DOE/RW-0006, Rev. 8

Integrated Data Base for 1992: U.S. Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics

October 1992

Prepared by:

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

Prepared for:

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

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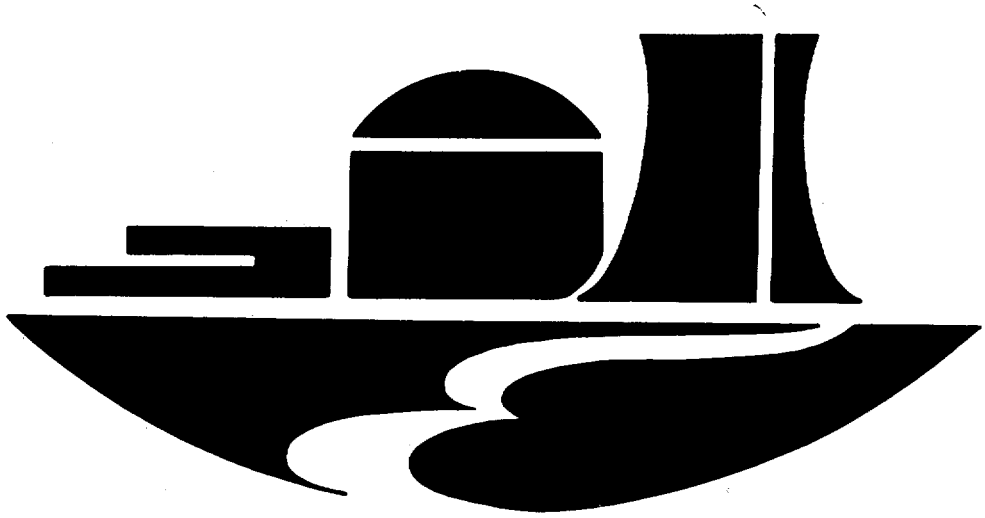

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PREFACE

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

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

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

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GLOSSARY OF ABBREVIATIONS AND ACRONYMS

AEA	Atomic Energy Act of 1954
AEC	Atomic Energy Commission
AMES	Ames Laboratory; Ames, Iowa
ANL-E	Argonne National Laboratory-East; Argonne, Illinois
ANL-W	Argonne National Laboratory-West; INEL, Idaho
ATL 1	Atlantic Site 1 (38'31'N, 72'06'W)
ATL 2	Atlantic Site 2 (37'50'N, 70'35'W)
BAPL	Bettis Atomic Power Laboratory; West Mifflin, Pennsylvania
BARN	Barnwell, South Carolina (commercial waste site)
BCL	Battelle Columbus Laboratories; Columbus, Ohio
BCLDP	Battelle Columbus Laboratories Decommissioning Project; Columbus, Ohio
BDM	BDM International, Inc.
BETY	Beatty, Nevada (commercial waste site)
BNI	Bechtel National, Inc.; Oak Ridge, Tennessee
BNL	Brookhaven National Laboratory; Brookhaven, New York
BWR	Boiling-water reactor
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act (of 1980)
CFC	Chlorinated fluorocarbon
CH	Contact-handled (TRU waste)
CISS	Colonie Interim Storage Site; Colonie, New York
CRWMS-M&O	Civilian Radioactive Waste Management System - Management and Operating (contractor)
CY	Calendar year
DOD	Department of Defense
DOE	Department of Energy
DOE/AL	DOE Field Office, Albuquerque; Albuquerque, New Mexico
DOE/CH	DOE Field Office, Chicago; Argonne, Illinois
DOE/DP	DOE/Office of Defense Programs (Headquarters); Germantown, Maryland
DOE/EIA	DOE/Energy Information Administration; Washington, D.C.
DOE/EM	DOE/Office of Environmental Restoration and Waste Management (Headquarters); Germantown, Maryland
DOE/HQ	DOE Headquarters; Washington, D.C. and Germantown, Maryland
DOE/ID	DOE Field Office, Idaho; Idaho Falls, Idaho
DOE/NV	DOE Field Office, Nevada; Las Vegas, Nevada
DOE/OR	DOE Field Office, Oak Ridge; Oak Ridge, Tennessee
DOE/OSTI	DOE/Office of Scientific and Technical Information; Oak Ridge, Tennessee
DOE/RL	DOE Field Office, Richland; Richland, Washington
DOE/RW	DOE/Office of Civilian Radioactive Waste Management (Headquarters); Washington, D.C.
DOE/SAN	DOE Field Office, San Francisco; Oakland, California
DOE/SR	DOE Field Office, Savannah River; Aiken, South Carolina
DOE/WIPP	DOE/WIPP Project Office; Carlsbad, New Mexico
DOE/WVP	DOE/West Valley Project Office; West Valley, New York
DOT	Department of Transportation

DWMP	Defense Waste Management Plan
DWPF	Defense Waste Processing Facility
D&D	Decontamination and decommissioning
EA	Environmental assessment
EG&G/ID	EG&G Idaho, Inc.; Idaho Falls, Idaho
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ER	Environmental restoration
ETEC	Energy Technology Engineering Center; Canoga Park, California [also referred to as the Santa Susana Field Laboratory (SSFL)]
FEMP	Fernald Environmental Management Project; Fernald, Ohio
FFTF	Fast Flux Test Facility; Hanford, Washington
FIS	Farallon Islands (Pacific Ocean off Central California)
FNAL	Fermi National Accelerator Laboratory; Batavia, Illinois
FSVR	Fort St. Vrain Reactor; Platteville, Colorado
FUSRAP	Formerly Utilized Sites Remedial Action Program
FY	Fiscal year
GA	General Atomics; San Diego, California
GDP	Gaseous diffusion plant
GEVNC	General Electric Vallecitos Nuclear Center; Vallecitos, California
GJPO	(DOE) Grand Junction Projects Office; Grand Junction, Colorado
GJRAP	Grand Junction Remedial Action Project
GPU	General Public Utilities Corporation; Parsippany, New Jersey
GTCC	Greater-than-Class-C (low-level waste)
HANF	Hanford Site; Richland, Washington
HAZWRAP	Hazardous Waste Remedial Actions Program
HEN	Cape Henry (Atlantic Ocean off Virginia)
HLW	High-level waste
HTGR	High-temperature, gas-cooled reactor
HWVP	Hanford Waste Vitrification Plant; Hanford Site
ICPP	Idaho Chemical Processing Plant; Idaho National Engineering Laboratory
IDB	Integrated Data Base (Program)
I/I	Industrial and institutional (waste)
INEL	Idaho National Engineering Laboratory; Idaho Falls, Idaho
ITRI	Inhalation Toxicology Research Institute, Kirtland Air Force Base; Albuquerque, New Mexico
JAI	(E.R.) Johnson Associates, Inc.
JIO	Joint Integration Office; Albuquerque, New Mexico
K-25	K-25 Site; Oak Ridge, Tennessee (formerly called the Oak Ridge Gaseous Diffusion Plant)
KAPL	Knolls Atomic Power Laboratory; Schenectady, New York
KCP	Kansas City Plant; Kansas City, Missouri
LANL	Los Alamos National Laboratory; Los Alamos, New Mexico
LBL	Lawrence Berkeley Laboratory; Berkeley, California
LGR	Light-water cooled, graphite-moderated reactor
LLNL	Lawrence Livermore National Laboratory; Livermore, California
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

LSA	Low specific activity
LTC	Lynchburg Technology Center; Lynchburg, Virginia
LWR	Light-water reactor
LWBR	Light-water breeder reactor
MASS	Massachusetts Bay
MED	Manhattan Engineer District (Manhattan Project)
MFKY	Maxey Flats, Kentucky (commercial waste site)
MFRP	Midwest Fuel Recovery Plant; Morris, Illinois (commercial spent fuel storage site)
MIMS	Manifest Information Management System
MMES	Martin Marietta Energy Systems, Inc.
MOUND	Mound Plant; Miamisburg, Ohio
MRM	Miscellaneous radioactive material
MTIHM	Metric tons initial heavy metal
MTU	Metric tons uranium
MW	Mixed waste
NA	Not applicable
NARM	Nuclear accelerator-generated radioactive material
NEPA	National Environmental Policy Act of 1969
NFS	Nuclear Fuel Services; Erwin, Tennessee
NORM	Naturally occurring radioactive material
NPL	National priorities list
NR	Naval reactor
NRC	Nuclear Regulatory Commission
NRF	Naval Reactor Facility; INEL, Idaho
NTIS	National Technical Information Service; Springfield, Virginia
NTS	Nevada Test Site; Mercury, Nevada
NUS	NUS Corporation; Gaithersburg, Maryland
NYSERDA	New York State Energy Research and Development Authority; Albany, New York
OR	Oak Ridge complex: ORNL, K-25 Site, and Y-12 Plant; Oak Ridge, Tennessee
ORAU	Oak Ridge Associated Universities
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
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
PNL	Pacific Northwest Laboratory; Richland, Washington
PNRO	DOE Pittsburgh Naval Reactor 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
RCRA	Resource Conservation and Recovery Act of 1976
REECO	Reynolds Electrical and Engineering Co., Inc.; Mercury, Nevada
RFP	Rocky Flats Plant; Golden, Colorado
RH	Remote-handled (TRU waste)
RI	Rockwell International Corporation; Pittsburgh, Pennsylvania

RICH	Richland, Washington (commercial waste site)
RMI	Reactive Metals, Incorporated Titanium Company Extrusion Plant; Astabula, Ohio
SCB	Santa Cruz Basin (Pacific Ocean off Santa Cruz, California)
SDG	San Diego (Pacific Ocean off San Diego, California)
SEG	Scientific Ecology Group, Inc.; Oak Ridge, Tennessee
SF	Spent fuel
SFMP	Surplus Facilities Management Program
SHEF	Sheffield, Illinois (commercial waste site)
SLAC	Stanford Linear Accelerator Center; Palo Alto, California
SNLA	Sandia National Laboratory; Albuquerque, New Mexico
SNLL	Sandia National Laboratory; Livermore, California
SNM	Special nuclear material
SRS	Savannah River Site; Aiken, South Carolina
SSFL	Santa Susana Field Laboratory; Canoga Park, California [also referred to as the Energy Technology Engineering Center (ETEC)]
SWIMS	Solid Waste Information Management System
SWU	Separative work unit
TBD	To be determined
TCLP	Toxicity characteristic leaching procedure
TESS	TRW Environmental Safety Systems, Inc.
THOREX	Thorium extraction
TMI	Three Mile Island reactor site; Middletown, Pennsylvania
TRIGA	Training Reactor, Isotopes, General Atomic
TRU	Transuranic
TSCA	Toxic Substances Control Act of 1976
T/S/D	Treatment, storage, and disposal
TVA	Tennessee Valley Authority; Knoxville, Tennessee
UMTRAP	Uranium Mill Tailings Remedial Action Program
WEC	Westinghouse Electric Corporation; Pittsburgh, Pennsylvania
WHC	Westinghouse Hanford Company; Richland, Washington
WHPP	(TRU) Waste Handling and Packaging Plant; Oak Ridge National Laboratory
WIPP	Waste Isolation Pilot Plant; Carlsbad, New Mexico
WMIS	Waste Management Information System
WPIO	Waste Isolation Pilot Plant Project Integration Office; Albuquerque, New Mexico
WSSRAP	Weldon Spring Site Remedial Action Project; Weldon Spring, Missouri
WVDP	West Valley Demonstration Project; West Valley, New York
WVNS	West Valley Nuclear Services Company, Inc.; West Valley, New York
WVNY	West Valley, New York (commercial waste site from 1963–1981)
W/WIPP	Westinghouse/WIPP Project; Carlsbad, New Mexico
Y-12	Y-12 Plant; Oak Ridge, Tennessee

INTEGRATED DATA BASE FOR 1992: U.S. SPENT FUEL AND RADIOACTIVE WASTE INVENTORIES, PROJECTIONS, AND CHARACTERISTICS

ABSTRACT

The Integrated Data Base (IDB) Program has compiled current data on inventories and characteristics of commercial spent fuel and both commercial and U.S. government-owned radioactive wastes through December 31, 1991. These data are based on the most reliable information available from government sources, the open literature, technical reports, and direct contacts. The information forecasted is consistent with the latest U.S. Department of Energy/Energy Information Administration (DOE/EIA) projections of U.S. commercial nuclear power growth and the expected DOE-related and private industrial and institutional (I/I) activities.

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

0. OVERVIEW

0.1 INTRODUCTION

This report is an update of the previous document[1] on radioactive waste inventories and projections that was prepared for use in the planning and analysis of waste management functions. Historical waste inventories compiled as of December 31, 1991, are reported. Projections of future wastes are generally reported through calendar year 2030. Such projections may change in future revisions of this report as waste minimization, environmental restoration, and decontamination and decommissioning (D&D) programs and activities at various government and commercial sites are defined and become operative.

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 establishing and maintaining files of pertinent data on current and projected inventories and characteristics of permanently discharged domestic spent nuclear fuel and radioactive wastes.

Radioactive waste originates from five major sources: (1) the commercial nuclear fuel cycle; (2) DOE-related activities; (3) institutions such as hospitals, universities, and research foundations; (4) industrial uses of radioisotopes; and (5) mining and milling of uranium ore. The waste is broadly categorized as high-level waste (HLW), transuranic (TRU) waste, low-level waste (LLW), and uranium mill tailings. Large quantities of radioactive waste will also result from future activities such as DOE environmental restoration activities and the D&D of DOE and commercial nuclear facilities.

The primary purpose of this document is to report U.S. spent fuel and radioactive waste inventories,

projections, and characteristics. The data presented were obtained through the cooperation and assistance of the offices and programs that were established by the U.S. Department of Energy (DOE) to oversee the management of the various radioactive wastes and spent fuels. In addition, the recent literature was reviewed to aid in selecting the data that are presented here and to help establish a basis for many of the calculated radioactivity levels and heat generation rates that are included. In this report, spent fuel and radioactive wastes are characterized from the standpoint of their volumes (or masses) and their nuclear, physical, and chemical properties. The data reported are selected from more extensive information that 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 field offices, waste sites, or relevant documents previously issued, some of which may be referenced in this report.

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

The DOE waste data contained in this report are furnished by DOE contractor sites through annual data calls. The DOE site data (waste inventories, projections, and characteristics) are used by DOE Headquarters, field 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. Most waste data are received from DOE contractors through DOE field offices. DOE Headquarters assigns to selected organizations major responsibilities for providing information on particular topics involving spent fuel and radioactive waste management. Table 0.1 lists the technical areas and major sources of raw data input required by the IDB Program for this annual report. Further detailed information is generally available from data bases maintained at the specific DOE and commercial sites. A list of reference sites and facilities referred to in this report is provided in Appendix D.

0.2 CHARACTERIZATION OF WASTE FORMS

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

- **Spent Fuel**

  Spent fuel consists of irradiated fuel discharged from a nuclear reactor. Unless otherwise identified, all spent fuels discussed in this report are assumed to be permanently discharged and eligible for repository disposal. Three categories of permanently discharged spent fuel are considered: (1) fuel from commercial light-water reactors (LWRs); (2) fuel from non-LWR commercial reactors [e.g., the Fort St. Vrain high-temperature, gas-cooled reactor (HTGR)]; and (3) special fuels associated with government-sponsored research and demonstration programs, universities, and private industries. This report does not track the inventories of government production reactor spent fuels, which are 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.

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

  Spent fuels discharged from a variety of reactors are currently stored at the Hanford Site and INEL. For example, some of the spent fuel from the Fort St. Vrain HTGR is stored at the Idaho Chemical Processing Plant (ICPP) at INEL. Some special spent fuels are stored at the Savannah River Site (SRS) and INEL. 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 spent nuclear fuel. This includes mainly the liquid wastes remaining from the recovery of uranium and

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

- **Transuranic (TRU) Waste**

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

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

  Low-level waste is radioactive waste not classified as spent fuel, HLW, TRU waste, or by-product material such as uranium mill tailings. The radiation level from this waste may sometimes be high enough to require shielding for handling and transport. In ref. 5, the U.S. Nuclear Regulatory Commission (NRC) has defined 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 naturally occurring and accelerator-produced radioactive material from the LLW category. This report documents only those inventories of solid LLW destined for burial. It does not include any liquid or gas waste in storage, nor inventories of soils contaminated with LLW.

- **Commercial Uranium Mill Tailings**

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

- **Miscellaneous Radioactive Materials**

  Miscellaneous radioactive materials (MRM) that could possibly require geologic disposal are presently stored at some DOE and commercial sites. These materials include spent fuel elements for which no reprocessing is planned and GTCC LLW from commercial sources.

- **Mixed LLW**

  Mixed LLW contains concentrations of both low-level radioactive materials and hazardous chemicals. The latter may include polychlorinated biphenyls (PCBs) and asbestos. The hazardous component of mixed waste has characteristics identified by either or both of the following federal statutes: the Resource Conservation and Recovery Act (RCRA), as amended;[6] or the Toxic Substance Control Act (TSCA).[7] Typically, mixed LLW from activities supporting DOE programs includes a variety of contaminated materials, such as air filters, cleaning solutions, engine oils and grease, paint residues, soils, construction and building materials, water treatment chemicals, and decommissioned plant equipment. This report documents inventories and generation rates of various types of mixed wastes stored at DOE sites based on information summarized and reported by the Waste Management Information System (WMIS). The WMIS contains information on hazardous and mixed wastes generated and stored at DOE sites and is maintained by the Hazardous Wastes Remedial Actions Program (HAZWRAP) in support of the DOE Office of Environmental Restoration and Waste Management.

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

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

  - Generated waste. A material stream 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 (m^3) or mass (kg) produced during a calendar year.

  - Treated waste. A waste stream 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 performed on a waste prior to either storage or disposal or both (discussed below).

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

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

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

0.3 METHODS AND ASSUMPTIONS USED IN REPORT PREPARATION

This report consolidates a large amount of information from many sources. Some of these data are historical in nature, some are current, and some are projected; some have been calculated or estimated, and some have been measured. Over the years, waste regulations have been revised, waste category definitions have changed, measurement instruments and calibration methods have been improved, and record-keeping has been upgraded at all waste generating and receiving sites. In preparing this report, a major effort has been made to integrate waste data from many sources, striving 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., radioactive decay 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 projection time frame and specific assumptions used for estimating commercial and government (DOE) waste projections. For the commercial fuel cycle, the spent fuel and waste projections depend upon the nuclear power growth scenario. The commercial fuel cycle waste projections reported in this document assume a reference projection of nuclear power growth and no spent fuel reprocessing. The reference nuclear power electrical growth projection (and associated discharged spent fuel schedule) used throughout this report is the 1992 DOE/EIA No New Orders Case.[8] In addition, this document also includes a set of nuclear capacity and spent fuel projections associated with the 1992 DOE/EIA Lower Reference Case to illustrate, for planning purposes, a conservative upper bound of commercial nuclear power growth.[8] The No New Orders and Lower Reference spent fuel and power capacity projection cases are each based on a unique set of assumptions involving nuclear electricity generation growth, reactor fuel burnup levels, reactor construction schedules, and reactor operating lifetimes and capacity factors. These assumptions are documented by DOE/EIA in ref. 8. In particular, the No New Orders Case assumes a standard 40-year reactor operating life, with 30% of the reactors having an extended 60-year operating life. By contrast, the 1992 Lower Reference Case assumes that 70% of the reactors will have an extended 60-year operating life.

Detailed information about reactors already built, being built, or planned in the United States for domestic use or export as of December 31, 1991, is provided in report DOE/OSTI-8200-R55 (ref. 9). That document contains a comprehensive listing of all domestic reactors as 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 December 31, 1991 — some as recently as October 1992. 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.

It should be noted that waste volumes accumulate with time by conventional addition, while total radioactivity and total heat generation rates do not, because radionuclides decay over time to nonradioactive, stable isotopes. The short-lived radionuclides found in spent fuel decay rapidly during the first few years after the fuel is removed from a reactor. In this report, radionuclide decay is fully accounted for using a simplified version of the ORIGEN2 code[10] for radionuclide decay calculations.

0.4 SUMMARY DATA AND CHAPTER OVERVIEWS

A few graphical presentations and summary tables are included in this chapter to provide a broad overview. Figures 0.1 and 0.2, respectively, show the volumes and activities of commercial and DOE wastes and spent fuel accumulated through 1991. Annual volume and radioactivity projections for various DOE and commercial wastes and spent fuel are shown in Figs. 0.3 and 0.4, respectively. These results exclude contributions from uranium mill tailings, wastes from commercial LWR D&D activities, and wastes from DOE environmental restoration activities. In addition, the spent fuel projections in Figs. 0.3 and 0.4 exclude DOE fuel to be reprocessed. The commercial projections represent fuel cycle requirements without reprocessing. Cumulative waste projections are shown in Figs. 0.5 and 0.6.

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

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

0.4.1 Spent Fuel

Chapter 1 of this report presents national data on the quantities of permanently discharged spent fuel from commercial nuclear power reactors. Historical data on commercial spent fuel inventories[11] are reported along with two sets of DOE/EIA projections,[8] the No New Orders and Lower Reference cases. The No New Orders Case (without reactor license renewal) is the baseline commercial scenario used throughout this report to make waste projections. In contrast, the Lower Reference Case (with reactor license renewal) represents a conservative upper limit of spent fuel projections. For the projection period considered in this report (1992–2030), the No New Orders Case assumes that no new reactors will be ordered.

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

In this report, the mass of discharged spent fuel is measured in metric tons of initial heavy metal (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.)

0.4.2 High-Level Waste

The inventories of HLW in storage at the end of 1991 and projected through the year 2030 are given in Chapter 2. The waste forms include liquid, sludge, salt cake, slurry, calcine, precipitate, zeolite, glass, and capsules of separated strontium and cesium. Vitrified defense HLW is projected after the startup of the Defense Waste Processing Facility (DWPF) at Savannah River in 1993, and projections of vitrified civilian HLW 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 INEL are also reported. In addition, Chapter 2 gives the locations, volumes, and radioactivities of HLW.

0.4.3 TRU Waste

The locations, inventories, and projections of TRU waste buried and stored at DOE sites are presented in Chapter 3. Current inventories of TRU waste are virtually all from government operations. The inventories documented in this report include waste volumes, masses, and radioactivity of the contained TRU waste elements. Also included are the physical characteristics and isotopic compositions of the waste. Projected TRU waste quantities are based on current generation rates reported by the DOE sites. TRU waste projections are reported through the year 2018 and do not include waste generated from environmental restoration and D&D activities.

In 1984, the DOE (with input from other federal agencies) revised the minimum radioactivity concentration level for defining TRU waste from greater than 10 nCi/g to greater than 100 nCi/g.[12] Consequently, the waste currently in the inventory contains wastes stored under both criteria. This redefinition, as well as the development of instrumentation to detect these low levels of radioactivity, will reduce the volume of TRU waste. As the waste is assayed, the waste which is greater than 10 nCi/g and less than 100 nCi/g will be reclassified to other waste categories. The forecasted quantities of this reclassification are provided for retrievably stored TRU waste in Chapter 3.

0.4.4 Low-Level Waste

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 UF_6, fuel fabrication, and reactor operation. Low-level waste 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. Government LLW is similar in nature to the industrial and institutional (I/I) waste and the commercial fuel cycle LLW.

A wide variety of radionuclides is 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 1991, approximately 66% of the cumulative volume of disposed LLW resulted from various DOE activities. The remaining 34% resulted from domestic commercial activities. During 1991, 42% of the volume of LLW disposed resulted from commercial activities. Approximately 79% of the annual commercial portion resulted from fuel cycle activities and reactor operations, while the remaining 21% resulted from I/I activities. In the future, these ratios may change according to the number of operating power reactors.

0.4.5 Commercial Uranium Mill Tailings

Current inventories and projections of tailings from commercial uranium mill operations are summarized in Chapter 5. Twenty-six licensed uranium mills have accumulated tailings from their operations. Half of these mills have both commercial and government tailings. By the end of 1991, only two of the NRC-licensed mills were still active. To date, most all domestic uranium has been produced by conventional mining and milling methods, from which these tailings derive. A small portion has been obtained via in situ leaching, recovery from mine water, recovery from copper/vanadium dump leach liquor, and recovery from wet-process phosphoric acid effluents. Projections of uranium mill tailings are based on commercial fuel cycle requirements, adjusted for foreign imports, as specified by the DOE/EIA No-New-Orders-Case projection of commercial reactor power growth. Tailings from the now-inactive mills that produced uranium only for government operations are classified as environmental restoration wastes (see Chapter 6).

0.4.6 Environmental Restoration Wastes

The DOE Assistant Secretary for Environmental Restoration and Waste Management (DOE/EM) oversees the assessment and cleanup (environmental restoration) of inactive waste facilities at all DOE sites and some non-DOE sites for which DOE has responsibility.

An overview of environmental restoration projects and activities is given below, and further details are provided in Chapter 6. The scope of Chapter 6 is limited to radioactive wastes from environmental restoration activities. Mixed LLW is reported in Chapter 8, and hazardous wastes are outside the scope of this report.

The major objective for DOE environmental restoration projects is to ensure that risks to the environment and to human health and safety posed by inactive and surplus installations contaminated by radioactive, hazardous, or mixed wastes are either eliminated or reduced to prescribed, safe levels. The EM-40 projects are comprised of remedial action (RA) and D&D activities. Remedial action involves the assessment and cleanup of inactive sites and deals mainly with contaminated soil and groundwater. D&D activities include the safe caretaking of surplus nuclear facilities and their complete dismantling and removal or in-place stabilization and isolation. About 500 contaminated facilities are currently included under D&D.

Activities associated with environmental restoration projects are presently found in 34 states. In this report, projections of wastes from these projects include contributions from RA and D&D activities.

DOE environmental restoration goals and objectives are detailed in the 1992 Five-Year Environmental Restoration and Waste Management Plan[13] developed for DOE sites. This document provides a detailed update of the mission and objectives for the DOE Office of Environmental Restoration and Waste Management.

0.4.7 Commercial Decommissioning Wastes

Chapter 7 presents waste projections for the decommissioning of commercial power reactors and fuel cycle facilities. The D&D activities at such installations may result in very large volumes of LLW, depending on the methods selected. The major LLW volumes will result from the decommissioning of power reactors, which will also produce a small volume of high-activity waste. Unlike that for other waste generation activities, the timing of decommissioning operations is very uncertain, since facilities may be either decommissioned upon shutdown or put into a mothballed or protective storage condition to allow for sufficient radioactive decay before decommissioning. Chapter 7 reports a set of projected characteristics for wastes from commercial LWR decommissioning activities. These projections are based on the assumption that each power reactor is immediately decommissioned after it is shut down. To date, only a few commercial reactors have been fully decommissioned, and several have been placed in protective storage. Wastes from completed decommissioning actions have been included with existing inventories discussed in other chapters. Because of timing uncertainties, projected decommissioning wastes are not included in the projections of either LLW (Chapter 4) or wastes from environmental restoration programs (Chapter 6). Rather, decommissioning waste projections are reported separately in Chapter 7.

0.4.8 Miscellaneous Radioactive Materials

Inventories and characteristics of miscellaneous radioactive materials that may require geologic disposal are reported in Appendix A. Such materials consist mainly of permanently discharged or damaged spent fuel (pellets, rods, and other fuel assembly components) from civilian and government-sponsored nuclear programs. Appendix A also summarizes quantities of GTCC LLW as well as

preliminary mass estimates of DOE spent fuel no longer scheduled for reprocessing.

0.4.9 Mixed Low-Level Waste

Current inventories and generation rates of mixed LLW from both DOE and commercial sources are summarized in Chapter 8. These wastes are comprised of mixed materials that are both low-level radioactively contaminated and chemically hazardous. The radioactive components are defined by the Atomic Energy Act,[14] while the hazardous components are defined by the Resource Conservation and Recovery Act[6] and the Toxic Substances Control Act.[7] As of the end of 1991, DOE site mixed LLW inventories totaled about 101,400 m^3. During 1991, over 66,000 m^3 of mixed LLW was generated at DOE sites.

0.4.10 Appendixes

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

0.5 REFERENCES

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

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

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

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

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

6. 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.

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

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

9. U.S. Department of Energy, Office of Scientific and Technical Information, Nuclear Reactors Built, Being Built, or Planned: 1991, DOE/OSTI-8200-R55, Oak Ridge, Tennessee (July 1992).

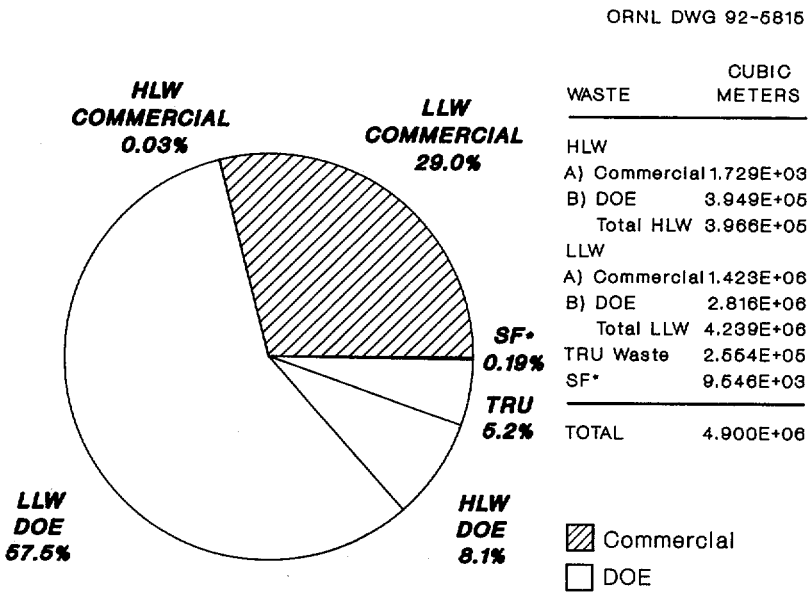
10. A. G. Croff, ORIGEN2 – A Revised and Updated Version of the Oak Ridge Isotope Generation and Depletion Code, ORNL-5621, Oak Ridge National Laboratory, Oak Ridge, Tennessee (July 1980).

11. U.S. Department of Energy, Energy Information Administration, Nuclear Fuel Data Form RW-859 (data as of Dec. 31, 1991).

12. U.S. Department of Energy, DOE Order 5820.2, Radioactive Waste Management, Feb. 6, 1984 (updated by DOE Order 5820.2A, ref. 4).

13. U.S. Department of Energy, Environmental Restoration and Waste Management Five-Year Plan – Fiscal Years 1994–1998, Vols. 1 and 2, Washington, D.C. (December 1992).

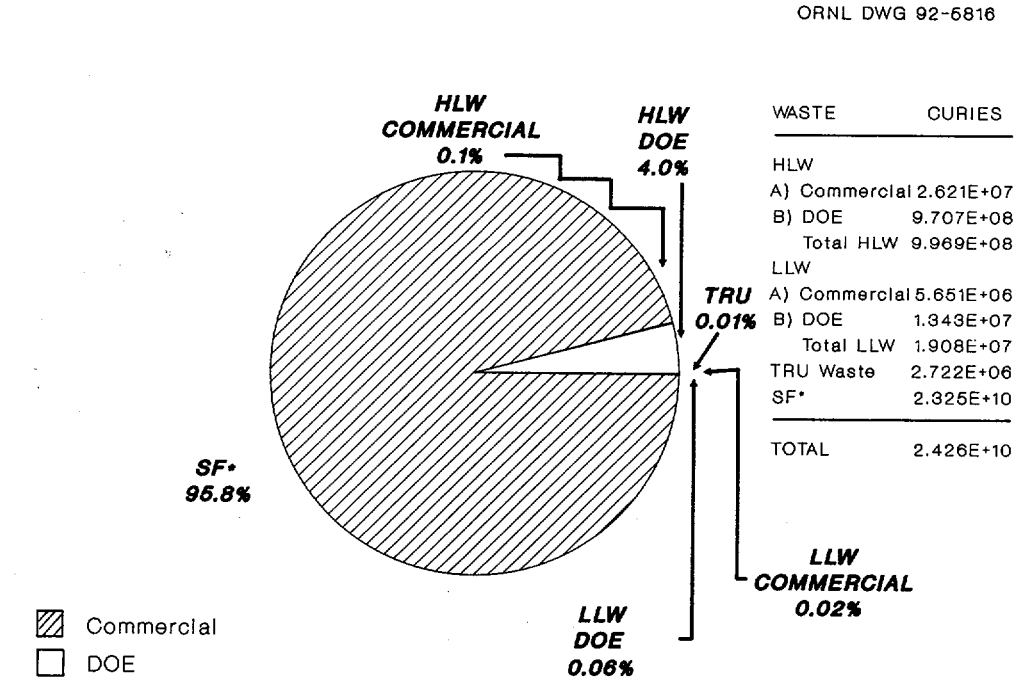
14. U.S. Congress, Atomic Energy Act of 1954, Pub. L. 83-703, Aug. 15, 1954.



WASTE	CUBIC METERS
HLW	
A) Commercial	1.729E+03
B) DOE	3.949E+05
Total HLW	3.966E+05
LLW	
A) Commercial	1.423E+06
B) DOE	2.816E+06
Total LLW	4.239E+06
TRU Waste	2.554E+05
SF*	9.546E+03
TOTAL	4.900E+06

*Includes spacing between fuel assembly rods.
Does not include DOE spent fuel to be reprocessed.

Fig. 0.1. Total volumes of commercial and DOE wastes and spent fuel through 1991.



WASTE	CURIES
HLW	
A) Commercial	2.621E+07
B) DOE	9.707E+08
Total HLW	9.969E+08
LLW	
A) Commercial	5.651E+06
B) DOE	1.343E+07
Total LLW	1.908E+07
TRU Waste	2.722E+06
SF*	2.325E+10
TOTAL	2.426E+10

*Does not include DOE spent fuel to be reprocessed.

Fig. 0.2. Total radioactivities of commercial and DOE wastes and spent fuel through 1991.

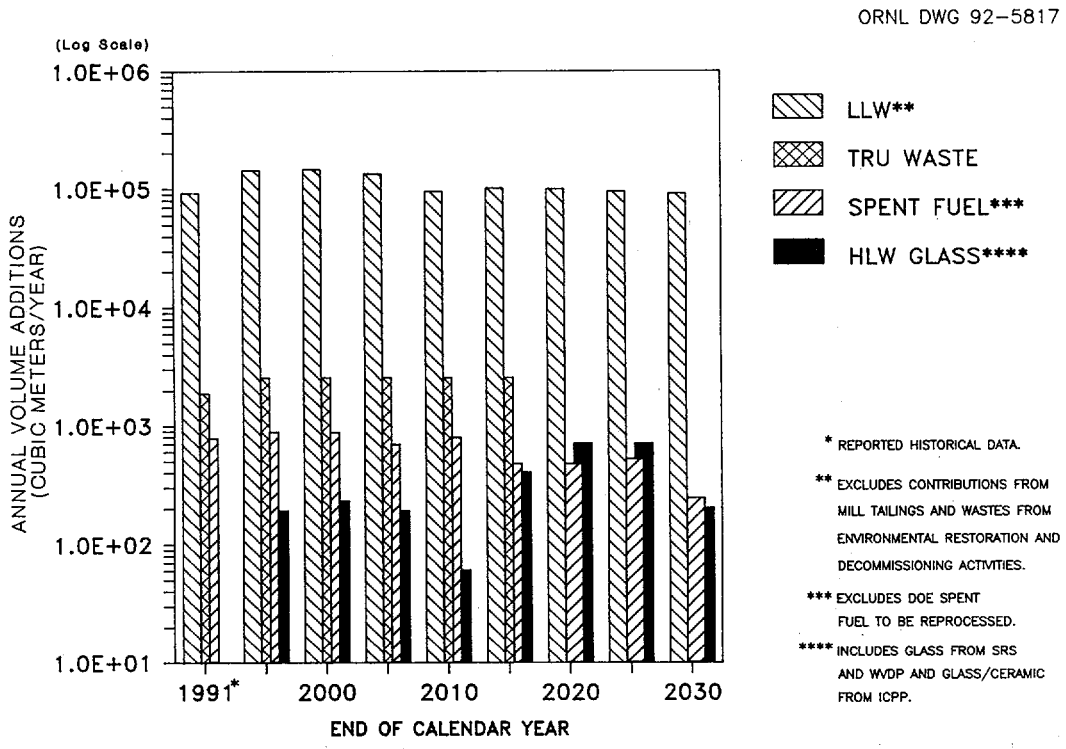


Fig. 0.3. Projections of annual volume additions for various wastes and spent fuel — DOE and commercial fuel cycle.

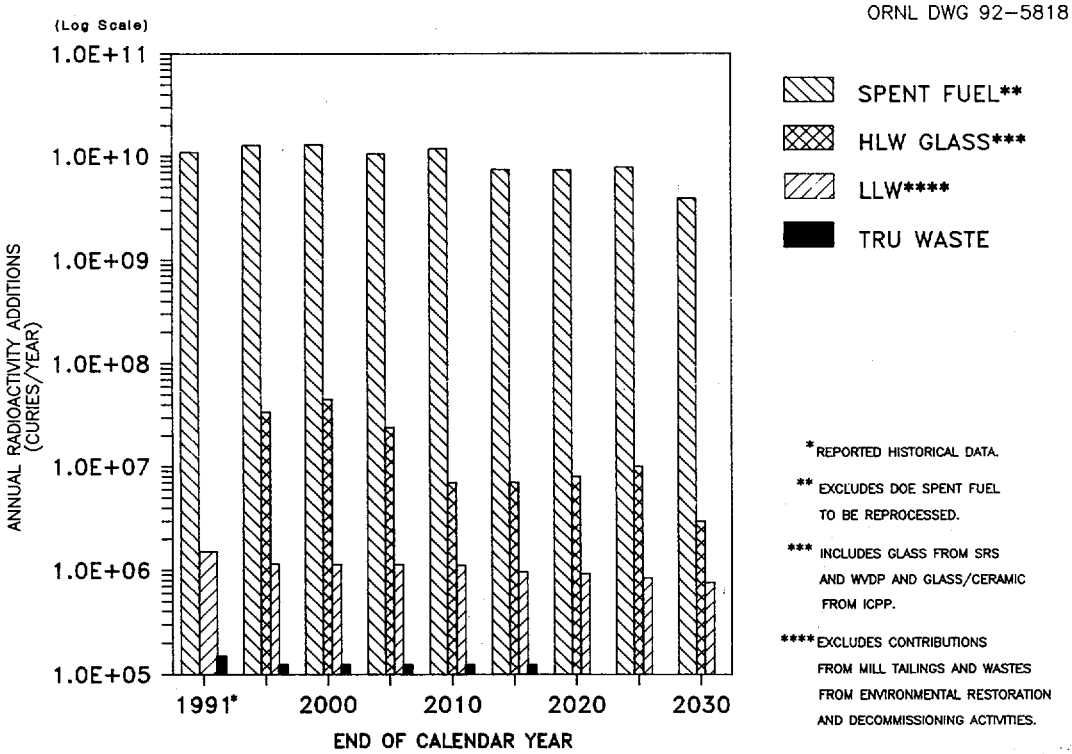


Fig. 0.4. Projections of annual radioactivity additions for various wastes and spent fuel — DOE and commercial fuel cycle.

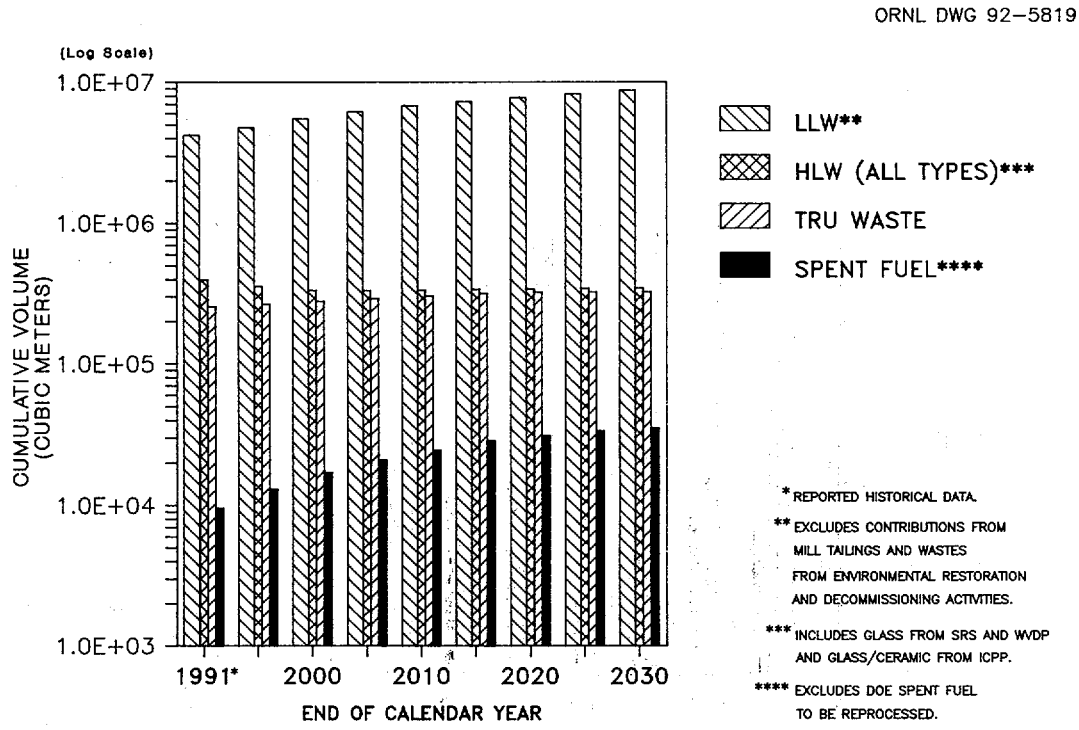


Fig. 0.5. Projections of cumulative volumes for various wastes and spent fuel — DOE and commercial fuel cycle.

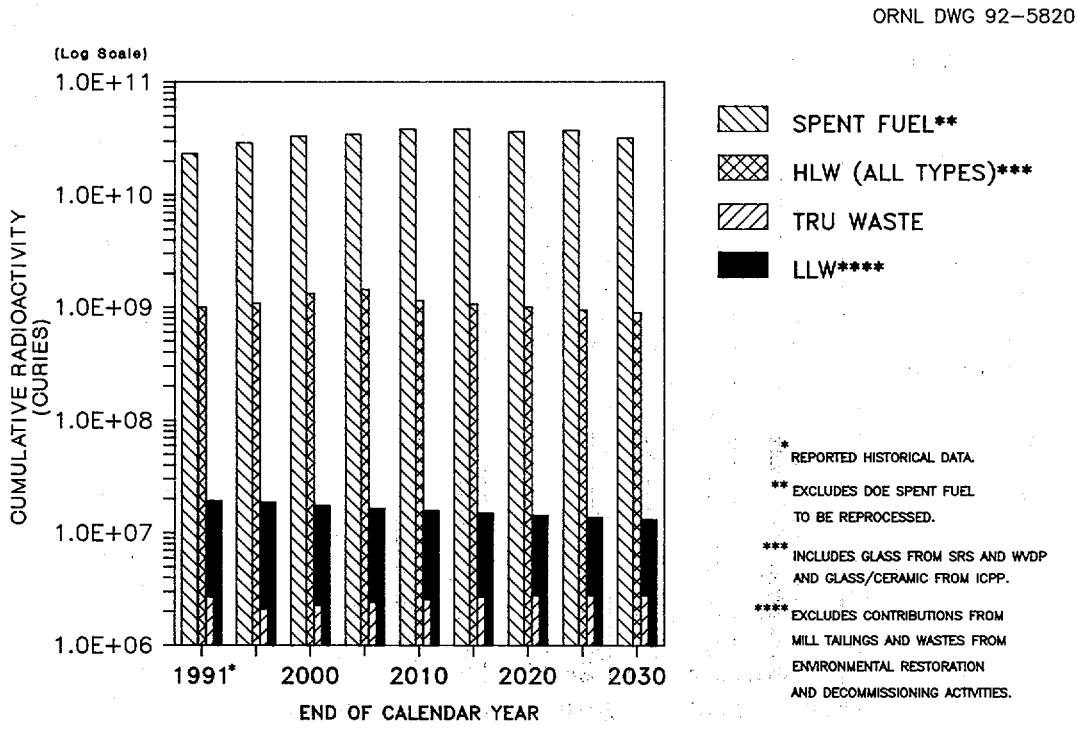


Fig. 0.6. Projections of cumulative radioactivity for various wastes and spent fuel — DOE and commercial fuel cycle.

Table 0.1. Major sources of information for the IDB Program

Technical area	Responsible DOE offices	Principal contractor(s)
Ground rules and assumptions	DOE Headquarters Office of Civilian Radioactive Waste Management Office of Environmental Restoration and Waste Management	
Spent fuel	DOE Headquarters Office of Civilian Radioactive Waste Management Energy Information Administration	CRWMS-M&O/TESS
High-level waste (HLW):		
DOE	Field Office, Richland	Westinghouse Hanford Company
Commercial	West Valley Project Office (Field Office, Idaho)	Westinghouse (West Valley Nuclear Services)
Transuranic (TRU) waste	Field Office, Albuquerque Waste Isolation Pilot Plant (WIPP) Project Office	Westinghouse (WIPP Project)
Low-level waste (LLW):		
DOE	DOE Headquarters Office of Environmental Restoration and Waste Management	Hazardous Waste Remedial Actions Program (Martin Marietta Energy Systems, Inc.)
Commercial	Field Office, Idaho	EG&G Idaho, Inc.
Active (licensed) mill tailings	Energy Information Administration	
Environmental restoration wastes:		
DOE environmental restoration projects	DOE Headquarters Office of Environmental Restoration and Waste Management	Booz, Allen, & Hamilton
Nuclear facility decommissioning wastes, principally from the following:		
Three Mile Island-Unit 2 Reactor	Field Office, Idaho	GPU Nuclear Corporation
West Valley Demonstration Project	West Valley Project Office (Field Office, Idaho)	Westinghouse (West Valley Nuclear Services)
Commercial electrical generation reactors		Public utilities
Mixed LLW (DOE sites)	DOE Headquarters Office of Environmental Restoration and Waste Management	Hazardous Waste Remedial Actions Program (Martin Marietta Energy Systems, Inc.)
Miscellaneous radioactive materials	DOE Field Offices	DOE contractors

Table 0.2. Major assumptions used in this report

Projection basis

- Projections are made for the years 1992-2030

Government activities

- Level of waste generating activities remains approximately constant
- The most recent operating campaign of the Hanford Site reprocessing plant began in 1983 and will conclude operations near the end of 2002
- HLW solidification schedules:
  - For WVDP, HLW solidification (glass production) starts in 1996 and is completed in 1998
  - For SRS, HLW solidification [glass production at the Defense Waste Processing Facility (DWPF)] starts in 1993 and continues solidification until 2010
  - For INEL, HLW solidification (immobilization) starts in 2015, achieves full production by 2018, and continues through 2039
  - For HANF, HLW solidification (borosilicate glass production at the Hanford Waste Vitrification Plant) starts in December 1999 and continues through 2030

Commercial activities

- Projections of installed net LWR electrical capacity for the DOE/EIA No New Orders Case[a] of ref. 9:

Year	GW(e)	Year	GW(e)	Year	GW(e)	Year	GW(e)	Year	GW(e)
1992	99	2000	103	2008	102	2016	69	2024	51
1993	100	2001	103	2009	101	2017	67	2025	45
1994	100	2002	102	2010	99	2018	66	2026	44
1995	101	2003	102	2011	98	2019	66	2027	38
1996	103	2004	102	2012	95	2020	64	2028	37
1997	103	2005	102	2013	85	2021	62	2029	33
1998	103	2006	102	2014	75	2022	59	2030	30
1999	103	2007	102	2015	74	2023	58		

- DOE/EIA projections for both the No New Orders Case and the Lower Reference Case assume that burnup levels of discharged spent fuel will increase from their current average levels of 27,800 and 35,040 MWd/MTIHM for BWR and PWR fuel, respectively, at the rate of about 2.8% per year for BWR fuel and about 3.3% per year for PWR fuel. This increase in burnup is projected to occur from 1991 to 2007 for BWR fuel and from 1991 to 2005 for PWR fuel, at which times the equilibrium cycle discharges will level out at values of roughly 43,000 and 55,000 MWd/MTIHM for BWR and PWR fuel, respectively

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

- Annual volume and radioactivity of industrial and institutional (I/I) waste for projections (1992-2030) are taken to be the same as those reported for 1991. The radioactivity added each year is decayed as if it had the composition given in Table C.11 of Appendix C

[a]This case is based on a standard 40-year reactor operating life.

Table 0.3. Spent fuel and radioactive waste inventories as of December 31, 1991

Waste category	TRU isotopes (kg)	Mass (MTIHM)	Volume (m^3)	Activity[a] (10^6 Ci)	Thermal power (10^3 W)
Spent fuel (commercial)					
BWRs		8,837	3,562[b]	6,261	22,827
PWRs		14,844	5,984[b]	16,984	64,809
High-level waste					
Savannah River (DOE)			127,900	538	1,509
Idaho (DOE)			10,400	59	172
Hanford (DOE)[c]			256,500	374	1,076
West Valley (commercial)			1,729	26	76
Transuranic waste (DOE)					
Buried TRU waste	766		190,584	0.28	2.4
Potentially contaminated soil	d		95,000-195,000	d	d
Stored TRU waste	2,261		64,790	2.44	39.1
Stored LLW[e]	14		37,360	d	d
Low-level waste					
DOE sites			2,816,300	13.43	18.68
Commercial sites			1,422,800	5.65	29.88
Uranium mill tailings (commercial)					
Licensed mill sites[f]			118,400,000	d	d
Environmental restoration projects (DOE)[g]					
TRU waste			d	d	d
LLW			d	d	d
By-product material[h]			11,390,000[i,j]	d	d
Reactor decommissioning			k	k	k
Miscellaneous radioactive materials		256.8	d	d	d
Mixed LLW					
DOE		186,459[l]	101,400	d	d
Commercial		d	d	d	d

[a]Activity data are calculated values as of December 31, 1991.

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

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

[d]Information not available.

[e]TRU-contaminated waste in interim storage, which may be managed as LLW after retrieval and assay for certification.

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

[g]Inventories reported in this table for environmental restoration activities include only contributions from projects completed at the end of 1991. Volume estimates include quantities determined or projected to be mixed wastes.

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

[i]The Grand Junction Remedial Action Project (GJRAP) was completed in 1988.

[j]Includes LLW and source material.

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

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

Table 0.4. Current and projected cumulative quantities of radioactive waste and spent fuel

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

Source and type of material	End of calendar year				
	1991	2000	2010	2020	2030
DOE					
HLW					
Interim storage	395	332	332	335	333
Glass[a]	0	1.6	3.3	6.8	13.4
TRU[b]					
Buried	191	191	191	191	191
Stored	63	84	108	c	c
LLW[d]	2,816	3,787	4,769	5,469	6,231
Environmental restoration projects[e]					
TRU waste	c	570	1,100	1,700	1,700
LLW[f]	c	920	18,000	29,000	29,000
By-product material[g,h]	11,390	33,000	36,000	38,000	38,000
Mixed LLW	101.4	c	c	c	c
Miscellaneous radioactive materials, mass, MTIHM	256.8	c	c	c	c
Commercial					
LWR spent fuel, mass, MTIHM[i] (no reprocessing)					
No New Orders Case	23,681	42,400	61,000	77,200	87,700
Lower Reference Case	23,681	42,300	61,200	81,600	103,200
Commercial HLW (WVDP)					
Interim storage	1.729	0.0	0.0	0.0	0.0
Glass	0.0	0.24	0.24	0.24	0.24
LLW (no reprocessing)	1,423	1,722	2,055	2,321	2,508
D&D (LLW)[j]					
Classes A, B, and C LLW	--	0.00	7.83	612.84	1,292.85
Greater-than-Class-C LLW	--	0.00	0.00	0.22	0.45
Mill tailings (no reprocessing)	118,400	119,400	c	c	c
Mixed LLW	c	c	c	c	c

[a]Includes projections for glass only at SRS.

[b]Projections are updated mainly as a result of improvements in detection methods. Approximately 37% of the currently stored volume will be managed as LLW.

[c]Information not available.

[d]Projections include contributions from SRS saltstone.

[e]Projections are based on the scheduled completion of environmental restoration activities by the year 2019. Volume estimates include quantities determined or projected to be mixed wastes. All projected values are given to two significant figures.

[f]Projected LLW volumes from environmental restoration activities are not included in the DOE LLW volumes reported above.

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

[h]Includes contributions from mill tailings stabilized from both GJRAP and UMTRAP activities, windblown contaminated soil, stabilization material from sites that may require environmental restoration, LLW, and source material.

[i]Historically, spent fuel has been measured in units of mass (MTIHM) rather than units of volume. The 1991 discharged spent fuel mass is a BWR and PWR mass sum rounded to the nearest metric ton. Such rounding may result in slight differences between the spent fuel inventories and projections reported in this document and those reported by DOE/EIA.

[j]Projected D&D wastes from light-water reactors shut down after 1991. Wastes collected from historical D&D of reactors are included in the LLW inventories listed above.

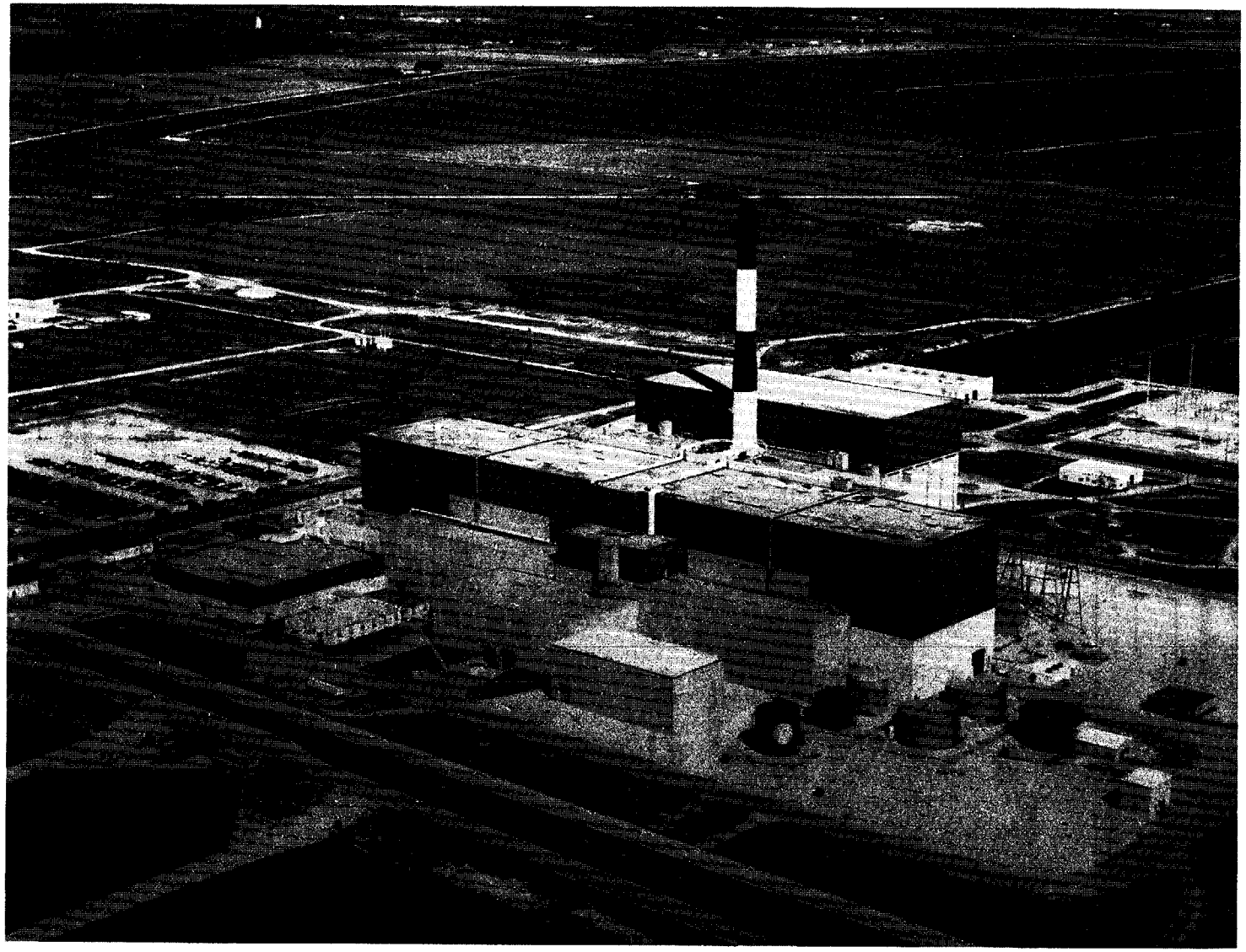


Photo 1.1. The LaSalle County Nuclear Power Station, two 1120-MW(e) boiling-water reactors, located in Seneca, Illinois. (Courtesy of the Commonwealth Edison Company, Downers Grove, Illinois.)

1. COMMERCIAL SPENT FUEL

1.1 INTRODUCTION

This chapter deals exclusively with spent fuel that has been permanently discharged from commercial LWRs and one-of-a-kind reactors and that ultimately requires geologic disposal. While the spent fuel data included in this chapter are believed to be accurate, the reader is advised that the data are still undergoing review for compliance with the formal quality assurance requirements of the Office of Civilian Radioactive Waste Management.

For inventories of special fuels (from DOE/civilian development programs) stored at various DOE and commercial sites as of December 31, 1991, and for projected estimates of commercially generated GTCC LLW, the reader is referred to Appendix A. The special fuels covered in Appendix A do not include DOE production and naval reactor fuels that are reprocessed at SRS, INEL, and Hanford. Though presently in storage at the locations cited in Appendix A, these special fuels and commercially generated GTCC LLW may possibly require geologic disposal.

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

Historical inventories of LWR spent fuel have been updated through December 31, 1991.[1] The data reported in this chapter include the inventories of spent fuel stored at the WVDP, the MFRP, and the INEL sites in addition to those stored at the various reactor sites. The map in Fig. 1.1 shows the locations of existing and planned power reactor sites and commercial LWR spent fuel storage facilities. A list of commercial reactors is given also in report DOE/OSTI-8200-R55 (ref. 2).

Projections of nuclear capacity and spent fuel discharges are given for the years 1992–2030 for two forecast schedules, the DOE/EIA No-New-Orders-Case forecast and the DOE/EIA Lower-Reference-Case forecast, reported in ref. 3. The No-New-Orders-Case forecast projects installed capacity to increase from 99.6 GW(e) at the end of 1991 to 102.5 GW(e) by 2000, ultimately decreasing to 30.0 GW(e) by 2030. The Lower-Reference-Case forecast predicts that the installed U.S. commercial nuclear electrical generating capacity will increase from 99.6 GW(e) at the end of 1991 to 103.7 GW(e) by 2000 and to 121.3 GW(e) by 2030.

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

DOE/EIA projections for both the No New Orders Case and the Lower Reference Case assume that burnup levels of discharged spent fuel will increase from their current average levels of 27,800 and 35,040 MWd/MTIHM for BWR and PWR fuel, respectively, at the rate of about 2.8% per year for BWR fuel and about 3.3% per year for PWR fuel. This increase in burnup is projected to occur from 1991 to 2007 for BWR fuel and from 1991 to 2005 for PWR fuel, at which times the equilibrium cycle discharges will level out at values of roughly 43,000 and 55,000 MWd/MTIHM for BWR and PWR fuel, respectively. The final cycle discharges will be somewhat lower because most of the final cycle cores will not have achieved the projected design burnups. Figure 1.6 graphically illustrates how the activity and thermal power of BWR and PWR spent fuels vary with burnup and time from discharge.[4]

1.2 INVENTORIES AND PROJECTIONS

The total inventory of commercial LWR spent fuel in storage at the WVDP site, the MFRP, INEL, and the reactor sites, as of December 31, 1991, amounted to 23,681 MTIHM. Of this total amount, 27 MTIHM are in storage at the WVDP site,[5] 674 MTIHM are in storage at

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

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

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

1.3 CHARACTERIZATION

Reference characteristics of BWR and PWR fuel assemblies, obtained from refs. 8 and 9, were used for this report. These characteristics are summarized in Table 1.8. Fuel assembly structural material masses and compositions, nonactinide fuel impurities, and other physical and irradiation characteristics of LWR spent fuel are discussed in ref. 10. More detailed information on spent fuel characteristics may be found in ref. 11. The BWR and PWR spent fuel annually discharged has a broad range of burnup levels, as illustrated in Tables 1.9 and 1.10, respectively. The mass, radioactivity, and thermal power of the nuclides contained in all stored domestic commercial LWR spent fuel as of December 31, 1991, are listed in Table C.4 in Appendix C.

1.4 DISPOSAL

The Department of Energy has made progress in obtaining site access to perform the necessary characterization activities to determine if Yucca Mountain, Nevada, is suitable for development as a repository. Recent developments include the start of new site characterization activities, the selection of a design for an underground studies facility, and efforts to conduct an early evaluation of the candidate site to look at features, or conditions, that could subsequently disqualify it as a permanent repository. In March 1992, following extensive hearings, the Nevada State Engineer issued DOE the water permit for the next stage of activities. Deep borehole dry drilling and coring began in May, and completion of the first borehole is expected in December 1992.

1.5 REFERENCES

1. U.S. Department of Energy, Energy Information Administration, Nuclear Fuel Data Form RW-859, Washington, D.C. (data as of December 31, 1991).

2. U.S. Department of Energy, Office of Scientific and Technical Information, Nuclear Reactors Built, Being Built, or Planned: 1991, DOE/OSTI-8200-R55, Oak Ridge, Tennessee (July 1992).

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

4. J. W. Roddy et al., Physical and Decay Characteristics of Commercial LWR Spent Fuel, ORNL/TM-9591/V1&R1, Oak Ridge National Laboratory, Oak Ridge, Tennessee (January 1986).

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

6. E. R. Johnson Associates, Inc., Review of the Operating History of the Nuclear Fuel Services, Inc., West Valley, New York, Irradiated Fuel Reprocessing Plant, ORNL/Sub-81/31066/1, Oak Ridge National Laboratory, Oak Ridge, Tennessee (September 1981).

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

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

10. A. G. Croff et al., Revised Uranium-Plutonium Cycle PWR and BWR Models for the ORIGEN Computer Code, ORNL/TM-6051, Oak Ridge National Laboratory, Oak Ridge, Tennessee (September 1978).

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

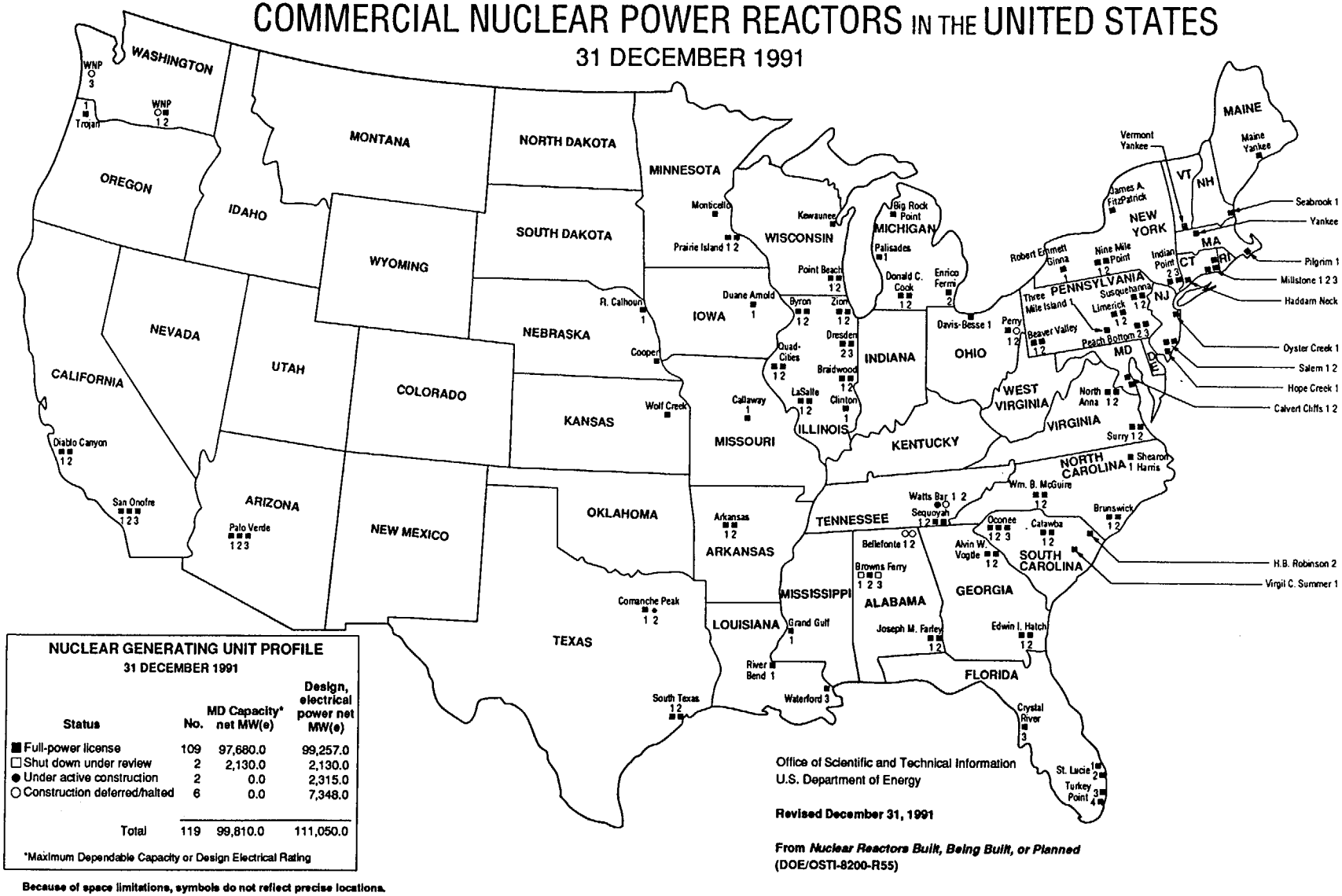

Fig. 1.1. Locations of existing and planned commercial reactors as of December 31, 1991. (Courtesy of U.S. Department of Energy, Office of Scientific and Technical Information, Oak Ridge, Tennessee.)

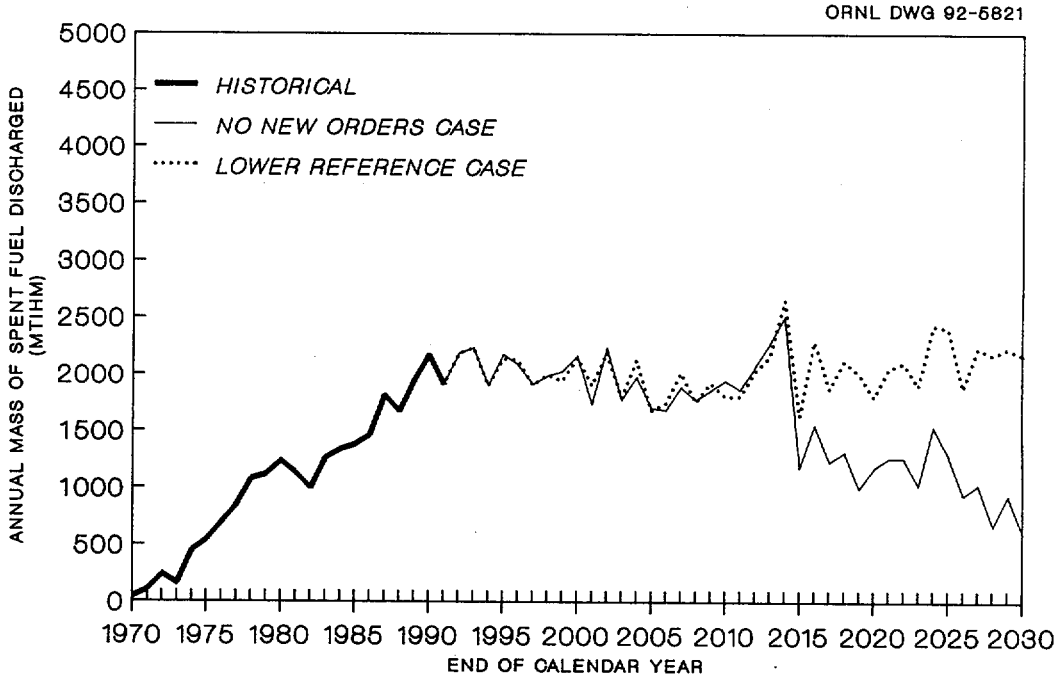

Fig. 1.2. Projected mass (MTIHM) of annual commercial spent fuel discharges for the DOE/EIA No New Orders and Lower Reference cases.

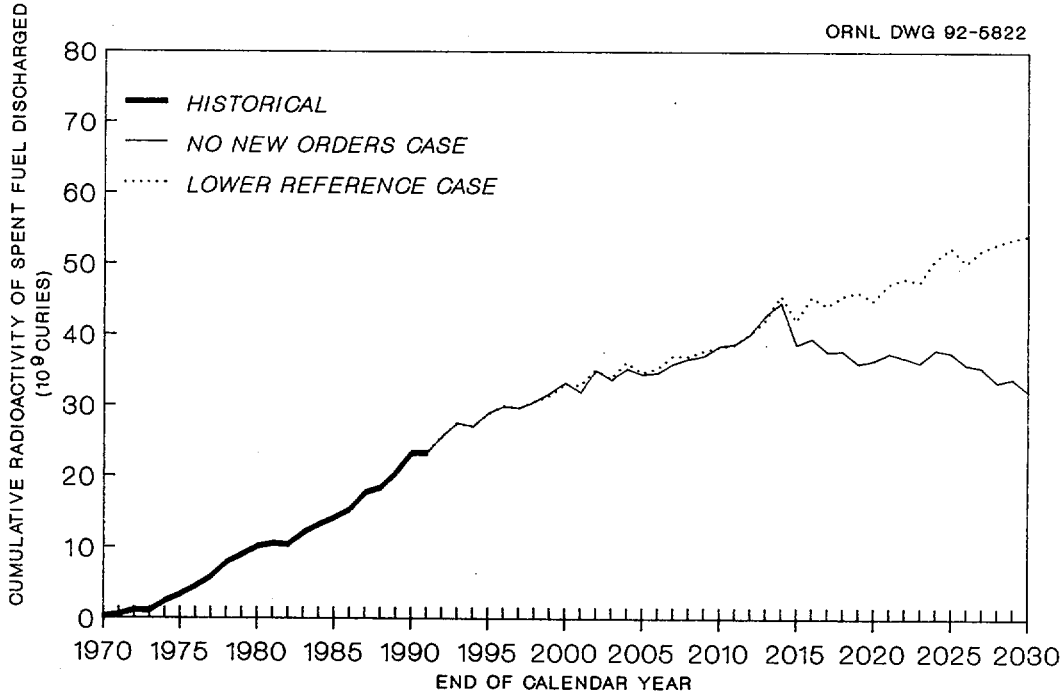

Fig. 1.3. Projected cumulative radioactivity of commercial spent fuel discharges for the DOE/EIA No New Orders and Lower Reference cases.

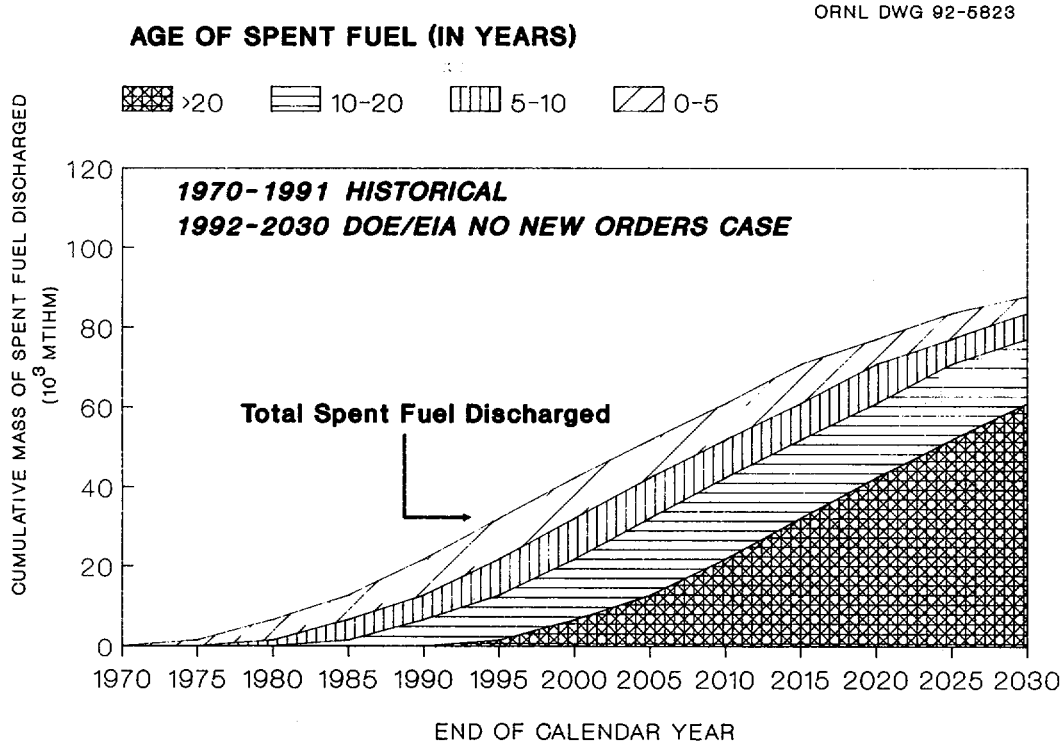

Fig. 1.4. Projected cumulative mass (MTIHM) of commercial spent fuel discharges for the DOE/EIA No New Orders Case.

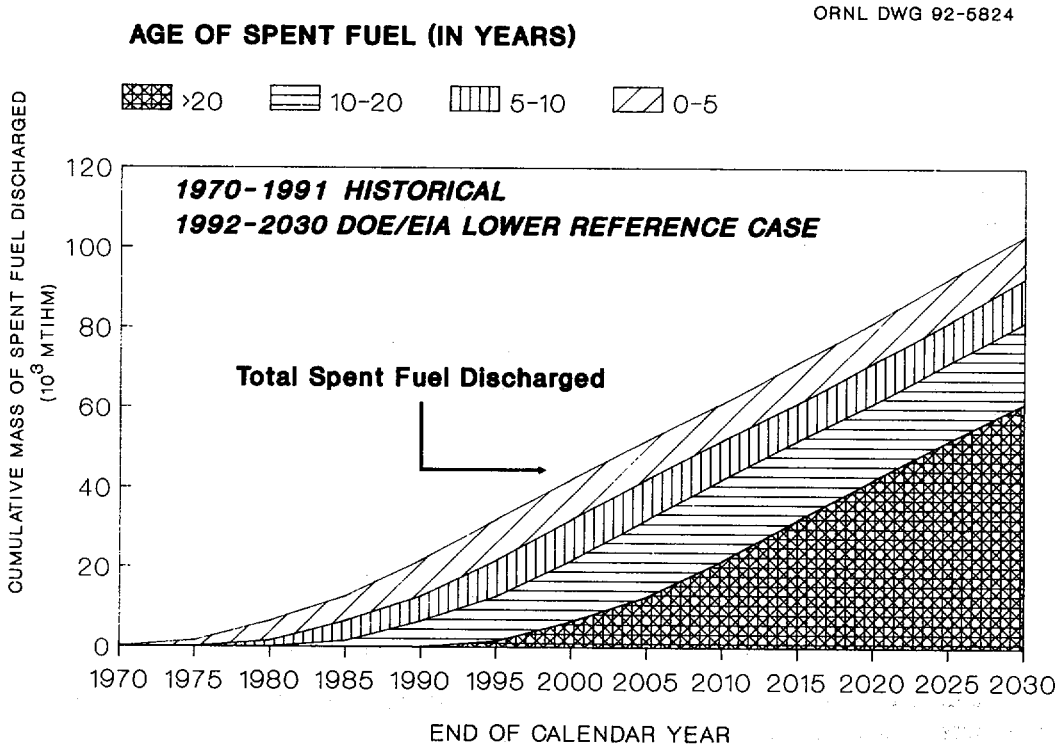

Fig. 1.5. Projected cumulative mass (MTIHM) of commercial spent fuel discharges for the DOE/EIA Lower Reference Case.

ORNL DWG 86-332

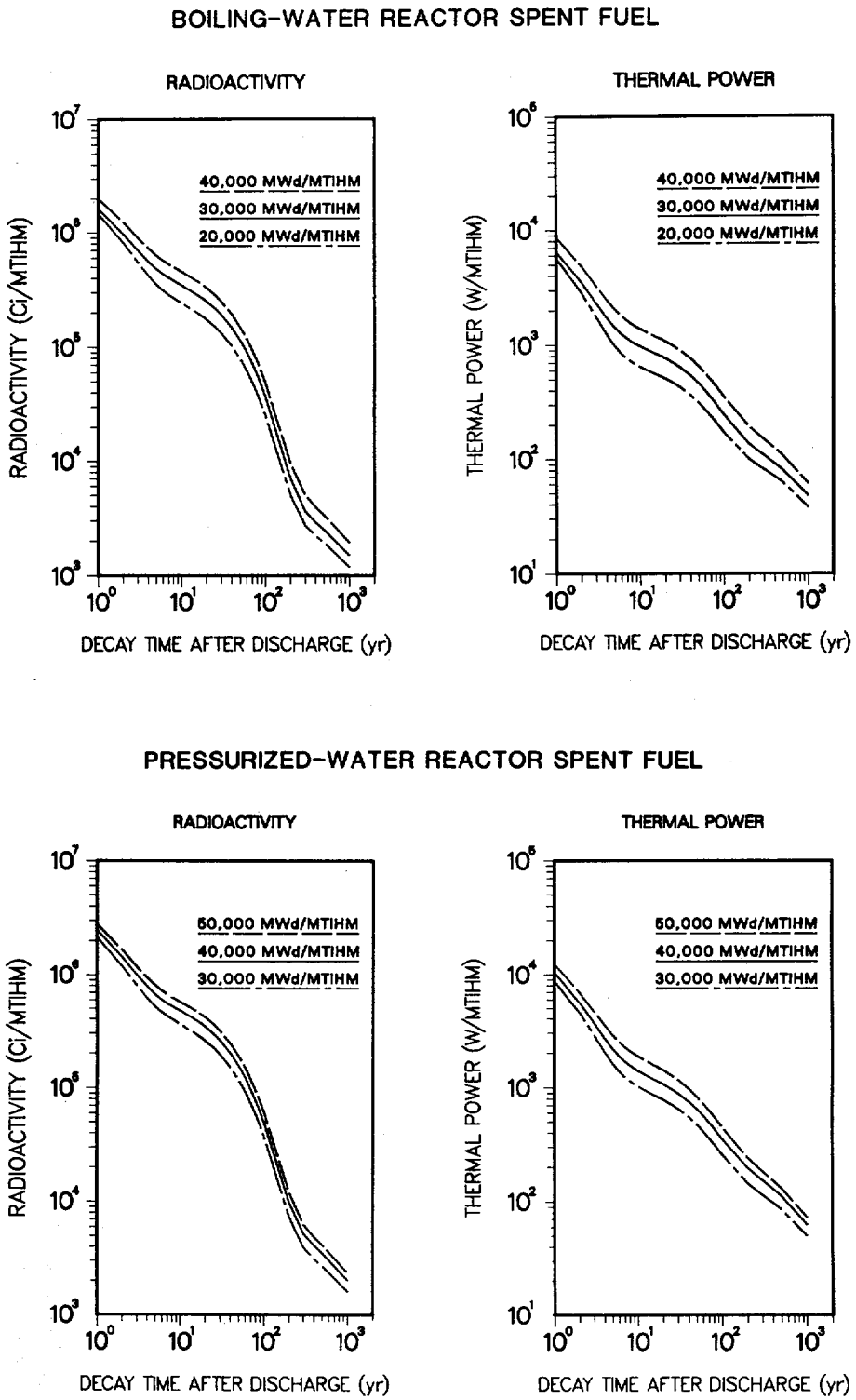

Fig. 1.6. Radioactivity and thermal power of 1 metric ton of heavy metal of BWR and PWR spent fuel as a function of burnup and time from reactor discharge.

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

End of calendar year	Historical capacity[a] [GW(e)]			End of calendar year	No New Orders Case projected capacity[b] [GW(e)]			Lower Reference Case projected capacity[c] [GW(e)]		
	BWR	PWR	Total		BWR	PWR	Total	BWR	PWR	Total
1960	0.1	0.2	0.3	1992	32.0	67.0	99.0	32.0	67.0	99.0
1961	0.1	0.2	0.3	1993	32.0	68.1	100.1	32.0	68.1	100.1
1962	0.1	0.2	0.4	1994	32.0	68.1	100.1	32.0	69.3	101.3
1963	0.1	0.2	0.4	1995	32.0	69.3	101.3	32.0	69.3	101.3
1964	0.1	0.2	0.4	1996	32.0	70.5	102.5	32.0	70.5	102.5
1965	0.1	0.2	0.4	1997	32.0	70.5	102.5	32.0	70.5	102.5
1966	0.1	0.2	0.4	1998	32.0	70.5	102.5	32.0	71.7	103.7
1967	0.1	1.3	1.4	1999	32.0	70.5	102.5	32.0	71.7	103.7
1968	0.2	1.2	1.4	2000	32.0	70.5	102.5	32.0	71.7	103.7
1969	0.8	1.7	2.6	2001	32.0	70.5	102.5	32.0	72.9	104.9
1970	2.9	2.9	5.8	2002	31.9	70.5	102.4	32.0	72.9	104.9
1971	4.3	3.7	8.0	2003	31.9	70.5	102.4	32.0	72.9	104.9
1972	7.0	6.5	13.5	2004	31.9	70.5	102.4	32.0	72.9	104.9
1973	8.1	14.1	22.1	2005	31.9	70.5	102.4	32.0	72.9	104.9
1974	13.3	19.4	32.7	2006	31.9	70.5	102.4	32.0	72.9	104.9
1975	15.0	23.3	38.3	2007	31.9	70.5	102.4	32.0	72.9	104.9
1976	16.8	27.9	44.7	2008	31.9	70.5	102.4	32.0	72.9	104.9
1977	16.8	30.4	47.2	2009	30.7	70.5	101.2	30.8	72.9	103.7
1978	17.6	32.2	49.8	2010	29.3	69.8	99.1	30.0	72.3	102.3
1979	17.6	32.2	49.8	2011	28.5	69.8	98.3	30.8	76.7	107.5
1980	17.6	34.3	51.9	2012	26.3	68.3	94.6	29.4	79.5	108.9
1981	17.6	38.6	56.2	2013	24.2	60.9	85.1	28.1	80.8	108.9
1982	18.7	40.5	59.2	2014	18.4	56.5	75.0	25.2	81.5	106.7
1983	19.7	43.6	63.3	2015	18.4	55.4	73.9	27.2	82.8	110.0
1984	24.2	45.8	70.0	2016	16.6	52.5	69.1	26.1	82.5	108.6
1985	26.8	51.7	78.5	2017	16.6	50.6	67.2	28.6	81.6	110.3
1986	28.9	55.2	84.1	2018	15.8	49.7	65.5	27.9	83.3	111.2
1987	31.8	60.8	92.6	2019	15.8	49.7	65.5	27.9	85.8	113.7
1988	31.8	63.1	94.9	2020	15.8	48.6	64.4	27.9	87.2	115.0
1989	33.8	64.1	97.9	2021	15.8	46.3	62.1	27.9	87.7	115.6
1990	32.9	66.7	99.6	2022	13.7	45.2	59.0	27.8	89.4	117.2
1991	32.0	67.7	99.6	2023	13.7	44.2	57.9	27.8	92.2	120.0
				2024	9.4	42.0	51.4	25.6	93.8	119.4
				2025	7.4	37.5	44.8	24.6	93.3	118.0
				2026	7.4	36.2	43.6	24.6	96.3	121.0
				2027	5.4	32.5	37.9	23.7	96.1	119.8
				2028	5.4	31.3	36.6	23.7	97.9	121.6
				2029	4.3	28.5	32.8	26.7	95.1	121.8
				2030	4.3	25.7	30.0	29.0	92.3	121.3

[a]Based on ref. 1.

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

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

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

End of calendar year	Cumulative spent fuel discharged, 10^3 MTIHM	
	No New Orders Case	Lower Reference Case
1991[a]	23.7	23.7
1992[b]	25.9	25.9
1993	28.1	28.1
1994	30.0	30.0
1995	32.2	32.1
1996	34.3	34.3
1997	36.2	36.2
1998	38.2	38.2
1999	40.2	40.1
2000	42.4	42.3
2001	44.1	44.2
2002	46.4	46.4
2003	48.1	48.2
2004	50.1	50.3
2005	51.8	52.0
2006	53.5	53.7
2007	55.4	55.8
2008	57.2	57.5
2009	59.0	59.4
2010	61.0	61.2
2011	62.8	63.1
2012	64.9	65.1
2013	67.2	67.2
2014	69.7	69.9
2015	70.9	71.5
2016	72.4	73.8
2017	73.7	75.7
2018	75.0	77.8
2019	76.0	79.8
2020	77.2	81.6
2021	78.4	83.7
2022	79.7	85.8
2023	80.7	87.7
2024	82.2	90.1
2025	83.5	92.6
2026	84.5	94.4
2027	85.5	96.7
2028	86.2	98.8
2029	87.1	101.1
2030	87.7	103.2

[a]Reported historical data from ref. 1.
[b]Data for years 1992-2030 from ref. 3.

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

End of calendar year	Mass,[a,b] MTIHM		Radioactivity, 10^6 Ci		Thermal power, 10^6 W	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
			Boiling-water reactor			
1968-1970		16		11		0.0
1971	64	80	190	197	0.7	0.8
1972	142	222	431	466	1.7	1.8
1973	95	317	350	442	1.4	1.7
1974	245	561	908	1,043	3.6	4.0
1975	226	787	921	1,218	3.7	4.7
1976	297	1,084	1,150	1,580	4.5	6.1
1977	383	1,467	1,566	2,129	6.2	8.2
1978	383	1,850	1,618	2,412	6.5	9.3
1979	400	2,250	1,734	2,728	7.1	10.5
1980	620	2,870	2,685	3,888	10.9	15.1
1981	459	3,329	2,014	3,664	8.2	14.0
1982	357	3,686	1,582	3,362	6.5	12.6
1983	491	4,177	2,218	4,015	9.1	15.1
1984	498	4,675	2,211	4,283	9.0	16.0
1985	515	5,190	2,245	4,518	9.1	16.7
1986	458	5,648	1,963	4,403	8.0	16.0
1987	699	6,347	2,919	5,410	11.7	19.8
1988	536	6,883	2,363	5,177	9.7	18.8
1989	715	7,598	3,090	6,038	12.6	22.1
1990	633	8,231	2,821	6,100	11.6	22.3
1991	606	8,837	2,771	6,261	11.4	22.8
1992	800	9,600	3,600	7,300	15.1	27.1
1993	700	10,300	3,300	7,500	13.8	27.7
1994	600	10,900	2,700	7,200	11.2	26.1
1995	800	11,700	3,800	8,400	16.1	31.1
1996	600	12,300	3,100	8,200	13.0	30.0
1997	600	12,900	2,900	8,100	12.1	29.5
1998	700	13,600	3,400	8,800	14.4	32.2
1999	600	14,200	2,800	8,500	12.0	31.0
2000	800	15,000	3,600	9,400	15.3	34.5
2001	600	15,600	3,000	9,200	12.8	33.4
2002	700	16,300	3,700	10,000	15.5	36.6
2003	600	16,900	3,000	9,700	12.7	35.2
2004	700	17,600	3,300	10,000	13.8	36.6
2005	500	18,100	2,600	9,700	11.2	34.8
2006	500	18,700	2,600	9,700	11.3	34.7
2007	800	19,500	3,900	11,000	16.6	40.3
2008	500	20,000	2,400	10,100	10.4	36.2
2009	900	20,800	4,200	11,800	17.9	43.1
2010	700	21,500	3,500	11,600	14.7	42.3
2011	800	22,300	3,700	12,000	15.5	43.5
2012	900	23,200	4,500	13,000	18.7	47.6
2013	700	23,900	3,200	12,200	13.3	43.8
2014	1,200	25,100	5,400	14,300	22.2	52.3
2015	300	25,400	1,600	11,200	6.8	39.5
2016	400	25,800	2,100	11,000	8.6	38.4
2017	400	26,200	2,200	10,900	9.4	38.4
2018	400	26,600	1,900	10,700	8.2	37.2
2019	200	26,900	1,200	9,900	5.4	34.1
2020	400	27,300	1,900	10,300	8.3	36.0
2021	200	27,400	900	9,300	4.0	32.1
2022	600	28,100	3,100	11,200	12.9	39.9
2023	100	28,200	700	9,300	2.9	32.1
2024	800	29,000	3,800	11,900	15.8	43.0
2025	400	29,400	2,000	10,800	8.5	38.7
2026	100	29,600	700	9,300	2.9	32.5
2027	300	29,900	1,600	9,800	6.6	34.3
2028	100	30,000	300	8,500	1.4	29.1
2029	300	30,300	1,400	9,100	6.0	32.0
2030	100	30,400	300	8,000	1.3	27.8

Table 1.3 (continued)

End of calendar year	Mass,[a,b] MTIHM		Radioactivity, 10^6 Ci		Thermal power, 10^6 W	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
			Pressurized-water reactor			
1970	39	39	204	204	0.8	0.8
1971	44	83	247	296	1.0	1.2
1972	100	183	545	638	2.2	2.5
1973	67	250	374	571	1.5	2.2
1974	208	458	1,098	1,320	4.4	5.2
1975	322	780	1,683	2,098	6.7	8.2
1976	401	1,181	2,222	2,894	8.9	11.3
1977	467	1,648	2,660	3,677	10.8	14.5
1978	699	2,347	4,030	5,428	16.4	21.5
1979	721	3,068	4,185	6,254	17.1	24.7
1980	618	3,686	3,667	6,248	15.0	24.5
1981	676	4,362	4,025	6,887	16.5	26.9
1982	641	5,003	3,799	7,040	15.6	27.2
1983	773	5,776	4,592	8,080	18.8	31.2
1984	842	6,617	4,978	8,944	20.4	34.4
1985	870	7,487	5,246	9,692	21.6	37.2
1986	1,009	8,496	6,018	10,974	24.7	42.1
1987	1,120	9,616	6,721	12,299	27.6	47.2
1988	1,140	10,756	6,947	13,240	28.7	50.7
1989	1,235	11,991	7,471	14,437	30.7	55.1
1990	1,544	13,535	9,477	17,139	39.2	65.9
1991	1,308	14,844	8,101	16,984	33.6	64.8
1992	1,400	16,200	8,800	18,200	36.7	69.5
1993	1,500	17,800	9,900	20,000	41.2	76.7
1994	1,300	19,100	8,700	19,900	36.3	75.7
1995	1,400	20,500	8,900	20,600	37.2	78.1
1996	1,500	21,900	9,400	21,700	39.4	82.3
1997	1,300	23,200	8,600	21,600	36.1	81.5
1998	1,300	24,500	8,400	21,800	35.1	81.8
1999	1,400	26,000	9,400	23,300	39.5	87.4
2000	1,400	27,400	9,300	23,900	39.2	89.9
2001	1,100	28,500	7,400	22,700	31.4	84.4
2002	1,500	30,000	9,800	25,100	41.5	94.2
2003	1,200	31,200	7,800	24,100	33.0	89.5
2004	1,300	32,500	8,800	25,200	37.4	94.1
2005	1,200	33,700	7,800	24,900	33.5	92.5
2006	1,200	34,800	7,800	25,100	33.2	93.1
2007	1,100	35,900	7,400	25,000	31.8	92.9
2008	1,300	37,200	8,800	26,600	37.7	99.7
2009	1,000	38,200	6,700	25,400	29.1	94.4
2010	1,200	39,400	8,300	26,900	35.6	100.6
2011	1,100	40,500	7,600	26,800	32.8	100.4
2012	1,100	41,700	7,600	27,200	32.5	101.5
2013	1,600	43,300	10,700	30,600	45.3	115.3
2014	1,400	44,600	9,100	30,300	38.8	113.7
2015	900	45,500	5,900	27,400	25.3	101.6
2016	1,100	46,600	7,600	28,600	32.5	106.2
2017	800	47,400	5,400	26,800	23.3	98.4
2018	900	48,400	6,200	27,200	26.9	100.2
2019	800	49,100	5,100	26,200	22.2	96.2
2020	800	49,900	5,400	26,200	23.2	96.3
2021	1,100	51,000	7,400	28,200	31.6	104.8
2022	600	51,600	4,200	25,700	18.1	94.3
2023	900	52,500	6,000	26,900	25.7	99.4
2024	700	53,200	5,000	26,100	21.2	96.2
2025	900	54,100	5,700	26,700	24.3	98.6
2026	800	54,900	5,400	26,600	23.3	98.2
2027	700	55,600	4,600	25,700	19.3	94.6
2028	600	56,200	4,100	25,000	17.4	91.6
2029	600	56,800	4,200	24,800	17.9	91.0
2030	500	57,400	3,600	24,000	15.3	87.9

Table 1.3 (continued)

End of calendar year	Mass,[a,b] MTIHM		Radioactivity, 10^6 Ci		Thermal power, 10^6 W	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
			Total			
1968-1970		55		215		0.8
1971	108	163	438	492	1.7	1.9
1972	241	405	976	1,104	3.9	4.3
1973	162	567	724	1,013	2.9	3.9
1974	452	1,020	2,006	2,363	7.9	9.2
1975	547	1,567	2,603	3,317	10.3	12.9
1976	698	2,265	3,372	4,474	13.4	17.4
1977	850	3,115	4,225	5,805	17.0	22.6
1978	1,082	4,197	5,648	7,840	22.9	30.8
1979	1,121	5,318	5,920	8,982	24.1	35.2
1980	1,238	6,556	6,351	10,136	26.0	39.6
1981	1,135	7,691	6,039	10,551	24.7	40.9
1982	998	8,689	5,381	10,402	22.1	39.8
1983	1,264	9,953	6,811	12,095	28.0	46.3
1984	1,340	11,292	7,188	13,227	29.4	50.4
1985	1,384	12,677	7,491	14,210	30.7	54.0
1986	1,467	14,144	7,981	15,377	32.7	58.1
1987	1,819	15,963	9,640	17,709	39.4	67.0
1988	1,676	17,639	9,310	18,417	38.3	69.6
1989	1,950	19,589	10,562	20,474	43.3	77.3
1990	2,177	21,766	12,298	23,239	50.7	88.2
1991	1,915	23,681	10,872	23,245	45.0	87.6
1992	2,200	25,900	12,500	25,600	51.8	96.7
1993	2,200	28,100	13,200	27,500	55.1	104.4
1994	1,900	30,000	11,300	27,000	47.6	101.8
1995	2,200	32,200	12,700	29,000	53.3	109.2
1996	2,100	34,300	12,500	29,900	52.5	112.2
1997	1,900	36,200	11,500	29,700	48.2	111.0
1998	2,000	38,200	11,800	30,600	49.5	114.0
1999	2,000	40,200	12,200	31,800	51.5	118.4
2000	2,200	42,400	12,900	33,300	54.5	124.4
2001	1,700	44,100	10,400	31,900	44.2	117.9
2002	2,200	46,400	13,500	35,100	57.0	130.8
2003	1,800	48,100	10,800	33,700	45.7	124.6
2004	2,000	50,100	12,100	35,300	51.3	130.6
2005	1,700	51,800	10,500	34,500	44.7	127.3
2006	1,700	53,500	10,400	34,700	44.5	127.9
2007	1,900	55,400	11,300	36,000	48.5	133.2
2008	1,800	57,200	11,200	36,700	48.1	135.9
2009	1,900	59,000	11,000	37,100	47.0	137.5
2010	1,900	61,000	11,800	38,500	50.3	142.8
2011	1,900	62,800	11,200	38,800	48.3	143.9
2012	2,100	64,900	12,100	40,200	51.2	149.1
2013	2,300	67,200	13,900	42,800	58.6	159.1
2014	2,500	69,700	14,500	44,600	61.1	166.0
2015	1,200	70,900	7,400	38,700	32.1	141.1
2016	1,600	72,400	9,600	39,600	41.1	144.6
2017	1,200	73,700	7,600	37,700	32.7	136.8
2018	1,300	75,000	8,200	37,800	35.1	137.5
2019	1,000	76,000	6,400	36,100	27.6	130.3
2020	1,200	77,200	7,300	36,500	31.5	132.3
2021	1,300	78,400	8,300	37,500	35.5	137.0
2022	1,300	79,700	7,300	36,900	31.0	134.2
2023	1,000	80,700	6,700	36,200	28.7	131.5
2024	1,500	82,200	8,800	38,000	37.0	139.2
2025	1,300	83,500	7,800	37,600	32.8	137.3
2026	900	84,500	6,100	35,900	26.2	130.7
2027	1,000	85,500	6,200	35,500	25.9	128.9
2028	700	86,200	4,400	33,400	18.8	120.7
2029	900	87,100	5,700	33,900	23.9	123.1
2030	600	87,700	3,900	32,100	16.5	115.7

[a]Ref. 1 (1968-1991).
[b]Ref. 3 (1992-2030). Assumes no future reprocessing.

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

End of calendar year	Mass,[a,b] MTIHM		Radioactivity, 10^6 Ci		Thermal power, 10^6 W	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
			Boiling-water reactor			
1968-1970		16		11		0.0
1971	64	80	190	197	0.7	0.8
1972	142	222	431	466	1.7	1.8
1973	95	317	350	442	1.4	1.7
1974	245	561	908	1,043	3.6	4.0
1975	226	787	921	1,218	3.7	4.7
1976	297	1,084	1,150	1,580	4.5	6.1
1977	383	1,467	1,566	2,129	6.2	8.2
1978	383	1,850	1,618	2,412	6.5	9.3
1979	400	2,250	1,734	2,728	7.1	10.5
1980	620	2,870	2,685	3,888	10.9	15.1
1981	459	3,329	2,014	3,664	8.2	14.0
1982	357	3,686	1,582	3,362	6.5	12.6
1983	491	4,177	2,218	4,015	9.1	15.1
1984	498	4,675	2,211	4,283	9.0	16.0
1985	515	5,190	2,245	4,518	9.1	16.7
1986	458	5,648	1,963	4,403	8.0	16.0
1987	699	6,347	2,919	5,410	11.7	19.8
1988	536	6,883	2,363	5,177	9.7	18.8
1989	715	7,598	3,090	6,038	12.6	22.1
1990	633	8,231	2,821	6,100	11.6	22.3
1991	606	8,837	2,771	6,261	11.4	22.8
1992	800	9,600	3,600	7,300	15.1	27.1
1993	700	10,300	3,300	7,500	13.8	27.7
1994	600	10,900	2,700	7,200	11.2	26.1
1995	800	11,700	3,700	8,200	15.4	30.3
1996	700	12,300	3,300	8,300	13.8	30.5
1997	600	12,900	2,900	8,100	12.1	29.6
1998	700	13,600	3,400	8,800	14.4	32.2
1999	500	14,100	2,400	8,100	10.3	29.3
2000	800	15,000	4,000	9,700	17.0	35.6
2001	600	15,600	2,800	9,100	12.1	33.0
2002	700	16,300	3,600	9,800	15.1	36.0
2003	600	16,900	2,900	9,500	12.4	34.6
2004	700	17,600	3,400	10,200	14.6	37.1
2005	500	18,100	2,600	9,700	11.3	34.9
2006	500	18,600	2,500	9,500	10.8	34.2
2007	900	19,500	4,200	11,200	17.8	41.3
2008	500	19,900	2,300	10,000	9.9	36.0
2009	900	20,800	4,400	11,900	18.5	43.6
2010	600	21,400	2,700	10,900	11.6	39.3
2011	700	22,100	3,400	11,500	14.5	41.6
2012	900	22,900	4,200	12,500	17.6	45.7
2013	700	23,700	3,500	12,300	14.7	44.5
2014	1,100	24,800	5,300	14,200	22.0	52.1
2015	400	25,100	1,800	11,300	7.5	40.2
2016	600	25,800	3,100	12,000	12.9	42.9
2017	500	26,300	2,400	11,400	10.0	40.5
2018	700	27,000	3,500	12,500	15.0	44.9
2019	400	27,400	2,100	11,400	8.8	40.3
2020	700	28,100	3,500	12,500	14.7	45.2
2021	400	28,500	2,000	11,400	8.7	40.8
2022	600	29,100	3,000	12,200	13.0	44.1
2023	600	29,700	2,900	12,300	12.4	44.7
2024	800	30,500	4,000	13,600	16.9	49.9
2025	600	31,100	2,900	13,000	12.5	47.3
2026	500	31,600	2,400	12,500	10.4	45.1
2027	600	32,200	3,200	13,100	13.6	47.9
2028	400	32,600	1,900	12,100	8.4	43.6
2029	600	33,200	2,900	12,800	12.3	46.6
2030	500	33,600	2,200	12,300	9.5	44.7

Table 1.4 (continued)

End of calendar year	Mass,[a,b] MTIHM		Radioactivity, 10^6 Ci		Thermal power, 10^6 W	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
			Pressurized-water reactor			
1970	39	39	204	204	0.8	0.8
1971	44	83	247	296	1.0	1.2
1972	100	183	545	638	2.2	2.5
1973	67	250	374	571	1.5	2.2
1974	208	458	1,098	1,320	4.4	5.2
1975	322	780	1,683	2,098	6.7	8.2
1976	401	1,181	2,222	2,894	8.9	11.3
1977	467	1,648	2,660	3,677	10.8	14.5
1978	699	2,347	4,030	5,428	16.4	21.5
1979	721	3,068	4,185	6,254	17.1	24.7
1980	618	3,686	3,667	6,248	15.0	24.5
1981	676	4,362	4,025	6,887	16.5	26.9
1982	641	5,003	3,799	7,040	15.6	27.2
1983	773	5,776	4,592	8,080	18.8	31.2
1984	842	6,617	4,978	8,944	20.4	34.4
1985	870	7,487	5,246	9,692	21.6	37.2
1986	1,009	8,496	6,018	10,974	24.7	42.1
1987	1,120	9,616	6,721	12,299	27.6	47.2
1988	1,140	10,756	6,947	13,240	28.7	50.7
1989	1,235	11,991	7,471	14,437	30.7	55.1
1990	1,544	13,535	9,477	17,139	39.2	65.9
1991	1,308	14,844	8,101	16,984	33.6	64.8
1992	1,400	16,200	8,800	18,200	36.7	69.5
1993	1,500	17,800	9,900	20,000	41.2	76.7
1994	1,300	19,100	8,700	19,900	36.3	75.7
1995	1,400	20,500	8,900	20,600	37.2	78.1
1996	1,500	21,900	9,400	21,700	39.4	82.3
1997	1,300	23,200	8,500	21,600	35.8	81.2
1998	1,300	24,500	8,400	21,900	35.3	82.0
1999	1,400	26,000	9,400	23,200	39.3	87.3
2000	1,300	27,300	8,700	23,300	36.5	87.1
2001	1,300	28,600	8,700	23,800	36.8	88.9
2002	1,500	30,100	9,700	25,200	40.8	94.6
2003	1,200	31,300	8,000	24,400	33.9	90.7
2004	1,400	32,700	9,500	26,100	40.5	97.5
2005	1,100	33,900	7,700	25,000	32.7	93.0
2006	1,200	35,100	8,400	25,800	35.8	96.2
2007	1,200	36,300	7,900	25,800	33.8	96.1
2008	1,300	37,600	8,800	27,000	37.9	101.3
2009	1,000	38,600	7,000	26,000	30.3	96.6
2010	1,200	39,900	8,400	27,400	36.1	102.3
2011	1,100	41,000	7,700	27,200	33.2	101.9
2012	1,200	42,100	7,800	27,700	33.6	103.6
2013	1,400	43,600	9,600	29,800	40.8	112.1
2014	1,500	45,100	10,300	31,500	44.1	118.8
2015	1,300	46,400	8,600	30,600	36.6	114.9
2016	1,700	48,100	11,200	33,400	47.7	126.2
2017	1,400	49,400	9,400	32,700	40.1	123.2
2018	1,400	50,800	9,500	33,000	40.6	124.5
2019	1,600	52,400	10,700	34,700	46.2	131.6
2020	1,100	53,500	7,500	32,300	32.0	121.2
2021	1,700	55,200	11,200	35,700	48.1	135.2
2022	1,500	56,700	10,100	35,800	43.4	135.3
2023	1,300	58,000	9,000	35,200	38.9	132.6
2024	1,600	59,600	10,900	37,200	46.7	140.8
2025	1,800	61,500	12,300	39,400	52.7	150.1
2026	1,400	62,900	9,500	37,700	40.8	142.8
2027	1,600	64,500	10,800	38,900	46.2	147.6
2028	1,800	66,200	12,100	40,900	52.0	155.7
2029	1,700	67,900	11,300	40,900	48.1	155.7
2030	1,700	69,600	11,600	41,800	49.7	158.8

Table 1.4 (continued)

End of calendar year	Mass,[a,b] MTIHM		Radioactivity, 10^6 Ci		Thermal power, 10^6 W	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
			Total			
1968-1970		55		215		0.8
1971	108	163	438	492	1.7	1.9
1972	241	405	976	1,104	3.9	4.3
1973	162	567	724	1,013	2.9	3.9
1974	452	1,020	2,006	2,363	7.9	9.2
1975	547	1,567	2,603	3,317	10.3	12.9
1976	698	2,265	3,372	4,474	13.4	17.4
1977	850	3,115	4,225	5,805	17.0	22.6
1978	1,082	4,197	5,648	7,840	22.9	30.8
1979	1,121	5,318	5,920	8,982	24.1	35.2
1980	1,238	6,556	6,351	10,136	26.0	39.6
1981	1,135	7,691	6,039	10,551	24.7	40.9
1982	998	8,689	5,381	10,402	22.1	39.8
1983	1,264	9,953	6,811	12,095	28.0	46.3
1984	1,340	11,292	7,188	13,227	29.4	50.4
1985	1,384	12,677	7,491	14,210	30.7	54.0
1986	1,467	14,144	7,981	15,377	32.7	58.1
1987	1,819	15,963	9,640	17,709	39.4	67.0
1988	1,676	17,639	9,310	18,417	38.3	69.6
1989	1,950	19,589	10,562	20,474	43.3	77.3
1990	2,177	21,766	12,298	23,239	50.7	88.2
1991	1,915	23,681	10,872	23,245	45.0	87.6
1992	2,200	25,900	12,500	25,600	51.8	96.7
1993	2,200	28,100	13,200	27,500	55.1	104.4
1994	1,900	30,000	11,300	27,000	47.6	101.8
1995	2,100	32,100	12,500	28,800	52.6	108.4
1996	2,100	34,300	12,700	30,000	53.2	112.7
1997	1,900	36,200	11,400	29,700	47.9	110.9
1998	2,000	38,200	11,800	30,600	49.8	114.2
1999	1,900	40,100	11,800	31,400	49.6	116.6
2000	2,200	42,300	12,700	33,000	53.4	122.7
2001	1,900	44,200	11,600	32,900	48.9	121.8
2002	2,200	46,400	13,200	35,100	56.0	130.7
2003	1,800	48,200	10,900	33,900	46.3	125.3
2004	2,100	50,300	13,000	36,200	55.1	134.6
2005	1,700	52,000	10,300	34,700	44.0	127.9
2006	1,700	53,700	10,900	35,300	46.6	130.4
2007	2,000	55,800	12,100	37,100	51.7	137.4
2008	1,800	57,500	11,100	37,000	47.8	137.3
2009	1,900	59,400	11,400	37,800	48.7	140.3
2010	1,800	61,200	11,200	38,300	47.7	141.7
2011	1,800	63,100	11,100	38,700	47.7	143.6
2012	2,000	65,100	12,000	40,200	51.1	149.3
2013	2,200	67,200	13,100	42,100	55.5	156.6
2014	2,700	69,900	15,600	45,600	66.1	170.8
2015	1,600	71,500	10,300	42,000	44.1	155.1
2016	2,300	73,800	14,200	45,400	60.6	169.1
2017	1,900	75,700	11,700	44,100	50.1	163.6
2018	2,100	77,800	13,000	45,500	55.5	169.5
2019	2,000	79,800	12,800	46,100	55.0	171.9
2020	1,800	81,600	10,900	44,900	46.7	166.4
2021	2,100	83,700	13,300	47,200	56.8	176.0
2022	2,100	85,800	13,200	48,000	56.3	179.4
2023	1,900	87,700	11,900	47,500	51.3	177.3
2024	2,400	90,100	14,900	50,700	63.7	190.6
2025	2,400	92,600	15,200	52,400	65.2	197.4
2026	1,900	94,400	11,900	50,200	51.2	187.9
2027	2,200	96,700	14,000	52,000	59.7	195.5
2028	2,200	98,800	14,100	52,900	60.4	199.3
2029	2,200	101,100	14,100	53,700	60.4	202.2
2030	2,200	103,200	13,900	54,100	59.1	203.5

[a]Ref. 1 (1968-1991).
[b]Ref. 3 (1992-2030). Assumes no future reprocessing.

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

End of calendar year	BWR		PWR		Total	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1991[a]	3,357	48,670	2,993	34,717	6,350	83,387
1992[b]	4,400	53,100	3,300	38,000	7,700	91,100
1993	4,000	57,100	3,500	41,500	7,500	98,600
1994	3,200	60,200	3,100	44,600	6,300	104,800
1995	4,500	64,700	3,200	47,800	7,700	112,500
1996	3,600	68,300	3,400	51,200	7,000	119,500
1997	3,400	71,700	3,000	54,200	6,400	125,900
1998	4,000	75,700	3,000	57,200	7,000	132,900
1999	3,300	78,900	3,400	60,600	6,600	139,500
2000	4,200	83,100	3,300	63,900	7,500	147,000
2001	3,500	86,600	2,600	66,500	6,100	153,100
2002	4,200	90,800	3,500	70,000	7,700	160,800
2003	3,400	94,200	2,700	72,700	6,100	166,900
2004	3,700	97,900	3,000	75,800	6,800	173,600
2005	3,000	100,900	2,700	78,500	5,700	179,400
2006	3,000	103,900	2,700	81,200	5,700	185,000
2007	4,500	108,300	2,600	83,700	7,000	192,100
2008	2,700	111,100	3,000	86,700	5,700	197,800
2009	4,900	116,000	2,300	89,000	7,200	205,000
2010	4,100	120,000	2,800	91,900	6,900	211,900
2011	4,300	124,300	2,600	94,400	6,900	218,800
2012	5,300	129,600	2,600	97,000	7,900	226,700
2013	3,700	133,300	3,700	100,800	7,400	234,000
2014	6,500	139,800	3,100	103,900	9,600	243,600
2015	1,700	141,500	2,000	105,900	3,700	247,300
2016	2,400	143,900	2,600	108,500	5,000	252,300
2017	2,400	146,300	1,800	110,300	4,200	256,600
2018	2,200	148,500	2,200	112,500	4,400	260,900
2019	1,400	149,800	1,800	114,200	3,100	264,100
2020	2,200	152,000	1,800	116,100	4,000	268,000
2021	1,000	153,000	2,500	118,600	3,500	271,500
2022	3,600	156,600	1,500	120,100	5,100	276,600
2023	800	157,300	2,100	122,100	2,800	279,500
2024	4,500	161,900	1,700	123,800	6,200	285,700
2025	2,400	164,200	2,100	125,900	4,400	290,100
2026	700	165,000	1,900	127,700	2,600	292,700
2027	2,000	166,900	1,600	129,400	3,600	296,300
2028	400	167,300	1,400	130,700	1,700	298,000
2029	1,700	169,000	1,400	132,200	3,100	301,100
2030	300	169,300	1,300	133,500	1,600	302,800

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

[b]Data for years 1992-2030 are based on 102.5 GW(e) installed in the year 2000 and 30.0 GW(e) installed in the year 2030 (ref. 3). Number of projected fuel assemblies reported has been rounded to the nearest 100.

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

End of calendar year	BWR		PWR		Total	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1991[a]	3,357	48,670	2,993	34,717	6,350	83,387
1992[b]	4,400	53,100	3,300	38,000	7,700	91,100
1993	4,000	57,100	3,500	41,500	7,500	98,600
1994	3,200	60,200	3,100	44,600	6,300	104,800
1995	4,300	64,500	3,200	47,800	7,500	112,300
1996	3,800	68,300	3,400	51,200	7,200	119,500
1997	3,400	71,700	3,000	54,200	6,400	125,900
1998	4,000	75,700	3,000	57,200	7,000	132,900
1999	2,800	78,500	3,400	60,600	6,200	139,100
2000	4,700	83,100	3,100	63,600	7,700	146,800
2001	3,300	86,400	3,000	66,700	6,300	153,100
2002	4,100	90,500	3,400	70,100	7,500	160,600
2003	3,300	93,800	2,800	73,000	6,100	166,700
2004	3,900	97,700	3,300	76,200	7,200	173,900
2005	3,000	100,700	2,700	78,900	5,700	179,600
2006	2,900	103,600	2,900	81,800	5,700	185,300
2007	4,800	108,300	2,700	84,500	7,500	192,900
2008	2,600	110,900	3,000	87,500	5,600	198,500
2009	5,000	116,000	2,400	89,900	7,400	205,900
2010	3,200	119,200	2,900	92,800	6,100	212,000
2011	3,800	123,000	2,600	95,400	6,500	218,400
2012	4,900	127,900	2,700	98,100	7,600	226,000
2013	4,100	132,000	3,300	101,400	7,400	233,400
2014	6,200	138,200	3,600	104,900	9,800	243,200
2015	2,000	140,200	2,900	107,900	4,900	248,100
2016	3,500	143,800	3,800	111,700	7,300	255,400
2017	2,700	146,500	3,200	114,800	5,900	261,300
2018	4,000	150,500	3,300	118,100	7,300	268,600
2019	2,400	152,900	3,600	121,700	6,100	274,600
2020	3,900	156,800	2,600	124,300	6,500	281,100
2021	2,200	159,100	3,800	128,000	6,000	287,100
2022	3,400	162,500	3,500	131,500	6,900	294,000
2023	3,200	165,700	3,000	134,600	6,200	300,200
2024	4,600	170,300	3,700	138,300	8,300	308,600
2025	3,300	173,500	4,200	142,500	7,500	316,000
2026	2,700	176,200	3,200	145,700	5,900	321,900
2027	3,500	179,700	3,700	149,400	7,200	329,200
2028	2,200	181,900	4,100	153,500	6,200	335,400
2029	3,200	185,000	3,800	157,300	7,000	342,300
2030	2,500	187,600	4,000	161,300	6,500	348,800

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

[b]Data for years 1992-2030 are based on 103.7 GW(e) installed in the year 2000 and 121.3 GW(e) installed in the year 2030 (ref. 3). Number of projected fuel assemblies reported has been rounded to the nearest 100.

Table 1.7. Historical and projected spent fuel discharged from the Fort St. Vrain HTGR[a]

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

[a]Based on ref. 7.

[b]This refueling replaced 246 spent fuel elements made up of 240 standard fuel elements and 6 fuel test elements.

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

[d]Fuel removed from the core in 1989 and 1990 remains on-site in temporary storage wells until shipment to ICPP can be accomplished or transfer to an on-site independent spent fuel storage installation is complete.

[e]In 1991, 18 discharged spent fuel elements were shipped to ICPP and 18 elements were transferred to an on-site independent spent fuel storage installation. The remaining 6 spent fuel elements discharged in 1991 are located in on-site temporary storage wells.

Table 1.8. IDB reference characteristics of LWR fuel assemblies

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

[a]Ref. 8.

[b]Ref. 9.

[c]Includes Zircaloy fuel-rod spacers and fuel channel.

[d]Includes Zircaloy control-rod guide thimbles.

[e]Includes stainless steel tie-plates, Inconel springs, and plenum springs.

[f]Includes stainless steel nozzles and Inconel-718 grids.

[g]Based on overall outside dimension. Includes spacing between the stacked fuel rods of an assembly.

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

End of calendar year	Annual mass of discharged spent fuel for various burnup ranges, MTIHM									Total annual mass over all burnup ranges (MTIHM)
	0-4,999[c]	5,000-9,999	10,000-14,999	15,000-19,999	20,000-24,999	25,000-29,999	30,000-34,999	35,000-39,999	40,000-44,999	
1968	0.6									0.6
1969		1.2	1.0	7.3	0.2	0.1				9.8
1970	5.6									5.6
1971	41.5	8.1	2.8	10.0	1.6					64.0
1972	97.9	12.1	27.6	4.0						141.5
1973	9.7	16.5	31.0	36.4	1.5	0.1				95.2
1974		78.4	117.7	44.7	3.8					244.6
1975	0.3	1.7	62.0	136.5	25.3					225.7
1976	0.9	67.1	108.7	118.2	2.3					297.1
1977		48.0	40.3	235.0	58.9	0.7				382.9
1978	6.3	32.4	13.1	84.2	232.0	15.2				383.2
1979			18.6	108.7	149.2	123.1	0.3			399.8
1980	14.0	0.4	0.6	93.3	413.3	87.6	10.7			619.9
1981		0.2	0.2	58.1	265.4	133.3	0.7	0.7		458.7
1982		0.2	4.6	25.6	138.5	173.6	13.8	0.6	0.4	357.2
1983			0.9	2.9	113.5	337.8	35.7	0.4		491.3
1984		7.9	43.0	0.3	136.2	239.5	70.8		0.4	498.0
1985	16.9	42.5	18.3	35.8	93.2	297.4	10.2		0.2	514.6
1986	50.8	32.4	42.5	66.6	43.1	180.7	41.7	0.4		458.2
1987	133.5	36.1	68.8	40.8	24.7	352.4	42.9		0.4	699.4
1988	17.0	24.5	1.8	42.9	168.3	192.4	88.7			535.6
1989	30.9	16.9	85.3	71.8	193.2	227.7	85.5	3.6		714.9
1990	17.0		34.0	67.7	106.1	247.5	158.9	1.6		632.8
1991	17.8	24.6		10.8	36.3	235.7	268.7	12.1		606.1

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

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

End of calendar year	Annual mass of discharged spent fuel for various burnup ranges, MTIHM												Total annual mass over all burnup ranges (MTIHM)
	0-4,999[c]	5,000-9,999	10,000-14,999	15,000-19,999	20,000-24,999	25,000-29,999	30,000-34,999	35,000-39,999	40,000-44,999	45,000-49,999	50,000-54,999	55,000-59,999	
1970			1.7	37.3									39.0
1971		4.6			6.2	33.7							44.5
1972			11.9	29.3	27.8	8.9	22.1						99.9
1973				26.2		33.3	7.6						67.1
1974	7.4	1.5	86.4	13.6	40.5	57.2	1.1						207.7
1975	2.7	42.6	95.0	53.6	79.4	25.3	23.1						321.8
1976			5.6	194.2	82.4	63.3	55.4						401.0
1977			2.8	108.3	115.9	137.5	87.1	15.4					466.9
1978		1.4	47.9	89.8	39.6	336.9	122.7	60.4	0.4				699.0
1979			30.6	109.4	64.0	232.3	234.3	50.1	0.5				721.2
1980			0.4		67.7	240.9	280.6	26.3	2.0				618.1
1981			17.2	1.9	25.8	228.5	350.2	51.0	1.3				675.9
1982			1.8	81.1	80.9	62.8	291.6	117.4	2.7	0.4	1.3	0.9	640.9
1983		5.5	4.5	80.6	44.2	176.4	321.2	134.6	5.4		0.5		772.7
1984			58.0	45.2	56.3	198.4	376.2	103.5	4.1				841.7
1985				49.4	13.6	224.4	318.6	239.4	24.1	0.4			869.8
1986		0.8	27.6	132.0	19.3	180.2	340.0	271.7	35.0	1.3	1.3		1,009.1
1987			27.2	78.1	53.4	175.7	423.6	309.9	51.8				1,119.6
1988				93.6	15.0	140.0	353.6	427.7	103.1	4.6	0.4	2.0	1,140.2
1989			48.5	93.2	68.6	112.1	290.8	417.3	189.3	15.2		0.4	1,235.5
1990			24.0	85.2	26.6	129.3	398.2	627.5	245.7	7.0	0.3		1,543.9
1991		10.6	53.2	1.4	86.5	62.2	163.5	618.2	245.1	64.2	3.4		1,308.4

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

ORNL PHOTO 6891-92

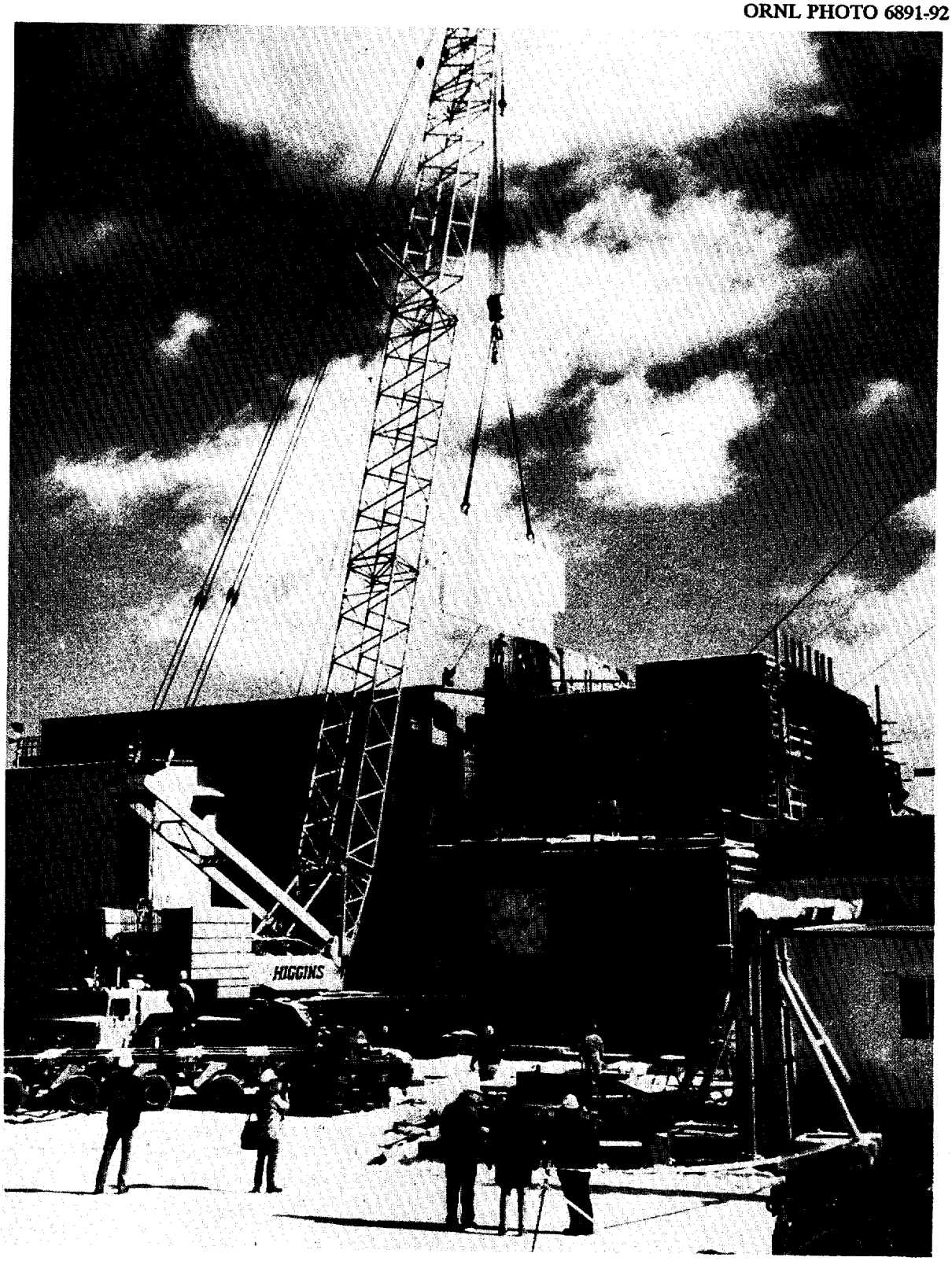

Photo 2.1. Construction of the West Valley Demonstration Project vitrification facility that will incorporate West Valley high-level waste into a glass. (Courtesy of the DOE West Valley Project Office, West Valley, New York.)

2. HIGH-LEVEL WASTE

2.1 INTRODUCTION

High-level waste (HLW), which is generated by the reprocessing of spent reactor fuel and irradiated targets, generally contains more than 99% of the nonvolatile fission products produced in the fuel or targets during reactor and plutonium contains approximately 0.5% of these elements, while the HLW from a facility that recovers only uranium contains approximately 0.5% of the uranium and essentially all of the plutonium. Most of the present U.S. inventory of HLW is the result of DOE activities and is stored at the Savannah River Site (SRS), Idaho National Engineering Laboratory (INEL) [at the Idaho Chemical Processing Plant (ICPP)], and Hanford Site (HANF). A small amount of commercial HLW was generated at the Nuclear Fuel Services (NFS) Plant near West Valley, New York, during 1966–1972. That facility (located on land leased from the state of New York) is now referred to as the West Valley Demonstration Project (WVDP) and is the responsibility of the DOE Field Office, Idaho, West Valley Project Office. West Valley Nuclear Services, Inc. (a subsidiary of Westinghouse Electric Corporation), is the prime contractor and site operator. The prime contractor and site operator for HLW at SRS is Westinghouse Savannah River Company; for INEL (the ICPP) is Westinghouse Idaho Nuclear Company, Inc.; and for HANF is Westinghouse Hanford Company (all subsidiaries of Westinghouse Electric Corporation). The historical/projected HLW inventories presented here (except for HLW solidified in glass or glass/ceramic forms) are for wastes in interim storage. These wastes have already undergone one or more treatment steps (e.g., neutralization, precipitation, decantation, or evaporation) and are not as generated. Their volumes depend strongly on the steps to which they are subjected. Most of these wastes will require incorporation into a stable, solid medium (e.g., glass) for final disposal. Data on the volume, radioactivity, distribution, and location of HLW (through 1991) are shown in Figs. 2.1–2.4. Present (and projected) HLW operations at these sites are depicted in Figs. 2.5–2.8.

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

At SRS (Fig. 2.5) and HANF (Fig. 2.7), the acidic liquid waste from reprocessing production reactor fuel has been made alkaline with caustic soda and stored in tanks. During storage, these alkaline wastes separate into two phases: liquid and sludge. When the liquid phase is volume reduced by evaporation, a third phase, called salt cake, is formed in those tanks holding evaporator concentrates (see Fig. 2.5). The relative proportions of liquid and salt cake depend upon how much water is removed by waste evaporators during interim waste management operations. The condensed water at HANF is sent to a double-lined surface impoundment. At SRS (Fig. 2.5), the condensate is sent to the Effluent Treatment Facility where it is treated and discharged to the environment. Also at SRS (Fig. C.10 in Appendix C), the processing of salt cake for future glassmaking generates a waste called precipitate. At HANF, all the wastes contained in double-shell tanks consist of mixtures of HLW, TRU waste, and several LLWs (Fig. 2.7), which have unique rheological properties and are referred to as slurry. In HANF storage practice, the double-shell tanks are managed as if they contain HLW. Thus, their contents are included in the HLW inventory.

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

The historical and projected inventories of HLW that is stored in tanks, bins, and capsules are presented in Table 2.1. Projected inventories of HLW that is incorporated into glass or glass/ceramic are given in Table 2.2. A year-by-year estimate of the number of HLW canisters, by source, is presented in Table 2.3. An estimate of DOE HLW canister totals, as required for repository program planning, is presented in Table 2.4. The volume and radioactivity of HLW in storage at the end of 1991 are given in Tables 2.5 and Table 2.6, respectively. Historical and projected volume, radioactivity, and thermal power

data for DOE and commercial HLW are given in Tables 2.7–2.9. The data for DOE sites represent a summary of information obtained from each of the sites.[1-3] The information on commercial HLW at WVDP was taken largely from data given in ref. 4.

2.2 INVENTORIES

Inventories of HLW at the various DOE sites and the WVDP through 1991 are presented in this section. Significant changes affecting HLW inventories are shown in Table 2.10.

2.2.1 HLW Inventories at SRS (DOE)

Approximately 127,900 m^3 of alkaline HLW that has accumulated at the SRS during the past several (about 4) decades is being stored in underground, high-integrity, double-walled, carbon steel tanks. The current inventories (Tables 2.5 and 2.6) include alkaline liquid (57,200 m^3), sludge (14,500 m^3), salt cake (55,700 m^3), and precipitate (545 m^3) that were generated primarily by the PUREX reprocessing of nuclear fuels and targets from production reactors. Most of the waste, as generated, is acidic liquid, and the sludge is formed during subsequent treatment with caustic and during aging. Salt cake results when the supernatant liquor is concentrated in evaporators. Precipitate results when salt cake is treated by the in-tank precipitation process.

2.2.2 HLW Inventories at INEL (DOE)

The 10,400 m^3 of HLW stored at INEL (at the ICPP) consists of 6,800 m^3 of liquid waste and 3,600 m^3 of calcine (Tables 2.5 and 2.6). Liquid HLW is generated at ICPP primarily by the reprocessing of spent fuel from naval propulsion nuclear reactors and reactor testing programs; a small amount is generated by reprocessing fuel from research reactors. This acidic liquid waste is stored in underground stainless steel tanks that are housed in concrete vaults. The waste is then converted to a calcine and stored retrievably in stainless steel bins that are housed in reinforced concrete vaults.

2.2.3 HLW Inventories at HANF (DOE)

The 256,500 m^3 of alkaline HLW stored at HANF is categorized as liquid (25,500 m^3), sludge (46,000 m^3), and salt cake (93,000 m^3) that are stored in single-shell tanks and as slurry (92,000 m^3) that is stored in double-shell tanks. This waste, which has been accumulating since 1944, was generated by the reprocessing of production reactor fuel for the recovery of plutonium, uranium, and neptunium for defense and other national programs. Most of the high-heat-emitting nuclides (^{90}Sr and ^{137}Cs, plus their daughters) were removed from the old waste, converted to solids (strontium fluoride and cesium chloride), placed in double-walled capsules, and stored in a water basin. At present, 1,338 cesium capsules (2.47 m^3) and 605 strontium capsules (1.08 m^3) require storage. The liquid, sludge, salt-cake, and slurry wastes are stored in underground concrete tanks with carbon steel liners. Current inventories of these wastes at HANF are listed in Tables 2.5 and 2.6.

2.2.4 HLW Inventories at WVDP (Commercial)

Reprocessing at the NFS plant was terminated in 1972, and no additional HLW has been generated since that time. As of December 31, 1991, the 1,729 m^3 of HLW stored at WVDP consists of 1,632 m^3 of alkaline waste (1,575 m^3 of liquid plus 57 m^3 of sludge), 45 m^3 of acidic waste, and 52 m^3 of an inorganic ion-exchange material (a zeolite) loaded with radioactive cesium (^{134}Cs, ^{135}Cs, and ^{137}Cs). The alkaline waste was generated by reprocessing commercial and Hanford N-Reactor spent fuels. As generated, the waste was acidic; treatment with excess sodium hydroxide resulted in the formation of an alkaline sludge. The small amount of acidic waste now in storage was generated by reprocessing a batch of thorium-uranium fuel from the Indian Point-1 Reactor. Storage for the alkaline waste is in an underground carbon steel tank, while the acidic waste is stored in an underground stainless steel tank.

In May 1988, the processing of high-level alkaline liquid waste started at the WVDP. This liquid is being 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, a batch process that utilizes ion exchange is employed to remove cesium from alkaline liquid waste, as depicted in Fig. 2.8. The ion-exchange columns are located in the underground carbon steel tank originally installed as a backup tank for alkaline HLW. When the liquid has been processed, the sludge in the bottom of the tank will be washed. The washed sludge, acidic waste, and loaded zeolite will be combined and incorporated into a glass. The current inventories of HLW at WVDP are presented in Tables 2.5 and 2.6.

2.3 WASTE CHARACTERIZATION

A generic characterization of HLW at any site is difficult, since over the years several different flowsheets have been used for the processes that generated the wastes and several methods have been employed to prepare the wastes for storage (e.g., evaporation and precipitation). In some instances, various types of wastes have been blended. However, representative data on chemical and radionuclide compositions are given in Tables 2.11–2.21 for current and projected HLW at SRS, ICPP, HANF, and WVDP. The

information used to construct these tables was taken from refs. 1–4, as well as from the references cited in the footnotes to the tables.

2.4 PROJECTIONS

Projected inventories (volume, radioactivity, and thermal power) for HLW are presented in Tables 2.7–2.9. These projections were generated by each site (based on the assumptions given below) and should be considered only as current best estimates. An estimate by each site[1-4] of a potential number of canisters of solidified HLW is shown in Table 2.3.

The HLW projections for SRS are based on the assumption that (1) one reactor will be operating during 1992 and will continue operating through 2007; (2) the irradiated (spent) fuel from this reactor will be reprocessed; and (3) the Defense Waste Processing Facility (DWPF) will begin to produce a glass waste form (see flowsheet in Fig. C.10 of Appendix C) in 1993, following the schedule shown in Table 2.3. The HLW glass will be stored on-site until a national repository[5-7] becomes available. Current plans call for the DWPF to produce 5,242 canisters of glass between 1993 and the end of 2010.

The HLW projections for ICPP are based on predictions of fuel delivery and estimates of continued operation of fuel reprocessing and waste management through 2030. A facility to immobilize newly generated HLW at ICPP is planned for operation by the early part of the next century.[8] It will also be able to process the stored calcine. Evaluations of waste immobilization processes are continuing at ICPP, with the identification of a reference waste form (glass, glass/ceramic, etc.) and process scheduled for completion in the 1990s. The projections of HLW presented in Tables 2.7–2.9 for ICPP are based on waste immobilization in a glass/ceramic form.

The HLW projections for HANF are based on the assumption that (1) the fuel reprocessing plant is not restarted and (2) the irradiated fuel remains in wet storage. A Hanford Waste Vitrification Plant (HWVP) is to begin operation in 1999.[8-9] The planned operations for the HWVP are discussed in the Hanford Defense Waste Environmental Impact Statement.[10] Estimates of the number of canisters of HLW incorporated in borosilicate glass that might be generated annually by the HWVP are given in Table 2.3. The projections of HLW given in Tables 2.7–2.9 for HANF do not include vitrification, since material balances for such processes are not yet available.

The cost for the disposal of DOE HLW in a national repository will be paid by DOE into the Nuclear Waste Fund. Reference 11 states that the number of canisters used in the estimates of this cost will be published in the IDB. Consequently, projections of the potential total number of DOE HLW canisters from SRS, ICPP, and HANF are presented in Table 2.4. Table 2.3 includes potential production schedules for canisters, which are not used in disposal cost estimates. Table 2.4 shows the possible number of canisters (that could be produced from various waste streams) separated into four categories. The projections, totaling 6,000 canisters, in the committed category are based on National Environmental Policy Act (NEPA)-supported commitments to geological disposal by DOE. The projections in the other three categories are not based on NEPA decisions and reflect differing levels of uncertainty in the information used to determine the values for the number of canisters.

At the WVDP, vitrification of the HLW (Fig. 2.8) is scheduled to begin in 1996 and to be completed in 1998.

2.5 REFERENCES

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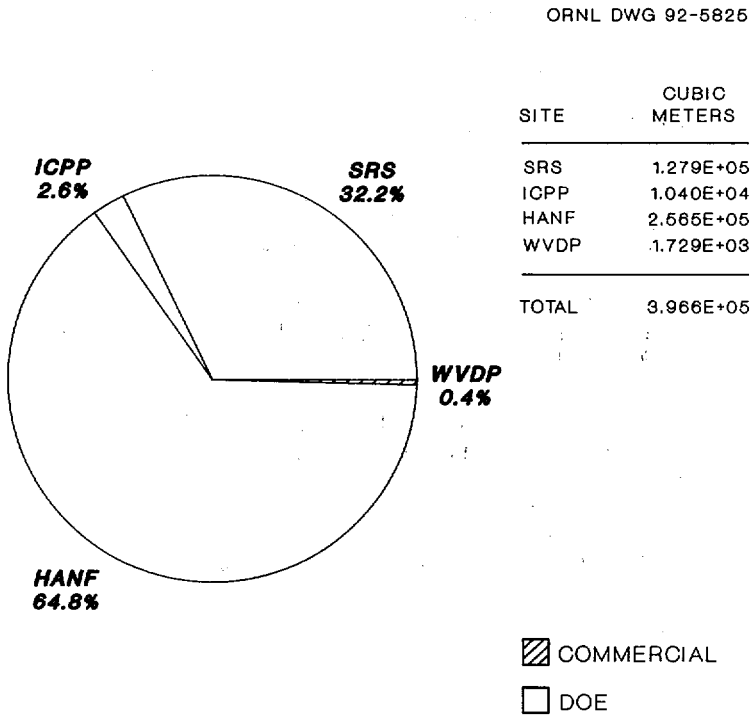

Fig. 2.1. Total volume of HLW through 1991.

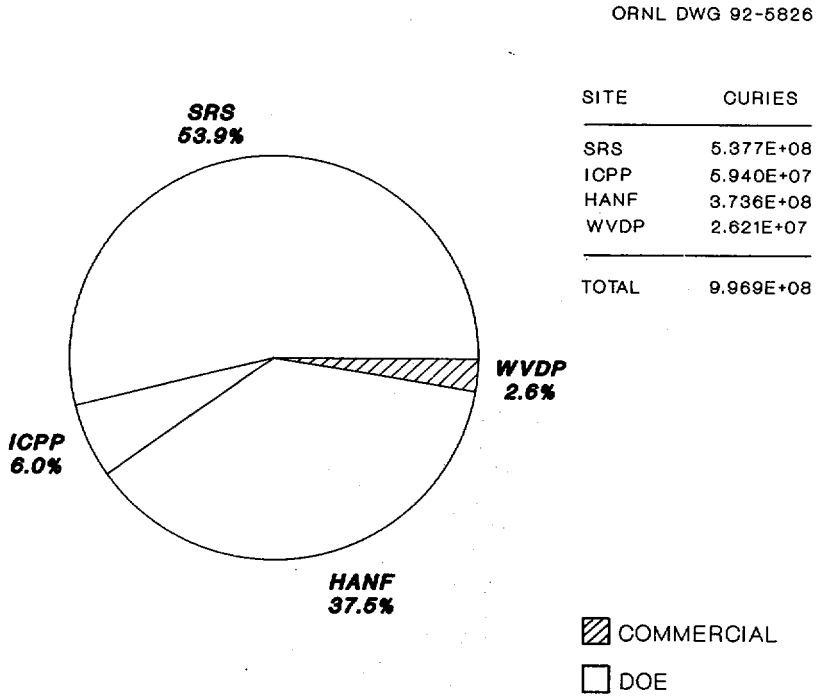

Fig. 2.2. Total radioactivity of HLW through 1991.

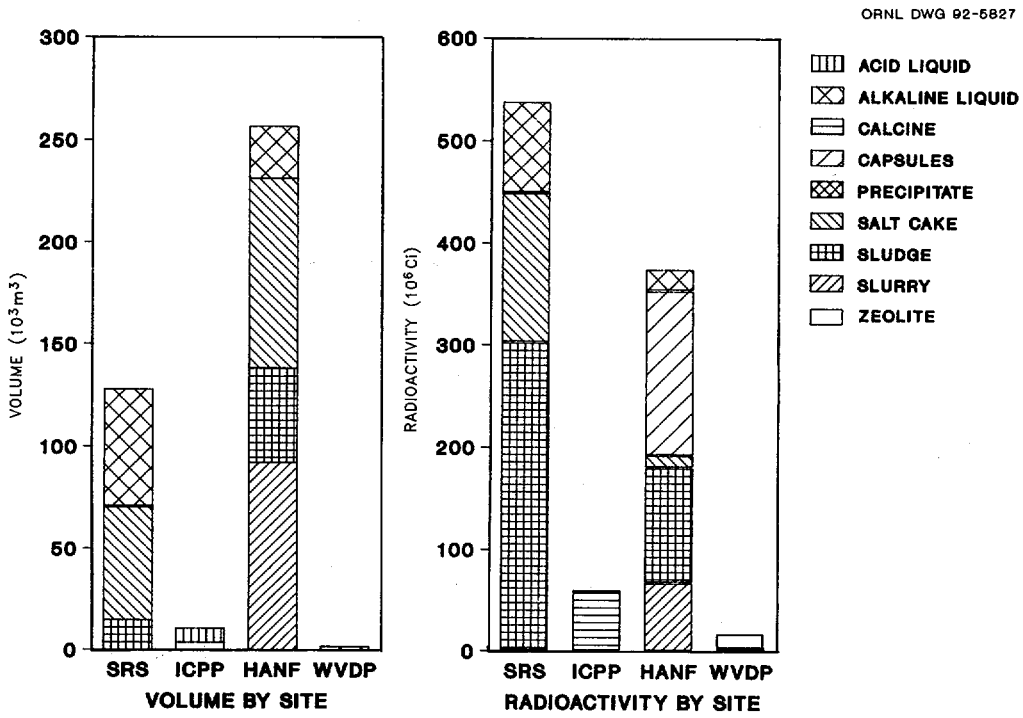

Fig. 2.3. Distribution of total cumulative volume and radioactivity of HLW by site and type through 1991.

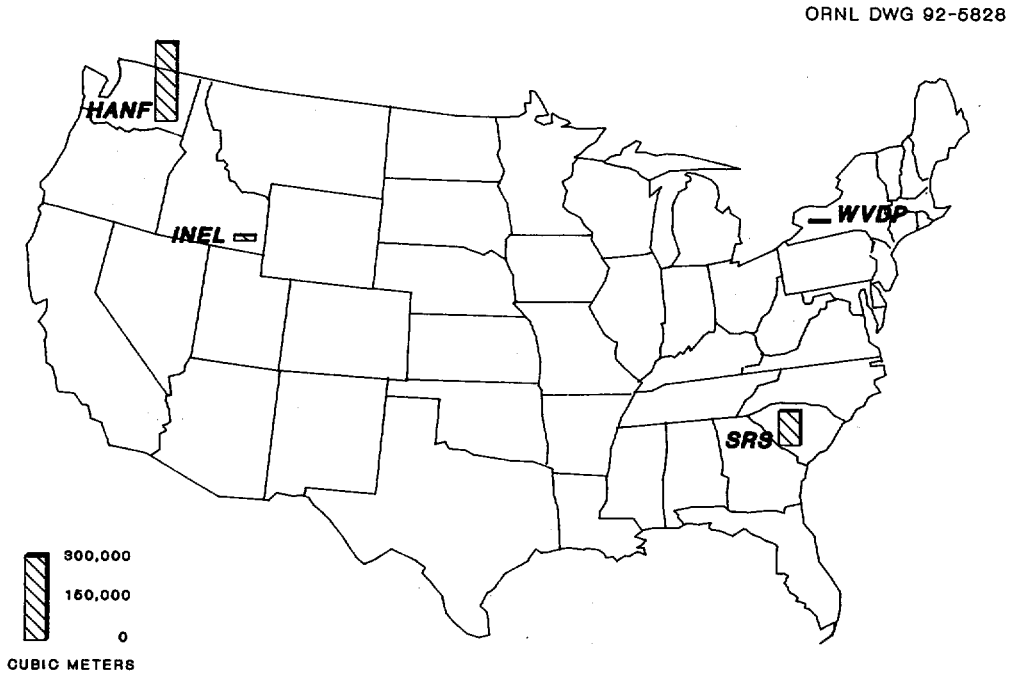

Fig. 2.4. Locations and total volumes of HLW through 1991.

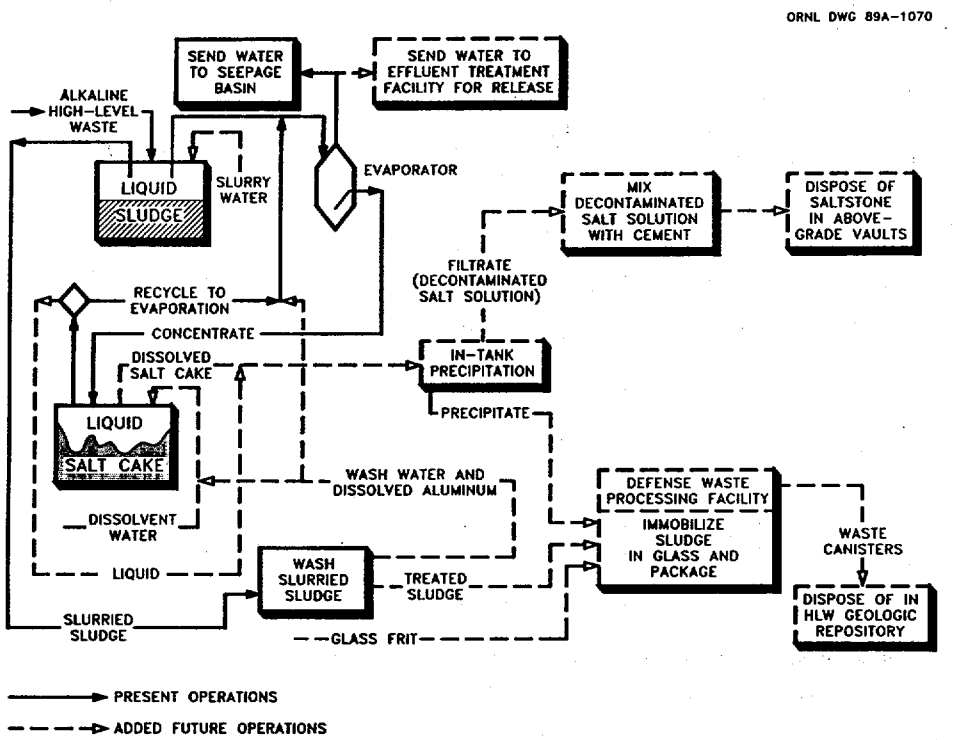

Fig. 2.5. Treatment methods for HLW in tanks and canisters at SRS.

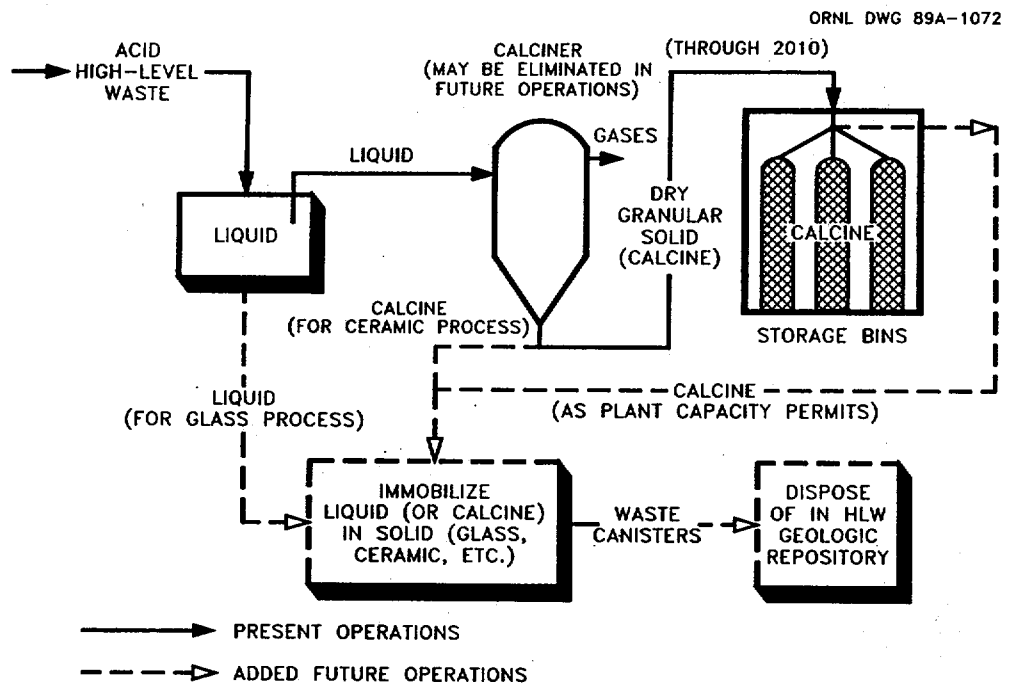

Fig. 2.6. Treatment methods for HLW in tanks, bins, and canisters at INEL.

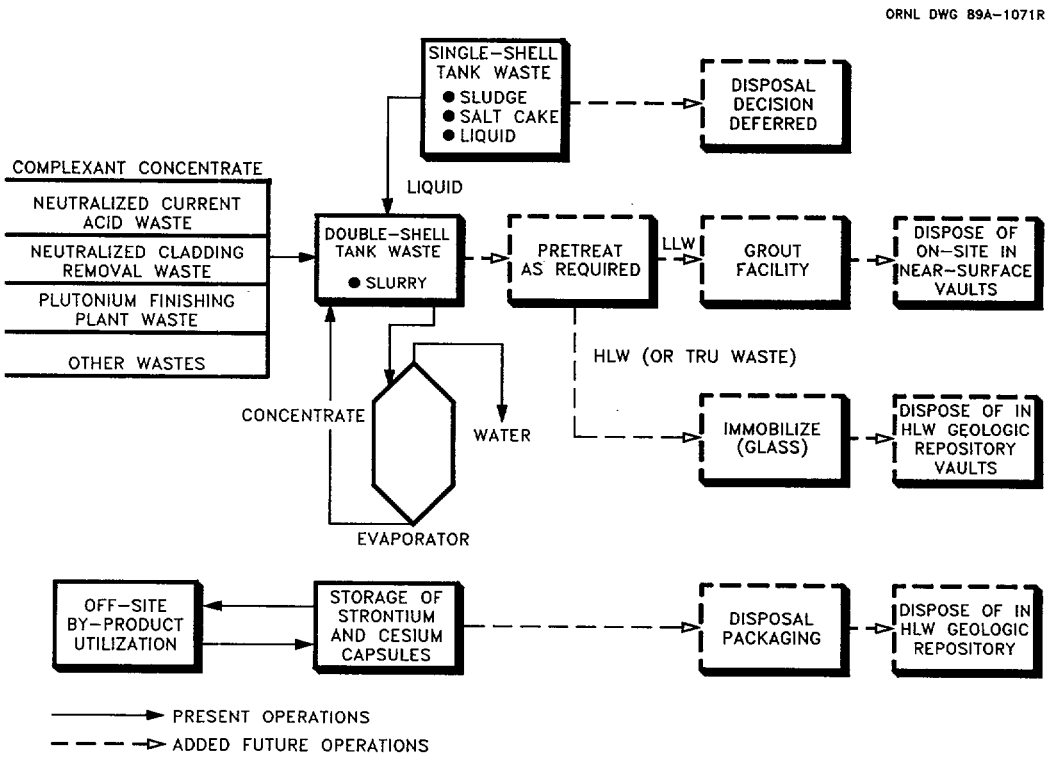

Fig. 2.7. Treatment methods for HLW in tanks, capsules, and canisters at HANF.

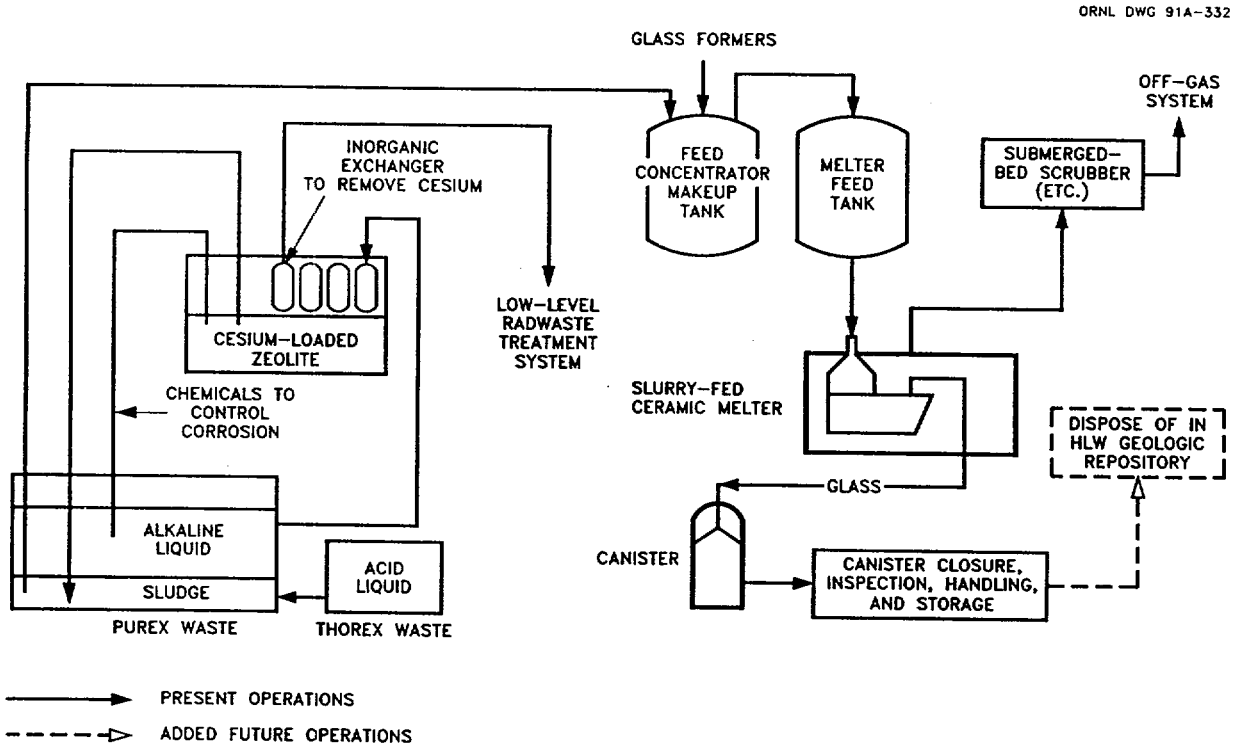

Fig. 2.8. Treatment methods for HLW in tanks and canisters at WVDP.

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

End of calendar year	Cumulative		
	Volume (10^3 m^3)	Radioactivity (10^6 Ci)	Thermal power (10^3 W)
	DOE (SRS, ICPP, and HANF)		
1980	295	1,310	3,298
1981	305	1,577	4,748
1982	340	1,317	3,918
1983	351	1,248	3,653
1984	361	1,397	4,227
1985	355	1,465	4,466
1986	364	1,417	4,475
1987	379	1,277	3,750
1988	383	1,174	3,380
1989	379	1,081	3,072
1990	397	1,015	2,876
1991	395	971	2,758
1992	397	988	2,806
1993	372	1,039	2,992
1994	373	1,005	2,896
1995	355	1,003	2,923
1996	351	984	2,868
1997	347	1,003	2,937
1998	345	983	2,880
1999	338	1,061	3,235
2000	332	993	2,999
2001	328	947	2,856
2002	323	1,007	3,103
2003	321	1,016	3,134
2004	334	1,009	3,109
2005	331	1,010	3,110
2006	320	992	3,050
2007	318	829	2,429
2008	325	778	2,232
2009	328	724	2,106
2010	332	699	2,033
2011	333	696	2,054
2012	335	680	2,015
2013	336	672	1,995
2014	335	664	1,976
2015	336	653	1,955
2016	336	643	1,926
2017	336	638	1,906
2018	336	628	1,876
2019	336	615	1,859
2020	335	603	1,826
2021	336	596	1,810
2022	335	585	1,787
2023	336	571	1,744
2024	334	561	1,719
2025	335	547	1,680
2026	334	532	1,642
2027	334	517	1,600
2028	333	505	1,568
2029	334	493	1,539
2030	333	490	1,536
	Commercial (WVDP)		
1980	2.2	33.4	96.9
1981	2.2	32.7	94.7
1982	2.2	31.9	92.6

Table 2.1 (continued)

End of calendar year	Cumulative		
	Volume (10^3 m^3)	Radioactivity (10^6 Ci)	Thermal power (10^3 W)
	Commercial (WVDP) (continued)		
1983	2.2	31.2	90.5
1984	2.2	30.5	88.4
1985	2.2	29.8	86.4
1986	2.2	29.1	84.5
1987	2.2	28.4	81.2
1988	2.1	27.9	80.8
1989	2.4	27.3	79.3
1990	1.2	26.7	77.0
1991	1.7	26.2	75.9
1992	1.2	25.6	74.2
1993	1.6	25.0	72.2
1994	1.6	24.4	70.7
1995	1.3	23.8	69.1
1996	0.6	15.5	45.0
1997	0.3	7.6	22.0
	Total		
1980	297	1,344	3,394
1981	307	1,610	4,843
1982	342	1,349	4,011
1983	353	1,279	3,743
1984	363	1,427	4,315
1985	357	1,495	4,553
1986	366	1,446	4,560
1987	381	1,306	3,831
1988	385	1,202	3,460
1989	381	1,108	3,151
1990	398	1,042	2,953
1991	397	997	2,833
1992	398	1,014	2,880
1993	374	1,064	3,064
1994	375	1,029	2,967
1995	356	1,027	2,992
1996	351	1,000	2,913
1997	347	1,010	2,959
1998	345	983	2,880
1999	338	1,061	3,235
2000	332	993	2,999
2001	328	947	2,856
2002	323	1,007	3,103
2003	321	1,016	3,134
2004	334	1,009	3,109
2005	331	1,010	3,110
2006	320	992	3,050
2007	318	829	2,429
2008	325	778	2,232
2009	328	724	2,106
2010	332	699	2,033
2011	333	696	2,054
2012	335	680	2,015
2013	336	672	1,995
2014	335	664	1,976
2015	336	653	1,955
2016	336	643	1,926
2017	336	638	1,906
2018	336	628	1,876
2019	336	615	1,859
2020	335	603	1,826

Table 2.1 (continued)

End of calendar year	Cumulative Volume (10^3 m^3)	Cumulative Radioactivity (10^6 Ci)	Cumulative Thermal power (10^3 W)
		Total (continued)	
2021	336	596	1,810
2022	335	585	1,787
2023	336	571	1,744
2024	334	561	1,719
2025	335	547	1,680
2026	334	532	1,642
2027	334	517	1,600
2028	333	505	1,568
2029	334	493	1,539
2030	333	490	1,536

[a]Historical inventories for HLW are taken from the previous edition of this report [i.e., DOE/RW-0006, Rev. 7 (October 1991)]. The inventories for 1991 and the projections through 2030 are taken from refs. 1-4.

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

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

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

End of calendar year	Volume (10^3 m^3)		Radioactivity (10^6 Ci)		Thermal power (10^3 W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
			DOE (SRS and ICPP)[b]			
1993	0.01	0.01	2	2	4	4
1994	0.13	0.14	22	24	55	59
1995	0.19	0.33	34	57	81	139
1996	0.26	0.59	45	101	117	253
1997	0.25	0.84	63	162	193	440
1998	0.26	1.10	65	223	194	624
1999	0.26	1.36	52	270	148	757
2000	0.23	1.59	45	309	153	892
2001	0.23	1.82	43	345	132	1,003
2002	0.23	2.05	29	366	90	1,070
2003	0.19	2.24	24	381	77	1,122
2004	0.19	2.43	25	397	76	1,172
2005	0.19	2.63	24	412	77	1,222
2006	0.19	2.82	25	427	77	1,270
2007	0.15	2.97	19	436	60	1,300
2008	0.13	3.10	16	442	51	1,321
2009	0.12	3.22	15	447	52	1,342
2010	0.06	3.28	7	444	21	1,332
2011	0.00	3.28	0	433	0	1,300
2012	0.00	3.28	0	423	0	1,271
2013	0.00	3.28	0	414	0	1,241
2014	0.00	3.28	0	404	0	1,212
2015	0.40	3.68	7	402	20	1,204
2016	0.40	4.08	5	398	18	1,194
2017	0.60	4.68	7	396	19	1,185
2018	0.70	5.38	7	394	24	1,181
2019	0.70	6.08	7	392	19	1,172
2020	0.70	6.78	8	391	23	1,168
2021	0.80	7.58	7	389	22	1,163
2022	0.70	8.28	9	389	25	1,161
2023	0.70	8.98	9	389	31	1,165
2024	0.80	9.78	9	389	25	1,163
2025	0.70	10.48	10	390	32	1,168
2026	0.70	11.18	13	394	40	1,181
2027	0.70	11.88	14	399	38	1,191
2028	0.80	12.68	12	402	38	1,201
2029	0.50	13.18	9	402	26	1,199
2030	0.20	13.38	3	396	9	1,180
			Commercial (WVDP)[c]			
1996	0.08	0.08	7.8	7.8	22.5	22.5
1997	0.08	0.16	7.6	15.2	21.9	43.9
1998	0.08	0.24	7.4	22.2	21.5	64.4
1999	-	0.24	-	21.7	-	62.9
2000	-	0.24	-	21.2	-	61.4
2001	-	0.24	-	20.7	-	60.0
2002	-	0.24	-	20.3	-	58.7
2003	-	0.24	-	19.8	-	57.3
2004	-	0.24	-	19.4	-	56.0
2005	-	0.24	-	18.9	-	54.6
2006	-	0.24	-	18.5	-	53.4
2007	-	0.24	-	18.1	-	52.2
2008	-	0.24	-	17.6	-	51.0
2009	-	0.24	-	17.2	-	49.8
2010	-	0.24	-	16.8	-	48.6

Table 2.2 (continued)

End of calendar year	Volume (10^3 m^3)		Radioactivity (10^6 Ci)		Thermal power (10^3 W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
			Commercial (WVDP)[c] (continued)			
2011	-	0.24	-	16.4	-	47.5
2012	-	0.24	-	16.0	-	46.4
2013	-	0.24	-	15.7	-	45.4
2014	-	0.24	-	15.3	-	44.3
2015	-	0.24	-	14.9	-	43.2
2016	-	0.24	-	14.6	-	42.2
2017	-	0.24	-	14.3	-	41.3
2018	-	0.24	-	13.9	-	40.3
2019	-	0.24	-	13.6	-	39.4
2020	-	0.24	-	13.3	-	38.4
2021	-	0.24	-	13.0	-	37.5
2022	-	0.24	-	12.7	-	36.7
2023	-	0.24	-	12.4	-	35.8
2024	-	0.24	-	12.1	-	35.0
2025	-	0.24	-	11.8	-	34.1
2026	-	0.24	-	11.5	-	33.4
2027	-	0.24	-	11.3	-	32.6
2028	-	0.24	-	11.0	-	31.9
2029	-	0.24	-	10.8	-	31.1
2030	-	0.24	-	10.5	-	30.4
			Total			
1993	0.01	0.01	2	2	4	4
1994	0.13	0.14	22	24	55	59
1995	0.19	0.33	34	57	81	139
1996	0.34	0.67	54	109	140	276
1997	0.33	1.00	71	178	215	484
1998	0.34	1.34	72	245	216	688
1999	0.26	1.60	52	291	148	819
2000	0.23	1.83	45	330	153	953
2001	0.23	2.06	43	366	132	1,063
2002	0.23	2.29	29	386	90	1,129
2003	0.19	2.48	24	401	77	1,179
2004	0.19	2.67	25	416	76	1,228
2005	0.19	2.87	24	431	77	1,277
2006	0.19	3.06	25	445	77	1,323
2007	0.15	3.21	19	454	60	1,352
2008	0.13	3.34	16	460	51	1,372
2009	0.12	3.46	15	464	52	1,392
2010	0.06	3.52	7	461	21	1,381
2011	0.00	3.52	0	450	0	1,348
2012	0.00	3.52	0	439	0	1,317
2013	0.00	3.52	0	430	0	1,286
2014	0.00	3.52	0	419	0	1,256
2015	0.40	3.92	7	417	20	1,247
2016	0.40	4.32	5	412	18	1,236
2017	0.60	4.92	7	410	19	1,226
2018	0.70	5.62	7	408	24	1,221
2019	0.70	6.32	7	405	19	1,211
2020	0.70	7.02	8	404	23	1,206
2021	0.80	7.82	7	402	22	1,201
2022	0.70	8.52	9	401	25	1,198
2023	0.70	9.22	9	401	31	1,201
2024	0.80	10.02	9	402	25	1,198
2025	0.70	10.72	10	402	32	1,202
2026	0.70	11.42	13	406	40	1,214

Table 2.2 (continued)

End of calendar year	Volume (10^3 m^3)		Radioactivity (10^6 Ci)		Thermal power (10^3 W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
			Total (continued)			
2027	0.70	12.12	14	411	38	1,224
2028	0.80	12.92	12	413	38	1,233
2029	0.50	13.42	9	413	26	1,230
2030	0.20	13.62	3	407	9	1,210

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

[b]Taken from, or calculated with, data given in refs. 1 and 2. At SRS, the DWPF (see Fig. C.10 in Appendix C) canisters are 2 ft in diam x 10 ft long. Each is assumed to be filled with 0.625 m^3 of glass [i.e., 85% of the usable capacity (0.735 m^3)] made with HLW from the reprocessing of spent fuel at SRS. The glass incorporates 36 wt % oxides from waste (28 wt % from spent fuel and 8 wt % from processing chemicals) and 64 wt % oxides from nonradioactive glass frit. Volumes reported are for the glass waste form and not the canisters (see Table 2.3 for the number of canisters and Table 2.7 for the volume of glass). At ICPP, each canister is assumed to contain nominally 1.82 m^3 of a glass/ceramic waste form made with HLW from the reprocessing of spent fuel. See Table 2.3 for the number of canisters and Table 2.7 for the volume of glass/ceramic at ICPP.

[c]Taken from data given in ref. 4. It is assumed that 300 canisters (2 ft in diam x 10 ft long) are filled with waste glass during 1996-1998 and that each canister contains 0.8 m^3 of glass at the filling temperature.

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

	Number of canisters[b]							
	SRS[c]		ICPP[d]		HANF[e]		WVDP[f]	
Year	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1993	17	17	-	-	-	-	-	-
1994	205	222	-	-	-	-	-	-
1995	307	529	-	-	-	-	-	-
1996	410	939	-	-	-	-	100	100
1997	410	1,349	-	-	-	-	100	200
1998	410	1,759	-	-	-	-	100	300
1999	410	2,169	-	-	-	-	-	300
2000	379	2,548	-	-	290	290	-	300
2001	369	2,917	-	-	290	580	-	300
2002	363	3,280	-	-	320	900	-	300
2003	307	3,587	-	-	320	1,220	-	300
2004	307	3,894	-	-	320	1,540	-	300
2005	307	4,201	-	-	320	1,860	-	300
2006	307	4,508	-	-	320	2,180	-	300
2007	239	4,747	-	-	320	2,500	-	300
2008	205	4,952	-	-	320	2,820	-	300
2009	205	5,157	-	-	320	3,140	-	300
2010	85	5,242	-	-	320	3,460	-	300
2011	-	5,242	-	-	320	3,780	-	300
2012	-	5,242	-	-	320	4,100	-	300
2013	-	5,242	-	-	320	4,420	-	300
2014	-	5,242	-	-	320	4,740	-	300
2015	-	5,242	200	200	320	5,060	-	300
2016	-	5,242	250	450	320	5,380	-	300
2017	-	5,242	300	750	320	5,700	-	300
2018	-	5,242	400	1,150	320	6,020	-	300
2019	-	5,242	400	1,550	320	6,340	-	300
2020	-	5,242	400	1,950	320	6,660	-	300
2021	-	5,242	400	2,350	320	6,980	-	300
2022	-	5,242	400	2,750	320	7,300	-	300
2023	-	5,242	400	3,150	320	7,620	-	300
2024	-	5,242	400	3,550	320	7,940	-	300
2025	-	5,242	400	3,950	320	8,260	-	300
2026	-	5,242	400	4,350	320	8,580	-	300
2027	-	5,242	400	4,750	320	8,900	-	300
2028	-	5,242	400	5,150	320	9,220	-	300
2029	-	5,242	302	5,452	320	9,540	-	300
2030	-	5,242	109	5,561	320	9,860	-	300

[a]Taken from refs. 1-4. The projected waste volumes, radioactivity, and thermal power values at SRS, ICPP, and WVDP are consistent with the number of canisters reported because these sites have developed material balances for their solidification facilities. The number of canisters at HANF is not related to projected waste volumes, radioactivity, and thermal power values because material balances for the solidification facility at this site are still in the planning stage.

[b]Canisters are 2-ft diam x 10-ft length.

[c]Each canister is assumed to contain 0.625 m^3 of glass made with HLW from the reprocessing of spent fuel at SRS. The glass incorporates 36 wt % oxides from waste (28 wt % from spent fuel and 8 wt % from processing chemicals) and 64 wt % oxides from nonradioactive glass frit.

[d]Each canister is assumed to contain nominally 1.82 m^3 of a glass/ceramic waste form.

[e]Each canister of vitrified waste is assumed to contain 0.62 m^3 of a borosilicate glass incorporating waste solids.

[f]Each canister is assumed to contain 0.8 m^3 of a borosilicate glass incorporating waste solids.

Table 2.4. Estimates of the number of DOE HLW canisters that could be produced from stored and projected HLW[a]

Interim waste form/ source and generation/ generation period	Estimated number of canisters (Values rounded to nearest 100)			
	Committed to disposal[b]	High potential for disposal[c]	Medium potential for disposal[d]	Not included[e]
Savannah River Site[f]				
Tank waste (liquid, salt cake, and sludge)				
Start-1987	4,600			
1988-2000	800			
Idaho Chemical Processing Plant[g]				
Calcined waste				
Start-1987		2,000		
1988-2020		4,900		
Hanford Site[h]				
Double-shell tanks				
Slurry				
NCAW[i]	600			
CC-1987[j]		400		
CC after 1987[k]				
PFP[l]				300
NCRW[m]				100
Cs and Sr capsules[n]		300		
Single-shell tanks[o] (liquid, salt cake, and sludge)			10,000-35,000	
Total	6,000	7,600	10,000-35,000	400

[a]Taken from a facsimile transmittal memo from J. L. Nelson, Westinghouse Hanford Company, Hanford Site, Richland, Washington, to S. N. Storch, Oak Ridge National Laboratory, Oak Ridge, Tennessee, dated Aug. 12, 1992, and from a letter from J. H. Roecker, Westinghouse Hanford Company, Hanford Site, Richland, Washington, to S. N. Storch, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Hanford High-Level Waste Update to the 1992 Integrated Data Base," 9201075B R1, dated Mar. 31, 1992. Data required for repository program planning.

[b]Committed values are well established (e.g., DWPF glass) and are based on National Environmental Policy Act (NEPA) decisions.

[c]High-potential values are not supported by a NEPA action and/or are less sharply known.

[d]Medium-potential values are not supported by a NEPA action and/or they are based on imprecise source estimates or undeveloped treatment technology.

[e]Projections are not included when values are very imprecisely known or the waste is non-HLW that has been associated with past canister estimates. Values are for reference only.

[f]Canisters from the DWPF contain glass made with existing HLW and HLW from the operation of existing reactors through 2000.

[g]Canisters contain a glass/ceramic waste form made with HLW from the reprocessing of naval nuclear propulsion fuels. Estimated projections beyond 2020 are less precise. Projected values assume no on-site disposal of calcine and no removal of inerts from the original waste streams.

[h]Slurry refers to all waste in double-shell tanks regardless of when it was generated.

[i]Neutralized current acid waste (NCAW) is HLW from existing N-Reactor fuel. The value does not include an additional 250 canisters that would have resulted from resumption of fuel reprocessing operations at Hanford.

[j]Complexant concentrate (CC) generated through 1987 will be vitrified, but the volume is not precisely known.

[k]Complexant concentrate (CC) source beyond 1987 is not clearly defined.

[l]Plutonium Finishing Plant (PFP) waste is not HLW by source definition.

[m]Neutralized coating removal waste (NCRW) is not HLW by source definition.

[n]Capsule waste will most likely go to a repository, but final form has not been determined.

[o]Single-shell tank waste has not been designated through NEPA to be sent to a repository. Final class and recommended treatment are still being studied.

Table 2.5. Current volume of HLW in storage by site through 1991

Site[a]	Volume, 10^3 m^3									
	Liquid	Sludge	Salt cake	Slurry[b]	Calcine	Precipitate[c]	Zeolite	Capsules[d] Sr	Capsules[d] Cs	Total
DOE[e]										
SRS	57.2	14.5	55.7	f	f	0.545	f	f	f	127.9
ICPP	6.8	f	f	f	3.6	f	f	f	f	10.4
HANF[g]	25.5	46.0	93.0	92.0	f	f	f	0.00108	0.00247	256.5
Subtotal	89.5	60.5	148.7	92.0	3.6	0.545	f	0.00108	0.00247	394.85
Commercial[h]										
WVDP										
Acid waste	0.045	f	f	f	f	f	f	f	f	0.045
Alkaline waste	1.575	0.057	f	f	f	f	f	f	f	1.632
Zeolite waste	f	f	f	f	f	f	0.052	f	f	0.052
Subtotal	1.620	0.057	f	f	f	f	0.052	f	f	1.729
Total	91.12	60.557	148.7	92.0	3.6	0.545	0.052	0.00108	0.00247	396.58

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

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

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

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

[e]Taken from refs. 1-3.

[f]Not applicable.

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

[h]Taken from ref. 4.

Table 2.6. Current radioactivity of HLW in storage by site through 1991

Site[b]	Radioactivity,[a] 10^6 Ci										Thermal power (10^6 W)
	Liquid	Sludge	Salt cake	Slurry[c]	Calcine	Precipitate[d]	Zeolite	Capsules[e] Sr	Capsules[e] Cs	Total	
DOE[f]											
SRS	89.0	302.1	146.4	g	g	0.15	g	g	g	537.65	1.509
ICPP	2.4	g	g	g	57.0	g	g	g	g	59.4	0.172
HANF[h]	20.7	113.0	11.8	66.9	g	g	g	49.7	111.5	373.6	1.076
Subtotal	112.1	415.1	158.2	66.9	57.0	0.15	g	49.7	111.5	970.65	2.757
Commercial[i]											
WVDP											
Acid waste	1.84	g	g	g	g	g	g	g	g	1.84	0.005
Alkaline waste	2.27	11.6	g	g	g	g	g	g	g	13.87	0.045
Zeolite waste	g	g	g	g	g	g	10.5	g	g	10.5	0.026
Subtotal	4.11	11.6	g	g	g	g	10.5	g	g	26.21	0.076
Total	116.21	426.7	158.2	66.9	57.0	0.15	10.5	49.7	111.5	996.86	2.833

[a]Calculated values allowing for radioactive decay.

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

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

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

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

[f]Taken from refs. 1-3.

[g]Not applicable.

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

[i]Taken from ref. 4.

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

End of calendar year	Volume, 10^3 m^3									
	Liquid	Sludge	Salt cake	Slurry	Calcine	Precipitate	Zeolite	Capsules[b]	Glass or glass/ceramic[c]	Total
					Savannah River Site					
1980	59.8	10.5	26.4	-	-	-	-	-	-	96.7
1985	71.3	13.8	37.6	-	-	-	-	-	-	122.7
1986	72.8	13.8	41.2	-	-	-	-	-	-	127.8
1987	63.2	13.8	50.5	-	-	0.1	-	-	-	127.6
1988	64.2	14.1	50.0	-	-	0.1	-	-	-	128.5
1989	53.3	13.8	54.8	-	-	0.1	-	-	-	122.1
1990	61.3	14.8	55.5	-	-	0.1	-	-	-	131.7
1991	57.2	14.5	55.7	-	-	0.5	-	-	-	128.0
1995	48.4	15.9	44.4	-	-	1.3	-	-	0.3	110.2
2000	43.4	11.2	27.4	-	-	1.4	-	-	1.6	85.0
2005	41.4	8.2	16.5	-	-	0.3	-	-	2.6	69.0
2010	42.9	8.9	18.1	-	-	-	-	-	3.3	73.2
2015	42.9	9.6	21.4	-	-	0.1	-	-	3.3	77.3
2020	42.2	10.3	21.4	-	-	0.7	-	-	3.3	77.9
2025	42.9	11.0	21.4	-	-	1.3	-	-	3.3	79.9
2030	42.2	11.8	21.4	-	-	2.0	-	-	3.3	80.7
					Idaho Chemical Processing Plant					
1980	9.3	-	-	-	2.1	-	-	-	-	11.4
1985	7.1	-	-	-	3.0	-	-	-	-	10.1
1986	6.5	-	-	-	3.0	-	-	-	-	9.5
1987	8.9	-	-	-	3.0	-	-	-	-	11.9
1988	7.6	-	-	-	3.4	-	-	-	-	11.0
1989	8.5	-	-	-	3.5	-	-	-	-	12.0
1990	8.5	-	-	-	3.5	-	-	-	-	12.0
1991	6.8	-	-	-	3.6	-	-	-	-	10.4
1995	7.3	-	-	-	4.2	-	-	-	-	11.5
2000	6.4	-	-	-	5.2	-	-	-	-	11.6
2005	5.5	-	-	-	6.0	-	-	-	-	11.5
2010	5.7	-	-	-	6.8	-	-	-	-	12.5
2015	4.7	-	-	-	7.1	-	-	-	0.4	12.2
2020	4.6	-	-	-	4.7	-	-	-	3.5	12.8
2025	3.8	-	-	-	2.0	-	-	-	7.2	13.0
2030	3.1	-	-	-	-	-	-	-	10.1	13.2

Table 2.7 (continued)

End of calendar year	Volume, 10^3 m^3									
	Liquid	Sludge	Salt cake	Slurry	Calcine	Precipitate	Zeolite	Capsules[b]	Glass or glass/ceramic[c]	Total
					Hanford Site					
1980	39.0	49.0	95.0	4.0	-	-	-	0.0017	-	187.0
1985	28.1	46.0	93.0	55.1	-	-	-	0.0040	-	222.1
1986	28.0	46.0	93.0	59.5	-	-	-	0.0040	-	226.4
1987	27.3	46.0	93.0	73.4	-	-	-	0.0040	-	239.7
1988	26.8	46.0	93.0	77.7	-	-	-	0.0036	-	243.4
1989	26.5	46.0	93.0	79.3	-	-	-	0.0036	-	244.8
1990	26.4	46.0	93.0	88.2	-	-	-	0.0036	-	253.6
1991	25.5	46.0	93.0	92.0	-	-	-	0.0035	-	256.4
1995	12.0	46.0	93.0	82.2	-	-	-	0.0035	-	233.2
2000	11.9	46.0	93.0	86.7	-	-	-	0.0035	-	237.5
2005	11.9	46.0	93.0	102.0	-	-	-	0.0035	-	252.8
2010	11.9	46.0	93.0	98.3	-	-	-	0.0035	-	249.1
2015	11.9	46.0	93.0	99.7	-	-	-	0.0035	-	250.5
2020	11.9	46.0	93.0	100.7	-	-	-	0.0035	-	251.5
2025	11.9	46.0	93.0	101.5	-	-	-	0.0035	-	252.3
2030	11.9	46.0	93.0	102.1	-	-	-	0.0035	-	252.9
					West Valley Demonstration Project					
1980	2.145	0.046	-	-	-	-	-	-	-	2.191
1985	2.145	0.046	-	-	-	-	-	-	-	2.191
1986	2.145	0.046	-	-	-	-	-	-	-	2.191
1987	2.145	0.046	-	-	-	-	-	-	-	2.191
1988	2.065	0.046	-	-	-	-	0.013	-	-	2.124
1989	2.305	0.046	-	-	-	-	0.031	-	-	2.382
1990	1.135	0.046	-	-	-	-	0.045	-	-	1.226
1991	1.620	0.057	-	-	-	-	0.052	-	-	1.729
1995	-	-	-	-	-	-	-	-	-	1.310[d]
2000	-	-	-	-	-	-	-	-	0.240	0.240
2005	-	-	-	-	-	-	-	-	0.240	0.240
2010	-	-	-	-	-	-	-	-	0.240	0.240
2015	-	-	-	-	-	-	-	-	0.240	0.240
2020	-	-	-	-	-	-	-	-	0.240	0.240
2025	-	-	-	-	-	-	-	-	0.240	0.240
2030	-	-	-	-	-	-	-	-	0.240	0.240

[a]Historical inventories for HLW are taken from the previous edition of this report [i.e., DOE/RW-0006, Rev. 7 (October 1991)]. The inventories for 1990 and the projections through 2030 are taken from refs. 1-4.

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

[c]Glass is waste form for SRS and WVDP. Glass/ceramic is waste form for ICPP. Glass is most likely waste form for HANF; however, HANF material balances are not available yet. Glass and glass/ceramic shown may be in storage at the site, in transit to a repository, or at a repository.

[d]This total volume is a mixture of acidic liquid, alkaline sludge, zeolite, and residual liquid, the exact proportions of which are not fully defined at this time.

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

End of calendar year	Radioactivity, 10^6 Ci									
	Liquid	Sludge	Salt cake	Slurry	Calcine	Precipitate	Zeolite	Capsules[b]	Glass or glass/ceramic[c]	Total
					Savannah River Site					
1980	187.4	429.0	82.6	-	-	-	-	-	-	699.0
1985	93.3	561.3	186.8	-	-	-	-	-	-	841.4
1986	88.1	517.2	189.4	-	-	-	-	-	-	794.7
1987	105.2	460.4	168.2	-	-	0.2	-	-	-	734.0
1988	99.0	403.1	162.1	-	-	0.2	-	-	-	664.4
1989	94.6	351.2	152.8	-	-	0.3	-	-	-	598.9
1990	91.6	319.8	150.1	-	-	0.1	-	-	-	561.6
1991	89.0	302.1	146.4	-	-	0.1	-	-	-	537.6
1995	68.0	392.4	118.0	-	-	25.9	-	-	57.1	661.4
2000	55.0	437.4	107.0	-	-	6.8	-	-	308.7	914.9
2005	45.0	507.1	88.0	-	-	5.6	-	-	411.7	1,057.4
2010	25.0	250.5	80.0	-	-	-	-	-	444.2	799.7
2015	18.0	247.5	74.0	-	-	0.7	-	-	394.8	735.0
2020	14.0	258.5	67.0	-	-	4.1	-	-	350.6	694.2
2025	11.0	269.6	59.0	-	-	5.6	-	-	311.4	656.6
2030	10.0	279.6	50.0	-	-	4.7	-	-	277.2	621.5
					Idaho Chemical Processing Plant					
1980	17.0	-	-	-	36.4	-	-	-	-	53.4
1985	21.7	-	-	-	47.7	-	-	-	-	69.4
1986	12.9	-	-	-	47.7	-	-	-	-	60.6
1987	14.3	-	-	-	48.2	-	-	-	-	62.5
1988	10.1	-	-	-	56.9	-	-	-	-	67.0
1989	11.5	-	-	-	56.9	-	-	-	-	68.4
1990	7.5	-	-	-	55.7	-	-	-	-	63.2
1991	2.4	-	-	-	57.0	-	-	-	-	59.4
1995	7.7	-	-	-	59.0	-	-	-	-	66.7
2000	7.7	-	-	-	86.0	-	-	-	-	93.7
2005	9.7	-	-	-	94.0	-	-	-	-	103.7
2010	5.3	-	-	-	107.0	-	-	-	-	112.3
2015	2.2	-	-	-	105.0	-	-	-	7.0	114.2
2020	2.0	-	-	-	75.0	-	-	-	40.0	117.0
2025	0.8	-	-	-	38.0	-	-	-	79.0	117.8
2030	1.1	-	-	-	-	-	-	-	119.0	120.1

Table 2.8 (continued)

End of calendar year	Radioactivity, 10^6 Ci									
	Liquid	Sludge	Salt cake	Slurry	Calcine	Precipitate	Zeolite	Capsules[b]	Glass or glass/ceramic[c]	Total
					Hanford Site					
1980	34.6	175.0	16.0	0.3	-	-	-	332.0	-	557.9
1985	26.2	130.5	13.6	171.2	-	-	-	212.8	-	554.3
1986	25.5	127.4	13.2	187.3	-	-	-	207.9	-	561.4
1987	24.4	124.4	12.9	115.8	-	-	-	203.1	-	480.6
1988	23.3	121.4	12.6	110.9	-	-	-	174.7	-	443.0
1989	22.6	118.5	12.3	89.6	-	-	-	170.8	-	413.9
1990	21.9	115.7	12.1	74.6	-	-	-	166.0	-	390.4
1991	20.7	113.0	11.8	66.9	-	-	-	161.1	-	373.6
1995	8.9	102.7	10.7	63.0	-	-	-	146.8	-	332.1
2000	7.8	91.1	9.5	54.1	-	-	-	130.6	-	293.2
2005	7.0	80.8	8.5	47.7	-	-	-	116.3	-	260.2
2010	6.2	71.7	7.5	42.3	-	-	-	103.5	-	231.2
2015	5.5	63.6	6.7	37.6	-	-	-	92.1	-	205.6
2020	4.9	56.4	6.0	33.5	-	-	-	82.0	-	182.8
2025	4.4	50.2	5.3	29.8	-	-	-	72.9	-	162.7
2030	3.9	44.7	4.7	26.5	-	-	-	64.9	-	144.8
					West Valley Demonstration Project					
1980	18.5	15.0	-	-	-	-	-	-	-	33.4
1985	16.4	13.3	-	-	-	-	-	-	-	29.8
1986	16.1	13.0	-	-	-	-	-	-	-	29.1
1987	15.7	12.7	-	-	-	-	-	-	-	28.4
1988	12.9	12.4	-	-	-	-	2.6	-	-	27.9
1989	8.5	12.2	-	-	-	-	6.6	-	-	27.3
1990	5.5	11.9	-	-	-	-	9.3	-	-	26.7
1991	4.1	11.6	-	-	-	-	10.5	-	-	26.2
1995	-	-	-	-	-	-	-	-	-	23.8[d]
2000	-	-	-	-	-	-	-	-	21.2	21.2
2005	-	-	-	-	-	-	-	-	18.9	18.9
2010	-	-	-	-	-	-	-	-	16.8	16.8
2015	-	-	-	-	-	-	-	-	14.9	14.9
2020	-	-	-	-	-	-	-	-	13.3	13.3
2025	-	-	-	-	-	-	-	-	11.8	11.8
2030	-	-	-	-	-	-	-	-	10.5	10.5

[a]Historical inventories for HLW are taken from the previous edition of this report [i.e., DOE/RW-0006, Rev. 7 (October 1991)]. The inventories for 1991 and the projections through 2030 are taken from refs. 1-4.

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

[c]Glass is waste form for SRS and WVDP. Glass/ceramic is waste form for ICPP. Glass is most likely waste form for HANF; however, material balances are not available yet. Glass and glass/ceramic shown may be in storage at the site, in transit to a repository, or at a repository.

[d]This total radioactivity is contained in a mixture (i.e., acidic liquid, alkaline sludge, zeolite, and residual liquid) and is to be incorporated into glass during 1995-1997.

Table 2.9. Historical and projected total cumulative thermal power of HLW in storage by site through 2030[a]

End of calendar year	Thermal power, 10^3 W									
	Liquid	Sludge	Salt cake	Slurry	Calcine	Precipitate	Zeolite	Capsules[b]	Glass or glass/ceramic[c]	Total
					Savannah River Site					
1980	213.5	1,440.5	396.0	-	-	-	-	-	-	2,050.0
1985	264.3	1,782.7	490.2	-	-	-	-	-	-	2,537.2
1986	302.2	1,794.1	479.0	-	-	-	-	-	-	2,575.3
1987	279.8	1,438.9	432.8	-	-	0.4	-	-	-	2,151.9
1988	231.9	1,280.5	370.9	-	-	0.4	-	-	-	1,883.7
1989	217.7	1,105.8	349.5	-	-	0.7	-	-	-	1,673.7
1990	209.0	1,015.6	341.7	-	-	0.4	-	-	-	1,566.7
1991	203.0	971.0	335.0	-	-	0.3	-	-	-	1,509.3
1995	173.0	1,258.0	275.0	-	-	59.4	-	-	139.2	1,904.6
2000	152.0	1,451.0	252.0	-	-	16.0	-	-	892.0	2,763.0
2005	138.0	1,685.0	210.0	-	-	13.3	-	-	1,222.0	3,268.3
2010	71.0	770.1	189.0	-	-	-	-	-	1,332.0	2,362.1
2015	55.0	809.6	176.0	-	-	1.6	-	-	1,184.0	2,226.2
2020	45.0	854.5	158.0	-	-	9.5	-	-	1,053.0	2,120.0
2025	38.0	901.1	139.0	-	-	13.4	-	-	937.0	2,028.5
2030	35.0	944.9	119.0	-	-	11.7	-	-	834.0	1,944.6
					Idaho Chemical Processing Plant					
1980	53.8	-	-	-	115.2	-	-	-	-	169.0
1985	72.5	-	-	-	137.4	-	-	-	-	210.0
1986	38.5	-	-	-	137.4	-	-	-	-	175.9
1987	43.5	-	-	-	139.0	-	-	-	-	182.5
1988	30.4	-	-	-	165.2	-	-	-	-	195.6
1989	34.3	-	-	-	164.9	-	-	-	-	199.2
1990	22.9	-	-	-	161.5	-	-	-	-	184.4
1991	7.0	-	-	-	165.0	-	-	-	-	172.0
1995	22.5	-	-	-	172.0	-	-	-	-	194.5
2000	22.7	-	-	-	251.0	-	-	-	-	273.7
2005	30.3	-	-	-	275.0	-	-	-	-	305.3
2010	15.4	-	-	-	313.0	-	-	-	-	328.4
2015	6.5	-	-	-	307.0	-	-	-	20.0	335.5
2020	5.9	-	-	-	220.0	-	-	-	115.0	340.9
2025	2.4	-	-	-	111.0	-	-	-	231.0	344.4
2030	3.3	-	-	-	-	-	-	-	346.0	349.3

Table 2.9 (continued)

End of calendar year	Thermal power, 10^3 W									
	Liquid	Sludge	Salt cake	Slurry	Calcine	Precipitate	Zeolite	Capsules[b]	Glass or glass/ceramic[c]	Total
					Hanford Site					
1980	75.1	325.9	32.8	0.5	-	-	-	644.4	-	1,078.6
1985	65.9	428.3	38.2	604.0	-	-	-	582.8	-	1,719.1
1986	64.1	418.1	37.3	635.0	-	-	-	569.3	-	1,723.8
1987	61.2	408.2	36.4	353.4	-	-	-	556.2	-	1,415.3
1988	58.6	398.4	35.5	328.5	-	-	-	479.3	-	1,300.4
1989	56.7	389.0	34.7	249.7	-	-	-	468.8	-	1,198.9
1990	55.1	379.7	33.9	200.4	-	-	-	455.8	-	1,125.0
1991	52.1	370.7	33.1	177.7	-	-	-	442.6	-	1,076.2
1995	22.4	336.7	30.1	170.5	-	-	-	403.1	-	962.9
2000	19.7	298.6	26.8	150.2	-	-	-	358.7	-	854.0
2005	17.5	264.9	23.8	133.4	-	-	-	319.1	-	758.8
2010	15.6	235.0	21.2	118.8	-	-	-	284.0	-	674.5
2015	13.9	208.5	18.8	105.8	-	-	-	252.7	-	599.7
2020	12.4	185.0	16.7	94.4	-	-	-	224.8	-	533.3
2025	11.1	164.5	14.9	84.2	-	-	-	200.0	-	474.7
2030	9.8	146.4	13.2	75.1	-	-	-	178.0	-	422.5
					West Valley Demonstration Project					
1980	47.8	49.1	-	-	-	-	-	-	-	96.9
1985	42.2	44.2	-	-	-	-	-	-	-	86.4
1986	41.3	43.2	-	-	-	-	-	-	-	84.5
1987	38.9	42.3	-	-	-	-	-	-	-	81.2
1988	32.9	41.5	-	-	-	-	6.5	-	-	80.8
1989	22.3	40.6	-	-	-	-	16.4	-	-	79.3
1990	14.1	39.7	-	-	-	-	23.1	-	-	77.0
1991	11.0	38.9	-	-	-	-	26.0	-	-	75.9
1995	-	-	-	-	-	-	-	-	-	69.1[d]
2000	-	-	-	-	-	-	-	-	61.4	61.4
2005	-	-	-	-	-	-	-	-	54.6	54.6
2010	-	-	-	-	-	-	-	-	48.6	48.6
2015	-	-	-	-	-	-	-	-	43.2	43.2
2020	-	-	-	-	-	-	-	-	38.4	38.4
2025	-	-	-	-	-	-	-	-	34.1	34.1
2030	-	-	-	-	-	-	-	-	30.4	30.4

[a]Historical inventories for HLW are taken from the previous edition of this report [i.e., DOE/RW-0006, Rev. 7 (October 1991)]. The inventories for 1991 and the projections through 2030 are taken from refs. 1-4.

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

[c]Glass is waste form for SRS and WVDP. Glass/ceramic is waste form for ICPP. Glass is most likely waste form for HANF; however, material balances are not available yet. Glass and glass/ceramic shown may be in storage at the site, in transit to a repository, or at a repository.

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

Table 2.10. Significant revisions and changes in the current values for HLW compared to the values in the previous year

Waste characteristics	1991 values[a]	Significant revisions and changes	1992 values	Reasons for significant changes and revisions or for none
		Savannah River Site		
Volume and radioactivity (liquid, sludge, salt cake, and precipitate)	See Tables 2.5 and 2.6	None	See Tables 2.5 and 2.6	No revisions. Changes are explained by routine plant operations and decay of radionuclides
Radioactivity of ^{99}Tc	See Table 2.12	Radioactivity of ^{99}Tc reduced by a factor of ~10	See Table 2.12	Previously reported Ci values for ^{99}Tc recognized to be too high. Factors used in calculation of values were adjusted
		Idaho Chemical Processing Plant		
Volume and radioactivity (liquid and calcine)	See Tables 2.5 and 2.6	None	See Tables 2.5 and 2.6	No revisions. Changes are explained by routine plant operations and decay of radionuclides
		Hanford Site		
Number of Cs and Sr capsules	See Sect. 2.2.3 of text	Number of capsules: Cs: 1,345 to 1,338 Sr: 597 to 605	See Sect. 2.2.3 of text	Seven additional Cs capsules are known to have been dismantled. Eight Sr capsules thought to have been dismantled are known to be intact
Volume and radioactivity (liquid, sludge, salt cake, slurry, and capsules)	See Tables 2.5 and 2.6	None	See Tables 2.5 and 2.6	No significant revisions. Changes are explained by routine plant operation
		West Valley Demonstration Project		
Radioactivity (acid liquid, alkaline liquid, sludge, and zeolite)	See Tables 2.5 and 2.6	None	See Tables 2.5 and 2.6	Changes are explained by routine plant operations, by radioactive decay, and by continued refinement of inplant measurements
Number of radionuclides reported	See Table 2.21	Only high-heat-emitting radionuclides (^{90}Sr and ^{137}Cs plus their daughters) are reported	See Table 2.21	Previous versions of the table were generated using an isotope generation/depletion code. The present table is based on analytical results which the site operators feel is more meaningful to their operations (the other radionuclides account for less than 2% of the activity in the HLW)

[a]See tables and text cited in Chapter 2 of U.S. Department of Energy, Integrated Data Base for 1991: Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics, DOE/RW-0006, Rev. 7 (October 1991).

Table 2.11. Representative chemical composition of current and future HLW at SRS[a]

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

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

Table 2.12. Representative radionuclide composition of current (end of 1991) HLW forms and future (to be generated in 1993) HLW glass at SRS[a]

Radionuclide	Radioactivity, Ci					
	Liquid	Sludge	Salt cake	Precipitate	Total[b]	Glass[c]
^{90}Sr	7.83E+05	1.24E+08	1.26E+06	1.75E+03	1.26E+08	1.29E+05
^{90}Y	7.83E+05	1.24E+08	1.26E+06	1.75E+03	1.26E+08	1.29E+05
^{99}Tc[b]	6.41E+02	2.11E+04	2.22E+03	–	2.40E+04	9.80E+01
^{106}Ru	9.82E+04	3.98E+05	3.60E+03	–	5.00E+05	–
^{106}Rh	9.82E+04	3.98E+05	3.60E+03	–	5.00E+05	–
^{125}Sb	8.62E+04	2.12E+05	2.04E+03	–	3.00E+05	1.07E+01
^{137}Cs	4.47E+07	1.14E+07	7.48E+07	7.86E+04	1.31E+08	8.32E+05
^{137m}Ba	4.13E+07	1.05E+07	6.88E+07	7.23E+04	1.21E+08	7.64E+05
^{144}Ce	8.80E+04	2.46E+06	2.50E+03	–	2.55E+06	–
^{144}Pr	8.80E+04	2.46E+06	2.50E+03	–	2.55E+06	–
^{147}Pm	9.31E+05	2.32E+07	2.18E+05	–	2.43E+07	8.03E+02
^{233}U	–	2.60E-01	–	–	2.60E-01	1.90E-02
^{235}U	–	2.80E-01	–	–	2.80E-01	2.00E-02
^{238}U	–	2.20E+01	–	–	2.20E+01	4.30E-02
^{238}Pu	–	1.60E+06	–	–	1.60E+06	6.60E+02
^{239}Pu	–	2.30E+04	–	–	2.30E+04	3.50E+01
^{240}Pu	–	1.00E+04	–	–	1.00E+04	2.30E+01
^{241}Pu	–	1.40E+06	–	–	1.40E+06	1.30E+02
^{242}Pu	–	1.70E+01	–	–	1.70E+01	3.30E-02
^{244}Cm	–	1.40E+04	–	–	1.40E+04	1.70E+03
Total	8.896E+07	3.021E+08	1.464E+08	1.544E+05	5.376E+08	1.857E+06
Specific activity,[d] Ci/L	1.56	20.8	2.63	0.28	4.20	186

[a]Taken or calculated from ref. 1.

[b]Liquid, sludge, salt cake, and precipitate curies are as of December 31, 1991.

[c]Glass curies are as of December 31, 1993 (the first year glass is to be generated). Liquid, sludge, salt cake, and precipitate will continue to be waste types in 1993.

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

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

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

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

Table 2.14. Representative chemical composition of current and future HLW calcine at ICPP[a]

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

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

Table 2.15. Representative radionuclide composition of current HLW at ICPP[a]

Radionuclide	Liquid (10^6 Ci)	Calcine (10^6 Ci)
^{90}Sr	0.543	13.468
^{90}Y	0.543	13.468
^{106}Ru	0.006	0.007
^{106}Rh	0.006	0.007
^{134}Cs	0.015	0.159
^{137}Cs	0.643	14.876
^{137m}Ba	0.608	14.073
^{144}Ce	0.006	0.021
^{144}Pr	0.006	0.021
^{147}Pm	0.000	0.609
^{154}Eu	0.005	0.094
Total	2.381	56.803
Specific activity,[b] Ci/L	0.35	15.8

[a]Taken from ref. 3. Curies as of December 31, 1991. Similar values for actinide nuclides are not available.

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

Table 2.16. Representative chemical composition of current and future HLW at HANF[a]

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

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

[b]Stored in single-shell tanks.

[c]Stored in double-shell tanks.

Table 2.17. Representative radionuclide composition (Ci) of current HLW at HANF[a]

Radionuclide	Liquid	Sludge	Salt cake	Slurry	Capsules	
					^{90}Sr-^{90}Y	^{137}Cs-^{137m}Ba
^{14}C	1.90E+03	-	2.50E+03	6.33E+02	-	-
^{55}Fe	-	-	-	6.20E+03	-	-
^{60}Co	-	3.67E+03	-	1.18E+04	-	-
^{59}Ni	-	-	-	9.06E+00	-	-
^{63}Ni	-	3.10E+05	-	1.06E+03	-	-
^{79}Se	-	-	-	6.58E+01	-	-
^{89}Sr	-	-	-	1.36E-03	-	-
^{90}Sr	4.30E+05	5.22E+07	2.25E+06	1.12E+07	2.48E+07	-
^{90}Y	4.30E+05	5.22E+07	2.25E+06	1.12E+07	2.48E+07	-
^{91}Y	-	-	-	5.06E-02	-	-
^{93}Zr	-	9.70E+03	-	3.21E+02	-	-
^{95}Zr	-	-	-	3.71E-01	-	-
^{93m}Nb	-	8.14E+03	-	1.08E+02	-	-
^{95}Nb	-	-	-	8.22E-01	-	-
^{95m}Nb	-	-	-	2.74E-03	-	-
^{99}Tc	1.83E+04	-	-	1.39E+04	-	-
^{103}Ru	-	-	-	1.03E-06	-	-
^{103m}Rh	-	-	-	9.27E-07	-	-
^{106}Ru	-	1.95E+01	-	6.05E+05	-	-
^{106}Rh	-	1.95E+01	-	6.05E+05	-	-
^{107}Pd	-	-	-	8.21E+00	-	-
^{110}Ag	-	-	-	5.99E-01	-	-
^{110m}Ag	-	-	-	4.51E+01	-	-
^{113m}Cd	-	-	-	3.92E+03	-	-
^{115m}Cd	-	-	-	5.94E-08	-	-
^{113}Sn	-	-	-	7.15E-01	-	-
^{119m}Sn	-	-	-	8.21E+02	-	-
^{121m}Sn	-	-	-	6.48E+01	-	-
^{123}Sn	-	-	-	1.25E+01	-	-
^{126}Sn	-	-	-	1.04E+02	-	-
^{124}Sb	-	-	-	3.00E-06	-	-
^{125}Sb	-	-	-	3.80E+05	-	-
^{126}Sb	-	-	-	1.46E+01	-	-
^{126m}Sb	-	-	-	1.15E+02	-	-
^{123m}Te	-	-	-	4.97E-05	-	-
^{125m}Te	-	-	-	9.28E+04	-	-
^{127}Te	-	-	-	6.68E+00	-	-
^{127m}Te	-	-	-	6.82E+00	-	-
^{129}Te	-	-	-	1.00E-10	-	-
^{129m}Te	-	-	-	1.54E-10	-	-
^{129}I	-	-	-	2.65E-01	-	-
^{134}Cs	-	-	-	1.96E+05	-	-
^{135}Cs	-	-	-	5.92E+01	-	-
^{137}Cs	1.02E+07	3.69E+06	3.74E+06	1.64E+07	-	5.73E+07
^{137m}Ba	9.66E+06	3.49E+06	3.54E+06	1.55E+07	-	5.42E+07
^{141}Ce	-	-	-	2.00E-09	-	-
^{144}Ce	-	-	-	1.13E+06	-	-
^{144}Pr	-	-	-	1.12E+06	-	-
^{144m}Pr	-	-	-	1.35E+04	-	-
^{147}Pm	-	-	-	8.05E+06	-	-

Table 2.17 (continued)

Radionuclide	Liquid	Sludge	Salt cake	Slurry	Capsules	
					^{90}Sr-^{90}Y	^{137}Cs-^{137m}Ba
^{148}Pm	-	-	-	2.29E-09	-	-
^{148m}Pm	-	-	-	4.06E-08	-	-
^{151}Sm	-	8.40E+05	-	2.32E+05	-	-
^{152}Eu	-	-	-	5.70E+02	-	-
^{154}Eu	-	-	-	7.32E+04	-	-
^{155}Eu	-	-	-	1.14E+05	-	-
^{153}Gd	-	-	-	3.06E-01	-	-
^{160}Tb	-	-	-	3.22E-05	-	-
^{234}U	-	-	-	1.23E+00	-	-
^{235}U	-	-	-	5.18E-02	-	-
^{236}U	-	-	-	1.08E-01	-	-
^{238}U	-	-	-	9.46E-01	-	-
^{237}Np	2.34E-03	-	-	4.51E+01	-	-
^{238}Np	-	-	-	2.18E-01	-	-
^{238}Pu	-	-	-	3.70E+02	-	-
^{239}Pu	-	2.20E+04	-	3.28E+03	-	-
^{240}Pu	-	5.30E+03	-	8.85E+02	-	-
^{241}Pu	-	5.51E+04	-	3.52E+04	-	-
^{242}Pu	-	-	-	8.68E-02	-	-
^{241}Am	7.51E+02	4.53E+04	-	5.24E+04	-	-
^{242}Am	-	-	-	4.33E+01	-	-
^{242m}Am	-	-	-	4.36E+01	-	-
^{243}Am	-	-	-	7.16E+00	-	-
^{242}Cm	-	-	-	3.78E+01	-	-
^{244}Cm	-	1.63E+02	-	1.34E+03	-	-
Total	2.07E+07	1.13E+08	1.18E+07	6.69E+07	4.97E+07	1.12E+08
Specific activity,[b] Ci/L	8.1E-01	2.5E+00	1.3E-01	7.3E-01	4.6E+04	4.5E+04

[a]Taken from ref. 3. Curies as of December 31, 1991.

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

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

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

[a]Taken from U.S. Department of Energy, Integrated Data Base for 1991: U.S. Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics, DOE/RW-0006, Rev. 7 (October 1991).

Table 2.19. Chemical composition of alkaline sludge HLW (from reprocessing via a PUREX flowsheet) at WVDP[a]

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

[a]Calculated from data given in U.S. Department of Energy, Integrated Data Base for 1991: U.S. Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics, DOE/RW-0006, Rev. 7 (October 1991).

[b]Excludes fission product zirconium.

Table 2.20. Chemical composition of acid liquid HLW (from reprocessing via a THOREX flowsheet) at WVDP[a]

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

[a]Adapted from U.S. Department of Energy, Integrated Data Base for 1991: U.S. Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics, DOE/RW-0006, Rev. 7 (October 1991).

Table 2.21. Radionuclide composition (December 31, 1991) of HLW at WVDP[a,b]

Radionuclide	Alkaline waste (PUREX)		Acid waste (THOREX)	Zeolite waste (Ion exchanger)	
	Liquid (Ci)	Sludge (Ci)	Liquid (Ci)	Slurry (Ci)	Total (Ci)
^{90}Sr	0.00E+00	5.80E+06	4.69E+05	0.00E+00	6.269E+06
^{90}Y	0.00E+00	5.80E+06	4.69E+05	0.00E+00	6.269E+06
^{137}Cs	1.17E+06	0.00E+00	4.69E+05	5.40E+06	7.039E+06
^{137m}Ba	1.10E+06	0.00E+00	4.39E+05	5.05E+06	6.589E+06
Total	2.270E+06	1.160E+07	1.846E+06	1.045E+07	2.617E+07
Specific activity,[c] Ci/L	1.44E+00	2.04E+02	4.10E+01	2.01E+02	1.51E+01

[a]Taken from ref. 4.

[b]An estimate (as of December 31, 1990) of other radionuclides that, according to fission theory, should be in this waste (i.e., calculated using an isotopic generation/depletion code) is given in U.S. Department of Energy, Integrated Data Base for 1991: U.S. Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics, DOE/RW-0006, Rev. 7 (October 1991).

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

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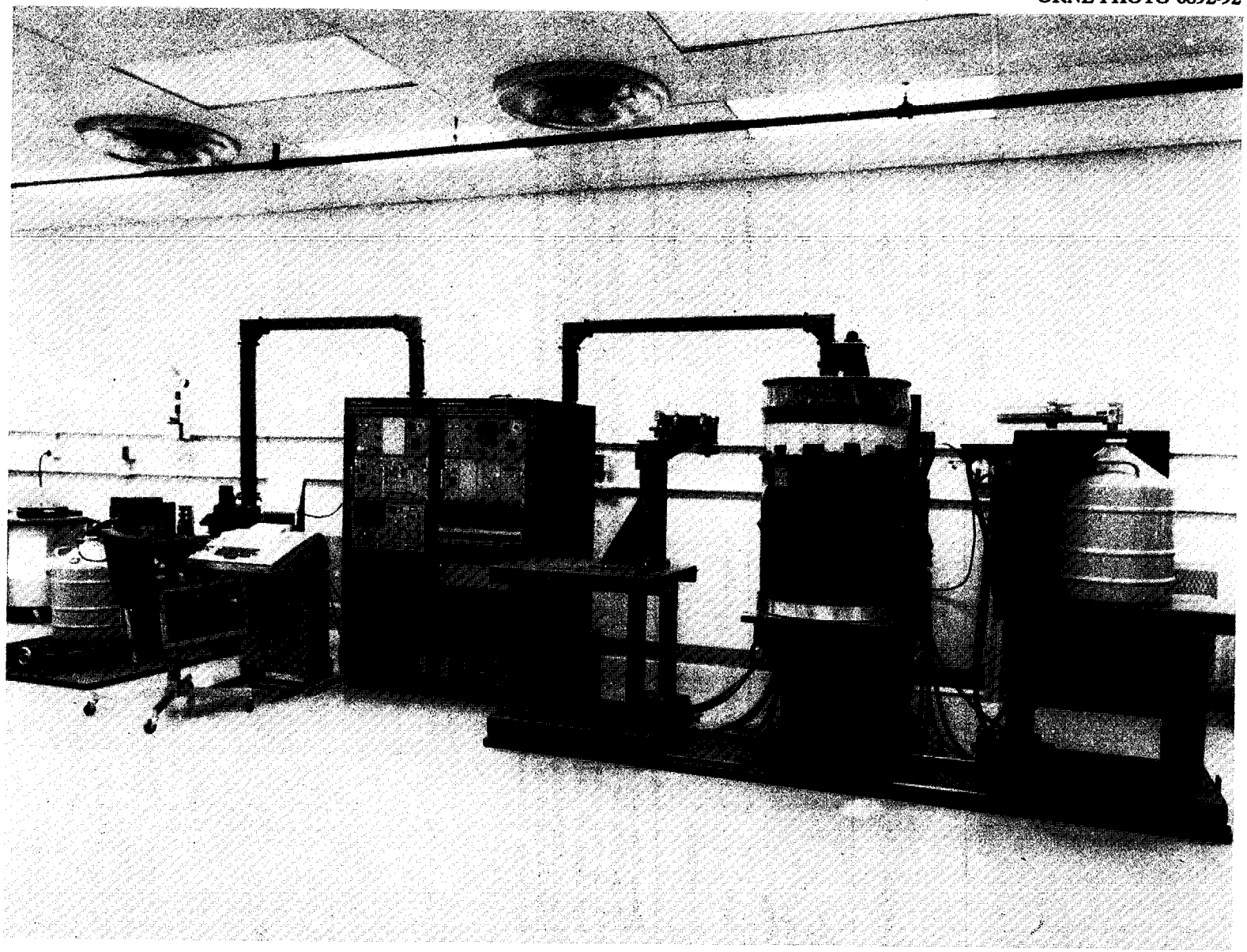

Photo 3.1. Assay equipment used at the Hanford Site to determine the radionuclide content of transuranic waste drums. (Courtesy of Westinghouse Hanford Company, Richland, Washington.)

3. TRANSURANIC WASTE

3.1 INTRODUCTION

Transuranic (TRU) waste is currently defined in DOE Order 5820.2A as, "without regard to source or form, waste that is contaminated with alpha-emitting transuranium radionuclides with half-lives greater than 20 years, and concentrations greater than 100 nCi/g at the time of assay. Heads of Field Elements can determine that other alpha-contaminated waste, peculiar to a specific site, must be managed as transuranic waste."[1] This definition includes isotopes of neptunium (Np), plutonium (Pu), americium (Am), curium (Cm), and californium (Cf). Waste containing TRU alpha contamination with less than 100 nCi/g is classified and managed as low-level waste (LLW).

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

The majority (>90%) of TRU waste contains mainly plutonium, which emits alpha particles and low-energy photons. Therefore, the packaging is designed to provide sufficient containment and shielding to minimize personnel exposure problems. This waste form is referred to as "contact handled" (CH). Some TRU waste also contains activation materials and fission products that decay by beta emission and produce penetrating gamma radiation. This waste is referred to as "remote handled" (RH) if the radiation level at the surface of the packaging exceeds 200 mrem/h.

It is estimated that as much as 50 to 60% of the TRU waste is mixed waste in that it also contains hazardous constituents defined and regulated by the Resource Conservation and Recovery Act (RCRA). Examples of mixed waste are radionuclide-contaminated spent solvents, discarded materials contaminated with both solvents and radioactive materials, scintillation fluids, and discarded contaminated lead shielding.

Under existing arrangements, retrievably stored TRU waste is the responsibility of the DOE/EM Office of Waste Management (EM-30). It is planned that the retrievably stored TRU waste and newly generated TRU waste from defense-related activities will be shipped to the Waste Isolation Pilot Plant (WIPP) for disposal. WIPP is beginning a 5- to 7-year test phase to ensure that the repository will meet all federal and state disposal requirements for mixed waste. If the test phase is successful, the retrievable TRU waste inventory will be disposed of in WIPP over approximately the next 20 years. Buried TRU waste and TRU waste generated from site remediation activities and D&D activities are the responsibility of the Office of Environmental Restoration (EM-40). The disposition of these TRU wastes is uncertain at this time.

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

3.2 TRU WASTE LOCATIONS

TRU waste management activities (generation, burial, storage, etc.) are performed at six major DOE sites: Hanford Site (HANF), Idaho National Engineering Laboratory (INEL), Los Alamos National Laboratory

(LANL), Oak Ridge National Laboratory (ORNL), Rocky Flats Plant (RFP), and the Savannah River Site (SRS); and five minor sites: Argonne National Laboratory-East (ANL-E), Lawrence Livermore National Laboratory (LLNL), Mound, Nevada Test Site (NTS), and Sandia National Laboratory (SNLA). Figure 3.1 shows the locations of these sites and associated volumes of buried and stored TRU waste. Figure 3.2 identifies the points of origin of TRU waste and the locations of retrievably stored TRU waste. HANF and RFP are no longer generating TRU waste as part of a weapons production process but are generating TRU waste as part of environmental restoration (cleanup) activities.

3.3 INVENTORIES

Early disposal practices did not include the current requirements for waste identification, categorization, and segregation. Consequently, the early inventory data are based on process knowledge and on various studies and summaries related to site-specific disposal practices.[3] As these efforts continue and TRU waste is further characterized (radioassayed), significant changes in the estimated overall quantities of TRU waste are anticipated.

Figures 3.3 and 3.4 show the total volumes, masses, and percentages by site of the buried TRU waste. Similar data for retrievably stored TRU waste are shown in Figs. 3.5 and 3.6. The majority of the buried waste is shown to be located at HANF and INEL, while most of the retrievably stored waste is divided among HANF, INEL, LANL, ORNL, and SRS.

Table 3.1 summarizes the total inventories and projected accumulations of buried and retrievably stored TRU wastes at DOE sites. Volumes and masses shown are based on the quantities reported by the storage sites, as shown in Tables 3.2, 3.14, and 3.16. Radioactivities and thermal powers shown in Table 3.1 are decayed values that take into account the processes of radioactive decay and ingrowth of daughter products. To obtain these decayed values, a simplified version of the decay portion of the ORIGEN2 code was applied to the estimated isotopic compositions of the wastes at the sites; these compositions are on an as-stored (undecayed) basis. The WIPP radionuclide inventory report (ref. 4) was used as the best source of data on the undecayed isotopic compositions at the sites because the site-supplied data (Tables 3.9 through 3.13) were not adequate, in most cases, to determine isotopic compositions. The WIPP radionuclide report was based on the site-supplied data, but used additional information obtained from the sites to establish isotopic compositions. Because the WIPP radionuclide inventory study did not include data on buried wastes, the isotopic compositions for the buried wastes were based on site-supplied data (Table 3.8). Buried waste radioactivities and thermal powers in Table 3.1 are not included for ORNL or SRS because compositions at these sites are unknown. Radioactivities and thermal powers for HANF-projected remote-handled waste were not included in the totals because the composition of this waste was specifically stated by HANF to be unknown.

There are inconsistencies in the projected volumes of TRU wastes in Tables 3.13 and 3.16. The volumes in Table 3.13 are those submitted by the sites on one of the submittal tables. These volumes do not agree with the volumes shown in other submittal tables used to prepare Table 3.16. In next year's IDB report, an effort will be made to eliminate such sources of inconsistency.

The estimated buried TRU waste volume and nuclide mass and the associated quantity of alpha radioactivity are shown in Table 3.2.[5,6] The alpha radioactivity has been estimated from historical records and will be later verified through radioassay. Over the years, many of the older disposed containers have breached and contaminated the adjacent soil. Also, at some sites, soil has become contaminated by liquid spills or the soil has been used as an ion-exchange medium for dilute liquid waste streams. These scenarios are represented by the data contained in Tables 3.3 and 3.4. It is difficult to accurately determine the actual quantity of contaminated soil, as noted by the ranges in the reported volumes. Additional characterization efforts will be required to reduce the uncertainty in these data.

Table 3.5 shows the inventory of CH-TRU and RH-TRU retrievably stored waste for each site. The table also provides estimates of the quantity of TRU waste that may be reclassified and managed as LLW. It is estimated that approximately 37% of the current inventory will be reclassified and designated as LLW. The CH waste inventories are reported in "as packaged" volumes for shipment to WIPP. These volumes assume a drum volume of 0.208 m^3 and a standard waste box volume of 1.9 m^3 for storage. Remote-handled waste volumes are reported as currently packaged for storage. Prior to shipment to WIPP, RH waste will be placed in canisters. Each canister can hold three 30-gal drums, three 55-gal drums, or loose waste in a total canister volume of 0.89 m^3. Therefore, the canistered volume of RH waste will be larger than the current inventory volume. Current estimates are that approximately 9,200 canisters will be available for disposal.[5]

The percentage of TRU waste certified for acceptance at the WIPP is not included in this year's report. In past years, these data have been based on the quantity of waste certified to the WIPP operational criteria. Although many of these certifications may still be valid, no determination has been made of the actual quantity of certified TRU waste that meets the requirements for either current WIPP waste acceptance criteria (WIPP-WAC),[7] TRUPACT-II shipment containers, or RCRA constituents for WIPP.

The ongoing efforts at the DOE sites in reviewing historical records, along with sampling and characterization programs, generate updated information that makes previously published information obsolete. Table 3.6

(based on refs. 5 and 8) provides continuity to the tables in this chapter. Listed below is a brief description of the current status or changes made in this year's data.

- Argonne National Laboratory-East: Newly generated CH-TRU waste was stored at ANL-E during 1991. Previously, TRU waste was shipped to a designated DOE storage site.
- Hanford Site: Most of the 30% volume increase in stored CH-TRU waste is due to a change in the assumed TRU waste/LLW ratio and an increase in the anticipated volume change after treatment.
- Idaho National Engineering Laboratory: There are no significant changes from last year's data.
- Lawrence Livermore National Laboratory: Newly generated CH-TRU waste was stored at LLNL during 1991. Previously, TRU waste was shipped to a designated DOE storage site.
- Los Alamos National Laboratory: The volume of retrievably stored RH-TRU waste was dramatically increased because of the reclassification of waste previously considered to be certifiable at a much smaller volume.
- Nevada Test Site: Small increases have been made in the volume reported because of continuing efforts to upgrade the data.
- Oak Ridge National Laboratory: Small changes have been made due to re-examination of existing data records.
- Rocky Flats Plant: Projections have been reduced based on the RFP mission change, and the revised projections reflect shutdown generation estimates. Small increases in the volume reported are due to this year's activities.
- Savannah River Site: The 35% increase in stored CH-TRU waste was due to additions listed in 1991 waste management reports.

3.4 WASTE CHARACTERIZATION

3.4.1 Physical Composition

The physical compositions of the TRU waste inventory are given in Table 3.7. These data are based on historical records, current activities, and projections for future operations.

3.4.2 Isotopic Composition

Isotopic compositions (weight and activity percentages) are given in Tables 3.8 through 3.12, respectively, for buried, CH, and RH waste at the DOE sites. These data are reported in Table 3.13 as a composite mixture for a site (Hanford CH-TRU) or as individual mixtures for the various types of site operations (SRS). Selected data in ref. 4 plus information from the sites reported in Table 3.14 and a simplified version of the ORIGEN2 computer code were utilized in the calculations of thermal power and total radioactivity included in Tables 3.1 and 3.15. Comparison of Tables 3.6 and 3.15 shows that in two cases (MOUND and NTS), the total decayed radioactivity of the stored CH waste is less than the undecayed alpha activity reported by the sites. This is, in part, due to inaccuracies in the composition data and the reported alpha activities, as well as the fact that the reported alpha activities do not include radioactive decay and contribution of radioactive daughter products.

3.5 SHIPMENT AND DISPOSAL

It is the goal of the DOE TRU Waste Program to terminate interim storage and to achieve permanent disposal of DOE TRU waste.[9] In compliance with Public Law 96-164,[10] the WIPP project is being 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."

The WIPP will receive TRU waste to conduct various experiments related to regulatory compliance of the repository. If WIPP meets the requirements, the waste will be emplaced on an operational basis through, approximately, the year 2018. Waste received at WIPP must meet the WIPP-WAC and associated quality assurance requirements specified in WIPP/DOE-069.[7] Table 3.16 provides the data on the estimated future generation of waste. Some quantities of TRU waste will be generated in environmental restoration activities, as discussed in Chapter 6.

3.6 REFERENCES

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

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4. U.S. Department of Energy, Radionuclide Inventory for the Waste Isolation Pilot Plant, DOE/WIPP 91-058, Rev. 0 (Draft) (Fall 1991).

5. W. J. Arthur III, U.S. Department of Energy, Field Office, Albuquerque, Project Director, WIPP Project Integration Office, Albuquerque, New Mexico, memorandum to T. C. Harms, U.S. Department of Energy, Office of Waste Management, Technical Support Division (EM-351), Washington, D.C., "Integrated Data Base for 1992," dated Oct. 19, 1992.

6. D. M. Lund, U.S. Department of Energy, Field Office, Albuquerque, Albuquerque, New Mexico, memorandum to J. A. Klein, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "TRU Waste Program's IDB Submittal through Dec. 31, 1986," dated Mar. 31, 1987.

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

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

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

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

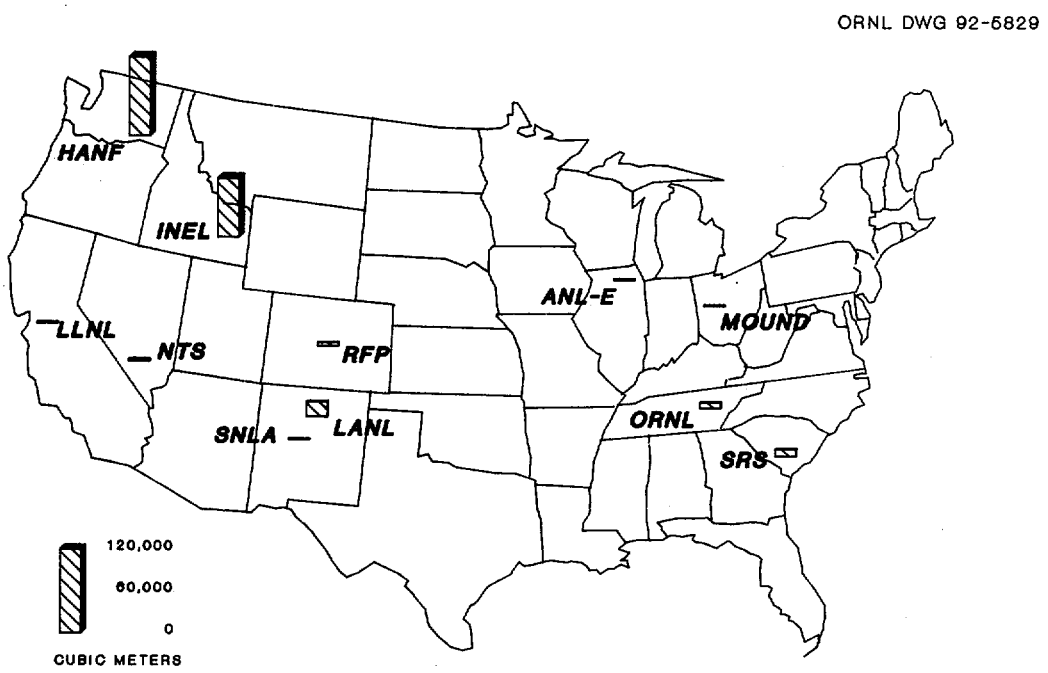


Fig. 3.1. Locations and total volumes of buried and stored DOE TRU waste through 1991.

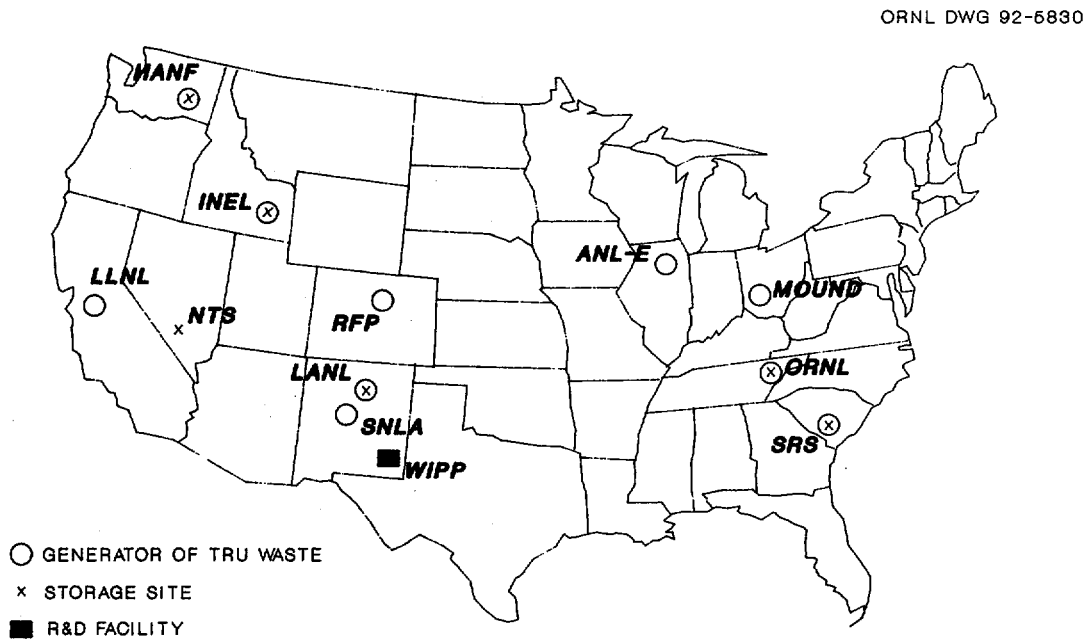
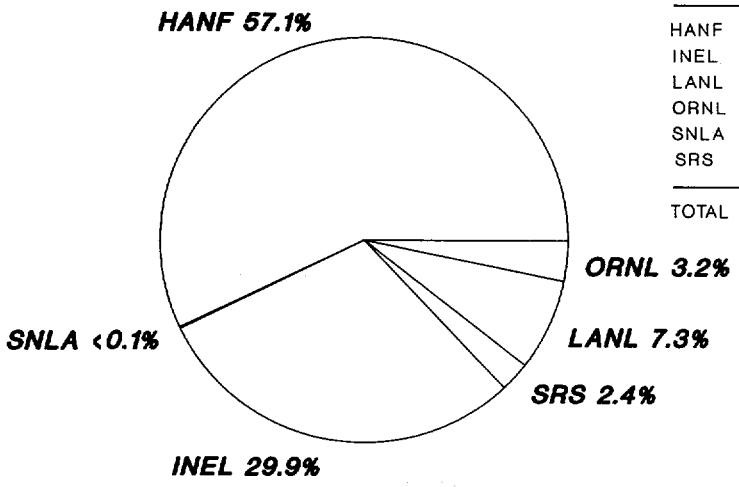


Fig. 3.2. Points of origin and storage sites of DOE TRU waste.

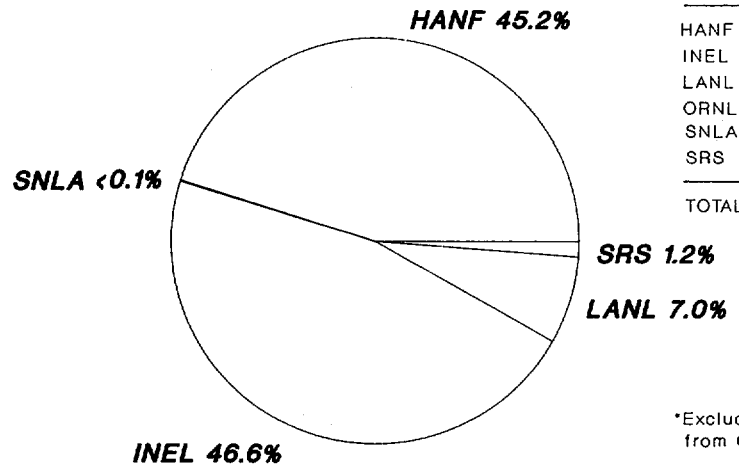
ORNL DWG 92-6831



SITE	CUBIC METERS
HANF	1.09E+05
INEL	5.71E+04
LANL	1.40E+04
ORNL	5.96E+03
SNLA	3.00E+00
SRS	4.53E+03
TOTAL	1.91E+05

Fig. 3.3. Total volume of buried DOE TRU waste through 1991.

ORNL DWG 92-5832



SITE	KILOGRAMS
HANF	3.46E+02
INEL	3.57E+02
LANL	5.35E+01
ORNL	UNKNOWN
SNLA	<1.00E+00
SRS	9.10E+00
TOTAL*	7.66E+02

*Excludes contributions from ORNL

Fig. 3.4. Total mass of TRU elements in buried DOE TRU waste through 1991.

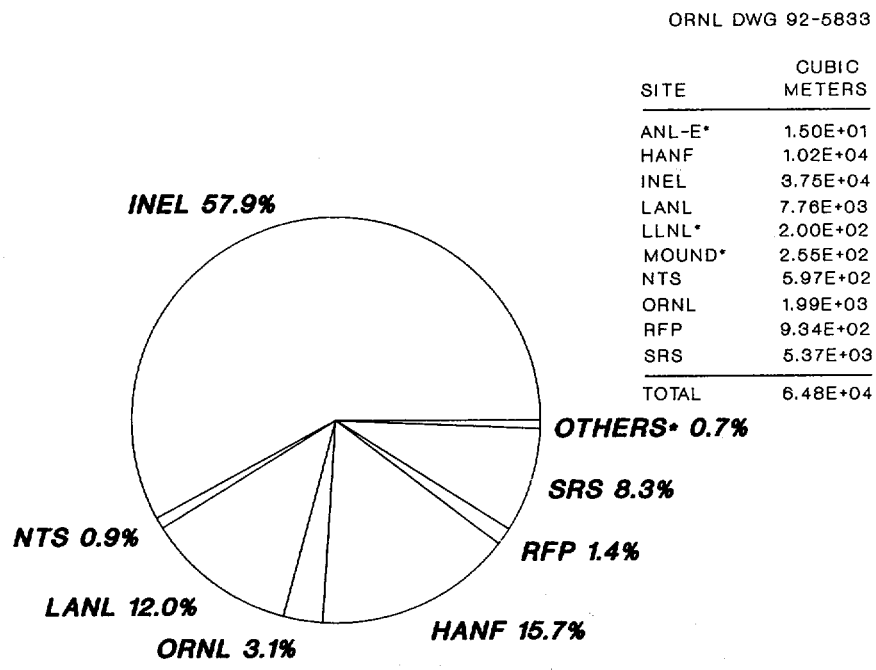


Fig. 3.5. Total volume of retrievably stored DOE TRU waste through 1991.

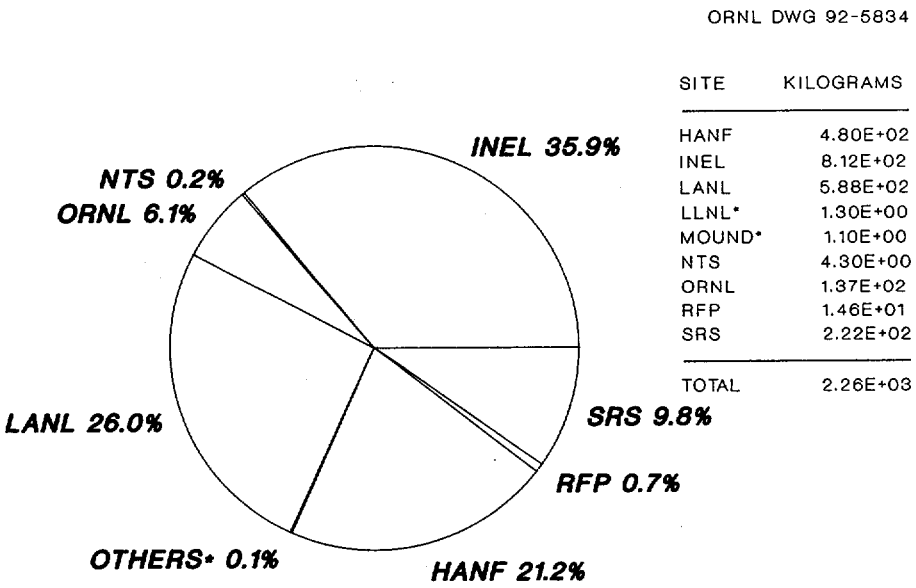


Fig. 3.6. Total mass of TRU elements in retrievably stored DOE TRU waste through 1991.

Table 3.1. Total system inventories, projections, and characteristics of buried and stored DOE TRU waste[a]

End of calendar year	Volume (m^3)		Mass[b] (kg)		Radioactivity[c] (10^3 Ci)		Thermal power[c] (10^3 W)	
	Annual[d]	Cumulative	Annual[d]	Cumulative	Annual[d]	Cumulative	Annual[d]	Cumulative
				Buried[e]				
1991		190,584.0		765.6		278.67		2.37
1992		190,584.0		765.6		272.59		2.35
1993		190,584.0		765.6		266.69		2.33
1994		190,584.0		765.6		260.96		2.31
1995		190,584.0		765.6		255.40		2.29
1996		190,584.0		765.6		249.99		2.27
1997		190,584.0		765.6		244.73		2.25
1998		190,584.0		765.6		239.61		2.23
1999		190,584.0		765.6		234.63		2.21
2000		190,584.0		765.6		229.78		2.19
2001		190,584.0		765.6		225.06		2.17
2002		190,584.0		765.6		220.47		2.15
2003		190,584.0		765.6		216.00		2.14
2004		190,584.0		765.6		211.64		2.12
2005		190,584.0		765.6		207.40		2.10
2006		190,584.0		765.6		203.27		2.08
2007		190,584.0		765.6		199.25		2.07
2008		190,584.0		765.6		195.32		2.05
2009		190,584.0		765.6		191.50		2.04
2010		190,584.0		765.6		187.78		2.02
2011		190,584.0		765.6		184.15		2.00
2012		190,584.0		765.6		180.61		1.99
2013		190,584.0		765.6		177.16		1.97
2014		190,584.0		765.6		173.80		1.96
2015		190,584.0		765.6		170.52		1.94
2016		190,584.0		765.6		167.32		1.93
2017		190,584.0		765.6		164.21		1.91
2018		190,584.0		765.6		161.17		1.90
				Stored, contact-handled[f]				
1991	1,827.7	63,138.8	22.8	2,138.4	110.34	1,887.51	1.76	36.06
1992	2,347.1	65,485.9	81.3	2,219.8	54.16	1,560.46	1.11	34.69
1993	2,347.1	67,833.0	81.3	2,301.1	54.16	1,584.32	1.11	35.59
1994	2,347.1	70,180.1	81.3	2,382.5	54.16	1,608.01	1.11	36.48
1995	2,347.1	72,527.2	81.3	2,463.8	54.16	1,631.58	1.11	37.37
1996	2,347.1	74,874.3	81.3	2,545.1	54.16	1,655.06	1.11	38.26
1997	2,347.1	77,221.4	81.3	2,626.5	54.16	1,678.46	1.11	39.13
1998	2,347.1	79,568.5	81.3	2,707.8	54.16	1,701.80	1.11	40.01
1999	2,347.1	81,915.6	81.3	2,789.2	54.16	1,725.09	1.11	40.87
2000	2,347.1	84,262.7	81.3	2,870.5	54.16	1,748.34	1.11	41.73
2001	2,347.1	86,609.8	81.3	2,951.8	54.16	1,771.56	1.11	42.59
2002	2,347.1	88,956.9	81.3	3,033.2	54.16	1,794.73	1.11	43.43
2003	2,347.1	91,304.0	81.3	3,114.5	54.16	1,817.87	1.11	44.28
2004	2,347.1	93,651.1	81.3	3,195.9	54.16	1,840.96	1.11	45.11
2005	2,347.1	95,998.2	81.3	3,277.2	54.16	1,864.02	1.11	45.95
2006	2,347.1	98,345.3	81.3	3,358.5	54.16	1,887.03	1.11	46.77
2007	2,347.1	100,692.4	81.3	3,439.9	54.16	1,909.99	1.11	47.59
2008	2,347.1	103,039.5	81.3	3,521.2	54.16	1,932.90	1.11	48.41
2009	2,347.1	105,386.6	81.3	3,602.6	54.16	1,955.75	1.11	49.22
2010	2,347.1	107,733.7	81.3	3,683.9	54.16	1,978.54	1.11	50.02
2011	2,347.1	110,080.8	81.3	3,765.2	54.16	2,001.27	1.11	50.82
2012	2,347.1	112,427.9	81.3	3,846.6	54.16	2,023.94	1.11	51.61
2013	2,347.1	114,775.0	81.3	3,927.9	54.16	2,046.53	1.11	52.40
2014	2,347.1	117,122.1	81.3	4,009.3	54.16	2,069.06	1.11	53.18
2015	2,347.1	119,469.2	81.3	4,090.6	54.16	2,091.50	1.11	53.96
2016	2,347.1	121,816.3	81.3	4,171.9	54.16	2,113.87	1.11	54.73
2017	2,347.1	124,163.4	81.3	4,253.3	54.16	2,136.16	1.11	55.50
2018[g]	2,347.1	126,510.5	81.3	4,334.6	54.16	2,158.36	1.11	56.26

Table 3.1 (continued)

End of calendar year	Volume (m^3)		Mass[b] (kg)		Radioactivity[c] (10^3 Ci)		Thermal power[c] (10^3 W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
				Stored, remote-handled[f,h]				
1991	60.6	1,651.6	4.0	122.1	37.58	555.38	0.16	3.04
1992	226.1	1,877.7	0.4	122.5	68.41	115.94	0.22	0.37
1993	226.1	2,103.8	0.4	122.9	68.41	159.69	0.22	0.49
1994	226.1	2,329.9	0.4	123.3	68.41	191.59	0.22	0.56
1995	226.1	2,556.0	0.4	123.7	68.41	216.99	0.22	0.61
1996	226.1	2,782.1	0.4	124.1	68.41	238.54	0.22	0.65
1997	226.1	3,008.2	0.4	124.5	68.41	257.59	0.22	0.69
1998	226.1	3,234.3	0.4	124.9	68.41	274.87	0.22	0.72
1999	226.1	3,460.4	0.4	125.3	68.41	290.83	0.22	0.76
2000	226.1	3,686.5	0.4	125.7	68.41	305.74	0.22	0.79
2001	226.1	3,912.6	0.4	126.1	68.41	319.78	0.22	0.82
2002	226.1	4,138.7	0.4	126.5	68.41	333.10	0.22	0.85
2003	226.1	4,364.8	0.4	126.9	68.41	345.78	0.22	0.88
2004	226.1	4,590.9	0.4	127.3	68.41	357.91	0.22	0.91
2005	226.1	4,817.0	0.4	127.7	68.41	369.55	0.22	0.93
2006	226.1	5,043.1	0.4	128.1	68.41	380.75	0.22	0.96
2007	226.1	5,269.2	0.4	128.5	68.41	391.54	0.22	0.99
2008	226.1	5,495.3	0.4	128.9	68.41	401.96	0.22	1.02
2009	226.1	5,721.4	0.4	129.3	68.41	412.03	0.22	1.04
2010	226.1	5,947.5	0.4	129.7	68.41	421.78	0.22	1.07
2011	226.1	6,173.6	0.4	130.1	68.41	431.22	0.22	1.10
2012	226.1	6,399.7	0.4	130.5	68.41	440.37	0.22	1.12
2013	226.1	6,625.8	0.4	130.9	68.41	449.25	0.22	1.15
2014	226.1	6,851.9	0.4	131.3	68.41	457.86	0.22	1.17
2015	226.1	7,078.0	0.4	131.7	68.41	466.22	0.22	1.20
2016	226.1	7,304.1	0.4	132.1	68.41	474.34	0.22	1.22
2017	226.1	7,530.2	0.4	132.5	68.41	482.23	0.22	1.25
2018[g]	226.1	7,756.3	0.4	132.9	68.41	489.89	0.22	1.27
				Total stored[h]				
1991	1,888.3	64,790.4	26.8	2,260.6	147.92	2,442.90	1.92	39.10
1992	2,573.2	67,363.6	81.7	2,342.3	122.56	1,676.39	1.33	35.06
1993	2,573.2	69,936.8	81.7	2,424.0	122.56	1,744.01	1.33	36.08
1994	2,573.2	72,510.0	81.7	2,505.8	122.56	1,799.60	1.33	37.04
1995	2,573.2	75,083.2	81.7	2,587.5	122.56	1,848.57	1.33	37.98
1996	2,573.2	77,656.4	81.7	2,669.3	122.56	1,893.60	1.33	38.91
1997	2,573.2	80,229.6	81.7	2,751.0	122.56	1,936.05	1.33	39.82
1998	2,573.2	82,802.8	81.7	2,832.7	122.56	1,976.67	1.33	40.73
1999	2,573.2	85,376.0	81.7	2,914.5	122.56	2,015.92	1.33	41.63
2000	2,573.2	87,949.2	81.7	2,996.2	122.56	2,054.08	1.33	42.52
2001	2,573.2	90,522.4	81.7	3,078.0	122.56	2,091.34	1.33	43.40
2002	2,573.2	93,095.6	81.7	3,159.7	122.56	2,127.83	1.33	44.28
2003	2,573.2	95,668.8	81.7	3,241.5	122.56	2,163.65	1.33	45.15
2004	2,573.2	98,242.0	81.7	3,323.2	122.56	2,198.88	1.33	46.02
2005	2,573.2	100,815.2	81.7	3,404.9	122.56	2,233.57	1.33	46.88
2006	2,573.2	103,388.4	81.7	3,486.7	122.56	2,267.78	1.33	47.73
2007	2,573.2	105,961.6	81.7	3,568.4	122.56	2,301.53	1.33	48.58
2008	2,573.2	108,534.8	81.7	3,650.2	122.56	2,334.86	1.33	49.42
2009	2,573.2	111,108.0	81.7	3,731.9	122.56	2,367.78	1.33	50.26
2010	2,573.2	113,681.2	81.7	3,813.6	122.56	2,400.32	1.33	51.09
2011	2,573.2	116,254.4	81.7	3,895.4	122.56	2,432.49	1.33	51.92
2012	2,573.2	118,827.6	81.7	3,977.1	122.56	2,464.31	1.33	52.73
2013	2,573.2	121,400.8	81.7	4,058.9	122.56	2,495.78	1.33	53.55
2014	2,573.2	123,974.0	81.7	4,140.6	122.56	2,526.92	1.33	54.36
2015	2,573.2	126,547.2	81.7	4,222.3	122.56	2,557.72	1.33	55.16
2016	2,573.2	129,120.4	81.7	4,304.1	122.56	2,588.21	1.33	55.96
2017	2,573.2	131,693.6	81.7	4,385.8	122.56	2,618.39	1.33	56.75
2018[g]	2,573.2	134,266.8	81.7	4,467.6	122.56	2,648.26	1.33	57.53

Table 3.1 (continued)

End of calendar year	Volume (m^3)		Mass[b] (kg)		Radioactivity[c] (10^3 Ci)		Thermal power[c] (10^3 W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
				Total stored and buried[i]				
1991	1,888.3	255,374.4	26.8	3,026.2	147.92	2,721.57	1.92	41.47
1992	2,573.2	257,947.6	81.7	3,107.9	122.56	1,948.98	1.33	37.41
1993	2,573.2	260,520.8	81.7	3,189.6	122.56	2,010.70	1.33	38.41
1994	2,573.2	263,094.0	81.7	3,271.4	122.56	2,060.56	1.33	39.35
1995	2,573.2	265,667.2	81.7	3,353.1	122.56	2,103.97	1.33	40.27
1996	2,573.2	268,240.4	81.7	3,434.9	122.56	2,143.59	1.33	41.18
1997	2,573.2	270,813.6	81.7	3,516.6	122.56	2,180.78	1.33	42.07
1998	2,573.2	273,386.8	81.7	3,598.3	122.56	2,216.28	1.33	42.96
1999	2,573.2	275,960.0	81.7	3,680.1	122.56	2,250.55	1.33	43.84
2000	2,573.2	278,533.2	81.7	3,761.8	122.56	2,283.86	1.33	44.71
2001	2,573.2	281,106.4	81.7	3,843.6	122.56	2,316.40	1.33	45.57
2002	2,573.2	283,679.6	81.7	3,925.3	122.56	2,348.30	1.33	46.43
2003	2,573.2	286,252.8	81.7	4,007.1	122.56	2,379.65	1.33	47.29
2004	2,573.2	288,826.0	81.7	4,088.8	122.56	2,410.52	1.33	48.14
2005	2,573.2	291,399.2	81.7	4,170.5	122.56	2,440.97	1.33	48.98
2006	2,573.2	293,972.4	81.7	4,252.3	122.56	2,471.05	1.33	49.81
2007	2,573.2	296,545.6	81.7	4,334.0	122.56	2,500.78	1.33	50.65
2008	2,573.2	299,118.8	81.7	4,415.8	122.56	2,530.18	1.33	51.47
2009	2,573.2	301,692.0	81.7	4,497.5	122.56	2,559.28	1.33	52.30
2010	2,573.2	304,265.2	81.7	4,579.2	122.56	2,588.10	1.33	53.11
2011	2,573.2	306,838.4	81.7	4,661.0	122.56	2,616.64	1.33	53.92
2012	2,573.2	309,411.6	81.7	4,742.7	122.56	2,644.92	1.33	54.72
2013	2,573.2	311,984.8	81.7	4,824.5	122.56	2,672.94	1.33	55.52
2014	2,573.2	314,558.0	81.7	4,906.2	122.56	2,700.72	1.33	56.32
2015	2,573.2	317,131.2	81.7	4,987.9	122.56	2,728.24	1.33	57.10
2016	2,573.2	319,704.4	81.7	5,069.7	122.56	2,755.53	1.33	57.89
2017	2,573.2	322,277.6	81.7	5,151.4	122.56	2,782.60	1.33	58.66
2018[g]	2,573.2	324,850.8	81.7	5,233.2	122.56	2,809.43	1.33	59.43

[a]Assembled from data in, and calculations based on, Tables 3.2, 3.5, 3.8 through 3.16, and ref. 4. Projected data listed as unknown in Table 3.16 are not included in Table 3.1.

[b]Mass of TRU nuclides.

[c]Radioactivities and thermal powers shown are decayed values. Values were calculated using the estimated isotopic compositions for TRU waste at the several sites given in ref. 4. See Sects. 3.3 and 3.4.2 for additional information.

[d]The projected annual rates shown are based on the simplifying assumption that each site produces waste at a constant annual rate during the period 1992-2018. For each site, the projected annual rate was taken as the average of the forecasted annual production rates estimated by that site.

[e]No TRU waste has been buried since the 1970s. Volumes shown include all sites shown on Table 3.2. Masses shown here exclude ORNL. Radioactivity and thermal power exclude ORNL, SNLA, and SRS, because compositions at these sites are unknown.

[f]Excludes waste currently managed as TRU waste but estimated to be LLW. See Table 3.5.

[g]Projections are based on a period beginning in 1992 and ending in 2018 (the approximate date for closure of WIPP).

[h]The total radioactivity and thermal power columns do not include values for Hanford's projected stored, remote-handled waste, because the isotopic composition of this waste is unknown.

[i]These totals are the sums of the buried, stored contact-handled, and stored remote-handled quantities.

Table 3.2. Inventories and characteristics of DOE buried TRU waste through 1991

Burial site	Values reported by storage site as of December 31, 1991[a]		
	Volume (m^3)	Mass of TRU nuclides (kg)	TRU alpha radioactivity[b] (Ci)
HANF[c]	109,000	346	29,000
INEL	57,100	357	73,267
LANL	14,000	53.5	9,230
ORNL	5,947	d	d
SNLA[e]	3	<<1	1
SRS	4,534	9.1	9,831
Total	190,584	>765.6	>121,329

[a]Data from ref. 5.
[b]As reported by storage sites. Does not include beta and gamma radioactivity or radiation from decay products.
[c]Includes soils mixed with buried waste.
[d]Reported as unknown.
[e]Data from ref. 6.

Table 3.3. Inventories and characteristics of soil contaminated by DOE TRU solid waste through 1991[a]

Site	Volume (m^3)	Mass of TRU nuclides (kg)	TRU alpha radioactivity (Ci)
HANF	b	b	b
INEL	56,000-156,000[c]	d	d
LANL	1,000	d	d
ORNL	d	d	d
SRS	38,000	d	d
Total	>95,000-195,000	d	d

[a]Data from ref. 5.
[b]Included with buried TRU wastes (Table 3.2).
[c]Larger value assumes that all the pit backfill soil is now contaminated.
[d]Reported as unknown.

Table 3.4. Inventories and characteristics of soil contaminated by DOE TRU liquid waste through 1991[a]

Site	Volume (m^3)	Mass of TRU nuclides (kg)	TRU alpha radioactivity (Ci)
HANF	32,610	190.2	16,706
LANL	140	0.12	8.6
MOUND	287.9	0.00237	39.21
ORNL	510	b	b
Total	33,547.9	>190.3	>16,753.8

[a]Data from ref. 5.
[b]Reported as unknown.

Table 3.5. Inventories and characteristics of retrievable DOE TRU waste at each storage site through 1991[a]

Site	Estimated to be TRU waste		Estimated to be LLW[b]		Total		
	Volume (m^3)	Mass of TRU nuclides (kg)	Volume (m^3)	Mass of TRU nuclides (kg)	Containerized volume[c] (m^3)	Mass of TRU nuclides[c] (kg)	Alpha radioactivity[c,d] (Ci)
				Contact-handled			
ANL-E[e]	15.0	f	0	0	15.0	f	32.5
HANF	9,987	474	5,378	0	15,365	474	54,500
INEL	37,426	811.4	27,335	11.6	64,761	823.0	206,151
LANL	7,685	583	272	0.02	7,957	583.0	195,351
LLNL[e]	199.6	1.3	0	0	199.6	1.3	517.4
MOUND[e]	255.1	1.1	8.5	0	263.6	1.1	1,713
NTS	596.5	4.3	0	0	596.5	4.3	806
ORNL	669.6	27.0	15.6	<<0.1	685.2	27.0	18,306
RFP[d]	934	14.6	0	0	934	14.6	4,730
SRS	5,371	221.7	4,330	2.7	9,701	224.4	676,862
Total	63,138.8	>2,138.4	37,339.1	14.42	100,477.9	>2,152.7	1,158,968.9
				Remote-handled			
HANF	201	6	0	0	201	6	873
INEL	55.54	0.57	21	0.01	76.54	0.58	100.4
LANL	78.52	5.4	0	0	78.52	5.4	132.4
ORNL	1,316.5	110.16	0	0	1,316.5	110.15	2,923
Total	1,651.56	122.13	21	0.01	1,672.56	122.13	4,028.8

[a]Data from ref. 5.
[b]Currently managed as TRU waste.
[c]Includes TRU waste plus stored waste that is to be managed as LLW.
[d]As reported by storage site. Does not include beta and gamma radioactivity or radiation from decay products.
[e]Temporary on-site storage.
[f]Unknown.

Table 3.6. Revisions and changes in historical inventories of stored DOE TRU waste from previous IDB report[a]

Site	Contact-handled				Remote-handled			
	Value as of Dec. 31, 1990[b]	Revisions and/or corrections to 1990 data[c]	Quantity added during 1991	Value as of Dec. 31, 1991	Value as of Dec. 31, 1990[b]	Revisions and/or corrections to 1990 data[c]	Quantity added during 1991	Value as of Dec. 31, 1991
				Total volume, m^3				
ANL-E[d]	0	0	15.0	15.0	0	0	0	0
HANF	7,665	2,287	35	9,987	201	0	0	201
INEL	37,422	0	4	37,426	49.9	+5.6	0	55.5
LANL	7,552	0	133	7,685	27.5	0	51.1	78.6
LLNL[d]	0	0	199.6	199.6	0	0	0	0
MOUND[d]	222.4	0	32.7	255.1	0	0	0	0
NTS	586.9	9.6	0	596.5	0	0	0	0
ORNL	666.8	-7.6	10.4	669.6	1,307	0	9.5	1,316.5
RFP[d]	915	0	19.0	934	0	0	0	0
SRS	3,992	0	1,379	5,371	0	0	0	0
Total	59,022.1	2,289.0	1,827.7	63,138.8	1,585.4	5.6	60.6	1,651.6
				Mass of TRU elements, kg				
ANL-E[d]	0	0	e	e	0	0	0	0
HANF	472	0	2	474	6	0	0	6
INEL	811.4	0	0	811.4	0.55	0	0.02	0.57
LANL	577	0	6.0	583	5.4	0	0	5.4
LLNL[d]	0	0	1.34	1.34	0	0	0	0
MOUND[d]	0.1	0	0.99	1.09	0	0	0	0
NTS	4.2	0	0.05	4.25	0	0	0	0
ORNL	26.7	-0.12	0.46	27.04	106.2	0	3.96	110.16
RFP[d]	14.3	0	0.3	14.6	0	0	0	0
SRS	208.7	0	13.0	221.7	0	0	0	0
Total	2,114.4	-0.12	>24.14	>2,138.4	118.15	0	3.98	122.13

Table 3.6 (continued)

Site	Contact-handled				Remote-handled			
	Value as of Dec. 31, 1990[b]	Revisions and/or corrections to 1990 data[c]	Quantity added during 1991	Value as of Dec. 31, 1991	Value as of Dec. 31, 1990[b]	Revisions and/or corrections to 1990 data[c]	Quantity added during 1991	Value as of Dec. 31, 1991
				Alpha radioactivity, Ci				
ANL-E[d]	0	0	32.5	32.5	0	0	0	0
HANF	54,467	0	33	54,500	873	0	0	873
INEL	207,412	-1,261	0	206,151	100	0	0.4	100.4
LANL	191,194	0	4,157	195,351	118.9	0	13.5	132.4
LLNL[d]	0	0	517.4	517.4	0	0	0	0
MOUND[d]	1,352	0	361	1,713	0	0	0	0
NTS	806	0	0	806	0	0	0	0
ORNL	18,348	-44.1	2.1	18,306	2,619	0	301.3	2,923.0
RFP[d]	4,760	-30.0	0	4,730	0	0	0	0
SRS	666,338	0	10,524	676,862	0	0	0	0
Total	1,144,677	-1,335.1	15,627.0	1,158,968.9	3,710.9	0	315.2	4,028.8

[a]Data from ref. 5.
[b]Data from ref. 8.
[c]Discussion of major changes in Sect. 3.3.
[d]Temporary on-site storage.
[e]Unknown.

Table 3.7. Estimated physical composition of retrievably stored, newly generated, and buried TRU waste at DOE sites[a]

Waste type	Waste composition, vol %: Contact-handled RSW[b]	Contact-handled NGW[c]	Remote-handled RSW[b]	Remote-handled NGW[c]	Buried
ANL-E					
Absorbed liquids or sludges		36			
Combustibles		32		50	
Filter or filter media		2			
Glass, metal, or similar noncombustibles		30		50	
Total		100		100	
HANF					
Absorbed liquids or sludges		47.9		4	1
Combustibles	37	0	50	0	43
Concreted or cemented sludge	9	4.6	20	6	
Dirt, gravel, or asphalt	3	6.1		1	3
Filters or filter media		6.5		5	1
Glass, metal, or similar noncombustibles	51	7.8	30	73	48
Other		27.1		11	4
Total	100	100.0	100	100	100
INEL					
Cellulosic materials	20	15	8	18	28
Cements	17	32	0	1	4
Corroding metal/aluminum	3	6	15	15	3
Corroding metal/steel	3	6	15	15	3
Inorganic sludges	17	1	0	1	25
Noncorroding metals	2	3	10	8	2
Other organic materials	5	2	0	0	0
Plastics	0	1	1	1	1
Rubber materials	0	1	1	1	1
Soils	0	1	0	0	7
Solid inorganic materials	13	32	50	40	15
Unknown	20	0	0	0	11
Total	100	100	100	100	100
LANL					
Cellulosic materials	1	3	10	10	2
Cements	4	18	0	0	42
Corroding metal/aluminum	14	15	10	10	2
Corroding metal/steel	20	20	15	15	5
Inorganic sludges	29	1	0	0	4
Noncorroding metals	20	20	20	20	5
Other organic materials	2	3	0	0	2
Plastics	1	10	30	30	5
Rubber materials	1	3	10	10	2
Soils	1	0	0	0	30
Solid inorganic materials	7	7	5	5	1
Total	100	100	100	100	100

Table 3.7 (continued)

Waste type	Waste composition, vol %				
	Contact-handled		Remote-handled		
	RSW[b]	NGW[c]	RSW[b]	NGW[c]	Buried
LLNL					
Cellulosic materials		65			
Cements		5			
Noncorroding metals		10			
Plastics		10			
Solid inorganic materials		10			
Total		100			
MOUND					
Cellulosic materials		0.82			
Corroding metal/steel		25.76			
Inorganic sludges		1.88			
Noncorroding metals		6.77			
Other organic materials		0.41			
Plastics		5.44			
Rubber materials		0.24			
Soils		56.64			
Solid inorganic materials		2.04			
Total		100.00			
ORNL					
Cellulosic materials	20	20	5	15	d
Cements	1	-	-	-	d
Corroding metal/aluminum	5	5	-	5	d
Corroding metal/steel	10	5	4	5	d
Inorganic sludges	-	-	64	-	d
Noncorroding metals	5	5	5	10	d
Other organic materials	-	-	-	-	d
Plastics	30	50	15	50	d
Rubber materials	14	5	2	5	d
Soils	-	-	-	-	d
Solid inorganic materials	15	10	5	10	d
Total	100	100	100	100	d
RFP					
Cellulosic materials		34.3			
Cements		28.4			
Corroding metal/aluminum		0.7			
Corroding metal/steel		13.2			
Inorganic sludges		0.0			
Noncorroding metals		1.0			
Other organic materials		0.1			
Plastics		4.5			
Rubber materials		5.0			
Soils		0.1			
Solid inorganic materials		12.7			
Total		100.0			

Table 3.7 (continued)

Waste type	Waste composition, vol %				
	Contact-handled		Remote-handled		
	RSW[b]	NGW[c]	RSW[b]	NGW[c]	Buried
	SRS				
Cellulosic materials		12			d
Cements		-			d
Corroding metal/aluminum		13			d
Corroding metal/steel		1			d
Inorganic sludges		-			d
Noncorroding metals		22			d
Other organic materials		1.2			d
Plastics		49			d
Rubber materials		0.8			d
Soils		-			d
Solid inorganic materials		1			d
Total		100.0			d

[a]Data from ref. 5.
[b]Retrievably stored waste (RSW). Vol % is best estimate of waste after processing and certification.
[c]Newly generated waste (NGW). This is waste that will be generated between 1992 and 2018.
[d]Unknown.

Table 3.8. Isotopic composition of buried TRU waste at each site[a]

Site	Major radionuclides	Composition	
		Wt %	Activity %
HANF	^{90}Sr-^{90}Y	-	1.2
	^{106}Ru-^{106}Rh	-	0.4
	^{137}Cs-$^{137m}Ba/^{137}Ba$	-	1.3
	^{144}Ce-^{144}Pr	-	4.0
	^{147}Pm	-	3.0
	^{232}Th	3.1	-
	U depleted	72.8	-
	U enriched	1.8	-
	U normal	19.9	-
	^{238}Pu	-	6.9
	^{239}Pu	2.2	2.0
	^{240}Pu	0.1	0.5
	^{241}Pu	-	13.5
	MFP	-	66.5
	Other	0.1	0.7
	Total	100.0	100.0
INEL	^{85}Kr	1.00	0.17
	^{90}Sr	26.40	1.47
	^{95}Zr	1.20	10.53
	^{134}Cs	3.10	1.69
	^{137}Cs	40.90	1.43
	^{144}Ce	13.70	18.15
	^{147}Pm	6.70	2.62
	^{238}Pu	3.60	0.03
	Total	96.60	36.09
LANL	^{238}U	5.00	b
	^{238}Pu	0.01	b
	^{239}Pu	91.00	b
	^{241}Am	3.30	b
	Total	99.31	b
ORNL	b	b	b
SRS	b	b	b

[a]Data from ref. 5. The data are as reported by the sites even though some of the columns do not add up to 100%.

[b]Information reported as unknown.

Table 3.9. Isotopic composition, by weight percent, of mixes used to describe composition of contact-handled TRU waste at each site[a] (retrievably stored and newly generated)

Site	Major radionuclides	Composition of mix, wt %							
		Mix-1[b]	Mix-2	Mix-3	Mix-4	Mix-5	Mix-6	Mix-7	Mix-8
ANL-E	^{235}U	-	25.20						
	^{238}U	88.50	-						
	^{239}Pu	11.50	74.80						
	^{240}Pu	<1.00	-						
	^{241}Pu	<1.00	<1.00						
	Total	100.00	100.00						
HANF	^{232}Th	3.10							
	U normal[c]	19.90							
	U enriched[d]	1.80							
	U depleted[e]	72.80							
	^{239}Pu	2.20							
	^{240}Pu	0.10							
	Other	0.10							
	Total	100.00							
INEL[f]	^{232}Th	-	-	-	-	-	96.00	-	-
	^{233}U	-	-	-	-	-	4.00	-	-
	^{235}U	-	-	-	58.50	37.63	-	-	-
	^{238}U	-	-	99.67	39.00	33.37	-	-	-
	^{238}Pu	Trace	-	-	-	-	-	-	-
	^{237}Np	-	-	-	-	-	-	-	100.00
	^{239}Pu	93.00	80.00	-	1.50	15.69	-	-	-
	^{240}Pu	5.80	10.00	-	1.38	3.05	-	-	-
	^{241}Pu	0.40	-	-	-	-	-	-	-
	^{242}Pu	0.03	-	-	1.87	-	-	-	-
	^{241}Am	0.08	5.00	-	-	-	-	-	-
	^{243}Am	-	-	-	-	-	-	100.00	-
	Other	0.70	5.00	-	-	-	-	-	-
	Total	100.00	100.00	99.67	102.25	89.74	100.00	100.00	100.00
LANL	^{238}Pu	5.00	0.50	1.20	0.50	-			
	^{239}Pu	92.00	21.50	98.80	93.00	100.00			
	^{241}Am	3.00	78.00	-	6.50	-			
	MFP[g]	-	Trace	-	-	-			
	Total	100.10	100.00	100.00	100.00	100.00			
LLNL	^{238}Pu	0.02	0.07	0.01	0.05	0.04			
	^{239}Pu	93.46	78.96	73.66	63.56	86.15			
	^{240}Pu	5.90	17.43	24.90	14.03	11.71			
	^{241}Pu	0.38	1.18	0.42	0.95	0.78			
	^{242}Pu	0.04	0.43	0.02	0.35	0.24			
	^{241}Am	0.20	1.94	0.99	21.07	1.08			
	Total	100.00	100.01	100.00	100.01	100.00			
MOUND	^{238}Pu	80.00							
	^{239}Pu	16.30							
	^{240}Pu	3.00							
	Other	0.70							
	Total	100.00							

Table 3.9 (continued)

Site	Major radionuclides	Composition of mix, wt %							
		Mix-1[b]	Mix-2	Mix-3	Mix-4	Mix-5	Mix-6	Mix-7	Mix-8
NTS	^{238}Pu	Trace							
	^{239}Pu	93.55							
	^{240}Pu	5.89							
	^{241}Pu	0.54							
	^{242}Pu	Trace							
	^{241}Am	Trace							
	Total	99.98							
ORNL	^{60}Co	-	0.01	-					
	^{99}Tc	-	0.95	-					
	^{137}Cs	-	0.03	-					
	^{232}Th	13.40	15.48	24.10					
	^{233}U	29.60	1.78	-					
	^{235}U	3.90	5.27	5.00					
	^{238}U	46.20	66.45	-					
	^{237}Np	-	0.41	-					
	^{238}Pu	-	0.42	-					
	^{239}Pu	6.50	5.18	69.70					
	^{240}Pu	-	2.77	-					
	^{241}Pu	Trace	0.67	-					
	^{241}Am	-	0.15	-					
	^{244}Cm	-	0.03	1.20					
	^{252}Cf	-	0.15	Trace					
	Other	0.40	0.40	-					
Total		100.00	99.16	100.00					
RFP	^{235}U	0.60							
	^{238}Pu	Trace							
	^{239}Pu	91.00							
	^{240}Pu	5.70							
	^{241}Pu	0.30							
	^{242}Pu	Trace							
	^{241}Am	1.70							
	Total	99.30							
SRS	^{237}Np	-	-	-	h	-	-		
	^{238}Pu	0.02	83.5	80.0	-	-	-		
	^{239}Pu	93.0	14.0	16.0	-	-	-		
	^{240}Pu	6.0	2.0	2.5	-	-	-		
	^{241}Pu	0.5	0.3	0.7	-	-	-		
	^{242}Pu	-	-	0.2	-	-	-		
	^{241}Am	0.3	-	-	-	h	-		
	^{244}Cm	-	-	-	-	-	h		
	Other	-	-	-	h	h	h		
	Total	99.82	99.8	99.4	100.00	100.00	100.00		

[a]Data from ref. 5. The data are as reported by the sites even though some of the columns do not add up to 100%.

[b]The mixes represent major waste stream composition variations or composite values. For the percent of each mix in the waste at each site, see Table 3.13.

[c]A mixture that contains a concentration of ^{235}U, which is the same as its natural abundance (0.711 wt %).

[d]A mixture that contains a concentration of ^{235}U that exceeds its natural abundance.

[e]A mixture that contains a concentration of ^{235}U that is less than its natural abundance.

[f]INEL also has a Mix-9, but no wt % data were provided for it.

[g]MFP is mixed fission product.

[h]Information reported as unknown.

Table 3.10. Isotopic composition, by activity percent, of mixes used to describe composition of contact-handled TRU waste at each site[a] (retrievably stored and newly generated)

Site	Major radionuclides	Composition of mix, activity %							
		Mix-1[b]	Mix-2	Mix-3	Mix-4	Mix-5	Mix-6	Mix-7	Mix-8
ANL-E	^{235}U	-	<1.0						
	^{238}U	1.0	-						
	^{239}U	22.9	36.6						
	^{240}U	6.9	-						
	^{241}U	70.2	63.4						
	Total	100.0	100.0						
HANF	^{90}Sr-^{90}Y	1.2							
	^{106}Ru-^{106}Rh	0.4							
	^{137}Cs-$^{137m}Ba/^{137}Ba$	1.3							
	^{144}Ce-^{144}Pr	4.0							
	^{147}Pm	3.0							
	^{238}Pu	6.9							
	^{239}Pu	2.0							
	^{240}Pu	0.5							
	^{241}Pu	13.5							
	MFP[c]	66.5							
	Other	0.7							
	Total	100.00							
INEL[d]	^{232}Th	-	-	-	e	-	10.00	-	-
	^{233}U	-	-	-	e	-	90.00	-	-
	^{235}U	-	-	3.5	e	-	-	-	-
	^{238}U	-	-	17.00	e	-	-	-	-
	^{237}Np	-	-	-	e	-	-	-	100.00
	^{238}Pu	0.30	-	-	e	-	-	-	-
	^{239}Pu	11.00	20.00	-	e	4.50	-	-	-
	^{240}Pu	2.60	9.30	-	e	3.20	-	-	-
	^{241}Pu	79.00	-	-	e	-	-	-	-
	^{242}Pu	Trace	-	-	e	-	-	-	-
	^{241}Am	5.40	70.00	-	e	-	-	-	-
	^{243}Am	-	-	-	e	-	-	100.00	-
	Other	1.70	0.70	-	e	-	-	-	-
	Total	100.00	100.00	20.50	e	7.70	100.00	100.00	100.00
LANL	^{238}Pu	80.0	1.9	74.0	10.0	-			
	^{239}Pu	18.0	0.5	26.0	62.0	100.0			
	^{241}Am	2.0	86.9	-	28.0	-			
	MFP[c]	-	10.7	-	-	-			
	Total	100.0	100.0	100.0	100.0	100.0			
LLNL	^{238}Pu	0.57	0.81	0.33	0.53	0.78			
	^{239}Pu	12.30	3.56	7.97	2.22	5.76			
	^{240}Pu	2.84	2.87	9.86	1.79	2.86			
	^{241}Pu	82.83	87.93	75.90	54.86	86.63			
	^{241}Am	1.46	4.83	5.94	40.60	3.98			
	Total	100.00	100.00	100.00	100.00	100.01			
MOUND	^{238}Pu	92.31							
	^{239}Pu	3.48							
	^{240}Pu	0.05							
	^{241}Pu	4.16							
	Total	100.00							

Table 3.10 (continued)

Site	Major radionuclides	Composition of mix, activity %							
		Mix-1[b]	Mix-2	Mix-3	Mix-4	Mix-5	Mix-6	Mix-7	Mix-8
NTS	^{238}Pu	3.51							
	^{239}Pu	63.11							
	^{240}Pu	25.37							
	^{241}Pu	8.00							
	^{242}Pu	0.01							
	^{241}Am	Trace							
	Total	100.00							
ORNL	^{60}Co	-	0.01	-					
	^{90}Sr	-	2.08	-					
	^{99}Tc	-	0.02	-					
	^{137}Cs	-	3.27	-					
	^{232}Th	Trace	Trace	Trace					
	^{233}U	24.6	0.02	-					
	^{235}U	Trace	Trace	Trace					
	^{238}U	Trace	Trace	-					
	^{237}Np	-	Trace	-					
	^{238}Pu	-	7.92	-					
	^{239}Pu	35.1	0.35	62.5					
	^{240}Pu	-	0.72	-					
	^{241}Pu	3.9	81.36	-					
	^{241}Am	-	0.52	-					
	^{244}Cm	-	2.83	31.6					
	^{252}Cf	-	-	5.7					
	Other	36.4	0.93	-					
	Total	100.0	100.03	99.8					
RFP	^{235}U	Trace							
	^{238}Pu	0.4							
	^{239}Pu	11.2							
	^{240}Pu	2.7							
	^{241}Pu	73.8							
	^{242}Pu	Trace							
	^{241}Am	11.9							
	Total	100.0							
SRS	^{237}Np	-	-	-	e	-	-		
	^{238}Pu	0.57	97.79	94.95	-	-	-		
	^{239}Pu	9.49	0.06	-	-	-	-		
	^{240}Pu	2.25	0.03	0.04	-	-	-		
	^{241}Pu	85.98	2.12	5.01	-	-	-		
	^{241}Am	1.71	-	-	-	e	-		
	^{244}Cm	-	-	-	-	-	e		
	Others	-	-	-	e	e	e		
	Total	100.00	100.00	100.00	100.00	100.00	100.00		

[a]Data from ref. 5. The data are as reported by the sites even though some of the columns do not add up to 100%.

[b]The mixes represent major waste stream composition variations or composite values. For the percent of each mix in the waste at each site, see Table 3.13.

[c]MFP is mixed fission product.

[d]INEL also has a Mix-9, but no activity percent data were provided for it.

[e]Information reported as unknown.

Table 3.11. Isotopic composition, by weight percent, of mixes used to describe composition of remote-handled TRU waste at each site[a] (retrievably stored and newly generated)

Site	Major radionuclides	Composition of mix, wt %						
		Mix-10[b]	Mix-11	Mix-12	Mix-13	Mix-14	Mix-15	Mix-16
ANL-E	^{137}Cs	1.30						
	^{238}U	57.60						
	^{239}Pu	35.40						
	^{240}Pu	5.70						
	^{241}Pu	<1.00						
	Total	100.00						
HANF	^{232}Th	3.10	16.00					
	U normal[c]	19.90	2.40					
	U enriched[d]	1.80	54.30					
	U depleted[e]	72.80	21.60					
	^{239}Pu	2.20	4.80					
	^{240}Pu	0.10	0.70					
	^{241}Pu	-	0.10					
	Other	0.10	0.10					
	Total	100.00	100.00					
INEL	^{63}Ni	-	-	-	-	-	-	2.00
	^{85}Kr	-	-	-	-	1.00	-	3.00
	^{90}Sr	-	-	-	-	26.40	-	-
	^{95}Zr	-	-	-	-	1.20	-	-
	^{99}Tc	-	-	-	-	-	-	4.00
	^{134}Cs	-	-	-	-	3.10	-	-
	^{137}Cs	-	-	-	-	40.90	-	4.00
	^{144}Ce	-	-	-	-	13.70	-	-
	^{147}Pm	-	-	-	-	6.70	-	-
	^{234}U	-	-	-	-	-	-	1.00
	^{235}U	38.20	39.40	58.50	65.10	-	-	44.00
	^{236}U	-	-	-	-	-	-	33.00
	^{238}U	55.20	59.10	39.00	32.10	-	-	2.00
	^{237}Np	-	-	-	-	-	-	3.00
	^{238}Pu	-	-	-	-	3.60	19.00	1.00
	^{239}Pu	5.00	1.35	1.50	-	-	-	-
	^{240}Pu	1.00	0.15	1.38	-	-	-	-
	^{242}Pu	-	-	1.87	2.08	-	-	-
	^{241}Am	-	-	-	-	-	81.00	-
	MFP[f]	0.60	-	-	-	-	-	-
	Total	100.00	100.00	102.25	99.28	96.60	100.00	97.00
LANL	^{235}U	47.00	47.00					
	^{238}U	28.00	28.00					
	^{239}Pu	22.70	22.70					
	^{240}Pu	2.10	2.10					
	^{241}Pu	0.20	0.20					
	MFP[f]	Trace	Trace					
	Total	100.00	100.00					

Table 3.11 (continued)

Site	Major radionuclides	Composition of mix, wt %						
		Mix-10[b]	Mix-11	Mix-12	Mix-13	Mix-14	Mix-15	Mix-16
ORNL	^{60}Co	0.01	-	0.01				
	^{90}Sr	-	Trace	1.98				
	^{137}Cs	-	0.01	0.78				
	^{154}Eu	-	-	0.14				
	^{232}Th	-	49.04	-				
	^{233}U	-	1.99	79.38				
	^{235}U	-	2.57	g				
	^{238}U	-	41.58	-				
	^{238}Pu	-	Trace	-				
	^{239}Pu	69.56	2.42	17.41				
	^{241}Am	0.31	0.06	0.16				
	^{244}Cm	0.54	0.02	0.14				
	^{252}Cf	0.03	-	-				
	Other	29.56	2.32	-				
	Total	100.01	100.01	100.00				

[a]Data from ref. 5. The data are as reported by the sites even though some of the columns do not add up to 100%.

[b]The mixes represent major waste stream composition variations or composite values. For the percent of each mix in the waste at each site, see Table 3.13.

[c]A mixture that contains a concentration of ^{235}U, which is the same as its natural abundance (0.711 wt %).

[d]A mixture that contains a concentration of ^{235}U that exceeds its natural abundance.

[e]A mixture that contains a concentration of ^{235}U that is less than its natural abundance.

[f]MFP is mixed fission product.

[g]Information reported as unknown.

Table 3.12. Isotopic composition, by activity percent, of mixes used to describe composition of remote-handled TRU waste at each site[a] (retrievably stored and newly generated)

Site	Major radionuclides	Composition of mix, activity %						
		Mix-10[b]	Mix-11	Mix-12	Mix-13	Mix-14	Mix-15	Mix-16
ANL-E	^{137}Cs	84.6						
	^{238}U	<1.0						
	^{239}Pu	1.4						
	^{240}Pu	1.0						
	^{241}Pu	13.0						
	Total	100.0						
HANF	^{60}Co	-	1.5					
	^{90}Sr-^{90}Y	1.2	-					
	^{106}Ru-^{106}Rh	0.4	-					
	^{137}Cs-$^{137m}Ba/^{137}Ba$	1.3	-					
	^{144}Ce-^{144}Pr	4.0	-					
	^{147}Pm	3.0	-					
	^{238}Pu	6.9	-					
	^{239}Pu	2.0	0.3					
	^{240}Pu	0.5	0.2					
	^{241}Pu	13.5	10.0					
	MFP[c]	66.5	87.9					
	Other	0.7	0.1					
	Total	100.00	100.0					
INEL	^{63}Ni	-	-	d	d	-	-	5.00
	^{85}Kr	-	-	d	d	0.17	-	-
	^{90}Sr	-	-	d	d	1.47	-	17.00
	^{95}Zr	-	-	d	d	10.53	-	-
	^{134}Cs	-	-	d	d	1.69	-	-
	^{137}Cs	-	-	d	d	1.43	-	18.00
	^{144}Ce	-	-	d	d	18.15	-	-
	^{147}Pm	-	-	d	d	2.62	-	-
	^{235}U	Trace	Trace	d	d	-	-	-
	^{238}U	Trace	Trace	d	d	-	-	-
	^{238}Pu	-	-	d	d	0.03	53.70	-
	^{239}Pu	3.00	71.00	d	d	-	-	-
	^{240}Pu	2.00	29.00	d	d	-	-	-
	^{241}Am	-	-	d	d	-	46.30	-
	MFP[c]	95.00	-	d	d	-	-	-
	Total	100.00	100.00	d	d	36.09	100.00	40.00
LANL	^{239}Pu	13.62	4.54					
	^{240}Pu	1.25	0.42					
	^{241}Pu	0.12	0.04					
	^{242}Pu	0.01	-					
	MFP[c]	85.00	95.00					
	Total	100.00	100.00					

Table 3.12 (continued)

Site	Major radionuclides	Composition of mix, activity %						
		Mix-10[b]	Mix-11	Mix-12	Mix-13	Mix-14	Mix-15	Mix-16
ORNL	^{60}Co	-	54.33	3.52				
	^{90}Sr	-	0.55	66.33				
	^{137}Cs	-	4.40	16.67				
	^{154}Eu	-	-	9.34				
	^{232}Th	-	Trace	-				
	^{233}U	-	0.17	0.19				
	^{235}U	-	Trace	d				
	^{238}U	-	Trace	-				
	^{238}Pu	-	Trace	0.27				
	^{239}Pu	4.52	1.38	-				
	^{241}Am	1.05	1.28	0.69				
	^{244}Cm	46.43	15.99	2.69				
	^{252}Cf	16.52	-	-				
	Other	31.48	21.90	-				
	Total	100.00	100.00	99.70				

[a]Data from ref. 5. The data are as reported by the sites even though some of the columns do not add up to 100%.

[b]The mixes represent major waste stream composition variations or composite values. For the percent of each mix in the waste at each site, see Table 3.13.

[c]MFP = mixed fission product.

[d]Information reported as unknown.

Table 3.13. Volumes, total activities, and isotopic mix ratios of TRU wastes stored or to be newly generated (1992-2018) at each site[a]

Site	Waste type	Volume (m^3)	Total activity (Ci)	Isotopic mix ratio[b,c]
			Contact-handled	
ANL-E	Stored	11.6	90.27	100% Mix-1
	Stored	3.4	14.61	100% Mix-2
	NGW[d]	64.89	503.0	100% Mix-1
	NGW	183.6	788.7	100% Mix-2
HANF	Stored	9,033	528,725	100% Mix-1
	NGW	11,324	288,770	100% Mix-1
INEL	Stored	32,801	380,540	100% Mix-1
	Stored	1,060	365	100% Mix-2
	NGW	65	20	13% Mix-4; 58% Mix-5; 29% Mix-9
	NGW	2	0	75% Mix-6; 12% Mix-7; 13% Mix-8
	NGW	3,802	56,230	100% Mix-1
	NGW	1	0	100% Mix-3
	NGW	234	12	100% Mix-6
LANL	Stored	4,241	469,300	e
	Stored	1,201	12,413	e
	Stored	775	4,098	e
	NGW	3,055	612,000	e
	NGW	219	4,790	e
LLNL	Stored	32.86	1,356.9	86% Mix-1; 1% Mix-2; 7% Mix-3; 5% Mix-4; 1% Mix-5
	Stored	149.54	61.2	98% Mix-1; 1% Mix-2; 1% Mix-3
	NGW	292.0	12,058	86% Mix-1; 1% Mix-2; 7% Mix-3; 5% Mix-4; 1% Mix-5
	NGW	79.8	169	98% Mix-1; 1% Mix-2; 1% Mix-3
MOUND	Stored	254.82	1,788.01	100% Mix-1
	NGW	4.78	0.72	100% Mix-1
NTS	Stored	596.5	806.0	100% Mix-1
ORNL	Stored	334.8	99,983	0.34 act % Mix-1; 99.65 act % Mix-2; 0.01 act % Mix-3
	NGW	447.9	227	10.0 act % Mix-1; 10.0 act % Mix-2; 80.0 act % Mix-3
RFP	Stored	934	18,126	100% Mix-1
	NGW	1,281	129,571	100% Mix-1
SRS	Stored	2,233	577,872	52.6% Mix-1, 29.7% Mix-2; 11.7% Mix-3; 1.3% Mix-4, 4.7% Mix-5
	Stored	2,724	236,400	32.0% Mix-1; 27.4% Mix-2; 36.3% Mix-3; 4.2% Mix-6
	NGW	8,043	461,253	58.6% Mix-1; 34.3% Mix-2; 3.7% Mix-4; 3.4% Mix-6
	NGW	11,907	39,739	60.6% Mix-1; 35.2% Mix-2; 4.2% Mix-4

Table 3.13 (continued)

Site	Waste type	Volume (m^3)	Total activity (Ci)	Isotopic mix ratio[b,c]
			Remote-handled	
ANL-E	NGW	88	953.6	100% Mix-10
HANF	Stored	328	759,220	100% Mix-10
	NGW	6,246	f	100% Mix-10
INEL	Stored	4	6,657	100% Mix-11
	Stored	42	824	100% Mix-10
	Stored	3	49	100% Mix-15
	NGW	8	1,520	100% Mix-16
	NGW	13	1,973	100% Mix-14
	NGW	52	141,680	88% Mix-12; 12% Mix-13
	NGW	65	296,000	100% Mix-12
LANL	Stored	19.8	2,651	e
	NGW	14.4	645	e
ORNL	Stored	1,901.04	52,966	0.6 act % Mix-10; 3.6 act % Mix-11; 95.8 act % Mix-12
	NGW	216.3	4.2	100% Mix-10

[a]Data from ref. 5.
[b]Isotopic mixes are found in Tables 3.9, 3.10, 3.11, and 3.12.
[c]The site information does not specify whether the mix percentages shown are by volume percent or total radioactivity percent.
[d]Newly generated waste (NGW). This is waste that will be generated between 1992 and 2018.
[e]LANL does not have the capability of determining the mix ratios.
[f]Unknown.

Table 3.14. Volume, mass, and total radioactivity of DOE TRU waste reported at each burial and storage site through 1991[a]

Site	Volume (m^3)		Mass of TRU nuclides (kg)		Total radioactivity (10^3 Ci)
	1991 rate	Cumulative	1991 rate	Cumulative	Cumulative
Buried					
HANF	0.0	109,000	0.0	346.0	531
INEL	0.0	57,100	0.0	357.0	253
LANL	0.0	14,000	0.0	53.5	9.2
ORNL	0.0	5,947	0.0	b	b
SNLA	0.0	3	0.0	0.0	1
SRS	0.0	4,534	0.0	9.1	b
Total	0.0	190,584	0.0	>765.6	>794.2
Stored, contact-handled					
ANL-E	15.0	15.0	0	b	0.105
HANF	35	9,987	2	474	528.7
INEL	4	37,426	0	811.4	421.4
LANL	133	7,685	6.0	583	497.5
LLNL	199.6	199.6	0	1.34	1.418
MOUND	32.7	255.1	0.99	1.09	1.787
NTS	0	596.5	0.03	4.25	0.806
ORNL	10.4	669.6	0.46	27.04	100.0
RFP	19.0	934	0.3	14.6	18.1
SRS	1,379	5,371	13.0	221.7	858.0
Total	1,827.7	63,138.8	22.78	>2,138.4	2,427.82
Stored, remote-handled					
HANF	0	201	0	6	759.22
INEL	0	55.5	0.02	0.57	8.31
LANL	51.1	78.6	0	5.4	6.18
ORNL	9.5	1,316.5	3.96	110.16	52.97
Total	60.6	1,651.6	3.98	122.13	826.7

[a]Assembled from data provided in ref. 5 and Tables 3.2 and 3.6.
[b]Unknown.

Table 3.15. Calculated decayed total radioactivity and thermal power at each burial and storage site through 1991

Site	Total radioactivity[a] (10^3 Ci) Cumulative	Thermal power (W) Cumulative
	Buried	
HANF	253.4	2,024.0
INEL	16.2	49.7
LANL	9.1	293.4
ORNL	b	b
SNLA	b	b
SRS	b	b
Total	>278.7	>2,367.1
	Stored, contact-handled	
ANL-E	0.08	0.9
HANF	351.15	2,281.2
INEL	328.53	5,714.2
LANL	370.69	5,319.3
LLNL	1.01	8.8
MOUND	1.65	54.5
NTS	0.55	3.2
ORNL	71.35	982.4
RFP	13.30	155.7
SRS	749.21	21,540.4
Total	1,887.52	36,060.6
	Stored, remote-handled	
HANF	506.42	2,876.4
INEL	3.63	12.6
LANL	4.22	13.2
ORNL	41.11	138.2
Total	555.38	3,040.4

[a]Values were calculated using the estimated isotopic compositions in ref. 4. See Sects. 3.3 and 3.4.2 for additional information.

Table 3.16. Projected volume, mass, and activity of TRU waste to be generated during 1992-2018[a]

Sites	Average annual container volume[b] (m^3)	Average annual TRU nuclide mass[c] (kg)	Average annual total radioactivity[c] (Ci)	Average annual alpha radioactivity[c] (Ci)
		Contact-handled		
Storage[d]				
HANF	465.2	e	e	e
INEL[f]	716.3	16.83	9,703.0	2,639.6
LANL	12.5	2.6	2,503.7	1,242.2
NTS	110.5	0.79	149.3	149.3
ORNL	17.7	0.02	4.2	3.9
SRS	605.4	54.5	36,229	36,229
Generation[g]				
ANL-E	47.07	1.26	245.6	83.4
LLNL	74.4	0.16	75.2	13.2
MOUND	59.6	1.48	518.5	0
RFP	238.4	3.7	4,728.1	1,235.9
Subtotal	2,347.1	>81.34	>54,156.6	>41,596.5
		Remote-handled		
Storage[d]				
HANF	175.5[h]	e	e	e
INEL	25.4	0.35	68,214.6	10.8
LANL	0.5	0.0002	12.04	0.05
ORNL	8.0	0.001	4.0	3.0
Generation[g]				
ANL-E	16.7	0.05	180.8	27.6
Subtotal	226.1	>0.4012	>68,411.44	>41.45

[a]Data from ref. 5.

[b]Volumes included are predominantly those associated with alpha activity greater than 100 nCi/g which had been averaged over the years 1992-2018.

[c]Values were generator-supplied.

[d]These sites have been designated as TRU waste storage sites.

[e]Information is unknown.

[f]Summary of CH contributions from ANL-W, Bettis Atomic Power Laboratory (BAPL), and ICPP.

[g]These sites generate but do not store TRU waste. Their waste will be sent to a designated site (HANF, INEL, LANL, NTS, ORNL, or SRS).

[h]Does not include a total of 34,000 m^3 of uncharacterized waste which will probably be RH TRU.

ORNL PHOTO 6893-92

Photo 4.1. Placement of waste in a low-level waste burial trench at the Hanford Site. (Courtesy of Westinghouse Hanford Company, Richland, Washington, and the Hazardous Waste Remedial Actions Program, Oak Ridge, Tennessee.)

4. LOW-LEVEL WASTE

4.1 INTRODUCTION

As used in this chapter, LLW has the same meaning as in The Low-Level Waste Policy Act (Pub. L. 95-573, Dec. 22, 1980). Namely, LLW is radioactive waste not classified as high-level radioactive waste, transuranic waste, spent nuclear fuel, or by-product material specified as uranium or thorium tailings and waste. The nuclear accelerator-generated radioactive material (NARM) and naturally occurring radioactive material (NORM) that are disposed of at DOE burial or commercial disposal sites are included in the inventories given, but are not treated as separate entities in this chapter. Tailings (viz., mill tailings) are considered in Chapters 5 and 6. Another waste classification not delineated in this chapter is "mixed" waste that contains both chemically hazardous and radioactive constituents (see Chapter 8). The DOE generates LLW through its defense activities, uranium enrichment operations, naval nuclear propulsion program, and various R&D activities.

Commercial nuclear fuel cycle facilities (see Table 4.1) currently account for almost four-fifths of the waste volume that is shipped to commercial disposal sites; the remainder comes from other non-fuel cycle-related industrial/institutional (I/I) activities. These non-fuel cycle I/I wastes include those from radiochemical manufacturers, research laboratories, hospitals, medical schools, universities, other radioactive materials licensees, and some non-DOE government agencies. More than 20,000 licenses have been issued by the NRC and "Agreement States" (see Glossary of Terms for definition) for the handling and use of radionuclides.

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

The categorization of LLW according to DOE activities, commercial reactor operations, and I/I applications permits a comparison of the types, radioactivity levels, and volumes of waste arising from each of these major sources (Figs. 4.1 and 4.2). Summary data on LLW (DOE and commercial) are given in Table 4.1. Historical and projected data by year for DOE LLW are presented in Table 4.2. In Table 4.3, similar data are shown for commercial LLW disposal (I/I and a commercial fuel cycle without spent fuel reprocessing). A plot showing a comparison of historical and projected LLW volumes for DOE and commercial (which includes some non-DOE government agencies classified as commercial) sources is shown in Fig. 4.3.

4.2 DOE LLW

4.2.1 Inventories at DOE LLW Disposal Sites

Prior to October 1979, some LLW generated by DOE contractors was shipped to commercial disposal sites. Currently, all LLW generated by DOE activities is buried at DOE sites (Figs. 4.4 and 4.5). A summary of historical additions, cumulative volumes, and cumulative undecayed radioactivity for solid LLW buried at all DOE sites through 1991 is presented in Tables 4.1, 4.2, 4.4–4.6, 4.9, and 4.10. Summaries of DOE site generated LLW volumes and activities are presented in Tables 4.7 and 4.8, respectively. The data in these tables are derived from the Waste Management Information System (WMIS) and subsequent site questionnaires obtained through the Hazardous Waste Remedial Actions Program (HAZWRAP).[1]

There are small quantities of DOE LLW that have been disposed of by sea dumping or by hydrofracture;[2] these wastes are not included in the WMIS data base. Table 4.11 shows the estimated quantity and radioactivity of LLW disposed of by these methods. Sea dumping of LLW was halted by the United States in 1970, and hydrofracture was terminated in 1983.

4.2.2 Characterization of LLW at DOE Sites

Based on information reported in ref. 1, summaries of radionuclide and physical characteristics for DOE LLW are reported in Tables 4.5–4.10. Summaries of representative radionuclide characteristics for generated, stored, and buried LLW at DOE sites are provided in Table 4.5. (Representative radionuclide compositions for the buried

waste types have been developed[3] and are given in Table C.5 of Appendix C.) Summaries of physical characteristics for generated, stored, and buried wastes are given in Table 4.6. Breakdowns of radionuclide characteristics for buried LLW at each DOE site are provided for cumulative waste volume in Table 4.9 and for total gross waste activity in Table 4.10.

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

Hydrofracture was developed at ORNL for the permanent disposal of locally generated, low-level (approximately 0.25 Ci/L) liquid waste concentrates.[4] Waste was mixed with a blend of cement and other additives, and the resulting grout was injected into shale at a depth of 200 to 300 m. The injected grout hardened into thin, horizontal sheets several hundred meters wide.

Significant changes in DOE LLW inventory and characteristics data reported in the 1991 edition (1990 data) of this report are summarized in Table 4.13.

4.2.3 DOE LLW Disposal Sites

A digest of data on the current status of land usage at DOE sites with active LLW disposal areas is shown in Table 4.12 (data from refs. 1, 2, and 5–7). Most of the DOE site land usage information currently reported in Table 4.12 is based on data given in ref. 1 with land usage factors taken from ref. 2.

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

4.2.4 DOE LLW Projections

An assumption used in this report is that the level of DOE waste burial activities will remain constant through 2030. Beginning in 1992, the volume and undecayed radioactivity added each year to each active LLW disposal area are assumed to remain constant through 2030 at the values projected for 1992. These volumes and activities are split into waste types using the radionuclide categories given in Tables 4.5, 4.9, and 4.10. The radioactivity (by waste type) is decayed from the year of addition through 2030 using the representative compositions given in Table C.5 of Appendix C.

Projections for burial of DOE LLW are presented in Tables 4.2, 4.14, and 4.15. Table 4.14 summarizes DOE LLW excluding saltstone. Table 4.15 summarizes projections of saltstone, an LLW by-product from the solidification of HLW at SRS. This saltstone (see Fig. C.10 and Table C.7 of Appendix C) is to be stored in concrete vaults at SRS. Grout-immobilized LLW derived from processing double-shell waste at Hanford (see Fig. 2.7 in Chapter 2) is excluded from the projections in Table 4.2, because the schedule and formulation for immobilization are not yet firmly defined.

4.3 COMMERCIAL LLW

4.3.1 Inventories at Commercial LLW Disposal Sites

There are six commercial shallow-land disposal sites for LLW (Figs. 4.2, 4.6, and 4.7), but only three are currently in operation. Commercial operations at the Maxey Flats, West Valley, and Sheffield 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 end of 1991 are listed in Tables 4.16 and 4.17, respectively (compiled from refs. 2, 6, 8–11). The volumes are depicted in Figs. 4.2, 4.3, 4.6, and 4.7. Sources of the historical reported data through 1984 are given in ref. 2 and through 1990 in ref. 6. Quantities of LLW shipped to disposal sites during 1991 are listed in Table 4.18 on a state-by-state basis.[8] These state-by-state values reflect the fact that the new Manifest Information Management System (MIMS) is able to assign, to the original shippers, the LLW collected and treated by waste brokers. Table 4.3 is a summary of historical and projected volumes and radioactivity (decayed) for commercial LLW. Not included in Table 4.3 are the drums of cemented LLW to be generated by the WVDP as a result of the vitrification of HLW. This LLW from the WVDP is described in Table C.10 of Appendix C.

A small portion (~5 vol %) of the LLW shipped to commercial sites originates with government operations other than DOE and is included in this chapter in the I/I waste category.

4.3.2 Characterization of LLW at Commercial Disposal Sites

All of the LLW accepted for commercial disposal is classified A, B, or C in compliance with NRC specifications.[12] The LLW that exceeds these specifications is currently in storage at the generator site or at a DOE site which has accepted it for study (see Sect. 4.3.3). A calculated representative radionuclide composition for disposed commercial LLW is given in Table C.6 of Appendix C. This composition is periodically updated to reflect changes in waste management practices and in the regulations governing LLW disposal.

Nuclear power plants in the United States are of two basic types: boiling-water reactors (BWRs) and

pressurized-water reactors (PWRs) (Figs. C.6 and C.7 of Appendix C). The BWRs are further classified as deep-bed or filter/demineralizer types, depending on the condensate cleanup system employed. The reference BWR used in this report is an average composite, based on the historical net electricity generation of both types. Although nonroutine, irradiated-component LLW is disposed of only sporadically, it accounts for a large portion of the total radioactivity (but only a minuscule portion of the volume) of the LLW shipped to disposal from nuclear power plants (see Table 4.1). Characteristics of LLW from the other fuel cycle facilities that ship to commercial disposal sites (UF_6 conversion and fuel fabrication) are presented in Figs. C.2, C.3, and C.5 of Appendix C. The LLW from nuclear power plant operations accounts for approximately 61% of the waste volume shipped to commercial LLW disposal sites (other fuel cycle operations account for about 18%).

Characteristics of the I/I wastes are presented in Table C.11 of Appendix C. Industrial LLW sources include, among others, radiochemical and pharmaceutical companies and manufacturers of smoke detectors and luminous dials, as well as UF_6 conversion and fuel fabrication facilities for LWRs. The latter two are shown separately in this chapter (Tables 4.1, 4.24, and 4.25) so that the contribution of the nuclear fuel cycle to LLW can be delineated.

In March 1981, the NRC removed some of the restrictions on the disposal of radioactive biomedical waste.[13] This was done to decrease the volumes of very low-level radioactive waste shipped to NRC-licensed commercial disposal facilities from hospitals, laboratories, medical schools, and other institutions. Representative characteristics of this institutional waste indicate three distinct waste streams, which can be categorized as bioresearch, nonbioresearch, and medical. This categorization was suggested by the University of Maryland in a survey published in 1979 (see ref. 2 for a succinct summary). Bioresearch waste results mainly from chemical tracers used in animal studies; nonbioresearch waste is derived from physical and earth science studies; and medical waste comes from medical diagnostic and therapeutic practices.

Significant changes in commercial LLW inventory and characteristics data reported in the 1991 edition (1990 data) of this report are summarized in Table 4.13.

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

In 1980, federal law made each state responsible for providing the disposal capacity for LLW generated within its borders, except for certain waste generated by the federal government.[14] In 10 CFR Part 61 (ref. 12), the NRC codifies disposal requirements for three classes of LLW, as mentioned above, generally suitable for near-surface disposal, namely, 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 LLRWPAA[15] made the states responsible for the disposal of Classes A, B, and C LLW and made the federal government (viz., DOE) responsible for disposal of GTCC LLW. The law also required that GTCC LLW generated by licensees of NRC be disposed of in a facility licensed by NRC. The projected amounts of GTCC LLW are uncertain, both because of regulatory uncertainties affecting the definition of HLW (i.e., a clearly defined all-inclusive list of wastes considered HLW may include more than those described in Chapter 2) and because of the lack of information on the sources, volumes, and characteristics of GTCC LLW.[16]

In May of 1989, NRC promulgated a rule that requires disposal of GTCC LLW in a deep geologic repository unless disposal elsewhere has been approved by NRC.[17] 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." A disposal facility (other than a deep geologic repository) for GTCC LLW will probably not be available for several decades due to the complexities of siting and NRC licensing. A generic description of estimated sources and forms of GTCC LLW is presented in Table C.9 of Appendix C.

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

The study determined that the largest volume of GTCC wastes, approximately 57%, is generated by nuclear power plants. The other generator waste category

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

4.3.4 Commercial LLW Disposal Sites

Three commercial LLW disposal sites in the eastern United States (Maxey Flats, Sheffield, and West Valley) have been closed to further use. Only a small amount of on-site generated LLW from site cleanup is occasionally buried at Maxey Flats. The closure of these three commercial LLW disposal sites resulted in increasing volumes of LLW being shipped to the three remaining operating sites in South Carolina, Nevada, and Washington. The increase prompted South Carolina to impose an upper limit on the volume of LLW that could be accepted at Barnwell. Eventually, a general concern developed that the responsibility for LLW disposal should not rest with only three states and that a coordinated national plan was needed. As described above, the LLRWPA[14] was passed in 1980, making each state responsible for its own LLW and encouraging formation of regional interstate compacts to deal with the disposal problem. The Act provided that any compact approved by Congress could restrict access to its LLW disposal facility to member states after Jan. 1, 1986. However, by 1984, it became evident that no new regional disposal facilities would be operating by the end of 1985. This gave rise to new legislation, the LLRWPAA,[15] which continued to encourage interstate compact formation while requiring that nonsited (i.e., without an operating disposal site) states and compacts meet specific milestones, leading to the operation of new regional facilities by Jan. 1, 1993. Additionally, the LLRWPAA established rates and limits of acceptance at the three commercial disposal sites now in operation, as well as space allocations for utility wastes. The utilities are required to meet certain waste volume reductions during a 7-year transition period, which is provided for the opening of new LLW disposal sites under state compact arrangements. The full impact of the law is being studied and evaluated by the nuclear industry as well as by federal and state regulators.

Barnwell now receives about 58% of the total volume of commercial LLW shipped for burial. The Beatty, Nevada, site is receiving about 12%, while the site at Richland, Washington, now receives about 30% (see Table 4.16). The nationwide distribution of this waste among the various LLW categories is shown in Fig. 4.1. Chem-Nuclear Systems, Inc., operates the Barnwell disposal site, and U.S. Ecology, Inc., operates the disposal sites at both Beatty and Richland. The land usage at existing commercial disposal sites is summarized in Table 4.12. Updated information reported for these commercial sites is based on data provided by state health and environmental control agencies (refs. 2, 5, 7, and 10).

Since the end of 1980, individual states have been encouraged to form compacts for the purpose of developing new regional LLW disposal sites.[14] The Low-Level Radioactive Waste Policy Amendments Act of 1985 (LLRWPAA) stipulates areas of responsibility in LLW disposal and defines penalties for future noncompliance.[15]

4.3.5 Commercial LLW Projections

All fuel-cycle LLW projections in this report are based on the DOE/EIA No-New-Orders Case (see Chapter 1 and Table C.8 of Appendix C), the fuel requirements needed to support this scenario, and the various processing steps required to provide the fuel. The source terms used in projecting the volume and radioactivity of commercial LLW are derived from reported historical data.[2,3,6,11,20-23] The UF_6 conversion and fuel fabrication LLW source terms (Figs. C.2, C.3, and C.5 of Appendix C) are taken from ref. 3. The reported historical waste data for BWR and PWR plants[6,11,21-23] and their net electrical outputs[20,21,23,24] provide the data for the reactor source terms in Figs. C.6 and C.7 of Appendix C. The source term composition used for I/I waste (Table 4.20) for 1980 through 2030 is presented in Table C.11 of Appendix C. The historical values for the volume and radioactivity of I/I wastes were obtained as the difference between the total volume (Table 4.16) and radioactivity (Table 4.17) reported shipped for disposal each year and the corresponding total fuel cycle (UF_6 conversion and fuel fabrication plus LWR operations) values from Tables 4.21–4.25. The composition of the radioactivity in pre-1980 I/I waste is given in ref. 2.

The projections for LLW resulting from nuclear reactor operations, normalized to the net electrical generation, are presented in Tables 4.21–4.23. The calculated historical and projected data for UF_6 conversion are given in Table 4.24; similar data for fuel fabrication are presented in Table 4.25. In 1991 UF_6 conversion and fuel fabrication facilities account for about 22 vol % of the total fuel-cycle LLW, while reactor operations account for the

remaining approximately 78 vol %. Under the LLRWPAA,[15] permissible waste volumes from reactors are not related directly to electrical generating capacity but are based on the reactor type (BWR or PWR) and its present and anticipated operating status.

The basis for the LLW projections from I/I sources (Table 4.20) was the assumption that the average annual addition of these wastes will remain essentially constant (at the 1991 value) from 1992 through 2030, because most measures to maximize volume reduction and minimize the radioactivity of these wastes have already been put into practice.[25]

Table 4.3 summarizes the LLW projected to result from I/I and commercial fuel-cycle sources through the year 2030. These waste projections may be altered as the I/I waste source terms are updated and the provisions in the LLRWPAA[15] are implemented.

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

4.4 REFERENCES

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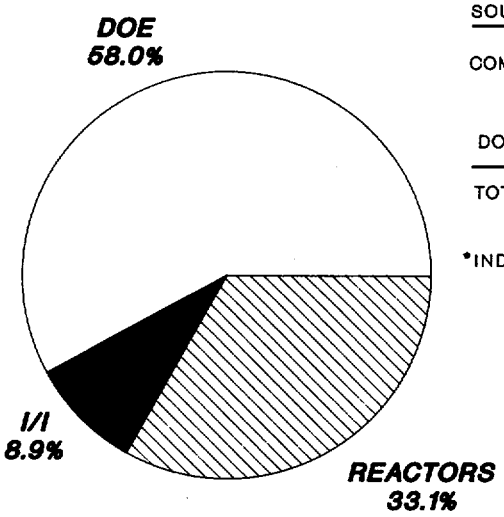
ORNL DWG 92-5835

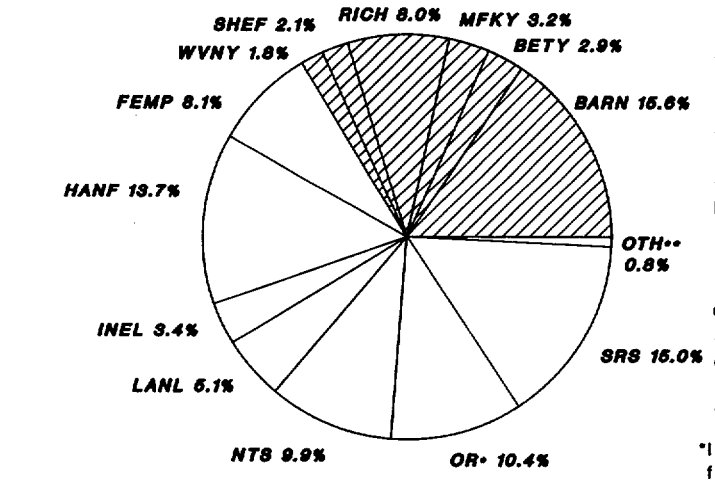


SOURCE	CUBIC METERS
COMMERCIAL	
REACTORS	3.059E+04
I/I*	0.819E+04
DOE	5.352E+04
TOTAL	9.230E+04

*INDUSTRIAL/INSTITUTIONAL

Fig. 4.1. Volume of LLW buried and disposed in 1991.

ORNL DWG 92-5836



SITE	CUBIC METERS
BARN	6.607E+05
BETY	1.229E+05
MFKY	1.353E+05
RICH	3.385E+05
SHEF	8.833E+04
WVNY	7.707E+04
FEMP	3.432E+05
HANF	5.828E+05
INEL	1.454E+05
LANL	2.157E+05
NTS	4.197E+05
OR*	4.397E+05
SRS	6.366E+05
OTHERS**	3.309E+04
TOTAL	4.239E+06

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

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

Fig. 4.2. Total volume of LLW buried and disposed through 1991.

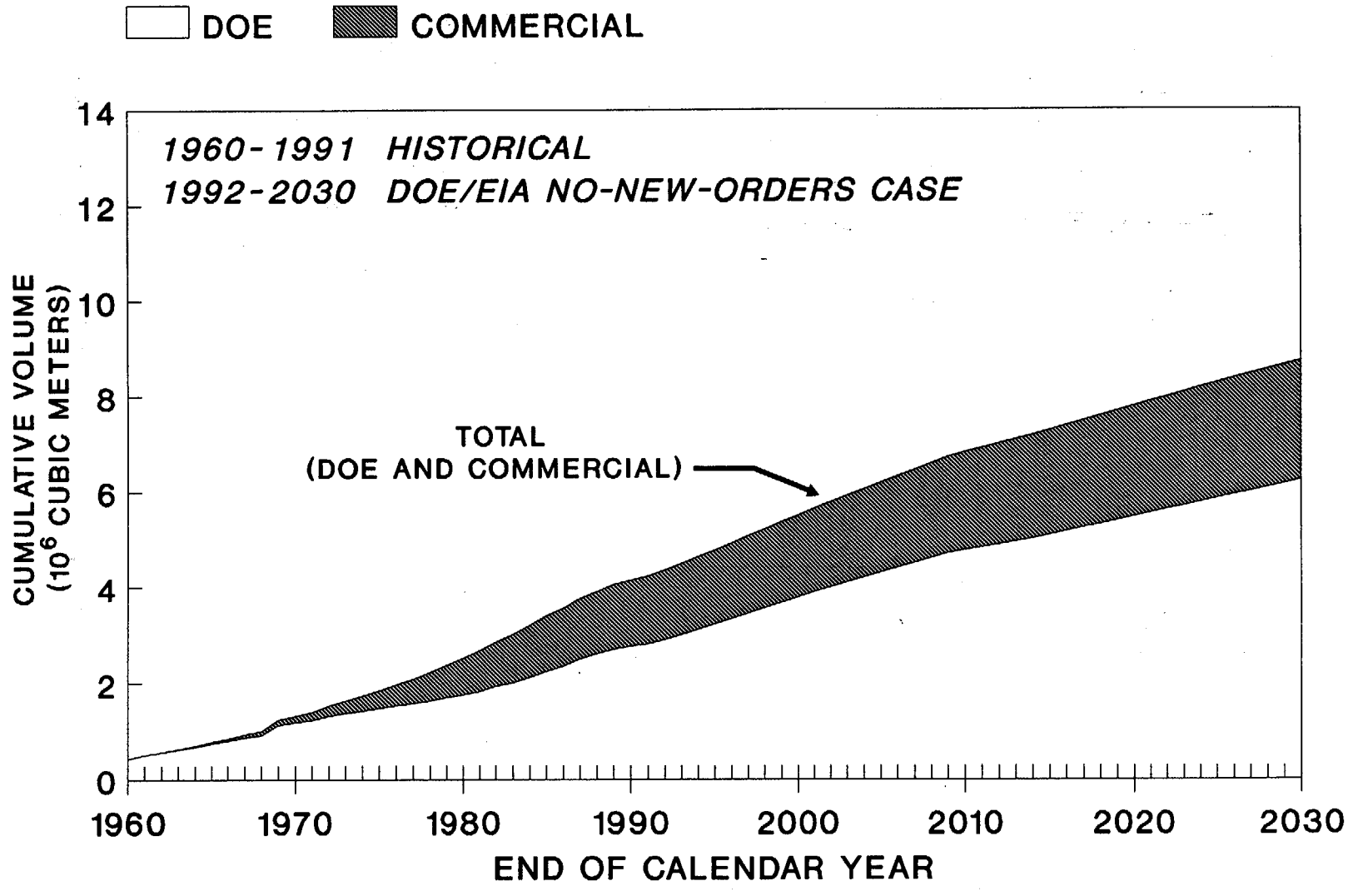
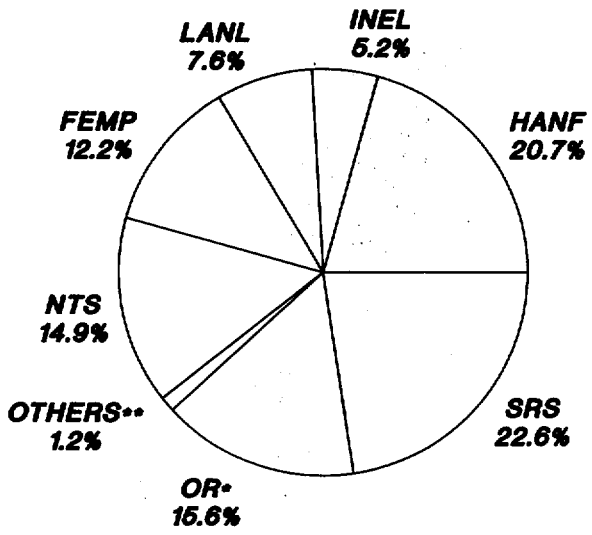


Fig. 4.3. Historical and projected cumulative volume of LLW.

ORNL DWG 92-5838



SITE	CUBIC METERS
FEMP	3.432E+05
HANF	5.828E+05
INEL	1.454E+05
LANL	2.157E+05
NTS	4.197E+05
OR*	4.397E+05
SRS	6.366E+05
OTHERS**	3.309E+04
TOTAL	2.816E+06

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

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

Fig. 4.4. Total volume of DOE LLW buried through 1991.

ORNL DWG 92-5839

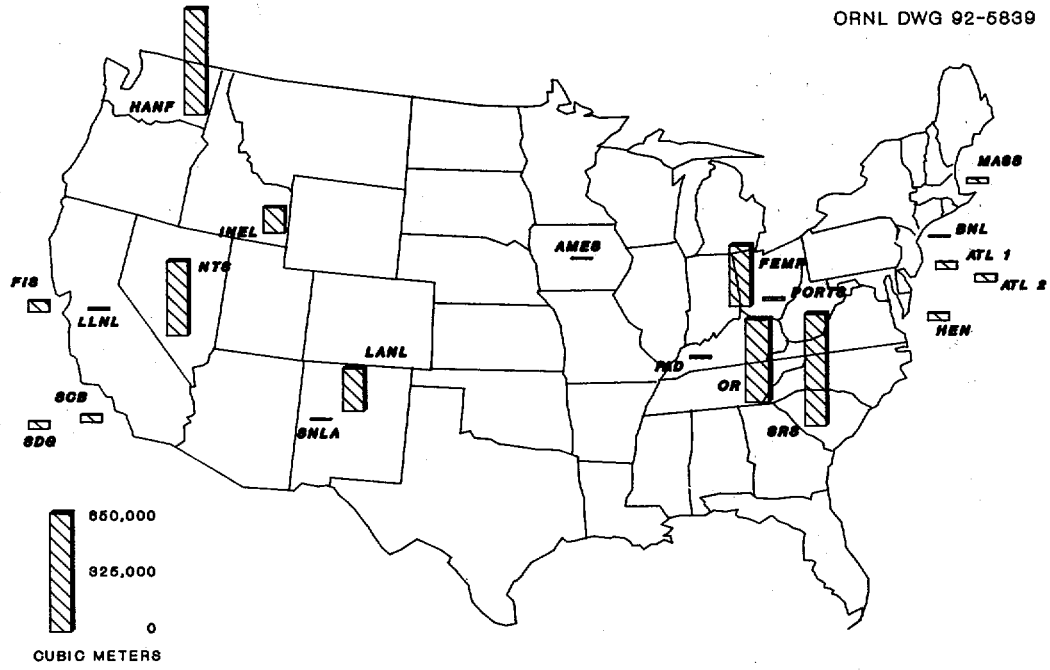
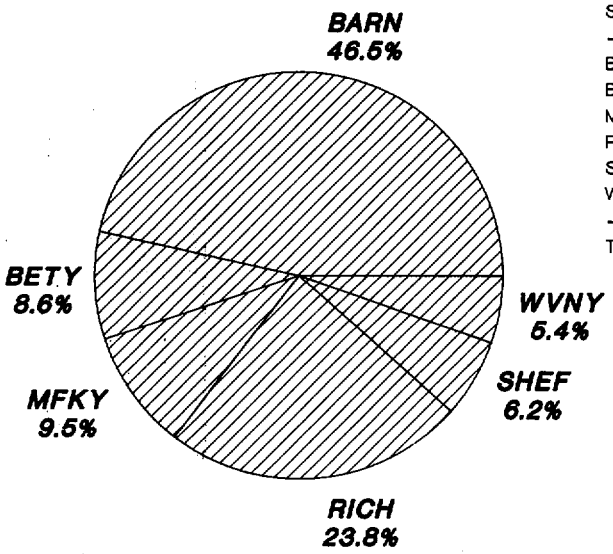


Fig. 4.5. Locations and total volumes of DOE LLW buried through 1991.

ORNL DWG 92-5840



SITE	CUBIC METERS
BARN	6.607E+05
BETY	1.229E+05
MFKY	1.353E+05
RICH	3.386E+05
SHEF	6.833E+04
WVNY	7.707E+04
TOTAL	1.423E+06

Fig. 4.6. Total volume of commercial LLW disposed through 1991.

ORNL DWG 92-5841

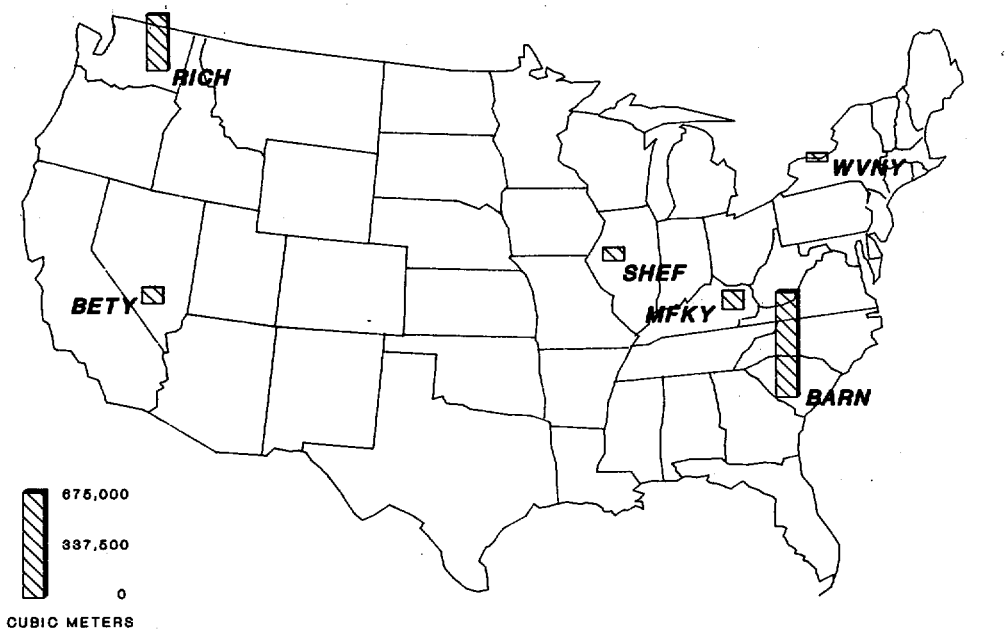


Fig. 4.7. Locations and total volumes of commercial LLW disposed through 1991.

Table 4.1. A summary of characteristics for buried/disposed LLW as of December 31, 1991

Category	Volume (10^3 m^3)		Radioactivity (10^3 Ci)		Thermal power (W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
DOE sites	53.52	2,816	717.6	13,430	2,789	18,681
Commercial sources						
I/I activities[a]	8.19	707.4	34.8	2,809	78.0	3,235
Fuel cycle activities						
LWR operations						
Routine	23.69	636.3	76.7	458.0	559.1	3,056
Nonroutine	0.11	5.7	688.4	2,384	6,515	23,580
UF_6 conversion	0.84	12.4	0.0006	0.010	0.010	0.16
Fuel fabrication	5.95	60.9	0.014	0.19	0.40	4.2
Commercial sites	38.78	1,423	799.8	5,651	7,152	29,876
Total buried/ disposed LLW	92.30	4,239	1,517	19,081	9,941	48,557

[a]I/I activities include academic, government (non-DOE), industry (other than fuel cycle operations), and medical generators of LLW. In other words, LLW from reactor operations, UF_6 conversion, and fuel fabrication are included in fuel cycle activities in this chapter.

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

End of calendar year	Volume (10^3 m^3)		Radioactivity (10^3 Ci)		Thermal power (W)	
	Annual	Cumulative	Annual	Cumulative[b]	Annual	Cumulative
1990	60.0	2,763	588	13,700	2,164	18,433
1991	53.5	2,816	718	13,430	2,789	18,681
1992	86.2	2,903	1,533	13,994	2,490	18,686
1993	101.0	3,004	642	13,661	2,467	18,801
1994	111.0	3,115	647	13,359	2,471	18,963
1995	110.1	3,225	643	13,075	2,467	19,141
1996	111.8	3,337	638	12,803	2,463	19,323
1997	114.3	3,451	635	12,547	2,458	19,505
1998	110.1	3,561	638	12,311	2,465	19,694
1999	113.5	3,675	634	12,087	2,458	19,877
2000	112.6	3,787	632	11,877	2,458	20,060
2001	110.9	3,898	631	11,680	2,458	20,241
2002	101.0	3,999	630	11,496	2,457	20,421
2003	101.0	4,100	629	11,324	2,457	20,599
2004	101.0	4,201	629	11,164	2,456	20,775
2005	101.0	4,302	628	11,016	2,456	20,948
2006	101.0	4,403	628	10,878	2,455	21,120
2007	101.0	4,505	628	10,750	2,455	21,289
2008	101.0	4,606	628	10,628	2,450	21,444
2009	101.0	4,707	628	10,514	2,450	21,597
2010	62.0	4,769	625	10,409	2,450	21,748
2011	60.8	4,830	624	10,312	2,450	21,898
2012	60.2	4,890	624	10,223	2,449	22,043
2013	60.4	4,950	624	10,141	2,449	22,189
2014	62.4	5,013	624	10,066	2,450	22,333
2015	75.8	5,088	624	9,997	2,450	22,473
2016	76.1	5,165	624	9,933	2,449	22,611
2017	76.1	5,241	624	9,875	2,449	22,746
2018	76.1	5,317	624	9,821	2,448	22,878
2019	76.1	5,393	624	9,771	2,448	23,008
2020	76.1	5,469	624	9,726	2,448	23,135
2021	76.1	5,545	624	9,685	2,448	23,259
2022	76.1	5,621	637	9,654	2,467	23,399
2023	76.1	5,698	637	9,626	2,466	23,537
2024	76.1	5,774	632	9,594	2,453	23,652
2025	76.1	5,850	633	9,567	2,452	23,766
2026	76.1	5,926	633	9,542	2,449	23,878
2027	76.1	6,002	628	9,520	2,449	23,988
2028	76.1	6,078	626	9,501	2,448	24,093
2029	76.1	6,154	624	9,483	2,448	24,197
2030	76.1	6,231	624	9,468	2,448	24,300

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

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

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

End of calendar year	Volume (10^3 m^3)		Radioactivity (10^3 Ci)		Thermal power (W)	
	Annual	Cumulative	Annual	Cumulative[b]	Annual	Cumulative
1990	32.4	1,384	548	5,349	4,603	25,662
1991	38.8	1,423	800	5,651	7,152	29,876
1992	32.9	1,456	496	5,612	3,725	30,269
1993	32.8	1,488	495	5,576	3,722	30,651
1994	33.1	1,522	497	5,544	3,737	31,031
1995	33.3	1,555	500	5,515	3,754	31,408
1996	33.3	1,588	501	5,489	3,766	31,774
1997	33.4	1,622	502	5,465	3,771	32,122
1998	33.4	1,655	502	5,442	3,773	32,452
1999	33.5	1,688	502	5,422	3,772	32,762
2000	33.3	1,722	502	5,403	3,772	33,056
2001	33.6	1,755	502	5,386	3,772	33,335
2002	33.4	1,789	502	5,371	3,770	33,598
2003	33.4	1,822	501	5,357	3,766	33,846
2004	33.3	1,856	501	5,345	3,766	34,084
2005	33.3	1,889	501	5,336	3,766	34,313
2006	33.4	1,922	501	5,328	3,766	34,534
2007	33.4	1,956	501	5,322	3,766	34,748
2008	33.4	1,989	501	5,318	3,766	34,956
2009	33.2	2,022	497	5,311	3,729	35,120
2010	32.8	2,055	487	5,297	3,653	35,209
2011	31.9	2,087	467	5,266	3,488	35,144
2012	31.5	2,118	460	5,237	3,440	35,064
2013	30.1	2,149	432	5,186	3,215	34,791
2014	27.3	2,176	378	5,093	2,790	34,156
2015	25.5	2,201	339	4,980	2,477	33,323
2016	25.0	2,226	331	4,881	2,414	32,563
2017	24.1	2,251	313	4,781	2,272	31,779
2018	23.7	2,274	306	4,692	2,217	31,064
2019	23.4	2,298	300	4,612	2,172	30,413
2020	23.4	2,321	300	4,544	2,167	29,859
2021	23.0	2,344	296	4,484	2,140	29,364
2022	22.5	2,366	287	4,425	2,068	28,879
2023	21.6	2,388	268	4,356	1,917	28,323
2024	20.5	2,409	244	4,275	1,720	27,661
2025	18.7	2,427	206	4,170	1,423	26,808
2026	17.5	2,445	186	4,064	1,262	25,928
2027	16.8	2,462	171	3,961	1,144	25,065
2028	16.0	2,478	157	3,861	1,034	24,222
2029	15.3	2,493	147	3,768	958	23,431
2030	14.7	2,508	135	3,676	862	22,662

[a]The values in this table are a summation of the corresponding values in Tables 4.20-4.25.
[b]The radioactivity added each year for each waste type is decayed as described in the footnotes of Tables 4.20-4.25.

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

Year	Volume of waste buried annually, 10^3 m^3										
	FEMP	HANF	INEL	LANL	NTS	ORNL	SRS	Y-12	All other[b]	Total annual addition	Total cumulative volume
1975[c]	309.5	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	11.6	3.2	4.5	57.0	1.3	22.4	2.2	2.0	107.0	1,931
1983	3.4	17.9	5.5	3.2	12.1	1.8	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	21.1	3.4	4.5	27.9	1.8	30.1	15.0	1.0	104.8	2,347
1987	0	21.1	3.0	3.7	81.1	0.5	28.2	16.2	1.0	154.8	2,502
1988	0	18.5	2.0	4.3	39.1	0.6	30.2	10.6	1.0	106.3	2,608
1989	0	15.6	1.3	6.4	35.0	1.3	26.8	5.7	2.3	94.4	2,703
1990	0	13.4	1.8	4.5	9.1	0.3	26.6	4.4	0.0	60.1	2,763
1991	0	10.5	1.3	5.8	11.6	0.2	23.8	0.3	0.0	53.5	2,816
Total	343.4	582.8	145.3	215.7	419.6	207.4	636.7	151.3	114.2	2,816	

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

[b]Includes contributions from AMES, BNL, K-25, LLNL, PAD, PANT, PORTS, and SNLA. See Tables 4.5, 4.6, 4.9, and 4.10 for breakdown of 1991 accumulation.

[c]Values for 1975 are cumulative volumes to this date (ref. 2).

[d]Does not include 5,190 m^3 of grouted liquid LLW disposed of at Hanford.

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

Waste type	Radionuclide characteristic[b]	Volume, m^3			Activity, Ci			
		1991	Cumulative[c]	1992 (projected)	1991	Total undecayed[d]	Total decayed[e]	1992 (projected)
Generated on-site	Uranium/thorium	31,773	f	34,665	420	f	f	552
	Fission product	24,218	f	5,487	16,356	f	f	9,165
	Induced activity	3,427	f	3,781	259,016	f	f	1,997,775
	Tritium	2,850	f	2,860	64,906	f	f	949,942
	Alpha	9,595	f	5,156	31	f	f	96
	Other	3,982	f	26,632	107,951	f	f	435
	Total	75,845	f	78,582	448,680	f	f	2,957,966
Stored	Uranium/thorium	18,120	127,202	11,936	214	898	g	54
	Fission product	894	2,902	1,181	564	574,820	g	411
	Induced activity	196	890	811	52,471	66,190	g	16
	Tritium	559	1,273	662	34,086	302,410	g	37,927
	Alpha	6,152	16,561	6,069	20	130	g	100
	Other	718	1,700	499	1,312	1,555	g	652
	Total	26,639	150,527	21,157	88,666	946,003	g	39,160
Buried	Uranium/thorium	14,512	1,068,341	40,849	21	38,186	49,424	160
	Fission product	28,797	1,001,421	7,119	501,946	9,887,275	4,972,470	414,178
	Induced activity	1,597	221,548	4,357	190,384	6,243,327	336,642	183,633
	Tritium	2,427	53,076	972	25,209	15,457,634	7,647,979	925,117
	Alpha	4,422	322,318	3,536	6	64,890	43,674	13
	Other	1,764	149,638	1,111	31	12,297,170	379,489	35
	Total	53,520	2,816,342	57,944	717,597	43,988,482	13,429,678	1,523,136

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

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

[c]From beginning of operations through 1991.

[d]Sum of annual additions without decay.

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

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

[g]Information not available.

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

Waste type	Physical characteristic[b]	Volume, m^3			Activity, Ci		
		1991	Cumulative[c]	1992 (projected)	1991	Total gross[d]	1992 (projected)
Generated on-site	Biological	82	e	173	<2	e	2
	Contaminated equipment	9,313	e	10,742	158,577	e	1,904,217
	Decontamination debris	14,246	e	14,994	267	e	185
	Dry solids	17,384	e	17,569	285,809	e	1,050,526
	Solidified sludge	2,288	e	2,581	480	e	402
	Other	32,532	e	32,522	3,545	e	2,634
	Total	75,845	e	78,582	448,680	e	2,957,966
Stored	Biological	783	f	868	4	f	4
	Contaminated equipment	4,826	f	6,320	59,095	f	9,812
	Decontamination debris	4,877	f	1,750	8	f	3
	Dry solids	7,109	f	6,625	26,583	f	26,668
	Solidified sludge	4,392	f	3,044	38	f	8
	Other	4,652	f	2,549	2,938	f	2,665
	Total	26,639	f	21,157	88,666	f	39,160
Buried[g]	Biological	23	f	120	<1	f	1
	Contaminated equipment	7,843	f	14,681	5,230	f	6,667
	Decontamination debris	3,915	f	13,726	682	f	369
	Dry solids	17,198	f	26,852	45,991	f	1,384,544
	Solidified sludge	33	f	614	53	f	12
	Other	24,508	f	1,951	665,640	f	131,543
	Total	53,520	f	57,944	717,597	f	1,523,136

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

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

[c]From beginning of operations through 1990.

[d]Sum of annual additions without decay.

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

[f]Information not available.

[g]The activity numbers (Ci) for 1991 buried waste are estimates based upon specific activity (Ci/m^3) values (calculated using numbers in Table 4.6 of ref. 6) and the 1991 volumes (m^3) for buried waste shown above.

Table 4.7. Breakdown of volumes of LLW generated during 1991 at DOE sites by radionuclide characteristic[a]

DOE site[b]	Volume, m^3						
	Uranium/ thorium	Fission product	Induced activity	Tritium	Alpha	Other[c]	Total
AMES	4	0	0	0	<<1	0	4
ANL-E	0	0	0	0	0	290	290
ANL-W	26	96	54	1	15	0	193
BNL	d	d	d	d	d	d	d
FEMP	11,981	0	0	0	0	0	11,981
FNAL	1	0	69	2	0	0	72
HANF	337	2,686	121	1,308	0	0	4,451
INEL	205	0	0	0	0	2,721	2,926
ITRI	0	0	0	0	0	51	51
K-25	977	0	0	0	0	0	977
KCP	0	0	0	<<1	0	<1	<1
LANL	1,404	1,429	602	97	2,203	31	5,766
LBL	0	0	12	8	0	43	62
LLNL	44	33	0	19	27	1	124
MOUND	0	0	0	260	1,588	0	1,848
NR sites[e]	170	354	1,595	<1	0	0	2,120
NTS	d	d	d	d	d	d	d
ORISE	<1	<<1	0	2	<<1	23	25
ORNL	19	868	101	15	33	10	1,047
PAD	1,908	0	0	0	c	327	2,235
PANT	158	0	0	146	0	0	304
Pinellas	0	0	0	63	0	0	63
PORTS	4,789	0	0	0	0	0	4,789
PPPL	0	0	2	8	0	1	11
RFP	4	0	0	0	1,930	0	1,934
RMI	2,412	0	0	0	0	0	2,412
SLAC	0	0	14	0	0	0	14
SNLA	<1	25	9	2	<<1	4	41
SNLL	2	0	0	11	0	1	14
SRS	665	18,727	847	909	3,799	478	25,425
Y-12	6,665	0	0	0	0	0	6,665
Total	31,773	24,218	3,427	2,850	9,595	3,982	75,845

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

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

[c]Unknown or mixture.

[d]Information not available from this site for 1991.

[e]NR sites include KAPL, BAPL, and NRF.

Table 4.8. Breakdown of activity of LLW generated during 1991 at DOE sites by radionuclide characteristic[a]

DOE site[b]	Activity, Ci						
	Uranium/ thorium	Fission product	Induced activity	Tritium	Alpha	Other[c]	Total
AMES	<<1	0	0	0	<<1	0	<<1
ANL-E	d	d	d	d	d	d	d
ANL-W	<<1	15	105,400	c	<<1	0	105,415
BNL	d	d	d	d	d	d	d
FEMP	<1	0	0	0	0	0	<1
FNAL	<<1	0	1	<1	0	0	<2
HANF	8	5,776	1,993	10	0	0	7,788
INEL	<1	0	0	0	0	105,180	105,180
ITRI	0	0	0	0	0	200	200
K-25	c	0	0	0	0	0	c
KCP	0	0	0	<<1	0	<1	<1
LANL	11	7	7,126	45	4	0	7,193
LBL	0	0	<<1	702	0	898	1,600
LLNL	<<1	1	<<1	13,000	1	<1	13,003
MOUND	0	0	0	6,061	3	0	6,064
NR sites[e]	387	33	99,970	<1	0	0	100,390
NTS	d	d	d	d	d	d	d
ORISE	<<1	<<1	0	<<1	<<1	<<1	<<1
ORNL	<<1	656	169	<<1	<<1	<<1	825
PAD	1	0	0	0	<<1	c	1
PANT	<<1	0	0	18	0	0	18
Pinellas	0	0	0	9,839	0	0	9,839
PORTS	<1	0	0	0	0	0	<1
PPPL	0	0	<<1	<1	0	<<1	<1
RFP	<<1	0	0	0	10	0	10
RMI	<<1	0	0	0	0	0	<<1
SLAC	0	0	<<1	0	0	0	<<1
SNLA	<1	<<1	<<1	1	1	<1	3
SNLL	<<1	0	0	11,512	0	5	11,517
SRS	10	9,868	44,356	23,716	12	1,666	79,628
Y-12	2	0	0	0	0	0	2
Total	420	16,356	259,016	64,906	31	107,951	448,680

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

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

[c]Unknown or mixture.

[d]Information was not available from this site for 1991.

[e]NR sites include KAPL, BAPL, and NRF.

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

DOE site[b]	Volume, m^3						
	Uranium/ thorium	Fission product	Induced activity	Tritium	Alpha	Other[c]	Total
AMES	200	0	0	0	0	0	200
ANL-E	0	0	0	0	0	0	0
ANL-W	0	0	0	0	0	0	0
BNL	0	0	5	832	0	3	839
FEMP	337,548	0	0	0	0	5,670	343,219
FNAL	0	0	0	0	0	0	0
HANF	226,411	231,560	121,511	3,358	0	0	582,839
INEL	4,136	25,500	374	1	961	114,400	145,371
ITRI	0	0	0	0	0	0	0
K-25	81,048	0	0	0	0	0	81,048
KCP	0	0	0	0	0	0	0
LANL	62,818	11,488	10,026	3,273	128,052	31	215,687
LBL	0	0	0	0	0	0	0
LLNL[d]	9,102	<<1	<<1	0	0	0	9,102
MOUND	0	0	0	0	0	0	0
NR sites[e]	0	0	0	0	0	0	0
NTS	83,331	216,804	12,853	8,346	89,231	9,134	419,699
ORISE	0	0	0	0	0	0	0
ORNL	18,982	122,582	33,958	3,792	12,982	15,076	207,372
PAD	7,613	<<1	0	0	0	0	7,613
PANT	121	0	0	13	0	0	134
Pinellas	0	0	0	0	0	0	0
PORTS	12,110	0	0	0	0	0	12,110
PPPL	0	0	0	0	0	0	0
RFP	0	0	0	0	0	0	0
RMI	0	0	0	0	0	0	0
SLAC	0	0	0	0	0	0	0
SNLA	3,178	7	33	<1	<<1	<<1	3,219
SNLL	0	0	0	0	0	0	0
SRS	70,496	393,481	42,789	33,462	91,093	5,324	636,645
Y-12	151,247	0	0	0	0	0	151,247
Total	1,068,342	1,001,421	221,548	53,076	322,318	149,638	2,816,342

[a]From beginning of operations through 1991. Based on DOE site information provided by the Waste Management Information System (ref. 1). Totals reported in this table may not equal the sum of component entries because of round-off and truncation of numbers.

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

[c]Unknown or mixture.

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

[e]NR sites include KAPL, BAPL, and NRF.

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

DOE site[b]	Total gross activity, Ci[a]						
	Uranium/ thorium	Fission product	Induced activity	Tritium	Alpha	Other[c]	Total
AMES	<1	0	0	0	0	0	<1
ANL-E	0	0	0	0	0	0	0
ANL-W	0	0	0	0	0	0	0
BNL	0	0	2	3	0	<1	<6
FEMP	2,610	0	0	0	0	1,804	4,414
FNAL	0	0	0	0	0	0	0
HANF	456	8,674,299	486,891	454,120	0	0	9,615,766
INEL	45	1,523	36	15	86	11,690,000	11,691,705
ITRI	0	0	0	0	0	0	0
K-25	59	0	0	0	0	0	59
KCP	0	0	0	0	0	0	0
LANL	264	17,832	32,311	1,053,707	4,060	0	1,108,174
LBL	0	0	0	0	0	0	0
LLNL[d]	13	<<1	<<1	0	0	0	13
MOUND	0	0	0	0	0	0	0
NR sites[e]	0	0	0	0	0	0	0
NTS	2,444	90,323	7,095	9,258,998	54,762	361,323	9,774,945
ORISE	0	0	0	0	0	0	0
ORNL	1,349	383,101	853,547	12,234	754	41	1,251,027
PAD	20,396	3	0	0	0	0	20,399
PANT	<8	0	<<1	<1	0	<1	<8
Pinellas	0	0	0	0	0	0	0
PORTS	26	0	0	0	0	0	26
PPPL	0	0	0	0	0	0	0
RFP	0	0	0	0	0	0	0
RMI	0	0	0	0	0	0	0
SLAC	0	0	0	0	0	0	0
SNLA	12	611	5,493	2,984	3	4	9,107
SNLL	0	0	0	0	0	0	0
SRS	103	719,583	4,857,952	4,675,572	5,225	243,996	10,502,431
Y-12	10,400	0	0	0	0	0	10,400
Total	38,186	9,887,275	6,243,327	15,457,634	64,890	12,297,170	43,988,482

[a]Sum of annual additions without decay, from beginning of operations through 1991. Based on DOE site information provided by the Waste Management Information System (ref. 1). Totals reported in this table may not equal the sum of component entries because of round-off and truncation of numbers.

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

[c]Unknown or mixture.

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

[e]NR sites include KAPL, BAPL, and NRF.

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

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

[a]Radioactivity is given at time of burial. Data taken from Table 4.5 of ref. 2.
[b]Estimated number of containers.
[c]Includes approximately 33,000 Ci of induced activity associated with the U.S.S. Seawolf reactor vessel.
[d]Retired after 18 injections.
[e]New facility started up with four injections in 1982 and completed campaign with seven injections in 1983.

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

Site	Site size (ha)	Estimated total usable area[b] (ha)	Estimated area utilized through 1991 (ha)[b]
DOE (burial sites)			
HANF[c]	145,040	234	151
INEL	230,510	35.6	21.2
K-25	607	d	d
LANL	11,137	37.1	17.2
NTS[e]	349,650	820	55
ORNL	1,174	26	7
SNLA	7,183	0.27	0.08
SNLL	167	0.013	d
SRS	84,175	78.9	78.2
Total	829,643	>1,232	>330
Commercial (disposal sites)			
West Valley, NY (Closed Mar. 11, 1975)[f]	8.9	7.2	3.8
Maxey Flats, KY (Closed Dec. 27, 1977)	102	<51	10.4
Sheffield, IL (Closed Apr. 8, 1978)	8.9	8.1	8.1
Barnwell, SC[g]	121	44.5	29.8
Beatty, NV	32	18.6	15.7
Richland, WA[h]	40	29.5	11.9
Total	313	159	79.7
Grand total	829,956	~1,391	>409

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

[b]DOE usable area and area utilized (except where noted) are generally taken from ref. 1. Comparable commercial values (except where noted) are taken from ref. 6.

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

[d]Information not available, or unknown.

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

[f]WVDP LLW was buried on-site in the noncommercial NRC disposal area from 1982 until late 1986. No waste was buried at West Valley in 1987, 1988, 1989, 1990, or 1991 (see Table 4.16).

[g]Based on information provided in ref. 5. Anticipated closure date for this site is December 31, 1995.

[h]Based on ref. 7.

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

Burial/ disposal site	DOE/RW-0006, Rev. 7 (1991) Table No.	DOE/RW-0006, Rev. 8 (1992) Table No.	Significant revision or net change	Explanation
DOE/commercial LLW	4.1 and 4.10	4.1 and 4.12	None	Updates of corresponding tables in DOE/RW-0006, Rev. 7 (1991)
DOE LLW	4.5	4.5	1991 values for U/Th generated on-site decreased by a factor of about 2,000	An error was made at one site in converting mass of Pu and Th to radioactivity (i.e., incorrect specific activities were applied)
	4.7 and 4.8	4.7 and 4.8	New content	Tables 4.7 and 4.8 in DOE/RW-0006, Rev. 8 (1992) contain information on generated waste; in the previous edition [DOE/RW-0006, Rev. 7 (1991)], they contained information on buried waste (now presented in Tables 4.9 and 4.10)
	4.2, 4.4, 4.6, and 4.9	4.2, 4.4, 4.6, 4.9, 4.10, and 4.11	None	Updates of corresponding tables in [DOE/RW-0006, Rev. 7 (1991)]. Tables 4.9 and 4.10 were Tables 4.7 and 4.8 in the previous edition
Commercial GTCC LLW	4.17	4.19	None	Update of corresponding table in DOE/RW-0006, Rev. 7 (1991)
LLW	4.3, 4.10, 4.14, 4.15, 4.16, 4.18, 4.19, 4.20, 4.21, 4.22, and 4.23	4.3, 4.12, 4.16, 4.17, 4.18, 4.20, 4.21, 4.22, 4.23, 4.24, and 4.25	None	Updates of corresponding tables in DOE/RW-0006, Rev. 7 (1991)

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

End of calendar year	Volume[a,b] (10^3 m^3)		Radioactivity[a,b] (10^3 Ci)		Thermal power (W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1990	60.0	2,763	588	13,700	2164	18,433
1991	53.5	2,816	718	13,430	2789	18,681
1992	57.9	2,874	1,523	13,984	2477	18,672
1993	57.9	2,932	623	13,634	2446	18,767
1994	57.9	2,990	623	13,314	2446	18,907
1995	57.9	3,048	623	13,017	2446	19,067
1996	57.9	3,106	623	12,741	2446	19,236
1997	57.9	3,164	623	12,483	2446	19,410
1998	57.9	3,222	623	12,243	2446	19,586
1999	57.9	3,280	623	12,018	2446	19,762
2000	57.9	3,338	623	11,808	2446	19,938
2001	57.9	3,396	623	11,612	2446	20,113
2002	57.9	3,454	623	11,429	2446	20,286
2003	57.9	3,512	623	11,259	2446	20,458
2004	57.9	3,570	623	11,100	2446	20,628
2005	57.9	3,628	623	10,952	2446	20,795
2006	57.9	3,685	623	10,815	2446	20,961
2007	57.9	3,743	623	10,687	2446	21,124
2008	57.9	3,801	623	10,568	2446	21,284
2009	57.9	3,859	623	10,458	2446	21,442
2010	57.9	3,917	623	10,356	2446	21,597
2011	57.9	3,975	623	10,261	2446	21,750
2012	57.9	4,033	623	10,173	2446	21,900
2013	57.9	4,091	623	10,092	2446	22,047
2014	57.9	4,149	623	10,018	2446	22,191
2015	57.9	4,207	623	9,949	2446	22,332
2016	57.9	4,265	623	9,885	2446	22,471
2017	57.9	4,323	623	9,827	2446	22,607
2018	57.9	4,381	623	9,773	2446	22,740
2019	57.9	4,439	623	9,724	2446	22,871
2020	57.9	4,497	623	9,680	2446	22,999
2021	57.9	4,555	623	9,639	2446	23,124
2022	57.9	4,613	623	9,602	2446	23,246
2023	57.9	4,671	623	9,569	2446	23,366
2024	57.9	4,728	623	9,538	2446	23,484
2025	57.9	4,786	623	9,511	2446	23,599
2026	57.9	4,844	623	9,487	2446	23,711
2027	57.9	4,902	623	9,465	2446	23,821
2028	57.9	4,960	623	9,446	2446	23,929
2029	57.9	5,018	623	9,429	2446	24,034
2030	57.9	5,076	623	9,414	2446	24,137

[a]Historical (beginning of operations through 1990) annual values of volume and radioactivity (by waste type) for each site are from ref. 6. Similar values for 1991 are from ref. 1. See Tables 4.4, 4.5, 4.9, and 4.10 for more detail. Radioactivity (by waste type) is decayed from the year of addition using the representative compositions given in Table C.5 of Appendix C.

[b]Beginning in 1992, the volume and radioactivity added each year are assumed to remain constant through 2030 at the 1992 values projected (ref. 1) by each site. An exception to this scheme is the 9×10^5 Ci of tritium projected by LANL in 1992 from a nonroutine activity. Thus, it is added only in 1992 and a much smaller value (1×10^2 Ci ^3H) is projected for LANL from 1993 to 2030. The radioactivity (by waste type) is decayed from the year of addition using the representative compositions given in Table C.5 of Appendix C.

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

End of calendar year	Volume (10^3 m^3)		Radioactivity[b] (10^3 Ci)		Thermal power (W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1992	28.3	28.3	9.8	9.8	13.3	13.3
1993	43.1	71.4	18.8	26.4	20.9	33.4
1994	53.1	124.5	23.4	45.3	24.5	56.2
1995	52.2	176.7	19.6	57.2	20.8	74.3
1996	53.9	230.6	14.6	62.2	16.3	86.9
1997	56.4	287.0	11.4	63.2	12.0	94.5
1998	52.2	339.2	14.5	67.9	18.6	108.3
1999	55.6	394.8	10.9	69.5	12.0	114.9
2000	54.7	449.5	9.1	69.3	12.0	122.1
2001	53.0	502.5	7.8	67.9	11.1	128.6
2002	43.1	545.6	6.7	66.4	11.0	135.4
2003	43.1	588.7	6.0	64.6	11.0	141.1
2004	43.1	631.8	5.5	64.0	9.1	147.6
2005	43.1	674.9	5.1	63.5	9.1	153.0
2006	43.1	718.0	4.8	63.4	9.0	159.6
2007	43.1	761.1	4.8	62.8	8.9	165.2
2008	43.1	804.2	4.6	59.4	4.0	160.3
2009	43.1	847.3	4.6	56.5	3.7	155.4
2010	4.1	851.4	1.5	53.8	3.4	151.0
2011	2.9	854.3	1.1	51.4	3.3	147.8
2012	2.3	856.6	0.9	49.9	2.6	143.0
2013	2.5	859.1	0.8	49.2	2.2	142.3
2014	4.5	863.6	1.2	48.9	3.9	142.1
2015	17.9	881.5	1.2	48.4	3.2	141.0
2016	18.2	899.7	1.2	48.1	3.0	140.1
2017	18.2	917.9	1.2	47.9	2.7	139.4
2018	18.2	936.1	1.2	47.2	2.0	138.3
2019	18.2	954.3	1.2	46.7	1.4	137.0
2020	18.2	972.5	1.1	46.2	1.4	136.1
2021	18.2	990.7	1.1	45.7	1.3	135.2
2022	18.2	1,008.9	14.1	52.4	20.7	153.2
2023	18.2	1,027.1	13.5	57.1	19.8	171.1
2024	18.2	1,045.3	8.4	55.8	6.6	168.2
2025	18.2	1,063.5	9.5	55.6	5.2	167.4
2026	18.2	1,081.7	9.4	55.5	2.9	167.1
2027	18.2	1,099.9	5.0	55.1	2.3	166.3
2028	18.2	1,118.1	2.5	54.9	1.4	164.1
2029	18.2	1,136.3	1.0	53.8	1.2	163.2
2030	18.2	1,154.5	1.0	53.6	1.2	162.4

[a]Taken from ref. 1 of Chapter 2. Solidification of HLW begins in 1993 at SRS. Feed preparation for this operation begins in 1992 and generates LLW saltstone (see Fig. C.10 and Table C.7 of Appendix C).

[b]Radionuclide composition as a function of time is given in Table C.7 of Appendix C.

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

Year	Volume, m^3							
	Beatty	West Valley[b]	Maxey Flats[c]	Richland	Sheffield[d]	Barnwell	Annual total	Cumulative total
1962	1,861						1,861	1,861
1963	3,512	127	2,206				5,845	7,706
1964	2,836	5,940	3,872				12,648	20,354
1965	1,988	5,192	5,753	668			13,601	33,955
1966	3,533	3,951	5,557	2,402			15,443	49,398
1967	3,206	7,475	7,820	773	2,527		21,801	71,199
1968	3,576	3,490	8,178	1,359	2,713		19,316	90,515
1969	4,526	4,099	10,354	438	2,012		21,429	111,944
1970	5,152	4,906	12,521	423	2,825		25,827	137,771
1971	4,916	7,002	13,173	584	4,430	1,171	31,276	169,047
1972	4,301	9,045	15,578	654	5,956	3,757	39,291	208,338
1973	4,076	7,535	10,074	1,033	8,524	15,839	47,081	255,419
1974	4,103	8,866	8,898	1,411	12,373	18,244	53,895	309,314
1975	4,943	2,243	17,098	1,500	14,116	18,072	57,972	367,286
1976	3,864	427	13,775	2,867	13,480	40,227	74,640	441,926
1977	4,742	351	423	2,718	17,643	45,663	71,540	513,466
1978	8,874	144		7,422	1,735	61,554	79,729	593,195
1979	6,491	138		12,185		63,861	82,675	675,870
1980	12,717	141		24,819		54,723[e]	92,400	768,270
1981	3,351	216		40,732		39,427[e]	83,726	851,996
1982	1,505	632		39,606		34,779	76,522	928,518
1983	1,111	1,284		40,458		35,132	77,985	1,006,503
1984	2,067	966		38,481		34,879	76,393	1,082,896
1985	1,388	809		40,135		34,389	76,721	1,159,617
1986	2,668	2,095		18,833		29,612	53,208	1,212,825
1987	9,414			15,765		27,060	52,239	1,265,064
1988	2,645			11,430		26,391	40,466	1,305,530
1989	3,291			11,562		31,242	46,095	1,351,625
1990	1,684			8,362		22,315	32,361	1,383,986
1991	4,539			11,872		22,368	38,779	1,422,765
Total	122,880	77,074	135,280	338,492	88,334	660,705		1,422,765

[a]For a summary of historical additions (1962-1984), see Table 4.6 in ref. 2. For operating sites (Beatty, Richland, and Barnwell), the additions for 1985-1989 are from Table 4.11 in ref. 6 and for 1990 are from ref. 8.

[b]West Valley includes a commercial state-licensed facility which opened Nov. 18, 1963, and closed Mar. 11, 1975, and an NRC-licensed facility (for on-site fuel reprocessing wastes) which opened in 1966 and continued to receive only on-site-generated LLW associated with water treatment and site cleanup until late 1986. This license is in abeyance. Disposal operations at the West Valley Demonstration Project (WVDP) have been suspended pending the preparation of an EIS report for the West Valley site closure. The WVDP began in 1982. The LLW volumes reported for 1982 through 1986 are for the WVDP only and are taken from ref. 6. Since the beginning of 1987, LLW generated at the WVDP is stored on-site in engineered facilities pending final disposal (ref. 6).

[c]Closed Dec. 27, 1977. Small perturbations in waste volumes have occurred during site cleanup operations (ref. 10) but are not included here since they are inconsequential.

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

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

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

Year	Radioactivity, Ci							
	Beatty	West Valley[b]	Maxey Flats[c]	Richland	Sheffield[d]	Barnwell	Annual total	Cumulative total
1962								
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[e]		116,108[e]	232,384	9,487,934
1987	3,353[e]	0		42,734[e]		211,026[e]	257,113	9,745,047
1988	8,690	0		32,067		218,901	259,658	10,004,705
1989	42,678	0		99,056		725,164	866,898	10,871,603
1990	11,323	0		92,985		444,277[e]	548,585	11,420,188
1991	29,679	0		158,784		611,348	799,811	12,219,999
Total	550,914	1,266,654	2,400,690	2,240,155	60,206	5,701,380		12,219,999

[a]For a summary of historical additions (1962-1984), see Table 4.6 in ref. 2. For operating sites (Beatty, Richland, and Barnwell), the additions for 1985-1989 are from Table 4.11 in ref. 6 and for 1990 are from ref. 8.

[b]West Valley includes a commercial state-licensed facility which opened Nov. 18, 1963, and closed Mar. 11, 1975, and an NRC-licensed facility (for on-site fuel reprocessing wastes) which opened in 1966 and continued to receive only on-site-generated LLW associated with water treatment and site cleanup until late 1986. This license is in abeyance. Disposal operations at the West Valley Demonstration Project (WVDP) have been suspended pending the preparation of an EIS report for the West Valley site closure. The WVDP began in 1982. The LLW radioactivity values reported for 1982 through 1986 are for the WVDP only and are taken from ref. 6. Since the beginning of 1987, LLW generated at the WVDP is stored on-site in engineered facilities pending final disposal (ref. 6).

[c]Closed Dec. 27, 1977.

[d]Closed Apr. 8, 1978.

[e]Changed due to manifest adjustments from original generators.

Table 4.18. Distribution of total volume and radioactivity, by state, of LLW shipped to commercial disposal sites in 1991[a]

State	Volume (m^3)	Radioactivity (Ci)	State	Volume (m^3)	Radioactivity (Ci)
Alabama	425	37,507	Nebraska	303	657
Alaska	2	743	Nevada	51	5
Arizona	530	908	New Hampshire	7	<1
Arkansas	420	831	New Jersey	1,629	45,707
California	2,044	7,050	New Mexico	21	2
Colorado	63	8,095	New York	2,812	103,358
Connecticut	1,382	3,596	North Carolina	949	6,789
Delaware	22	<1	North Dakota	<1	55
District of Columbia	34	3	Ohio	689	3,840
Florida	542	1,140	Oklahoma	499	18
Georgia	1,003	6,828	Oregon	2,273	49
Hawaii	84	6	Pennsylvania	6,360	354,340
Idaho	<1	42	Puerto Rico	0	0
Illinois	2,887	9,713	Rhode Island	10	<1
Indiana	162	370	South Carolina	1,290	1,399
Iowa	363	529	South Dakota	276	603
Kansas	104	1,356	Tennessee	1,712	2,071
Kentucky	67	631	Texas	1,503	4,155
Louisiana	282	820	Utah	222	62
Maine	268	376	Vermont	485	119,642
Maryland	545	9,347	Virgin Islands	0	0
Massachusetts	971	51,068	Virginia	1,884	3,664
Michigan	0	0	Washington	1,323	1,544
Minnesota	1,233	4,031	West Virginia	10	15
Mississippi	282	2,703	Wisconsin	205	1,012
Missouri	540	3,047	Wyoming	<1	3
Montana	2	2	Other[b]	10	82
			Total	38,779[c]	799,812[c]

[a]Data provided by EG&G, Idaho (ref. 8), to be published by the Low-Level Waste Management Program.
[b]Wastes generated by U.S. Army bases located inside and outside the United States.
[c]Differences in the 1991 annual totals (i.e., the volume in Table 4.16 and the radioactivity in Table 4.17 and the summations of shipments by state, as shown above) result from round-off and truncation of numbers.

Table 4.19. Summary of projected GTCC wastes for LWRs based on packaged waste volume[a]

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

[a]Based on ref. 19.
[b]GE = General Electric, B&W = Babcock & Wilcox, CE = Combustion Engineering, and WH = Westinghouse.
[c]These projections cover the time frame 1985-2035. The low case corresponds to the lowest volume expected, the base case to the most likely volume, and the high case to the largest volume expected.
[d]The same amount of activity is associated with each volume projection case.
[e]Not included in the low and base cases.
[f]Not reported (information not reported in ref. 19).

Table 4.20. Historical and projected volume, radioactivity, and thermal power of LLW shipped for disposal from I/I activities[a,b,c]

End of calendar year	Volume (10^3 m^3)		Radioactivity (10^3 Ci)		Thermal power (W)	
	Annual	Cumulative	Annual	Cumulative[d]	Annual	Cumulative
1990	7.8	699	35	2,915	77.6	3,026
1991	8.2	707	35	2,809	78.0	3,235
1992	8.2	716	35	2,709	78.0	3,443
1993	8.2	724	35	2,616	78.0	3,648
1994	8.2	732	35	2,528	78.0	3,848
1995	8.2	740	35	2,445	78.0	4,044
1996	8.2	748	35	2,367	78.0	4,236
1997	8.2	757	35	2,294	78.0	4,423
1998	8.2	765	35	2,225	78.0	4,605
1999	8.2	773	35	2,161	78.0	4,783
2000	8.2	781	35	2,100	78.0	4,957
2001	8.2	789	35	2,043	78.0	5,127
2002	8.2	798	35	1,990	78.0	5,294
2003	8.2	806	35	1,940	78.0	5,458
2004	8.2	814	35	1,893	78.0	5,619
2005	8.2	822	35	1,849	78.0	5,777
2006	8.2	830	35	1,808	78.0	5,932
2007	8.2	839	35	1,769	78.0	6,086
2008	8.2	847	35	1,734	78.0	6,237
2009	8.2	855	35	1,700	78.0	6,387
2010	8.2	863	35	1,669	78.0	6,535
2011	8.2	871	35	1,640	78.0	6,682
2012	8.2	880	35	1,613	78.0	6,827
2013	8.2	888	35	1,588	78.0	6,971
2014	8.2	896	35	1,564	78.0	7,114
2015	8.2	904	35	1,543	78.0	7,256
2016	8.2	912	35	1,523	78.0	7,398
2017	8.2	920	35	1,504	78.0	7,538
2018	8.2	929	35	1,487	78.0	7,677
2019	8.2	937	35	1,471	78.0	7,816
2020	8.2	945	35	1,457	78.0	7,955
2021	8.2	953	35	1,444	78.0	8,093
2022	8.2	961	35	1,432	78.0	8,230
2023	8.2	970	35	1,421	78.0	8,367
2024	8.2	978	35	1,412	78.0	8,503
2025	8.2	986	35	1,403	78.0	8,639
2026	8.2	994	35	1,395	78.0	8,775
2027	8.2	1,002	35	1,388	78.0	8,911
2028	8.2	1,011	35	1,382	78.0	9,046
2029	8.2	1,019	35	1,376	78.0	9,181
2030	8.2	1,027	35	1,372	78.0	9,316

[a]Although this table shows 1990 as the beginning, the computer-generated table from which it is extracted goes back to 1962.

[b]The source term composition of the radioactivity in pre-1980 I/I waste is given in ref. 2. The source term composition used for I/I waste for 1980 through 2030 is presented in Table C.11 of Appendix C. The values for the volume and radioactivity of I/I wastes were obtained as the difference between the total volume (Table 4.16) and radioactivity (Table 4.17) reported shipped for disposal each year and the corresponding total fuel cycle (UF_6 conversion and fuel fabrication plus LWR operations) values from Tables 4.21-4.25.

[c]The projected volume of I/I waste is assumed to remain constant from 1991 through 2030 (see ref. 25 for rationale). The radioactivity associated with this volume is calculated using the composition given in Table C.11 of Appendix C.

[d]The radioactivity added each year is decayed as if it had the composition given in Table C.11 of Appendix C.

Table 4.21. Historical and projected volume, radioactivity, and thermal power of routine LLW shipped for disposal from BWRs[a,b]

End of calendar year	Volume (10^3 m^3)		Radioactivity (10^3 Ci)		Thermal power (W)	
	Annual	Cumulative	Annual	Cumulative[c]	Annual	Cumulative
1990	10.3	328	34	196	254	1,649
1991	15.6	343	53	221	402	1,829
1992	9.6	353	34	220	248	1,823
1993	9.5	362	34	223	247	1,823
1994	9.5	372	34	225	247	1,826
1995	9.5	381	34	228	248	1,831
1996	9.5	391	34	231	247	1,835
1997	9.5	401	34	233	247	1,840
1998	9.5	410	34	235	247	1,845
1999	9.5	420	34	238	247	1,850
2000	9.5	429	34	240	247	1,854
2001	9.5	439	34	242	247	1,859
2002	9.5	448	34	244	247	1,863
2003	9.5	458	34	246	246	1,867
2004	9.5	467	34	248	246	1,871
2005	9.5	477	34	250	246	1,875
2006	9.5	486	34	252	246	1,878
2007	9.5	496	34	254	246	1,882
2008	9.5	505	34	256	246	1,886
2009	9.4	514	34	257	243	1,886
2010	9.1	523	33	258	236	1,880
2011	8.5	532	30	256	221	1,860
2012	8.4	540	30	255	217	1,842
2013	7.8	548	28	253	202	1,811
2014	6.6	555	24	247	170	1,754
2015	5.6	560	20	239	144	1,681
2016	5.4	566	20	233	141	1,618
2017	5.1	571	18	227	132	1,554
2018	4.9	576	18	222	129	1,497
2019	4.8	581	17	217	125	1,444
2020	4.8	585	17	213	125	1,399
2021	4.8	590	17	210	125	1,359
2022	4.7	595	17	206	121	1,320
2023	4.2	599	15	202	108	1,273
2024	3.5	602	12	195	91	1,215
2025	2.6	605	9	188	69	1,145
2026	2.2	607	8	180	58	1,074
2027	1.9	609	7	173	50	1,005
2028	1.7	611	6	166	44	940
2029	1.5	612	6	159	40	881
2030	1.3	614	5	153	35	823

[a]Although this table shows 1990 as the beginning, the computer-generated table from which it is extracted goes back to 1962.

[b]Annual volume and radioactivity additions through 1991 are reported values (refs. 6, 21, and 22). Beginning in 1992, these values are calculated using the energy values presented in Table C.8 and the source term (which describes routine waste) shown in Fig. C.6 of Appendix C.

[c]The radioactivity added each year is decayed as if it had the composition given in Fig. C.6 of Appendix C.

Table 4.22. Historical and projected volume, radioactivity, and thermal power of routine LLW shipped for disposal from PWRs[a,b]

End of calendar year	Volume (10^3 m^3)		Radioactivity (10^3 Ci)		Thermal power (W)	
	Annual	Cumulative	Annual	Cumulative[c]	Annual	Cumulative
1990	7.8	285	27	234	182	1,244
1991	8.1	293	24	237	157	1,227
1992	7.8	301	29	247	190	1,252
1993	7.9	309	30	257	191	1,275
1994	8.0	317	30	267	193	1,299
1995	8.1	325	30	277	196	1,325
1996	8.2	333	31	287	198	1,351
1997	8.2	341	31	297	199	1,376
1998	8.2	349	31	307	199	1,400
1999	8.3	358	31	316	200	1,423
2000	8.3	366	31	326	200	1,445
2001	8.3	374	31	334	200	1,466
2002	8.3	383	31	343	200	1,486
2003	8.3	391	31	352	200	1,505
2004	8.3	399	31	360	200	1,523
2005	8.3	407	31	368	200	1,540
2006	8.3	416	31	376	200	1,557
2007	8.3	424	31	384	200	1,573
2008	8.3	432	31	392	200	1,588
2009	8.3	440	31	400	200	1,603
2010	8.2	449	31	407	199	1,616
2011	8.1	457	31	414	197	1,627
2012	8.0	465	30	420	195	1,636
2013	7.6	472	28	425	183	1,634
2014	6.9	479	26	427	166	1,618
2015	6.5	486	24	429	158	1,599
2016	6.3	492	24	430	152	1,580
2017	6.0	498	22	431	144	1,557
2018	5.8	504	22	431	141	1,536
2019	5.7	510	21	432	138	1,516
2020	5.7	515	21	433	138	1,499
2021	5.5	521	21	433	133	1,481
2022	5.3	526	20	433	128	1,461
2023	5.2	531	19	433	126	1,442
2024	5.1	536	19	433	122	1,423
2025	4.5	541	17	431	110	1,395
2026	4.2	545	16	428	102	1,364
2027	3.9	549	15	425	95	1,332
2028	3.6	553	13	422	87	1,297
2029	3.3	556	12	418	80	1,261
2030	3.0	559	11	413	73	1,224

[a]Although this table shows 1990 as the beginning, the computer-generated table from which it is extracted goes back to 1962.

[b]Annual volume and radioactivity additions through 1991 are reported values (refs. 6, 21, and 22). Beginning in 1992, these values are calculated using the energy values presented in Table C.8 and the source term (which describes routine waste) shown in Fig. C.7 of Appendix C.

[c]The radioactivity added each year is decayed as if it had the composition given in Fig. C.7 of Appendix C.

Table 4.23. Historical and projected volume, radioactivity, and thermal power of nonroutine LLW shipped for disposal from LWRs[a,b]

End of calendar year	Volume (10^3 m^3)		Radioactivity (10^3 Ci)		Thermal power (W)	
	Annual	Cumulative	Annual	Cumulative[c]	Annual	Cumulative
1990	0.08	5.6	452	2,004	4,088	19,739
1991	0.11	5.7	688	2,384	6,515	23,580
1992	0.53	6.3	397	2,435	3,209	23,746
1993	0.53	6.8	397	2,480	3,206	23,900
1994	0.54	7.3	398	2,523	3,218	24,052
1995	0.54	7.9	400	2,565	3,232	24,202
1996	0.54	8.4	401	2,604	3,242	24,345
1997	0.54	9.0	402	2,640	3,246	24,477
1998	0.54	9.5	402	2,675	3,248	24,595
1999	0.54	10.0	402	2,707	3,247	24,699
2000	0.54	10.6	402	2,737	3,247	24,791
2001	0.54	11.1	402	2,766	3,247	24,874
2002	0.54	11.7	402	2,793	3,245	24,946
2003	0.54	12.2	401	2,819	3,242	25,007
2004	0.54	12.8	401	2,843	3,242	25,062
2005	0.54	13.3	401	2,868	3,242	25,111
2006	0.54	13.8	401	2,891	3,242	25,156
2007	0.54	14.4	401	2,914	3,242	25,196
2008	0.54	14.9	401	2,936	3,242	25,233
2009	0.54	15.4	397	2,953	3,208	25,232
2010	0.52	16.0	389	2,963	3,140	25,165
2011	0.50	16.5	371	2,956	2,992	24,962
2012	0.49	17.0	365	2,948	2,950	24,746
2013	0.46	17.4	341	2,920	2,751	24,362
2014	0.40	17.8	294	2,854	2,376	23,656
2015	0.36	18.2	260	2,769	2,097	22,772
2016	0.35	18.5	253	2,694	2,042	21,953
2017	0.32	18.9	238	2,618	1,917	21,115
2018	0.32	19.2	232	2,551	1,870	20,338
2019	0.31	19.5	227	2,491	1,830	19,621
2020	0.31	19.8	226	2,441	1,826	18,990
2021	0.30	20.1	224	2,396	1,803	18,416
2022	0.29	20.4	216	2,352	1,740	17,852
2023	0.27	20.7	199	2,300	1,605	17,225
2024	0.24	20.9	177	2,235	1,429	16,502
2025	0.20	21.1	145	2,149	1,167	15,612
2026	0.18	21.3	127	2,061	1,025	14,698
2027	0.16	21.4	115	1,975	921	13,800
2028	0.14	21.6	103	1,892	825	12,922
2029	0.13	21.7	95	1,814	760	12,091
2030	0.12	21.8	84	1,738	676	11,281

[a]Although this table shows 1990 as the beginning, the computer-generated table from which it is extracted goes back to 1962.

[b]Annual volume and radioactivity additions through 1991 are reported values (refs. 6, 21, and 22). Beginning in 1992, these values are calculated using the energy values presented in Table C.8 and the source terms (which describe nonroutine waste) shown in Figs. C.6 (BWRs) and C.7 (PWRs) of Appendix C.

[c]The radioactivity added each year is decayed as if it had the composition given in Figs. C.6 (BWRs) and C.7 (PWRs) of Appendix C.

Table 4.24. Historical and projected volume, radioactivity, and thermal power of LLW shipped for disposal from UF_6 conversion for LWRs[a,b]

End of calendar year	Volume (10^3 m^3)		Radioactivity (10^3 Ci)		Thermal power[d] (W)	
	Annual	Cumulative	Annual	Cumulative[c]	Annual	Cumulative
1990	0.76	11.6	0.0006	0.009	0.009	0.15
1991	0.84	12.4	0.0006	0.010	0.010	0.16
1992	0.91	13.3	0.0007	0.010	0.011	0.17
1993	0.76	14.1	0.0006	0.011	0.009	0.17
1994	0.90	15.0	0.0007	0.012	0.011	0.19
1995	0.90	15.9	0.0007	0.012	0.011	0.20
1996	0.80	16.7	0.0006	0.013	0.009	0.21
1997	0.83	17.5	0.0006	0.014	0.010	0.21
1998	0.85	18.3	0.0006	0.014	0.010	0.22
1999	0.92	19.2	0.0007	0.015	0.011	0.24
2000	0.75	20.0	0.0006	0.016	0.009	0.24
2001	0.96	21.0	0.0007	0.016	0.011	0.26
2002	0.78	21.7	0.0006	0.017	0.009	0.26
2003	0.88	22.6	0.0007	0.017	0.010	0.28
2004	0.78	23.4	0.0006	0.018	0.009	0.28
2005	0.77	24.2	0.0006	0.019	0.009	0.29
2006	0.86	25.0	0.0007	0.019	0.010	0.30
2007	0.85	25.9	0.0006	0.020	0.010	0.31
2008	0.80	26.7	0.0006	0.021	0.009	0.32
2009	0.83	27.5	0.0006	0.021	0.010	0.33
2010	0.84	28.4	0.0006	0.022	0.010	0.34
2011	0.77	29.1	0.0006	0.022	0.009	0.35
2012	0.68	29.8	0.0005	0.023	0.008	0.36
2013	0.72	30.5	0.0005	0.024	0.008	0.37
2014	0.54	31.1	0.0004	0.024	0.006	0.37
2015	0.56	31.6	0.0004	0.024	0.007	0.38
2016	0.52	32.2	0.0004	0.025	0.006	0.39
2017	0.59	32.7	0.0004	0.025	0.007	0.39
2018	0.50	33.2	0.0004	0.026	0.006	0.40
2019	0.53	33.8	0.0004	0.026	0.006	0.41
2020	0.56	34.3	0.0004	0.026	0.007	0.41
2021	0.44	34.8	0.0003	0.027	0.005	0.42
2022	0.48	35.3	0.0004	0.027	0.006	0.42
2023	0.41	35.7	0.0003	0.027	0.005	0.43
2024	0.35	36.0	0.0003	0.028	0.004	0.43
2025	0.42	36.4	0.0003	0.028	0.005	0.44
2026	0.25	36.7	0.0002	0.028	0.003	0.44
2027	0.29	37.0	0.0002	0.028	0.003	0.44
2028	0.29	37.3	0.0002	0.029	0.003	0.45
2029	0.20	37.5	0.0002	0.029	0.002	0.45
2030	0.29	37.8	0.0002	0.029	0.003	0.45

[a]Although this table shows 1990 as the beginning, the computer-generated table from which it is extracted goes back to 1962.

[b]These values are calculated based on the UF_6 conversion demand needed to support the electrical generation shown in Table C.8 of Appendix C and the assumption that the settling pond sludges from the direct-fluorination process (Fig. C.2 of Appendix C) are the only LLW thus far shipped for commercial disposal.

[c]The radioactivity added each year is decayed as if it had the composition given in Fig. C.2 of Appendix C.

[d]These values are small since the radionuclides involved have low energy per disintegration; however, they are presented in the interest of completeness.

Table 4.25. Historical and projected volume, radioactivity, and thermal power of LLW shipped for disposal from fuel fabrication for LWRs[a,b]

End of calendar year	Volume (10^3 m^3)		Radioactivity (10^3 Ci)		Thermal power[d] (W)	
	Annual	Cumulative	Annual	Cumulative[c]	Annual	Cumulative
1990	5.6	55	0.013	0.17	0.37	3.8
1991	6.0	61	0.014	0.19	0.40	4.2
1992	5.9	67	0.014	0.21	0.39	4.6
1993	5.9	73	0.014	0.23	0.40	5.0
1994	6.0	79	0.014	0.25	0.40	5.4
1995	6.0	85	0.014	0.27	0.40	5.8
1996	6.0	91	0.014	0.28	0.41	6.2
1997	6.1	97	0.014	0.30	0.41	6.7
1998	6.1	103	0.014	0.32	0.41	7.1
1999	6.1	109	0.014	0.34	0.41	7.5
2000	6.1	115	0.014	0.36	0.41	7.9
2001	6.1	121	0.014	0.38	0.41	8.3
2002	6.1	127	0.014	0.40	0.41	8.8
2003	6.1	133	0.014	0.42	0.41	9.2
2004	6.1	139	0.014	0.44	0.41	9.6
2005	6.1	145	0.014	0.46	0.41	10.0
2006	6.1	151	0.014	0.48	0.41	10.4
2007	6.1	158	0.014	0.50	0.41	10.9
2008	6.1	164	0.014	0.52	0.41	11.3
2009	6.0	170	0.014	0.54	0.40	11.7
2010	6.0	176	0.014	0.56	0.40	12.1
2011	5.8	181	0.014	0.57	0.39	12.5
2012	5.7	187	0.014	0.59	0.38	12.9
2013	5.4	192	0.013	0.61	0.36	13.3
2014	4.7	197	0.011	0.63	0.32	13.6
2015	4.3	202	0.010	0.64	0.29	13.9
2016	4.2	206	0.010	0.65	0.28	14.2
2017	4.0	210	0.009	0.67	0.27	14.5
2018	3.9	214	0.009	0.68	0.26	14.7
2019	3.8	217	0.009	0.69	0.26	15.0
2020	3.8	221	0.009	0.70	0.25	15.3
2021	3.7	225	0.009	0.72	0.25	15.5
2022	3.6	229	0.009	0.73	0.24	15.8
2023	3.4	232	0.008	0.74	0.23	16.0
2024	3.2	235	0.008	0.75	0.21	16.2
2025	2.7	238	0.007	0.76	0.18	16.4
2026	2.5	240	0.006	0.77	0.17	16.6
2027	2.3	243	0.005	0.77	0.15	16.7
2028	2.1	245	0.005	0.78	0.14	16.9
2029	1.9	247	0.005	0.79	0.13	17.0
2030	1.7	248	0.004	0.79	0.12	17.1

[a]Although this table shows 1990 as the beginning, the computer-generated table from which it is extracted goes back to 1962.

[b]Calculated using the energy values presented in Table C.8 and the source term (which describes fuel fabrication waste) in Fig. C.5 of Appendix C.

[c]The radioactivity added each year is decayed as if it had the composition given in Fig. C.5 of Appendix C.

[d]These values are small since the radionuclides involved have low energy per disintegration; however, they are presented in the interest of completeness.

ORNL PHOTO 3996-92

Photo 5.1. The Panna Maria open pit uranium mine operated by General Atomics Corporation in Karns County, Texas. (Courtesy of the U.S. Department of Energy, Energy Information Administration, Washington, D.C.)

5. URANIUM MILL TAILINGS FROM COMMERCIAL OPERATIONS

5.1 INTRODUCTION

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

Mill tailings are generated during the process of extracting uranium from the ore fed to the mill. Uranium mills employ either an acid leach or an alkaline leach process to recover uranium, depending on the ore's chemical characteristics. Currently, more than 96% of the U.S. milling capacity uses the acid leach process. Mill tailings from both processes consist of slurries of sands and clay-like particles called slimes; the tailings slurries are pumped to tailings impoundment ponds for disposal.

U.S. uranium production from conventional milling has declined since 1980, and, as a consequence, the quantity of mill tailings generated each year has declined (see Table 5.1). During 1991, two mills operated and generated tailings. The location of each of these mills is indicated in the map of Fig. 5.1. At the end of 1991, two conventional mills were operating in the United States,[1,2] capable of processing a total of 4,800 t of uranium ore per day. These two mills represent about 24% of the total available domestic conventional uranium milling capacity.[1,2] This small utilization of U.S. capacity can be attributed in large part to nuclear power plant cancellations and deferments. Since the late 1970s, these have led to lower uranium demand. This, in turn, has contributed to lower uranium prices and a steady decline in domestic uranium mining. In addition, cost increases for domestic uranium mining and milling have led to increased reliance on imports of lower cost uranium.

In recent years, U.S. uranium concentrate production from conventional milling of ore has declined. The total processing of ore at conventional mills in 1991 was 11% less than in 1990. Concentrate production in 1991 was about 1,200 t U_3O_8, about 900 t less than 1990 production.[2] Nonconventional concentrate production in 1991 increased to about 2,430 t U_3O_8, or 26% above 1990 production.[2] Nonconventional concentrate production includes by-product processing from the mining of phosphate ore as well as the processing of in situ leach mining solutions, heap-leach solutions, mine water, and other solutions. In situ leaching (ISL) technology has been increasingly applied in recent years in mining operations. Of the total $80-per-kg U uranium reserves estimated by EIA, the amount for which ISL is the proposed mining method has increased from 32% in 1990 to 38% in 1991. Because ISL mining generally is successful at lower costs compared with conventional mining methods, it could gain even wider use in the near future. ISL and by-product production methods do not generate mill tailings. Residual wastes from nonconventional methods are not considered in this section.

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

5.2 INVENTORIES

The status of the licensed mills, including their estimated commercial and government-related tailings inventories at the end of 1991, is shown in Table 5.2 (data based on refs. 1–12). For each mill, the amount of tailings generated depends on the amount of ore processed, the ore-feed grade (U_3O_8 assay), and the percentage of U_3O_8 recovered. Table 5.3 lists the annual milling rate, ore grade, and U_3O_8 recovery; the associated mill tailings generated through 1991 are 190×10^6 t (119×10^6 m^3). The DOE/EIA estimates[1] that 0.58×10^6 t (3.60×10^5 m^3) of tailings were added to the tailings piles at operating mill sites during 1991.

5.3 WASTE CHARACTERIZATION

Because the amount of uranium (by weight) extracted from the ore during milling is relatively small, the dry

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

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

5.4 PROJECTIONS

An average tailings density of 1.6 t/m^3 was used to calculate mill tailings volumes resulting from the milling of uranium ore mined by open pit and underground operations. The quantity of material produced is based on projections of uranium production as reported in the EIA publication, Domestic Uranium Mining and Milling Industry 1990 — Viability Assessment, DOE/EIA-0477(91). These projections were based on uranium requirements associated with the DOE/EIA 1990 No-New-Orders nuclear growth scenario and assumed a 2-year lead time from the mining/milling of uranium to its use as a reactor fuel.

The volumes of tailings generated from 1992 through 2005 are projected to come from six conventional mine/mill operations of which only two are shown to have any significant production. Most of the U.S. production is projected to come from nonconventional extraction operations (in situ, by-product, etc.). Imports and U.S. inventory drawdowns are projected to make up over 80% of U.S. requirements through 2005 and will not add to U.S. tailings buildup.

5.5 REFERENCES

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

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11. 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., Apr. 28, 1988, pp. 19–21.

12. Paul Estey, Exxon Coal and Minerals Company, Houston, Texas, telephone call to L. L. Smith, Energy Information Administration, Washington, D.C., regarding status of reclamation of Ray Point mill site and Felder mine site, Aug. 22, 1988.

ORNL DWG 92-5842

Fig. 5.1. Locations of uranium mill tailings sites active during at least part of 1991.

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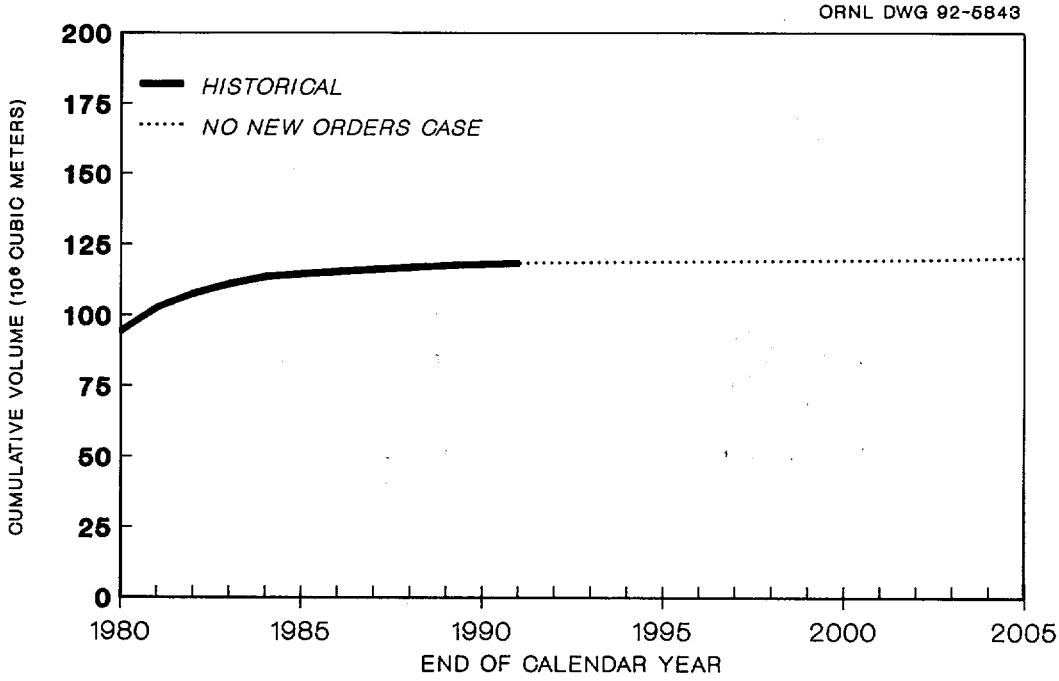

Fig. 5.2. Historical and projected cumulative volume of commercial mill tailings.

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

End of calendar year	Volume (10^6 m^3) Annual	Cumulative
Prior to 1978		68.0
1978	7.9	75.8
1979	9.1	84.9
1980	9.5	94.4
1981	8.2	102.7
1982	5.0	107.7
1983	3.4	111.1
1984	2.5	113.6
1985	1.0	114.6
1986	0.7	115.4
1987	0.8	116.2
1988	0.7	116.9
1989	0.7	117.6
1990	0.4	118.0
1991	0.4	118.4
1992	0.2	118.6
1993	0.1	118.7
1994	0.1	118.8
1995	0.1	118.9
1996	0.1	119.0
1997	0.1	119.1
1998	0.1	119.2
1999	0.1	119.3
2000	0.1	119.4
2001	<0.1	119.5
2002	0.1	119.6
2003	0.2	119.8
2004	0.3	120.1
2005	0.3	120.4

[a]Projections of domestic tailings are generated from estimates of U.S. uranium production under current market conditions described in ref. 3, which is the No-New-Orders Case of ref. 4.

[b]Sources: Prior to 1984 — U.S. Department of Energy, Grand Junction Project Office data files. 1984-1991 — Energy Information Administration, Form EIA-858, "Uranium Industry Annual Survey."

Table 5.2. Status of conventional uranium mill sites at the end of 1991[a]

Location	Operator	Rated capacity[b] (t ore/d)	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	Wood chip covering	81	1.3	2.1	0.3
Uravan	Umetco Minerals	1,180[g]	Decommissioning	Partially stabilized	44	5.9	9.5	5.2
Subtotal		1,090			125	7.2	11.6	5.5
New Mexico								
Cebolleta	Sohio Western Mining	1,450[g]	Decommissioned, 1986	h	73	1.2	1.9	0
Church Rock	United Nuclear	2,720[g]	Decommissioned, 1986	h	83	2.0	3.2	0
Grants	Anaconda	5,440[g]	Decommissioned, 1987	Partially stabilized	199	13.6	21.7	8.0
Grants	Quivira Mining	6,350	Shut down, 1985	Fenced	142	18.8	30.1	9.1
Grants	Homestake Mining	3,080[g]	Decommissioning	Unstabilized	105	12.7	20.3	10.4
Marquez	Bokum Resources	1,820[g]	New (on standby)	Never operated	0	0	0	0
Subtotal		6,350			602	48.3	77.2	27.5
South Dakota								
Edgemont	TVA	680[g]	Decommissioned, 1983	Partially stabilized	50	1.2	1.8	1.5
Subtotal		0			50	1.2	1.8	1.5
Texas								
Falls City	Continental Oil/ Pioneer Nuclear	3,080[g]	Decommissioned, 1981	h	89	6.5	10.5	0
Hobson	Rio Grande Resources	2,720	Active	h	101	3.8	5.8	0
Ray Point (Felder Facility)	Exxon	1,000[g]	Decommissioned, 1973[i]	Stabilized[j]	18	0.2	0.4[k]	0
Subtotal		2,720			208	10.5	16.7	0
Utah								
Blanding	Umetco/Energy Fuels Nuclear	1,810	Shut down, 1990	Partially stabilized	135	1.9	3.2	0
La Sal	Rio Algom	680	Shut down, 1988	h	14	2.2	3.5	0
Moab	Atlas	1,270[g]	Decommissioning	Unstabilized	>80	6.0	9.6	5.4
Hanksville	Plateau Resources	910	New (on standby)	Never operated	28	0	0	0
Subtotal		3,400			>257	10.1	16.3	5.4

Table 5.2 (continued)

Location	Operator	Rated capacity[b] (t ore/d)	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)
Washington								
Ford	Dawn Mining	410	Shut down, 1982	Wood chip covering	43	1.8	2.8	1.1
Wellpinit	Western Nuclear	1,810[g]	Shut down, 1984	h	17	1.6	2.6	0
Subtotal		410			60	3.4	5.4	1.1
Wyoming								
Gas Hills	American Nuclear	860[g]	Decommissioned, 1988	Unstabilized	52	3.3	5.3	1.9
Gas Hills	Pathfinder	2,540[g]	Shut down, 1988	Unstabilized	55	6.6	10.6	2.4
Jeffrey City	Western Nuclear	1,540[g]	Decommissioned, 1988	Interim stabilization	34	4.4	7.0	3.0
Natrona	Umetco	1,270[g]	Decommissioned, 1987	Unstabilized	70	4.6	7.3	1.9
Powder River	Exxon	2,900[g]	Decommissioned, 1984	Partially stabilized	81	6.4	10.3	0
Powder River	Rocky Mountain Energy	1,810[g]	Decommissioned, 1987	Unstabilized	61	2.7	4.3	0
Shirley Basin	Pathfinder	1,630	Inactive Dec. 1988; resumed 1989	h	94	4.6	7.3	0
Shirley Basin	Petrotomics	1,360[g]	Decommissioned, 1985	Unstabilized	65	3.9	6.3	0.7
Red Desert	Minerals Exploration/ Union Energy Mining	2,720	Shut down, May 1983	Partially stabilized	121	1.3	2.1	0
Subtotal		4,350			633	37.8	60.5	9.9
1990 total for all sites[b,l,m]		18,320[n]			h	118.5	189.5	50.9[o]

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

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

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

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

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

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

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

[h]Not available.

[i]From ref. 10.

[j]From ref. 12.

[k]From ref. 11.

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

[m]From ref. 1.

[n]Mills reported as permanently closed on Form GIA-858 for 1991. This is not the same as decommissioned, according to industry contacts.

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

Table 5.3. Uranium ore processed, recovery rate, and tailings generated through 1991[a,b]

End of calendar year	Ore processed: Mass[c] (10^6 t)	Ore processed: Grade (% U_3O_8)	U_3O_8 recovery from ore (%)	U_3O_8 product[d] (10^6 t)	Tailings generated: Mass[e] (10^6 t)	Tailings generated: 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
Total[h]					189.3	118.3

[a]Sources: Prior to 1984 — U.S. Department of Energy, Grand Junction Area Office data files. 1984–1991 — Energy Information Administration, Form EIA-858, "Uranium Industry Annual Survey."

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

[c]Before in-process inventory adjustments.

[d]Conventional U_3O_8 concentrate production.

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

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

[g]Not available.

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

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

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

[a]Adapted from information in ref. 9.

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

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

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

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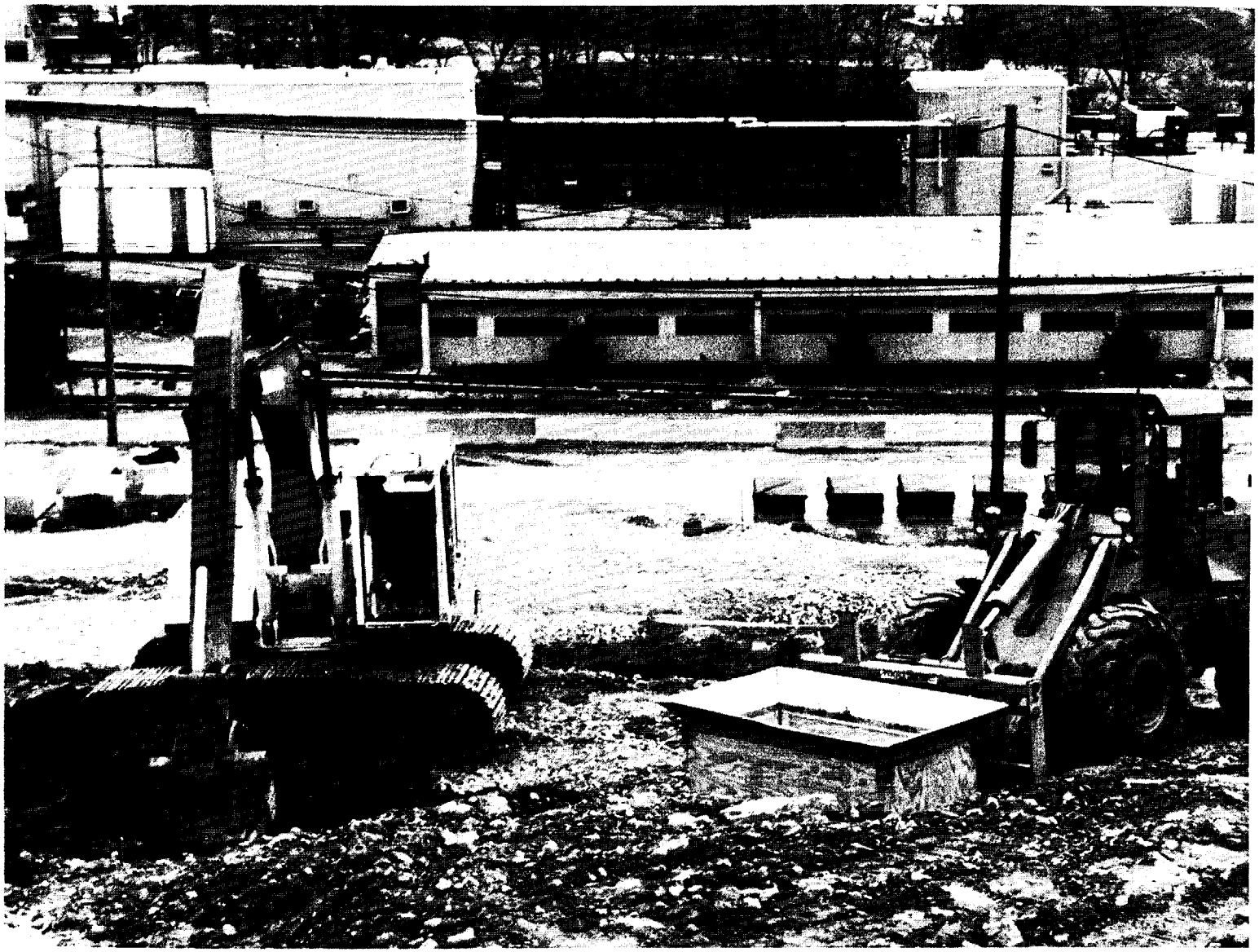

Photo 6.1. Low-level radioactive soil being loaded into boxes at the Mound Plant. (Courtesy of EG&G Mound Applied Technologies, Miamisburg, Ohio, and the Hazardous Waste Remedial Actions Program, Oak Ridge, Tennessee.)