	3.4	4.5	27.9	1.8	30.1	15.0	1.0	104.8	2,348
1987	0.0	20.3	3.0	3.7	81.1	0.5	28.2	16.2	1.0	154.0	2,501
1988	0.0	16.8	2.0	4.3	39.1	0.6	30.2	10.6	1.0	104.6	2,606
1989	0.0	13.7	1.3	6.4	35.0	1.3	26.8	5.7	2.3	92.5	2,699
1990	0.0	13.4	1.8	4.5	9.1	0.3	26.6	4.4	0.0	60.1	2,759
1991	0.0	10.6	1.3	5.8	11.6	0.2	23.8	0.3	0.0	53.6	2,812
1992	0.0	10.9	0.8	2.3	20.1	1.1	13.0	0.0	0.0	48.2	2,860
1993	0.0	12.1	0.9	2.7	18.6	0.8	15.3	0.1	0.0	50.5	2,911
1994	0.0	13.7	1.9	1.9	22.9	0.3	11.4	0.0	0.0	52.1	2,963
1995	0.0	14.9	0.9	1.6	20.0	0.4	10.6	0.0	0.0	48.5	3,011
1996	0.0	9.7	0.3	4.0	12.7	0.4	6.5	0.0	0.0	33.7	3,045
Total	343.2	639.9	150.2	228.2	514.1	210.4	693.5[g]	151.3	114.2	3,045	

[a]No TRUW included; data from refs. 1 and 5. Slight differences in values shown and those actually reported result from round-off and truncation of numbers. Certain of the burial grounds in which these wastes were previously disposed of are being addressed in the Environmental Restoration (EM-40) program.

[b]See Table 4.11 for breakdown of disposed volumes by matrix parameter category (MPC) code.

[c]Data for years 1975–1995 are given on a CY basis. Data for 1996 represent FY data.

[d]Land disposal of LLW at Y-12 was terminated July 1, 1991. A single exception was made in 1993 when waste was placed in the Bear Creek Burial Ground walk-in pits.

[e]Includes contributions from Ames, BNL, ETTP, LLNL, PAD, PANT, PORTS, and SNL/NM.

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

[g]Excludes contributions of LLW from final HLW form production.

Table 4.5. Description of physical forms used to characterize LLW from DOE activities[a]

MPC code	Name	IDB Rev. 12 category[b]	Description
		Liquids	
L0000	Liquids	NA	Liquids and slurries that cannot be categorized as aqueous liquids/slurries or organic liquids because it is not known if the total organic carbon (TOC) level is less or greater than 1%
L1000	Aqueous liquids/slurries	NA	Liquids and slurries containing less than 1% TOC
L1100	Wastewaters	NA	Aqueous liquids and slurries that meet the U.S. Environmental Protection Agency (EPA) Land Disposal Restriction (LDR) criteria for wastewaters [<1% total suspended/settled solids (TSS) content]
L1110	Acidic wastewaters	NA	Wastewaters with a pH $\leq$ 2.0
L1120	Basic wastewaters	NA	Wastewaters with a pH $\geq$ 12.5
L1130	Neutral wastewaters	NA	Wastewaters with 2.0 < pH < 12.5
L1200	Aqueous slurries	NA	Aqueous liquids and slurries for which either (a) it is known that the TSS $\geq$1%, or (b) it is unknown if the TSS $\geq$1%
L2000	Organic liquids	NA	Liquids and slurries containing $\geq$1% TOC
L2000a	Organic liquids—oils	NA	Waste meeting the definition of L2000 for which the organic component is oil
L2120	Aqueous non-halogenated organic compound (HOC) organic liquids	NA	Aqueous and organic liquids that contain less than 1000 ppm HOC
L2220	Non-HOC pure organic liquids	NA	Pure organic liquids that contain less than 1000 ppm HOC
		Solids	
S0000	Solids	Solids	Wastes with physically solid matrices for which insufficient characterization information exists to enable categorizing as a homogeneous solid, soil/gravel, or debris

Table 4.5 (continued)

MPC code	Name	IDB Rev. 12 category[b]	Description
		Solids (continued)	
S3000	Homogeneous solids	Unknown/other homogeneous solids	Wastes that are at least 50 vol % homogeneous solids, but: • are insufficiently characterized to enable categorization as either inorganic or organic homogeneous solids, or • do not meet the criteria for categorization as either inorganic or organic homogeneous solids
S3100	Inorganic homogeneous solids	Other inorganic particulates	Wastes that are at least 50 vol % inorganic homogeneous solids. Homogeneous solids are defined as solid waste materials, excluding soil/gravel, that do not meet the EPA LDR criteria for classification as debris. Inorganic homogeneous solids are further defined as those with sufficient inorganic solids content such that a minimum of approximately 20 wt % would remain as residue (i.e., ash/solids) following incineration
S3111	Ash	Incinerator ash	Waste that is primarily (i.e., ≥50 vol %) bottom or fly ash resulting from incineration
S3113	Inorganic particulate absorbents	NA	Waste that is primarily (i.e., ≥50 vol %) inorganic particulate absorbent materials, including absorbed aqueous liquids, if present. Examples include clay, vermiculite, and diatomaceous earth
S3114	Absorbed organic liquids	NA	Waste that is primarily (i.e., >50 vol %) inorganic particulate absorbent materials with absorbed organic liquids
S3118	Activated carbon	Activated carbon (charcoal)	Waste that is primarily (i.e., ≥50 vol %) spent or unused activated carbon, including any residual liquids. The activated carbon may be in powdered (typically 50 to 100 μm) or granular (typically 0.1 to 1 mm) form
S3121	Wastewater treatment sludges	NA	Waste that is at least 50 vol % secondary sludge, filter cake from wastewater treatment processes, or heavy metal sludges resulting from recovery processes, excluding HLW
S3130	Paint waste	Paint waste	Waste that is at least 50 vol % new, used, or removed paint. This includes such paint waste packaged in a lab pack configuration
S3140	Salt waste	Salt waste	Waste that is at least 50 vol % salts, including interstitial liquids, if present

Table 4.5 (continued)

MPC code	Name	IDB Rev. 12 category[b]	Description
		Solids (continued)	
S3150	Solidified homogeneous solids	Solidified sludge/resin	Waste that is at least 50 vol % solidified forms that require further treatment before disposal. The original, unsolidified waste may be either inorganic or organic, while the solidification agent must be inorganic. An example might be a particulate or sludge waste that has been immobilized with cement and cured into a solidified form, but that does not meet LDR treatment standards, if applicable, or other relevant disposal criteria
S3152a	Solidified homogeneous solids (chelates/oils)	Solidified liquids/chelates/oils	Waste meeting the definition of solidified homogeneous solids (S3150) for which the solidified wastes are either chelates or oils
S3200	Organic homogeneous solids	NA	Wastes that are at least 50 vol % organic homogeneous solids. Homogeneous solids are defined as solid waste materials, excluding soil/gravel, that do not meet the EPA LDR criteria for classification as debris. Organic homogeneous solids are further defined as those with a base structure that is primarily organic such that a maximum of approximately 20 wt % would remain as residue (i.e., ash/solids) following incineration
S3212	Organic absorbents	NA	Waste that is primarily (i.e., ≥50 vol %) organic particulate absorbent materials, including any absorbed aqueous or organic liquids. Examples include sawdust and ground corncobs
S4000	Soil/gravel	Soil/sediment/rubble	Waste estimated to be 50 vol % soil, including sand and silt, or rock and gravel that does not meet the U.S. Environmental Protection Agency (EPA) LDR criteria for classification as debris
S4100	Soil	Soil/sediment/rubble	Waste estimated to be ≥95 vol % soil, including sand, silt, and rock and gravel, with rock and gravel volumes <50 vol % of the matrix
S5000	Debris waste	Debris waste	Wastes that are at least 50 vol % materials that meet the EPA LDR criteria for classification as debris but lack adequate characterization information to enable categorizing as inorganic, organic, or heterogeneous debris
S5000a	Debris compactible	Debris—noncombustible and compactible	Wastes meeting criteria of S5000 that are at least 50 wt % compactible materials
S5000b	Debris—combustible and noncombustible	Debris—combustible and noncombustible (mixed)	Wastes meeting criteria of S5000 that are at least 50 wt % noncombustible materials

Table 4.5 (continued)

MPC code	Name	IDB Rev. 12 category[b]	Description
		Solids (continued)	
S5100	Inorganic debris	NA	Wastes that are at least 80 vol % inorganic materials that meet the EPA LDR criteria for classification as debris. Examples include scrap metal, concrete, glass, and brick
S5111	Nonactivated metal debris	Contaminated metal/ equipment/hardware	Waste estimated to be 80 vol %, or more, metal debris that is not activated (i.e., radioactivity is due to surface contamination)
S5111a	Metal debris—reactor components	Reactor components/ compartments	Waste meeting the definition of S5111 for which metal is reactor components
S5112	Activated metal debris	Activated metal/equipment/ hardware	Waste estimated to be 80 vol %, or more, activated metal debris
S5120	Inorganic nonmetal debris	NA	Wastes that are at least 80 vol % inorganic nonmetal debris
S5122	Glass debris	NA	Wastes that are at least 80 vol % glass debris
S5125	Asbestos debris	Asbestos-contaminated waste	Waste estimated to be 80 vol %, or more, asbestos or asbestos-based debris materials. Examples of waste that might be included in this category are asbestos-containing gloves, fire hoses, aprons, flooring tiles, pipe insulation, boiler jackets, and laboratory tabletops
S5300	Organic debris	Debris—combustible	Waste estimated to be 80 vol %, or more, organic debris materials. Examples of organic debris are materials constructed of plastic, rubber, wood, paper, cloth, and biological materials
S5310	Plastic/rubber debris	NA	Wastes that are at least 80 vol % plastic or rubber debris materials. Examples include plastic or rubber sheeting, containers, gloves, gaskets, and components of benelex or plexiglass
S5330	Paper/cloth debris	NA	Wastes that are at least 80 vol % paper or cloth debris materials. Examples include protective clothing, rags, or wipes
S5340	Biological debris	Biological waste and carcasses	Waste estimated to be 80 vol %, or more, biological debris materials, including any chemical agents such as lime or formaldehyde. Examples of waste that might be included in this category are biological samples and animal carcasses

Table 4.5 (continued)

MPC code	Name	IDB Rev. 12 category[b]	Description
		Solids (continued)	
S5400	Heterogeneous debris	NA	Wastes that are at least 50 vol % debris materials that meet the EPA LDR criteria for classification as debris but are not dominant (i.e., at least 80 vol %) in either inorganic or organic debris materials
S5410	Composite filter debris	Filter media	Debris estimated to be 50 vol %, or more, high-efficiency particulate air (HEPA) filters or other filters constructed of more than one material type (e.g., metal, inorganic nonmetal, and organic materials). Filters constructed of a single material type are assigned into the appropriate inorganic, organic, or heterogeneous debris category depending on the composition of the entire waste matrix
		Specific waste forms	
X6000	Lab packs	Other	A lab-pack configuration is defined as two or more waste containers packaged within a larger outer container. Typically, the inner containers are surrounded by absorbent materials; however, this is not an absolute criterion. If present, the absorbents can be homogeneous solids or debris materials. Examples may include rags, vermiculite, diatomaceous earth, and paper wipes. This summary category includes waste that either (a) is packaged as a lab pack upon generation or (b) will be packaged as a lab pack before transfer to long-term storage or treatment. This category does not include lab packs of elemental liquid mercury or paint waste. In addition, waste packaged in a lab-pack configuration that is considered overpacked is excluded. A typical example of an overpack is a single 55-gal drum of waste that is placed in an 85-gal drum because of deterioration of the 55-gal container. This waste should be assigned the appropriate category based on the waste within the inner, overpacked container(s)
X7210	Elemental lead—shielding	Elemental lead shielding	Waste that contains at least 50 vol % bulk elemental lead. Examples of waste in this category are lead bricks, sheets, and pipes

Table 4.5 (continued)

MPC code	Name	IDB Rev. 12 category[b]	Description
		Specific waste forms (continued)	
X7800	Sealed sources	Sources	Includes waste consisting of encapsulated radioactive material whose main purpose is to generate known amounts of radiation. Sealed sources are defined in 10 CFR Part 71.4 as a category of special-form radioactive material. Special-form radioactive material means radioactive material which satisfies the following conditions: 1. It is either a single solid piece or is contained in a sealed capsule that can be opened only by destroying the capsule; 2. The piece or capsule has at least one dimension not less than 5 mm; and 3. It satisfies the test requirements of 10 CFR Part 71.75
U9999	Unknown/other matrix	Other	Wastes for which insufficient characterization information is known to enable categorization as a liquid or solid or as one of the specific waste forms

[a]Sources: T. D. Kirkpatrick, *DOE Waste Treatability Group Guidance*, DOE/LLW-217, Revision 0, Idaho National Engineering Laboratory, Lockheed Idaho Technologies Company, Idaho Falls, Idaho, January 1995; Mark W. Frei, "Collection of Waste Management Technical Information," U.S. Department of Energy, EM-35, Washington, D.C., Apr. 11, 1997.

[b]If applicable. In this column, NA means not applicable.

Table 4.6. Actual FY 1996 generation and projected generation of LLW at DOE sites[a]

Waste description	MPC code	Fiscal-year LLW volume (m^3) generation			
		Actual	Projected total generation		
		1996	1997	1998–2006	2007–2030
Liquids	L0000	227	237	576	1,171
Wastewaters	L1100	76	86	672	1,470
Acidic wastewaters	L1110	0	0	0	0
Neutral wastewaters	L1130	6	15	16	10
Aqueous slurries	L1200	6	1	54	7
Organic liquids	L2000	15	12	113	265
Organic liquids–oils	L2000a	10	6	9	21
Aqueous non-HOC[b] organic liquids	L2120	2	1	4	3
Non-HOC pure organic liquids	L2220	12	17	36	23
Solids	S0000	5,714	8,569	48,577	215,149
Homogeneous solids	S3000	0	1	7	19
Inorganic homogeneous solids	S3100	34	176	7,711	657
Ash	S3111	5	5	23	32
Inorganic particulate absorbents	S3113	23	12	47	30
Absorbed organic liquids	S3114	0	1	7	20
Activated carbon	S3118	6	1	18	18
Wastewater treatment sludges	S3121	157	159	1,883	2,200
Paint waste	S3130	0	0	2	0
Salt waste	S3140	0	0	0	0
Solidified homogenous solids	S3150	585	535	21,890	2,062
Solidified homogeneous solids—chelates/oils	S3152a	9	6	51	120
Organic homogeneous solids	S3200	0	0	4	11
Organic absorbents	S3212	6	7	101	271
Soil/gravel	S4000	3,818	8,994	27,916	3,678
Soil	S4100	942	1,134	15,904	29,377
Debris waste	S5000	119	119	167	257
Debris compactible	S5000a	468	227	1,303	2,576
Debris—combustible and noncombustible	S5000b	8,535	9,874	65,581	133,518
Inorganic debris	S5100	28	31	467	1,017
Nonactivated metal debris	S5111	915	1,998	18,598	24,104
Nonactivated metal debris—reactor component	S5111a	90	131	1,486	1,274
Activated metal debris	S5112	119	182	294	397
Inorganic nonmetal debris	S5120	0	6	0	0
Glass debris	S5122	2	3	36	97
Asbestos debris	S5125	241	266	2,293	4,069
Organic debris	S5300	3,144	2,310	26,842	33,230
Plastic/rubber debris	S5310	3	4	56	150
Paper/cloth debris	S5330	169	215	3,018	7,132
Biological debris	S5340	1	6	28	67
Heterogeneous debris	S5400	2,067	2,101	32,112	50,293
Composite filters	S5410	36	245	8,106	1,817
Unknown/other matrix	U9999	15	278	959	0
Lab packs	X6000	0	0	0	0
Sealed sources	X7800	2	0	1	1
Total (without ORR[c] contributions)		27,605	37,965	286,970	516,613
Total ORR		3,159	2,477	22,293	58,449
Grand total		30,764	40,452	309,263	575,062

[a]Based on ref. 1.
[b]HOC = halogenated organic compound.
[c]ORR = Oak Ridge Reservation.

Table 4.7. Actual FY 1996 disposal and projected disposal of LLW at DOE sites[a]

Waste description	MPC code	Fiscal-year LLW volume (m^3) disposed			
		Actual	Projected		
		1996	1997	1998–2006	2007–2030
Liquids	L0000	9	84	432	1,020
Neutral wastewaters	L1130	0	16	16	10
Aqueous slurries	L1200	0	0	0	16
Aqueous/nonhalogenated organic liquids	L2120	0	1	4	3
Non-HOC pure organic liquids	L2220	0	17	36	23
Solids	S0000	5,576	8,646	43,891	171,407
Homogeneous solids	S3000	0	1	7	19
Inorganic homogeneous solids	S3100	648	179	7,618	777
Ash	S3111	b	5	22	27
Inorganic particulate absorbents	S3113	0	12	47	30
Absorbed organic liquids	S3114	0	1	7	20
Wastewater treatment sludges	S3121	71	183	1,884	2,200
Salt waste	S3140	0	0	1	0
Solidified homogenous solids	S3150	187	453	15,629	2,466
Organic homogeneous solids	S3200	0	0	4	11
Organic absorbents	S3212	6	7	101	271
Soil/gravel	S4000	604	7,319	9,758	3,318
Soil	S4100	926	1,134	15,904	29,377
Debris waste	S5000	0	113	113	113
Debris compactible	S5000a	991	123	543	1,097
Debris—combustible and noncombustible	S5000b	6,064	9,168	34,733	54,360
Inorganic debris	S5100	25	31	467	1,017
Nonactivated metal debris	S5111	461	1,321	17,147	21,275
Nonactivated metal debris—reactor component	S5111a	4,150	0	355	0
Activated metal debris	S5112	3	162	242	381
Inorganic nonmetal debris	S5120	0	6	0	0
Glass debris	S5122	2	3	36	97
Asbestos debris	S5125	115	154	1,942	3,886
Organic debris	S5300	332	770	18,745	16,388
Plastic/rubber debris	S5310	3	4	56	150
Paper/cloth debris	S5330	169	215	3,018	7,132
Biological debris	S5340	b	7	29	67
Heterogeneous debris	S5400	2,041	2,101	32,112	50,293
Composite filters	S5410	16	180	7,796	1,689
Sealed sources	X7800	0	1	0	6
Unknown/other matrix	U9999	11,273	614	19,823	47,690
Total		33,672	33,031	232,518	416,637

[a]Based on ref. 1.
[b]Information unknown.

Table 4.8. Actual and projected volumes (m^3) of LLW generated, by site[a]

Site	Actual FY 1996	FY projections		
		1997	1998–2006	2007–2030
Ames	2	0	0	0
ANL–E	211	255	255	255
ANL–W	270	532	3,359	6,433
BNL	416	477	466	466
ETEC	925	3,990	15,500	0
FNAL	30	0	0	0
Hanford	3,922	6,711	40,272	201,234
INEEL	6,791	3,783	18,638	44,289
LANL	4,022	4,296	66,882	120,000
LBNL	23	23	206	681
LEHR	308	410	7,205	0
LLNL	279	205	1,611	3,412
Mound	749	595	9,144	0
Naval laboratories[b]				
BAPL	439	891	3,380	2,646
KAPL	96	96	859	2,376
KESS	113	115	1,069	990
KWIN	141	112	121	0
NTS	6	1	30	0
ORR[c]	3,159	2,477	22,293	58,449
PANT	174	437	809	340
PPPL	34	71	147	672
RFETS	0	1,170	57,548	2,558
SNL/CA	1	0	7	4
SRS	8,195	13,534	57,757	130,258
TTR[d]	15	0	0	0
WVDP	444	272	1,705	0
Total	30,764	40,452	309,263	575,062

[a]Based on ref. 1.

[b]DOE Office of Naval Reactors (NE-60) sites. Naval laboratory contributions include Bettis Atomic Power Laboratory (BAPL), Knolls Atomic Power Laboratory (KAPL)–Schenectady, Knolls Kesselring Site (KESS), and Knolls Windsor Site (KWIN).

[c]Oak Ridge Reservation. Includes contributions from three Oak Ridge sites: ETTP, ORNL, and Y-12.

[d]Tonopah Test Range, Nellis Air Force Base, Nevada.

Table 4.9. Breakdown by waste description of volumes of LLW generated during FY 1996 at DOE sites[a]

MPC name	MPC code	Total	Breakdown of MPC total generated volume, by site					
			Ames	ANL–E	ANL–W	BAPL	BNL	ETEC
Liquids	L0000	227					210	
Wastewaters	L1100	76						
Acidic wastewaters	L1110	0						
Neutral wastewaters	L1130	6						
Aqueous slurries	L1200	6						
Organic liquids	L2000	15					0	
Organic liquids—oils	L2000a	10					2	0
Aqueous non-HOC[b] organic liquids	L2120	2						
Non-HOC pure organic liquids	L2220	12						
Solids	S0000	5,714		211				
Homogeneous solids	S3000	0						
Inorganic homogeneous solids	S3100	34						
Ash	S3111	5						
Inorganic particulate absorbents	S3113	23						
Absorbed organic liquids	S3114	0						
Activated carbon	S3118	6						
Wastewater treatment sludges	S3121	157						
Paint waste	S3130	0						
Salt waste	S3140	0						0
Solidified homogenous solids	S3150	585				34		
Solidified homogeneous solids—chelates/oils	S3152a	9						
Organic homogeneous solids	S3200	0						
Organic absorbents	S3212	6						
Soil/gravel	S4000	3,818				0		434
Soil	S4100	942						
Debris waste	S5000	119	2		33		84	
Debris compactible	S5000a	468			46		32	
Debris—combustible and noncombustible	S5000b	8,535				212		482
Inorganic debris	S5100	28						
Nonactivated metal debris	S5111	915			99	26		
Nonactivated metal debris—reactor components	S5111a	90				90		
Activated metal debris	S5112	119			0		86	
Inorganic nonmetal debris	S5120	0						
Glass debris	S5122	2						
Asbestos debris	S5125	241				77	1	8
Organic debris	S5300	3,144			92			
Plastic/rubber debris	S5310	3						
Paper/cloth debris	S5330	169						
Biological debris	S5340	1						
Heterogeneous debris	S5400	2,067						
Composite filters	S5410	36						
Unknown/other matrix	U9999	15			0		0	
Lab packs	X6000	0						
Sealed sources	X7800	2						2
Total (without ORR[c])		27,607	2	211	270	439	415	926

(Continued on next page.)

Table 4.9 (continued)

MPC name	MPC code	Total	Breakdown of MPC total generated volume, by site					
			FNAL	Hanford	INEEL	KAPL	KESS	KWIN
Liquids	L0000	227		7	9			
Wastewaters	L1100	76						
Acidic wastewaters	L1110	0						
Neutral wastewaters	L1130	6						
Aqueous slurries	L1200	6						
Organic liquids	L2000	15						
Organic liquids—oils	L2000a	10			0			
Aqueous non-HOC organic liquids	L2120	2						
Non-HOC pure organic liquids	L2220	12						
Solids	S0000	5,714		3,752	1,171			
Homogeneous solids	S3000	0						
Inorganic homogeneous solids	S3100	34			12	0		
Ash	S3111	5			0			
Inorganic particulate absorbents	S3113	23						
Absorbed organic liquids	S3114	0						
Activated carbon	S3118	6			4	0	1	
Wastewater treatment sludges	S3121	157						
Paint waste	S3130	0						
Salt waste	S3140	0						
Solidified homogenous solids	S3150	585		164	24	8	4	
Solidified homogeneous solids—chelates/oils	S3152a	9				2	3	
Organic homogeneous solids	S3200	0						
Organic absorbents	S3212	6						
Soil/gravel	S4000	3,818			2,708	3	0	
Soil	S4100	942						
Debris waste	S5000	119						
Debris compactible	S5000a	468			0	3		
Debris—combustible and noncombustible	S5000b	8,535				24	98	3
Inorganic debris	S5100	28						
Nonactivated metal debris	S5111	915			231	44	0	108
Nonactivated metal debris—reactor components	S5111a	90						
Activated metal debris	S5112	119	30		3			0
Inorganic nonmetal debris	S5120	0						
Glass debris	S5122	2						
Asbestos debris	S5125	241			1	8	6	24
Organic debris	S5300	3,144			2,616	2		
Plastic/rubber debris	S5310	3						
Paper/cloth debris	S5330	169						
Biological debris	S5340	1			0			
Heterogeneous debris	S5400	2,067						
Composite filters	S5410	36			11	1		5
Unknown/other matrix	U9999	15						
Lab packs	X6000	0						
Sealed sources	X7800	2			0		0	0
Total (without ORR[c])		27,607	30	3,923	6,791	96	113	141

(Continued on next page.)

Table 4.9 (continued)

MPC name	MPC code	Total	Breakdown of MPC total generated volume, by site					
			LANL	LBNL	LEHR	LLNL	Mound	NTS
Liquids	L0000	227		1				
Wastewaters	L1100	76		5		70		
Acidic wastewaters	L1110	0						
Neutral wastewaters	L1130	6						
Aqueous slurries	L1200	6				0		
Organic liquids	L2000	15		4		11		
Organic liquids—oils	L2000a	10				5		
Aqueous non-HOC organic liquids	L2120	2						
Non-HOC pure organic liquids	L2220	12						
Solids	S0000	5,714					560	
Homogeneous solids	S3000	0	0					
Inorganic homogeneous solids	S3100	34		3		3		
Ash	S3111	5						
Inorganic particulate absorbents	S3113	23						
Absorbed organic liquids	S3114	0	0					
Activated carbon	S3118	6						
Wastewater treatment sludges	S3121	157	63		0		94	
Paint waste	S3130	0						
Salt waste	S3140	0				0		
Solidified homogenous solids	S3150	585				89	95	
Solidified homogeneous solids—chelates/oils	S3152a	9						
Organic homogeneous solids	S3200	0	0					
Organic absorbents	S3212	6	6					
Soil/gravel	S4000	3,818		0	18	9		
Soil	S4100	942	925					
Debris waste	S5000	119		0				
Debris compactible	S5000a	468		0	291	59		6
Debris—combustible and noncombustible	S5000b	8,535				9		
Inorganic debris	S5100	28	25					
Nonactivated metal debris	S5111	915	340	4	0	18		
Nonactivated metal debris—reactor components	S5111a	90						
Activated metal debris	S5112	119						
Inorganic nonmetal debris	S5120	0						
Glass debris	S5122	2	2					
Asbestos debris	S5125	241	114	0		0		
Organic debris	S5300	3,144	317	4		7		
Plastic/rubber debris	S5310	3	3					
Paper/cloth debris	S5330	169	169					
Biological debris	S5340	1			0	0		
Heterogeneous debris	S5400	2,067	2,041					
Composite filters	S5410	36	16			0		
Unknown/other matrix	U9999	15						
Lab packs	X6000	0						
Sealed sources	X7800	2			0	0		
Total (without ORR[c])		27,607	4,022	21	308	280	749	6

(Continued on next page.)

Table 4.9 (continued)

MPC name	MPC code	Total	Breakdown of MPC total generated volume, by site					
			PPPL	PANT	SNL/CA	SRS	TTR	WVDP
Liquids	L0000	227						
Wastewaters	L1100	76						
Acidic wastewaters	L1110	0		0				
Neutral wastewaters	L1130	6		6				
Aqueous slurries	L1200	6						6
Organic liquids	L2000	15						
Organic liquids—oils	L2000a	10						3
Aqueous non-HOC organic liquids	L2120	2		2				
Non-HOC pure organic liquids	L2220	12		12				
Solids	S0000	5,714	20		1			
Homogeneous solids	S3000	0						
Inorganic homogeneous solids	S3100	34						16
Ash	S3111	5		5				0
Inorganic particulate absorbents	S3113	23		23				
Absorbed organic liquids	S3114	0						
Activated carbon	S3118	6						0
Wastewater treatment sludges	S3121	157						
Paint waste	S3130	0						0
Salt waste	S3140	0						
Solidified homogenous solids	S3150	585	14					154
Solidified homogeneous solids—chelates/oils	S3152a	9						3
Organic homogeneous solids	S3200	0						
Organic absorbents	S3212	6						
Soil/gravel	S4000	3,818		0		519	15	112
Soil	S4100	942		16				
Debris waste	S5000	119						
Debris compactible	S5000a	468						31
Debris—combustible and noncombustible	S5000b	8,535				7,676		32
Inorganic debris	S5100	28		3				
Nonactivated metal debris	S5111	915		7				37
Nonactivated metal debris—reactor components	S5111a	90						
Activated metal debris	S5112	119						
Inorganic nonmetal debris	S5120	0		0				
Glass debris	S5122	2						
Asbestos debris	S5125	241						3
Organic debris	S5300	3,144		75				30
Plastic/rubber debris	S5310	3						
Paper/cloth debris	S5330	169						
Biological debris	S5340	1						0
Heterogeneous debris	S5400	2,067		27				
Composite filters	S5410	36						4
Unknown/other matrix	U9999	15						15
Lab packs	X6000	0		0				
Sealed sources	X7800	2						
Total (without ORR[c])		27,607	34	174	1	8,195	15	444

[a]Based on ref. 1.
[b]HOC = halogenated organic compound.
[c]ORR = Oak Ridge Reservation, which generated an additional 3,157 m^3.

Table 4.10. Cumulative volumes of contaminated media in storage at DOE sites classified as LLW[a]

Site	Volume, m^3
FEMP	140,000
FUSRAP[b]	27,000
GA[c]	350
GJPO Site	6
PAD	110,000
PORTS	13,000
RMI	640
Total	290,000[d]

[a]Based on Table 6.8 in Chapter 6. Volumes are given to two significant figures or the nearest integer (for volumes less than 10 m^3).

[b]FUSRAP = Formerly Utilized Sites Remedial Action Program. The reported volume represents soil in bulk storage at the Middlesex Sampling Plant. This program was recently transferred to the U.S. Army Corps of Engineers.

[c]General Atomics Site.

[d]Rounded to two significant figures.

Table 4.11. Breakdown by waste description of volumes of LLW disposed during FY 1996 at DOE sites[a]

Waste description	MPC code	Volume, m^3						
		Hanford	INEEL	LANL	NTS	ORNL	SRS	Total
Liquids	L0000		9					9
Solids	S0000	5,400	119		57			5,576
Homogeneous solids	S3000							0
Inorganic homogeneous solids	S3100		12		636			648
Ash	S3111							b
Absorbed organic liquids	S3114							0
Wastewater treatment sludges	S3121			63	8			71
Solidified homogenous solids	S3150	164	23					187
Organic homogeneous solids	S3200							0
Organic absorbents	S3212			6				6
Soil/gravel	S4000		32		127		445	604
Soil	S4100			926				926
Debris compactible	S5000a				991			991
Debris—combustible and noncombustible	S5000b						6,064	6,064
Inorganic debris	S5100			25				25
Nonactivated metal debris	S5111		121	340				461
Nonactivated metal debris—reactor components	S5111a	4,150						4,150
Activated metal debris	S5112		3					3
Glass debris	S5122			2				2
Asbestos debris	S5125		1	114				115
Organic debris	S5300		15	317				332
Plastic/rubber debris	S5310			3				3
Paper/cloth debris	S5330			169				169
Biological debris	S5340							b
Heterogeneous debris	S5400			2,041				2,041
Composite filters	S5410			16				16
Unknown/other matrix	U9999				10,904	369		11,273
Total		9,714	335	4,022	12,723	369	6,509	33,672

[a]Based on ref. 1.
[b]Information unknown.

Table 4.12. 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			55,389	14,766
Total (oceans)			89,472	94,273
		Hydrofracture facility		
ORNL	Bedded Conasauga shale underlying the ORNL site	1959–1965	Small experimental amounts of grout	
		1966–1980[d]	8.0×10^3 m^3	600,000
		1982[e]	3.8×10^3 m^3	200,000
		1983[e]	5.5×10^3 m^3	500,000
Total			17.3×10^3 m^3	1,300,000

[a]Radioactivity is given at time of disposal. 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 4.13. Historical and projected volume, radioactivity, and thermal power characteristics of disposed DOE LLW, except LLW from HLW vitrification

End of year[a]	Volume[b,c] (10^3 m^3)		Radioactivity[b,c] (10^3 Ci)		Thermal power (W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1990	60.0	2,759	545	13,516	2,013	17,844
1991	53.6	2,812	717	13,277	2,788	18,220
1992	48.3	2,860	1,078	13,401	4,947	20,741
1993	50.5	2,911	894	13,147	3,263	20,398
1994	52.1	2,963	621	12,858	3,463	21,534
1995	48.5	3,011	422	12,550	2,378	22,195
1996	33.7	3,045	245	12,148	1,331	22,022
1997	33.0	3,078	463	12,023	2,521	23,171
1998	25.8	3,104	365	11,811	2,087	23,767
1999	25.8	3,130	365	11,611	2,087	24,285
2000	25.8	3,156	365	11,421	2,087	24,727
2001	25.8	3,182	365	11,240	2,087	25,096
2002	25.8	3,207	365	11,068	2,087	25,399
2003	25.8	3,233	365	10,904	2,087	25,642
2004	25.8	3,259	365	10,747	2,087	25,833
2005	25.8	3,285	365	10,599	2,087	25,978
2006	25.8	3,311	365	10,459	2,087	26,082
2007	17.4	3,329	247	10,209	1,360	25,425
2008	17.4	3,346	247	9,986	1,360	24,847
2009	17.4	3,364	247	9,783	1,360	24,320
2010	17.4	3,381	247	9,598	1,360	23,839
2011	17.4	3,398	247	9,429	1,360	23,397
2012	17.4	3,416	247	9,273	1,360	22,990
2013	17.4	3,433	247	9,129	1,360	22,613
2014	17.4	3,451	247	8,996	1,360	22,265
2015	17.4	3,468	247	8,873	1,360	21,940
2016	17.4	3,485	247	8,760	1,360	21,638
2017	17.4	3,503	247	8,654	1,360	21,356
2018	17.4	3,520	247	8,556	1,360	21,090
2019	17.4	3,537	247	8,465	1,360	20,841
2020	17.4	3,555	247	8,381	1,360	20,607
2021	17.4	3,572	247	8,303	1,360	20,385
2022	17.4	3,589	247	8,231	1,360	20,175
2023	17.4	3,607	247	8,164	1,360	19,975
2024	17.4	3,624	247	8,102	1,360	19,786
2025	17.4	3,642	247	8,044	1,360	19,605
2026	17.4	3,659	247	7,992	1,360	19,432
2027	17.4	3,676	247	7,943	1,360	19,267
2028	17.4	3,694	247	7,898	1,360	19,109
2029	17.4	3,711	247	7,857	1,360	18,957
2030	17.4	3,728	247	7,820	1,360	18,811

[a]Historical data prior to 1996 are expressed on an EOCY basis.

[b]Historical (beginning of operations through 1995) annual values of volume and radioactivity for each site are from ref. 5. Similar values for 1996 are from ref. 1. See Tables 4.4, 4.7, and 4.11 for more detail. For disposals prior to 1994, radioactivity (by waste type) is decayed from the year of addition using the representative compositions given in Table A.2 of Appendix A. Starting with 1994, representative compositions provided by the sites in the data call for Rev. 11 of this report are used to decay radioactivity.

[c]Beginning in 1997, projected disposals are estimated for each active disposal site. Estimated values reported in this table may not agree with summary data reported in Table 4.7 because projections were reported as either unknown or unavailable by some sites.

Table 4.14. Projected volume, radioactivity, and thermal power characteristics of DOE LLW from final HLW form production at Hanford[a]

End of year	Volume[b] (10^3 m^3)		Radioactivity[c] (10^3 Ci)		Thermal power[c] (W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1996–2001	0.0	0.0	0	0	0	0
2002	3.1	3.1	197	197	554	554
2003	3.1	6.2	193	385	541	1,082
2004	3.1	9.3	188	565	528	1,585
2005	3.1	12.4	184	736	516	2,065
2006	3.1	15.4	180	898	504	2,522
2007	3.1	18.5	176	1,053	493	2,957
2008	3.1	21.6	172	1,200	482	3,371
2009	3.1	24.7	168	1,340	471	3,764
2010	3.1	27.8	164	1,473	460	4,137
2011	3.1	30.8	160	1,599	449	4,491
2012	14.3	45.2	725	2,287	2,036	6,424
2013	21.7	67.0	1,075	3,310	3,018	9,295
2014	21.7	88.7	1,050	4,283	2,949	12,030
2015	21.7	110.4	1,026	5,211	2,881	14,640
2016	21.7	132.2	1,003	6,094	2,815	17,120
2017	21.7	153.9	980	6,933	2,751	19,480
2018	21.7	175.7	957	7,731	2,688	21,720
2019	21.7	197.4	935	8,488	2,626	23,850
2020	21.7	219.1	914	9,206	2,566	25,870
2021	21.7	240.9	893	9,888	2,507	27,780
2022	0.0	240.9	0	9,661	0	27,140
2023	0.0	240.9	0	9,439	0	26,520
2024	0.0	240.9	0	9,223	0	25,920
2025	0.0	240.9	0	9,011	0	25,320
2026	0.0	240.9	0	8,804	0	24,750
2027	0.0	240.9	0	8,603	0	24,180
2028	0.0	240.9	0	8,405	0	23,630
2029	0.0	240.9	0	8,213	0	23,090
2030	0.0	240.9	0	8,024	0	22,560

[a]Based on ref. 1(a) of Chapter 2.

[b]Low-activity waste (LAW) generated from Hanford tank waste disposal operations is to be immobilized in glass. Estimate of volume represents only LLW glass, excluding any possible voids, binders, or encasement materials.

[c]Levels of radionuclides in vitrified LLW are based on data developed to support the report, *Technical Basis for Classification of Low-Activity Waste Fraction from Hanford Site Tanks*, WHC-SD-WM-TI-699, Rev. 1, Westinghouse Hanford Company, Richland, Washington (July 1996).

Table 4.15. Projected volume, radioactivity, and thermal power characteristics of DOE LLW (grout) from HLW vitrification at INEEL[a]

End of FY	Volume (10^3 m^3)		Radioactivity (10^3 Ci)		Thermal power (W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1996–2018	0.00	0.00	0	0	0	0
2019	0.25	0.25	0	0	0	0
2020	2.32	2.57	0	0	0	1
2021	1.64	4.21	0	1	0	2
2022	1.64	5.85	0	1	0	3
2023	1.69	7.54	0	1	0	4
2024	1.70	9.24	0	2	0	5
2025	1.71	10.95	0	2	0	5
2026	2.06	13.01	0	2	0	6
2027	2.07	15.08	0	2	0	6
2028	2.40	17.48	0	2	0	6
2029	2.87	20.34	0	2	0	6
2030	2.87	23.21	0	2	0	6
2031	2.71	25.92	0	2	0	6
2032	2.14	28.07	0	2	0	6
2033	2.13	30.20	0	2	0	6
2034	1.82	32.02	0	2	0	6
2035	0.00	32.02	0	2	0	6

[a]Based on ref. 1(b) of Chapter 2.

Table 4.16. Actual and projected volume, radioactivity, and thermal power characteristics of DOE LLW saltstone from HLW glass production at SRS[a]

End of FY	Volume (10^3 m^3)		Radioactivity (10^3 Ci)		Thermal power (W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1996[b]	0.5	22.8	0.2	0.2	2.0	2.0
1997	2.0	24.8	8.7	8.9	80.8	82.4
1998	26.9	51.7	8.4	16.4	75.1	147.0
1999	40.3	92.0	8.5	23.9	72.2	202.0
2000	29.9	121.9	8.8	31.8	68.3	246.0
2001	25.8	147.7	9.0	39.9	62.6	277.0
2002	25.3	173.0	9.1	48.3	56.4	298.0
2003	26.1	199.1	9.2	56.7	51.4	317.0
2004	24.6	223.7	9.2	65.0	48.2	342.0
2005	27.0	250.7	9.1	73.3	46.6	373.0
2006	26.0	276.7	9.1	81.4	45.9	412.0
2007	27.2	303.9	9.0	89.5	45.9	455.0
2008	25.9	329.8	8.9	97.3	46.1	502.0
2009	27.4	357.2	8.9	105.0	46.5	551.0
2010	25.2	382.4	8.8	113.0	46.9	602.0
2011	25.4	407.8	8.7	120.0	47.4	654.0
2012	27.0	434.8	8.6	127.0	47.9	707.0
2013	25.0	459.8	8.6	135.0	48.4	760.0
2014	25.2	485.0	8.5	142.0	48.9	815.0
2015	26.4	511.4	8.4	149.0	49.4	870.0
2016	24.1	535.5	8.4	155.0	49.9	927.0
2017	24.9	560.4	8.3	162.0	50.5	984.0
2018	24.4	584.8	8.3	169.0	51.0	1,040.0
2019	0.1	584.8	8.2	175.0	51.5	1,100.0
2020		584.8		173.0		1,110.0
2021		584.8		172.0		1,120.0
2022		584.8		170.0		1,120.0
2023		584.8		169.0		1,130.0
2024		584.8		167.0		1,140.0
2025		584.8		165.0		1,150.0
2026		584.8		164.0		1,150.0
2027		584.8		162.0		1,160.0
2028		584.8		161.0		1,170.0
2029		584.8		160.0		1,180.0
2030		584.8		158.0		1,190.0

[a]Based on ref. 1(c) of Chapter 2.

[b]The cumulative quantities reported for FY 1996 include contributions of LLW generated from prior years. Most of this material is LLW from the processing of concentrate from the SRS Effluent Treatment Facility.

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

Year	Volume, m^3							
	Beatty[b]	West Valley[c]	Maxey Flats[d]	Richland	Sheffield[e]	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[f]	92,400	768,270
1981	3,351	216		40,732		39,427[f]	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
1993				5,288		17,145	22,433	1,494,562
1994				3,533		20,783	24,316	1,518,878
1995				5,804		13,734	19,538	1,538,416
1996[g]				1,899		5,146	7,045	1,545,461
Total	137,455	77,074	135,280	366,287	88,334	741,031		1,545,461

[a]For a summary of historical additions (1962–1984), see Table 4.6 in ref. 3. For Beatty, Richland, and Barnwell, the additions for 1985–1995 are from Table 4.19 in ref. 5. Information for 1996 is taken from ref. 7.

[b]Beatty ceased accepting LLW Dec. 31, 1992.

[c]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 1980. The LLW volumes reported for 1982 through 1986 are for the WVDP only and are taken from ref. 5. Since the beginning of 1987, LLW generated at the WVDP is stored on-site in engineered facilities pending final disposal (ref. 5).

[d]Closed Dec. 27, 1977.

[e]Closed Apr. 8, 1978.

[f]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 included in the annual quota.

[g]Data presented are for Jan. 1, 1996–Sept. 30, 1996, to adjust total to a FY basis. Years prior to 1996 are calendar years.

Table 4.18. Historical annual additions and total undecayed radioactivity of LLW at commercial disposal sites[a]

Year	Radioactivity, Ci							
	Beatty[b]	West Valley[c]	Maxey Flats[d]	Richland	Sheffield[e]	Barnwell	Annual total	Cumulative total
1962	f						f	f
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			42,734		211,026	257,113	9,745,047
1988	8,690			32,067		218,901	259,658	10,004,705
1989	42,678			99,056		725,164	866,898	10,871,603
1990	11,323			92,985		444,277	548,585	11,420,188
1991	29,679			158,784		611,348	799,811	12,219,999
1992	90,206			93,923		815,974	1,000,103	13,220,102
1993				31,422		611,785	643,207	13,863,309
1994				6,078		745,301	751,379	14,614,688
1995				2,836		168,981	171,817	14,786,505
1996[g]				572		287,228	287,800	15,074,305
Total	641,120	1,266,654	2,400,690	2,374,986	60,206	8,330,649		15,074,305

[a]For a summary of historical additions (1962–1984), see Table 4.6 in ref. 3. For Beatty, Richland, and Barnwell, the additions for 1985–1995 are from Table 4.20 in ref. 5. Information for 1996 is taken from ref. 7.

[b]Beatty ceased accepting LLW Dec. 31, 1992.

[c]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 1980. The LLW radioactivity values reported for 1982 through 1986 are for the WVDP only and are taken from ref. 5. Since the beginning of 1987, LLW generated at the WVDP is stored on-site in engineered facilities pending final disposal (ref. 5).

[d]Closed Dec. 27, 1977.

[e]Closed Apr. 8, 1978.

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

[g]Data presented are for Jan. 1, 1996–Sept. 30, 1996, to adjust total to a FY basis. Years prior to 1996 are calendar years.

Table 4.19. Distribution of total volume and radioactivity, by state, of LLW shipped to commercial disposal sites during Jan. 1–Sept. 30, 1996[a]

State	Volume (m^3)	Radioactivity (Ci)	State	Volume (m^3)	Radioactivity (Ci)
Alabama	189	623	Missouri	44	104
Arizona	91	11	Nebraska	78	32,423
Arkansas	7	1	Nevada	3	<0.01
California	208	1,674	New Hampshire	<1	<0.01
Colorado	131	11	New Jersey	185	226
Connecticut	205	1,076	New Mexico	1	<1
Delaware	2	<1	New York	262	803
District of Columbia	2	<1	North Dakota	<1	<1
Florida	106	136	Ohio	110	1,137
Georgia	269	122,339	Oklahoma	1	<1
Hawaii	45	1	Oregon	1,119	339
Illinois	916	6,067	Pennsylvania	281	68,373
Indiana	7	9	Rhode Island	2	<1
Iowa	73	134	South Carolina	180	956
Kansas	22	1,600	Tennessee	600	492
Kentucky	5	215	Texas	70	2,068
Louisiana	75	254	Utah	63	<1
Maine	64	302	Vermont	<1	<0.01
Maryland	36	215	Virginia	350	1,177
Massachusetts	179	2,056	Washington	555	222
Michigan	356	41,674	West Virginia	<1	<0.01
Minnesota	41	763	Wisconsin	32	3
Mississippi	80	318			
			Total	7,045	287,800

[a]Source: ref. 7. States not shipping any LLW for disposal are not listed.

Table 4.20. Breakdown of LLW by type, volume, and radioactivity received at Barnwell and Richland during Jan. 1–Sept. 30, 1996[a]

Type of waste	Volume (m^3)	Radioactivity (Ci)
Academic	160	28
Government	753	11,115
Industrial	1,723	698
Medical	29	3
Utility	4,380	275,956
	7,045	287,800

[a]Source: ref. 7.

Table 4.21. Historical and projected cumulative volume and radioactivity summary of commercial GTCC LLW[a]

Category	1993[b]			2035[c,d]		
	Volume (m^3)		Radioactivity (Ci)	Volume (m^3)		Radioactivity (Ci)
	Unpackaged	ACA packaged[e]		Unpackaged	ACA packaged	
Nuclear utility wastes						
BWR operations	3.20	1.10	28,200	105.2	36.7	1,155,517
PWR operations	2.82	0.12	18,300	77.7	10.0	573,510
LWR operations total	6.02	1.22	46,500	182.9	46.7	1,729,027
BWR decommissioning	6.26	14.48	757,000	115.4	188.8	3,270,412
PWR decommissioning	3.98	10.32	3,086,500	398.9	570.9	30,548,517
LWR decommissioning total	10.24	24.80	3,843,500	514.3	759.7	33,818,929
Nuclear utility total	16.26	26.02	3,890,000	697.2	806.4	35,547,956
Sealed sources						
General license	0.007	0.474	1,119	0.123	8.09	18,440
Specific license	0.125	38.22	354,000	0.87	234	1,560,000
Sealed sources total	0.13	38.69	355,119	0.99	242	1,578,440
DOE-held potential GTCC waste	0	0	0	0	0	0
Other generator waste[f]	46.9	74.2	2,738	235	465	12,680
Grand total	63.3	138.9	4,247,857	933	1,513	37,139,076

[a]Based on the INEEL study of ref. 13. Projected data reported represent base-case scenario projections.

[b]Reported cumulative inventory as of December 31, 1993.

[c]Projected cumulative inventory for end of CY 2035.

[d]Reference 13 also projects quantities of nuclear utility GTCC LLW by the end of CY 2055. For the base case, these include an unpackaged volume of 1,144 m^3, an after-concentration-averaged (ACA) packaged volume of 1,347 m^3, and an associated radioactivity of 88,400,000 Ci.

[e]ACA packaged waste. This is the packaged volume of waste that is classified as GTCC LLW, after all other waste has been classified as Class A, B, or C LLW using concentration-averaging practices.

[f]Includes contributions from ^{14}C users, irradiation laboratories, sealed source manufacturers, a nuclear fuel fabrication facility, and a university reactor.

5. URANIUM MILL TAILINGS

5.1 INTRODUCTION

Uranium mill tailings are the residual wastes of milled ore that remain after the uranium has been recovered. The tailings are generated during the extraction of the uranium from the ore as it is fed to the mill. Depending on the chemical characteristics of the ore, uranium mill operators use either an acid leach or an alkaline leach process to recover uranium. Currently, all operable U.S. mills are designed to use 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.

5.2 BY-PRODUCT MATERIAL

Uranium mill tailings are part of a broad category of radioactive wastes called by-product materials. As defined in DOE Order 5820.2A, by-product material includes two major waste groups:

(1) any radioactive material [except special nuclear material (SNM) such as plutonium or fissile uranium] yielded in, or made radioactive either by exposure to incident radiation or by the process of producing or utilizing SNM; and

(2) the tailings or waste produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material (i.e., uranium, thorium, or both) content. This excludes underground ores depleted by uranium solution extraction operations (in situ leaching) that continue to remain underground.

The basis for the definition of the second group of by-product materials is Sect. 11e(2) of the Atomic Energy Act (AEA) of 1954 (P.L. 83-703, as amended). For this reason, these wastes, which, of course, include uranium mill tailings, are referred to as 11e(2) by-product materials.

Uranium mill tailings are the only by-product materials considered in this chapter. Additional information and data on 11e(2) by-product materials from DOE Environmental Restoration Program activities are provided in Chapter 6, which also reports the volumes of mixed DOE Environmental Restoration 11e(2) by-product materials, which have both hazardous and radioactive components. The 11e(2) by-product materials at the Wayne and Maywood Formerly Utilized Sites Remedial Action Program (FUSRAP) sites (see Chapter 6) are thorium mill tailings. For this chapter, information on thorium mill tailings or other by-product materials is not considered.

5.3 COMMERCIAL URANIUM MILL TAILINGS

This section describes the inventories and characteristics of uranium mill tailings generated from uranium ore production at commercially licensed facilities.

5.3.1 Uranium Ore Production

U.S. uranium production from conventional milling has declined since 1980; as a consequence, the quantity of mill tailings generated each year has declined (Table 5.1). During a part of 1996, one conventional mill in the United States was commercially producing uranium concentrates from stockpiled ore mined before 1993. This mill accounted for sole generation of 48,519 t of mill tailings (Table 5.2). At the end of 1996, however, none of the U.S. mills were operational. Six of the 27 mills were on standby status, and the rest were decommissioned or undergoing various stages of decommissioning. The location and status, respectively, of each of these mills are indicated on the map shown in Fig. 5.1 (ref. 1). The nonutilization of U.S. uranium mill 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 importing less expensive uranium.

In the history of U.S. uranium production, 1993 and 1994 were the only years with no production from conventional milling of ore. Nonconventional concentrate production in 1996 increased to about 2,477 t U_3O_8, or 23% above 1995 production.[2,3] Nonconventional concentrate production includes by-product processing resulting 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 to mining operations. Of the total 1996 $80/kg-U uranium reserves estimated by the Energy Information Administration (EIA), the amount for which ISL is the proposed mining method was about 41%. Because ISL mining usually is successful at lower costs as compared with conventional mining methods, it could gain even wider use in the near future. ISL and by-product (from phosphate ore) production methods do not generate uranium mill tailings. Residual wastes from nonconventional methods are not considered in this chapter.

5.3.2 Inventories

The status of the licensed mills, including their estimated commercial and government-related tailings inventories at the end of 1996, is shown in Table 5.2 (data based on refs. 1–11). 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 5.1 lists the annual milling rate, ore grade, and U_3O_8 recovery. Through 1996, 189.7×10^6 t (118.7×10^6 m^3) associated mill tailings were generated.

5.3.3 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 wt % 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 5.3 (ref. 8).

The tailings pile must have a cover designed to control radiological hazards for a minimum of 200 years and for 1,000 years to the greatest extent reasonably achievable. It must also limit radon (^{222}Rn) releases to 20 pCi/m^2/s averaged over the disposal area. Radon release limitation requirements apply to any portion of the tailings disposal site unless radium concentrates do not exceed 5 pCi/g in the first 15 cm below the surface and 15 pCi/g in layers more than 15 cm below the surface.[11]

5.4 DOE URANIUM MILL TAILINGS

DOE uranium mill tailings include those resulting from uranium ore milled for defense purposes as well as those at inactive sites no longer licensed that are administered under the DOE Uranium Mill Tailings Remedial Action Project, which is discussed in Chapter 6.

5.5 REFERENCES

1. U.S. Department of Energy, Energy Information Administration, "Comparison of Uranium Mill Tailings Reclamation in the United States and Canada," *Uranium Industry Annual 1994*, DOE/EIA-0478(94), Washington, D.C. (July 1995).

2. U.S. Department of Energy, Energy Information Administration, "Uranium Industry Annual Survey," Form EIA-858, Washington, D.C. (1996).

3. U.S. Department of Energy, Energy Information Administration, *Uranium Industry Annual 1996*, DOE/EIA-0478(96), Washington, D.C. (April 1997).

4. U.S. Department of Energy, *Integrated Data Base Report—1995: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, DOE/RW-0006, Rev. 10, Oak Ridge National Laboratory, Oak Ridge, Tennessee (December 1996).

5. 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).

6. 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).

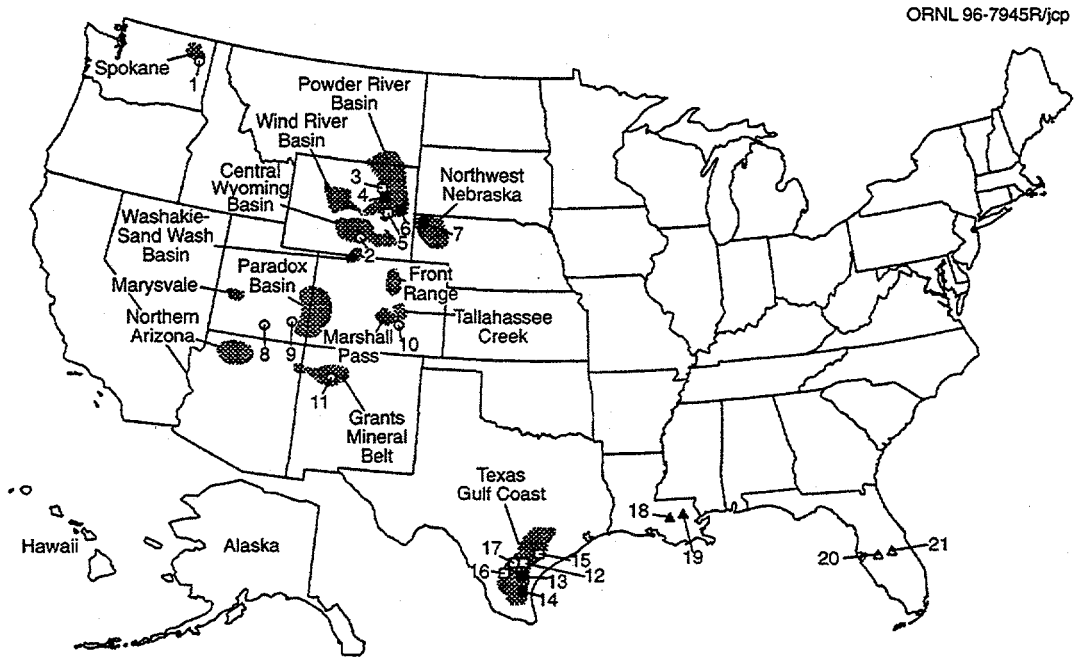
7. U.S. Environmental Protection Agency, "National Emission Standard for Radon-222 Emissions from Licensed Uranium Mill Tailings," *Code of Federal Regulations*, 40 CFR Part 61, Subpart W (September 1986).

8. U.S. Nuclear Regulatory Commission, *Final Generic Environmental Impact Statement on Uranium Milling, Project M-25*, NUREG-0706, Washington, D.C. (September 1980).

9. U.S. Department of Energy, Grand Junction Office, *Statistical Data of the Uranium Industry*, GJ0-100(73), Grand Junction, Colorado (Jan. 1, 1973).

10. U.S. Congress, House of Representatives, Committees on Energy and Commerce; Interior and Insular Affairs; Science, Space, and Technology; and Ways and Means, *Uranium Revitalization, Tailings Reclamation and Enrichment Act of 1988: Hearing on H.R. 4489*, 100th Congress, 2nd sess., pp. 19–21 (Apr. 28, 1988).

11. U.S. Department of Energy, Energy Information Administration, *Decommissioning of U.S. Uranium Production Facilities*, DOE-EIA-0592, Washington, D.C. (February 1995).



Active at the End of 1996

4. Malapai Resources, Christensen Ranch
6. Converse County Mining Venture, Highland
7. Crow Butte Resources, Crow Butte
13. Uranium Resources, Rosita
14. Uranium Resources, Kingsville Dome
18. IMC-Agrico, Sunshine Bridge
19. IMC-Agrico, Uncle Sam

Inactive at the End of 1996

1. Dawn Mining, Ford
2. Green Mountain Mining Venture, Sweetwater
3. Malapai Resources, Irigaray
5. Rio Algom Mining, Smith Ranch
8. U.S. Energy, Shootaring
9. Energy Fuels Nuclear, White Mesa
10. Cotter Corp., Canon City
11. Rio Algom Mining, Ambrosia
12. Malapai Resources, Holiday-El Mesquite
15. Everest Minerals, Hobson
16. COGEMA Mining, West Cole
17. Malapai Resources, O'Hem
20. IMC-Agrico, Plant City
21. IMC-Agrico, New Wales

Uranium Production Centers

Active	Inactive	
●	○	Conventional Mills
■	□	In Situ Leach Plant
▲	△	Byproduct From Phosphate Processing
▨		Major Uranium Reserve Areas

Fig. 5.1. Location and status of currently available uranium mills and plants at EOCY 1996. ***Courtesy of U.S. Department of Energy, Energy Information Administration, Washington, D.C.***

Table 5.1. Uranium ore processed, U_3O_8 recovery rate, and tailings generated through 1996[a,b]

End of calendar year	Ore processed		U_3O_8 recovery rate		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
1993	0.0	0.000	0	0.0	0.0	0.0
1994	0.0	0.000	0	0.0	0.0	0.0
1995	0.1[h]	0.531	93	0.8	0.1	0.1
1996	<0.1[h]	0.524	87	0.7	<0.1	<0.1
Total[i]					189.7	118.7

[a]Sources: Prior to 1984—U.S. Department of Energy, Grand Junction Area Office data files. 1984–1996—Energy Information Administration, "Uranium Industry Annual Survey," Form EIA-858.

[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.

[g]Not available.

[h]Stockpiled ore mined before 1993.

[i]Because of independent rounding, totals may not equal the sum of components.

Table 5.2. Status of conventional uranium mill sites at the end of 1996[a]

Location	Operator	Rated capacity[b] (t/d ore)	Status		Tailings storage area (ha)[d]	Total tailings		
			Operations[b]	Tailings[c]		Volume[e] (10^6 m^3)	Mass (10^6 t)	Government portion[f] (10^6 t)
Colorado								
Canon City	Cotter	1,090	Shut down, 1987		66R[g]	1.3	2.0	0.3
Uravan	Umetco Minerals	1,180[h]	Decommissioning	Partially stabilized	34R	5.9	9.5	5.2
Subtotal		1,090			100R	7.2	11.5	5.5
New Mexico								
Ambrosia Lake	Quivira Mining	6,350	Shut down, 1985	Fenced	131R	18.8	30.1	9.1
Bluewater	Anaconda	5,440[h]	Decommissioning	Partially stabilized	199	13.6	21.7	8.0
Church Rock	United Nuclear	2,720[h]	Decommissioning	i	40R	2.0	3.2	0
Grants	Homestake Mining	3,080[h]	Decommissioning	Unstabilized	86R	12.7	20.2	10.4
L-Bar	Sohio Western Mining	1,450[h]	Decommissioning	i	46R	1.2	1.9	0
Marquez	Bokum Resources	1,820[h,j]	New (on standby)	Never operated	0	0	0	0
Subtotal		6,350			502R	48.3	77.1	27.5
South Dakota								
Edgemont	Tennessee Valley Authority	680[h]	Decommissioned	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[h]	Decommissioned	Stabilized	89	6.5	10.5	0
Panna Maria	Rio Grande Resources	2,720[h]	Decommissioned	Stabilized	101	3.9	5.9	0
Ray Point (Felder Facility)	Exxon	1,000[h]	Decommissioned	Stabilized[k]	18	0.2	0.4[l]	0
Subtotal		2,720			208	10.6	16.8	0

Table 5.2 (continued)

Location	Operator	Rated capacity[b] (t/d ore)	Status		Tailings storage area (ha)[d]	Total tailings		
			Operations[b]	Tailings[c]		Volume[e] (10^6 m^3)	Mass (10^6 t)	Government portion[f] (10^6 t)
Utah								
Lisbon	Rio Algom	680	Decommissioning	i	14	2.2	3.5	0
Moab	Atlas	1,270[h]	Decommissioning	Relocation sought	>80	6.0	9.6	5.4
Shootering	Plateau Resources	910	New (on standby)	Never operated	28	0	0	0
White Mesa	Energy Fuels	1,810	Shut down, 1990; restarted, 1995; shut down, 1996	Partially stabilized	135	2.0	3.4	0
Subtotal		3,400			>257	10.2	16.5	5.4
Washington								
Ford	Dawn Mining	410	Shut down, 1982	Wood chip covering	53R	1.8	2.8	1.1
Sherwood	Western Nuclear	1,810[h]	Decommissioning	i	17	1.6	2.6	0
Subtotal		410			70R	3.4	5.4	1.1
Wyoming								
Bear Creek	Rocky Mountain Energy	1,810[h]	Decommissioning	Unstabilized	61	2.7	4.3	0
Gas Hills	American Nuclear	860[h]	Decommissioning	Unstabilized	47R	3.3	5.4	2.0
Gas Hills	Umetco	1,270[h]	Decommissioning	Unstabilized	58R	4.6	7.3	1.9
Highland	Exxon	2,900[h]	Decommissioning	Partially stabilized	116R	6.4	10.3	0
Lucky Mc	Pathfinder	2,540[h]	Decommissioning	Unstabilized	99R	6.6	10.6	2.6
Petrotomics	Petrotomics	1,360[h]	Decommissioning	Unstabilized	65	3.9	6.3	0.7
Shirley Basin	Pathfinder	1,630[h]	Decommissioning	i	105R	4.7	7.4	0
Split Rock	Western Nuclear	1,540[h]	Decommissioning	Interim stabilization	67R	4.4	7.0	3.0
Sweetwater	Minerals Exploration/ Union Energy Mining	2,720	Shut down, May 1983	Partially stabilized	121	1.3	2.1	0
Subtotal		4,350			739R	37.9	60.7	10.2
1996 total for all sites[b,m,n]		18,320[o]			>1,926R	118.7	189.7	51.2[p]

(Footnotes on next page.)

Table 5.2 (continued)

[a]Data based on refs. 1–11. 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. 2, 5, 9, and 11. 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. 7.

[d]From refs. 6 and 11; 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. 5, Table 8.0. These tailings are from government contracts only and are included in the "Total tailings" column.

[g]R = revised. From ref. 11.

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

[i]Not available.

[j]Mill construction has not been 100% complete.

[k]From ref. 11.

[l]From ref. 10.

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

[n]From ref. 2.

[o]From ref. 2.

[p]Total at the end of government-contracted deliveries in 1970 (ref. 5).

Table 5.3. Typical characteristics of uranium mill tailings[a]

Tailings component	Particle size (μm)	Chemical composition	Radioactivity characteristics
Sands	75 to 500	SiO_2 with <1 wt % 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 wt % 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 wt %	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: pH 10 to 10.5; CO_3^{-2} and HCO_3^-; dissolved solids ~10 wt %	Alkaline leaching: 200 pCi ^{226}Ra/L; essentially no ^{230}Th (insoluble)

[a]Adapted from information in ref. 8.

[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 vol % of the liquid may be recycled. Recycle potential is greater in the alkaline process.

6. ENVIRONMENTAL RESTORATION PROGRAM

6.1 INTRODUCTION

The mission of the DOE Office of Environmental Restoration (EM-40) is to protect human health and the environment from risks posed by inactive and surplus facilities and contaminated areas by remediating sites and facilities in the most cost-efficient and responsible manner possible in order to provide for future beneficial use. These facilities and environmental media contain radioactive and chemically hazardous contaminants as a result of previous activities conducted by DOE and its predecessor agencies.

The environmental restoration program includes a bias for action to expedite actual cleanup wherever and whenever possible. Activities are prioritized based upon several factors, including the need to eliminate risks at sites not controlled by the federal government, the goal of reducing risks at all sites, and compliance with various laws, regulations, and agreements. Most actions are designed to either remove or contain contamination in the environment (such as contaminated soil, debris, and ground water) or to decommission contaminated structures (including reactors, chemical processing buildings, and support facilities). Related activities to support remediation actions include treatment of contaminated materials and wastes, transportation of these materials and wastes to storage and disposal facilities, and disposal of wastes in permitted facilities.

Environmental restoration activities include cleanup of buildings 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). Remedial actions 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 limited to the areas directly impacted by the release but also include additional areas to which contaminants may have migrated (such as to ground water).

Cleanup goals and remedies for each contaminated area are developed through processes established by federal and state laws and other legal agreements. These processes involve decision-makers outside DOE, such as EPA and the impacted state, and include input from other stakeholders such as local citizens and national environmental groups. The principal regulatory requirements for remediation activities are derived from the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Resource Conservation and Recovery Act (RCRA). Activities may be subject further to requirements associated with compliance with the National Environmental Policy Act (NEPA) and with regulatory requirements imposed by the states. Other requirements are set forth in various DOE Orders and standards and in other guidance documents.

Decommissioning activities, which occur after facilities have been stabilized and deactivated, address contamination within the structures. The objectives of decommissioning are to eliminate potential risks to human health and safety and the environment and to allow for the reuse of materials, equipment, and buildings to the greatest extent practicable. Most decommissioning 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.

Decommissioning activities are carried out according to requirements set forth in various DOE Orders and standards and other guidance documents. State requirements also apply in certain instances. Based on a joint policy between DOE and EPA, provisions of CERCLA generally govern decommissioning activities, which are conducted as non-time-critical removal actions. The EM-40 program has placed a priority on minimizing secondary waste and has recycled more than 7,000 metric tons (t) (8,000 tons) of scrap metal from dismantled facilities and equipment.[1] Only those decommissioning activities

at facilities currently in the EM-40 program are addressed in this chapter.

The first steps in the remediation process for contamination in environmental media are to identify the contaminants of concern, determine the extent of contamination, and assess potential threats to human health and the environment. If a significant contamination problem is indicated and if a fast and limited cleanup or containment action could mitigate this problem, DOE may conduct an expedited response action or interim remedial action.

Upon completion of characterization, a detailed analysis of remedial alternatives is conducted. This analysis is followed by a formal decision-making process, possibly including public meetings and a formal public comment period. If the results of the analysis indicate (a) that a contaminated area does not pose a threat to human health or the environment or (b) that a previously completed limited action adequately addressed the contamination condition, a determination that "no further action" is necessary may be made. Such a determination would be made in conjunction with EPA, the host state, and other stakeholders. However, if a threat is deemed to be present, the appropriate action would be identified and implemented.

A wide range of actions can be implemented to address environmental contamination problems at DOE sites. Current and projected land use is a key component in the decision-making process. For example, in-situ remedies that rely on containment of contaminated materials would be appropriate for the large DOE reservations that are projected to remain under the control of the federal government. In contrast, ex-situ remedies in which contaminated materials are exhumed for treatment and disposal at off-site locations would likely be appropriate for small sites destined to be released for unrestricted or industrial (non-DOE) uses. The most appropriate action to be taken at any given area is site-specific and depends on the types of contaminants present, the medium in which they are found, and the likelihood of current or future exposures.

Environmental restoration activities under the auspices of EM-40 are managed in a decentralized manner. That is, much of the responsibility for program implementation rests with the various Operations/Field offices. These offices have the responsibility for determining the appropriate course of action to take at the various contaminated sites and then directing the remediation activities. The locations of the offices responsible for directing the DOE environmental restoration program are shown in Fig. 6.1. A listing of the sites in the EM-40 program is given in Table 6.1.

In general, the offices directing the environmental restoration program in the field are the same offices that directed activities at these sites when facilities were operational. For example, the Chicago Operations Office directs energy research and development activities at Argonne National Laboratory and Brookhaven National Laboratory, and manages the environmental restoration program at these two laboratories.

Over half of the sites in the EM-40 program are managed under the Uranium Mill Tailings Remedial Action Project (UMTRAP) and the Formerly Utilized Sites Remedial Action Program (FUSRAP). UMTRAP consists of two separate projects: UMTRA–Surface, which is managed by the Albuquerque Operations Office and is scheduled for completion in 1999, and UMTRA–Ground Water, which is managed by the Grand Junction Office and is scheduled to continue through 2011. Congress transferred responsibility for FUSRAP to the U.S. Army Corps of Engineers in October 1997. Information on this program is included in this chapter for completeness since this chapter is based on environmental restoration activities as of July 1997.

UMTRAP was authorized in 1978 and involves the stabilization and control of (a) 24 uranium-processing sites and associated vicinity properties located in 10 states and 2 Indian tribal lands and (b) vicinity properties associated with the Edgemont, South Dakota uranium mill site, which was owned by the Tennessee Valley Authority (Fig. 6.2). All of the sites are located in the western United States, except for one in Canonsburg, Pennsylvania. Remedial actions have been completed at 20 of the 24 uranium processing sites. DOE is seeking revocation, at the state's request, of the two sites in North Dakota. Remediation of the remaining two UMTRAP sites is expected to be completed in 1998.[2] In addition to the surface contamination present at these sites (mill tailings, soil, and structures), the ground water can be contaminated with metals (including uranium and radium) and/or nonmetallic constituents associated with the milling process. Ground water is contaminated at all sites, except for the one at Lowman, Idaho.[3] Active remediation of contaminated ground water is expected to be necessary at approximately three sites. The U.S. Nuclear Regulatory Commission (NRC) has approved ground water compliance strategies for two sites (Maybell, Colorado, and Spook, Wyoming). Thus, including Lowman, three UMTRA sites have been closed out in terms of ground water compliance.

Until recently, the Oak Ridge Operations Office was responsible for implementing 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). Responsibility for this program was transferred to the U.S. Army Corps of Engineers in October 1997. Private firms and institutions were contracted by the federal government in the early stages of the nation's atomic development program 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. Most FUSRAP sites are in the eastern half of the country. Currently, 46 sites have been identified in 14 states; 25 of these sites have already been remediated (Fig. 6.3). Remediation of the remaining FUSRAP sites is expected to be completed within the next ten years.

6.2 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 minimal remedial action were required (e.g., pumping and treating a small pocket of contaminated ground water followed by constructing 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 restoration wastes generally have much lower concentrations of radioactive and chemically hazardous substances. Much of the material requiring remediation is a consequence of past activities (e.g., 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. Decommissioning of these facilities will result in wastes such as wipes, concrete, metal, personal protective clothing, and decontamination solvents that generally have 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 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 present in 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 many DOE environmental restoration projects are still in the remedy-selection phase, it is not possible to project definitively the wastes that will result from all of these projects. However, reasonable waste projections can be made based on current site characterization information and planned restoration activities for sites and facilities in the EM-40 program. These estimates are presented in Tables 6.2 through 6.7. In addition to waste projections, the volumes of contaminated materials associated with in-situ remedies are also provided in these tables. These estimates do not include contaminated media outside the scope of the current EM-40 program. Materials in inventory (i.e., those with potential economic value) are also not included in these estimates.

In addition to wastes to be generated, environmental media projected to be left in place have also been assigned a "waste" class in this report. This was done to simplify the tracking of all contaminated materials at the various sites, even though these media are technically not wastes unless or until they are removed. Three major radioactive waste classes are associated with environmental restoration activities: LLW, TRUW, 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, TRUW, spent nuclear fuel (SNF), or 11e(2) by-product material. Environmental restoration activities are not expected to generate any HLW or SNF, although some sites may have to address previously generated HLW as a component of environmental restoration activities. TRUW 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 Section 11e(2) of the Atomic Energy Act (AEA) of 1954 (Pub. 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. Materials being managed under Title 1 of the Uranium Mill Tailings Radiation Control Act of 1978 (Pub. L. 95–604) are defined as residual radioactive material distinct from 11e(2) by-product material. This residual radioactive material is largely uranium mill tailings (UMT), as well as soil and debris contaminated with UMT. Since this material has the same physical and radioactive properties as 11e(2) by-product material, it is included in this report with 11e(2) by-product material.

These radioactive wastes and materials can also be contaminated with hazardous constituents as regulated by RCRA or TSCA; such wastes are considered mixed wastes. Thus, a total of six waste classes are relevant for radioactively contaminated material resulting from environmental restoration activities: LLW, mixed LLW (MLLW), TRUW, mixed TRUW (MTRUW), 11e(2) by-product material, and mixed 11e(2) by-product material.

The EM-40 program is currently in the process of updating contaminated media and waste management information for the DOE/EM 2006 Plan. A key component of this activity is the development of baseline disposition maps summarizing the flow of materials and wastes at each site. These maps will encompass the entire EM-40 program at each site and will include information on the planned disposition of the entire inventory of contaminated media and wastes, including that projected to be managed in-situ, as well as that to be managed ex-situ and will address inter-site transfers of wastes. There will likely be differences between the information contained in this chapter with that in the 2006 Plan due to changing plans and schedules for the EM-40 program attributable to reduced funding for environmental restoration activities.

The estimated volumes of radioactively contaminated materials being managed by the EM-40 program are summarized in Table 6.2. Additional information, including proposed dispositions for these materials, is provided in Tables 6.3 through 6.6 for LLW, MLLW, TRUW, and 11e(2) by-product material, respectively. The volumes given in Table 6.5 for TRUW include the contribution of mixed wastes (the mixed waste volumes are identified in footnotes). No mixed 11e(2) by-product material was reported for any site. The mixed wastes reported in Tables 6.4 and 6.5 are limited to RCRA mixed wastes and do not include the contribution of TSCA mixed wastes. TSCA mixed wastes are reported separately in Table 6.7. In addition, radioactive wastes currently in storage at EM-40 facilities are reported in Table 6.8.

The estimated volumes given in Tables 6.3 through 6.7 are grouped into the following six categories:

1. collection for treatment, storage, and/or disposal by EM-40;
2. collection for treatment, storage, and/or disposal by EM-30;
3. collection for disposition at a commercial facility;
4. in-situ treatment or containment;
5. access/institutional controls or no further action; and
6. not yet determined.

Contaminated materials will be removed and wastes will be generated under the first three categories (ex-situ responses) with responsibility for final disposition either maintained within the EM-40 program, transferred to the EM-30 program, or targeted for a commercial facility. The first category represents wastes projected for on-site disposal (such as the Hanford, Fernald, Monticello, Nevada Test, and Weldon Spring sites) or for which disposal decisions have not been finalized. The second and third categories represent wastes for which specific disposal decisions have been made. Wastes will not be generated under the fourth or fifth category, which will involve such measures as capping, monitoring, and retention of land-use controls. The last category addresses materials for which the final disposition is not currently known.

The estimates represent the initial response volumes, that is, the amount collected, not the final waste forms. Thus, changes due to activities such as treatment have not been incorporated. Treatment can result in higher or lower final volumes depending on the specific process used (e.g., stabilization versus incineration). Treatment can also change the waste class (e.g., stabilizing a MLLW material could result in an LLW product). These changes are not reflected in the information provided in Tables 6.2 through 6.8.

The total volume of solid radioactively contaminated material being address by the EM-40 program is approximately 57 million cubic meters (Table 6.2). An additional 27 million cubic meters of UMTs and debris have already been disposed of at the 20 completed UMTRAP sites. Most of this material (72 vol %) is classified as LLW. Of the material classified as LLW, most (78 vol %) is projected to be managed in-situ. Los Alamos National Laboratory and the Hanford Site account for most of this volume.

The other waste classes combined contribute about 28 vol % of the total volume of radioactively contaminated material being addressed by the EM-40 program. Most of this volume is associated with material currently classified as MLLW and 11e(2) by-product material. The contribution for material classified as TRUW is small, representing less than 1% of the total volume of material being addressed by the EM-40 program. The contribution from TSCA mixed waste is less than 0.1% of the total volume.

As described earlier, remedial actions are currently being conducted at a number of sites. Many of these are small, interim actions. Wastes resulting from these activities are generally being managed at the site where the remedial action occurred. In addition, wastes resulting from remedial actions at some sites (such as those being remediated under FUSRAP) are being managed at commercial disposal facilities.

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 6.2 through 6.8 are also limited to solid materials. Liquids, such as contaminated surface water and ground water and liquid wastes currently in storage, are not included. It should not be concluded that sites for which no (or minimal) volumes are indicated in Tables 6.2 through 6.8 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.

The volumes of radioactively contaminated materials given in Tables 6.2 through 6.8 are limited to those sites and facilities currently in the EM-40 program. These data are summed across all elements of a site in Tables 6.2 through 6.7 including environmental media, wastes currently in storage, and radioactively contaminated materials that could result from future decommissioning activities. Stored wastes are reported separately in Table 6.8. At a number of sites, wastes resulting from EM-40 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.

The DOE Office of Nuclear Material and Facility Stabilization (EM-60) is responsible for coordinating the transfer of facilities to the Office of Environmental Management (EM). As facilities are transferred to EM, environmental restoration and waste management information will be developed and included in future updates of this report.

6.3 REFERENCES

1. U.S. Department of Energy, Office of Strategic Planning and Analysis, Office of Environmental Management, *The 1996 Baseline Environmental Management Report*, DOE/EM-0290, Washington, D.C. (June 1996).

2. U.S. Department of Energy, Office of Environmental Management, *Environmental Management 1996—Progress and Plans of the Environmental Management Program*, DOE/EM-0317, Washington, D.C. (November 1996).

3. U.S. Department of Energy, Office of Environmental Restoration, Office of Environmental Management, EM-40 Core Database, electronic database accessed in August 1997, Washington, D.C.

ORNL DWG 96-7946R

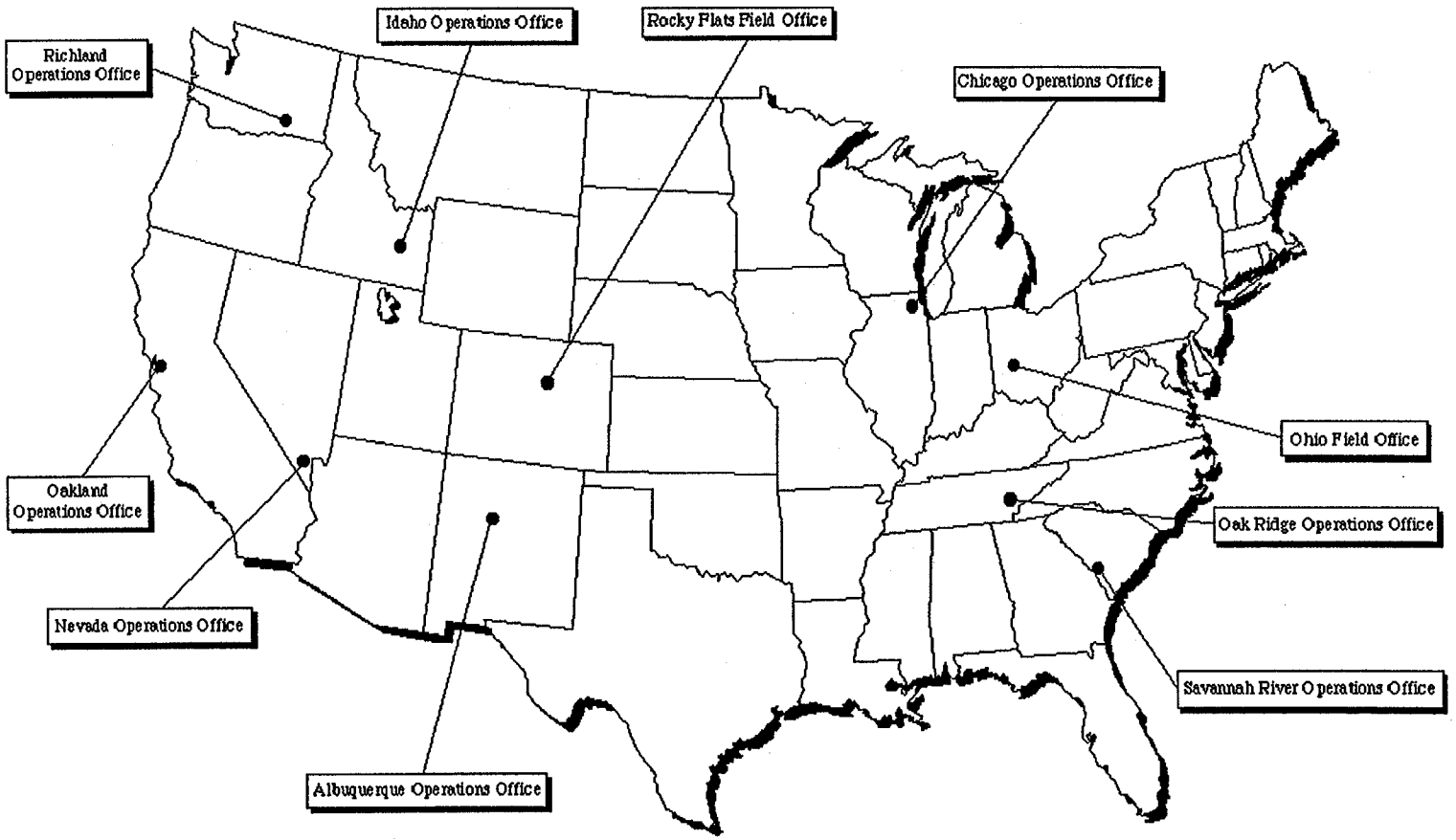
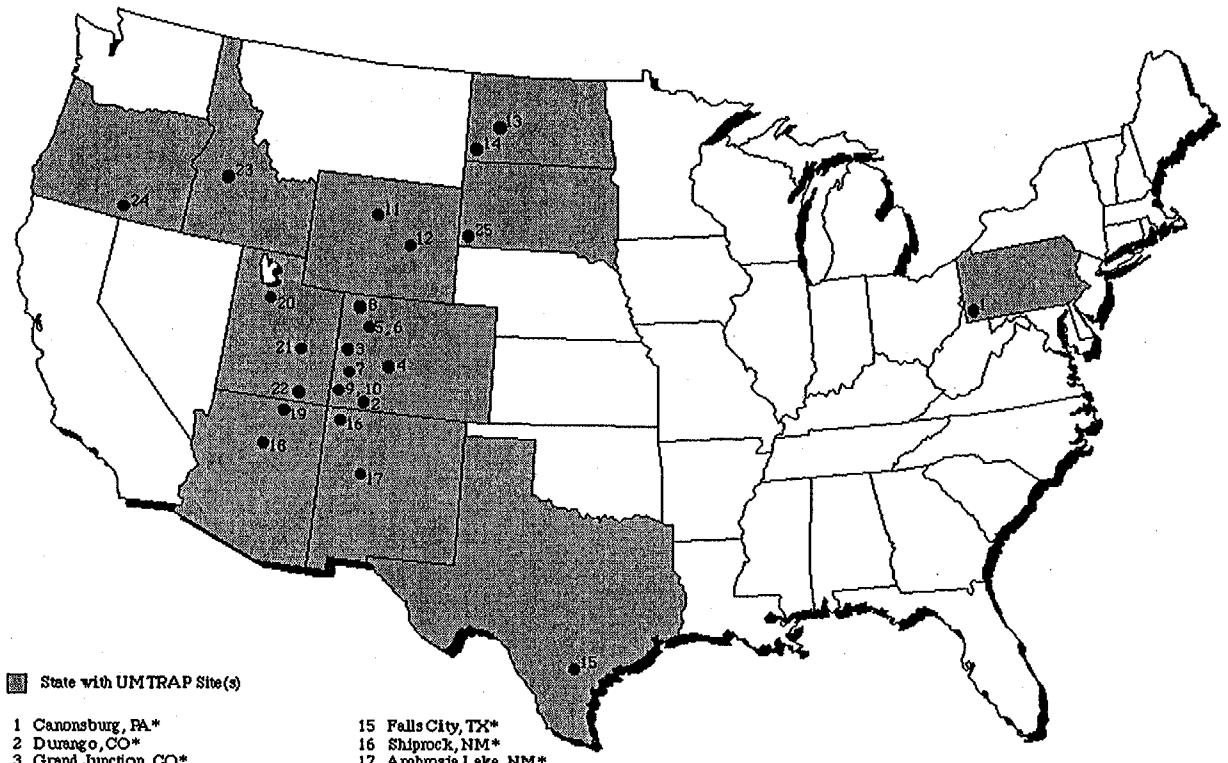


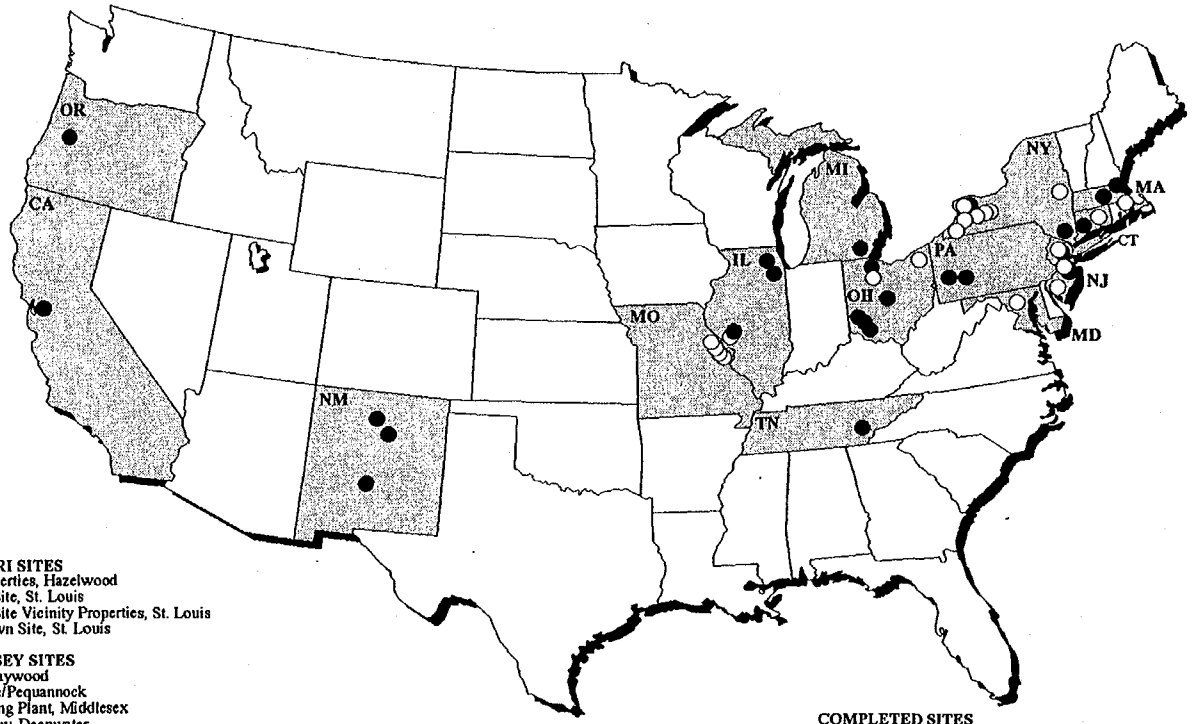
Fig. 6.1. Locations of field offices that direct the DOE environmental restoration program.



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 Spook, 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; Vicinity Properties*

* Surface remediation completed
** At the request of the state, the Department is planning to administratively revoke the designations of the Belfield and Bowman, ND sites

Fig. 6.2. Locations and status of UMTRAP sites.



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 Site, Maywood
¥*† Wayne Site, Wayne/Pequannock
† Middlesex Sampling Plant, Middlesex
DuPont & Company, Deepwater

NEW YORK SITES
† Niagara Falls Storage Site, Lewiston
¥† Colonie Site, Colonie
Ashland 1, Tonawanda
Ashland 2, Tonawanda
Linde Air Products, Tonawanda
Seaway Industrial Park, Tonawanda
Bliss & Laughlin Steel, Buffalo

OHIO SITES
Luckey Site, Luckey
Painesville Site, Painesville

ADDITIONAL SITES
CE Site, Windsor, CT
Madison Site, Madison, IL
* Shpack Landfill, Norton, MA
W. R. Grace & Company, Curtis Bay, MD

COMPLETED SITES
Acid/Pueblo Canyons, Los Alamos, NM
Alba Craft, Oxford, OH
Albany Research Center, Albany, OR
Aliquippa Forge, Aliquippa, PA
Associate Aircraft, Fairfield, OH
B&T Metals, Columbus, OH
Baker & Williams Warehouse, New York City
Baker Brothers, Toledo, OH
Bayo Canyon, Los Alamos, NM
C.H. Schnoor, Springdale, PA
Chapman Valve, Indian Orchard, MA
Chupadera Mesa, White Sands Missile Range, NM
Elza Gate Site, Oak Ridge, TN
General Motors, Adrian, MI
Granite City Steel, Granite City, IL
HHM Safe Co., Hamilton, OH
Kellex/Pierpont, Jersey City, NJ
Middlesex Municipal Landfill, Middlesex, NJ
National Guard Armory, Chicago, IL
New Brunswick Site, New Brunswick, NJ
Niagara Falls Storage Site Vicinity Prop., Lewiston, NY
Seymour Specialty Wire, Seymour, CT
University of California, Berkeley, CA
University of Chicago, Chicago, IL
Ventron Corporation, Beverly, MA

○ 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 and status of FUSRAP sites.

Table 6.1. List of sites in the DOE Environmental Restoration Program[a]

Responsible office[b]	Site
Albuquerque	Grand Junction Office Site
	Holloman Air Force Base (completed)
	Kansas City Plant
	Kauai Test Facility (completed)
	Los Alamos National Laboratory
	Lovelace Biomedical and Environmental Research Institute
	Maxey Flats Disposal Site
	Monticello Mill and Vicinity Properties sites
	Oxnard Facility (completed)
	Pagano Salvage Yard (completed)
	Pantex Plant
	Peak Oil Potentially Responsible Party (PRP) (completed)
	Pinellas Plant (responsibility transferred to the EM Office of Site Operations)
	Salton Sea Test Base (completed)
	Sandia National Laboratories/California
	Sandia National Laboratories/New Mexico
	South Valley Superfund Site
	Uranium Mill Tailings Remedial Action Project[c]
Chicago	Ames Laboratory (completed)
	Argonne National Laboratory–East
	Argonne National Laboratory–West
	Brookhaven National Laboratory
	Fermi National Accelerator Laboratory (completed)
	Hallam Site (completed)
	Piqua Site (completed)
	Princeton Plasma Physics Laboratory
	Site A/Plot M (completed)
Idaho	Idaho National Engineering and Environmental Laboratory
Nevada	Nevada Test Site
	Nevada off-site locations[d]
	Tonopah Test Range[e]
Oak Ridge	Center for Energy and Environmental Research
	East Tennessee Technology Park
	Formerly Utilized Sites Remedial Action Program[f]
	Oak Ridge National Laboratory
	Oak Ridge Reservation Off-Site Areas[g]
	Paducah Gaseous Diffusion Plant
	Portsmouth Gaseous Diffusion Plant
	Weldon Spring Site
	Y-12 Plant
Oakland	Energy Technology Engineering Center
	General Atomics Site
	General Electric Vallecitos Nuclear Center
	Laboratory for Energy-Related Health Research
	Lawrence Berkeley National Laboratory
	Lawrence Livermore National Laboratory (Main Site and Site 300)
	Stanford Linear Accelerator Center

Table 6.1 (continued)

Responsible office[b]	Site
Ohio	Battelle Columbus Laboratories (King Avenue and West Jefferson) Fernald Environmental Management Project Mound Plant (responsibility transferred to the EM Office of Site Operations) Reactive Metals, Inc., Site Separations Process Research Unit
Richland	Hanford Site
Rocky Flats	Rocky Flats Environmental Technology Site
Savannah River	Savannah River Site

[a]Obtained from information included in the DOE Environmental Restoration web page (http://www.em.doe.gov/er/opsmap.html) accessed in August 1997.

[b]All of the offices listed here are Operations offices except for Ohio and Rocky Flats (which are Field offices). The locations of these offices are shown in Fig. 6.1.

[c]A listing of sites being addressed under UMTRAP is given in Fig. 6.2.

[d]Consists of Amchitka Island and Project Chariot sites in Alaska, Rio Blanco and Rulison sites in Colorado, Gnome-Coach and Gasbuggy sites in New Mexico, Salmon Site in Mississippi, and Shoal and Central Nevada Test sites in Nevada. Remedial actions at the Project Chariot Site have been completed.

[e]The Tonopah Test Range is located about 50 km (30 miles) northwest of the Nevada Test Site. Environmental restoration activities for the Tonopah Test Range are often reported together with those for the Nevada Test Site.

[f]A listing of sites being addressed under FUSRAP is given in Fig. 6.3. This program was transferred to the U.S. Army Corps of Engineers in October 1997.

[g]Consists of contaminated areas beyond the boundaries of the major Oak Ridge facilities including the Oak Ridge Associated Universities/Institute for Science and Education, Clinch River/Watts Bar Lake, Lower East Fork Poplar Creek, and several small privately owned sites in the area.

Table 6.2. Estimated volume of radioactively contaminated solid materials associated with the environmental restoration program[a]

Site	Volume,[b] m³					
	LLW	MLLW	TRUW[c]	11e(2) by-product material	TSCA mixed waste	Total
Argonne National Laboratory–East	11,000	140,000				150,000
Argonne National Laboratory–West	750					750
Battelle Columbus Laboratories	11,000	31	370		6	12,000
Brookhaven National Laboratory	90,000	150				90,000
Energy Technology Engineering Center	1,600					1,600
Fernald Site	2,500,000	3,800		11,000		2,500,000
Formerly Utilized Sites Remedial Action Program[d]						
Missouri sites				600,000		600,000
New Jersey sites	40,000	24,000		270,000		340,000
New York sites	29,000	5,100		130,000		170,000[e]
Ohio sites				31,000		31,000
Other sites	14,000			29,000		43,000
General Atomics Site	580	9				590
General Electric Vallecitos Nuclear Center	20		20			40
Grand Junction Office Site	6			7,500	110	7,600
Hanford Site	24,000,000	320	1,900			24,000,000
Idaho National Engineering and Environmental Laboratory	430,000	160,000	370,000			950,000
Laboratory for Energy-Related Health Research	1,400					1,400
Lawrence Berkeley National Laboratory	9,400	42,000				52,000
Los Alamos National Laboratory	9,300,000	500,000	4,400			9,800,000
Lovelace Biomedical and Environmental Research Institute	9,100					9,100
Monticello Mill and Vicinity Properties sites				1,600,000		1,600,000
Mound Plant	120,000				870	120,000
Nevada off-site locations[f]	26,000	11,000				37,000
Nevada Test Site	2,700,000	50				2,700,000
Oak Ridge Reservation[g]	120,000	93,000	32		11,000	220,000
Paducah Gaseous Diffusion Plant	110,000	600	1		3,400	120,000
Pantex Plant	700					700
Portsmouth Gaseous Diffusion Plant	740,000	330,000			4,700	1,100,000
Reactive Metals, Inc., Site	37,000	18			600	38,000
Rocky Flats Environmental Technology Site	110,000	310,000	4,900			430,000

Table 6.2 (continued)

Site	Volume, [b] m³					
	LLW	MLLW	TRUW[c]	11e(2) by-product material	TSCA mixed waste	Total
Sandia National Laboratories/New Mexico	50,000	4,300	4,000			58,000
Savannah River Site	970,000	6,900,000	130,000			8,000,000
Separations Process Research Unit	15,000		36		2	15,000
Uranium Mill Tailings Remedial Action Project[h]				3,200,000		3,200,000
Weldon Spring Site				1,000,000		1,000,000
Total	41,000,000	8,500,000	520,000	6,900,000	21,000	57,000,000

[a]Information obtained from the EM-40 Core Database (August 1997). Volume estimates include environmental media such as soil, sediment, sludge, and intermixed rubble/debris; stored wastes; and standing structures and equipment. Blank entries mean there are no radioactively contaminated solid materials for the indicated waste class. Additional information including projected dispositions for these materials is provided in Tables 6.3 through 6.7. Stored waste information is given in Table 6.8.

[b]These volume estimates represent the initial response volumes, not final waste forms. Changes in volumes and waste classes due to treatment are not reflected in this table. All values are preliminary and are being updated as site characterization and engineering studies continue. Values are given to two significant figures or the nearest integer (for volumes less than 10 m³). Some totals may not equal sum of components due to independent rounding.

[c]Includes the contribution of material classified as mixed wastes.

[d]A listing of the sites being addressed under FUSRAP is given in Fig. 6.3. This program was transferred to the U.S. Army Corps of Engineers in October 1997.

[e]Additional 190,000 m³ of contaminated soil and residues have been disposed of in a containment cell at the Niagara Falls Storage Site (see Table 6.8).

[f]Consists of Amchitka Island and Project Chariot sites in Alaska, Rio Blanco and Rulison sites in Colorado, Gnome-Coach and Gasbuggy sites in New Mexico, Salmon Site in Mississippi, and Shoal and Central Nevada Test sites in Nevada. Remedial actions at the Project Chariot Site have been completed.

[g]Consists of East Tennessee Technology Park, Y-12 Plant, Oak Ridge National Laboratory, and contaminated areas in the vicinity of Oak Ridge, Tennessee, beyond the boundaries of these three facilities.

[h]A listing of the sites being addressed under UMTRAP is given in Fig. 6.2. The volume of mill tailings and debris associated with the 20 sites for which remedial actions have been completed is 27,000,000 m³ (see Table 6.8).

Table 6.3. Projected disposition of radioactively contaminated solid materials classified as LLW[a]

Site	Response volume,[b] m³						
	Ex-situ			In-situ treatment/ containment	Access control or no further action	Not yet determined	Total
	Managed by EM-40	Transferred to EM-30	Commercial disposal				
Argonne National Laboratory–East		2,700				8,400	11,000
Argonne National Laboratory–West		140				610	750
Battelle Columbus Laboratories		1,600	9,700				11,000
Brookhaven National Laboratory	44,000	3,000	7,900		35,000[c]		90,000
Energy Technology Engineering Center		1,600					1,600
Fernald Site	1,800,000	180,000	480,000				2,500,000
Formerly Utilized Sites Remedial Action Program[d]							
New Jersey sites	33,000		7,000				40,000[e]
New York sites			380	1,700	27,000		29,000
Other sites			4,200	2,700	6,700		14,000
General Atomics Site	580						580
General Electric Vallecitos Nuclear Center	20						20
Grand Junction Office Site			6				6
Hanford Site	3,900,000[f]	700		20,000,000			24,000,000
Idaho National Engineering and Environmental Laboratory	210,000	150,000		44,000	9,200	17,000	430,000
Laboratory for Energy-Related Health Research		1,400					1,400
Lawrence Berkeley National Laboratory		9,400					9,400
Los Alamos National Laboratory		15,000		200,000	8,900,000	110,000	9,300,000
Lovelace Biomedical and Environmental Research Institute		9,100					9,100
Mound Plant		3,100	120,000				120,000
Nevada off-site locations[g]				26,000			26,000
Nevada Test Site	290,000			820,000	1,600,000		2,700,000
Oak Ridge Reservation[h]	110,000	11,000					120,000
Paducah Gaseous Diffusion Plant	110,000				200		110,000
Pantex Plant	700						700
Portsmouth Gaseous Diffusion Plant	740,000	4,700			1,200		740,000
Reactive Metals, Inc., Site			37,000				37,000
Rocky Flats Environmental Technology Site	95,000	17,000					110,000

Table 6.3 (continued)

Site	Response volume,[b] m³						
	Ex-situ			In-situ treatment/ containment	Access control or no further action	Not yet determined	Total
	Managed by EM-40	Transferred to EM-30	Commercial disposal				
Sandia National Laboratories/New Mexico		36,000			14,000		50,000
Savannah River Site		430,000		21,000	1,200	520,000	970,000
Separations Process Research Unit			15,000				15,000
Total	7,400,000	870,000	680,000	21,000,000	11,000,000	140,000	41,000,000

[a]Information obtained from the EM-40 Core Database (August 1997). Volume estimates include environmental media such as soil, sediment, sludge, and intermixed rubble/debris; stored wastes; and standing structures and equipment. Sites not listed in this table do not have any radioactively contaminated solid material classified as LLW. The stored waste volumes are also provided separately in Table 6.8.

[b]These volume estimates represent the initial response volumes, not final waste forms. Changes in volumes and waste classes due to treatment are not reflected in this table. All values are preliminary and are being updated as site characterization and engineering studies continue. Values are given to two significant figures or the nearest integer (for volumes less than 10 m³). Some totals may not equal sum of components due to independent rounding.

[c]Consists of contaminated materials (mostly metal) projected to be recycled.

[d]A listing of the sites being addressed under FUSRAP is given in Fig. 6.3. This program was transferred to the U.S. Army Corps of Engineers in October 1997.

[e]Includes 27,000 m³ of low-level waste soil in bulk storage at the Middlesex Sampling Plant (see Table 6.8).

[f]Approximately 370,000 t [410,000 tons (or about 200,000 m³)] of waste has been transferred to the Environmental Restoration Disposal Facility (ERDF) for disposal as of early August 1997.

[g]Consists of Amchitka Island and Project Chariot sites in Alaska, Rio Blanco and Rulison sites in Colorado, the Gnome-Coach and Gasbuggy sites in New Mexico, Salmon Site in Mississippi, and Shoal and Central Nevada Test sites in Nevada. Remedial actions at the Project Chariot Site have been completed.

[h]Consists of East Tennessee Technology Park, Y-12 Plant, Oak Ridge National Laboratory, and contaminated areas in the vicinity of Oak Ridge, Tennessee, beyond the boundaries of these three facilities.

Table 6.4. Projected disposition of radioactively contaminated solid materials classified as MLLW[a]

Site	Response volume,[b] m³						
	Ex-situ			In-situ treatment/ containment	Access control or no further action	Not yet determined	Total
	Managed by EM-40	Transferred to EM-30	Commercial disposal				
Argonne National Laboratory–East			30	140,000		46	140,000
Battelle Columbus Laboratories		11	20				31
Brookhaven National Laboratory	25		120				150
Fernald Environmental Management Project		1,300	2,400				3,800
Formerly Utilized Sites Remedial Action Program[c]							
New Jersey sites	18,000		5,700				24,000[d]
New York sites			5,100				5,100
General Atomics Site	1		8				9
Hanford Site	220	100					320
Idaho National Engineering and Environmental Laboratory	120,000	120		38,000			160,000
Lawrence Berkeley National Laboratory					42,000		42,000
Los Alamos National Laboratory			980		500,000		500,000
Nevada off-site locations[e]				11,000			11,000
Nevada Test Site	50						50
Oak Ridge Reservation[f]	84,000	8,800					93,000
Paducah Gaseous Diffusion Plant	110	160	330				600
Portsmouth Gaseous Diffusion Plant	330,000	810			170		330,000
Reactive Metals, Inc., Site		9	9				18
Rocky Flats Environmental Technology Site	110,000	8,300		9,900	180,000		310,000
Sandia National Laboratories/New Mexico			1,700		2,600		4,300
Savannah River Site		62,000		410,000		6,400,000[g]	6,900,000
Total	660,000	81,000	16,000	610,000	730,000	6,400,000	8,500,000

[a]Information obtained from the EM-40 Core Database (August 1997). Volume estimates include environmental media such as soil, sediment, sludge, and intermixed rubble/debris; stored wastes; and standing structures and equipment. Sites not listed in this table do not have any radioactively contaminated solid material classified as MLLW. The stored waste volumes are also provided separately in Table 6.8.

[b]These volume estimates represent the initial response volumes, not final waste forms. Changes in volumes and waste classes due to treatment are not reflected in this table. All values are preliminary and are being updated as site characterization and engineering studies continue. Values are given to two significant figures or the nearest integer (for volumes less than 10 m³). Some totals may not equal sum of components due to independent rounding.

(Footnotes are continued on next page.)

Table 6.4 (continued)

[c]A listing of the sites being addressed under FUSRAP is given in Fig. 6.3. This program was transferred to the U.S. Army Corps of Engineers in October 1997.

[d]Mixed low-level waste soil in bulk storage at the Middlesex Sampling Plant (see Table 6.8).

[e]Consists of Amchitka Island and Project Chariot sites in Alaska, Rio Blanco and Rulison sites in Colorado, the Gnome-Coach and Gasbuggy sites in New Mexico, Salmon Site in Mississippi, and the Shoal and Central Nevada Test sites in Nevada. Remedial actions at the Project Chariot Site have been completed.

[f]Consists of East Tennessee Technology Park, Y-12 Plant, Oak Ridge National Laboratory, and contaminated areas in the vicinity of Oak Ridge, Tennessee, beyond the boundaries of these three facilities.

[g]Most of this material is contaminated soil which will likely be managed in-situ.

Table 6.5. Projected disposition of radioactively contaminated solid materials classified as TRUW[a]

Site	Response volume,[b] m³					
	Ex-situ		In-situ treatment/ containment	Access control or no further action	Not yet determined	Total
	Managed by EM-40	Transferred to EM-30				
Battelle Columbus Laboratories		370				370
General Electric Vallecitos Nuclear Center	20					20
Hanford Site		1,900				1,900
Idaho National Engineering and Environmental Laboratory[c]		370,000[d]				370,000
Los Alamos National Laboratory			4,400			4,400
Oak Ridge Reservation[e]	28[f]	4				32
Paducah Gaseous Diffusion Plant	1[g]					1
Rocky Flats Environmental Technology Site		4,900[h]				4,900
Sandia National Laboratories/New Mexico				4,000[g]		4,000
Savannah River Site		130,000[i]				130,000
Separations Process Research Unit		36				36
Total	49	510,000	4,400	4,000		520,000

[a]Information obtained from the EM-40 Core Database (August 1997). Volume estimates include environmental media such as soil, sediment, sludge, and intermixed rubble/debris; stored wastes; and standing structures and equipment and include the contribution of material classified as MTRUW. Sites not listed in this table do not have any radioactively contaminated solid material classified as TRUW. The stored waste volumes are provided separately in Table 6.8.

[b]These volume estimates represent the initial response volumes, not final waste forms. Changes in volumes and waste classes due to treatment are not reflected in this table. All values are preliminary and are being updated as site characterization and engineering studies continue. Values are given to two significant figures or the nearest integer (for volumes less than 10 m³). Some totals may not equal sum of components due to independent rounding.

[c]In addition to TRUW, 1,600 m³ of HLW-contaminated soil is being addressed at the Idaho Chemical Processing Plant (ICPP).

[d]Soil and debris associated with the Radioactive Waste Management Complex contaminated with transuranic radionuclides. Only a small fraction (on the order of 10,000 m³) is expected to be managed as TRUW following excavation, sorting, and treatment.

[e]Consists of East Tennessee Technology Park, Y-12 Plant, Oak Ridge National Laboratory, and contaminated areas in the vicinity of Oak Ridge, Tennessee, beyond the boundaries of these three facilities.

[f]At Oak Ridge National Laboratory, 23 m³ of the TRUW is MTRUW.

[g]MTRUW.

[h]At the Rocky Flats Environmental Technology Site, 4,100 m³ of the TRUW is MTRUW.

[i]TRUW projected to be generated during decontamination and decommissioning (D&D) activities. The actual volume of TRUW associated with D&D activities will likely be lower than indicated here.

Table 6.6. Projected disposition of radioactively contaminated solid materials classified as 11e(2) by-product material[a,b]

Site	Response volume,[c] m³						
	Ex-situ			In-situ treatment/ contaminant	Access control or no further action	Not yet determined	Total
	Managed by EM-40	Transferred to EM-30	Commercial disposal				
Fernald Site		11,000[d]					11,000
Formerly Utilized Sites Remedial Action Program[e]							
Missouri sites	19,000		290,000	290,000			600,000[f]
New Jersey sites	110,000		130,000	34,000			270,000[g]
New York sites			84,000	50,000			130,000[h]
Ohio sites			4,600	27,000			31,000
Other sites			770	28,000	770		29,000
Grand Junction Office Site	7,500						7,500
Monticello Mill and Vicinity Properties sites	1,600,000						1,600,000
Uranium Mill Tailings Remedial Action Project[i]	3,200,000						3,200,000
Weldon Spring Site	1,000,000[j]						1,000,000
Total	5,900,000	11,000	510,000	430,000	770		6,900,000

[a]Information obtained from the EM-40 Core Database (August 1997). Volume estimates include environmental media such as soil, sediment, sludge, and intermixed rubble/debris; stored wastes; and standing structures and equipment. Sites not listed in this table do not have any radioactively contaminated solid material classified as 11e(2) by-product material. The stored waste volumes are provided separately in Table 6.8.

[b]By-product material as defined in Section 11e(2) of the Atomic Energy Act of 1954 (Pub. L. 83–703), as amended. Materials being managed under Title 1 of the Uranium Mill Tailings Radiation Control Act of 1978 (Pub. L. 95–604) are defined as residual radioactive material. Since this material has the same physical and radioactive properties as 11e(2) by-product material, it is reported here under 11e(2) by-product material.

[c]These volume estimates represent the initial response volumes, not final waste forms. Changes in volumes and waste classes due to treatment are not reflected in this table. All values are preliminary and are being updated as site characterization and engineering studies continue. Values are given to two significant figures. Some totals may not equal sum of components due to independent rounding.

[d]Residues in storage in four concrete silos (see Table 6.8).

[e]A listing of the sites being addressed under FUSRAP is given in Fig. 6.3. This program was transferred to the U.S. Army Corps of Engineers in October 1997.

[f]Includes 24,000 m³ of 11e(2) by-product material soil in bulk storage at the Hazelwood Interim Storage Site (see Table 6.8).

[g]Includes 20,000 m³ of 11e(2) by-product material soil in bulk storage at the Wayne Site (see Table 6.8).

[h]Additional 190,000 m³ of contaminated soil and residues have been disposed of in a containment cell at the Niagara Falls Storage Site (see Table 6.8).

[i]A listing of the sites being addressed under UMTRAP is given in Fig. 6.2. The volume of mill tailings and debris associated with the 20 sites for which remedial actions have been completed is 27,000,000 m³ (see Table 6.8).

[j]Includes 700,000 m³ of 11e(2) by-product material soil and debris in interim storage at the chemical plant area of the Weldon Spring Site (see Table 6.8).

Table 6.7. TSCA mixed waste associated with EM-40 activities[a]

Site	Response volume,[b] m³	
	RASB[c]	RPCB[d]
Battelle Columbus Laboratories		6[e]
Grand Junction Office Site	65[f]	47[f]
Mound Plant	870[e]	
Oak Ridge Reservation[g]	10,000[h]	700[f]
Paducah Gaseous Diffusion Plant		3,400[f]
Portsmouth Gaseous Diffusion Plant	340[f]	4,300[i]
Reactive Metals, Inc., Site	600[e]	
Separations Process Research Unit	2[e]	
Total	12,000	8,500

[a]Information obtained from the EM-40 Core Database (August 1997). Volume estimates include environmental media such as soil, sediment, sludge, and intermixed rubble/debris; stored wastes; and standing structures and equipment. Sites not listed in this table do not have any radioactively contaminated solid material classified as TSCA mixed wastes. The stored waste volumes are provided separately in Table 6.8.

[b]These volume estimates represent the initial response volumes, not final waste forms. Changes in volumes and waste types due to treatment are not reflected in this table. All values are preliminary and are being updated as site characterization and engineering studies continue. Values are given to two significant figures or the nearest integer (for volumes less than 10 m³).

[c]Radioactive asbestos (i.e., materials contaminated with both radionuclides and asbestos).

[d]Radioactive PCBs (i.e., materials contaminated with both radionuclides and polychlorinated biphenyls).

[e]Projected to be transferred to a commercial facility for final disposition.

[f]Projected to be managed by EM-40 through final disposition.

[g]Consists of East Tennessee Technology Park, Y-12 Plant, Oak Ridge National Laboratory, and contaminated areas in the vicinity of Oak Ridge, Tennessee, beyond the boundaries of these three facilities.

[h]For the radioactive asbestos (RASB) at the Oak Ridge Reservation, 1,900 m³ is projected to be managed by EM-40 through final disposition and 8,300 m³ is projected to be transferred to EM-30 for final disposition.

[i]For the radioactive polychlorinated biphenyl (RPCB) at the Portsmouth Gaseous Diffusion Plant, 3,800 m³ is projected to be managed by EM-40 through final disposition and 500 m³ is projected to be transferred to EM-30 for treatment by incineration.

Table 6.8. Volumes (m^3) of solid radioactive wastes in storage at EM-40 facilities[a]

Site	Waste type								
	TRUW	MTRUW	LLW	MLLW[b]	11e(2) by-product material	Mixed 11e(2) by-product material	RASB[c]	RPCB[d]	Total
Battelle Columbus Laboratories	41								41
Fernald Environmental Management Project			140,000	3,500	11,000[e]				150,000
Formerly Utilized Sites Remedial Action Program[f]									
Missouri sites					24,000[g]				24,000
New Jersey sites			27,000[h]	24,000[i]	20,000[j]				71,000
New York sites					190,000[k]				190,000
General Atomics Site			350	3					360
Grand Junction Office Site			6		140	1		47[l]	190
Oak Ridge Reservation[m]				6,900[n]					6,900
Paducah Gaseous Diffusion Plant	1		110,000	580				3,400	110,000
Portsmouth Gaseous Diffusion Plant			13,000	5,400			340	4,300	23,000
Reactive Metals, Inc., Site			640	18			16		670
Uranium Mill Tailings Remedial Action Project					27,000,000[o]				27,000,000
Weldon Spring Site					700,000[p]				700,000

[a]Information obtained from the EM-40 Core Database (August 1997). Waste volumes are limited to solid wastes and do not include EM-40-generated wastes that are currently in storage facilities managed by EM-30. Volumes are given to two significant figures or the nearest integer (for volumes less than 10 m^3). Some totals may not equal sum of components due to independent rounding.

[b]Management plans for these wastes are provided in site treatment plans developed to meet the requirements of the Federal Facility Compliance Act.

[c]Radioactive asbestos, i.e., materials contaminated with both radionuclides and asbestos.

[d]Radioactive PCBs, i.e., materials contaminated with both radionuclides and polychlorinated biphenyls.

[e]11e(2) by-product material residues in storage in four concrete silos.

[f]A listing of sites being addressed under FUSRAP is given in Fig. 6.3. This program was transferred to the U.S. Army Corps of Engineers in October 1997.

[g]11e(2) by-product material soil in bulk storage at the Hazelwood Interim Storage Site. The storage pile is covered with a tarp.

[h]Low-level waste soil in bulk storage at the Middlesex Sampling Plant. The storage pile is covered with a tarp.

[i]Mixed low-level waste soil in bulk storage at the Middlesex Sampling Plant. The storage pile is covered with a tarp. This material has been recently classified as "hazardous waste containing residual radioactive material."

[j]11e(2) by-product material soil in bulk storage at the Wayne Site. The storage pile is covered with a tarp. This material is being removed from the site and transferred to a commercial facility for disposal.

[k]11e(2) by-product material residues and soil disposed of in a containment cell at the Niagara Falls Storage Site.

[l]The radioactive classification of this waste is 11e(2) by-product material.

[m]Consists of East Tennessee Technology Park, Y-12 Plant, Oak Ridge National Laboratory, and contaminated areas in the vicinity of Oak Ridge, Tennessee, beyond the boundaries of these three facilities.

[n]Mixed low-level waste soil and debris in storage at the East Tennessee Technology Park.

[o]Waste volume associated with the 20 completed UMTRAP sites (see Fig. 6.2).

[p]11e(2) by-product material soil and debris in interim storage at the chemical plant area of the Weldon Spring Site.

7. NATURALLY OCCURRING AND ACCELERATOR-PRODUCED RADIOACTIVE MATERIAL

7.1 INTRODUCTION

Naturally occurring and accelerator-produced radioactive material (NARM) is a broad category that includes accelerator-produced radioactive material and naturally occurring radioactive material (NORM) and is not source, special nuclear, or by-product material. Accelerator-produced radioactive materials (the "A" in NARM) include wastes generated by accelerators used in subatomic particle physics research.

The term NORM refers to materials not covered under the Atomic Energy Act (AEA) whose radioactivity has been enhanced (i.e., materials whose radionuclide concentrations are either increased or redistributed compared to typical background levels either naturally or as the result of human intervention or processes). Examples are exploration and production wastes from the oil and natural gas industries and phosphate slag piles from the phosphate mining industry. NORM is not used to describe or discuss the natural radioactivity of rocks and soils or background radiation.

NARM wastes are currently not regulated by any federal agency. Responsibility for regulating the disposal of NARM is not addressed in the AEA.[1] Regulation of NARM disposal currently rests with the states as part of their authority for ensuring the protection of public health and safety.[2,3] However, currently a few states do not have regulatory programs for NARM wastes. Table 7.1 (data from refs. 4 and 5) summarizes the current status of state regulations for NORM wastes.

7.2 WASTE CHARACTERIZATION

As described in ref. 6, accelerator-produced materials are generated in small quantities and are comprised of radionuclides with short half-lives. Table 7.2 (data from ref. 7) lists the radionuclides found in accelerator-produced radioactive materials. Except for ^{81}Kr, ^{145}Pm, and ^{22}Na, most of these radionuclides have short half-lives that are measured in days, hours, or minutes. Accelerator wastes include accelerator targets, wastes from accelerator maintenance and D&D, and wastes from radiopharmaceutical manufacture. Because accelerator-produced material is caused by the bombardment of radiation, it has the same properties as material that is regulated by the AEA and is, therefore, typically handled in the same regulatory manner as AEA material. Because of its usually short half-life, accelerator-produced material can often be stored until it has decayed to insignificant levels. However, it is not clear whether this approach will work for the possibly large volumes of such materials that may result from the future decommissioning of large accelerator facilities.

Compared to radioactive wastes associated with most research, industrial, and medical applications, NARM wastes have low radioactivity concentrations. NARM wastes with more than 2 nCi/g of ^{226}Ra or equivalent are commonly referred to as discrete NARM waste; below this threshold, the waste is referred to as diffuse NARM waste.

NORM wastes, which exclude accelerator-produced radioactive materials, result from concentrations of naturally occurring radionuclides found in the earth's crust. Table 7.3 summarizes the major characteristics of all the naturally occurring radionuclides identified in the *Chart of the Nuclides* (ref. 8).

7.2.1 Discrete Wastes

Discrete wastes have a relatively small volume but large radioactivity; these include industrial gauges, old radium watch and industrial dials, radium needles in medical equipment, and resins (filters) that remove radioactive radium and other NORM from ground water.

7.2.2 Diffuse Wastes

Diffuse wastes are characterized by a relatively large volume with small radioactivity.[9] These materials result from industrial processes and include:

- coal ash and slag from utility electrical generation;
- solid wastes from geothermal energy production;
- slag, leachate, and tailings from the mining and processing of metals other than uranium or thorium (e.g., copper);
- sludge from drinking-water treatment;
- scale, sludge, produced water, and equipment from oil and natural-gas production containing NORM; and
- wastes (phosphogypsum and slag) from mining phosphate ores for fertilizer (ammonium phosphate) production.

A summary of domestic processes that generate NORM wastes are given in Table 7.4 (based on refs. 10–13). Levels of specific activity for these wastes typically vary from 2–200 pCi/g.[10,14] Table 7.5 (adapted from refs. 13 and 15) lists major radionuclides found in diffuse NORM wastes. Estimated radionuclide concentrations reported by the Environmental Protection Agency (EPA) in ref. 13 for each diffuse NORM category are provided in Tables 7.6–7.11.

Descriptions of the specific characteristics of diffuse NORM wastes are given in the following and are based on the EPA waste characterization and preliminary risk assessment study of ref. 13.

7.2.2.1 Coal combustion

Fossil fuels such as coal contain naturally occurring radioactivity from uranium, thorium, radium, and their daughter products. The combustion of coal as a fossil fuel for electric power and industrial applications results in the generation of ash, which is collected at the bottom of power-plant boilers and in exhaust-stack filters. Consisting mostly of aluminum, iron, calcium, and silicon, coal ash is retained either as bottom ash and boiler slag or as fly ash trapped in exhaust-stack filtration devices. Most of the waste is generated as fly ash, which is entrained with the hot flue gases of the combustion process. The remainder of the ash is heavier and settles to the bottom of the boiler to form what is referred to as bottom ash. Liquid boiler slag is formed when some of the bottom ash melts under the intense heat.[13] Table 7.6 (based on ref. 13) gives a breakdown of the radionuclide concentrations found in NORM wastes from coal combustion. These concentrations, however, can vary widely depending on the mineral content of the coal which, in turn, can vary with mining location and region of the country.

7.2.2.2 Geothermal energy production

Geothermal energy is heat produced and stored in the earth. This energy can be economically extracted from high-temperature crustal rocks, sediments, volcanic deposits, water, steam, and other gases found at accessible depths from the earth's surface. Concentrations of NORM are found in the solid wastes generated by the exploration and development of geothermal systems and the extraction of the earth's geothermal energy for use in either producing electric power or supplying direct heat. These NORM wastes include minerals that precipitate out of solution and form scale or sludge on the inside surfaces of the drilling and production equipment (e.g., steam turbines, heat exchangers, process lines, valves, turbines, and fluid-handling equipment) used to extract geothermal heat. Such wastes contain barium, calcium, and strontium salts (carbonates, sulfates, and silicates) and silica as well as significant concentrations of radium and radium decay products. Radium is slightly soluble and, consequently, can be brought to the surface and coprecipitated with barium and calcium salts onto the inside surfaces of drilling and production equipment. The principal wastes of concern are the scales in piping and production equipment and the filter cake produced from treatment of spent geothermal fluids prior to their reinjection. Scales are hard, insoluble sulfate deposits that form on the inside of pipes, tubulars, filters, pumps, well heads, and other water-handling equipment.[12] Concentrations of NORM in geothermal wastes will vary with the geology and mineralogy of a geothermal resource area along with the physical and chemical changes that occur during energy extraction.[13] Table 7.7 (based on ref. 13) gives a breakdown of typical radionuclide concentrations found in NORM wastes from geothermal energy production.

7.2.2.3 Metal mining and processing

The mining and processing of metal ores, other than uranium and phosphate, generates large quantities of NORM wastes. These wastes include ore tailings and smelter slag, some of which contain elevated concentrations of uranium, thorium, radium, and their decay products that were originally part of the process feed ore. The extraction process for some ores can yield a waste product (e.g., tailings or slag) that has a higher radionuclide concentration than the original ore. Tailings are the solid materials remaining after physical

or chemical benefication (washing, flotation, grinding, and drying) removes the valuable metal constituents from the ore. Slag is the vitreous residue mass left from the smelting (blast furnace melting and conversion) of metal ore for extraction and purification.[13]

The EPA study (ref. 13) describes NORM wastes from the mining and processing of three categories of metals: rare earth metals, special application metals, and metals produced in bulk quantities (i.e., large volumes) by industrial extraction processes. Rare earth (or lanthanide) metals comprise 16 chemical elements, including those with atomic numbers 57 (lanthanum) through 71 (lutetium) as well as yttrium (atomic number 39), which has similar chemical properties. Special application metals are regarded as metals that have unique commercial and industrial uses and include hafnium, tin, titanium, and zirconium. Metals mined and processed in bulk for industrial applications include aluminum, copper, iron, lead, zinc, and precious metals like gold and silver.[13]

The level of NORM found in metal ores depends more on the geologic formation or region than on the particular mineral being mined. Table 7.8 (based on ref. 13) gives a breakdown of typical radionuclide concentrations found in NORM wastes from each of the three categories of mined metals.[13]

7.2.2.4 Municipal water treatment

A small portion of the public water supply systems in the United States treat water containing elevated NORM radionuclide concentrations—most significantly, uranium and radium. Radionuclides are leached into ground or surface water when the water comes in contact with uranium- and thorium-bearing geologic media. The predominant radionuclides found in water include those of uranium, radium, radon, and their decay products. Many water-treatment technologies typically used for removing solids from water for softening and purification can significantly reduce the level of NORM radioactivity. NORM wastes from municipal water treatment consist of radioactive-contaminated sludges and solids that include filter sludges, spent ion-exchange resins, spent granular activated carbon, and water from filter backwash. Radium-selective ion-exchange resins generate wastes at much higher concentrations than do those found in sludge, but in smaller quantities. In fact, some of these wastes fall into the discrete NARM waste category because their concentrations exceed 2 nCi/g.[13] Table 7.9 (based on ref. 13) gives estimated typical radionuclide concentrations of NORM wastes from municipal water treatment. These concentrations can vary significantly from location to location because of the varying geologic characteristics of different water sources in different regions of the country.

7.2.2.5 Oil and natural gas production and processing

Some oil and natural gas production and processing activities generate NORM wastes. Radium is a major contributor to the radioactivity found in these wastes, which are found in pipe scale and sludge from production and processing operations. Uranium and thorium compounds are mostly insoluble, and as oil and natural gas are brought to the surface, these compounds tend to remain embedded in underground geologic formations. However, some radium and radium daughter products are slightly soluble in water and can become mobilized when ground water (containing dissolved mineral salts) is brought to the surface from production and processing. When this occurs, some radium and its daughters may precipitate out of solution because of geologic chemical changes and reduced temperature and pressure. Radium concentrations from geologic formations can precipitate out in sludges and on the internal surfaces of oil and natural gas piping and production and processing equipment. The solid scale residue typically consists mainly of barium, calcium, and strontium sulfates, silicates, and carbonates along with smaller portions of radium compounds. Sludge deposits, consisting of barium and silica compounds, are generally in the form of oily, loose material. NORM radionuclide concentrations in scales that accumulate in process piping and surface equipment may vary from background soil levels (about 1 pCi/g) to several hundred thousand picocuries per gram—with an average activity of about 1000–2000 pCi/g.[16] Concentrations in sludges range from background levels to several hundred picocuries per gram. Radium and its decay products are also found in elevated concentrations in ground water extracted to the surface from oil drilling. However, these concentrations are much less than those found for the scale or sludge wastes.[13]

NORM wastes from natural gas plant deposits differ from oil production NORM wastes and typically consist of radon decay products plated out on the interior surfaces of pipes, valves, filters, and other gas production and processing equipment.[13]

Table 7.10 (based on ref. 13) gives estimated radionuclide concentrations of NORM wastes from both oil and natural gas production and processing. As with other NORM wastes, the radioactivity concentrations for the scale and sludge wastes are strongly influenced by

the natural abundance of radionuclides, the geologic formation conditions where the oil and natural gas are produced, and the characteristics of the production process.[13,17]

7.2.2.6 Phosphate mining and fertilizer production

NORM wastes are generated from the mining and processing of phosphate rock (phosphorite) needed to produce phosphate fertilizers, detergents, animal feed, food products, pesticides, and other phosphorous chemicals. These wastes include ferrophosphorus, phosphogypsum (a hydrated calcium sulfate slurry), piping scale, and slag (calcium silicate).[13]

Phosphogypsum and scale are the principal waste by-products generated during the production of phosphoric acid and fertilizers. Scale is deposited in small quantities in process piping and in filtration receiving tanks. Phosphate scale wastes are generally regarded as discrete NORM because ^{226}Ra concentrations in small volumes of these materials have been found be as high as 100,000 pCi/g.[13,18]

Ferrophosphorus and phosphate slag are the principal waste by-products from the production of elemental phosphorous, which is produced by the reduction of phosphate rock in large electric furnaces that use carbon and silica as catalysts. Both ferrophosphorus and slag are found in the residual solids that remain from the furnace processing.[13]

Table 7.11 (based on ref. 13) gives estimated radionuclide concentrations in the principal NORM wastes from phosphate mining and fertilizer production. These concentrations include contributions from uranium, thorium, radium, and their radioactive decay products, which are found in mined phosphate ores and have become concentrated in the waste by-products. Actual radionuclide concentrations will vary in location because of varying geological characteristics of phosphate ores in different regions of the country as well as variations in the processes used for phosphate mining and production.[13]

7.3 GENERATION, INVENTORIES AND PROJECTIONS

Limited information is available on the generation, inventories, and projections of domestic NARM wastes. Table 7.12 reports the inventories of radium disposed of in recent years by New York State generators.[10]

Like inventories, projections of NARM (and NORM) are limited and vary according to the region of the country. Table 7.13 (adapted from refs. 13 and 15) reports a summary of estimates of domestic diffuse NORM waste generation, material density, cumulative inventory, and radioactive (^{226}Ra) concentration. These estimates are reported in refs. 13 and 15 and pertain to wastes from commercial rather than DOE activities. EPA information and data reported from ref. 13 are, in turn, based on refs. 17–30. It should be cautioned that the large quantities reported in Table 7.13 for total NORM inventories are preliminary estimates associated with large ranges of uncertainty. These estimates do not indicate how much of these materials would actually be managed and disposed of as radioactive waste. Consequently, caution should be used in trying to extrapolate any of the referenced information and data for purposes such as risk assessment or determining needed disposal facilities. The estimates given in Table 7.13 also do not reflect possible opportunities for the reuse and recycling of NORM materials in commercial and industrial applications. Such applications are further discussed in ref. 13.

The ubiquitous nature of NORM wastes accounts for the apparent enormous inventory of these materials. Even allowing for uncertainties, the estimated cumulative volume of these materials is much larger than the cumulative volume of DOE and commercial radioactive waste and SNF being managed through CY 1996 (see the tables of Chapter 0 and Chapter 6).

The total inventory that should be associated with NORM will depend on what regulatory concentration standards can be applied to these materials on a national basis. Future updates of this document will include additional and updated information and data on both accelerator-produced waste and NORM waste inventories, projections, and characteristics as they become available.

7.4 REFERENCES

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

2. Robert E. Berlin and Catherine C. Stanton, *Radioactive Waste Management*, John Wiley and Sons, New York (1989).

3. "NRC, States Grapple with BRC, NORM Waste Issues," *Nuclear Waste News*, *12*(10), 85 (Mar. 5, 1992).

4. Peter Gray and Associates, *The NORM Report—Naturally Occurring Radioactive Material Contamination*, Winter 1977, Tulsa, Oklahoma.

5. William F. Wilson, *NORM, A Guide to Naturally Occurring Radioactive Material*, pp. 3–7, PennWell Publishing Company, Tulsa, Oklahoma (1994).

6. F. L. Galpin and V. C. Rogers, Rogers and Associates Engineering Corporation, Salt Lake City, Utah, "NARM Classifications: Their Ethical and Regulatory Implications," pp. 3–7 in *NORM/NARM Regulation and Risk Assessment, Proceedings of the 29th Midyear Topical Meeting of the Health Physics Society, Jan. 7–10, 1996*, Scottsdale, Arizona, Health Physics Society, McLean, Virginia (1996).

7. Conference of Radiation Control Program Directors, Inc., *Guides for Naturally Occurring and Accelerator-Produced Radioactive Materials (NARM)*, HHS Publication FDA 81–8025, Frankfort, Kentucky (June 1981).

8. Josef R. Parrington et al., *Nuclides and Isotopes—Chart of the Nuclides*, 15th ed., General Electric Company and Knolls Atomic Power Laboratory, Schenectady, New York, 1996.

9. The League of Women Voters Education Fund, *The Nuclear Waste Primer*, Lyons & Burford, New York (1993).

10. New York State Low-Level Radioactive Waste Siting Commission, *1994 Source Term Report—Low-Level Radioactive Waste Projections for New York State*, Vols. 1 and 2, 2d ed., Enserch Environmental Corporation, Troy, New York (October 1994).

11. K. P. Smith, *An Overview of Naturally Occurring Radioactive Materials (NORM) in the Petroleum Industry*, ANL/EAIS-7, Argonne National Laboratory, Argonne, Illinois (December 1992).

12. K. P. Smith and D. L. Blunt, Argonne National Laboratory, Argonne, Illinois, "Scrap Metal Management Issues Associated with Naturally Occurring Radioactive Material," in *Beneficial Reuse '95—The Third Annual Conference on the Recycle and Reuse of Radioactive Scrap Metal, July 31–August 3, 1995, Knoxville, Tennessee*, University of Tennessee Energy, Environment, and Resources Center, Knoxville, Tennessee (1996).

13. U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, *Diffuse NORM Wastes—Waste Characterization and Preliminary Risk Assessment*, Draft, RAE-9232/1–2, SC&A, Inc., and Rogers & Associates Engineering Corporation, Salt Lake City, Utah (May 1993).

14. Edward L. Gershey et al., *Low-Level Radioactive Waste—From Cradle to Grave*, Van Nastrand Reinhold, New York (1990), pp. 34–35.

15. U.S. Environmental Protection Agency, Science Advisory Board, *Review of the Office of Radiation and Indoor Air Draft Document on Diffuse Naturally-Occurring Radioactive Material (NORM): Waste Characterization and Preliminary Risk Assessment*, EPA-SAB-RAC-94-013, Washington, D.C. (May 1994).

16. Kevin J. Grice, Texaco Exploration and Production, Inc., Houston, Texas, correspondence to S. N. Storch, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Comments on Draft Chapter 7 Naturally Occurring and Accelerator-Produced Radioactive Material," dated Aug. 20, 1996.

17. A. McArthur, "Development and Operation of a NORM Processing and Disposal Facility for the U.S. Oil and Gas Industry," in *19th Annual National Conference on Radiation Control, May 18–21, 1987, Boise, Idaho*, Publication 88-2, Conference of Radiation Control Program Directors, Frankfort, Kentucky (1988).

18. Harlan W. Keaton, "Naturally Occurring Radioactive Materials in the Construction Industry and Current Building Codes," in *19th Annual National Conference on Radiation Control, May 18–21, 1987, Boise, Idaho,* Publication 88-2, Conference of Radiation Control Program Directors, Frankfort, Kentucky (1988).

19. United Nations Scientific Committee on the Effects of Atomic Radiation, *Sources and Effects of Ionizing Radiation*, report to the General Assembly, United Nations, New York (1994).

20. ERC Environmental Energy Services Company, *Final Environmental Impact Report for General Plan Amendment, Zone Charge, and Conditional Use Permit*, prepared for Planning Department, Imperial County, California (1990).

21. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, *Report to Congress: Wastes from the Extraction and Beneficiation of Metallic Ores, Phosphate Rock, Asbestos, Overburden from Uranium Mining, and Oil Shale*, EPA 530-SW-85-033, Washington, D.C. (December 1985).

22. J. B. Hedrick and D. A. Templeton, "Rare-Earth Minerals and Metals," *Rare-Earth Minerals and Metals Yearbook*, U.S. Department of Interior, Washington, D.C. (1985).

23. J. B. Hedrick and D. A. Templeton, "Zirconium and Hafnium," *Zirconium and Hafnium Minerals Yearbook*, U.S. Department of Interior, Washington, D.C. (1989).

24. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, *Report to Congress on Special Wastes from Mineral Processing*, EPA/530-SW-90-070C, Washington, D.C. (July 1990).

25. American Water Works Association, *1984 Water Utility Operating Data*, Denver, Colorado (1986).

26. American Water Works Association, *1985 Water Utility Operating Data*, Denver, Colorado (1987).

27. U.S. Department of Energy, Energy Information Administration, *Annual Energy Review—1991*, DOE/EIA-0384(91), Washington, D.C. (June 1992).

28. U.S. Environmental Protection Agency, Office of Radiation Programs, *Radioactivity Distribution in Phosphate Products, By-Products, Effluents, and Wastes*, Technical Note ORP/CSD-75-3, Washington, D.C. (August 1975).

29. Conference of Radiation Control Program Directors, *Natural Radioactivity Contamination Problems*, Report No. 2, Frankfort, Kentucky (August 1981).

30. American Petroleum Institute, *A Naturally Occurring Radioactive Material (NORM) Disposal Cost Study*, API Publication 7100, Washington, D.C. (November 1996).

Table 7.1. Current status of state NORM regulations[a]

Status description	List of states
States that currently either have NORM regulations in place or a set of regulations drafted	Alabama, Alaska, Arkansas, Georgia, Hawaii, Illinois, Kansas, Kentucky, Louisiana, Michigan, Mississippi, New Mexico, Ohio, Oklahoma, Texas
States that have NORM regulations in preparation or anticipated	Colorado, Connecticut, New Jersey, Washington
States awaiting CRCPD[b] guidelines for NORM	California, North Dakota, Oregon
States who feel that their NORM wastes are covered adequately by existing regulations	Delaware, Idaho, Maine, Maryland, Massachusetts, Minnesota, Nebraska, Nevada, New Hampshire, New York, Rhode Island, South Carolina, Utah, Vermont, Virginia, West Virginia, Wisconsin
States that have no current action plans for NORM	Arizona, Florida, Indiana, Iowa, Missouri, Montana, North Carolina, Pennsylvania, South Dakota, Tennessee, Wyoming

[a]As of the end of February 1997. Based on refs. 3 and 4.
[b]Conference of Radiation Control Program Directors.

Table 7.2. Radionuclides found in accelerator-produced radioactive materials[a]

Nuclide	Atomic number	Half-life[b]	Principal mode(s) of decay[c]	Nuclide	Atomic number	Half-life[b]	Principal mode(s) of decay[c]
^{11}C	6	20.4 min	β^+	^{81}Rb	37	4.6 h	EC
^{13}N	7	10.0 min	β^+	^{82}Rb	37	6.4 h	β^+, γ
^{15}O	8	2.0 min	β^+	^{84}Rb	37	34.0 d	EC
^{18}F	9	1.8 h	β^+	^{82}Sr	38	25.0 d	EC
^{22}Na	11	2.6 y	β^+, γ	^{87m}Sr	38	2.8 h	IT
^{28}Mg	12	21.1 h	β, γ	^{87}Y	39	80.3 h	EC
^{28}Al	13	2.2 min	β, γ	^{97m}Tc	43	90.0 d	IT
^{33}P	15	25.3 d	β	^{111}In	49	2.83 d	EC, γ
^{37}Ar	17	34.8 d	EC	^{123}I	53	13.1 h	EC, γ
^{43}K	19	22.2 h	β, γ	^{124}I	53	4.2 d	EC, γ
^{49}Sc	21	57.3 min	β, γ	^{125}I	53	59.7 d	EC, γ
^{52}Mn	25	5.7 d	β^+, γ	^{126}I	53	13.0 d	EC, γ
^{52}Fe	26	8.3 h	β^+, γ	^{127}Xe	54	36.4 d	EC, γ
^{57}Co	27	271 d	EC	^{131}Cs	55	9.7 d	EC
^{58}Co	27	71 d	EC	^{145}Pm	61	18 y	EC
^{62}Cu	29	9.8 min	β^+, γ	^{157}Dy	66	8.1 h	EC, γ
^{67}Cu	29	61.7 h	β, γ	^{190}Os	76	9.9 min	IT
^{62}Zn	30	9.2 h	EC, γ	^{190}Ir	77	12.2 d	EC, γ
^{66}Ga	31	9.5 h	β^+, γ	^{190m}Ir	77	1.2 h	IT
^{68}Ge	32	287 d	EC, γ	^{193m}Pt	78	4.3 d	IT
^{73}As	33	80.3 d	EC	^{195}Au	79	184.0 d	EC, γ
^{73}Se	34	7.1 h	β^+	^{197}Hg	80	64.1 h	EC, γ
^{77}Br	35	56.0 h	β^+, γ	^{199}Tl	81	7.4 h	EC, γ
^{77}Kr	36	1.2 h	β^+	^{203}Pb	82	52.1 h	EC, γ
^{81}Kr	36	2.1E+05 y	EC	^{204}Bi	83	11.3 h	EC, γ

[a]Based on ref. 7.

[b]y = years, d = days, h = hours, and min = minutes.

[c]α = alpha decay, β = negative beta decay, β^+ = positive beta decay, γ = gamma emission, EC = electron capture, and IT = isomeric transition.

Table 7.3. Characteristics of naturally occurring radionuclides present in the Earth's crust and in associated fluids and gases[a]

Radionuclide	Atomic number	Half-life[b]	Principal mode(s) of decay[c]
^{3}H	1	12.33 y	β
^{7}Be	4	53.28 d	EC, γ
^{14}C	6	5730 y	β
^{40}K	19	1.277E+09 y	β (89%), EC (11%), γ
^{50}V	23	1.4E+17 y	β (30%), EC (70%), γ
^{87}Rb	37	4.88E+10 y	β
^{113}Cd	48	9.3E+15 y	β
^{115}In	49	4.4E+14 y	β
^{123}Te	52	>1.3E+13 y	EC
^{138}La	57	1.05E+11 y	β (30%), EC (70%)
^{144}Nd	60	2.38E+15 y	α
^{147}Sm	62	1.06E+11 y	α
^{148}Sm	62	7E+15 y	α
^{152}Gd	64	1.1E+14 y	α
^{176}Lu	71	3.78E+10 y	β, γ
^{174}Hf	72	2.0E+15 y	α
^{180}Ta	73	>1.2E+15 y	EC, β^+, γ
^{187}Re	75	4.6E+10 y	β
^{186}Os	76	2E+15 y	α
^{190}Pt	78	6.5E+11 y	α
^{215}Bi	83	7.6 min	β, γ
^{215}At	85	1.0E-04 s	α, γ
^{218}At	85	1.5 s	α, β
^{219}At	85	56 s	α, β
^{232}Th[d]	90	1.405E+10 y	α
^{235}U[d]	92	7.037E+08 y	α
^{238}U[d]	92	4.468E+09 y	α

[a]Based on ref. 8.

[b]y = years, d = days, h = hours, min = minutes, and s = seconds.

[c]α = alpha decay, β = negative beta decay, β^+ = positive beta decay, γ = gamma emission, EC = electron capture, and IT = isomeric transition.

[d]Also includes other radionuclides in its decay chain series (see Table A.5 of Appendix A).

Table 7.4. Domestic processes that generate NORM waste[a]

Process	Waste generated	Classification by specific activity[b]	Major generator locations(s)
Coal combustion	Fly ash	Diffuse	Midwestern and South Atlantic states
	Bottom ash and slag	Diffuse	
Geothermal energy production	Solid wastes	Diffuse	California
Manufacturing	Old/used products: industrial gauges, radium watches and industrial dials, and radium needles in medical equipment	Discrete	Various commercial sites
Metal mining and processing	Slag, leachate, and tailings from the following:		
	Rare earth metals	Diffuse	California, Florida, and North Carolina
	Special-application metals (zirconium, hafnium, titanium, and tin)	Diffuse	Ohio, Delaware, and Florida
	Large-volume metal-processing industries (copper, iron, etc.)	Diffuse	Ohio, Pennsylvania, Indiana, Illinois, Michigan, and some western states
Municipal water treatment	Sludge	Diffuse	North central (e.g., Illinois) and coastal plain (e.g., North Carolina) states and other states
	Radium selective resins	Discrete	
Oil and natural gas production and processing	Scale	Discrete or diffuse	In all petroleum and natural gas states having production and processing facilities[c]
	Sludge	Diffuse	
	Contaminated water and production/processing equipment	Diffuse	
Phosphate mining and fertilizer production	Ferrophosphorous	Diffuse	Florida, Idaho, and other states in the West and Southeast
	Phosphogypsum[d]	Diffuse	
	Scale	Discrete	
	Slag	Diffuse	

[a]Based on ref. 10 (p. 13–9), and refs. 11 and 12.

[b]In fact, many of the wastes generated can be either diffuse or discrete. What is listed in this column is the classification most typically associated with a particular waste generated.

[c]As yet, the geographic distribution of NORM from oil and natural gas production and processing has not been well characterized statistically.

[d]Calcium sulfate.

Table 7.5. Major radionuclides found in diffuse NORM wastes[a]

Nuclide	Atomic number	Half-life[b]	Principal mode(s) of decay[c]	Natural decay series[d]	Principal source(s)[e]
^{238}U	92	4.468E+09 y	α	U	1, 2, 4, 5, 7
^{235}U	92	7.037E+08 y	α	A	1, 5, 7
^{234}U	92	2.454E+05 y	α	U	1, 2, 4, 5, 7
^{231}Pa	91	3.276E+04 y	α	A	1, 5
^{232}Th	90	1.405E+10 y	α	T	1, 5, 7
^{230}Th	90	7.54E+04 y	α	U	1, 2, 4, 5, 7
^{228}Th	90	1.913 y	α	T	1, 5, 6, 7
^{227}Ac	89	2.177E+01 y	β	A	1, 5
^{228}Ra	88	5.75 y	β	T	1, 5, 6
^{226}Ra	88	1.600E+03 y	α	U	1, 2, 3, 4, 5, 6, 7
^{224}Ra	88	3.66 d	α	T	1, 5, 6, 7
^{222}Rn	86	3.825 d	α	U	1, 2, 3, 4, 5, 6, 7
^{210}Po	84	1.383E+02 d	α	U	1, 2, 4, 5, 6, 7
^{210}Pb	82	1.94E+01 y	β	U	1, 2, 4, 5, 6, 7
^{40}K	19	1.277E+09 y	β		1, 2, 4, 6, 7

[a]Based on refs. 13 and 15.

[b]y = years and d = days.

[c]α = alpha decay and β = negative beta decay.

[d]U = uranium series (^{238}U parent, ^{206}Pb stable end daughter); A = actinium series (^{235}U parent, ^{207}Pb stable end daughter); and T = thorium series (^{232}Th parent, ^{208}Pb stable end daughter).

[e]1 = coal combustion; 2 = geothermal energy production; 3 = manufacturing (industrial gauges, watches, etc., and medical needles); 4 = metal mining and processing; 5 = municipal water treatment; 6 = oil and gas production; and 7 = phosphate mining and fertilizer production.

Table 7.6. Radionuclide concentrations in coal combustion wastes[a]

Nuclide	Concentration (pCi/g)	
	Fly ash	Bottom ash and slag
^{238}U	2.6	0.7
^{235}U	0.13	0.03
^{234}U	2.6	0.7
^{231}Pa	0.13	0.03
^{232}Th	1.7	0.4
^{230}Th	1.8	0.5
^{228}Th	2.6	0.6
^{227}Ac	0.13	0.03
^{228}Ra	1.4	0.4
^{226}Ra	3.0	0.7
^{210}Po	5.6	1.4
^{210}Pb	5.4	1.4
Total[b]	27.1	6.9

[a]Based on ref. 13, which assumes that 80 wt % of the concentration is fly ash.

[b]Excludes contributions from other (short-lived) radionuclides in decay chains.

Table 7.7. Radionuclide concentrations in geothermal energy production waste[a]

Nuclide	Waste concentration (pCi/g)
^{228}Th	25
^{228}Ra	93
^{226}Ra	132
^{210}Po	96
^{210}Pb	96
Total[b]	442

[a]Based on ref. 13.

[b]Excludes contributions from other (short-lived) radionuclides in decay chains.

Table 7.8. Radionuclide concentrations in metal mining and processing wastes[a]

Nuclide	Waste concentration, pCi/g		
	Rare earth metals	Special-application metals	Large-volume industry metals
^{238}U	900	43	10.0
^{235}U	45	2.2	0.5
^{234}U	900	43	10.0
^{231}Pa	45	2.2	0.5
^{232}Th	2,000	22	10.0
^{230}Th	900	43	10.0
^{228}Th	2,000	22	10.0
^{227}Ac	45	2.2	0.5
^{228}Ra	2,000	22	10.0
^{226}Ra	900	43	5.0
^{210}Po	630	30	3.5
^{210}Pb	630	30	3.5
Total[b]	10,995	305	73.5

[a]Based on ref. 13.

[b]Excludes contributions from other (short-lived) radionuclides in decay chains.

Table 7.9. Radionuclide concentrations in municipal water treatment wastes[a]

Nuclide	Concentration (pCi/g)	
	Sludges	Radium selective resins
^{238}U	4.0	b
^{235}U	0.03	b
^{234}U	4.0	b
^{231}Pa	0.03	b
^{232}Th	0.2	b
^{230}Th	0.2	b
^{228}Th	9.0[c]	b
^{227}Ac	0.03	b
^{228}Ra	16[c]	b
^{226}Ra	16	35,000[d]
^{210}Po	11.0	b
^{210}Pb	11.0	b
Total[e]	71.5	b

[a]Based on ref. 13.
[b]Unknown.
[c]Concentration after 2 years of decay and ingrowth.
[d]Rough estimate.
[e]Excludes contributions from other (short-lived) radionuclides in decay chains.

Table 7.10. Radionuclide concentrations in oil and natural gas production and processing wastes[a]

Nuclide	Concentration (pCi/g)	
	Scale	Sludge
^{228}Th	120	19
^{228}Ra	120	19
^{226}Ra	360	56
^{210}Po	360	56
^{210}Pb	360	56
Total[b]	1,320	206

[a]Based on ref. 13.
[b]Excludes contributions from other (short-lived) radionuclides in decay chains.

Table 7.11. Radionuclide concentrations in phosphate wastes[a]

Nuclide	Concentration (pCi/g)			
	Ferrophosphorous	Phosphogypsum	Scale	Slag
^{238}U	b	6.0	b	25
^{235}U	b	0.3	b	1.3
^{234}U	b	6.2	b	24
^{231}Pa	b	0.3	b	1.3
^{232}Th	b	0.27	b	0.77
^{230}Th	b	13	b	32
^{228}Th	b	1.4	b	0.77
^{227}Ac	b	0.3	b	1.3
^{228}Ra	b	0.27	b	0.77
^{226}Ra	1.2[c]	33	1000[d]	35
^{210}Po	b	26	b	35
^{210}Pb	b	26	b	35
Total[e]	b	113	b	192

[a]Based on ref. 13.
[b]Unknown.
[c]Average for Florida plants.
[d]Rough estimate for purposes of illustration and comparison.
[e]Excludes contributions from other (short-lived) radionuclides in decay chains.

Table 7.12. Quantities of radium disposed of by New York State generators during 1987–91[a]

CY	Volume (m^3)	Radioactivity (Ci)
1987	16.1	1.32
1988	4.0	4.23
1989	26.7	123
1990	6.4	0.08
1991	6.7	1.28
Totals	59.9	129.91

[a]Based on ref. 10 (p. 13–9).

Table 7.13. Estimates of domestic diffuse NORM waste generation, material density, total inventory, and radioactive concentration[a]

Process/waste material	Current annual generation (10^6 t/year)	Waste material density (t/m^3)	Total inventory			Average ^{226}Ra concentration (pCi/g)
			Mass (10^6 t)	Volume[b] (10^6 m^3)	Radioactivity[c] (Ci)	
Coal combustion						
Bottom ash and slag	17	(1.50)[d]	>337[e]	>225	2,300	(3.1)
Fly ash	44	1.20	>959[e]	>800	26,000	(3.9)
Geothermal energy production (scale and filter cake)	0.054	1.80	0.74	0.41	330	132
Metal mining and processing—slag leachate, and tailings from the following:						
• Large bulk metal industries (e.g., aluminum, copper, iron, and steel)	1,000	2.00	50,000[f]	25,000	3,700,000	(5)
• Rare earths	0.021	2.00	1[f]	0.5	11,000	900
• Special-application metals (zirconium, hafnium, titanium, and tin)	0.47	2.00	20[f]	10	6,100	43
Municipal water treatment						
Radium selective resins	0.04	(1.50)	2[g]	>1	>35,000	(35,000)
Sludges	0.26	1.60	10[g]	6	700	16
Oil and gas production waste (scale and sludge)[h]	0.056	1.70	4	2.3	1,210	84
Phosphate production						
Ferrophosphorous	i	(1.50)	i	i	i	1.2[j]
Phosphogypsum	48	1.44	8,200	5,700	930,000	33
Scale	0.003	(2.00)	<<1	<<1	<1,000	(1,000)
Slag	1.6	1.90	324[k]	171	62,200	35
Total	1,112	1.88[l]	>59,857	>31,917	>4,775,840	9.6[l]

[a]Based on refs. 13 and 15. Information and data from ref. 13 are, in turn, based on refs. 17–30.
[b]Estimated from listed waste material density.
[c]Estimated from total radionuclide concentrations listed in Tables 7.6–7.11. Excludes contributions from ^{40}K.
[d]Data listed in parentheses represent rough estimates developed for illustration and comparison.
[e]Based on cumulative ash production rate from 1966 through 1990. Assumes that 74 wt % of cumulative production is fly ash.
[f]Based on average annual generation applied to a 50-year period.
[g]Based on the average annual generation applied to a 40-year period.
[h]Based on ref. 30.
[i]Unknown.
[j]Average for Florida plants.
[k]Midpoint value in a range based on ref. 29.
[l]Calculated average for all waste materials listed.

8. MIXED LOW-LEVEL WASTE

8.1 INTRODUCTION

This chapter reports the estimated inventories and generation rates of mixed low-level waste (MLLW) from DOE-site and commercial-site operations. Mixed wastes are radioactive wastes that are also considered hazardous. MLLWs are mixed wastes which, radiologically, are low level, as defined in Chapter 4.

Other types of radioactive wastes may also be mixed. All high-level wastes (HLWs) are regarded as mixed and are discussed in Chapter 2. Mixed transuranic wastes (TRUWs) are not included in this chapter, but they are addressed in the TRUW inventories and projections reported in Chapter 3.

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 the U.S. Nuclear Regulatory Commission (NRC) (unless a state has obtained agreement-state status). As defined in this report, the hazardous components of 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 authorization status): the Resource Conservation and Recovery Act (RCRA), as amended,[2] and the Toxic Substances Control Act (TSCA).[3] Table 8.1 (based on ref. 4) lists those states and territories designated by EPA to have mixed waste authorization. The management of RCRA- and TSCA-regulated mixed wastes are subject to the regulations of EPA[5,6] and NRC (or the authorized and agreement states), or DOE.

8.2 SCOPE

This chapter summarizes the quantities (inventory and generation) and associated characteristics of MLLW from both DOE-site and commercial-site operations. The DOE MLLWs include MLLW for which the hazardous component is subject to regulation under either RCRA or TSCA (PCBs only). These are hereafter referred to as either RCRA MLLW or TSCA MLLW, respectively. In this report, TSCA-regulated MLLWs pertain only to PCB wastes. Asbestos wastes are excluded in this chapter, but are included in the DOE LLW data of Chapter 4. DOE MLLWs which are subject to regulation under both RCRA and TSCA (PCBs only) are considered RCRA MLLW.

Relative to the previous issue of this report (DOE/RW-0006, Rev. 12), a key change of scope is the exclusion of seven sites from this chapter: (1) Fernald Environmental Management Project (FEMP), (2) Paducah Gaseous Diffusion Plant (PAD), (3) Portsmouth Gaseous Diffusion Plant (PORTS), (4) Reactive Metals, Inc., Extrusion Plant (RMI), (5) Colonie Interim Storage Site (CISS), (6) Battelle Columbus Laboratories Decommissioning Project (BCLDP), and (7) the General Atomics Site (GA). The MLLW at these sites are addressed exclusively in Chapter 6 ("Environmental Restoration Program") of this report. This change in scope accounts for most of the differences in the total nationwide inventory of DOE RCRA MLLW from that of the previous issue of this report.

A significant volume of MLLW is associated with environmental restoration activities. For example, remediation of former landfills used for the disposal of radioactively contaminated materials can result in large quantities of RCRA MLLW. MLLWs resulting from such activities are provided in Chapter 6 within pertinent tables. The environmental restoration program is a very dynamic program in which (a) wastes are currently being generated by ongoing remedial action activities and (b) certain stored wastes are being treated either on- or off-site before their disposal. As such, waste volumes can change significantly in very short periods of time.

For commercial MLLW, this chapter presents a summary of the cumulative stored inventories and generation documented for a baseline CY (1990) in a national profile study [NUREG/CR-5938 (ref. 7)] made

for the NRC and EPA. The wastes reported in that study are grouped by facility categories and by major hazardous waste classifications.

Unless otherwise noted, the inventories and projections given for MLLW in this chapter are separate from those reported for strictly radioactive LLW in Chapter 4. Inventories of MLLW currently stored at DOE sites are being thoroughly characterized. As a result, the waste at some sites could require future reclassification, thereby causing significant changes in current inventory data that are currently reported.

8.3 DOE MLLW DATA SOURCES

DOE MLLW information reported in this chapter is based on DOE site submittals recently provided to the DOE/EM Technical Information Collection Database and cited in ref. 8.

8.4 DOE MLLW

Figure 8.1 summarizes the estimated combined volume inventories of RCRA and TSCA MLLW for major sites in the DOE complex. A corresponding illustration of the estimated annual volume generation is shown in Fig. 8.2. For comparison, Table 8.2 summarizes estimated nationwide volume inventory and annual volume generation of DOE MLLW (RCRA and PCB) and commercial MLLW.

Approximately 76,200 m^3 of RCRA and RCRA PCB MLLW are in storage throughout the DOE complex, and an estimated 70,400 m^3 are anticipated to be generated over the next 10 years. Table 8.3 summarizes the RCRA and RCRA PCB distribution of inventory and generation across the DOE sites. More than 95% of the volume inventory is stored at 7 sites: (ETTP, Hanford, INEEL, ORNL, RFETS, SRS, and Y-12). Volume inventories of non-RCRA PCB MLLW at DOE sites are reported in Table 8.4. The Oak Ridge ETTP site has over 85% of this volume inventory.

Tables 8.6 and 8.7 summarize the distribution of MLLW volume inventories and generation for the DOE sites according to various physical form categories, which are defined in Table 8.5 (based on ref. 9). The physical forms described define the treatability group matrix parameter categories that are used to characterize DOE MLLW. Table 8.6 provides a physical form breakdown of site volume inventory and generation for RCRA and RCRA PCB MLLW. A corresponding breakdown for non-RCRA PCB MLLW is provided in Table 8.7. The DOE complex-wide aggregate of the site distributions is provided in Table 8.8 for RCRA and RCRA PCB MLLW and in Table 8.9 for non-RCRA MLLW. Complex-wide, most of the RCRA inventory consists of inorganic homogeneous solids, debris (inorganic, organic, heterogeneous), aqueous slurries/liquids, and soil/gravel for RCRA MLLW and soil/gravel and inorganic debris for non-RCRA MLLW.

8.5 COMMERCIAL MLLW

In 1992, the NRC and EPA published a survey study to compile a national profile of the volumes, characteristics, and treatability of commercially generated MLLW. 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 MLLW, as mandated by the Low-Level Radioactive Waste Policy Amendments Act;[10]
- 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 of 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. 7 and summarized in this report.

The study identified the types and volumes of MLLW 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 1323 facilities from a total target population of 2936 facilities. Data from the 1016 completed mixed waste survey questionnaires (77% response rate) received and the use of appropriate weighting factors indicate that approximately 3950 m^3 of MLLW—of which 72% was liquid scintillation fluids—were generated in the United States in 1990.

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. Wayne E. Roepe, U.S. Environmental Protection Agency, Arlington, Virginia, correspondence to Steve Storch, IDB Program, ORNL, Oak Ridge, Tennessee, dated Feb. 26, 1997, containing the updated respective EPA mixed waste authorization statuses for states and U.S. territories as of Dec. 31, 1996.

5. U.S. Environmental Protection Agency, "Subchapter I—Solid Wastes (continued)," *Code of Federal Regulations*, 40 CFR Parts 260–299 (July 1, 1996).

6. U.S. Environmental Protection Agency, "Subchapter R—Toxic Substances Control Act," *Code of Federal Regulations*, 40 CFR Parts 700–789 (July 1, 1996).

7. J. A. Klein et al., *National Profile on Commercial 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).

8. U.S. Department of Energy, Office of Environmental Restoration, Office of Waste Management, *Technical Information Collection Database*, updated through Oct. 30, 1997.

9. U.S. Department of Energy, Office of Waste Management, *DOE Waste Treatability Group Guidance*, Washington, D.C., DOE/LLW-217, Rev. 0 (January 1995).

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

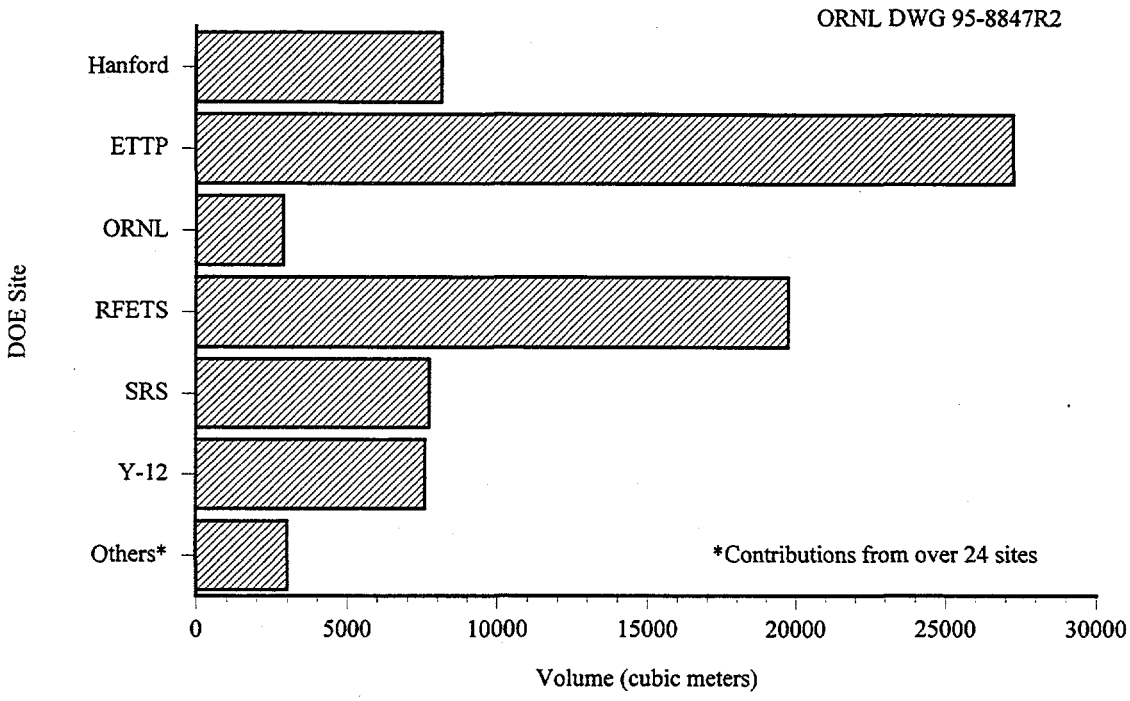


Fig. 8.1. Volume inventory of DOE MLLW (RCRA and TSCA) by site.

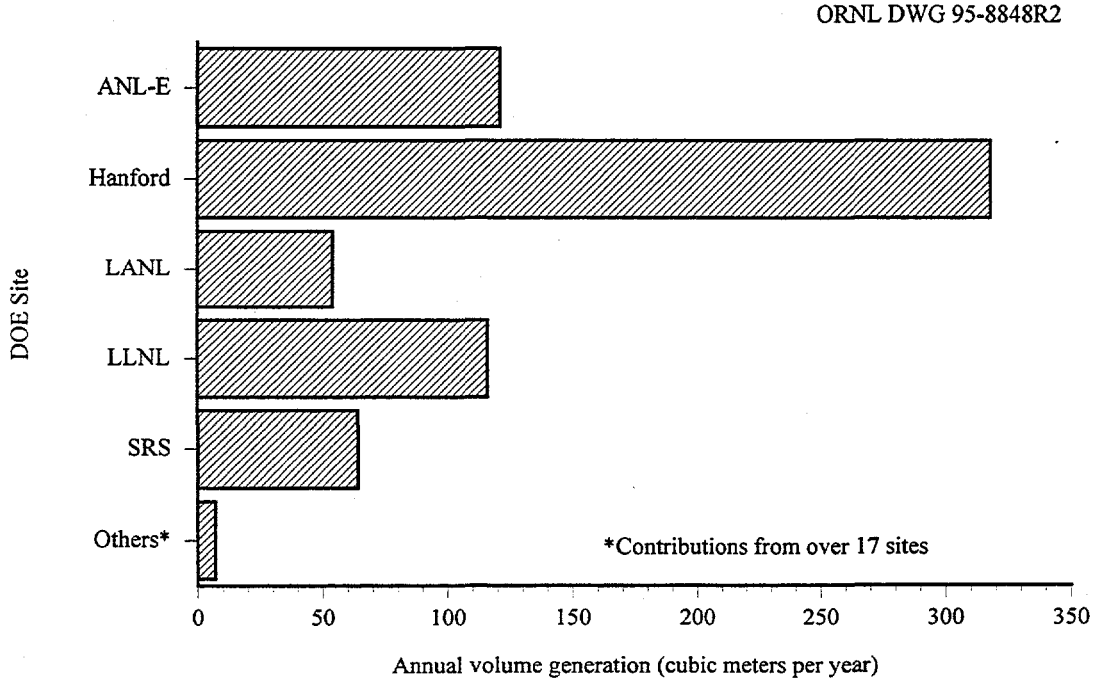


Fig. 8.2. Volume generation of DOE MLLW (RCRA and TSCA) by site, during FY 1996.

Table 8.1. Forty states and territories with EPA mixed waste authorization as of the end of CY 1996[a]

State or territory	Effective date	State or territory	Effective date
Alabama	05/17/93	Montana	03/21/94
Arizona	01/22/93	Nebraska	12/03/88
Arkansas	05/29/90	Nevada	06/29/92
California	08/01/92	New Hampshire	01/13/95
Colorado	11/07/86	New Mexico	07/25/90
Connecticut	12/31/90	New York	05/07/90
Delaware	10/07/96	North Carolina	11/21/89
Florida	02/12/91	North Dakota	08/24/90
Georgia	09/26/88	Ohio	06/30/89
Guam	10/10/89	Oklahoma	11/27/90
Idaho	04/09/90	Oregon	05/29/90
Illinois	04/30/90	South Carolina	09/13/87
Indiana	09/30/91	South Dakota	06/17/91
Kansas	06/25/90	Tennessee	08/11/87
Kentucky	12/19/88	Texas	03/15/90
Louisiana	10/25/91	Utah	03/07/89
Michigan	01/23/90	Vermont	08/06/93
Minnesota	06/23/89	Washington	11/23/87
Mississippi	05/28/91	Wisconsin	04/24/92
Missouri	03/12/93	Wyoming	10/18/95

[a]Based on ref. 4. Information as of December 31, 1996.

Table 8.2. Summary of estimated total MLLW inventories and FY 1996 generation

Category	Volume, m^3	
	Total inventory	FY 1996 generation[a]
DOE sites		
RCRA and RCRA PCB MLLW	71,710[b]	608
Non-RCRA PCB MLLW	4,530[b]	73
DOE MLLW total	76,240	681
Major commercial sites[c]	2,116	3,949
Other commercial sites[d]	31,014	0

[a]Except where indicated.

[b]Based on ref. 8. The currentness of these data for the various DOE sites ranges from September 1995 to July 1997.

[c]Reported for CY 1990.

[d]Wastes from commercial- and government-sponsored (DOE, EPA, DOD) activities that are disposed of at other commercially operated disposal facilities.

Table 8.3. Volume (m^3) inventory and generation of DOE RCRA and RCRA PCB MLLW, by site[a]

Site(s)	Inventory[b]	FY generation			
		Actual 1996	Projected		
			1997	1998–2006	2007–2030
Ames	0.00	0.00	c	c	c
ANL-E	50.77	c	c	c	c
ANL-W	390.18	c	c	c	c
BNL	3.93	1.73	0.30	0.92	2.10
ETEC	39.39	8.80	1.47	8.95	0.00
ETTP	23,237.18	d	d	d	d
Hanford	8,017.76	318.19	616.47	12,771.03	47,684.95
INEEL	846.28	c	c	c	c
ITRI	0.00	c	c	c	c
LANL	765.10	53.87	83.35	2,420.76	474.86
LBNL	6.67	1.04	c	c	c
LEHR	1.70	0.00	0.00	0.00	0.00
LLNL	493.43	115.70	188.82	1,745.29	3,796.80
Mound	37.00	0.00	0.00	5.36	0.00
MURR	1.40	0.27	c	c	c
Naval laboratories[e,f]					
BAPL	14.17	0.46	1.07	9.61	25.63
KAPL	1.75	2.84	7.84	70.54	188.11
KESS	3.59	8.27	7.96	39.71	80.04
KWIN	0.25	0.24	6.34	10.02	0.00
Naval shipyards[e,g]					
NNS	1.12	0.66	1.80	16.20	43.20
PHNS	3.39	2.00	0.89	8.05	21.46
PNS	0.81	0.01	0.09	0.81	2.16
PSNS	42.86	1.74	4.54	40.82	108.86
NTS	24.85	c	c	4.80	c
ORNL	2,843.13	d	d	d	d
PANT	147.35	27.86	23.01	326.40	63.49
PPPL	0.00	0.30	0.90	19.70	12.00
RFETS	19,730.02	c	179.00	47,050.00	13,873.52
SNL/CA	c	c	c	7.20	0.80
SNL/NM	c	c	c	c	c
SRS[h]	7,717.12	61.39	336.20	4,386.18	c
WVDP	26.60	2.24	3.12	0.00	0.00
Y-12	7,262.01	d	d	d	d
Total	71,709.82	607.61	1,463.17	68,942.36	66,377.99

[a]Based on ref. 8.

[b]The currentness of the inventory data for the various sites ranges from September 1995 to July 1997.

[c]Not reported.

[d]Generation data for ETTP, ORNL, and Y-12 were reported as combined values for the entire Oak Ridge Reservation (ORR). The following volumes were not distributed according to RCRA and non-RCRA PCB MLLW: 880.00 m^3 (FY 1996); 1,054.00 m^3 (FY 1997); 9,505.00 m^3 (FY 1998–2006); and 28,458.00 m^3 (FY 2007–2030).

[e]DOE Office of Naval Reactors (NE-60) sites.

[f]Naval laboratory contributions include Bettis Atomic Power Laboratory (BAPL), Knolls Atomic Power Laboratory (KAPL)–Schenectady, Knolls Kesselring Site (KESS), and Knolls Windsor Site (KWIN).

[g]Naval shipyard contributions include Norfolk Naval Shipyard (NNS), Pearl Harbor Naval Shipyard (PHNS), Portsmouth Naval Shipyard (PNS), and Puget Sound Naval Shipyard (PSNS).

[h]SRS generation for the 1998–2006 period account for only that from 1998–2001.

Table 8.4. Volume (m^3) inventory and generation of DOE non-RCRA PCB MLLW, by site[a]

Site(s)	Inventory[b]	FY generation			
		Actual 1996	Projected		
			1997	1998–2006	2007–2030
ANL-E	70.00	70.00	0.63	0.63	0.63
BNL	0.28	0.00	0.40	0.10	0.10
ETTP	4,000.98	c	c	c	c
Hanford	102.46	d	d	d	d
Mound	0.40	0.00	0.00	0.00	0.00
Naval laboratories[e,f]					
BAPL	7.35	0.00	6.76	59.80	24.00
KAPL	0.81	0.81	0.90	8.10	21.60
KESS	0.00	1.45	1.45	6.85	3.30
KWIN	0.10	0.00	3.90	6.00	0.00
Naval shipyards[e,g]					
NNS	0.07	0.14	0.62	0.20	0.53
PHNS	0.02	0.02	0.74	3.33	8.88
PSNS	10.76	0.18	0.18	1.58	4.22
ORNL	8.54	c	c	c	c
SNL/NM	e	e	e	e	e
SRS	2.80	0.20	1.00	d	d
Y-12	325.32	c	c	c	c
Total	4,529.89	72.80	16.58	86.59	63.26

[a]Based on ref. 8.

[b]The currentness of the inventory data for the various sites ranges from September 1995 to July 1997.

[c]Generation data for ETTP, ORNL, and Y-12 were reported as combined values for the entire Oak Ridge Reservation (ORR). The following volumes were not distributed according to RCRA and non-RCRA PCB MLLW: 880.00 m^3 (FY 1996); 1,054.00 m^3 (FY 1997); 9,505.00 m^3 (FY 1998–2006); and 28,458.00 m^3 (FY 2007–2030).

[d]Not reported.

[e]DOE Office of Naval Reactors (NE-60) sites.

[f]Naval laboratory contributions include Bettis Atomic Power Laboratory (BAPL), Knolls Atomic Power Laboratory (KAPL)–Schenectady, Knolls Kesselring Site (KESS), and Knolls Windsor Site (KWIN).

[g]Naval shipyard contributions include Norfolk Naval Shipyard (NNS), Pearl Harbor Naval Shipyard (PHNS), and Puget Sound Naval Shipyard (PSNS).

Table 8.5. Treatability group matrix parameter categories used to characterize DOE MLLW[a]

Matrix parameter category (code)	Description
	Liquids[b]
Liquids (L0000)	Liquids and slurries which cannot be categorized as aqueous liquids/slurries or organic liquids because it is not known if the total organic carbon (TOC) level is less or greater than 1%
Aqueous liquids/slurries (L1000)	Liquids and slurries containing less than 1% TOC
Organic liquids (L2000)	Liquids and slurries containing ≥1% TOC
	Solids[c]
Solids (S0000)	Wastes with physically solid matrices for which insufficient characterization information exists to enable categorizing as a homogeneous solid, soil/gravel, or debris
Homogeneous solids (S3000)	Wastes that are at least 50 vol % homogeneous solids, but: • are insufficiently characterized to enable categorization as either inorganic or organic homogeneous solids, or • do not meet the criteria for categorization as either inorganic or organic homogeneous solids
Inorganic homogeneous solids (S3100)	Wastes that are at least 50 vol % inorganic homogeneous solids. Homogeneous solids are defined as solid waste materials, excluding soil/gravel, that do not meet the U.S. Environmental Protection Agency (EPA) land disposal restrictions (LDRs) criteria for classification as debris. Inorganic homogeneous solids are further defined as those with sufficient inorganic solids content such that a minimum of approximately 20 wt % would remain as residue (i.e., ash/solids) following incineration
Organic homogeneous solids (S3200)	Wastes that are at least 50 vol % organic homogeneous solids. Homogeneous solids are defined as solid waste materials, excluding soil/gravel, that do not meet the EPA LDR criteria for classification as debris. Organic homogeneous solids are further defined as those with a base structure that is primarily organic such that a maximum of approximately 20 wt % would remain as residue (i.e., ash/solids) following incineration
Soil/gravel (S4000)	Wastes that are at least 50 vol % soil, including sand and silt or rock and gravel, that do not meet EPA LDR criteria for classification as debris
Debris (S5000)	Wastes that are at least 50 vol % materials that meet the EPA LDR criteria for classification as debris but lack adequate characterization information to enable categorizing as inorganic, organic, or heterogeneous debris
Inorganic debris (S5100)	Wastes that are at least 80 vol % inorganic materials that meet the EPA LDR criteria for classification as debris. Examples include scrap metal, concrete, glass, and brick
Organic debris (S5300)	Wastes that are at least 80 vol % organic materials that meet the EPA LDR criteria for classification as debris. Examples include plastic, rubber, wood, paper, cloth, and biological materials
Heterogeneous debris (S5400)	Wastes that are at least 50 vol % debris materials that meet the EPA LDR criteria for classification as debris but are not dominant (i.e., at least 80 vol %) in either inorganic or organic debris materials

Table 8.5 (continued)

Matrix parameter category (code)	Description
	Specific waste forms[d]
Lab packs (X6000)	Wastes packaged in lab pack configurations. A lab pack configuration is defined as two or more waste containers packaged within a larger outer container. Typically, the inner containers are surrounded by absorbent materials. If present, the absorbents can be homogeneous solids or debris materials
Reactive metals (X7500)	Reactive metal wastes that meet the criteria for classification as water-reactive or ignitable-reactive per the Third Third LDR rule (55 FR 22545 and 22553). Typically, this waste is sodium metal or sodium metal alloys, but can also include particulate fines of aluminum, uranium, zirconium, or other pyrophoric materials
Explosives/propellants (X7600)	Wastes consisting of substances which undergo rapid chemical transformations that produce large amounts of gases and heat. The gases rapidly expand at velocities exceeding the speed of sound (due to the heat of reaction), which creates a shock wave and explosion. Waste that meets this definition is categorized as an explosive/propellant regardless of the specific physical form
Compressed gases/aerosols (X7700)	Wastes consisting of pressurized gas cylinders or aerosol cans
Elemental mercury (X7100)	Wastes that are bulk, pourable liquid mercury. The liquid mercury may be packaged in a lab pack configuration
Elemental hazardous metals (X7200)	Wastes that are at least 50 vol % solid, bulk, elemental hazardous metals that meet the EPA LDR size criteria for classification as debris. Typical examples of solid elemental hazardous metals are lead and cadmium
Beryllium dust (X7300)	Wastes that are subject to the metal recovery treatment standard for beryllium dust as specified in the Third Third LDR rule (55 FR 22545)
Batteries (X7400)	Wastes consisting of lead acid, cadmium, or other batteries. The batteries may be packaged with absorbent materials
Unknown/other matrix (U9999)	Wastes for which insufficient characterization information is known to enable categorization as a liquid or solid or as one of the specific waste forms
	Final waste forms[e]
Final waste forms (Z0000)	Final waste forms other than immobilized forms and decontaminated solids
Immobilized forms (Z1000)	Wastes that have been immobilized. These include wastes considered to be either micro- or macro-encapsulated
Decontaminated solids (Z2000)	Waste that has been decontaminated and is ready for disposal or recycling

[a]Based on ref. 9.

[b]This category addresses wastes that are liquid, including slurries, and are packaged in bulk, free form (i.e., excludes lab packs). Slurries are defined as liquids with a total suspended/settled solids (TSS) content of $\geq$1% and $\leq$30%.

[c]This category addresses waste with physically solid matrices, including sludges. Sludges are defined as having a TSS >30%. Certain waste with physically solid matrices are excluded from this category (see the "specific waste forms" and "final waste forms" categories above).

[d]This category addresses lab packs and other specific waste forms. The other specific waste forms include waste that (a) is inherently hazardous (i.e., the bulk material itself is RCRA hazardous), or (b) presents unique treatment or management concerns.

[e]This category addresses waste that is in final form and meets applicable disposal criteria, including applicable LDR and PCB treatment standards.

Table 8.6. Volume (m^3) inventory and generation of DOE RCRA and RCRA PCB MLLW, by site and physical form[a]

Site	Physical form[b]	MPC code	Current inventory	FY generation			
				Actual 1996	Projections		
					1997	1998–2006	2007–2030
Ames	Organic liquids (09/30/95)[c]	L2000	0.00	d	d	d	d
ANL–E	Aqueous liquids/slurries	L1000	3.41	d	d	d	d
	Inorganic homogeneous solids	S3100	1.21	d	d	d	d
	Soil/gravel	S4000	1.03	d	d	d	d
	Inorganic debris	S5100	12.72	d	d	d	d
	Organic debris	S5300	1.26	d	d	d	d
	Lab packs	X6000	2.87	d	d	d	d
	Elemental mercury	X7100	0.02	d	d	d	d
	Elemental hazardous metals	X7200	27.90	d	d	d	d
	Reactive metals	X7500	0.35	d	d	d	d
	ANL–E total (07/09/97)		50.77	d	d	d	d
ANL–W	Aqueous liquids/slurries	L1000	0.42	d	d	d	d
	Inorganic homogeneous solids	S3100	0.21	d	d	d	d
	Inorganic debris	S5100	0.99	d	d	d	d
	Organic debris	S5300	0.15	d	d	d	d
	Heterogeneous debris	S5400	2.83	d	d	d	d
	Elemental mercury	X7100	0.00	d	d	d	d
	Elemental hazardous metals	X7200	0.52	d	d	d	d
	Reactive metals	X7500	385.06	d	d	d	d
	ANL–W total (09/30/95)		390.18	d	d	d	d
BAPL	Aqueous liquids/slurries	L1000	2.10	0.00	0.13	1.13	3.02
	Organic liquids	L2000	2.16	0.01	0.12	1.12	2.98
	Inorganic homogeneous solids	S3100	0.22	0.21	0.17	1.53	4.08
	Organic homogeneous solids	S3200	3.57	0.01	0.34	3.02	8.06
	Soil/gravel	S4000	1.47	0.00	0.00	0.00	0.00
	Inorganic debris	S5100	0.00	0.00	0.01	0.09	0.24
	Heterogeneous debris	S5400	1.92	0.23	0.23	2.11	5.62
	Elemental hazardous metals	X7200	2.73	0.00	0.07	0.61	1.63
	BAPL total (08/08/96)		14.17	0.46	1.07	9.61	25.63
BNL	Organic liquids	L2000	0.91	0.35	0.17	0.17	0.16
	Inorganic homogeneous solids	S3100	0.00	0.00	0.00	0.02	0.01
	Lab packs	X6000	1.12	0.28	0.13	0.72	1.92
	Elemental mercury	X7100	1.45	0.00	d	0.01	0.01
	Elemental hazardous metals	X7200	0.45	1.10	d	d	d
	BNL total (09/30/95)		3.93	1.73	0.30	0.92	2.10
ETEC	Aqueous liquids/slurries	L1000	0.00	0.00	0.00	0.00	0.00
	Organic liquids	L2000	0.15	0.00	0.00	0.00	0.00
	Inorganic homogeneous solids	S3100	5.68	8.70	0.50	2.85	0.00

Table 8.6 (continued)

Site	Physical form[b]	MPC code	Current inventory	FY generation			
				Actual 1996	Projections		
					1997	1998–2006	2007–2030
ETEC (contd.)	Heterogeneous debris	S5400	32.50	0.10	0.95	2.10	0.00
	Elemental hazardous metals	X7200	1.06	0.00	0.02	4.00	0.00
	ETEC total (09/30/95)		39.39	8.80	1.47	8.95	0.00
ETTP	Aqueous liquids/slurries	L1000	322.84	e	e	e	e
	Organic liquids	L2000	482.36	e	e	e	e
	Inorganic homogeneous solids	S3100	20,994.13	e	e	e	e
	Organic homogeneous solids	S3200	442.11	e	e	e	e
	Soil/gravel	S4000	283.08	e	e	e	e
	Inorganic debris	S5100	192.05	e	e	e	e
	Organic debris	S5300	153.75	e	e	e	e
	Heterogeneous debris	S5400	172.68	e	e	e	e
	Unknown/other matrix	U9999	45.34	e	e	e	e
	Lab packs	X6000	31.96	e	e	e	e
	Elemental mercury	X7100	2.80	e	e	e	e
	Elemental hazardous metals	X7200	91.15	e	e	e	e
	Beryllium dust	X7300	0.16	e	e	e	e
	Batteries	X7400	17.74	e	e	e	e
	Reactive metals	X7500	0.08	e	e	e	e
	Explosives/propellants	X7600	0.00	e	e	e	e
	Compressed gases/aerosols	X7700	4.94	e	e	e	e
	ETTP total (09/30/96)		23,237.18	e	e	e	e
Hanford	Organic liquids	L2000	1.04	0.21	d	d	d
	Solids	S0000	0.62	d	d	d	d
	Homogeneous solids	S3000	20.00	d	4.57	44.38	47.89
	Inorganic homogeneous solids	S3100	3,779.41	56.58	42.44	548.67	4,404.56
	Organic homogeneous solids	S3200	0.00	0.21	d	d	d
	Soil/gravel	S4000	476.38	11.20	29.60	389.10	160.61
	Debris waste	S5000	45.39	23.19	d	d	d
	Inorganic debris	S5100	557.01	30.34	139.75	7,481.58	34,527.35
	Organic debris	S5300	1,690.50	54.60	66.84	778.61	1,972.08
	Heterogeneous debris	S5400	808.78	104.48	271.66	2,768.04	5,009.97
	Unknown/other matrix	U9999	60.15	d	d	d	d
	Lab packs	X6000	291.35	12.93	27.58	184.42	112.44
	Special waste	X7000	1.30	1.82	d	d	d
	Elemental mercury	X7100	1.45	0.42	0.26	0.41	0.67
	Elemental hazardous metals	X7200	235.09	21.81	32.33	234.24	197.58
	Batteries	X7400	1.86	0.42	1.29	3.16	27.04
	Reactive metals	X7500	5.43	d	d	d	d
	Explosives/propellants	X7600	0.00	d	0.15	2.90	22.48
	Immobilized forms	Z1000	42.00	d	d	41.53	1,067.63
	Decontaminated solids	Z2000	0.00	d	d	293.98	134.64
	Hanford total (09/30/95)		8,017.76	318.19	616.47	12,771.03	47,684.95
INEEL[f]	Aqueous liquids/slurries	L1000	3.40	d	d	d	d
	Organic liquids	L2000	6.43	d	d	d	d

Table 8.6 (continued)

Site	Physical form[b]	MPC code	Current inventory	FY generation			
				Actual 1996	Projections		
					1997	1998–2006	2007–2030
INEEL[f] (contd.)	Homogeneous solids	S3000	0.23	d	d	d	d
	Inorganic homogeneous solids	S3100	63.62	d	d	d	d
	Organic homogeneous solids	S3200	0.00	d	d	d	d
	Soil/gravel	S4000	9.76	d	d	d	d
	Inorganic debris	S5100	91.82	d	d	d	d
	Organic debris	S5300	244.67	d	d	d	d
	Heterogeneous debris	S5400	88.46	d	d	d	d
	Lab packs	X6000	4.77	d	d	d	d
	Elemental mercury	X7100	0.03	d	d	d	d
	Elemental hazardous metals	X7200	327.43	d	d	d	d
	Reactive metals	X7500	0.25	d	d	d	d
	Immobilized forms	Z1000	5.44	d	d	d	d
	INEEL total (09/30/95)		846.28	d	d	d	d
ITRI	Lab packs (09/30/95)	X6000	0.00	d	d	d	d
KAPL[g]	Organic liquids	L2000	0.22	0.00	0.08	0.70	1.87
	Inorganic homogeneous solids	S3100	0.36	0.06	0.18	1.62	4.32
	Organic homogeneous solids	S3200	0.03	0.12	0.28	2.62	6.72
	Soil/gravel	S4000	0.00	0.00	3.36	30.24	80.64
	Inorganic debris	S5100	0.39	2.52	1.66	14.94	39.84
	Organic debris	S5300	0.46	0.01	1.32	11.92	31.78
	Heterogeneous debris	S5400	0.11	0.06	0.18	1.62	4.32
	Lab packs	X6000	0.02	0.04	0.52	4.68	12.48
	Elemental mercury	X7100	0.03	0.00	0.02	0.14	0.38
	Elemental hazardous metals	X7200	0.13	0.04	0.24	2.16	5.76
	KAPL total (08/08/96)		1.75	2.84	7.84	70.54	188.11
KESS[h]	Organic liquids	L2000	0.00	0.00	0.08	1.22	3.30
	Homogeneous solids	S3000	1.28	0.79	4.50	9.30	12.00
	Inorganic homogeneous solids	S3100	0.32	0.01	0.20	1.70	4.60
	Organic homogeneous solids	S3200	0.00	0.00	0.15	1.40	3.50
	Soil/gravel	S4000	0.02	0.00	0.00	10.00	20.00
	Inorganic debris	S5100	0.94	7.42	2.24	10.66	22.02
	Organic debris	S5300	0.00	0.04	0.12	1.08	2.72
	Heterogeneous debris	S5400	1.02	0.01	0.25	1.60	4.60
	Lab packs	X6000	0.01	0.00	0.26	0.95	2.70
	Elemental mercury	X7100	0.00	0.00	0.00	0.00	0.00
	Elemental hazardous metals	X7200	0.00	0.00	0.16	1.80	4.60
	KESS total (08/08/96)		3.59	8.27	7.96	39.71	80.04
KWIN[i]	Homogeneous solids	S3000	0.00	0.07	0.70	1.30	0.00
	Inorganic homogeneous solids	S3100	0.00	0.07	0.15	0.40	0.00
	Organic homogeneous solids	S3200	0.00	0.00	0.50	1.15	0.00
	Soil/gravel	S4000	0.00	0.00	1.40	2.80	0.00
	Organic debris	S5300	0.00	0.03	0.50	1.00	0.00

Table 8.6 (continued)

Site	Physical form[b]	MPC code	Current inventory	FY generation			
				Actual 1996	Projections		
					1997	1998–2006	2007–2030
KWIN[i] (contd.)	Heterogeneous debris	S5400	0.00	0.00	0.38	0.75	0.00
	Lab packs	X6000	0.00	0.00	0.11	0.21	0.00
	Elemental hazardous metals	X7200	0.25	0.07	2.60	2.41	0.00
	KWIN total (08/08/96)		0.25	0.24	6.34	10.02	0.00
LANL	Liquids	L0000	122.64	12.15	19.27	645.96	107.10
	Solids	S0000	413.56	40.93	62.78	1,839.19	360.78
	Unknown/other matrix	U9999	224.96	0.79	1.30	35.46	6.96
	Compressed gases/aerosols	X7700	3.94	0.00	d	0.14	0.03
	LANL total (09/30/95)		765.10	53.87	83.35	2,420.76	474.86
LBNL	Aqueous liquids/slurries	L1000	0.60	0.30	d	d	d
	Organic liquids	L2000	1.29	0.56	d	d	d
	Inorganic homogeneous solids	S3100	1.52	0.05	d	d	d
	Heterogeneous debris	S5400	1.02	0.00	d	d	d
	Lab packs	X6000	1.53	0.00	d	d	d
	Elemental mercury	X7100	0.01	0.00	d	d	d
	Elemental hazardous metals	X7200	0.69	0.13	d	d	d
	LBNL total (09/30/95)		6.67	1.04	d	d	d
LEHR	Elemental hazardous metals (09/30/95)	X7200	1.70	0.00	0.00	0.00	0.00
LLNL	Organic liquids	L2000	95.28	66.66	137.42	1,287.19	2,910.00
	Inorganic homogeneous solids	S3100	281.02	19.93	25.10	225.90	432.00
	Organic homogeneous solids	S3200	1.20	0.00	0.60	5.40	7.20
	Soil/gravel	S4000	16.85	10.23	2.00	18.00	72.00
	Inorganic debris	S5100	15.20	4.07	4.20	37.80	96.00
	Heterogeneous debris	S5400	12.54	4.21	7.00	55.60	120.00
	Lab packs	X6000	6.51	0.22	1.30	11.70	26.40
	Special waste	X7000	4.40	0.01	d	d	d
	Elemental mercury	X7100	0.11	0.09	d	d	d
	Elemental hazardous metals	X7200	59.11	10.28	11.00	99.00	132.00
	Reactive metals	X7500	1.21	0.00	0.20	1.80	1.20
	LLNL total (09/30/95)		493.43	115.70	188.82	1,745.29	3,796.80
Mound	Organic liquids	L2000	1.00	0.00	0.00	0.90	0.00
	Inorganic homogeneous solids	S3100	15.60	0.00	0.00	0.00	0.00
	Organic debris	S5300	0.02	0.00	0.00	0.02	0.00
	Heterogeneous debris	S5400	1.00	0.00	0.00	0.00	0.00
	Unknown/other matrix	U9999	1.00	0.00	0.00	0.00	0.00
	Lab packs	X6000	12.74	0.00	0.00	3.00	0.00
	Elemental mercury	X7100	0.00	0.00	0.00	0.00	0.00

Table 8.6 (continued)

Site	Physical form[b]	MPC code	Current inventory	FY generation			
				Actual 1996	Projections		
					1997	1998–2006	2007–2030
Mound (contd.)	Elemental hazardous metals	X7200	5.64	0.00	0.00	0.65	0.00
	Batteries	X7400	0.00	0.00	0.00	0.79	0.00
	Mound total (09/30/95)		37.00	0.00	0.00	5.36	0.00
MURR	Heterogeneous debris (09/30/95)	S5400	1.40	0.27	d	d	d
NNS	Inorganic homogeneous solids	S3100	0.80	0.19	1.09	9.77	26.06
	Inorganic debris	S5100	0.08	0.43	0.37	3.37	8.98
	Organic debris	S5300	0.24	0.04	0.34	3.06	8.15
	NNS total (08/08/96)		1.12	0.66	1.80	16.20	43.20
NTS	Organic liquids	L2000	0.10	d	d	d	d
	Organic homogeneous solids	S3200	0.10	d	d	d	d
	Soil/gravel	S4000	22.55	d	d	d	d
	Lab packs	X6000	0.00	d	d	d	d
	Elemental hazardous metals	X7200	2.10	d	d	4.80	d
	NTS total (09/30/95)		24.85	d	d	4.80	d
ORNL	Liquids	L0000	3.14	e	e	e	e
	Aqueous liquids/slurries	L1000	2,685.34	e	e	e	e
	Organic liquids	L2000	59.85	e	e	e	e
	Solids	S0000	2.64	e	e	e	e
	Inorganic homogeneous solids	S3100	52.13	e	e	e	e
	Organic homogeneous solids	S3200	0.47	e	e	e	e
	Soil/gravel	S4000	4.09	e	e	e	e
	Inorganic debris	S5100	1.89	e	e	e	e
	Organic debris	S5300	1.70	e	e	e	e
	Heterogeneous debris	S5400	2.55	e	e	e	e
	Unknown/other matrix	U9999	0.08	e	e	e	e
	Lab packs	X6000	25.30	e	e	e	e
	Elemental mercury	X7100	0.70	e	e	e	e
	Elemental hazardous metals	X7200	1.39	e	e	e	e
	Beryllium dust	X7300	0.00	e	e	e	e
	Batteries	X7400	1.25	e	e	e	e
	Reactive metals	X7500	0.63	e	e	e	e
	Explosives/propellants	X7600	0.00	e	e	e	e
	Compressed gases/aerosols	X7700	0.00	e	e	e	e
	ORNL total (09/30/96)		2,843.13	e	e	e	e
PANT	Aqueous liquids/slurries	L1000	1.67	0.04	0.15	0.62	0.43
	Organic liquids	L2000	1.37	0.66	0.69	3.66	4.38
	Inorganic homogeneous solids	S3100	27.54	1.78	0.00	0.00	0.00
	Soil/gravel	S4000	0.00	0.00	0.00	229.37	0.00
	Inorganic debris	S5100	41.31	5.64	5.67	29.84	20.05
	Organic debris	S5300	57.65	10.28	9.44	34.83	21.01

Table 8.6 (continued)

Site	Physical form[b]	MPC code	Current inventory	FY generation			
				Actual 1996	Projections		
					1997	1998–2006	2007–2030
PANT (contd.)	Lab packs	X6000	2.03	0.10	0.01	0.06	0.04
	Explosives/propellants	X7600	15.79	9.37	7.04	28.04	17.59
	PANT total (09/30/95)		147.35	27.86	23.01	326.40	63.49
PHNS	Inorganic homogeneous solid	S3100	2.14	0.74	0.25	2.23	5.95
	Debris	S5000	0.04	1.13	0.25	2.29	6.10
	Inorganic debris	S5100	0.90	0.00	0.22	1.94	5.18
	Organic debris	S5300	0.23	0.13	0.14	1.30	3.46
	Elemental hazardous metals	X7200	0.08	0.00	0.03	0.29	0.77
	PHNS total (08/08/96)		3.39	2.00	0.89	8.05	21.46
PNS	Inorganic homogeneous solids	S3100	0.22	0.00	0.04	0.36	0.96
	Inorganic debris	S5100	0.45	0.01	0.01	0.12	0.31
	Organic debris	S5300	0.00	0.00	0.01	0.05	0.14
	Heterogeneous debris	S5400	0.00	0.00	0.03	0.27	0.71
	Elemental hazardous metals	X7200	0.14	0.00	0.00	0.01	0.03
	PNS total (12/31/95)		0.81	0.01	0.09	0.81	2.16
PPPL	Aqueous liquids/slurries	L1000	0.00	0.00	0.00	2.00	0.00
	Organic liquids	L2000	0.00	0.30	0.50	4.50	12.00
	Inorganic homogeneous solids	S3100	0.00	0.00	0.00	0.20	0.00
	Inorganic debris	S5100	0.00	0.00	0.20	8.00	0.00
	Elemental hazardous waste	X7200	0.00	0.00	0.20	5.00	0.00
	PPPL total (09/30/95)		0.00	0.30	0.90	19.70	12.00
PSNS	Aqueous liquids/slurries	L1000	0.30	0.00	0.00	0.00	0.00
	Inorganic homogeneous solids	S3100	0.60	1.45	1.81	16.25	43.34
	Organic debris	S5300	5.05	0.00	1.13	10.15	27.07
	Heterogeneous debris	S5400	36.71	0.20	0.93	8.41	22.42
	Elemental hazardous metals	X7200	0.20	0.09	0.67	6.01	16.03
	PSNS total (08/08/96)		42.86	1.74	4.54	40.82	108.86
RFETS	Aqueous liquids/slurries	L1000	1,688.59	d	14.00	3,764.00	1,229.00
	Organic liquids	L2000	167.22	d	d	d	d
	Inorganic homogeneous solids	S3100	15,328.21	d	36.00	9,410.00	3,074.00
	Organic homogeneous solids	S3200	0.42	d	d	d	d
	Soil/gravel	S4000	617.85	d	27.00	7,058.00	2,305.00
	Inorganic debris	S5100	268.88	d	33.00	8,940.00	1,426.52
	Organic debris	S5300	18.82	d	9.00	2,352.00	768.00
	Heterogeneous debris	S5400	1,369.61	d	42.00	10,822.00	3,535.00
	Lab packs	X6000	127.06	d	9.00	2,352.00	768.00
	Elemental hazardous metals	X7200	43.47	d	9.00	2,352.00	768.00

Table 8.6 (continued)

Site	Physical form[b]	MPC code	Current inventory	FY generation			
				Actual 1996	Projections		
					1997	1998–2006	2007–2030
RFETS (contd.)	Beryllium dust	X7300	5.09	d	d	d	d
	Immobilized forms	Z1000	94.81	d	d	d	d
	RFETS total (09/30/96)		19,730.02	d	179.00	47,050.00	13,873.52
SNL/CA	Organic liquids	L2000	d	d	d	3.60	0.40
	Solids	S0000	d	d	d	3.60	0.40
	SNL/CA total		d	d	d	7.20	0.80
SRS[j]	Aqueous liquids/slurries	L1000	150.60	2.10	240.90	2,938.10	d
	Organic liquids	L2000	177.60	0.60	1.00	137.50	d
	Solids	S0000	1.70	0.00	0.00	0.00	d
	Inorganic homogeneous solids	S3100	2,797.46	0.21	40.68	1,057.80	d
	Organic homogeneous solids	S3200	1.80	0.00	0.00	0.00	d
	Soil/gravel	S4000	17.20	0.00	0.00	0.00	d
	Debris waste	S5000	739.00	0.00	0.00	0.00	d
	Inorganic debris	S5100	154.35	55.50	31.61	142.96	d
	Organic debris	S5300	17.10	1.98	5.00	44.60	d
	Heterogeneous debris	S5400	3,569.80	1.00	1.70	6.80	d
	Lab packs	X6000	19.00	d	0.90	0.80	d
	Elemental mercury	X7100	0.28	d	0.21	0.82	d
	Elemental hazardous metals	X7200	66.93	d	0.20	0.80	d
	Reactive metals	X7500	0.80	0.00	0.00	0.00	d
	Immobilized forms	Z1000	3.50	0.00	14.00	56.00	d
	SRS total (09/01/96)		7,717.12	61.39	336.20	4,386.18	d
WVDP	Aqueous liquids/slurries	L1000	0.83	2.23	0.00	0.00	0.00
	Organic liquids	L2000	0.00	0.00	0.00	0.00	0.00
	Inorganic homogeneous solids	S3100	0.00	0.00	0.00	0.00	0.00
	Organic debris	S5300	0.00	0.00	3.12	0.00	0.00
	Heterogeneous debris	S5400	25.77	0.00	0.00	0.00	0.00
	WVDP total (09/30/95)		26.60	2.24	3.12	0.00	0.00
Y-12	Liquids	L0000	22.56	e	e	e	e
	Aqueous liquids/slurries	L1000	43.42	e	e	e	e
	Organic liquids	L2000	314.55	e	e	e	e
	Solids	S0000	72.00	e	e	e	e
	Inorganic homogeneous solids	S3100	6,639.00	e	e	e	e
	Organic homogeneous solids	S3200	52.19	e	e	e	e
	Soil/gravel	S4000	9.06	e	e	e	e
	Inorganic debris	S5100	14.17	e	e	e	e
	Organic debris	S5300	66.29	e	e	e	e
	Heterogenous debris	S5400	17.31	e	e	e	e
	Unknown/other matrix	U9999	0.03	e	e	e	e

Table 8.6 (continued)

Site	Physical form[b]	MPC code	Current inventory	FY generation			
				Actual 1996	Projections		
					1997	1998–2006	2007–2030
Y-12 (contd.)	Lab packs	X6000	0.88	e	e	e	e
	Elemental mercury	X7100	1.24	e	e	e	e
	Elemental hazardous metals	X7200	2.26	e	e	e	e
	Beryllium dust	X7300	0.00	e	e	e	e
	Batteries	X7400	5.20	e	e	e	e
	Reactive metals	X7500	0.83	e	e	e	e
	Explosives/propellants	X7600	0.00	e	e	e	e
	Compressed gases/aerosols	X7700	1.01	e	e	e	e
	Y-12 total (09/30/96)		7,262.01	e	e	e	e
	Grand total (DOE complex)		71,709.82	607.61	1,463.17	68,942.36	66,377.99

[a]Based on ref. 8. The currentness of these data for the various DOE sites ranges from September 1995 to July 1997.
[b]As described in Table 8.5.
[c]Latest date of site inventory reported (month/day/calendar year).
[d]Information not reported by site.
[e]Generation numbers for ETTP, ORNL, and Y-12 were reported at a rolled up level across the entire Oak Ridge Reservation (ORR). The values were not distributed according to RCRA and non-RCRA (i.e., PCB only), nor were the values distributed according to physical form (i.e., treatability group MPC). The ORR generation values reported were 880.00 m^3 (FY 1996); 1,054.00 m^3 (FY 1997); 9,505.00 m^3 (FY 1998–2006); and 28,458.00 m^3 (FY 2007–2030).
[f]Includes contributions from the Idaho Naval Reactors Facility.
[g]Knolls Atomic Power Laboratory (KAPL) Schenectady site.
[h]KAPL Kesselring site.
[i]KAPL Windsor site.
[j]Savannah River generation estimates for the 1998–2006 period account for only those from 1998–2001.

Table 8.7. Volume (m^3) inventory and generation of non-RCRA PCB MLLW, by site and physical form[a]

Site	Physical form[b]	MPC code	Current inventory	FY generation			
				Actual 1996	Projections		
					1997	1998–2006	2007–2030
ANL–E	Solids	S0000	70.00	70.00	0.63	0.63	20.63
	ANL–E total (07/09/97)[c]		70.00	70.00	0.63	0.63	0.63
BAPL	Organic liquids	L2000	0.01	0.00	0.00	0.00	0.00
	Debris waste	S5000	7.34	0.00	6.76	59.80	24.00
	BAPL total (08/08/96)		7.35	0.00	6.76	59.80	24.00
BNL	Unknown/other matrix	U9999	0.28	0.00	0.40	0.10	0.10
	BNL total (09/30/95)		0.28	0.00	0.40	0.10	0.10
ETTP	Liquids	L0000	18.25	d	d	d	d
	Aqueous liquids/slurries	L1000	2.68	d	d	d	d
	Organic liquids	L2000	22.48	d	d	d	d
	Solids	S0000	214.43	d	d	d	d
	Inorganic homogeneous solids	S3100	16.25	d	d	d	d
	Organic homogeneous solids	S3200	0.18	d	d	d	d
	Soil/gravel	S4000	2,627.51	d	d	d	d
	Inorganic debris	S5100	1,029.94	d	d	d	d
	Organic debris	S5300	20.13	d	d	d	d
	Heterogeneous debris	S5400	46.19	d	d	d	d
	Unknown/other matrix	U9999	2.92	d	d	d	d
	Lab packs	X6000	0.00	d	d	d	d
	ETTP total (09/30/96)		4,000.98	d	d	d	d
Hanford	Solids	S0000	0.21	e	e	e	e
	Inorganic homogeneous solids	S3100	0.21	e	e	e	e
	Organic homogeneous solids	S3200	0.21	e	e	e	e
	Soil/gravel	S4000	29.28	e	e	e	e
	Debris waste	S5000	0.21	e	e	e	e
	Inorganic debris	S5100	32.16	e	e	e	e
	Organic debris	S5300	24.28	e	e	e	e
	Heterogeneous debris	S5400	4.80	e	e	e	e
	Lab packs	X6000	11.11	e	e	e	e
	Hanford total (09/30/95)		102.46	e	e	e	e
KAPL[f]	Debris waste	S5000	0.41	0.41	0.45	4.05	10.80
	Organic debris	S5300	0.40	0.40	0.45	4.05	10.80
	KAPL total (08/08/96)		0.81	0.81	0.90	8.10	21.60
KESS[g]	Solids	S0000	0.00	0.05	0.05	0.45	0.80
	Inorganic homogeneous solids	S3100	0.00	0.60	0.60	5.40	2.00
	Inorganic debris	S5100	0.00	0.80	0.80	1.00	0.50
	KESS total (08/08/96)		0.00	1.45	1.45	6.85	3.30

Table 8.7 (continued)

Site	Physical form[b]	MPC code	Current inventory	FY generation			
				Actual 1996	Projections		
					1997	1998–2006	2007–2030
KWIN[h]	Debris waste	S5000	0.10	0.00	3.90	6.00	0.00
	KWIN total (08/08/96)		0.10	0.00	3.90	6.00	0.00
Mound	Organic debris	S5300	0.40	0.00	0.00	0.00	0.00
	Mound total (09/30/95)		0.40	0.00	0.00	0.00	0.00
NNS	Organic debris	S5300	0.07	0.14	0.62	0.20	0.53
	NNS total (08/08/96)		0.07	0.14	0.62	0.20	0.53
ORNL	Liquids	L0000	0.00	d	d	d	d
	Aqueous liquids/slurries	L1000	0.61	d	d	d	d
	Organic liquids	L2000	2.25	d	d	d	d
	Solids	S0000	0.95	d	d	d	d
	Inorganic homogeneous solids	S3100	0.00	d	d	d	d
	Organic homogeneous solids	S3200	0.00	d	d	d	d
	Soil/gravel	S4000	0.00	d	d	d	d
	Inorganic debris	S5100	0.33	d	d	d	d
	Organic debris	S5300	0.28	d	d	d	d
	Heterogeneous debris	S5400	3.81	d	d	d	d
	Unknown/other matrix	U9999	0.26	d	d	d	d
	Lab packs	X6000	0.05	d	d	d	d
	ORNL total (09/30/96)		8.54	d	d	d	d
PHNS	Inorganic homogeneous solid	S3100	0.00	0.00	0.37	0.11	0.31
	Organic debris	S5300	0.02	0.02	0.37	3.22	8.58
	PHNS total (08/08/96)		0.02	0.02	0.74	3.33	8.88
PSNS	Solids	S0000	8.31	0.11	0.11	0.95	2.54
	Heterogeneous debris	S5400	2.45	0.07	0.07	0.63	1.68
	PSNS total (09/08/96)		10.76	0.18	0.18	1.58	4.22
SRS	Inorganic debris	S5100	2.80	0.20	1.00	e	e
	SRS total (09/01/96)		2.80	0.20	1.00	e	e
Y-12	Liquids	L0000	2.50	d	d	d	d
	Aqueous liquids/slurries	L1000	2.44	d	d	d	d
	Organic liquids	L2000	35.25	d	d	d	d
	Solids	S0000	22.58	d	d	d	d
	Inorganic homogeneous solids	S3100	3.66	d	d	d	d
	Organic homogeneous solids	S3200	0.98	d	d	d	d
	Soil/gravel	S4000	10.58	d	d	d	d
	Inorganic debris	S5100	37.39	d	d	d	d
	Organic debris	S5300	36.96	d	d	d	d

Table 8.7 (continued)

Site	Physical form[b]	MPC code	Current inventory	FY generation			
				Actual 1996	Projections		
					1997	1998–2006	2007–2030
Y-12 (contd.)	Heterogenous debris	S5400	170.76	d	d	d	d
	Unknown/other matrix	U9999	1.82	d	d	d	d
	Lab packs	X6000	0.40	d	d	d	d
	Y-12 total (09/30/96)		325.32	d	d	d	d
	Grand total (DOE complex)		4,529.89	72.80	16.58	86.59	63.26

[a]Based on ref. 8. The currentness of these data for the various DOE sites ranges from September 1995 to July 1997.
[b]As described in Table 8.5.
[c]Latest date of site inventory reported (month/day/calendar year).
[d]Generation numbers for ETTP, ORNL, and Y-12 were reported at a rolled up level across the entire Oak Ridge Reservation (ORR). The values were not distributed according to RCRA and non-RCRA (i.e., PCB only), nor were the values distributed according to physical form (i.e., treatability group MPC). The ORR generation values reported were 880.00 m^3 (FY 1996); 1,054.00 m^3 (FY 1997); 9,505.00 m^3 (FY 1998–2006); and 28,458.00 m^3 (FY 2007–2030).
[e]Information not reported by site.
[f]Knolls Atomic Power Laboratory (KAPL) Schenectady site.
[g]KAPL Kesselring site.
[h]KAPL Windsor site.

Table 8.8. Total volume (m^3) inventory and generation of DOE RCRA and RCRA PCB MLLW, by physical form[a]

MPC name	MPC code	Current inventory	FY generation			
			Actual 1996	FY projections		
				1997	1998–2006	2007–2030
Liquids	L0000	148.34	12.15	19.27	545.96	107.10
Aqueous liquids/slurries	L1000	4,903.52	4.67	255.18	6,705.85	1,232.45
Organic liquids	L2000	1,311.53	69.36	140.06	1,440.56	2,935.09
Solids	S0000	490.52	40.93	62.78	1,842.79	361.18
Homogeneous solids	S3000	21.51	0.86	9.77	54.98	59.89
Inorganic homogeneous solids	S3100	49,991.40	89.98	148.60	11,279.31	7,999.89
Organic homogeneous solids	S3200	501.68	0.33	1.87	13.49	25.48
Soil/gravel	S4000	1,459.34	21.43	63.36	7,737.51	2,638.25
Debris waste	S5000	784.43	24.32	0.25	2.29	6.10
Inorganic debris	S5100	1,353.16	105.93	218.95	16,671.29	36,146.50
Organic debris	S5300	2,257.89	67.10	96.96	3,238.62	2,834.41
Heterogeneous debris	S5400	6,146.02	110.56	325.31	13,672.19	8,702.63
Unknown/other matrix	U9999	331.56	0.79	1.30	35.46	6.96
Lab packs	X6000	527.13	13.57	39.82	2,558.53	923.98
Special waste	X7000	5.70	1.83			
Elemental mercury	X7100	8.11	0.51	0.49	1.39	1.07
Elemental hazardous metals	X7200	870.41	33.52	56.52	2,713.79	1,126.41
Beryllium dust	X7300	5.25				
Batteries	X7400	26.05	0.42	1.29	3.95	27.04
Reactive metals	X7500	394.63	0.00	0.20	1.80	1.20
Explosives/propellants	X7600	15.79	9.37	7.19	30.94	40.07
Compressed gases/aerosols	X7700	9.89	0.00		0.14	0.03
Immobilized forms	Z1000	145.75	0.00	14.00	97.53	1,067.63
Decontaminated solids	Z2000	0.00			293.98	134.64
Total		71,709.82	607.61	1,463.17	68,942.36	66,377.99

[a]Based on ref. 8.

Table 8.9. Total volume (m^3) inventory and generation of DOE non-RCRA PCB MLLW, by physical form[a]

MPC name	MPC code	Current inventory	FY generation			
			Actual 1996	FY projections		
				1997	1998–2006	2007–2030
Liquids	L0000	20.75				
Aqueous liquids/slurries	L1000	5.73				
Organic liquids	L2000	59.99	0.00	0.00	0.00	0.00
Solids	S0000	316.48	70.16	0.79	2.03	3.97
Inorganic homogeneous solids	S3100	20.12	0.60	0.97	5.51	2.31
Organic homogeneous solids	S3200	1.37				
Soil/gravel	S4000	2,667.38				
Debris waste	S5000	8.06	0.41	11.11	69.85	34.80
Inorganic debris	S5100	1,102.63	1.00	1.80	1.00	0.50
Organic debris	S5300	82.54	0.56	1.44	7.46	19.90
Heterogeneous debris	S5400	228.01	0.07	0.07	0.63	1.68
Unknown/other matrix	U9999	5.28	0.00	0.40	0.10	0.10
Lab packs	X6000	11.55				
Total		4,529.89	72.80	16.58	86.59	63.26

[a]Based on ref. 8.

APPENDIX A. RADIOACTIVE WASTE SOURCE TERMS AND CHARACTERISTICS

A.1 DISCUSSION

In this report, a number of engineering estimates, assumptions, and ground rules are used to determine radioactive waste projections through the year 2030. Many of these involve parameters that characterize certain types of waste (e.g., see Table A.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 source terms and characteristics used for making radioactive waste projections. Source terms are used to describe quantitative and qualitative characteristics of radioactive wastes. As used in this report, 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 5). Detailed information on how these source terms and modeling parameters were derived is available, mainly in ref. 1 and its update (ref. 2).

Representative DOE LLW radionuclide compositions are described in Table A.2 (based on ref. 1). Average concentrations for representative radionuclides in LLW disposed of at commercial sites are given in Table A.3. This information was adapted from ref. 3. Table A.4 gives a summary of major sources and estimated characteristics of commercial greater-than-Class-C LLW (data from refs. 4 and 5).

The characteristics of many types of naturally occurring radioactive materials are based on the properties of the radionuclides from the natural decay series of ^{232}Th, ^{235}U, and ^{238}U. Major characteristics of the radionuclides that comprise each of these three natural decay chains are given in Table A.5 (adapted from refs. 6 and 7).

A.2 SPECIAL-CASE WASTE

Special-case waste (SCW) is radioactive waste that is generated from DOE-sponsored activities that has limited or no planned disposal alternatives because it does not fit into the typical management plans developed for the major radioactive waste types. As defined by DOE, SCW is not HLW or TRUW, but is waste that requires greater confinement than shallow-land burial.[8] Except for indefinite storage, no management strategy for SCW currently exists. SCW has been generated over the history of DOE missions and reflects a wide spectrum of radiological characteristics. The following categories of materials have been identified as SCWs:

- excess nuclear material,
- "failed" spent nuclear fuel debris,
- materials requiring special PA [also called special performance assessment required (SPAR) wastes],
- sealed source(s) awaiting a disposal option, and
- uncharacterized waste.

A summary of current (FY 1997) SCW inventories is provided in Table A.6 (data from ref. 9).

A.3 REFERENCES

1. 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).

2. S. L. Loghry, A. H. Kibbey, H. W. Godbee, A. S. Icenhour, and S. M. DePaoli, *Low-Level Radioactive Waste Source Terms for the 1992 Integrated Data Base*, ORNL/TM-11710, Oak Ridge National Laboratory, Oak Ridge, Tennessee (January 1995).

3. G. W. Roles, *Characteristics of Low-Level Radioactive Waste Disposed During 1987 Through 1989*, NUREG-1418, U.S. Nuclear Regulatory Commission, Washington, D.C. (December 1990).

4. U.S. Department of Energy, *Recommendations for Management of Greater-than-Class-C Low-Level Radioactive Waste*, DOE/NE-0077, Washington, D.C. (February 1987).

5. O. I. Oztunali, W. D. Pon, R. Eng, and G. W. Roles, *Update of Part 61 Impacts Analysis Methodology*, Vol. 2, NUREG/CR-4370, U.S. Nuclear Regulatory Commission, Washington, D.C. (January 1986).

6. Sigmund F. Zakrzewski, *Principles of Environmental Toxicology*, 2d ed., p. 249, American Chemical Society, Washington, D.C. (1997).

7. Josef R. Parrington et al., *Nuclides and Isotopes—Chart of the Nuclides*, 15th ed., Knolls Atomic Power Laboratory, Schenectady, New York (1996).

8. U.S. Department of Energy, Office of Environmental Management, *Linking Legacies—Connecting the Cold War Nuclear Weapons Production Processes to their Environmental Consequences*, DOE/EM-0319 (January 1997).

9. Kenneth G. Picha, DOE Office of Waste Management, Germantown, Maryland, correspondence to W. Dixon, DOE Yucca Mountain Site Characterization Office, Yucca Mountain, Nevada, "Response to Repository Environmental Impact Statement Data Call for SPAR and GTCC," dated Sept. 26, 1997.

Table A.1. Estimated representative unit activity and thermal power characteristics of various types of radioactive materials and wastes

Radioactive material or waste type	Unit activity (Ci/m^3)	Unit thermal power (W/m^3)
Spent nuclear 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 (untreated)	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 nuclear 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 Part 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 determines the lower activity boundary. There is no limit on concentrations of ^{3}H, ^{60}Co, or nuclides with half-lives <5 years.

Table A.2. 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					^{99}Tc	0.12
^{228}Th	0.0045	^{106}Ru	6.39					^{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						
^{235}U	0.0258	^{144}Pr	14.67						
^{238}U	33.197	^{147}Pm	0.06						
		^{151}Sm	0.11						
		^{152}Eu	0.09						
		^{154}Eu	0.09						
		^{155}Eu	0.06						
Total	100.0000		100.00		100.00		100.00		100.00

[a]Based on ref. 1.

Table A.3. Average concentrations for representative radionuclides in LLW at commercial disposal sites[a]

Radionuclide	Half-life[b]	Concentration (Ci/m^3)	Radionuclide	Half-life[b]	Concentration (Ci/m^3)
^{3}H	1.228E+01 y	1.083E+00	^{129}I	1.570E+07 y	2.101E-05
^{14}C	5.730E+03 y	5.079E-03	^{131}I	8.040E+00 d	5.299E-03
^{26}Al	7.300E+05 y	2.980E-10	^{134}Cs	2.062E+00 y	8.661E-02
^{32}Si	1.000E+02 y	3.725E-11	^{135}Cs	3.000E+06 y	1.105E-05
^{32}P	1.428E+01 d	9.292E-04	^{137}Cs	3.017E+01 y	2.431E-01
^{35}S	8.751E+01 d	2.208E-03	^{137m}Ba	2.552E+00 min	2.300E-01
^{36}Cl	3.010E+05 y	6.143E-06	^{141}Ce	3.250E+01 d	1.649E-03
^{40}K	1.280E+09 y	1.766E-07	^{144}Ce	2.849E+02 d	1.463E-02
^{51}Cr	2.770E+01 d	7.137E-02	^{144}Pr	1.728E+01 min	1.463E-02
^{54}Mn	3.122E+02 d	3.895E-01	^{144}Nd	2.100E+15 y	1.689E-10
^{55}Fe	2.730E+00 y	3.112E+00	^{147}Pm	2.623E+00 y	1.317E-02
^{59}Fe	4.445E+01 d	5.081E-03	^{157}Tb	1.100E+02 y	1.012E-10
^{58}Co	7.092E+01 d	2.047E-01	^{158}Tb	1.800E+02 y	3.768E-10
^{60}Co	5.271E+00 y	2.242E+00	^{175}Hf	7.000E+01 d	1.427E-03
^{59}Ni	7.500E+04 y	1.364E-03	^{181}Hf	4.240E+01 d	3.235E-03
^{63}Ni	1.001E+02 y	2.692E-01	^{187}Re	4.100E+10 y	1.772E-11
^{65}Zn	2.441E+02 d	1.174E-01	^{209}Po	3.253E+00 h	1.284E-10
^{85}Kr	1.072E+01 y	8.147E-04	^{226}Ra	1.600E+03 y	2.852E-04
^{89}Sr	5.055E+01 d	6.032E-03	^{229}Th	7.340E+03 y	1.310E-10
^{90}Sr	2.850E+01 y	6.987E-02	^{230}Th	7.540E+04 y	1.721E-08
^{90}Y	2.671E+01 d	6.987E-02	^{232}Th	1.405E+10 y	8.482E-03
^{91}Y	5.851E+01 d	8.859E-03	^{231}Pa	3.276E+04 y	1.016E-10
^{95}Zr	6.402E+01 d	1.036E-02	^{233}U	1.592E+05 y	2.308E-07
^{94}Nb	2.030E+04 y	1.659E-05	^{234}U	2.454E+05 y	5.368E-05
^{95}Nb	3.497E+01 d	1.916E-02	^{235}U	7.037E+08 y	3.179E-05
^{93}Mo	3.500E+03 y	9.273E-12	^{236}U	2.432E+07 y	7.886E-07
^{99}Tc	2.130E+05 y	1.949E-04	^{238}U	4.468E+09 y	9.970E-03
^{103}Ru	3.925E+01 d	5.900E-04	^{237}Np	2.140E+06 y	2.210E-07
^{108m}Ag	1.300E+02 y	5.534E-06	^{239}Pu	2.413E+04 y	1.021E-05[c]
^{110m}Ag	2.498E+02 d	3.600E-02	^{240}Pu	6.563E+03 y	2.504E-06[c]
^{113}Cd	9.000E+15 y	4.223E-12	^{242}Pu	3.763E+05 y	6.148E-07[c]
^{124}Sb	6.020E+00 d	2.621E-03	^{241}Am	4.322E+02 y	4.053E-05
^{125}Sb	2.730E+00 y	1.901E-02	^{243}Am	7.380E+03 y	1.398E-08
^{123}Te	1.300E+13 y	5.710E-07	^{248}Cm	3.400E+05 y	6.220E-07
^{125}I	6.014E+00 d	4.570E-04			
				Total	8.380E+00

[a]Adapted from ref. 3.

[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 A.4. Estimated sources and characteristics of commercial Greater-Than-Class-C LLW[a]

Waste source	Physical form	Primary isotopes of concern for disposal
Utilities		
Reactor operations	Activated metals, instruments, filters, ion-exchange resins, sludges	^{59}Ni, ^{63}Ni, ^{94}Nb, and TRU isotopes
Reactor 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. 4 and 5.

Table A.5. Major characteristics of the radionuclides that comprise the natural decay series for ^{232}Th, ^{235}U, and ^{238}U[a]

Natural ^{232}Th decay series			Natural ^{235}U decay series			Natural ^{238}U decay series		
Nuclide	Half-life[b]	Principle mode of decay[c]	Nuclide	Half-life[b]	Principle mode of decay[c]	Nuclide	Half-life[b]	Principle mode of decay[c]
^{232}Th	1.4E+10 y	α	^{235}U	7.0E+08 y	α	^{238}U	4.5E+09 y	α
^{228}Ra	5.75 y	β	^{231}Th	1.06 d	β	^{234}Th	24.10 d	β
^{228}Ac	6.13 h	β	^{231}Pa	3.3E+04 y	α	^{234}Pa	1.17 min	β
^{228}Th	1.913 y	α	^{227}Ac	2.2E+01 y	α (1.4 %) β (98.6 %)	^{234}U	2.5E+05 y	α
^{224}Ra	3.66 d	α	^{227}Th	18.7 d	α	^{230}Th	7.5E+04 y	α
^{220}Rn	55.6 s	α	^{223}Fr	21.8 min	β	^{226}Ra	1.6E+03 y	α
^{216}Po	1.5E-02 s	α	^{223}Ra	11.43 d	α	^{222}Rn	3.285 d	α
^{212}Pb	10.64 h	β	^{219}At	56 s	α	^{218}Po	3.1 min	α
^{212}Bi	1.01 h	α (36%) β (64%)	^{219}Rn	3.96 s	α	^{218}At	1.5 s	α
^{212}Po	3.0E-07 s	α	^{215}Bi	7.6 min	β	^{214}Pb	27 min	β
^{208}Tl	3.053 min	β	^{215}Po	1.8E-03 s	α	^{214}Bi	19.9 min	β
^{208}Pb	(stable)	(stable)	^{215}At	1.0E-07 s	α	^{214}Po	1.6E-04 s	α
			^{211}Pb	36.1 min	β	^{210}Tl	1.30 min	β
			^{211}Po	25.2 s	α	^{210}Pb	22.6 y	β
			^{211}Bi	2.14 min	α	^{210}Bi	5.01 d	β
			^{207}Tl	4.77 min	β	^{210}Po	138.4 d	α
			^{207}Pb	(stable)	(stable)	^{206}Hg	8.2 min	β
						^{206}Tl	4.20 min	β
						^{206}Pb	(stable)	(stable)

[a]Adapted from refs. 6 and 7. Other characteristics for these radionuclides are described in Appendix B.

[b]y—years; d–days; h—hours; min—minutes; and s—seconds.

[c]α—alpha decay; β—negative beta decay; EC—electron capture; and IT—isomeric transition (radioactive transition from one nuclear isomer to another of lower energy).

Table A.6. Current volume inventories of DOE site SCW (SPAR)[a]

Site/category	Volume (m^3)	Radioactivity (Ci)	Mass (kg)
Hanford	148.0	9.7×10^7	3.6×10^5
INEEL[b]	55.5	5.4×10^6	1.4×10^5
ORNL			
Activated metal[c]	1,651.6	2.5×10^4	3.9×10^4
Beryllium reflectors	26.4	3.8×10^6	2.0×10^4
Reactor control plates and source materials	184.8	1.0×10^4	4.4×10^4
Solid beta-gamma waste	536.2	d	1.3×10^6
ORNL total	2,399.0	$>3.8 \times 10^6$	1.4×10^6
WVDP	d	d	d
NR Sites[e]	1,017.5	d	2.5×10^6
Grand total	3,620.0	$>8.3 \times 10^8$	3.4×10^7

[a]Based on ref. 9. SPAR = special performance assessment required.
[b]Includes contributions from ANL–W.
[c]Activated metals from four reactors: High Flux Isotope Reactor (HFIR), Oak Ridge Research Reactor (ORRR), Bulk Shielding Reactor (BSR), and Molten Salt Reactor Experiment (MSRE).
[d]Unknown.
[e]DOE Naval Reactors Program (NE-60) sites.

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, TRUW, LLW, and UMT 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 Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," *Code of Federal Regulations*, 40 CFR Part 191 (July 1, 1997).

2. U.S. Nuclear Regulatory Commission, "Licensing Requirements for Land Disposal of Radioactive Waste," *Code of Federal Regulations*, 10 CFR Part 61 (Jan. 1, 1997).

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 1992—Viability Assessment*, DOE/EIA-0477(92), Washington, D.C. (December 1993).

6. D. C. Kocher, *Radioactive Decay Data Tables*, DOE/TIC-11026, U.S. Department of Energy, 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*, ed. V. S. Shirley, John Wiley and Sons, Inc., New York (1986).

9. 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).

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	∈	γ and 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	4.457E+00	^{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

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 and X	(MeV/dis)	(W/Ci)		
^{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
^{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	1.10E+00	^{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

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 and X	(MeV/dis)	(W/Ci)		
^{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
^{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

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 and X	(MeV/dis)	(W/Ci)		
^{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	0.0248	8.04E-02	4.77E-04	1.765E-04	^{129}Xe
^{131}I	53	8.040 d	β		0.1913	0.3826	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-01	3.94E-03	5.379E+08	^{137}Ba
^{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

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 and X	(MeV/dis)	(W/Ci)		
^{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
^{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
^{210}Pb	82	2.232E+01 y	β		0.0343		3.43E-02	2.029E-04	7.630E+01	^{210}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	4.184E+08	^{207}Tl; ^{211}Po

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 and X	(MeV/dis)	(W/Ci)		
^{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
^{210}Po	84	138.4 d	α	5.3044			5.304	3.144E-02	4.493E+03	^{206}Pb
^{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	7.0657		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	0.0067	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	8.038E-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 (Ci/g)	Daughter(s)
				α	ϵ	γ and X	(MeV/dis)	(W/Ci)		
^{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	5.3065		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	6.248E-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	0.0108	0.0015	4.492	2.662E-02	6.469E-05	^{232}Th
^{238}U	92	4.468E+09 y	α	4.1945	0.0095	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	8.26E+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	3.432E+00	^{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

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 and X	(MeV/dis)	(W/Ci)		
^{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	9.718E+00	^{242}Am; ^{238}Np
^{243}Am	95	7.380E+03 y	α	5.2656		0.0481	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
^{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. 6–9.

[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 and 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 "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. 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 C.1, along with the sites for which they have responsibility. This is followed by Table C.2, which lists DOE Naval Reactors Program (NE-60) offices and sites. Table C.3 lists major DOE sites and facilities referred to in this report, and major commercial radioactive waste disposal sites are given in Table C.4. For each site or facility listed in Tables C.3 and C.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 C.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 Pantex Plant Pinellas Plant Sandia National Laboratories/California Sandia National Laboratories/New Mexico Uranium Mill Tailings Remedial Action Project sites Waste Isolation Pilot Plant
Chicago Operations Office[c]	DOE/CH	Building 201 9800 South Cass Avenue Argonne, IL 60439 (630/252-2001)	Ames Laboratory Argonne National Laboratory–East Argonne National Laboratory–West Brookhaven National Laboratory Fermi National Accelerator Laboratory Princeton Plasma Physics Laboratory
Idaho Operations Office	DOE/ID	850 Energy Drive Idaho Falls, ID 83401-1563 (208/526-0111)	Idaho National Engineering and Environmental Laboratory
Nevada Operations Office	DOE/NV	P.O. Box 98518 Las Vegas, NV 89193-8518 (702/295-1212)	Nevada Test Site
Oakland Operations Office	DOE/OAK	1301 Clay Street Oakland, CA 94612-5208 (510/273-6383)	Energy Technology Engineering Center (Santa Susana Field Laboratory) Laboratory for Energy-Related Health Research (Institute of Toxicology and Environmental Health) Lawrence Berkeley National Laboratory Lawrence Livermore National Laboratory Stanford Linear Accelerator Center

Table C.1 (continued)

DOE office	Symbol/label	General mailing address (Phone number)[a]	Radioactive waste sites for which DOE office has responsibility
Oak Ridge Operations Office[d]	DOE/OR	P.O. Box 2001 Oak Ridge, TN 37831 (423/576-5454)	East Tennessee Technology Park Formerly Utilized Sites Remedial Action Program (FUSRAP) sites Oak Ridge Institute for Science and Education Oak Ridge National Laboratory Oak Ridge Y-12 Plant Paducah Gaseous Diffusion Plant Portsmouth Gaseous Diffusion Plant Weldon Spring Site Remedial Action Project
Ohio Field Office	DOE/OH	P.O. Box 3020 Miamisburg, OH 45343-3020 (513/865-3977)	Battelle Columbus Laboratories Decommissioning Project Fernald Environmental Management Project Mound Plant Reactive Metals, Inc., Extrusion Plant West Valley Demonstration Project
Richland Operations Office	DOE/RL	P.O. Box 550 825 Jadwin Avenue Richland, WA 99352 (509/376-7411)	Hanford Site Pacific Northwest National Laboratory
Rocky Flats Field Office	DOE/RF	P.O. Box 928 Golden, CO 80401-0928 (303/966-7000)	Rocky Flats Environmental Technology Site
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), 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: East Tennessee Technology Park, Oak Ridge National Laboratory, Oak Ridge Y-12 Plant, Paducah Gaseous Diffusion Plant, Portsmouth Gaseous Diffusion Plant, and the Weldon Spring Site Remedial Action Project.

Table C.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 Hwy Arlington, VA 22202 (703/603-7321)	Oversees Pittsburgh and Schenectady area offices and their sites; oversees the following shipyards: • Charleston Naval Shipyard, Charleston, SC • Mare Island Naval Shipyard, Mare Island, CA • Norfolk Naval Shipyard, Norfolk, VA • Pearl Harbor Naval Shipyard, Pearl Harbor, HI • Portsmouth Naval Shipyard, Portsmouth, ME • Puget Sound Naval Shipyard, Puget Sound, WA
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[b]

[a]Access to main organizations.

[b]Comprised of three separate sites: Schenectady, New York (KAPL); Kesselring, New York (KESS); and Windsor, Connecticut (KWIN). In this report, the abbreviation KAPL is used to refer in general to Knolls Atomic Power Laboratory.

Table C.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/field office (Phone number)[a]
Ames Laboratory	Ames	Iowa State University Technical Administration Services Facility Ames, IA 50011-3020 (515/294-2680)	Chicago (630/252-2001)
Argonne National Laboratory–East	ANL–E	University of Chicago 9700 South Cass Avenue Argonne, IL 60439 (630/252-2000)	Chicago Argonne Area Office (630/252-2001)
Argonne National Laboratory–West[b]	ANL–W	University of Chicago Idaho Site P.O. Box 2528 Idaho Falls, ID 83403-2528 (208/533-7000)	Chicago (630/252-2001)
Battelle Columbus Laboratories Decommissioning Project	BCLDP	Battelle Memorial Institute 505 King Avenue Columbus, OH 43201-2693 (614/424-3989)	Ohio Field Office (513/865-3977)
Brookhaven National Laboratory	BNL	Associated Universities, Inc. 16 South Railroad Street Upton, NY 11973-2310 (516/344-8000)	Chicago Brookhaven Area Office (516/344-3427)
Colonie Interim Storage Site	CISS	Bechtel National, Inc. P.O. Box 5169 Albany, NY 12205 (518/482-0237)	Oak Ridge (423/576-5454)
East Tennessee Technology Park[c]	ETTP	Lockheed Martin Energy Systems, Inc. P.O. Box 2003 Oak Ridge, TN 37831-7358 (423/576-5454)	Oak Ridge (423/576-5454)

Table C.3 (continued)

Site/facility	Symbol/label	Principal contractor(s) for site operations and mailing address (Phone number)[a]	DOE operations/field office (Phone number)[a]
Energy Technology Engineering Center (Santa Susana Field Laboratory)	ETEC (SSFL)	Rockwell International Rocketdyne Division 6633 Canoga Avenue P.O. Box 1449 Canoga Park, CA 91304 (818/586-5326)	Oakland (510/273-6383)
Fermi National Accelerator Laboratory	FNAL	University Research Association P.O. Box 500 Batavia, IL 60510 (630/840-3000)	Chicago Batavia Area Office (630/840-3281)
Fernald Environmental Management Project	FEMP	Fluor Daniel Fernald Environmental Restoration Management Corporation P.O. Box 398704 7400 Wiley Road Cincinnati, OH 45239-8704 (513/738-6200)	Ohio Field Office Fernald Area Office (513/648-3119)
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	Hanford	Fluor Daniel Hanford, Inc. P.O. Box 1970 Richland, WA 99352 (509/376-7411)	Richland (509/376-7411)
Idaho National Engineering and Environmental Laboratory	INEEL	Lockheed Martin Idaho Technologies Co. P.O. Box 1625 Idaho Falls, ID 83415-4201 (208/526-0111)	Idaho (208/526-0111)

Table C.3 (continued)

Site/facility	Symbol/label	Principal contractor(s) for site operations and mailing address (Phone number)[a]	DOE operations/field office (Phone number)[a]
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)
Laboratory for Energy-Related Health Research (Institute of Toxicology and Environmental Health)	LEHR (ITEH)	University of California–Davis Old Davis Road Davis, CA 95616-8615 (916/752-1340)	Oakland (510/273-6383)
Lawrence Berkeley National Laboratory	LBNL	University of California One Cyclotron Road Berkeley, CA 94720 (510/486-4000)	Oakland 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)	Oakland (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)

Table C.3 (continued)

Site/facility	Symbol/label	Principal contractor(s) for site operations and mailing address (Phone number)[a]	DOE operations/field office (Phone number)[a]
Mound Plant	Mound	EG&G Mound Applied Technologies P.O. Box 3000 Miamisburg, OH 45343-3000 (513/865-4020)	Ohio Field Office Miamisburg 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	Lockheed Martin Services Group 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 (INEEL)	NRF	Lockheed Martin Idaho Technologies 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)
Nevada Test Site	NTS	Bechtel Nevada Corporation 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 (423/576-3000)	Oak Ridge (423/576-5454)

Table C.3 (continued)

Site/facility	Symbol/label	Principal contractor(s) for site operations and mailing address (Phone number)[a]	DOE operations/field office (Phone number)[a]
Oak Ridge National Laboratory	ORNL	Lockheed Martin Energy Research Corporation P.O. Box 2008 Oak Ridge, TN 37831-6235 (423/576-5454)	Oak Ridge (423/576-5454)
Oak Ridge Y-12 Plant	Y-12	Lockheed Martin Energy Systems, Inc. P.O. Box 2009 Oak Ridge, TN 37831-8010 (423/576-5454)	Oak Ridge (423/576-5454)
Pacific Northwest National Laboratory[d]	PNNL	Battelle Memorial Institute Battelle Boulevard P.O. Box 999 Richland, WA 99352 (509/375-2121)	Richland (509/376-7411)
Paducah Gaseous Diffusion Plant	PAD	Lockheed Martin Utility 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	Lockheed Martin Specialty Components, Inc. P.O. Box 2908 Largo, FL 34649-2908 (813/541-8001)	Albuquerque Pinellas Area Office (813/541-8196)

Table C.3 (continued)

Site/facility	Symbol/label	Principal contractor(s) for site operations and mailing address (Phone number)[a]	DOE operations/field office (Phone number)[a]
Portsmouth Gaseous Diffusion Plant	PORTS	Lockheed Martin Utility 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)	Ohio Field Office RMI Decommissioning Project Office (216/992-7442)
Rocky Flats Environmental Technology Site	RFETS	Kaiser-Hill, Inc. P.O. Box 464 Golden, CO 80401-0464 (303/966-7000)	Rocky Flats Field Office (303/966-7000)
Sandia National Laboratories California site	SNL/CA	Lockheed Martin Sandia Corporation P.O. Box 969 Livermore, CA 94551-0969 (510/294-3000)	Albuquerque (505/845-4154)
New Mexico site	SNL/NM	Lockheed Martin Sandia Corporation P.O. Box 5800 Albuquerque, NM 87185-5800 (505/844-5678)	Albuquerque (505/845-4154)
Savannah River Site	SRS	Westinghouse Savannah River Company P.O. Box 616 Aiken, SC 29802 (803/725-6211)	Savannah River (803/725-6211)

Table C.3 (continued)

Site/facility	Symbol/label	Principal contractor(s) for site operations and mailing address (Phone number)[a]	DOE operations/field office (Phone number)[a]
Stanford Linear Accelerator Center	SLAC	Stanford University P.O. Box 4349 Palo Alto, CA 94309 (415/926-3300)	Oakland 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)
Waste Isolation Pilot Plant	WIPP	Westinghouse Electric Corporation WIPP Project Office P.O. Box 2078 Carlsbad, NM 88221 (505/885-7500)	Albuquerque Carlsbad Area Office (505/234-7327)
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. 10282 Rock Springs Road P.O. Box 191 West Valley, NY 14171-0191 (716/942-3235)	Ohio Field Office West Valley Area Office (716/942-4313)

[a]Phone number for access to main organization.
[b]Part of the Idaho National Engineering and Environmental Laboratory Reservation.
[c]Previously called the Oak Ridge K-25 Site.
[d]Part of the Hanford Site.

Table C.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. 10282 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.

GLOSSARY OF TERMS

This glossary gives definitions of some terms commonly used in the main body of this report.

Actinides: Elements with atomic numbers from 89 (actinium) or 90 (thorium) to 103 (lawrencium) inclusive.

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 or positive electron) is emitted.

Borosilicate glass: A type of glass containing at least 5 wt % 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 to the process of producing or utilizing special nuclear material. For purposes of determining the applicability of the Resource Conservation and Recovery Act of 1976 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 nonradioactive volatile oxides, thus producing 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.

Capsules: Encapsulated strontium and cesium high-level wastes produced from defense reactor fuel reprocessing at the Hanford Site. For purposes of this report, inventories of encapsulated strontium and cesium

are included in a separate table in the high-level waste section (Chapter 2).

Cladding: A corrosion-resistant tube (commonly aluminum, 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, 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 ft or more 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 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 used 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 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 uranium hexafluoride (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 non-regenerable powered resins.

Fissile nuclide: A nuclide capable of undergoing nuclear fission with thermal 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 nuclear fuel, reenrichment of the fuel material, and/or 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 concentrations of radionuclides 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 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 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.

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-oxide fuel: Nuclear reactor fuel composed of plutonium and uranium in oxide form.

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 nuclear 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 materials: Radioactive materials that are considered either naturally occurring and are not source, special nuclear, or by-product material or are 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 used in the reprocessing of uranium/plutonium-based nuclear fuels.

Radioactivity: The property possessed by certain nuclides of spontaneously emitting alpha or beta particles and, sometimes, gamma radiation by the disintegration of atomic nuclei. The units for the rate of decay of radioactive nuclides are the curie, Ci (3.7×10^{10} disintegrations per second exactly), or, in SI units, the becquerel, Bq (1 disintegration per second).

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 and 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 U.S. Navy vessel.

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 nuclear 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 that contain 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 by exploiting the relative chelating ability of different chemicals which preferentially dissolve in one of the two phases. In spent nuclear fuel reprocessing, liquid-liquid contact of two immiscible solvents (one aqueous, one organic) permits recovery and separation of uranium and plutonium in one phase and fission products in the other phase.

Source material: (1) material containing any combination of uranium or thorium in any physical or chemical form, or (2) ores containing 0.05 wt % or more of uranium, thorium, or both. Source material excludes special nuclear material (see below).

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 case waste: Radioactive waste that is currently stored throughout the DOE complex for which a management strategy beyond indefinite storage does not currently exist.

Special nuclear material: Plutonium or fissile uranium (i.e., ^{233}U, ^{235}U) enriched to a higher-than-natural assay.

Spent nuclear fuel: Nuclear fuel that has been permanently discharged from a reactor after it has been irradiated. Typically, spent nuclear 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 nuclear 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.

Standard Contract: A contract between DOE and each commercial owner or generator of irradiated nuclear fuel. As indicated in 10 CFR Part 961, the contract specifies the terms and methods of payment, how fees are to be calculated, and how spent nuclear fuel is to be transferred to DOE custody.

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 to reprocess 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 requirements/criteria that must be satisfied prior to transport to and emplacement in the Waste Isolation Pilot Plant for disposal.

Transuranic waste certification: The process for verifying that waste meets the applicable requirements/criteria for transport to and emplacement in a repository for disposal.

Transuranic waste, contact-handled: Transuranic waste with a surface dose rate of less than 200 mrem/h.

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.

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 defense-related activities.

Yellowcake: A uranium oxide concentrate that results from milling (concentrating) uranium ore. It typically contains 80 to 90 wt % U_3O_8.

DISTRIBUTION

DOE Headquarters

Energy Information Administration, Office of Coal, Nuclear, Electric, and Alternate Fuels, Route Symbol EI-53, 950 L'Enfant Plaza, S.W., Washington, DC 20024

Office of Civilian Radioactive Waste Management, Waste Acceptance Division, Route Symbol RW-44, 1000 Independence Ave., S.W., Washington, DC 20585-0001

Office of Environment, Safety, and Health, Route Symbol EH-20, 1000 Independence Ave., S.W., Washington, DC 20585-0001

Office of Environmental Management, Office of Waste Management, Office of Planning and Analysis, Route Symbol EM-35, Trevion II, 19901 Germantown Road, Germantown, MD 20874-1290

Office of Environmental Management, Office of Environmental Restoration, Office of Program Integration, Route Symbol EM-43, Cloverleaf Building, 20400 Century Blvd., Germantown, MD 20874

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DOE Operations and Field Offices

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DOE Brookhaven Area Office, 53 Bell Ave., Upton, NY 11973-2311

DOE Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831

Fermi National Accelerator Laboratory:
DOE Batavia Area Office, P.O. Box 2000, Batavia, IL 60510

University Research Association, P.O. Box 500, Batavia, IL 60510

Fernald Environmental Management Project:
DOE Fernald Area Office, P.O. Box 398705, 7400 Wiley Road, Cincinnati, OH 45239-8705

Fluor Daniel, Fernald Environmental Restoration Management Corporation, P.O. Box 398704, 7400 Wiley Road, Cincinnati, OH 45239-8704

Formerly Utilized Sites Remedial Action Program:
Bechtel National, Inc., 151 Lafayette Drive, P.O. Box 350, Oak Ridge, TN 37831-0350

DOE Oak Ridge Operations Office, P.O. Box 2001, Oak Ridge, TN 37831-8723

Grand Junction Remedial Action Project:
Department of Energy, Grand Junction Projects Office, P.O. Box 2567, Grand Junction, CO 81502

Hanford Site, Fluor Daniel Hanford, Inc., P.O. Box 1970, Richland, WA 99352

Hazardous Waste Remedial Actions Program, Tri-County Mall, P.O. Box 2003, Oak Ridge, TN 37831-7606

Idaho National Engineering and Environmental Laboratory:
Argonne National Laboratory–West, P.O. Box 2528, Idaho Falls, ID 83401-2528

Idaho Chemical Processing Plant, Lockheed Martin Idaho Technologies Company, P.O. Box 4000, Idaho Falls, ID 83404

Lockheed Martin Idaho Technologies Company, P.O. Box 1625, Idaho Falls, ID 83415-4201

Naval Reactors Facility, P.O. Box 2068, Idaho Falls, ID 83403-2068

Inhalation Toxicology Research Institute:
DOE Kirtland Area Office, P.O. Box 5890, Kirtland Air Force Base, Albuquerque, NM 87185

Lovelace Biomedical and Environmental Research Institute, Inc., P.O. Box 5890, Albuquerque, NM 87185

Kansas City Plant:
Allied-Signal Inc., Kansas City Division, Bannister Federal Complex, Kansas City, MO 64141

DOE Kansas City Area Office, P.O. Box 410202, Kansas City, MO 64141-0202

Lawrence Berkeley National Laboratory, University of California, One Cyclotron Road, Berkeley, CA 94720

Lawrence Livermore National Laboratory, P.O. Box 808, L-1, 7000 East Ave., Livermore, CA 94550

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DOE Los Alamos Area Office, 528 35th Street, Los Alamos, NM 87544

University of California, P.O. Box 1663, Los Alamos, NM 87545

Mound Plant:
DOE Miamisburg Area Office, P.O. Box 66, Miamisburg, OH 45343-0066

EG&G Mound Applied Technologies, Inc., P.O. Box 3000, Miamisburg, OH 45343-3000

Naval Reactors Program (DOE/HQ, NE-60) Facilities:
Bettis Atomic Power Laboratory, Westinghouse Electric Corporation, P.O. Box 79, West Mifflin, PA 15122-0079

DOE Pittsburgh Naval Reactors Office, P.O. Box 109, West Mifflin, PA 15122-0109

DOE Schenectady Naval Reactors Office, P.O. Box 1069, Schenectady, NY 12301-1069

Knolls Atomic Power Laboratory, General Electric Company, P.O. Box 1072, Schenectady, NY 12301-1072

Naval Reactors Facility (see Idaho National Engineering Laboratory)

Nevada Test Site:
Bechtel Nevada Corporation, P.O. Box 98521, Mail Stop 738, Las Vegas, NV 89193-8521

Oak Ridge Reservation:
East Tennessee Technology Park, Lockheed Martin Energy Systems, P.O. Box 2003, Oak Ridge, TN 37831-7358

Oak Ridge Institute of Science and Education, Oak Ridge Associated Universities, 246 Laboratory Road, P.O. Box 117, Oak Ridge, TN 37831-0117

Oak Ridge National Laboratory, Lockheed Martin Energy Research Corporation, P.O. Box 2008, Oak Ridge, TN 37831-6235

Oak Ridge Y-12 Plant, Lockheed Martin Energy Systems, P.O. Box 2009, Oak Ridge, TN 37831-8010

Pacific Northwest National Laboratory, Battelle Memorial Institute, Battelle Boulevard, P.O. Box 999, Richland, WA 99352

Paducah Gaseous Diffusion Plant, Lockheed Martin Utility Systems, P.O. Box 1410, Paducah, KY 42001

Pantex Plant:
DOE Amarillo Area Office, P.O. Box 30030, Amarillo, TX 79120-0030

Mason and Hanger—Silas Mason Co., P.O. Box 30020, Amarillo, TX 79177

Pinellas Plant:
DOE Pinellas Area Office, P.O. Box 2900, Largo, FL 34649

Lockheed Martin Specialty Components, P.O. Box 2908, Largo, FL 34649-2908

Portsmouth Gaseous Diffusion Plant, Lockheed Martin Utility Systems, P.O. Box 628, Piketon, OH 45661

Princeton Plasma Physics Laboratory, Princeton University, P.O. Box 451, Princeton, NJ 08543

Reactive Materials Incorporated (RMI) Extrusion Plant, P.O. Box 579, Ashtabula, OH 44004

Rocky Flats Environmental Technology Site:
DOE Rocky Flats Office, P.O. Box 928, Golden, CO 80401-0928

Kaiser-Hill, Inc., P.O. Box 464, Golden, CO 80401-0464

Sandia National Laboratories/California, Lockheed Martin Sandia Corporation, P.O. Box 969, Livermore, CA 94551-0969

Sandia National Laboratories/New Mexico, Lockheed Martin Sandia Corporation, P.O. Box 5800, Albuquerque, NM 87185-5800

Savannah River Site, Westinghouse Savannah River Company, P.O. Box 616, Aiken, SC 29802

Stanford Linear Accelerator Center, P.O. Box 4349, Palo Alto, CA 94309

Uranium Mill Tailings Remedial Action Project (UMTRAP):
DOE Albuquerque Operations Office, UMTRA Project Office, P.O. Box 5400, Albuquerque, NM 87115

Jacobs Engineering Group, Inc., Suite 1700, 5301 Central Ave., NE, Albuquerque, NM 87108

Waste Isolation Pilot Plant:
Department of Energy, Waste Isolation Pilot Plant Project Office, P.O. Box 3090, Carlsbad, NM 88221

Westinghouse Electric Corporation, Waste Isolation Pilot Plant Project Office, P.O. Box 2078, Carlsbad, NM 88221

West Valley Demonstration Project:
DOE West Valley Area Office, 10282 Rock Springs Road, P.O. Box 191, West Valley, NY 14171-0191

West Valley Nuclear Services Company, Inc., 10282 Rock Springs Road, P.O. Box 191, West Valley, NY 14171-0191

Federal (non-DOE) Agencies

Congressional General Accounting Office, P.O. Box 321, Richland, WA 99352

Congressional Office of Technology Assessment, 600 Pennsylvania Ave., S.E., Washington, DC 20510-8025

Environmental Protection Agency, 401 M St., S.W., Washington, DC 20460

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