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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

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Prepared for:

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

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PREFACE

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

U.S. Department of Energy
Office of Civilian Radioactive Waste Management
Route Symbol RW-432
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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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CONTENTS

PREFACE iii

LIST OF PHOTOS xi

LIST OF FIGURES xiii

LIST OF TABLES xvii

GLOSSARY OF ABBREVIATIONS AND ACRONYMS xxv

ABSTRACT 1

0. OVERVIEW 1
   0.1 INTRODUCTION 1
   0.2 CHARACTERIZATION OF WASTE FORMS 2
   0.3 METHODS AND ASSUMPTIONS USED IN REPORT PREPARATION 4
   0.4 SUMMARY DATA AND CHAPTER OVERVIEWS 5
      0.4.1 Spent Fuel 5
      0.4.2 High-Level Waste 5
      0.4.3 TRU Waste 5
      0.4.4 Low-Level Waste 5
      0.4.5 Commercial Uranium Mill Tailings 6
      0.4.6 Environmental Restoration Wastes 6
      0.4.7 Commercial Decommissioning Wastes 6
      0.4.8 Miscellaneous Radioactive Materials 6
      0.4.9 Mixed Low-Level Waste 7
      0.4.10 Appendixes 7
   0.5 REFERENCES 7

1. COMMERCIAL SPENT FUEL 17
   1.1 INTRODUCTION 17
   1.2 INVENTORIES AND PROJECTIONS 17
   1.3 CHARACTERIZATION 18
   1.4 DISPOSAL 18
   1.5 REFERENCES 18

2. HIGH-LEVEL WASTE 39
   2.1 INTRODUCTION 39
   2.2 INVENTORIES 40
      2.2.1 HLW Inventories at SRS (DOE) 40
      2.2.2 HLW Inventories at INEL (DOE) 40
      2.2.3 HLW Inventories at HANF (DOE) 40
      2.2.4 HLW Inventories at WVDP (Commercial) 40
   2.3 WASTE CHARACTERIZATION 40
   2.4 PROJECTIONS 41
   2.5 REFERENCES 41

3. TRANSURANIC WASTE 77
3.1 INTRODUCTION 77
3.2 TRU WASTE LOCATIONS 77
3.3 INVENTORIES 78
3.4 WASTE CHARACTERIZATION 79
3.4.1 Physical Composition 79
3.4.2 Isotopic Composition 79
3.5 SHIPMENT AND DISPOSAL 79
3.6 REFERENCES 79

4. LOW-LEVEL WASTE 111
4.1 INTRODUCTION 111
4.2 DOE LLW 111
4.2.1 Inventories at DOE LLW Disposal Sites 111
4.2.2 Characterization of LLW at DOE Sites 111
4.2.3 DOE LLW Disposal Sites 112
4.2.4 DOE LLW Projections 112
4.3 COMMERCIAL LLW 112
4.3.1 Inventories at Commercial LLW Disposal Sites 112
4.3.2 Characterization of LLW at Commercial Disposal Sites 112
4.3.3 Greater-Than-Class-C Low-Level Waste (GTCC LLW) 113
4.3.4 Commercial LLW Disposal Sites 114
4.3.5 Commercial LLW Projections 114
4.4 REFERENCES 115

5. URANIUM MILL TAILINGS FROM COMMERCIAL OPERATIONS 147
5.1 INTRODUCTION 147
5.2 INVENTORIES 147
5.3 WASTE CHARACTERIZATION 147
5.4 PROJECTIONS 148
5.5 REFERENCES 148

6. ENVIRONMENTAL RESTORATION WASTES 157
6.1 INTRODUCTION 157
6.2 THE OFFICE OF ENVIRONMENTAL RESTORATION 157
6.2.1 Activities 157
6.2.1.1 Remedial action 157
6.2.1.2 Decontamination and decommissioning 158
6.2.2 Programs 158
6.2.2.1 Southwestern Area Programs 158
6.2.2.2 Northwestern Area Programs 159
6.2.2.3 Eastern Area Programs 160
6.3 REFERENCES 161

7. COMMERCIAL DECOMMISSIONING WASTES 179
7.1 INTRODUCTION 179
7.2 WASTE CHARACTERIZATION 179
7.3 INVENTORIES AND PROJECTIONS 180
7.4 REFERENCES 182

8. MIXED LOW-LEVEL WASTE 209
8.1 INTRODUCTION 209
8.2 WASTE CHARACTERIZATION 209
8.3 DOE SITE INVENTORIES AND GENERATION RATES 209
8.4 COMMERCIAL MIXED LOW-LEVEL WASTES 210
8.5 REFERENCES 211

APPENDIX A. MISCELLANEOUS RADIOACTIVE MATERIALS 227
A.1 INTRODUCTION 229
A.2 INVENTORIES AND PROJECTIONS 229
A.3 REFERENCES 230

APPENDIX B. CHARACTERISTICS OF IMPORTANT RADIONUCLIDES 253
B.1 DISCUSSION 255
B.2 REFERENCES 255

APPENDIX C. WASTE FLOWSHEETS, SOURCE TERMS, AND CHARACTERISTICS 263
C.1 DISCUSSION 265
C.2 REFERENCES 265

APPENDIX D. REFERENCE SITES AND FACILITIES 295
D.1 DISCUSSION 297

GLOSSARY OF TERMS 303

INDEX 309

DISTRIBUTION 315

LIST OF PHOTOS

COMMERCIAL SPENT FUEL

1.1 The LaSalle County Nuclear Power Station, two 1120-MW(e) boiling-water reactors, located in Seneca, Illinois 16

HIGH-LEVEL WASTE

2.1 Construction of the West Valley Demonstration Project vitrification facility that will incorporate West Valley high-level waste into a glass 38

TRANSURANIC WASTE

3.1 Assay equipment used at the Hanford Site to determine the radionuclide content of transuranic waste drums 76

LOW-LEVEL WASTE

4.1 Placement of waste in a low-level waste burial trench at the Hanford Site 110

URANIUM MILL TAILINGS FROM COMMERCIAL OPERATIONS

5.1 The Panna Maria open pit uranium mine operated by General Atomics Corporation in Karns County, Texas 146

ENVIRONMENTAL RESTORATION WASTES

6.1 Low-level radioactive soil being loaded into boxes at the Mound Plant 156

COMMERCIAL DECOMMISSIONING WASTES

7.1 Burial of the 290-ton Pathfinder boiling-water reactor vessel at a low-level radioactive waste disposal site on August 27, 1991 178

MIXED LOW-LEVEL WASTE

8.1 Retrieval of the mixed low-level waste sludge from a Hanford Site solar evaporation basin 208

LIST OF FIGURES

OVERVIEW

0.1 Total volumes of commercial and DOE wastes and spent fuel through 1991 9

0.2 Total radioactivities of commercial and DOE wastes and spent fuel through 1991 9

0.3 Projections of annual volume additions for various wastes and spent fuel – DOE and commercial fuel cycle 10

0.4 Projections of annual radioactivity additions for various wastes and spent fuel – DOE and commercial fuel cycle 10

0.5 Projections of cumulative volumes for various wastes and spent fuel – DOE and commercial fuel cycle 11

0.6 Projections of cumulative radioactivity for various wastes and spent fuel – DOE and commercial fuel cycle 11

COMMERCIAL SPENT FUEL

1.1 Locations of existing and planned commercial reactors as of December 31, 1991 20

1.2 Projected mass (MTIHM) of annual commercial spent fuel discharges for the DOE/EIA No New Orders and Lower Reference cases 21

1.3 Projected cumulative radioactivity of commercial spent fuel discharges for the DOE/EIA No New Orders and Lower Reference cases 21

1.4 Projected cumulative mass (MTIHM) of commercial spent fuel discharges for the DOE/EIA No New Orders Case 22

1.5 Projected cumulative mass (MTIHM) of commercial spent fuel discharges for the DOE/EIA Lower Reference Case 22

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 23

HIGH-LEVEL WASTE

2.1 Total volume of HLW through 1991 43

2.2 Total radioactivity of HLW through 1991 43

2.3 Distribution of total cumulative volume and radioactivity of HLW by site and type through 1991 44

2.4 Locations and [illegible] of HLW through 1991 44

2.5 Treatment methods for HLW in tanks and canisters at SRS 45

2.6 Treatment methods for HLW in tanks, bins, and canisters at INEL 45

2.7 Treatment methods for HLW in tanks, capsules, and canisters at HANF 46

2.8 Treatment methods for HLW in tanks and canisters at WVDP 46

TRANSURANIC WASTE

3.1 Locations [illegible] and stored DOE TRU waste through 1991 81

3.2 Points of origin [illegible] DOE TRU waste 81

3.3 Total volume [illegible] TRU waste through 1991 82

3.4 Total mass of [illegible] DOE TRU waste through 1991 82

3.5 Total volume [illegible] stored DOE TRU waste through 1991 83

3.6 Total mass [illegible] stored DOE TRU waste through 1991 83

LOW-LEVEL WASTE

4.1 Volume [illegible] disposed in 1991 117

4.2 Total volume [illegible] disposed through 1991 117

4.3 Historical [illegible] cumulative volume of LLW 118

4.4 Total volume [illegible] LLW buried through 1991 119

4.5 Locations [illegible] of DOE LLW buried through 1991 119

4.6 Total volume [illegible] LLW disposed through 1991 120

4.7 Locations [illegible] commercial LLW disposed through 1991 120

URANIUM MILL TAILINGS FROM COMMERCIAL OPERATIONS

5.1 Locations [illegible] tailings sites active during at least part of 1991 150

5.2 Historical [illegible] cumulative volume of commercial mill tailings 150

ENVIRONMENTAL RESTORATION WASTES

6.1 Locations [illegible] for DOE environmental restoration activities 163

6.2 Estimated [illegible] classes of wastes from environmental restoration activities 164

6.3 Locations of UMTRAP sites 165

6.4 Locations of FUSRAP sites 166

6.5 Estimated total volumes of wastes from UMTRAP activities in various states 167

6.6 Estimated total volumes of wastes from FUSRAP activities in various states 167

MIXED LOW-LEVEL WASTE

8.1 Total volume inventory of DOE mixed LLW through 1991 212

8.2 Volume generation of DOE mixed LLW during 1991 212

APPENDIX A. MISCELLANEOUS RADIOACTIVE MATERIALS

A.1 Locations and total masses of miscellaneous radioactive materials through 1991 232

A.2 Mass and locations of miscellaneous radioactive materials as of December 31, 1991 232

A.3 Types of miscellaneous radioactive materials in storage through 1991 233

APPENDIX C. WASTE FLOWSHEETS, SOURCE TERMS, AND CHARACTERISTICS

C.1 Principal waste and product streams from a uranium mine/mill complex 267

C.2 Principal waste and product streams from a direct-fluorination UF_6 conversion plant 268

C.3 Principal waste and product streams from a solvent extraction-fluorination UF_6 conversion plant 269

C.4 Principal waste and product streams from a gaseous diffusion uranium enrichment plant 270

C.5 Principal waste and product streams from a fuel fabrication plant 271

C.6 Principal waste and product streams from a boiling-water reactor 272

C.7 Principal waste and product streams from a pressurized-water reactor 273

C.8 Boiling-water reactor decommissioning wastes per 1-MW(e) capacity 274

C.9 Pressurized-water reactor decommissioning wastes per 1-MW(e) capacity 275

C.10 Waste flow diagram for the SRS Defense Waste Processing Facility 276

LIST OF TABLES

OVERVIEW

0.1 Major sources of information for the IDB program 12

0.2 Major assumptions used in this report 13

0.3 Spent fuel and radioactive waste inventories as of December 31, 1991 14

0.4 Current and projected cumulative quantities of radioactive waste and spent fuel 15

COMMERCIAL SPENT FUEL

1.1 Historical and projected installed LWR electric power generating capacity for the DOE/EIA No New Orders and Lower Reference cases 24

1.2 Projected cumulative mass of commercial spent fuel discharges for alternative DOE/EIA scenarios 25

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 26

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 29

1.5 Projected number of permanently discharged LWR spent fuel assemblies for the DOE/EIA No New Orders Case 32

1.6 Projected number of permanently discharged LWR spent fuel assemblies for the DOE/EIA Lower Reference Case 33

1.7 Historical and projected spent fuel discharged from the Fort St. Vrain HTGR 34

1.8 IDB reference characteristics of LWR fuel assemblies 34

1.9 Historical mass of commercial BWR spent fuel discharged at various ranges of burnup 35

1.10 Historical mass of commercial PWR spent fuel discharged at various ranges of burnup 36

HIGH-LEVEL WASTE

2.1 Historical and projected total cumulative volume, radioactivity, and thermal power of HLW stored in tanks, bins, and capsules by source 47

2.2 Projected volume, radioactivity, and thermal power of HLW glass and glass/ceramic stored in canisters by source 50

2.3 Estimated potential number of HLW canisters by source 53

2.4 Estimates of the number of DOE HLW canisters that could be produced from stored and projected HLW 54

2.5 Current volume of HLW in storage by site through 1991 55

2.6 Current radioactivity of HLW in storage by site through 1991 56

2.7 Historical and projected total cumulative volume of HLW in storage by site through 2030 57

2.8 Historical and projected total cumulative radioactivity of HLW in storage by site through 2030 59

2.9 Historical and projected total cumulative thermal power of HLW in storage by site through 2030 61

2.10 Significant revisions and changes in the current values for HLW compared to the values in the previous year 63

2.11 Representative chemical composition of current and future HLW at SRS 64

2.12 Representative radionuclide composition of current (end of 1991) HLW forms and future (to be generated in 1993) HLW glass at SRS 65

2.13 Representative chemical composition of current and future HLW liquid at ICPP 66

2.14 Representative chemical composition of current and future HLW calcine at ICPP 67

2.15 Representative radionuclide composition of current HLW at ICPP 68

2.16 Representative chemical composition of current and future HLW at HANF 69

2.17 Representative radionuclide composition (Ci) of current HLW at HANF 70

2.18 Chemical composition of alkaline liquid HLW (from reprocessing via a PUREX flowsheet) at WVDP 72

2.19 Chemical composition of alkaline sludge HLW (from reprocessing via a PUREX flowsheet) at WVDP 73

2.20 Chemical composition of acid liquid HLW (from reprocessing via a THOREX flowsheet) at WVDP 74

2.21 Radionuclide composition (December 31, 1991) of HLW at WVDP 75

TRANSURANIC WASTE

3.1 Total system inventories, projections, and characteristics of buried and stored DOE TRU waste 84

3.2 Inventories and characteristics of DOE buried TRU waste through 1991 87

3.3 Inventories and characteristics of soil contaminated by DOE TRU solid waste through 1991 87

3.4 Inventories and characteristics of soil contaminated by DOE TRU liquid waste through 1991 88

3.5 Inventories and characteristics of retrievable DOE TRU waste at each storage site through 1991 89

3.6 Revisions and changes in historical inventories of stored DOE TRU waste from previous IDB report 90

3.7 Estimated physical composition of retrievably stored, newly generated, and buried TRU waste at DOE sites 92

3.8 Isotopic composition of buried TRU waste at each site 95

3.9 Isotopic composition, by weight percent, of mixes used to describe composition of contact-handled TRU waste at each site 96

3.10 Isotopic composition, by activity percent, of mixes used to describe composition of contact-handled TRU waste at each site 98

3.11 Isotopic composition, by weight percent, of mixes used to describe composition of remote-handled TRU waste at each site 100

3.12 Isotopic composition, by activity percent, of mixes used to describe composition of remote-handled TRU waste at each site 102

3.13 Volumes, total activities, and isotopic mix ratios of TRU wastes stored or to be newly generated (1992–2018) at each site 104

3.14 Volume, mass, and total radioactivity of DOE TRU waste reported at each burial and storage site through 1991 106

3.15 Calculated decayed total radioactivity and thermal power at each burial and storage site through 1991 107

3.16 Projected volume, mass, and activity of TRU waste to be generated during 1992–2018 108

LOW-LEVEL WASTE

4.1 A summary of characteristics for buried/disposed LLW as of December 31, 1991 121

4.2 Historical and projected volume, radioactivity, and thermal power of buried DOE LLW 122

4.3 Historical and projected volume, radioactivity, and thermal power of commercial LLW shipped for disposal 123

4.4 Historical annual additions and total volume of LLW buried at DOE sites 124

4.5 Summary of radionuclide characteristics for LLW at DOE sites 125

4.6 Summary of physical characteristics for LLW at DOE sites 126

4.7 Breakdown of volumes of LLW generated during 1991 at DOE sites by radionuclide characteristic 127

4.8 Breakdown of activity of LLW generated during 1991 at DOE sites by radionuclide characteristic 128

4.9 Breakdown of cumulative volumes of LLW buried at DOE sites by radionuclide characteristic 129

4.10 Breakdown of total gross activity of LLW buried at DOE sites by radionuclide characteristic 130

4.11 DOE LLW disposed by methods other than shallow-land burial 131

4.12 Status of land usage at LLW burial and disposal sites 132

4.13 Significant revisions and changes in the current values for LLW compared to the values in the previous year 133

4.14 Historical and projected volume, radioactivity, and thermal power characteristics of buried DOE LLW, except SRS saltstone 134

4.15 Projected volume, radioactivity, and thermal power characteristics of DOE LLW saltstone at SRS 135

4.16 Historical annual additions and total volume of LLW at commercial disposal sites 136

4.17 Historical annual additions and total undecayed radioactivity of LLW at commercial disposal sites 137

4.18 Distribution of total volume and radioactivity, by state, of LLW shipped to commercial disposal sites in 1991 138

4.19 Summary of projected GTCC wastes for LWRs based on packaged waste volume 139

4.20 Historical and projected volume, radioactivity, and thermal power of LLW shipped for disposal from I/I activities 140

4.21 Historical and projected volume, radioactivity, and thermal power of routine LLW shipped for disposal from BWRs 141

4.22 Historical and projected volume, radioactivity, and thermal power of routine LLW shipped for disposal from PWRs 142

4.23 Historical and projected volume, radioactivity, and thermal power of nonroutine LLW shipped for disposal from LWRs 143

4.24 Historical and projected volume, radioactivity, and thermal power of LLW shipped for disposal from UF_6 conversion for LWRs 144

4.25 Historical and projected volume, radioactivity, and thermal power of LLW shipped for disposal from fuel fabrication for LWRs 145

URANIUM MILL TAILINGS FROM COMMERCIAL OPERATIONS

5.1 Historical and projected volume of uranium mill tailings 151

5.2 Status of conventional uranium mill sites at the end of 1991 152

5.3 Uranium ore processed, recovery rate, and tailings generated through 1991 154

5.4 Typical characteristics of uranium mill tailings 155

ENVIRONMENTAL RESTORATION WASTES

6.1 Summary of current and projected waste volumes from environmental restoration activities 168

6.2 Estimated volumes of radioactive soils from environmental restoration activities 169

6.3 Estimated volumes of radioactive solid waste from environmental restoration activities 170

6.4 UMTRAP site descriptions, status, scheduled duration, and estimated waste volumes 171

6.5 Projected volume and ^{226}Ra concentration in wastes at uncompleted UMTRAP sites as of December 31, 1991 173

6.6 FUSRAP site descriptions, status, schedule, and volume of stored wastes 174

6.7 Projected waste characteristics at uncompleted FUSRAP sites as of December 31, 1991 176

COMMERCIAL DECOMMISSIONING WASTES

7.1 Schedule of final shutdown dates for commercial light-water reactors 186

7.2 Projections of cumulative volume, radioactivity, and thermal power of wastes from decommissioning commercial light-water reactors shut down during 1992–2030 187

7.3 Projections of radioactive wastes from decommissioning reference commercial power reactors and fuel cycle facilities 188

7.4 List of U.S. civilian reactors shut down or dismantled as of December 31, 1991 189

7.5 Types and quantities of wastes from decommissioning the Elk River reactor site 191

7.6 Types and volumes of wastes from decommissioning the Santa Susana Sodium Reactor Experiment site 192

7.7 Estimated volumes and activities of wastes from decommissioning alternatives considered for reference LWRs 193

7.8 Characteristics of wastes from decommissioning activities at the Shippingport Station Decommissioning Project 194

7.9 Inventories and projections of wastes from various activities at the West Valley Demonstration Project 195

7.10 Characteristics of wastes from decontamination activities at the Three Mile Island–Unit 2 reactor site 196

7.11 Projected characteristics of radioactive wastes from Dresden Unit 1 decommissioning activities 197

7.12 Inventories and projections of low-level radioactive wastes from La Crosse BWR decommissioning activities 198

7.13 Projected volumes of wastes from Saxton PWR decommissioning activities 199

7.14 Projected burial volumes of radioactive wastes from SAFSTOR (mothballing/delayed dismantling) of Humboldt Bay Unit 3 200

7.15 Projected burial volumes of radioactive wastes from DECON (prompt removal/dismantling) of Diablo Canyon Power Plant Units 1 and 2 201

7.16 Projected volumes of wastes from Rancho Seco PWR decommissioning activities 202

7.17 Projected characteristics of wastes from DECON (dismantling) of the Fort St. Vrain HTGR 203

7.18 Projected volumes of radioactive wastes from DECON (prompt removal/dismantling) of the Peach Bottom reactors 204

7.19 Characteristics of radioactive wastes associated with decommissioning the Pathfinder reactor 204

7.20 Projected characteristics of wastes from Shoreham BWR decommissioning activities 205

7.21 Projected volumes of wastes from Indian Point Unit 1 PWR decommissioning activities 206

7.22 Characteristics of wastes from decommissioning activities at the Cimarron Fuel Fabrication Facility 206

MIXED LOW-LEVEL WASTE

8.1 States and territories with EPA mixed waste authorization 213

8.2 Cumulative mass (kg) inventories of DOE site mixed LLW, by physical category, through 1991 214

8.3 Cumulative volume (m^3) inventories of DOE site mixed LLW, by physical category, through 1991 215

8.4 Mass generation rates (kg/year) of DOE site mixed LLW, by physical category, for 1991 216

8.5 Volume generation rates (m^3/year) of DOE site mixed LLW, by physical category, for 1991 217

8.6 Hazard categories used in this report for characterizing DOE site mixed LLW 218

8.7 Cumulative mass (kg) inventories of DOE site mixed LLW, by hazard category, through 1991 219

8.8 Cumulative volume (m^3) inventories of DOE site mixed LLW, by hazard category, through 1991 220

8.9 Mass generation rates (kg/year) of DOE site mixed LLW, by hazard category, for 1991 221

8.10 Volume generation rates (m^3/year) of DOE site mixed LLW, by hazard category, for 1991 222

8.11 Projected annual mixed LLW mass generation rates (kg/year) for various DOE sites 223

8.12 Projected annual mixed LLW volume generation rates (m^3/year) for various DOE sites 224

8.13 National commercially generated mixed LLW profile volume summary, by facility category 225

8.14 National commercially generated mixed LLW profile volume summary, by hazardous waste stream 225

APPENDIX A. MISCELLANEOUS RADIOACTIVE MATERIALS

A.1 Inventory of miscellaneous radioactive materials that may require geologic disposal, as of December 31, 1991 234

A.2 Miscellaneous radioactive materials stored at Argonne National Laboratory-West, as of December 31, 1991 235

A.3 Miscellaneous radioactive materials stored at Babcock & Wilcox, Lynchburg Technology Center, as of December 31, 1991 236

A.4 Miscellaneous radioactive materials stored at Battelle Pacific Northwest Laboratory, as of December 31, 1991 237

A.5 Miscellaneous radioactive materials stored at the Hanford 200-Area burial grounds, as of December 31, 1991 238

A.6 Miscellaneous radioactive materials stored at the Idaho National Engineering Laboratory, as of December 31, 1991 239

A.7 Miscellaneous radioactive materials stored at the Los Alamos National Laboratory, as of December 31, 1991 244

A.8 Miscellaneous radioactive materials stored at the Oak Ridge National Laboratory, as of December 31, 1991 245

A.9 Miscellaneous radioactive materials stored at the Savannah River Site, as of December 31, 1991 247

A.10 Volume and activity summary of commercial GTCC LLW 251

A.11 Mass summary of DOE spent fuel no longer scheduled for reprocessing 251

APPENDIX B. CHARACTERISTICS OF IMPORTANT RADIONUCLIDES

B.1 Characteristics of important radionuclides 256

APPENDIX C. WASTE FLOWSHEETS, SOURCE TERMS, AND CHARACTERISTICS

C.1 Estimated representative unit activity and thermal power characteristics of various types of radioactive materials and wastes 277

C.2 Basic factors used for fuel cycle, DOE waste, and I/I waste projections 278

C.3 Lifetime radioactive waste generation by light-water reactors and supporting fuel cycle activities 279

C.4 Mass, radioactivity, and thermal power of nuclides in domestic commercial LWR spent fuel at the end of calendar year 1991 280

C.5 Representative DOE LLW radionuclide composition by percent activity 287

C.6 Average concentrations for representative radionuclides in LLW at commercial disposal sites 288

C.7 Projected chemical and radionuclide composition of saltstone at SRS 290

C.8 Historical and projected DOE/EIA No New Orders Case commercial LWR net annual electrical generation 291

C.9 Estimated sources and characteristics of commercial greater-than-Class-C LLW 292

C.10 Projected number and volume of drums and classes of LLW incorporated in cement to be generated in the WVDP Low-Level Radwaste Treatment System 293

C.11 Composition of industrial and institutional waste by category 294

APPENDIX D. REFERENCE SITES AND FACILITIES

D.1 Major DOE sites and facilities referred to in this report 298

D.2 Major commercial radioactive waste disposal sites included in this report 302

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.

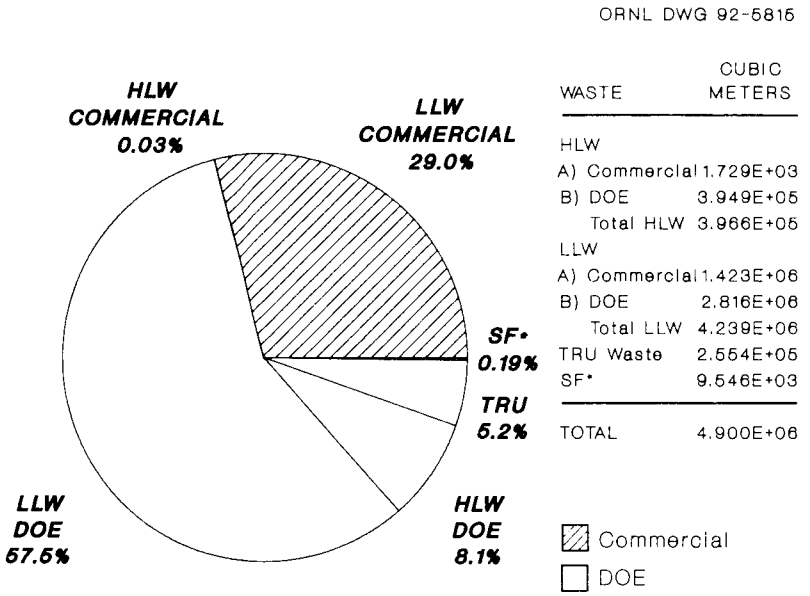
0.4.4 Low-Level Waste

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

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).

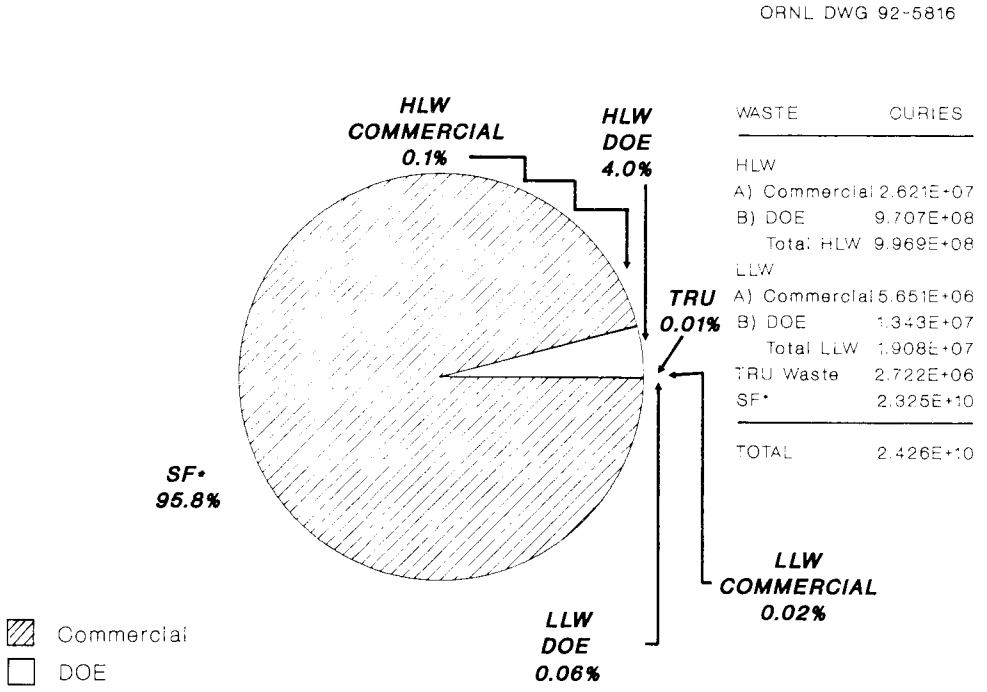
14. U.S. Congress, Atomic Energy Act of 1954, Pub. L. 83–703, Aug. 15, 1954.



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.

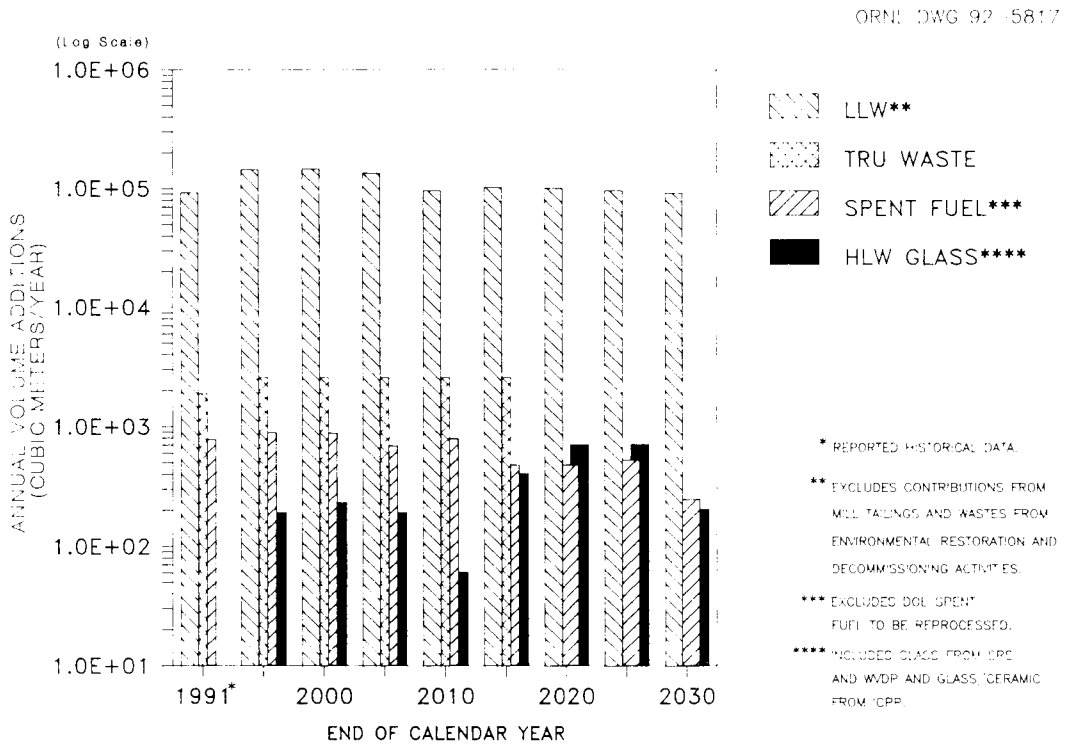


Fig. 0.3. Projections of annual volume additions for various wastes and spent fuel — DOE and commercial fuel cycle.

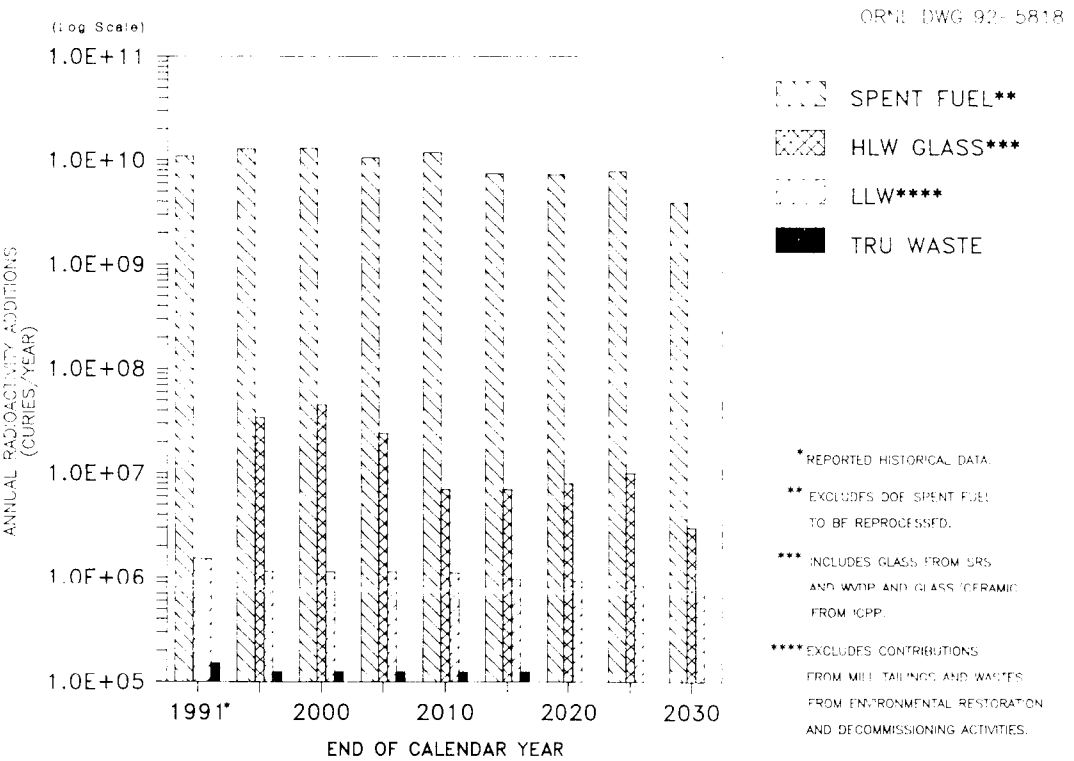


Fig. 0.4. Projections of annual radioactivity additions for various wastes and spent fuel — DOE and commercial fuel cycle.

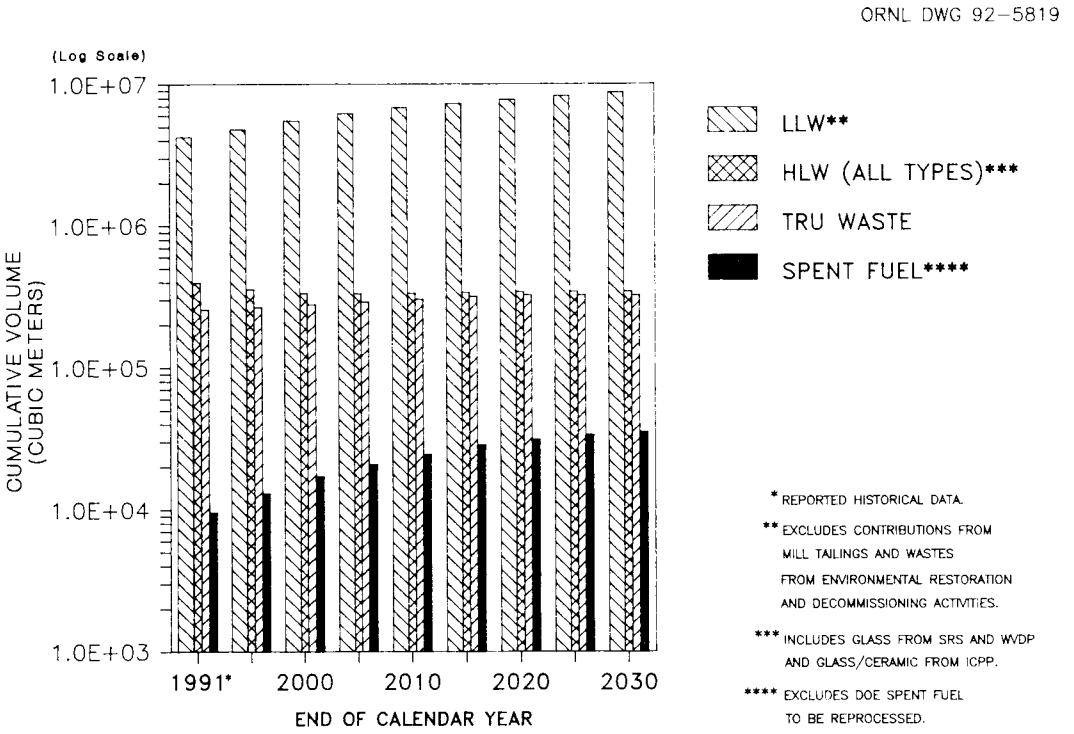


Fig. 0.5. Projections of cumulative volumes for various wastes and spent fuel — DOE and commercial fuel cycle.

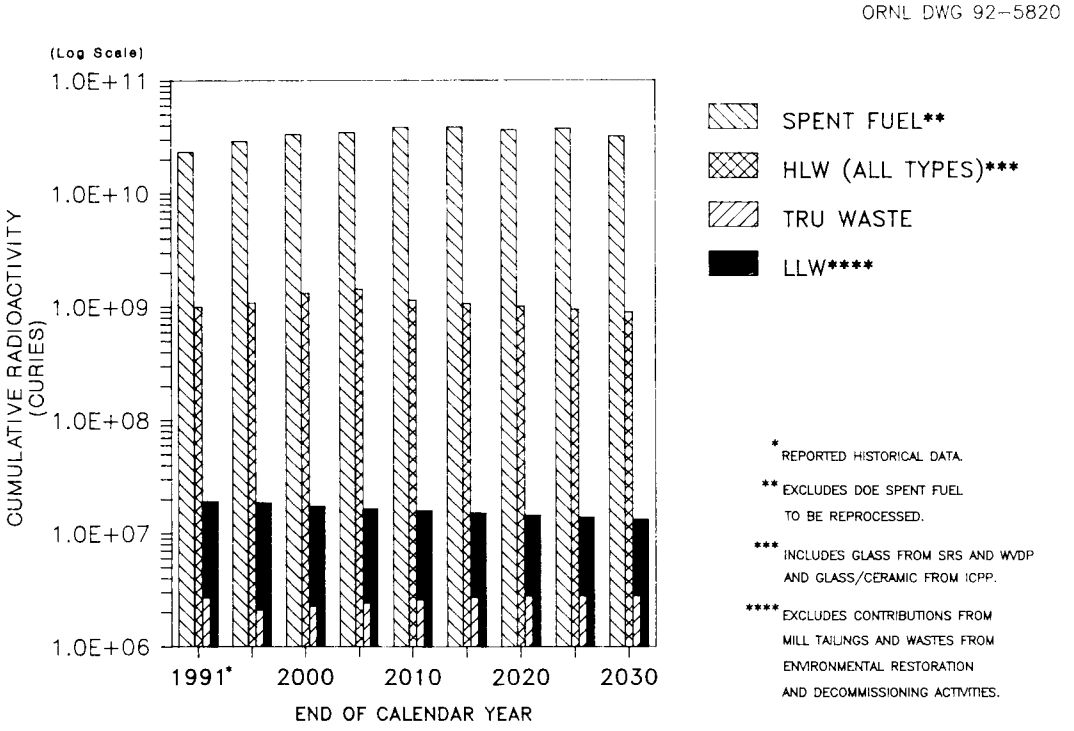


Fig. 0.6. Projections of cumulative radioactivity for various wastes and spent fuel — DOE and commercial fuel cycle.

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		258.8	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.

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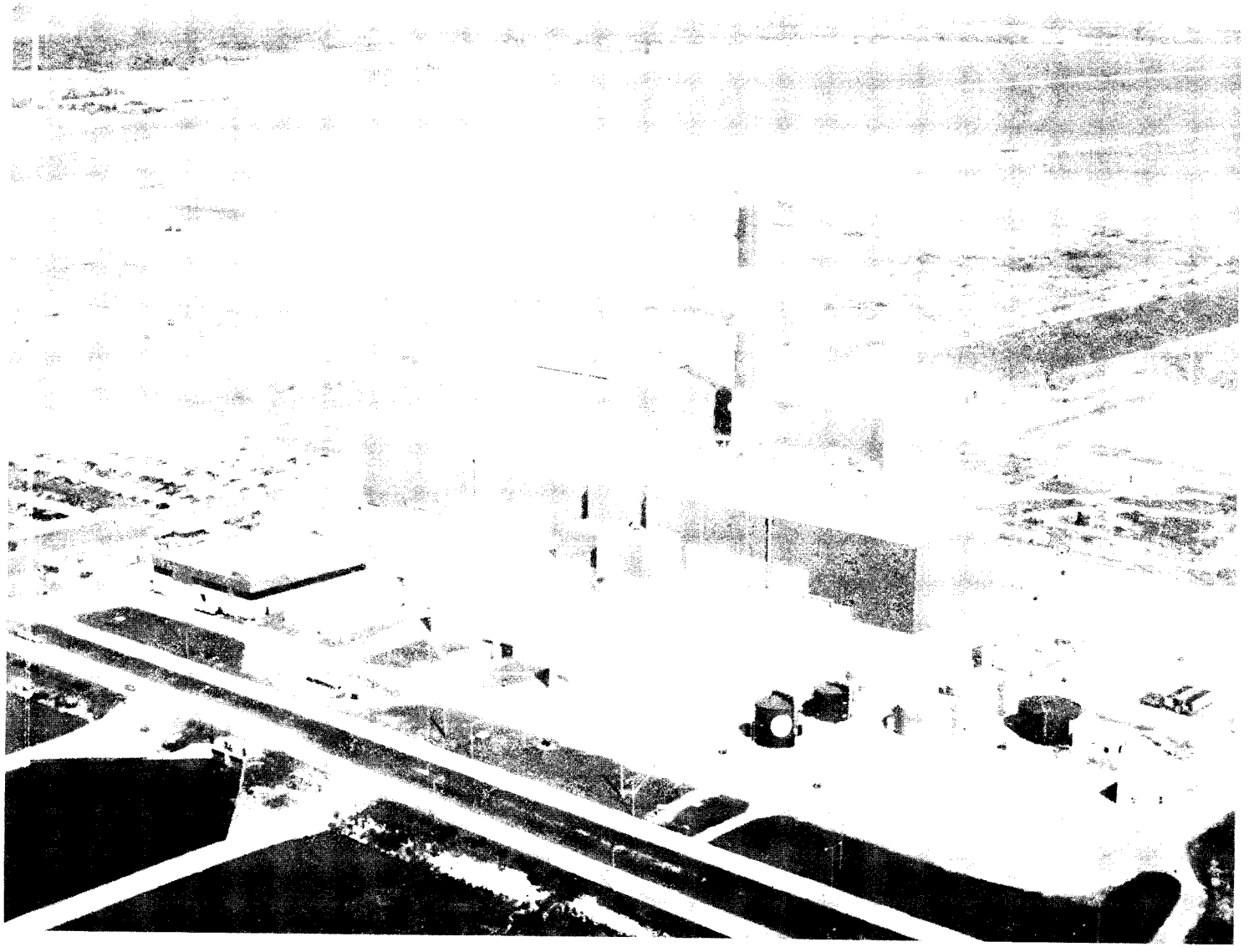

Photo 1.1. The LaSalle County Nuclear Power Station, two 1120-MW(e) boiling-water reactors, located in Seneca, Illinois. (Courtesy of the Commonwealth Edison Company, Downers Grove, Illinois.)

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 MTHM 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).

7. F. J. Novachek, Public Service Company of Colorado, Platteville, Colorado, letter to R. C. Ashline, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Fort St. Vrain Spent Fuel Data," Docket No. 50-267, dated Apr. 10, 1992.

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).

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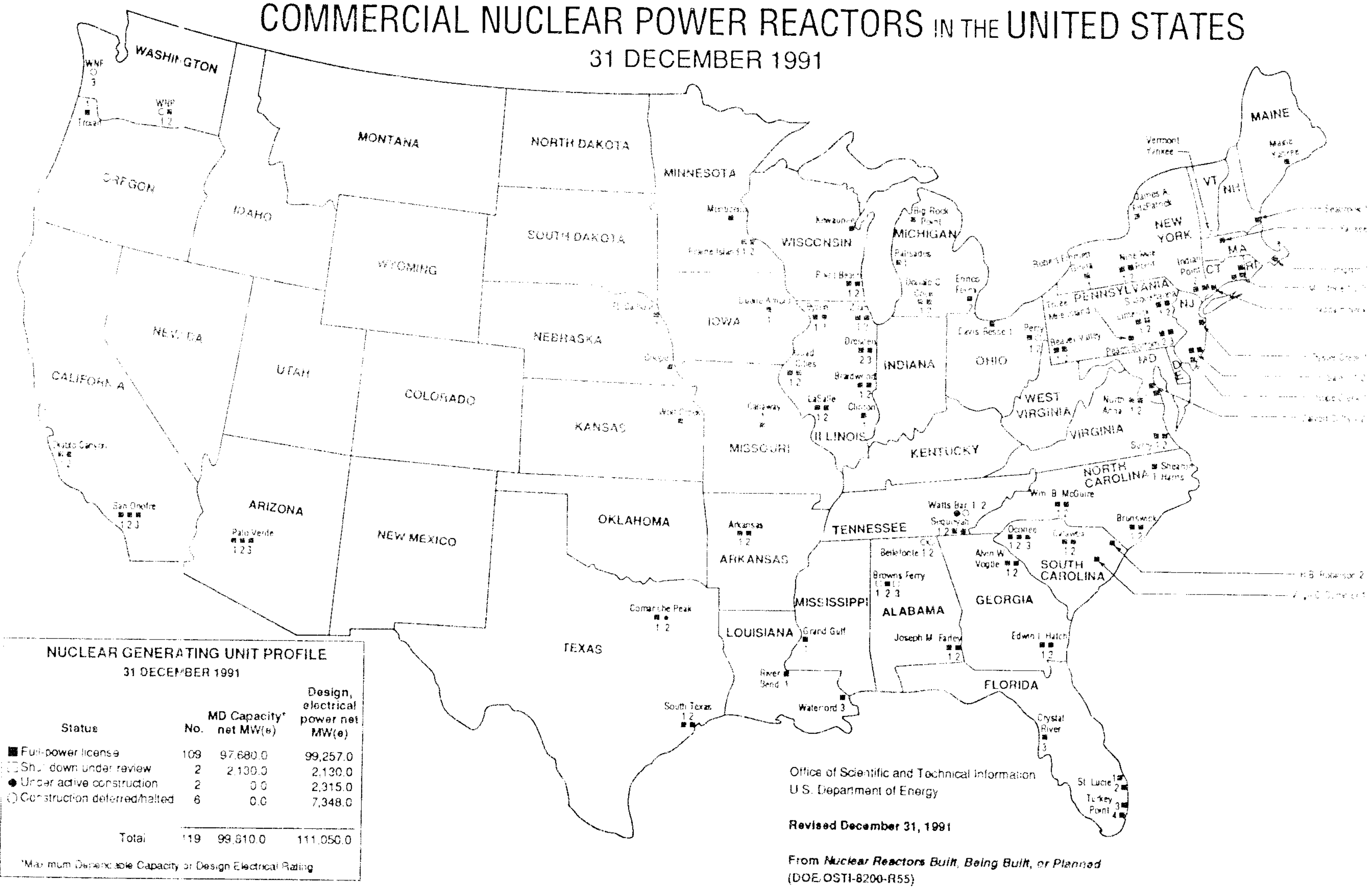

NUCLEAR GENERATING UNIT PROFILE
31 DECEMBER 1991

Status	No.	MD Capacity* net MW(e)	Design, electrical power net MW(e)
■ Full-power license	109	97,680.0	99,257.0
□ Shut down under review	2	2,130.0	2,130.0
● Under active construction	2	0.0	2,315.0
○ Construction deferred/halted	6	0.0	7,348.0
Total	119	99,810.0	111,050.0

*Maximum Dependable Capacity or Design Electrical Rating

Because of space limitations, symbols do not reflect precise locations.
DOE OSTI-8200-R55 (Suppl.)
DE92012402

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.)

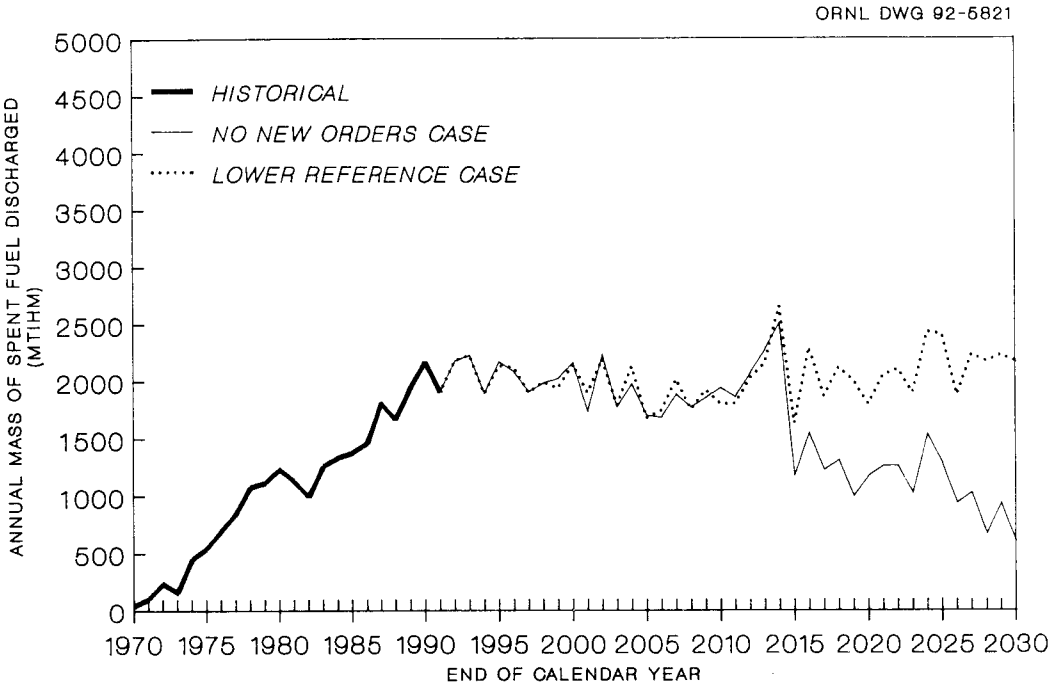

Fig. 1.2. Projected mass (MTIHM) of annual commercial spent fuel discharges for the DOE/EIA No New Orders and Lower Reference cases.

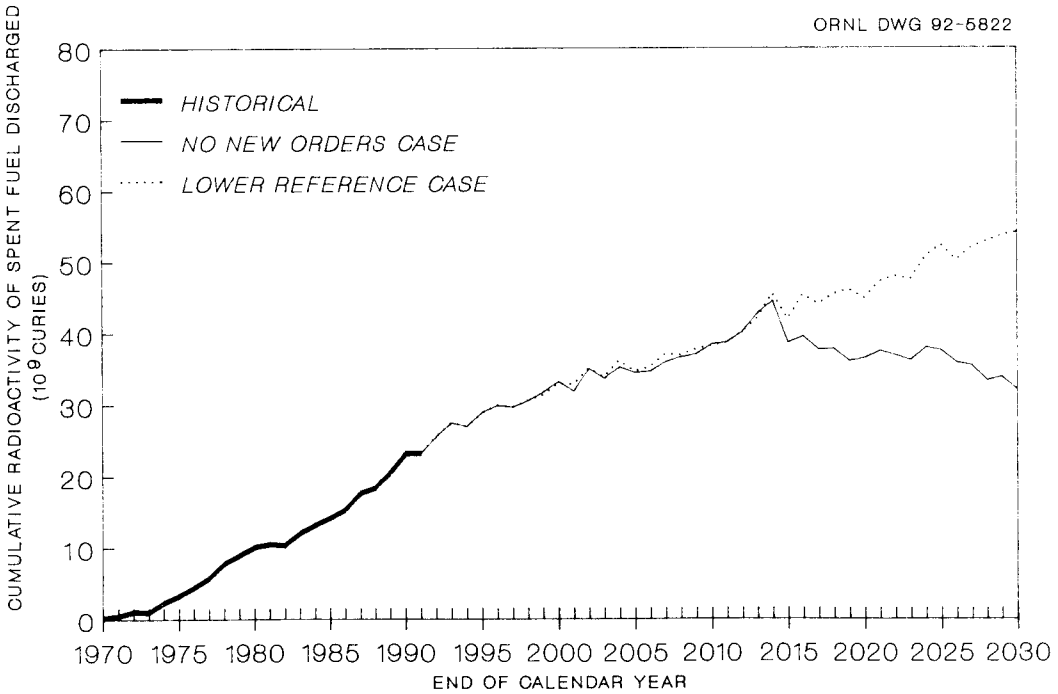

Fig. 1.3. Projected cumulative radioactivity of commercial spent fuel discharges for the DOE/EIA No New Orders and Lower Reference cases.

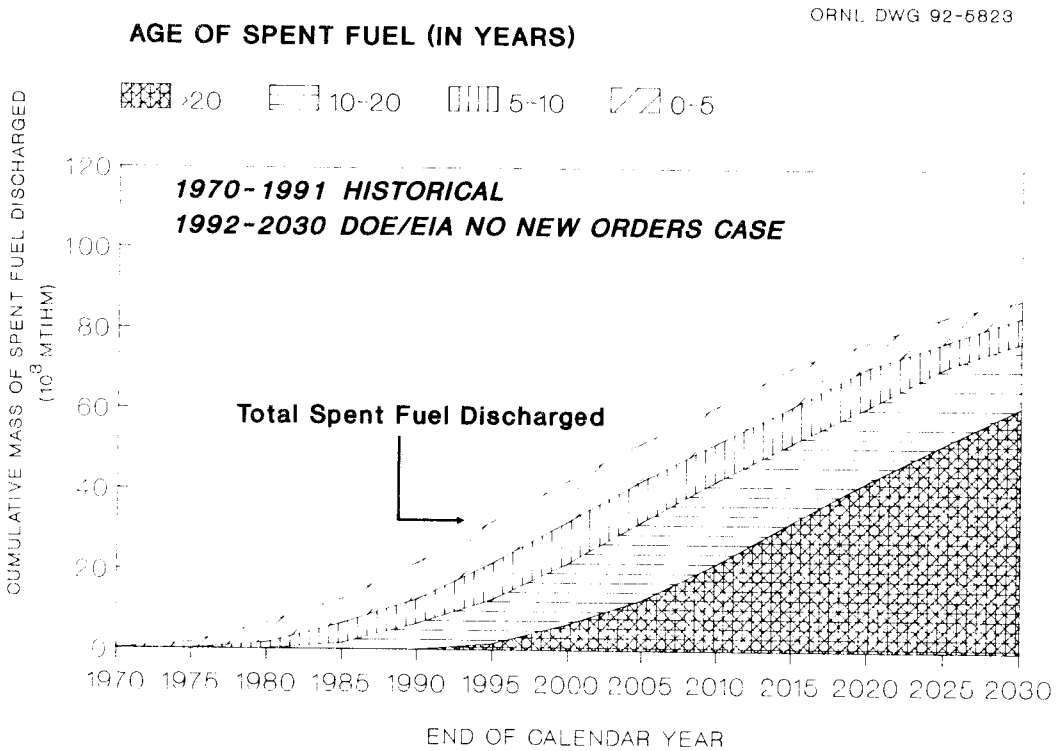

Fig. 1.4. Projected cumulative mass (MTIHM) of commercial spent fuel discharges for the DOE/EIA No New Orders Case.

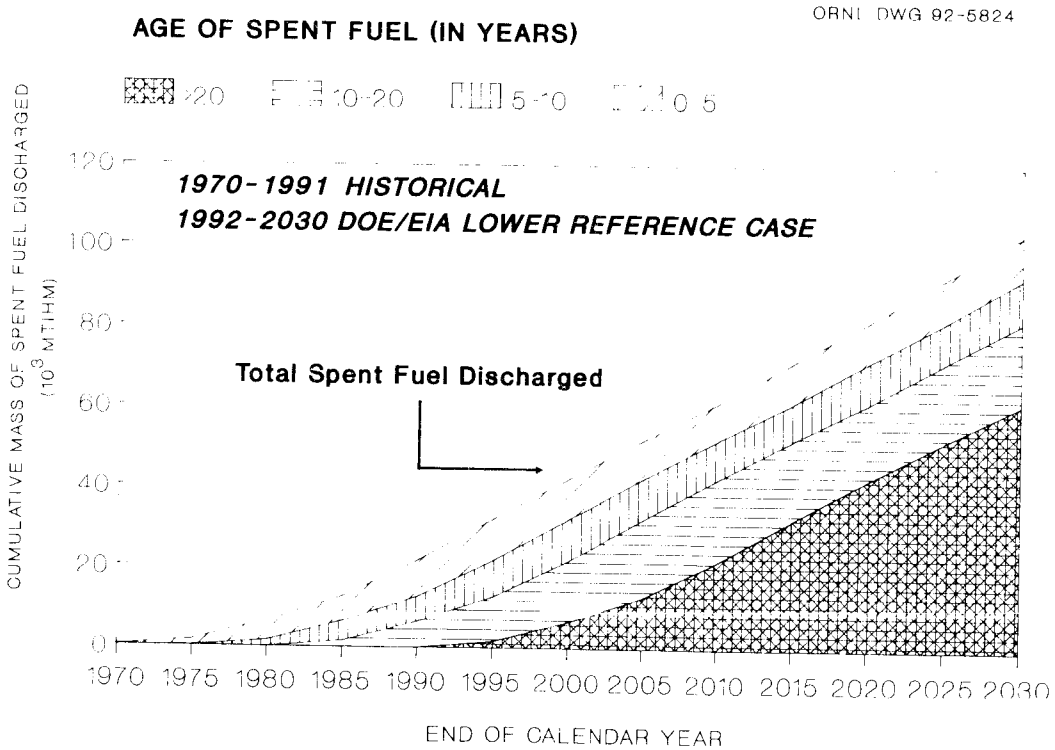

Fig. 1.5. Projected cumulative mass (MTIHM) of commercial spent fuel discharges for the DOE/EIA Lower Reference Case.

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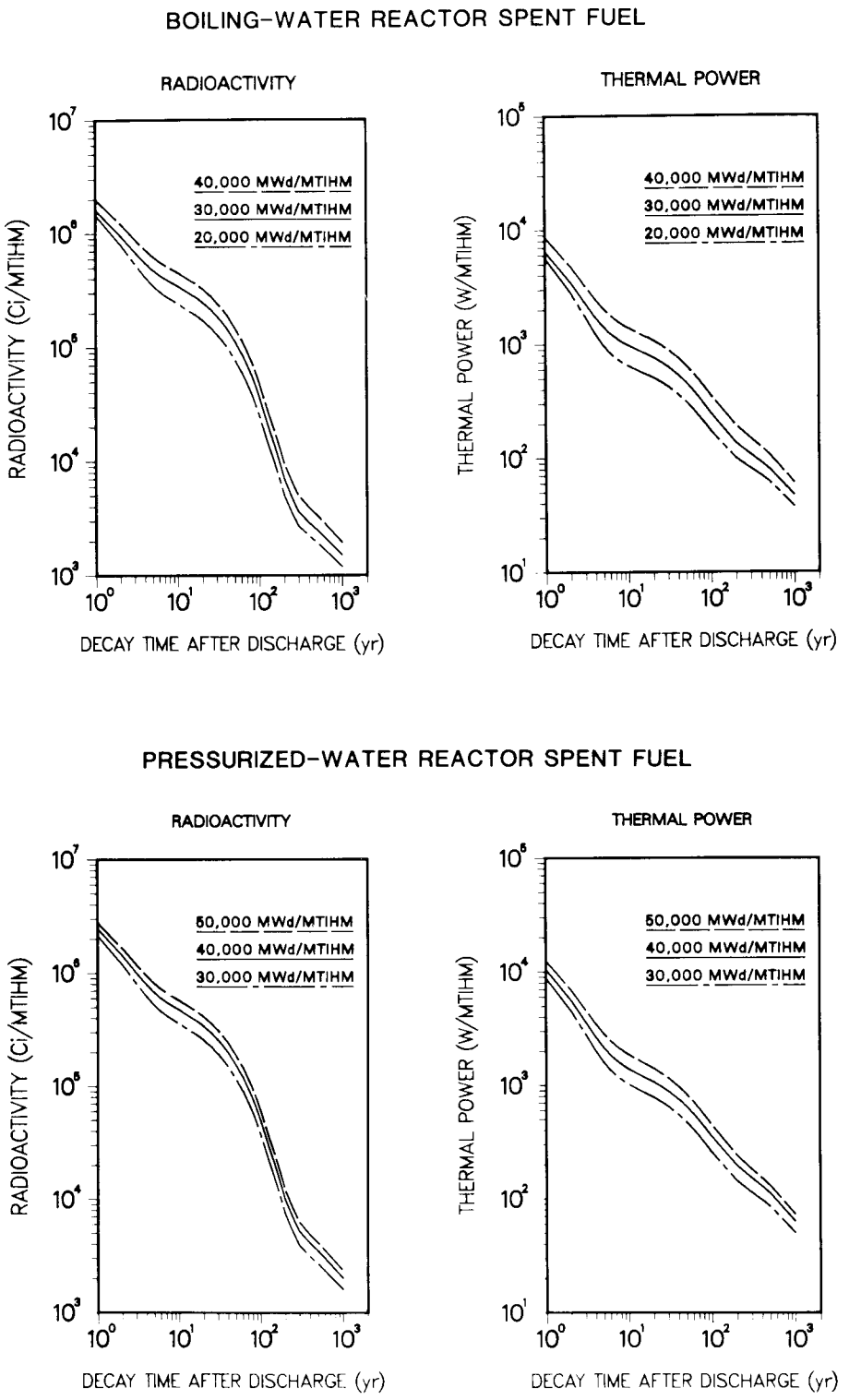

Fig. 1.6. Radioactivity and thermal power of 1 metric ton of heavy metal of BWR and PWR spent fuel as a function of burnup and time from reactor discharge.

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 × 13.9	21.4 × 21.4
Fuel rod length, m	4.064	3.851
Active fuel height, m	3.759	3.658
Fuel rod outer diameter, cm	1.252	0.950
Fuel rod array	8 × 8	17 × 17
Fuel rods per assembly	62	264
Assembly total weight, kg	319.3	657.9
Uranium/assembly, kg	183.5	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	0.0884[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 dimensions. Includes spacing between assembly fuel rods and 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

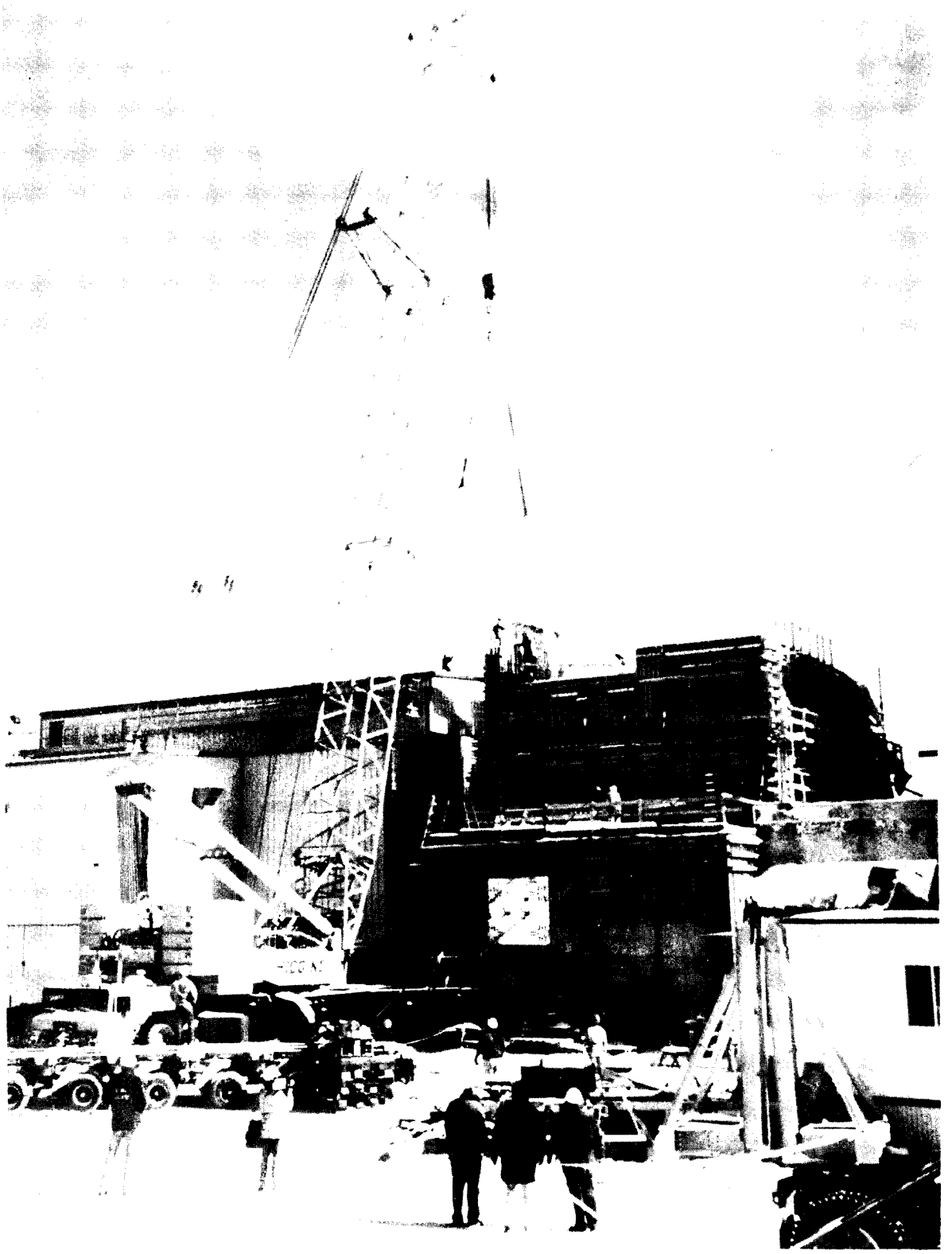

Photo 2.1. Construction of the West Valley Demonstration Project vitrification facility that will incorporate West Valley high-level waste into a glass. (Courtesy of the DOE West Valley Project Office, West Valley, New York.)

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

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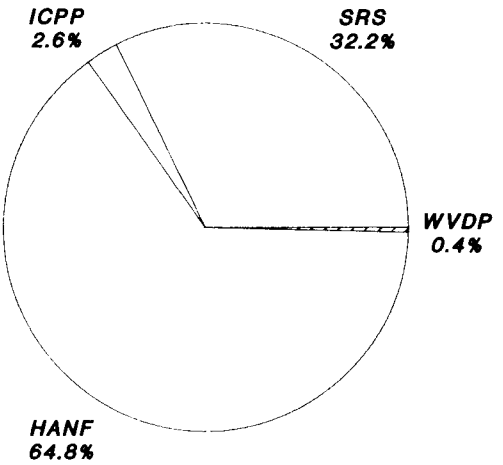


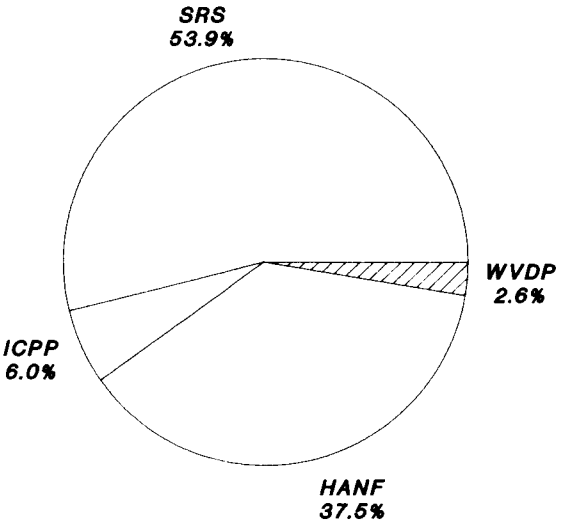
SITE	CUBIC METERS
SRS	1.279E+05
ICPP	1.040E+04
HANF	2.565E+05
WVDP	1.729E+03
TOTAL	3.966E+05

COMMERCIAL

DOE

Fig. 2.1. Total volume of HLW through 1991.

ORNL DWG 92-5826



SITE	CURIES
SRS	5.377E+08
ICPP	5.940E+07
HANF	3.736E+08
WVDP	2.621E+07
TOTAL	9.969E+08

COMMERCIAL

DOE

Fig. 2.2. Total radioactivity of HLW through 1991.

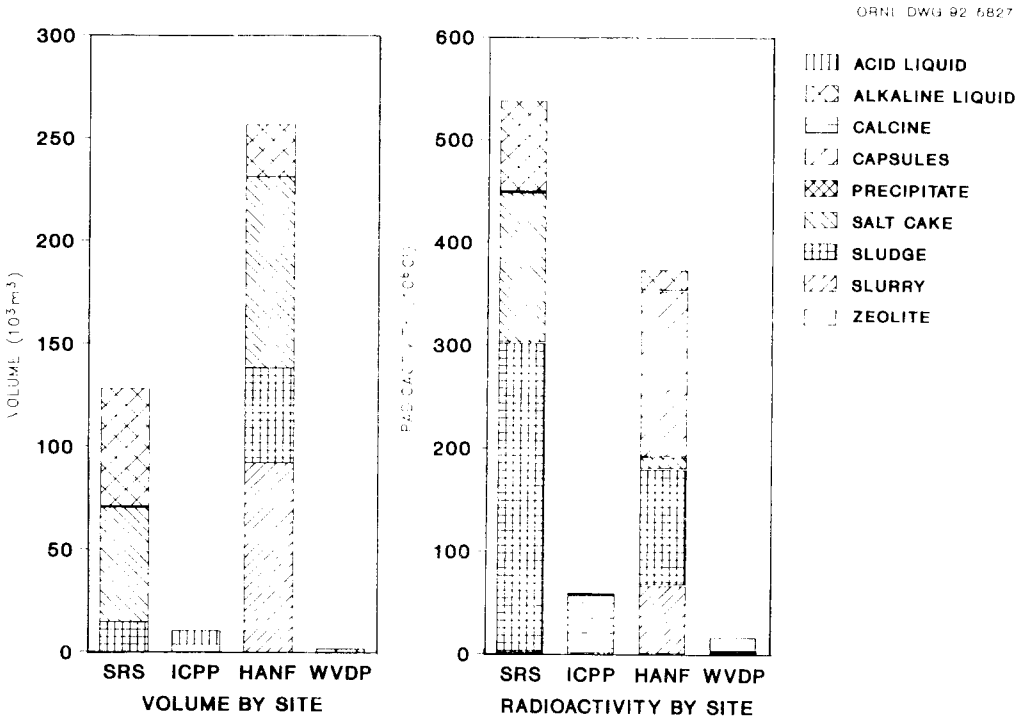


Fig. 2.3. Distribution of total cumulative volume and radioactivity of HLW by site and type through 1991.

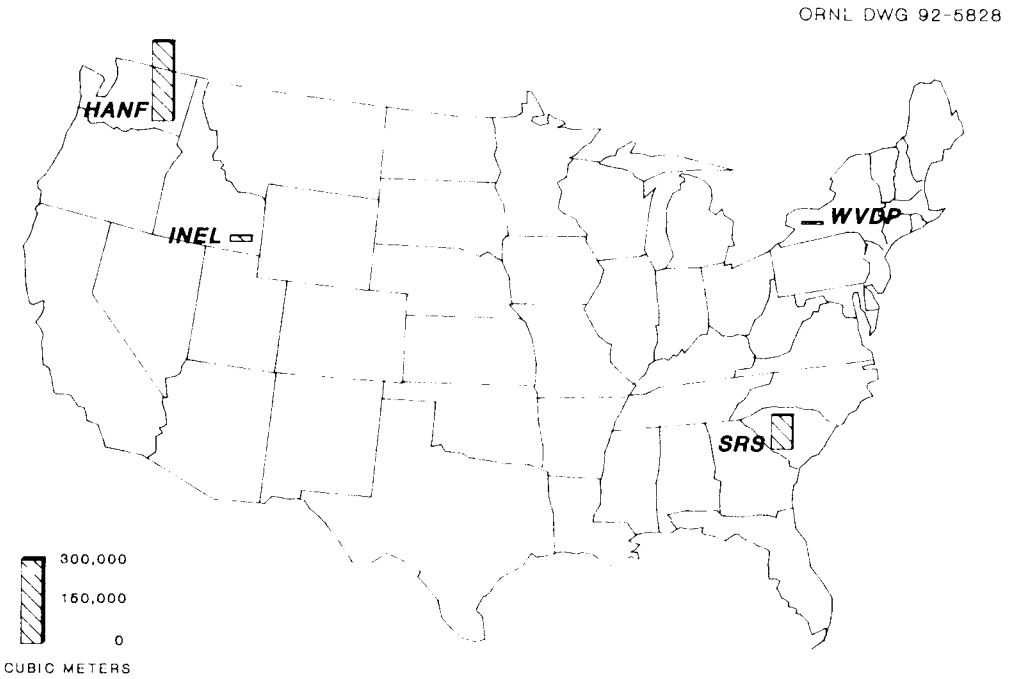


Fig. 2.4. Locations and total volumes of HLW through 1991.

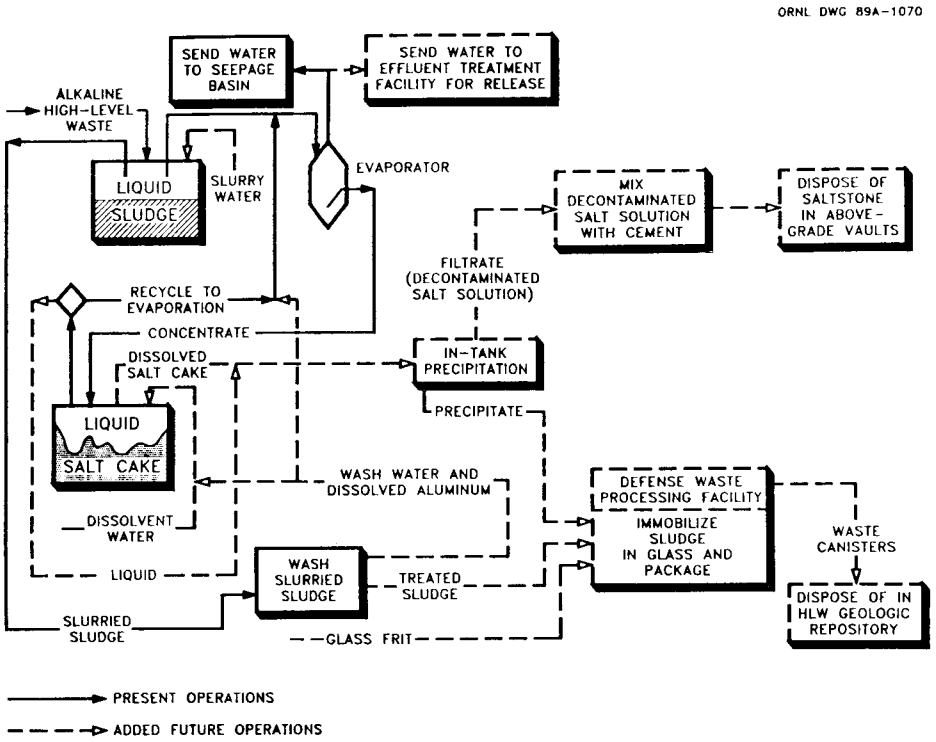


Fig. 2.5. Treatment methods for HLW in tanks and canisters at SRS.

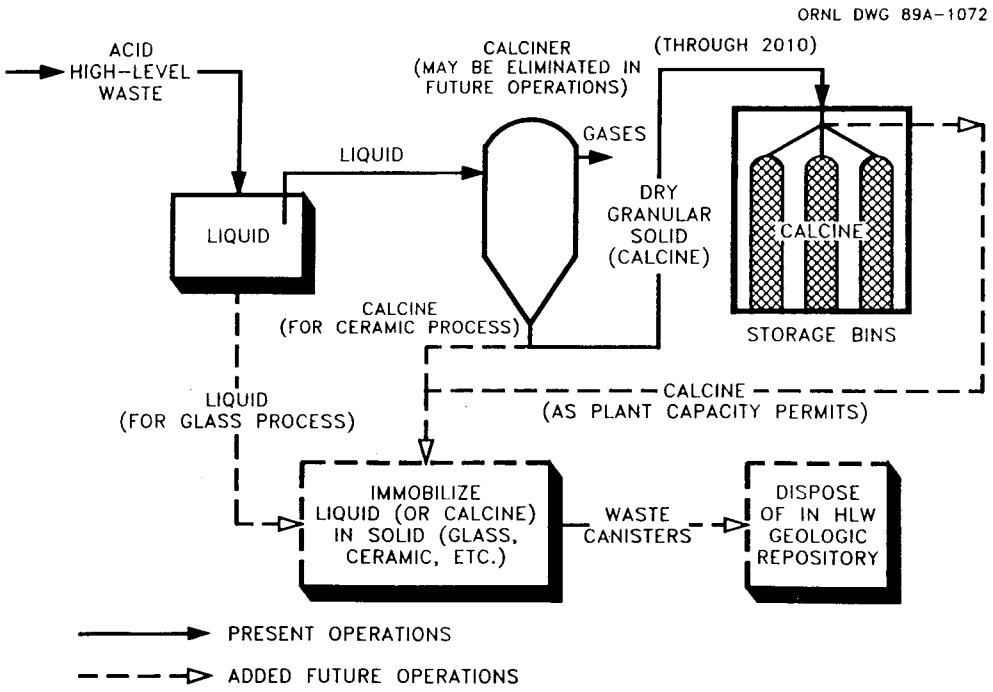


Fig. 2.6. Treatment methods for HLW in tanks, bins, and canisters at INEL.

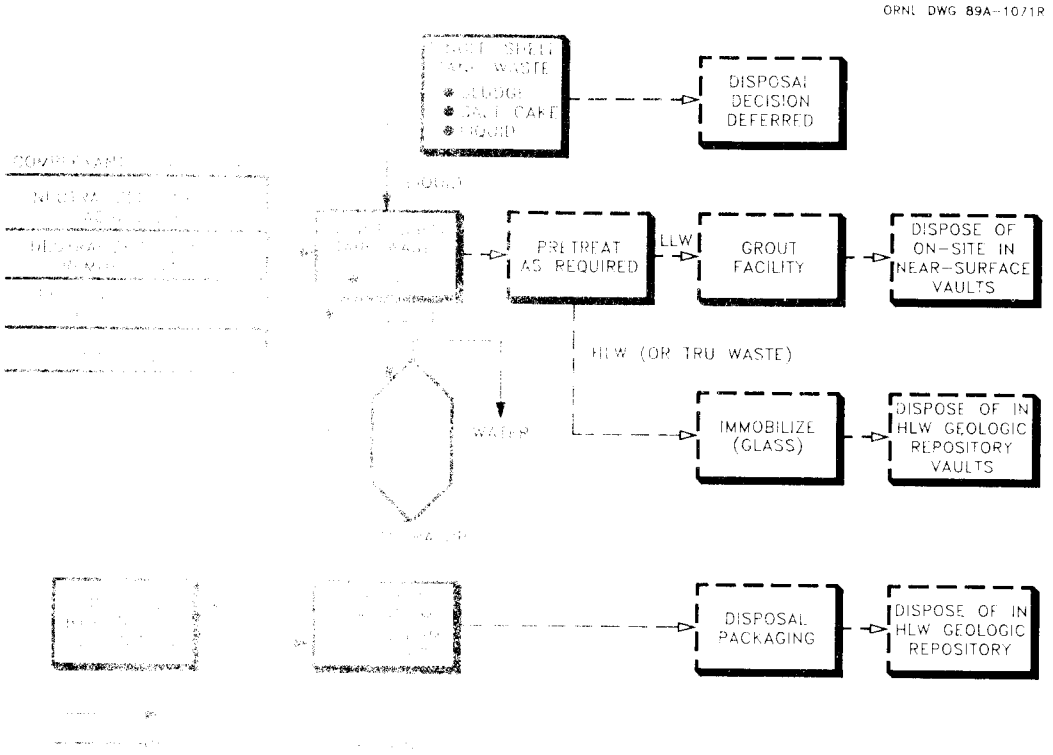
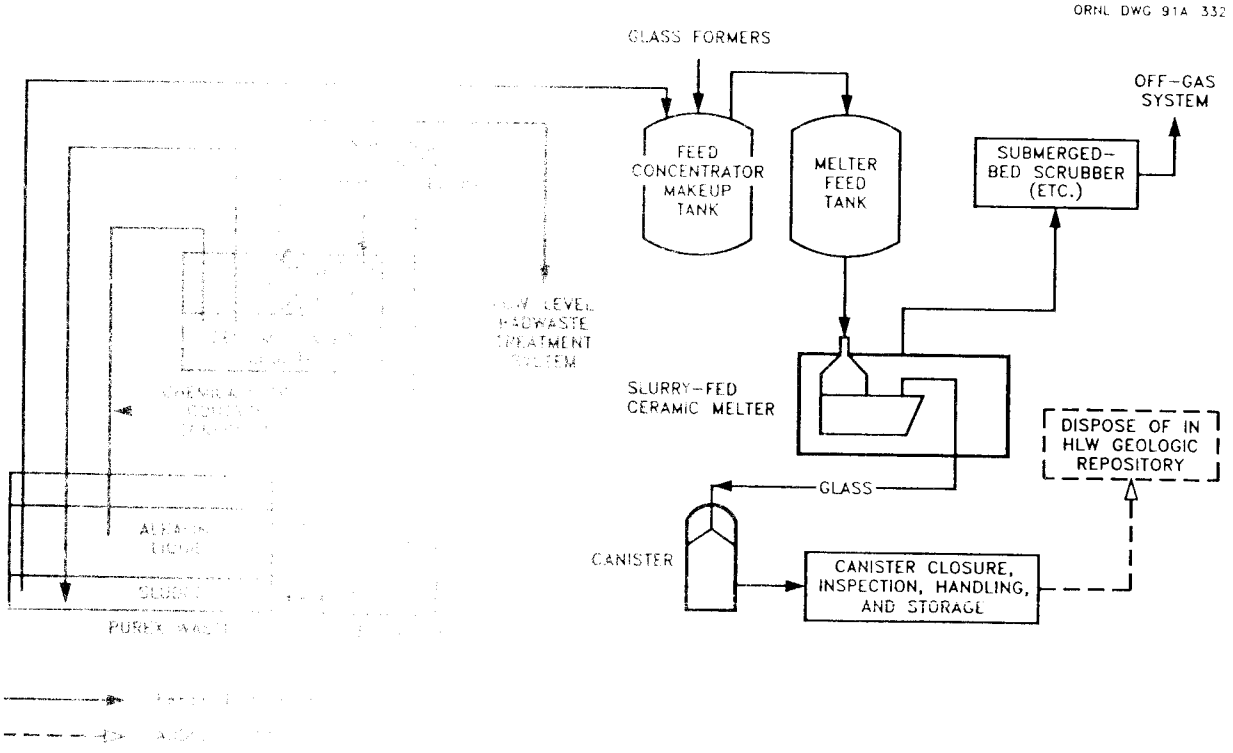


Fig. 2.7 [illegible] for HLW in tanks, capsules, and canisters at HANF.



[illegible] 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)	Cumulative Radioactivity (10^6 Ci)	Cumulative Thermal power (10^3 W)
	Commercial (WVDP) (continued)		
1983	2.2	31.2	90.5
1984	2.2	30.5	88.4
1985	2.2	29.8	86.4
1986	2.2	29.1	84.5
1987	2.2	28.4	81.2
1988	2.1	27.9	80.8
1989	2.4	27.3	79.3
1990	1.2	26.7	77.0
1991	1.7	26.2	75.9
1992	1.2	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)	Radioactivity (10^6 Ci)	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 × 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 × 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 × 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									
								Capsules[d]		
	Liquid	Sludge	Salt cake	Slurry[b]	Calcine	Precipitate[c]	Zeolite	Sr	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	1.8-1.6	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^-	1.3	0.003-0.1	0.032	5.99
Fe	0.04	0.05-0.55	0.18	0.023
H^+	1.12	0.03-0.1	0.12	0.18
K	1.1	0.03-0.15	0.15	–
Mg	–	–	0.082	–
Mn	–	–	0.046	0.0004
Na	0.13	0.1-4.1	1.31	–
Ni	–	–	0.016	0.0049
NO_3^-	15.7	18.4-23.1	23.1	11.47
SO_4^{2-}	–	0.3-0.5	0.65	1.52
Zr	4.47	–	–	3.80
H_2O	75.6	75.6-89.2	70.9	75.0
	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, Plan for 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.

ORNL PHOTO 6892-92

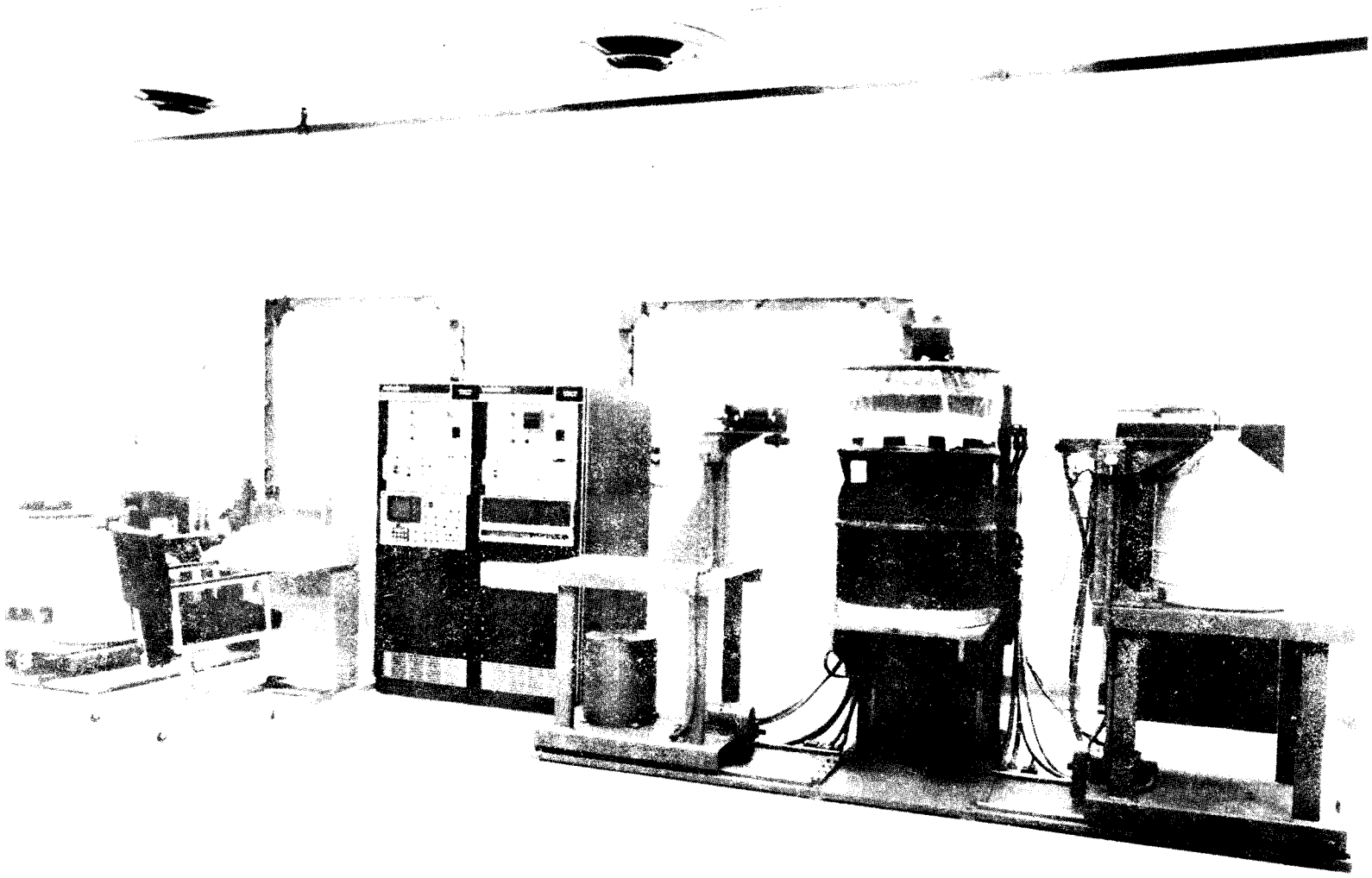


Photo 3.1. Assay equipment used at the Hanford Site to determine the radionuclide content of transuranic waste drums. (Courtesy of Westinghouse Hanford Company, Richland, Washington.)

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), [illegible] Rocky Flats Plant [illegible] and five minor [illegible] (ANL-E), [illegible] Laboratory (LLNL), [illegible] National [illegible] the locations of these [illegible] buried and stored [illegible] origin of TRU [illegible] stored TRU waste [illegible] TRU waste [illegible] but are generating [illegible] restoration [illegible]

3.3 INVENTORIES

Early [illegible] requirements [illegible] and segregation [illegible] based on [illegible] summaries [illegible] As these efforts [illegible] characterized [illegible] estimated [illegible]

Figure [illegible] and percent [illegible] data for [illegible] Figs. 3.5 [illegible] shown to [illegible] the retrievably [illegible] INEL, LANL [illegible]

Table [illegible] projected [illegible] TRU waste [illegible] are based on [illegible] as shown in Table [illegible] and thermal power [illegible] take into [illegible] and ingrowth of [illegible] values, a [illegible] ORIGEN2 [illegible] composition [illegible] are on an [illegible] WIPP radionuclide [illegible] source of [illegible] the sites because [illegible] 3.13) were not [illegible] isotopic composition [illegible] was based on the [illegible] information [illegible] compositions [illegible] study did not [illegible] compositions [illegible] supplied data [illegible] thermal power [illegible]

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

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

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

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

4. U.S. Department of Energy, 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).

ORNL DWG 92-5829

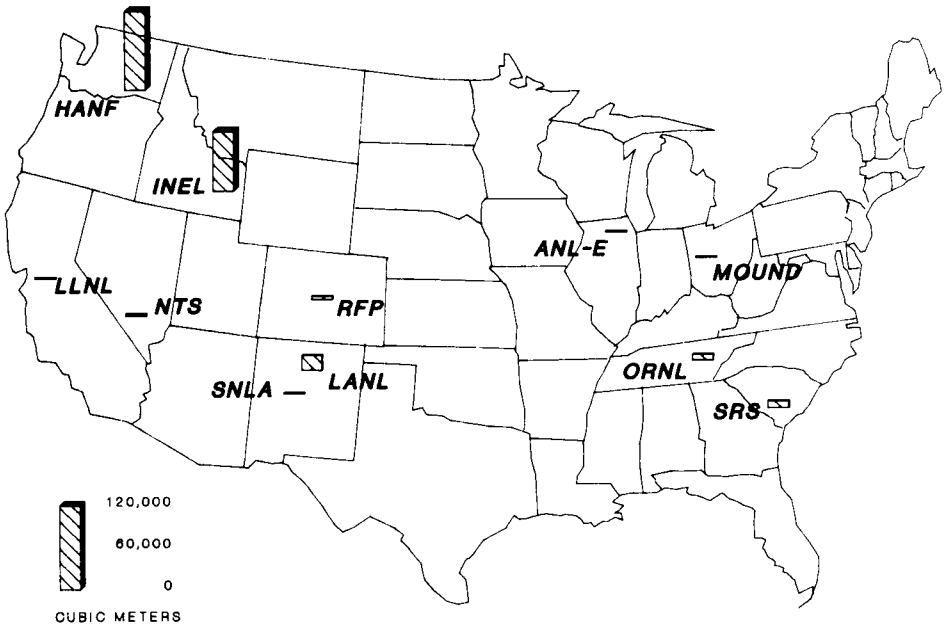


Fig. 3.1. Locations and total volumes of buried and stored DOE TRU waste through 1991.

ORNL DWG 92-5830

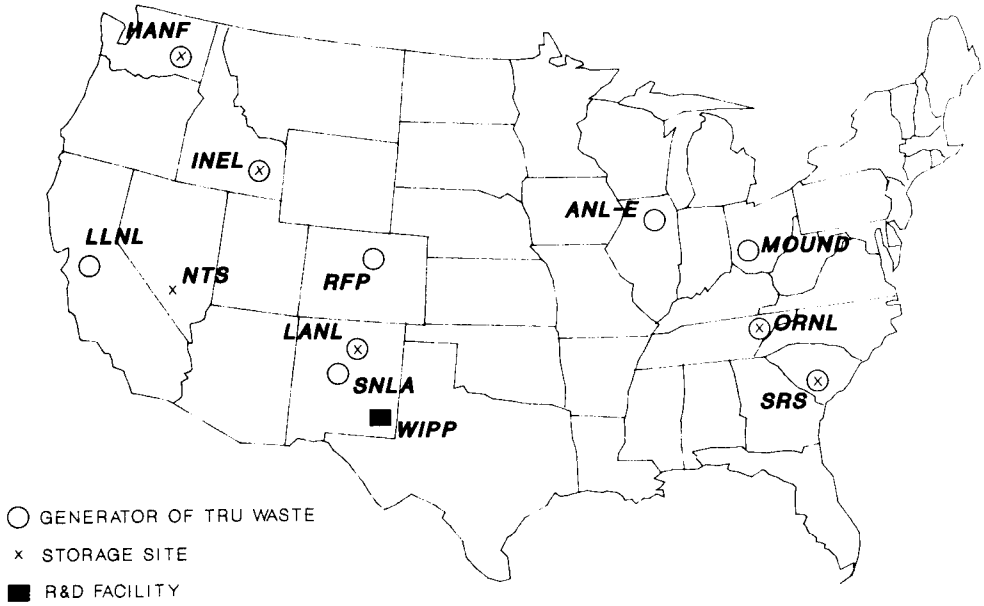
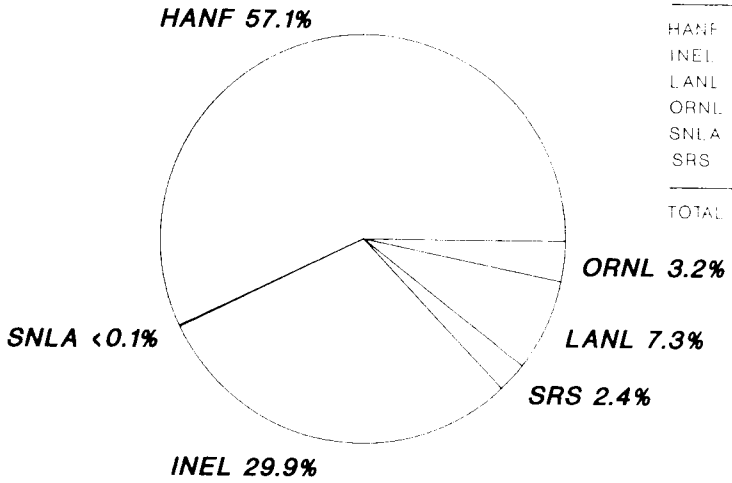


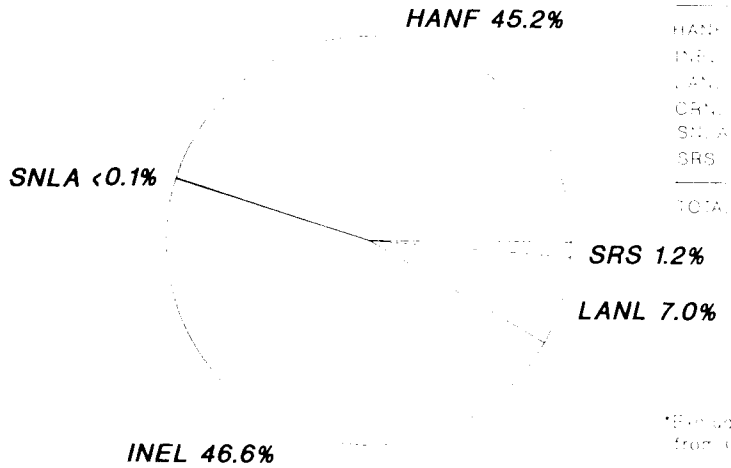
Fig. 3.2. Points of origin and storage sites of DOE TRU waste.

ORNL DWG 92-5831



SITE	CUBIC METERS
HANF	1.09E+05
INEL	5.71E+04
LANL	1.40E+04
ORNL	5.95E+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.



SITE	KILOGRAMS
HANF	3.46E+02
INEL	3.57E+02
LANL	4.38E+01
ORNL	[illegible]
SNLA	<1.00E+00
SRS	9.10E+00
TOTAL*	7.66E+02

*[illegible] for ORNL

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

ORNL DWG 92-5833

SITE	CUBIC METERS
ANL-E*	1.50E+01
HANF	1.02E+04
INEL	3.75E+04
LANL	7.76E+03
LLNL*	2.00E+02
MOUND*	2.55E+02
NTS	5.97E+02
ORNL	1.99E+03
RFP	9.34E+02
SRS	5.37E+03
TOTAL	6.48E+04

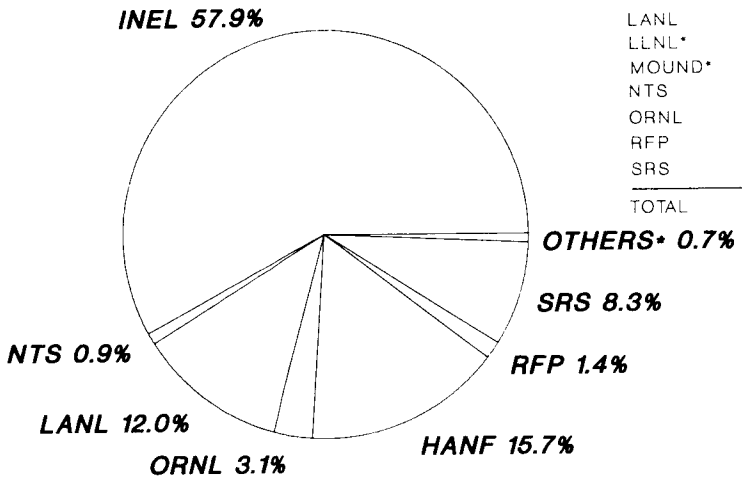


Fig. 3.5. Total volume of retrievably stored DOE TRU waste through 1991.

ORNL DWG 92-5834

SITE	KILOGRAMS
HANF	4.80E+02
INEL	8.12E+02
LANL	5.88E+02
LLNL*	1.30E+00
MOUND*	1.10E+00
NTS	4.30E+00
ORNL	1.37E+02
RFP	1.46E+01
SRS	2.22E+02
TOTAL	2.26E+03

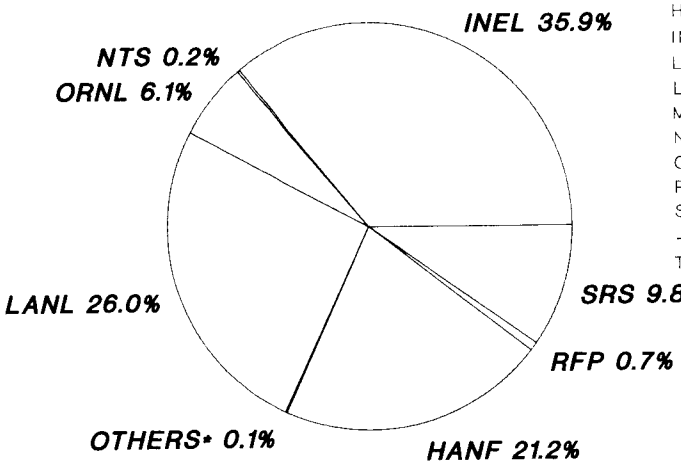


Fig. 3.6. Total mass of TRU elements in retrievably stored DOE TRU waste through 1991.

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] (10^6 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.[illegible]		2.35
1993		190,584.0		765.6		266.69		2.33
1994		190,584.0		765.6		260.66		2.31
1995		190,584.0		765.6		255.30		2.29
1996		190,584.0		765.6		249.[illegible]		2.27
1997		190,584.0		765.6		[illegible]		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.[illegible]		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.[illegible]		2.14
2004		190,584.0		765.6		211.[illegible]		2.12
2005		190,584.0		765.6		207.40		2.10
2006		190,584.0		765.6		203.[illegible]		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.[illegible]		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		[illegible]		1.97
2014		190,584.0		765.6		173.80		1.96
2015		190,584.0		765.6		170.[illegible]		1.94
2016		190,584.0		765.6		[illegible]		1.93
2017		190,584.0		765.6		164.[illegible]		1.91
2018		190,584.0		765.6		[illegible]		1.90
				Stored, contact-handled[f]				
1991	1,827.7	63,138.8	22.8	2,138.4	110.94	1,887.[illegible]	1.76	36.06
1992	2,347.1	65,485.9	81.3	2,219.8	54.16	1,941.[illegible]	1.11	34.63
1993	2,347.1	67,833.0	81.3	2,301.1	54.16	1,994.[illegible]	1.11	35.59
1994	2,347.1	70,180.1	81.3	2,382.5	54.16	1,[illegible]	1.11	36.48
1995	2,347.1	72,527.2	81.3	2,463.8	54.16	1,[illegible]	1.11	37.37
1996	2,347.1	74,874.3	81.3	2,545.1	54.16	1,[illegible]	1.11	38.26
1997	2,347.1	77,221.4	81.3	2,626.5	54.16	1,[illegible]	1.11	39.13
1998	2,347.1	79,568.5	81.3	2,707.8	54.16	1,[illegible]	1.11	40.01
1999	2,347.1	81,915.6	81.3	2,789.2	54.16	1,[illegible]	1.11	40.87
2000	2,347.1	84,262.7	81.3	2,870.5	54.16	1,[illegible]	1.11	41.73
2001	2,347.1	86,609.8	81.3	2,951.8	54.16	1,[illegible]	1.11	42.59
2002	2,347.1	88,956.9	81.3	3,033.2	54.16	1,[illegible]	1.11	43.43
2003	2,347.1	91,304.0	81.3	3,114.5	54.16	1,817.87	1.11	44.26
2004	2,347.1	93,651.1	81.3	3,195.9	54.16	1,840.95	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.[illegible]	1.11	52.40
2014	2,347.1	117,122.1	81.3	4,009.3	54.16	2,068.06	1.11	53.18
2015	2,347.1	119,469.2	81.3	4,090.6	54.16	2,089.50	1.11	53.96
2016	2,347.1	121,816.3	81.3	4,171.9	54.16	2,110.87	1.11	54.73
2017	2,347.1	124,163.4	81.3	4,253.3	54.16	2,132.18	1.11	55.48
2018[g]	2,347.1	126,510.5	81.3	4,334.6	54.16	2,153.36	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: Value as of Dec. 31, 1990[b]	Contact-handled: Revisions and/or corrections to 1990 data[c]	Contact-handled: Quantity added during 1991	Contact-handled: Value as of Dec. 31, 1991	Remote-handled: Value as of Dec. 31, 1990[b]	Remote-handled: Revisions and/or corrections to 1990 data[c]	Remote-handled: Quantity added during 1991	Remote-handled: 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	656.8	-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		Remote-handled		
	RSW[b]	NGW[c]	RSW[b]	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
Solidified or cemented sludge	9	4.6	20	6	
Soil, 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]	58.5							
	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	9.50	-	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	2.34	2.87	9.86	1.79	2.86			
	^{241}Pu	82.83	87.93	75.90	54.35	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	90.91							
	^{239}Pu	3.40							
	^{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

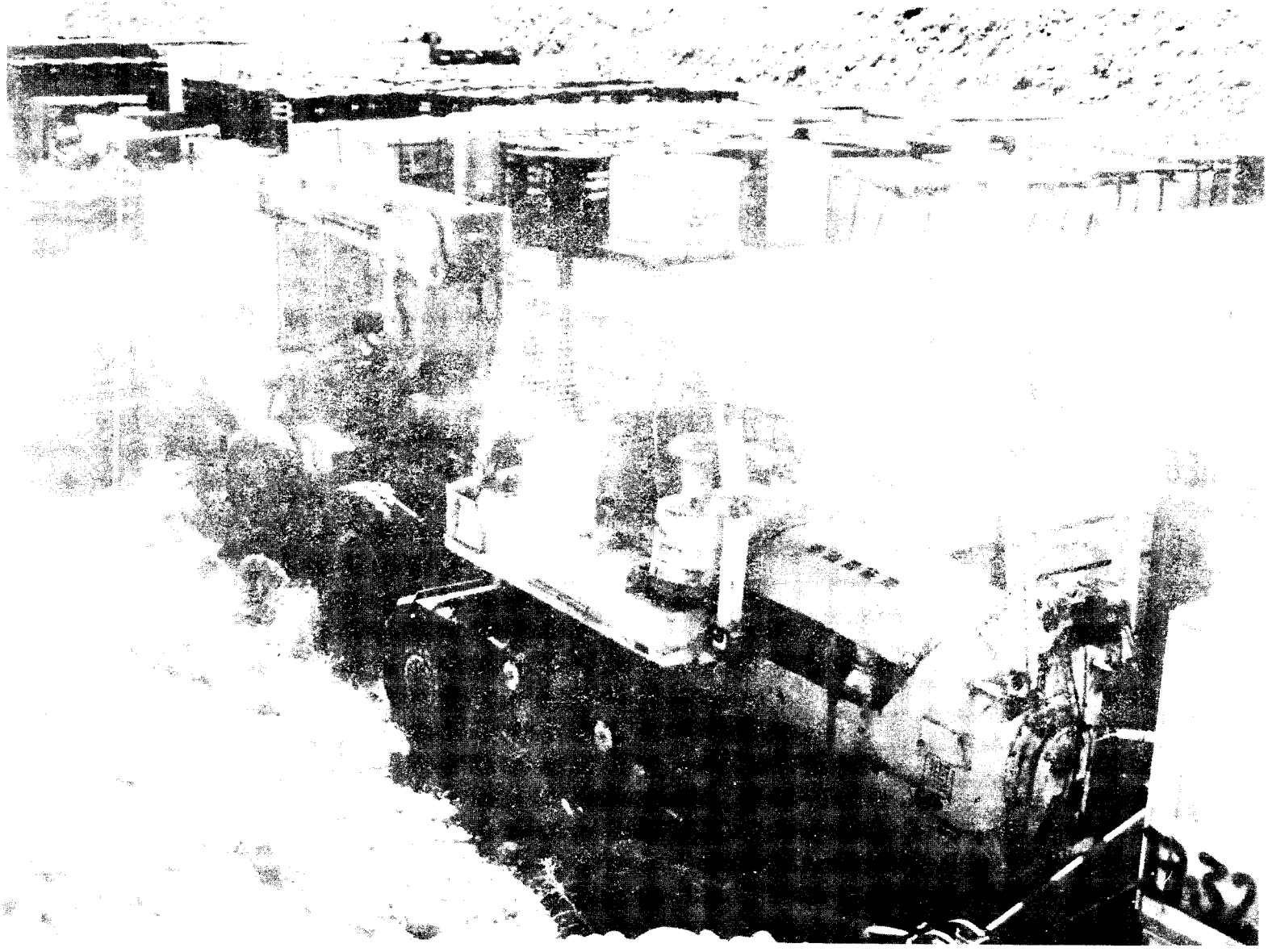


Photo 4.1. Placement of waste in a low-level waste burial trench at the Hanford Site. (Courtesy of Westinghouse Hanford Company, Richland, Washington, and the Hazardous Waste Remedial Actions Program, Oak Ridge, Tennessee.)

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.

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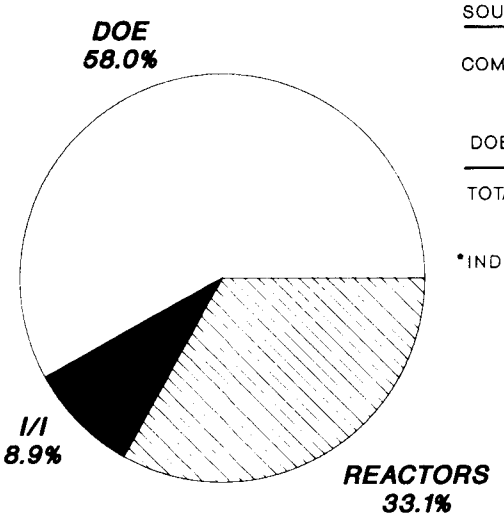
ORNL DWG 92-5835

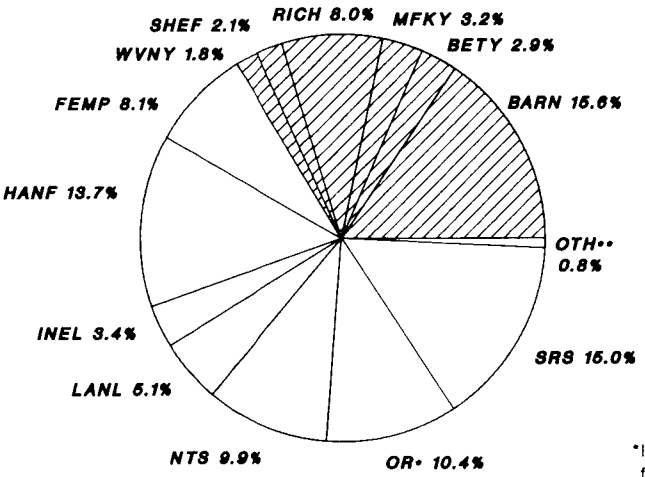


SOURCE	CUBIC METERS
COMMERCIAL	
REACTORS	3.059E+04
I/I*	0.819E+04
DOE	5.352E+04
TOTAL	9.230E+04

*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.

▨ Commercial

□ DOE

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

ORNL DWG 92-5837

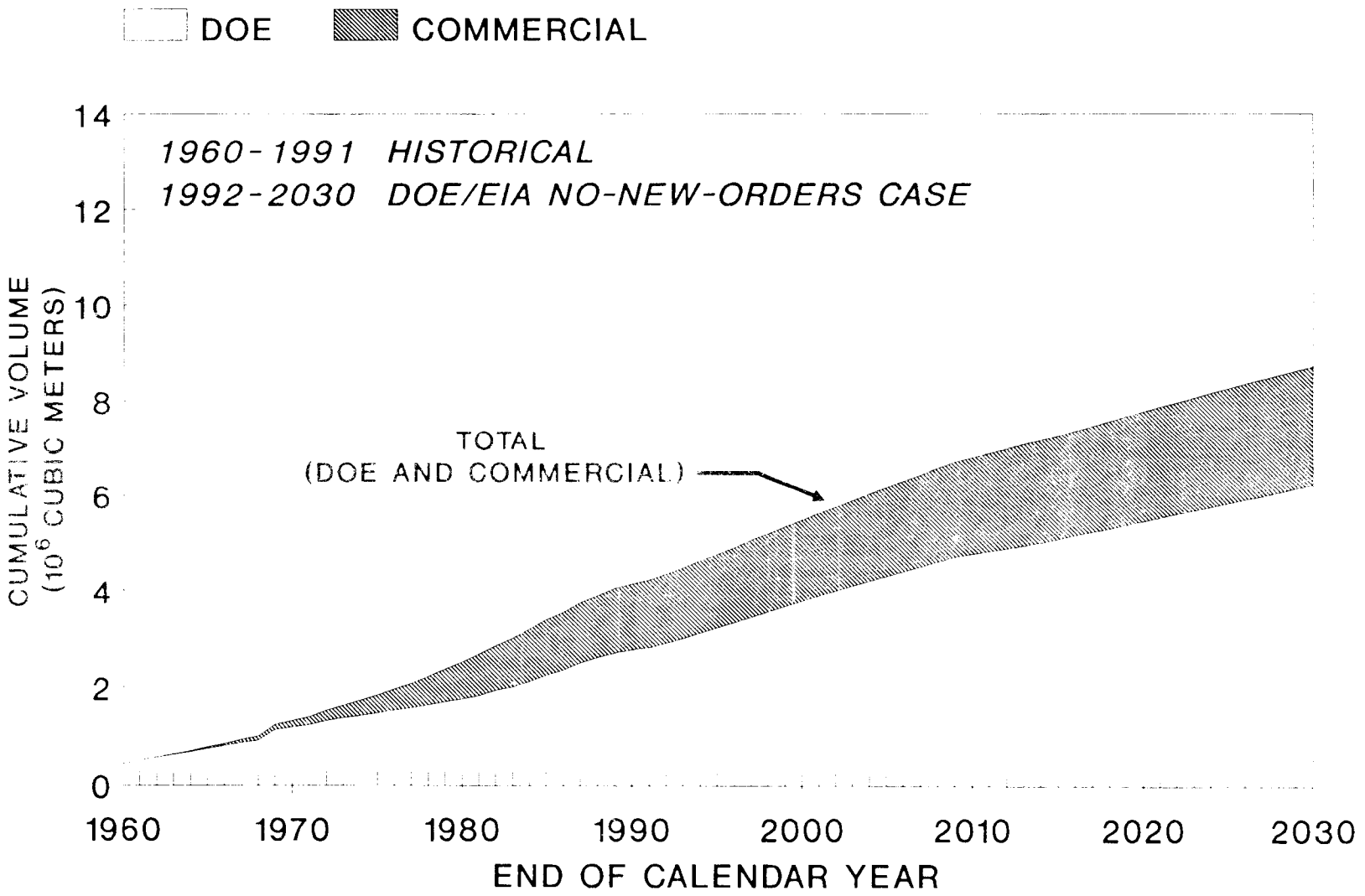
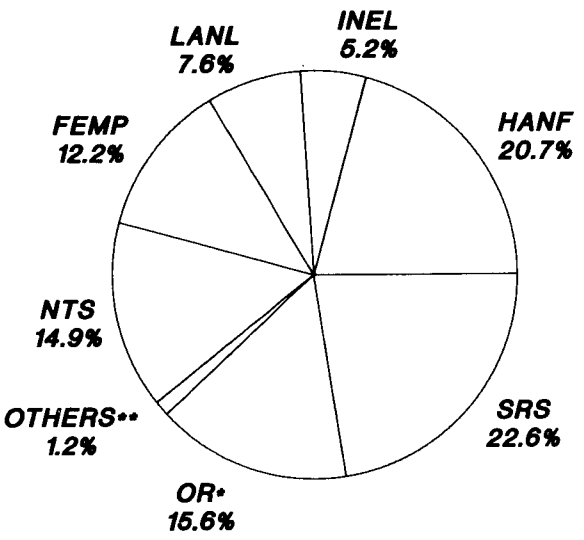


Fig. 4.3. Historical and projected cumulative volume of LLW.

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

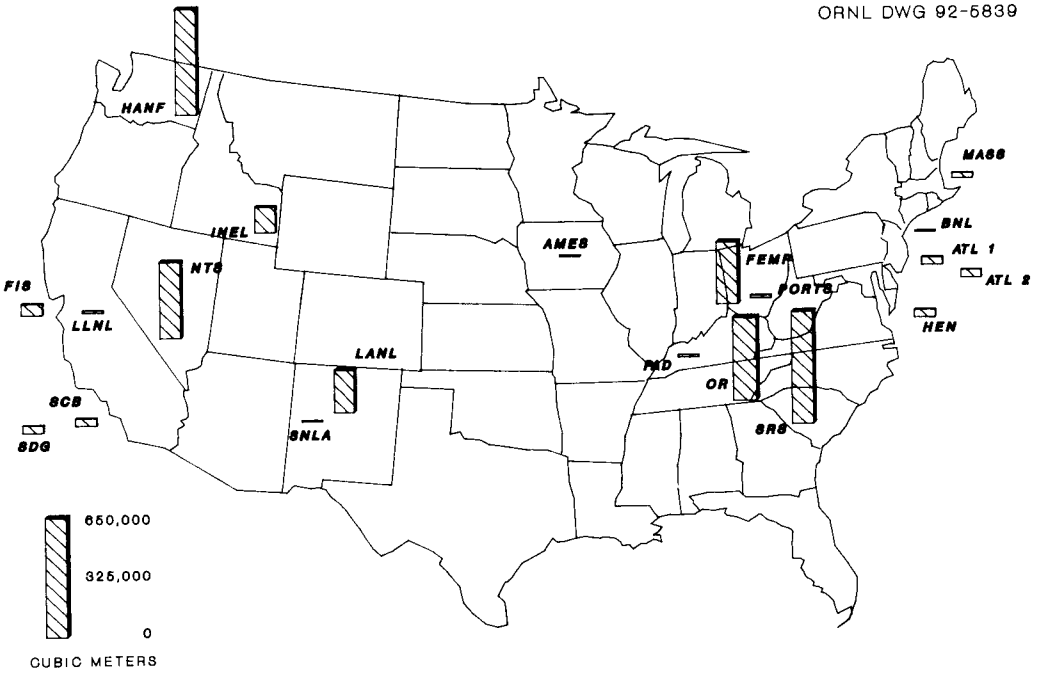
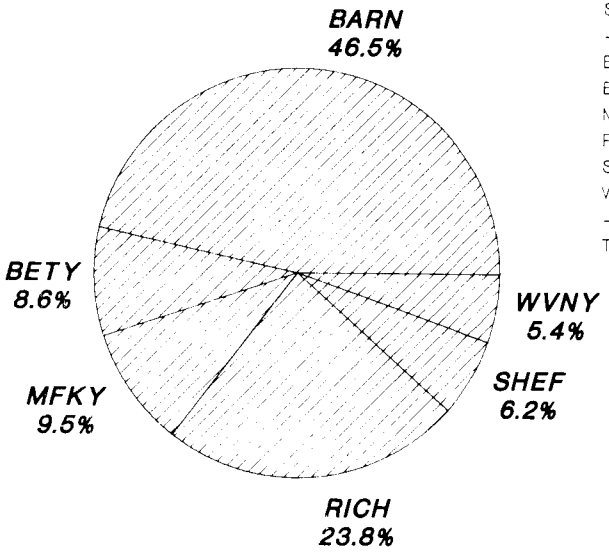


Fig. 4.5. Locations and total volumes of DOE LLW buried through 1991.

ORNL DWG 92-5840



SITE	CUBIC METERS
BARN	6.607E+05
BETY	1.229E+05
MFKY	1.353E+05
RICH	3.385E+05
SHEF	8.833E+04
WVNY	7.707E+04
TOTAL	1.423E+06

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

ORNL DWG 92-5841

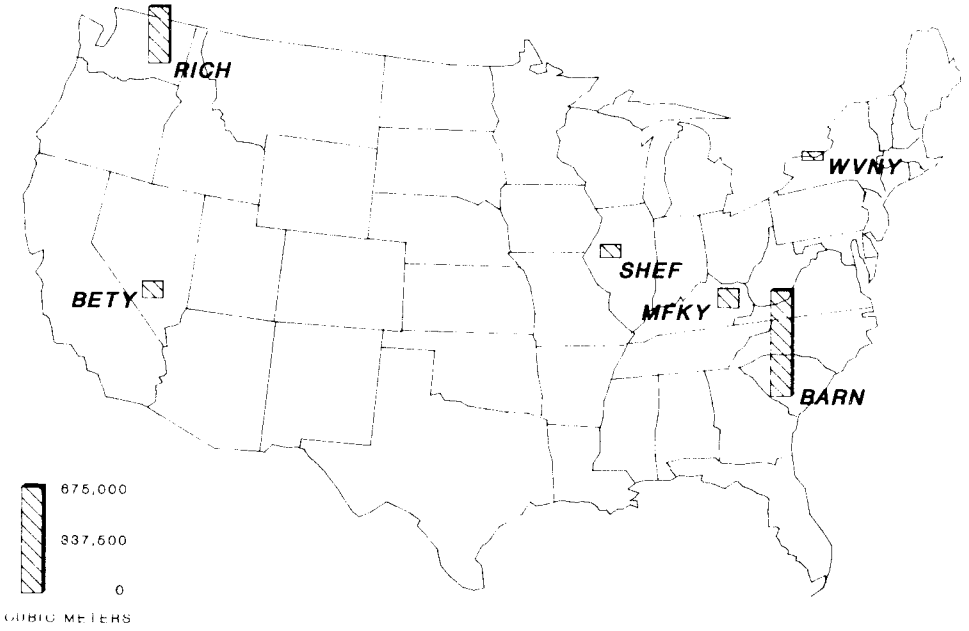


Fig. 4.7. Locations and total volumes of commercial LLW disposed through 1991.

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 given[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	88,656	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]	[illegible]	Fission product	Induced activity	Tritium	Alpha	Other[c]	Total
		Activity, Ci					
AMES	<<1	0	0	0	<<1	0	<<1
ANL-E	[illegible]	d	d	d	d	d	d
ANL-W	<<1	15	105,400	c	<<1	0	105,415
[illegible]	[illegible]	d	d	d	d	d	d
[illegible]		0	0	0	0	0	<1
[illegible]	[illegible]	0	1	<1	0	0	<2
[illegible]		[illegible]	1,993	10	0	0	7,788
[illegible]	[illegible]	0	0	0	0	105,180	105,180
[illegible]		0	0	0	0	200	200
[illegible]	[illegible]	0	0	0	0	0	c
[illegible]	[illegible]	0	0	<<1	0	<1	<1
[illegible]	[illegible]	7	7,126	45	4	0	7,193
[illegible]		9	<<1	702	0	898	1,600
[illegible]	[illegible]	1	<<1	13,000	1	<1	13,003
[illegible]	[illegible]	0	0	6,061	3	0	6,064
[illegible]	[illegible]	33	99,970	<1	0	0	100,390
[illegible]	[illegible]	d	d	d	d	d	d
[illegible]	[illegible]	<<1	0	<<1	<<1	<<1	<<1
[illegible]	[illegible]	[illegible]	169	<<1	<<1	<<1	825
[illegible]	[illegible]	0	0	0	<<1	c	1
[illegible]	[illegible]	0	0	18	0	0	18
[illegible]	[illegible]	0	0	9,839	0	0	9,839
[illegible]	<1	0	0	0	0	0	<1
[illegible]	[illegible]	0	<<1	<1	0	<<1	<1
[illegible]	<1	0	0	0	10	0	10
[illegible]		0	0	0	0	0	<<1
[illegible]	[illegible]	0	<<1	0	0	0	<<1
[illegible]	[illegible]	<<1	<<1	1	1	<1	3
[illegible]	[illegible]	[illegible]	0	11,512	0	5	11,517
[illegible]	[illegible]	9,888	44,356	23,716	12	1,666	79,628
Y-12	2	0	0	0	0	0	2
Total	[illegible]	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 [illegible]

[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]DOE 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

	Total gross activity, Ci[a]						
DOE site[b]	Uranium/ thorium	Fission product	Induced activity	Tritium	Alpha	Other[c]	Total
AMES	<1	0	0	0	0	0	<1
ANL-E	0	0	0	0	0	0	0
ANL-W	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]

	Radioactivity, Ci							
Year	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	2,837	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] Low	Base	High	Activity[d] (Ci)
GE/BWR	Cartridge filters	5.80E-02	1.16E+00	2.32E+00	6.62E+00
	Control rod components				
	Bearings	1.42E-04	1.42E-04	1.42E-04	8.93E+00
	Blade	3.53E+02	4.41E+02	8.83E+02	1.62E+05
	Inner drive strainers	2.55E-02	5.09E-01	1.02E+00	6.85E+01
	Outer drive strainers	1.12E+00	2.22E+01	4.55E+01	6.76E+01
	Core shroud	1.80E+02	2.57E+02	3.86E+02	4.93E+06
	Dry tubes	1.31E+01	2.13E+01	4.36E+01	1.08E+05
	Fuel in decontamination resins	1.13E+01	5.66E+01	1.13E+02	2.02E+03
	Local power range monitor	5.80E+01	9.67E+01	1.93E+02	6.65E+04
	Poison curtains	6.78E-03	6.78E-03	6.78E-03	1.55E+02
	Pool filters	1.68E+00	3.36E+01	6.72E+01	2.00E+02
	BWR total	6.18E+02	9.30E+02	1.73E+03	5.27E+06
B&W/PWR	Cartridge filters	1.32E+00	2.64E+01	5.29E+01	3.28E+02
	Control rod drive	3.20E-02	3.20E-02	3.20E-02	6.14E+02
	Core barrel	e	e	4.59E+01	3.64E+05
	Core shroud	1.44E+01	2.06E+01	3.09E+01	1.78E+06
	Crud tank filters	2.32E-01	4.64E+00	9.28E+00	3.47E+01
	Flux wire	4.00E-01	4.00E-01	4.00E-01	1.55E+04
	Fuel in decontamination resins	1.70E+00	8.48E+00	1.70E+01	1.18E+03
	In-core detectors	1.17E+01	1.95E+01	3.90E+01	1.75E+04
	Miscellaneous metals	3.80E-02	3.80E-02	3.80E-02	f
	Primary sources	1.13E-02	1.13E-02	1.13E-02	1.21E+04
	B&W total	2.98E+01	8.01E+01	1.95E+02	2.19E+06
CE/PWR	Cartridge filters	2.30E+00	4.59E+01	9.19E+01	8.33E+01
	Control rod drive	7.40E-01	7.40E-01	7.40E-01	1.45E+03
	Core barrel	e	e	3.69E+02	7.06E+05
	Core shroud	4.63E+01	6.62E+01	9.93E+01	5.54E+06
	Flux wire	6.00E-02	6.00E-02	6.00E-02	f
	Fuel in decontamination resins	9.34E+00	4.66E+01	9.33E+01	4.54E+03
	In-core detectors	2.75E+01	4.59E+01	9.17E+01	2.39E+04
	Primary sources	7.47E-02	7.47E-02	7.47E-02	9.26E+06
	Miscellaneous metals	3.00E-01	3.00E-01	3.00E-01	f
	Thimble plug assemblies	4.00E-01	8.00E-01	1.20E+00	f
	CE total	8.70E+01	2.07E+02	7.48E+02	1.55E+07
WH/PWR	Cartridge filters	8.50E+00	1.70E+02	3.34E+02	3.12E+02
	Control rod drive	1.72E+01	1.72E+01	1.72E+01	6.76E+06
	Core barrel	e	e	5.95E+02	3.94E+06
	Core shroud	1.25E+02	1.79E+02	2.68E+02	2.44E+07
	Fuel in decontamination resins	3.24E+01	1.61E+02	3.22E+02	1.78E+04
	In-core instruments	1.34E+01	2.15E+01	4.47E+01	1.22E+05
	Miscellaneous metals	1.25E+00	1.25E+00	1.25E+00	f
	Source rods	1.15E+00	1.15E+00	1.15E+00	6.73E+06
	Thimble plug assemblies	3.89E+01	7.78E+01	1.17E+02	1.66E+04
	WH total	2.38E+02	6.29E+02	1.70E+03	4.20E+07
	PWR total	3.55E+02	9.16E+02	2.64E+03	5.97E+07
	LWR total	9.73E+02	1.85E+03	4.37E+03	6.50E+07

[a]Based on ref. 19.

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

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

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

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

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

Table 4.20. 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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Fig. 5.1. Locations of uranium mill [illegible] 1981.

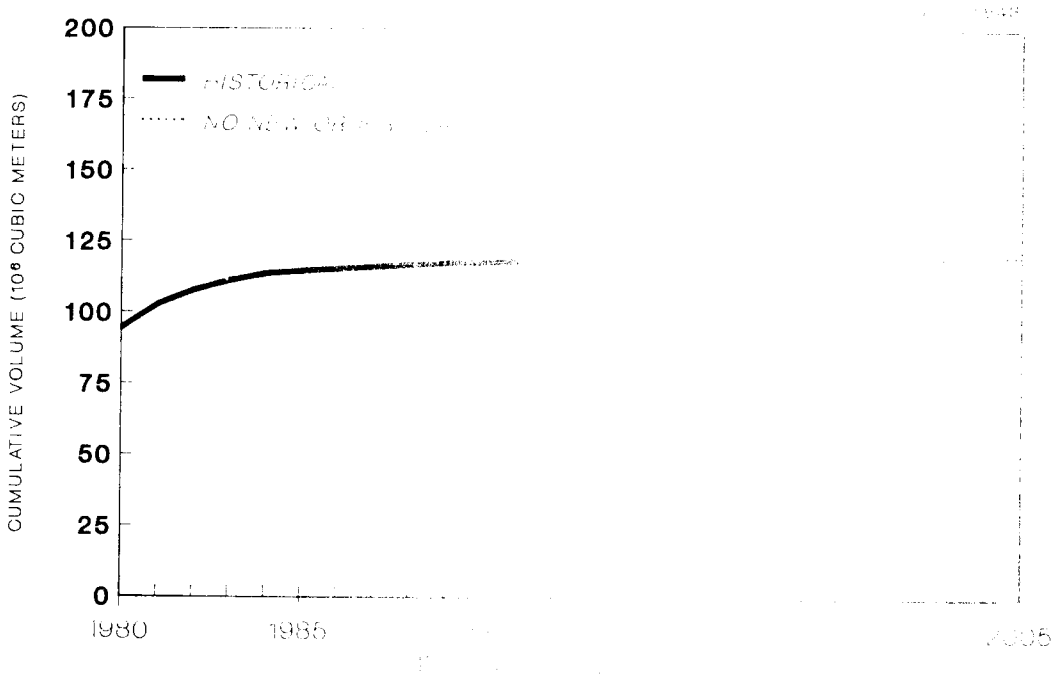

Fig. 5.2. Historical and projected [illegible] tailings.

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: Operations[b]	Status: Tailings[c]	Tailings storage area (ha)[d]	Total tailings: Volume[e] (10^6 m^3)	Total tailings: Mass (10^6 t)	Total tailings: Government portion[f] (10^6 t)
Colorado								
Canon City	Cotter	1,090	Shut down, 1987	Wood chip covering	81	1.3	2.1	0.3
Uravan	Umetco Minerals	1,180[g]	Decommissioning	Partially stabilized	44	5.9	9.5	5.2
Subtotal		1,090			125	7.2	11.6	5.5
New Mexico								
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	193	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: Operations[b]	Status: Tailings[c]	Tailings storage area (ha)[d]	Total tailings: Volume[e] (10^6 m^3)	Total tailings: Mass (10^6 t)	Total tailings: Government portion[f] (10^6 t)
Washington								
Ford	Dawn Mining	410	Shut down, 1982	Wood chip covering	43	1.8	2.8	1.1
Wellpinit	Western Nuclear	1,810[g]	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		U_3O_8 recovery from ore (%)	U_3O_8 product[d] (10^6 t)	Tailings generated	
	Mass[c] (10^6 t)	Grade (% U_3O_8)			Mass[e] (10^6 t)	Volume[f] (10^6 m^3)
Prior to 1978	g	g	g	g	108.8	68.0
1978	12.5	0.134	91	15.6	12.6	7.9
1979	14.6	0.113	91	15.3	14.5	9.1
1980	15.3	0.118	93	17.2	15.2	9.5
1981	13.2	0.115	94	14.5	13.2	8.2
1982	7.9	0.119	96	9.9	8.1	5.0
1983	5.4	0.128	97	7.0	5.4	3.4
1984	3.9	0.112	95	4.4	4.0	2.5
1985	1.6	0.161	96	2.8	1.6	1.0
1986	1.2	0.338	97	4.0	1.2	0.7
1987	1.3	0.284	96	3.8	1.3	0.8
1988	1.1	0.288	95	3.2	1.1	0.7
1989	1.1	0.323	95	3.7	1.0	0.7
1990	0.7	0.293	94	2.1	0.7	0.4
1991	0.6	0.188	92	1.2	0.6	0.4
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.

ORNL PHOTO 6894-92

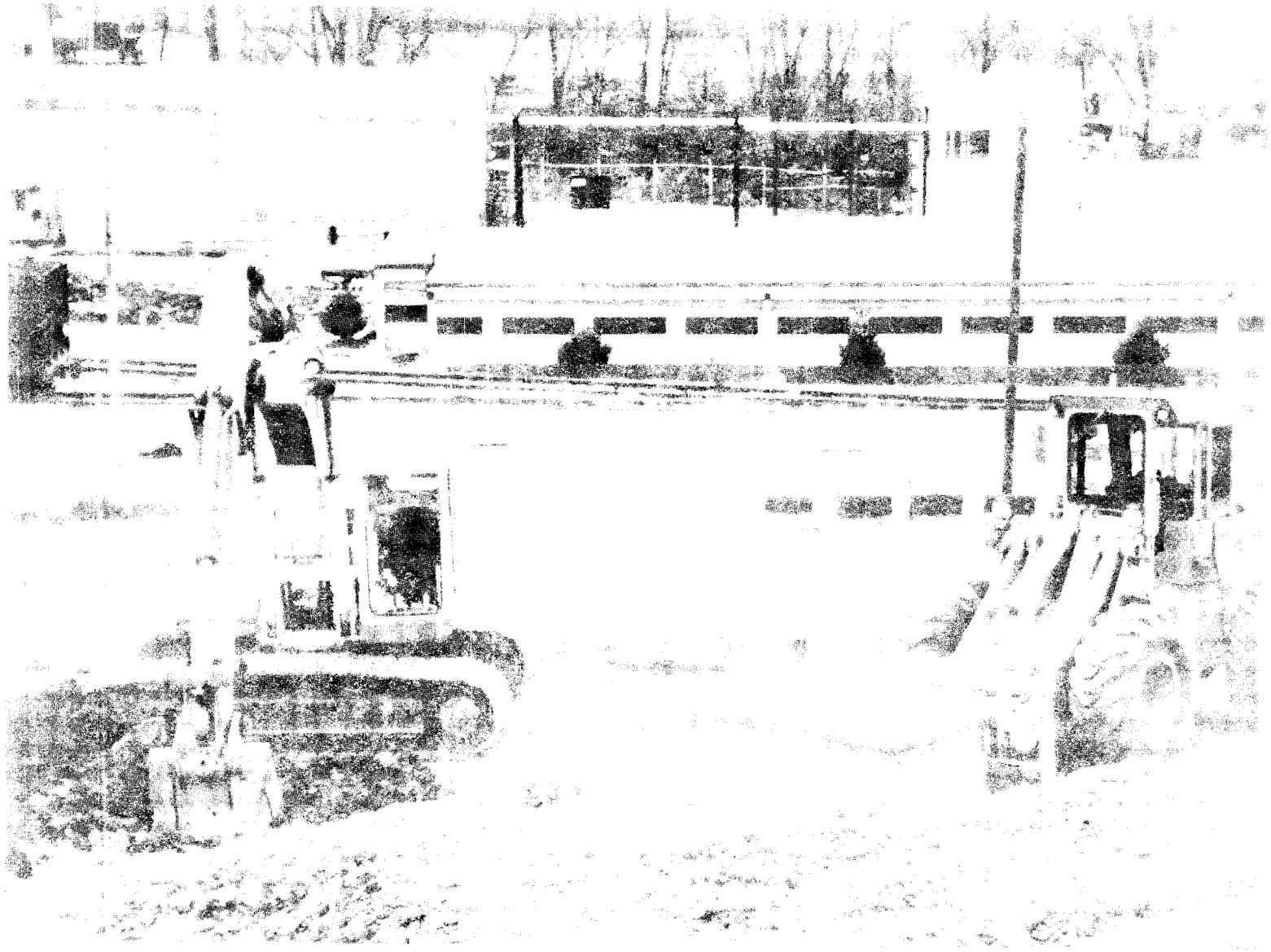

Photo 6.1. Low-level radioactive soil being loaded into boxes at the Mound Plant. (Courtesy of EG&G Mound Applied Technologies, Miamisburg, Ohio, and the Hazardous Waste Remedial Actions Program, Oak Ridge, Tennessee.)

6. ENVIRONMENTAL RESTORATION WASTES

6.1 INTRODUCTION

The fundamental goal of the Department of Energy's Office of Environmental Restoration is to ensure that risks to the environment and to human health and safety posed by inactive and surplus facilities and sites contaminated by radioactive, hazardous, or mixed wastes are either eliminated or reduced to prescribed, safe levels. The main objective is to clean up the current waste inventory within the DOE nuclear complex by the year 2019. Although encompassing all requirements prescribed by applicable federal, state, and local environmental statutes and regulatory requirements, this goal is not limited to regulatory compliance. Protection of human health and safety and the environment is DOE's paramount concern.

Environmental restoration efforts are proceeding in two major areas: remedial action (RA) and decontamination and decommissioning (D&D) activities. RA and D&D activities include cleanup of facilities and areas that supported defense-related activities, such as nuclear weapon component fabrication, and nondefense, civilian nuclear power activities, such as the development of heat sources for the space program and the operation of small test reactors. These activities include the Uranium Mill Tailings Remedial Action Program (UMTRAP), the Formerly Utilized Sites Remedial Action Program (FUSRAP), and other environmental restoration activities associated with DOE Field Offices throughout the country. Only D&D activities at facilities transferred to the Office of Environmental Restoration and Waste Management (EM) are discussed.

The map in Fig. 6.1 locates the DOE offices responsible for environmental restoration activities. The distribution by waste class of the estimated volume of waste to be generated by the environmental restoration activities is shown in Fig. 6.2. Additional details on UMTRAP sites and FUSRAP sites are identified in Fig. 6.3 and Fig. 6.4, respectively. The total volume of waste associated with UMTRAP is shown in Fig. 6.5, and the total volume of FUSRAP waste is shown in Fig. 6.6.

The estimated total volumes of waste from DOE environmental restoration activities are summarized in Table 6.1. Waste inventories from completed environmental restoration activities are indicated as being in either permanent or interim storage. Projected additional waste volumes from future environmental restoration activities are reported as estimated remaining inventories.

6.2 THE OFFICE OF ENVIRONMENTAL RESTORATION

The Office of Environmental Restoration (EM-40) has responsibility for RA and D&D activities within EM.[1] RA activities involve the assessment and cleanup of inactive DOE sites and deal primarily with contaminated environmental media such as soil and groundwater. D&D activities entail the safe caretaking of surplus nuclear facilities and their complete dismantling and removal, or in-place stabilization and isolation. As shown in Fig. 6.1, RA and D&D activities are managed under 17 projects through 9 DOE Field Offices and 1 DOE project office: Albuquerque, Chicago, Fernald, Idaho, Nevada, Oak Ridge, Richland, Rocky Flats, Savannah River, and San Francisco. UMTRAP, authorized by Congress in 1978, and FUSRAP, authorized by DOE in 1974, are 2 of the 17 projects.

6.2.1 Activities

The RA and D&D activities under the auspices of EM-40 were formerly supported under the DOE Offices of Defense Programs, Energy Research, and Nuclear Energy.

6.2.1.1 Remedial action

RA activities entail site discovery, preliminary assessment, and inspection; site characterization, analysis of cleanup alternatives, and selection of remedy; cleanup and site closure; and site compliance monitoring. Although such activities may deal with tanks, buildings, or structures, most are concerned with contaminated environmental media such as soil and groundwater.

The principal regulatory requirements for RA activities are derived from the Resource Conservation and Recovery Act (RCRA);[2] the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA);[3] and the National Environmental Policy Act (NEPA).[4]

RA activities may further be subject to important regulatory requirements imposed by the states. Other requirements are set forth in various DOE Orders and standards and other guidance documents.[1]

6.2.1.2 Decontamination and decommissioning

D&D activities emphasize the safe caretaking of surplus nuclear facilities and their decontamination for dismantlement and removal. They include surveillance and maintenance, assessment and characterization, environmental review, engineering, D&D operation, and project closeout. Most D&D activities are performed on facilities such as reactors, hot cells, processing plants, storage tanks, and other structures from which, in general, there have been no known releases. There are approximately 500 contaminated facilities currently included in the EM-40 inventory for D&D. The objectives of D&D activities are to decontaminate these facilities and to eliminate any potential hazards to public health and the environment.

D&D activities are carried out in accordance with the provisions prescribed in NEPA and the Atomic Energy Act (AEA)[5] and with requirements set forth in various DOE Orders and standards and other guidance documents. In addition, the provisions of CERCLA and RCRA may also apply to those facilities from which there has been a release or from which there is a potential release. State requirements may apply in certain instances.

6.2.2 Programs

Environmental restoration activities under the auspices of the Office of Environmental Restoration are managed by three offices: Southwestern Area Programs, Northwestern Area Programs, and Eastern Area Programs. Each office manages both RA and D&D activities.

The projected remaining volumes of radioactive waste that will result from environmental restoration activities are listed by program in Tables 6.2 through 6.7. The wastes include low-level, mixed, transuranic, and other radioactive materials. The estimated volumes of radioactive soils and radioactive solid waste resulting from the environmental restoration activities are reported in Tables 6.2 and 6.3, respectively.

6.2.2.1 Southwestern Area Programs

Southwestern Area Programs include all EM-40 activities conducted out of the DOE Nevada Field Office, Albuquerque Field Office, and Rocky Flats Site Office.

At the DOE Nevada Field Office, the environmental restoration program includes conducting D&D, characterization, remedial design, and remedial actions for 11 subprojects at the Nevada Test Site (NTS) and at off-site areas where nuclear tests have been conducted. Off-site locations include: Amchitka Island, Alaska; the Rio Blanco and Rulison Gas Stimulation sites in Colorado; the Gasbuggy Gas Stimulation and Gnome Coach sites in New Mexico; and the Tatum Dome Site in Mississippi. The EM-40 activities at NTS involve cleanup of areas of contamination from aboveground and underground nuclear weapons testing. The main contaminants include radionuclides, organic compounds, metals, hydrocarbons, and various residues used during test boring, drilling, and instrumentation.

DOE Albuquerque Field Office operations are managed as five separate projects. There are more than 2,500 potential RA sites under the auspices of the Albuquerque Field Office and more than 20 surplus facilities identified for D&D. The main contaminants include radionuclides, solvents, gasoline, organics, metals, high-explosive residues, and uranium mill tailings.

Albuquerque Laboratories activities take place at the South Valley Superfund Site, the Inhalation Toxicology Research Institute, Sandia National Laboratories, and Los Alamos National Laboratory (LANL). D&D is currently being conducted on a separator pit at LANL. Albuquerque Production environmental restoration activities include RA at the Pantex, Kansas City, Pinellas, and Mound plants. D&D is currently under way at the special metallurgical building at the Mound Plant. There are ongoing site assessments, Remedial Investigations/Feasibility Studies (RI/FS), and remedial design and remedial action activities for lagoons, waste ponds, landfills, disposal areas, firing sites, underground storage tanks, and other structures.

The Uranium Mill Tailings Radiation Control Act of 1978 (Public Law 95-604) authorized DOE to undertake the stabilization and control of uranium mill tailings in a safe and environmentally sound manner and, where appropriate and practical, to reprocess existing tailings to extract residual uranium and other mineral values. The Act also specifies RA, as required, on properties in the vicinity of the tailings sites.[6] Initial tasks under UMTRAP were to (1) designate inactive uranium mill tailings sites for RA and (2) evaluate the economic viability of reprocessing tailings. Currently, two Albuquerque projects oversee work for UMTRAP surface and groundwater assessment and cleanup.

Twenty-five inactive uranium processing sites and associated vicinity properties located in ten states and four Indian reservations, and the vicinity properties associated with the Edgemont, South Dakota, inactive uranium mill, currently owned by the Tennessee Valley Authority (TVA), are presently included in UMTRAP. All of the sites are located in the western United States except for one site in Canonsburg, Pennsylvania. Engineering assessment and economic evaluation documents about each site have been published.

During FY 1991, the UMTRAP achieved the following major accomplishments:

- Completed remedial actions at the Lowman, Idaho, processing site.
- Completed 43% of the Phase II remedial actions at Grand Junction, Colorado.
- Completed remedial actions on 332 vicinity properties; certified 446 vicinity properties; initiated contracts covering remedial actions on 233 vicinity properties; and completed vicinity property activities at the Lowman, Idaho, UMTRAP site.

Table 6.4 gives the current RA status, duration schedules, and estimated total waste volume for the 25 UMTRAP sites.[7,8] At the end of 1991, over 10.6 million cubic meters of mill tailings and other (subordinate) wastes, reported in this document as 11e(2) by-product material, had been stabilized at 11 sites where site remedial action activities were completed. The subordinate wastes include soils contaminated by windblown tailings, ore in storage areas, material underlying tailings piles, and contaminated soils from vicinity properties. It should be noted that quantities of subordinate wastes typically increase as RA work commences and efforts are made to ensure the adequacy of the cleanup procedures.

The uranium mill tailings at the UMTRAP sites have a low specific activity that is the result of naturally occurring radioactive elements. Depending on specific site characteristics, these tailings may be stabilized on-site or removed to other locations and stabilized. The criteria used in UMTRAP site cleanup and waste disposal work are based on EPA standards[9] that became effective in March 1983. As shown in Table 6.4, UMTRAP remedial activities are scheduled to be completed by June 1995; however, certification and licensing activities will not be completed until September 1998.

The projected volumes of wastes from uncompleted UMTRAP sites are given in Table 6.5. Also given in this table is the estimated concentration of ^{226}Ra associated with the waste at their sites which has been determined from representative samples obtained from these sites.

The Grand Junction Projects Office and Monticello RA Projects are also managed out of the Albuquerque Field Office. There are ongoing RA activities for surface and groundwater cleanup at the Monticello Mill Tailings Site in Utah and at the Grand Junction Projects Office Site in Colorado.

The Rocky Flats Plant is a nuclear weapons manufacturing facility. The EM-40 activities there are responsible for the site assessments, RI/FS, and RA for 178 sites contaminated from earlier waste storage and disposal. Storage and disposal of hazardous, radioactive, and mixed wastes occurred on-site in the past. Off-site locations include three reservoirs and one land area; these areas may have received contaminated effluent and sediments originating from the Plant. Rocky Flats is also tasked to design, procure, construct, operate, and maintain decontamination facilities for waste generated by EM-40 activities.

6.2.2.2 Northwestern Area Programs

Northwestern Area Programs encompass all EM-40 activities that are managed through the DOE Idaho, Richland, and San Francisco Field Offices. These activities are located on both DOE and contractor-owned sites and facilities located in Idaho, Washington, and California.

The Idaho National Engineering Laboratory (INEL) was established in 1949 as a site where nuclear reactors, support facilities, and equipment could be safely built, tested, and operated -- primarily to prove that the atom could be used safely to generate electric power. Today, INEL is one of DOE's principal centers for conducting nuclear energy research and development. Previous activities have resulted in the generation of high-level, low-level, transuranic, and mixed wastes, as well as acids, solvents, asbestos, and heavy metals. There is contamination of structures, groundwater, and surface water within the site. The EM-40 program consists of the remediation of 8 waste area groups containing about 370 waste release sites at burial grounds, ponds, reactor areas, landfills, and underground storage tanks; and the D&D of 15 areas including reactors, tanks, laundry, and other facilities.

DOE activities at the Hanford Site, under the direction of the DOE Richland Field Office, have been producing nuclear fuel and materials since the early 1940s. The wastes at Hanford include radioactive materials, hazardous chemicals, and mixed wastes primarily from the production and chemical processing of plutonium for defense purposes, but also from nuclear fuel research and fabrication activities. About 1,100 waste sites have been identified, most having resulted from on-site storage or soil column disposal of low-level, hazardous, and mixed wastes. More than 100 surplus facilities are contaminated with radioactivity and are scheduled for D&D. These facilities include nine former production reactors, chemical process buildings, structures, and ancillary structures. As part of the remediation of the site, the EM-40 project at Hanford is responsible for the construction of a disposal facility to receive cleanup wastes and the closure of underground storage tanks and other RCRA closures.

The mission of the DOE San Francisco Field Office has been nuclear weapons research, as well as nuclear and other energy research. The wastes generated include transuranic, low-level, hazardous, and mixed wastes; contaminants include a wide variety of radionuclides, polychlorinated biphenyls (PCBs), volatile organic compounds, and metals. The San Francisco Field Office installations where EM-40 has program activities include Lawrence Livermore National Laboratory (LLNL), Lawrence Berkeley Laboratory (LBL), Stanford Linear Accelerator Center (SLAC), General Atomics Facility, Laboratory for Energy-Related Health Research (LEHR), General Electric Vallecitos Nuclear Center, and the DOE portion of Santa Susana Field Laboratory (SSFL), known as the Energy Technology Engineering Center (ETEC).

LLNL consists of two sites: the Main Site and Site 300. Past operations at the Main Site involved the handling and storage of hazardous materials by both DOE and the former site owner, the Department of Defense, and have resulted in the release and subsequent migration of contaminants into soil and groundwater. Chlorinated hydrocarbons are dissolved in groundwater at concentrations as high as 10 ppm. The groundwater is being remediated by pumping and treating within the area of the contaminated plume. The LLNL Site 300 (about 15 miles east of the LLNL Main Site, near Tracy, California) consists of nonnuclear explosive test facilities. Past operations at Site 300 involved processing, testing, and deactivating high-explosive materials and have resulted in soil and groundwater contamination at the facility. There are several small plumes of chlorinated hydrocarbons and two plumes of tritium in the groundwater emanating from waste pits, landfills, and debris piles. Two of the largest pits have been capped, and an interim groundwater treatment facility is extracting and treating trichloroethylene-contaminated groundwater at one of the debris piles.

The LBL site is leased to DOE by the University of California. A wide range of energy-related areas, such as particle accelerators and chemical and biomedical research, are carried out in laboratories and supporting facilities at LBL. The current EM-40 program involves the systematic assessment of soil and groundwater at the site to determine the existence and nature of any contamination prior to characterization and eventual cleanup.

The SLAC is operated by Stanford University under contract to DOE. SLAC was established in 1962 as an energy research facility dedicated to research and development of new techniques for high-energy accelerators and experimental apparatus. Past waste management practices and facility operations have resulted in PCB contamination of soils and volatile organic compound contamination of groundwater.

The DOE-owned LFHR occupies a site leased from the University of California at Davis (UCD). UCD used the laboratory for more than 30 years to conduct a DOE-sponsored research program on the health effects of exposure to low-level radiation. The research contaminated five buildings, outdoor dog pens and cages, and a tank trailer with low-level radioactive wastes and generated radioactive sludge wastes and contaminated soils in trenches and pits. Some chemical and radioactive contaminants have reached groundwater.

The ETEC portion of the SSFL consists of facilities that are used to test systems and components for use in energy, power conversion, and liquid metal development programs. Ongoing site characterization includes assessments of radioactive contaminants as well as chemical pollutants in surface water, groundwater, soil, biota, and air.

6.2.2.3 Eastern Area Programs

EM-40 activities in the Eastern Area are managed out of the DOE Oak Ridge, Fernald, Chicago, and Savannah River Field Offices. The Oak Ridge Field Office oversees EM-40 activities at Oak Ridge National Laboratory, the K-25 Site, and the Y-12 Plant on the Oak Ridge Reservation in Tennessee; the Portsmouth Gaseous Diffusion Plant, in Piketon, Ohio; and the Paducah Gaseous Diffusion Plant, in Paducah, Kentucky. DOE Defense Programs activities have generated various types of radioactive and hazardous wastes: low-level radioactive material (primarily uranium), organic solvents, corrosive waste, PCBs, heavy metals, and mixed waste. Contamination resulting from earlier waste management practices has affected groundwater, soils, surface waters, buildings, structures, and equipment. EM-40 work out of Oak Ridge includes cleanup of the K-25 Site (specifically, RA activities for the K-25 main and process plants and waste storage locations) and RA of facilities at the Y-12 Plant.

The Weldon Spring Site Remedial Action Project (WSSRAP) is also managed by the DOE Oak Ridge Field Office. WSSRAP activities include the D&D of the chemical plant processing buildings; the RA of the raffinate pits and the quarry; the restoration of contaminated vicinity properties; construction and operation of two water treatment plants and waste processing facilities; and disposal of all waste generated by site cleanup activities.

FUSRAP is primarily concerned with the cleanup of waste at sites that were formerly used to support the activities of the Manhattan Engineer District (MED), established for the Manhattan Project, and the Atomic Energy Commission (AEC). In the 1940s and 1950s, private firms and institutions were contracted by the federal government to develop processes and perform research on radioactive materials. Often the storage and processing of uranium and thorium ores, concentrates, and residues were involved. Although these sites were cleaned up to formerly acceptable levels, FUSRAP was established in 1974 to identify, re-evaluate, and, if necessary, remediate these sites. Currently, 33 sites have been identified in 13 states. Approximately one-half of these sites are in the northeastern part of the country.

RA activities for FUSRAP are ongoing at sites that include residential properties, municipal landfills, open fields, abandoned industrial plants, and operating industrial and commercial facilities. To date, RA on 171 of the designated 311 FUSRAP vicinity properties has been completed. Initial RA activities have been completed at 10 of the 33 sites and partially completed at 12 additional sites, as shown in Table 6.6.[10] Table 6.7 gives the estimated volumes of waste from FUSRAP activities remaining to be completed; only waste with low concentrations of radioactivity is anticipated. The total

volume of radioactive waste is expected to be about 1,600,000 m^3, including waste that has already been placed in storage. Most of this waste will be classified as 11e(2) by-product material. Site radiological surveys have developed considerable detailed information, and comprehensive site-by-site data have been compiled.

The DOE Fernald Field Office has responsibility for environmental restoration of the Fernald Environmental Management Project (FEMP). FEMP, formerly the Feed Materials Production Center, had the mission to produce feed materials for nuclear reactor fuel as a part of the nation's defense program. At FEMP, the main contaminants include residues containing uranium and radium, wastewaters and various solid waste contaminated with uranium and thorium materials, reactive chemicals, oils contaminated with uranium, and organic solvents. A site-wide RI/FS was initiated in 1986 to formulate, assess, and recommend RA alternatives. The FEMP program also includes the Reactive Metals, Inc. (RMI) Extrusion Plant, which has on-site and off-site surface soil and groundwater uranium contamination, and the adjacent Fields Brook site, which has contamination from PCBs, chlorinated solvents, toxic metals, and trichloroethylene. Currently, RA is ongoing for waste ponds, landfills, disposal areas, silos, surface water, and groundwater. D&D is being conducted for production area structures, equipment, and stockpiles. Waste management activities for the characterization, storage, treatment, disposal, and minimization of currently generated or backlog waste are also ongoing.

The DOE Chicago Field Office oversees two EM-40 activities, Chicago and Battelle Columbus Laboratories. The primary mission at Chicago is energy research, development, and demonstration. Waste types include transuranic, low-level, hazardous, and mixed wastes. Chicago projects involve six sites: Argonne National Laboratory-East, Illinois; Argonne National Laboratory-West, Idaho; Brookhaven National Laboratory, New York; Fermi National Accelerator Laboratory, Illinois; Princeton Plasma Physics Laboratory, New Jersey; and Ames Laboratory, Iowa. Activities include D&D of two retired nuclear reactors and RA for soil and groundwater contamination, disposal sites, underground storage tanks, and PCB cleanup.

The Battelle Columbus Laboratory Decommissioning Project (BCLDP) in Ohio includes the D&D of 15 contaminated buildings and surrounding soils which have been used for government-sponsored nuclear research.

The DOE Savannah River Field Office manages the EM-40 activities at the Savannah River Site in South Carolina. Its historical mission of producing nuclear materials for defense programs has resulted in the generation of waste by-products including liquid high-level, solid transuranic, low-level, hazardous, and mixed wastes. Soil and groundwater contamination has resulted from contaminants migrating from seepage and settling basins, unlined disposal pits, waste piles, burial grounds, and underground storage tanks. D&D activities are currently under way at the Heavy Water Components Test Reactor and two other facilities. RA activities are ongoing for burial grounds, tanks, pits, basins, and other groundwater areas.

6.3 REFERENCES

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4. U.S. Congress, National Environmental Policy Act of 1969, Pub. L. 91-190, Jan. 1, 1970.

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6. U.S. Nuclear Regulatory Commission, "Standards for Cleanups of Land and Buildings Contaminated with Residential Radioactive Materials from Inactive Uranium Processing Sites," Code of Federal Regulations, 40 CFR Part 192, Sect. 10 (July 1, 1987).

7. Frank Bosiljevac, U.S. Department of Energy, Uranium Mill Tailings Project Office, Albuquerque, New Mexico, memo to Marilyn Tolbert-Smith, Computer Specialist, EM-433, Headquarters, "Update of the Integrated Data Base Report," dated Feb. 27, 1992.

8. Mark Minteer, Jacobs Engineering Group, Inc., Albuquerque Operations, letter to Marilyn Tolbert-Smith, U.S. Department of Energy, Headquarters, EM-433, dated Sept. 17, 1992.

9. U.S. Environmental Protection Agency, Final Environmental Impact Statement for Remedial Action Standards for Inactive Uranium Processing Sites (40 CFR 192), EPA 520/4-82-013-1 and EPA 520/4-82-013-2, Washington, D.C. (October 1982).

10. Lester K. Price, U.S. Department of Energy, DOE Field Office, Oak Ridge, Tennessee, letter to R. L. Pearson, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Update of Formerly Utilized Sites Remedial Action Data in the Integrated Data Base Report," dated Mar. 24, 1992.

ORNL DWG 92-704

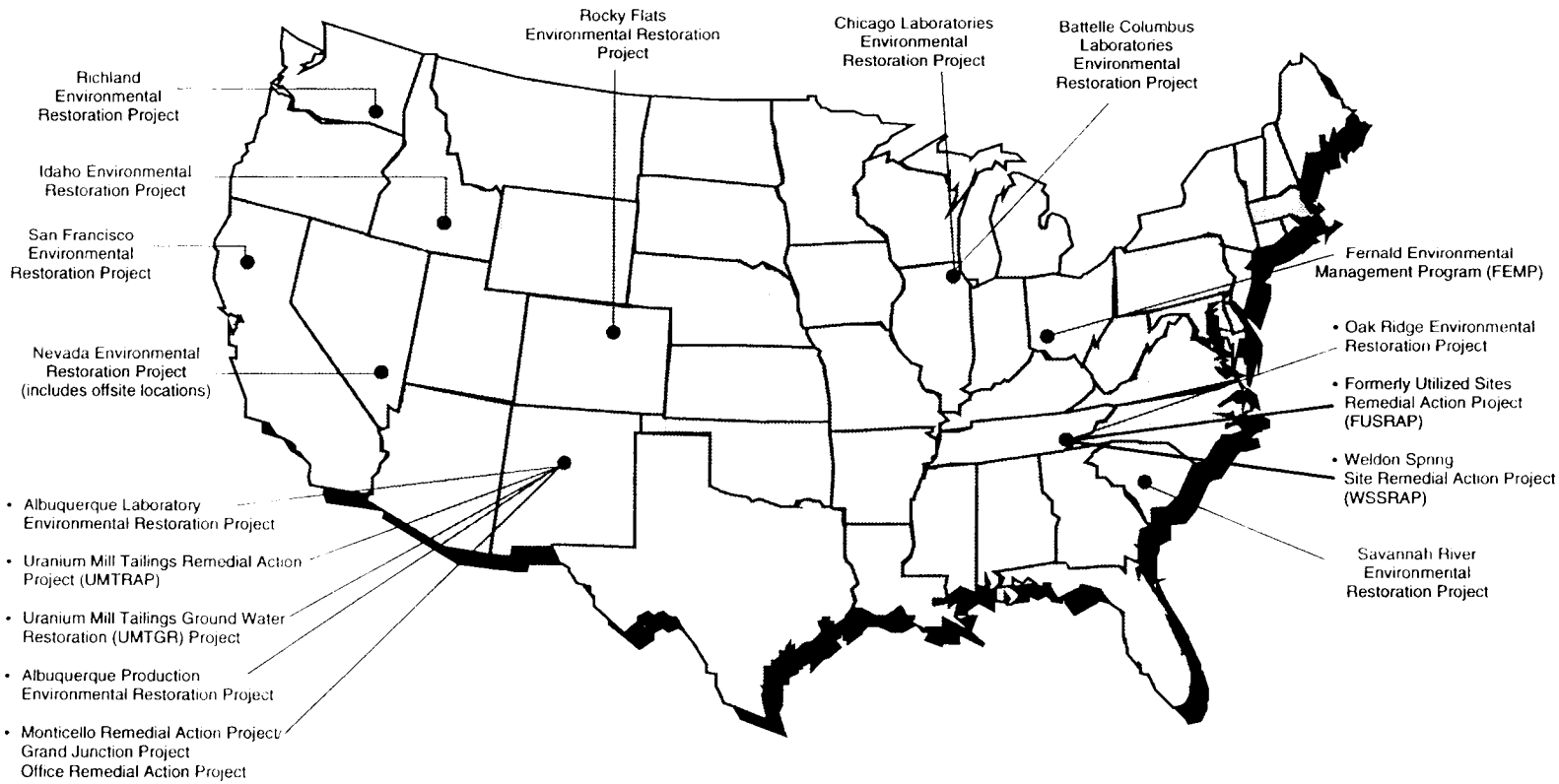
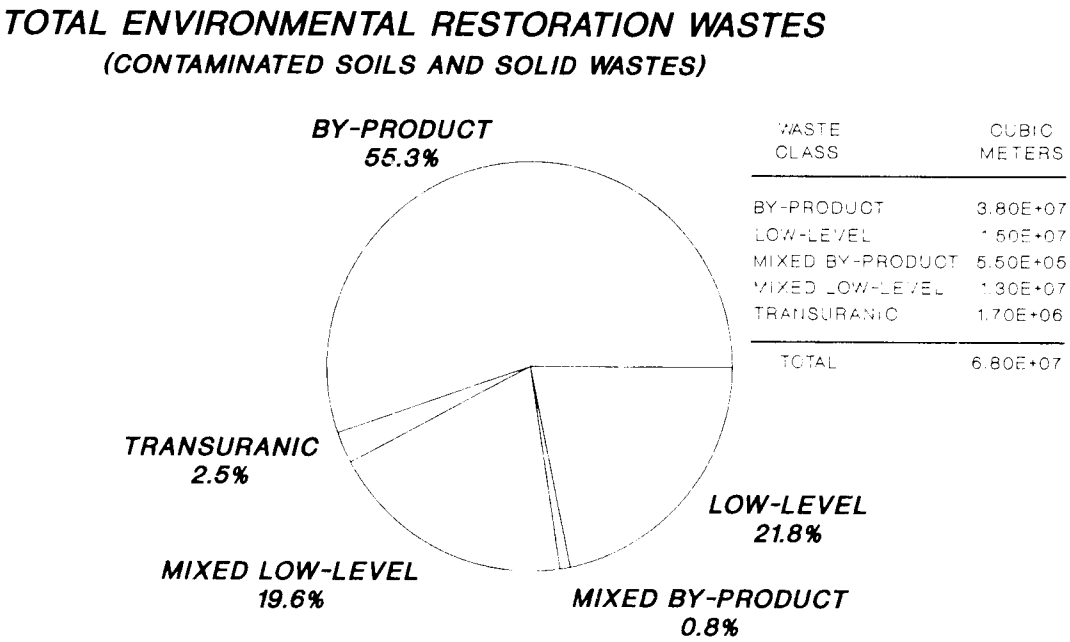


Fig. 6.1. Locations of 17 project offices for DOE environmental restoration activities.

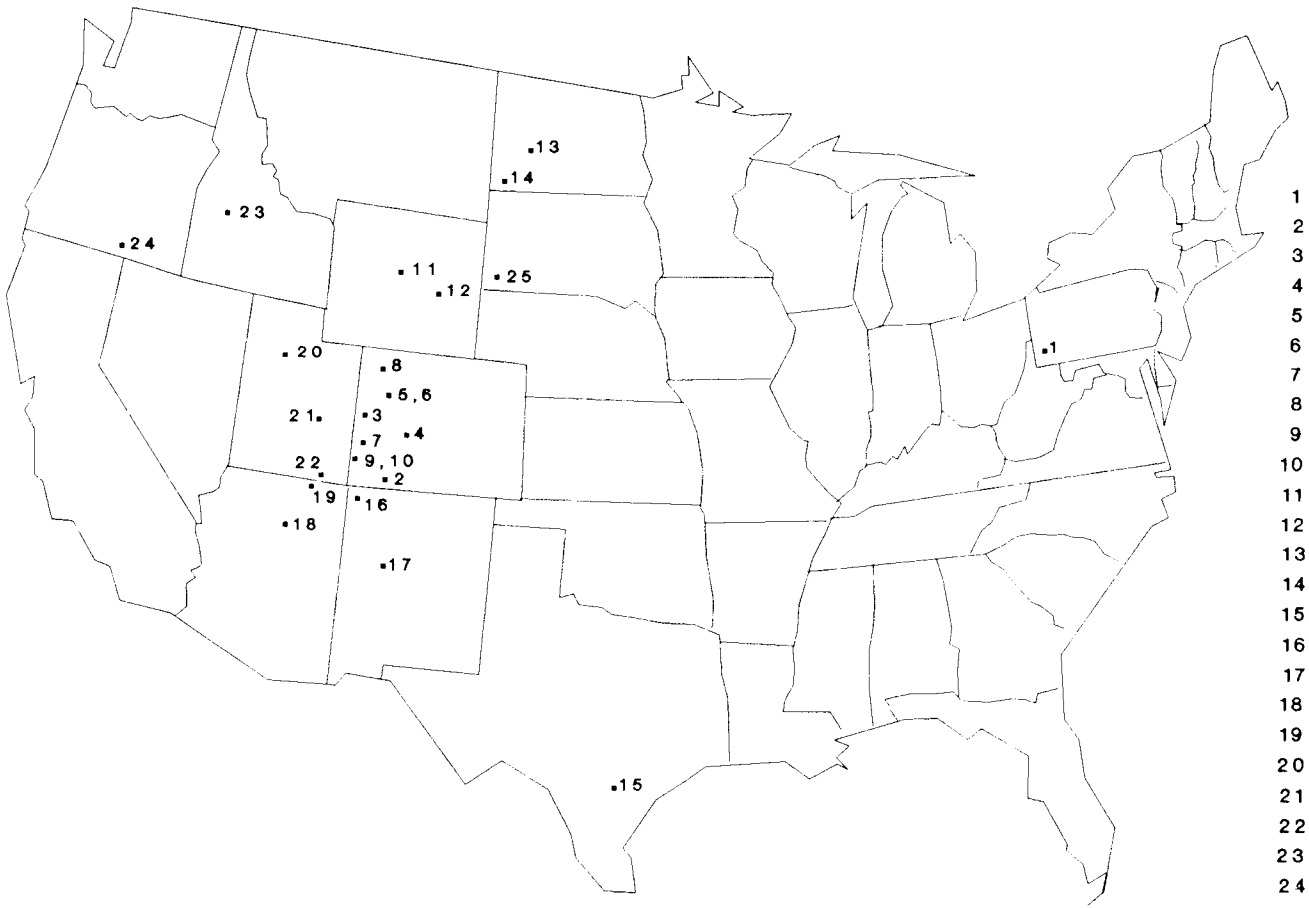
ORNL DWG 92-5844



WASTE CLASS	CUBIC METERS
BY-PRODUCT	3.80E+07
LOW-LEVEL	1.50E+07
MIXED BY-PRODUCT	5.50E+05
MIXED LOW-LEVEL	1.30E+07
TRANSURANIC	1.70E+06
TOTAL	6.80E+07

Fig. 6.2. Estimated total volumes of different classes of wastes from environmental restoration activities.

ORNL DWG 92-5845

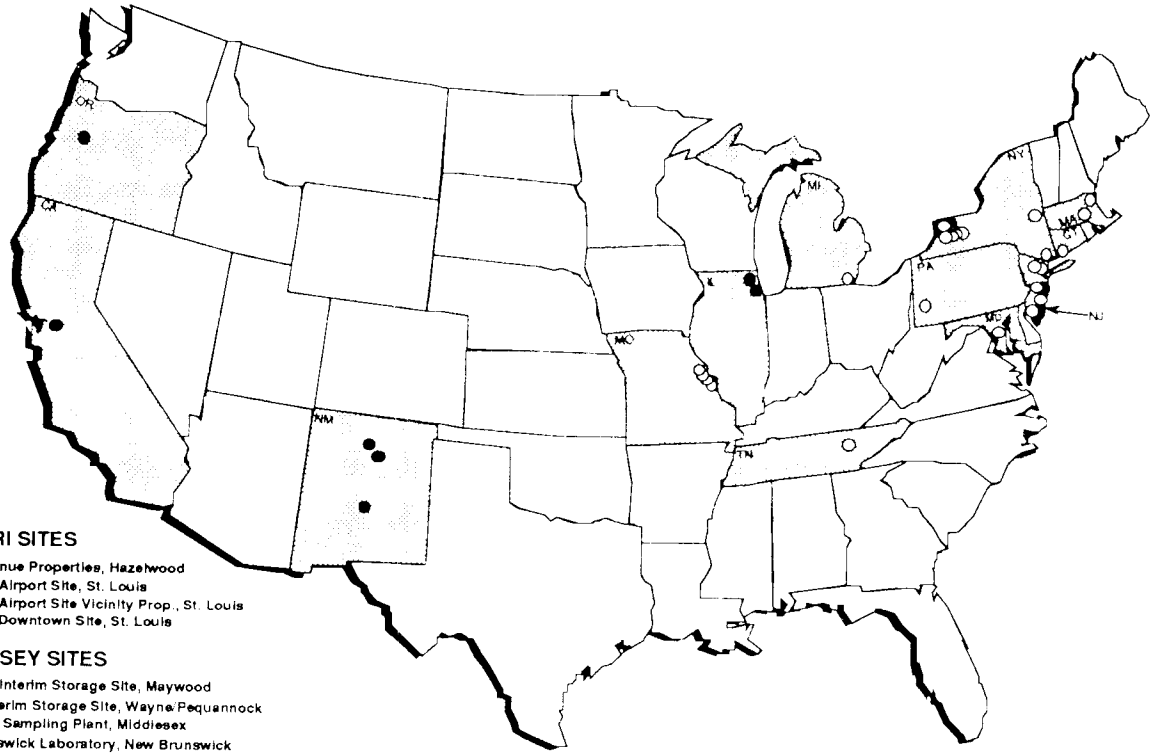


1 CANONSBURG, PA•
2 DURANGO, CO•
3 GRAND JUNCTION, CO
4 GUNNISON, CO
5 NEW RIFLE, CO
6 OLD RIFLE, CO
7 NATURITA, CO
8 MAYBELL, CO
9 SLICK ROCK (NC), CO••
10 SLICK ROCK (UC), CO•••
11 RIVERTON, WY•
12 CONVERSE CO., WY•
13 BELFIELD, ND
14 BOWMAN, ND
15 FALLS CITY, TX
16 SHIPROCK, NM•
17 AMBROSIA LAKE, NM
18 TUBA CITY, AZ•
19 MONUMENT VALLEY, AZ
20 SALT LAKE CITY, UT•
21 GREEN RIVER, UT•
22 MEXICAN HAT, UT
23 LOWMAN, ID•
24 LAKEVIEW, OR•
25 EDGEMONT, SD•

• SITE WORK COMPLETED
•• NORTH CONTINENT SITE
••• UNION CARBIDE SITE

Fig. 6.3. Locations of UMTRAP sites.

ORNL DWG 92-674



MISSOURI SITES

* † Latty Avenue Properties, Hazelwood
* St. Louis Airport Site, St. Louis
* St. Louis Airport Site Vicinity Prop., St. Louis
  St. Louis Downtown Site, St. Louis

NEW JERSEY SITES

* † Maywood Interim Storage Site, Maywood
* † Wayne Interim Storage Site, Wayne/Pequannock
  † Middlesex Sampling Plant, Middlesex
  † New Brunswick Laboratory, New Brunswick
  Du Pont & Company, Deepwater

NEW YORK SITES

† Niagara Falls Storage Site, Lewiston
† Colonie Interim Storage Site, Colonie
Ashland 1, Tonawanda
Ashland 2, Tonawanda
Linde Center, Tonawanda
Seaway Industrial Park, Tonawanda
Baker and Williams Warehouses, New York City

ADDITIONAL SITES

Aliquippa Forge, Aliquippa, PA
Elza Gate Site, Oak Ridge, TN
General Motors, Adrian, MI
Seymour Specialty Wire, Seymour, CT
* Shpack Landfill, Norton, MA
Ventron Corporation, Beverly, MA
W.R. Grace & Company, Curtis Bay, MD

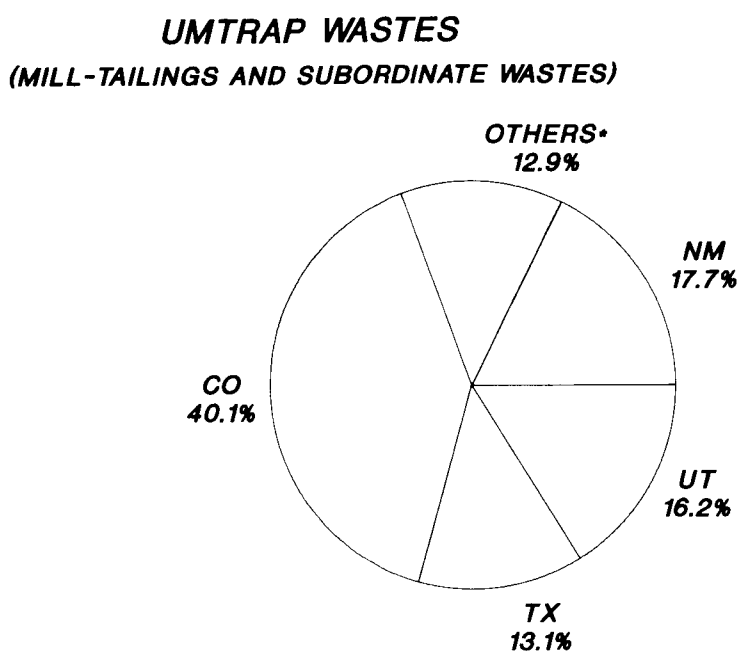
COMPLETED SITES

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

○ REMEDIAL ACTION ONGOING OR PLANNED
● REMEDIAL ACTION COMPLETED
† DOE-OWNED OR -LEASED SITE
★ NPL SITE
STATE WITH FUSRAP SITE(S)

Fig. 6.4. Locations of FUSRAP sites.

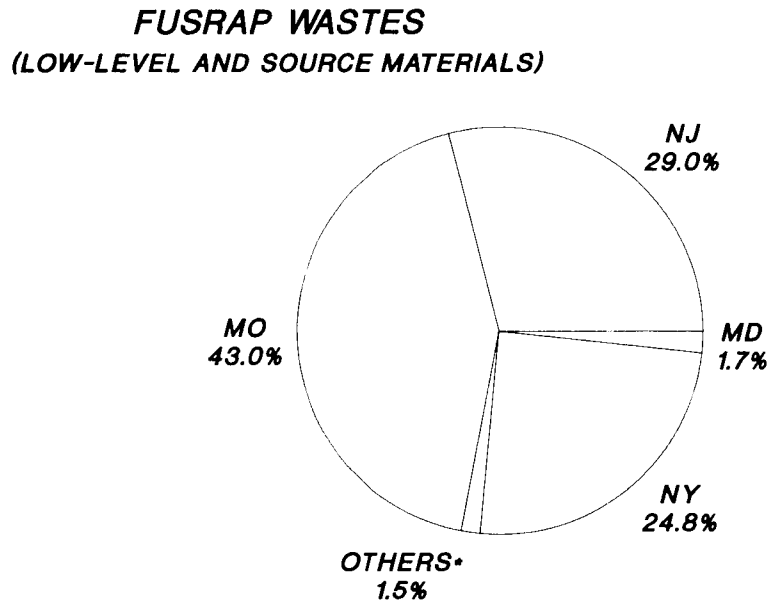
ORNL DWG 92-5847



STATE	CUBIC METERS
AZ*	1.26E+06
CO	1.28E+07
ID*	1.01E+05
ND*	1.21E+05
NM	5.64E+06
OR*	7.31E+05
PA*	2.26E+05
SD*	3.44E+04
TX	4.17E+06
UT	5.16E+06
WY*	1.67E+06
TOTAL	3.19E+07

Fig. 6.5. Estimated total volumes of wastes from UMTRAP activities in various states.

ORNL DWG 92-5848



STATE	CUBIC METERS
CA*	2.30E+01
CT*	1.90E+01
IL*	5.00E+01
MA*	1.25E+04
MD	2.75E+04
MI*	1.53E+02
MO	6.85E+05
NJ	4.63E+05
NM*	1.46E+03
NY	3.95E+05
OR*	2.73E+03
PA*	2.90E+01
TN*	6.80E+03
TOTAL	1.59E+06

Fig. 6.6. Estimated total volumes of wastes from FUSRAP activities in various states.

Table 6.1. Summary of current and projected waste volumes from environmental restoration activities

Program	Waste volume, 10^3 m^3		
	TRU[a]	LLW[a]	By-product material[a,b]
	A. Permanent storage[c]		
UMTRAP			11,000[d]
FUSRAP			11[e]
GJRAP			52[f]
Total			11,000
	B. Interim storage		
FUSRAP			330[e]
	C. Estimated remaining inventory[g]		
ER soils[h]	1,700	27,000	27,000
ER solids[i]	5.6	1,400	660
Total	1,700	28,000	28,000

[a]Volume estimates include quantities determined or projected to be mixed wastes. All values are given to two significant figures.

[b]By-product material is defined in Section 11e(2) of the Atomic Energy Act of 1954 (P.L. 83-703) as the tailings or waste products produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content.

[c]Volumes in permanent storage as of December 31, 1991.

[d]Includes uranium mill tailings and all contaminated material outside the immediate tailings pile. Once the cover is placed, all permanently stored material is considered to be tailings.

[e]Includes LLW and source material.

[f]GJRAP completed in 1988.

[g]Detailed waste projections for environmental restoration activities, for UMTRAP, and for FUSRAP are given in Tables 6.2 and 6.3, in Tables 6.4 and 6.5, and in Tables 6.6 and 6.7, respectively.

[h]Radioactively contaminated soils from environmental restoration activities.

[i]Radioactively contaminated solid wastes from environmental restoration activities.

Table 6.2. Estimated volumes of radioactive soils from environmental restoration activities[a,b]

ER Programs	Waste volume, m^3					
	LLW	Mixed LLW	By-product[c]	Mixed by-product[c]	TRU[d]	Total
Southwestern Programs						
Nevada Field Office	3,200,000	1,600,000			1,600,000	6,400,000
Albuquerque Labs	510					510
Albuquerque Production	200,000	220,000				420,000
UMTRA (UMTRAP)			32,000,000			32,000,000
Grand Junction Projects Office			1,800,000			1,800,000
Rocky Flats Plant (RFP)[e]						
Northwestern Programs						
Richland Field Office	9,000,000	11,000,000				20,000,000
San Francisco Field Office	1,000	110			64,000	65,000
Idaho Field Office	48,000	13,000			28,000	89,000
Eastern Programs						
Oak Ridge Field Office	10,000	340,000			360	350,000
Weldon Spring (WSSRAP)			220,000			220,000
FUSRAP	66,000	28,000	1,500,000			1,600,000
Fernald (FEMP)	690,000		1,200,000	540,000		2,400,000
Chicago Field Office	29,000	17,000		120	360	47,000
Battelle Columbus Labs (BCLDP)	170				10	180
Savannah River Field Office	350,000	210,000		2,600	290	560,000
Total	14,000,000	13,000,000	37,000,000	540,000	1,700,000	66,000,000

[a]Estimated as of December 31, 1991.

[b]These volume estimates represent the quantity of in-place contaminated materials; the waste volumes resulting from remedial action activities may be larger or smaller depending upon the selected remedy and treatment technology utilized. All values are preliminary and are being updated as site characterization activities proceed. All values are given to two significant figures.

[c]By-product material is defined in Section 11e(2) of the Atomic Energy Act of 1954 (P.L. 83-703) as the tailings or waste products produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content.

[d]Includes TRU mixed wastes. The radioactive characteristics of TRU wastes dictate the methods by which these materials need to be treated, handled, stored, and disposed.

[e]No volume estimates are available.

Table 6.3. Estimated volumes of radioactive solid waste from environmental restoration activities[a,b]

ER Programs	Waste volume, m^3					
	LLW	Mixed LLW	By-product[c]	Mixed by-product[c]	TRU[d]	Total
Southwestern Programs						
Nevada Field Office	8,200					8,200
Albuquerque Labs	19,000	330				19,000
Albuquerque Production	29,000					29,000
UMTRA (UMTRAP)			340,000			340,000
Grand Junction Projects Office						
Rocky Flats Plant (RFP)[e]						
Northwestern Programs						
Richland Field Office	840,000	300,000				1,100,000
San Francisco Field Office	11,000	15			120	11,000
Idaho Field Office	10,000	1,200			3,800	15,000
Eastern Programs						
Oak Ridge Field Office	36,000	120,000			260	160,000
Weldon Spring (WSSRAP)			420,000			420,000
FUSRAP	4,600	27	950			6,000
Fernald (FEMP)	4,700		230,000	7,600		240,000
Chicago Field Office	4,900	17,000			20	22,000
Battelle Columbus Labs (BCLDP)	2,100	88			1,300	3,500
Savannah River Field Office	550	1,100		25	140	1,800
Total	970,000	440,000	991,000	7,600	5,600	2,400,000

[a]Estimated as of December 31, 1991.

[b]These volume estimates represent the quantity of in-place contaminated materials; the waste volumes resulting from remedial action activities may be larger or smaller depending upon the selected remedy and treatment technology utilized. All values are preliminary and are being updated as site characterization activities proceed. All values are given to two significant figures.

[c]By-product material is defined in Section 11e(2) of the Atomic Energy Act of 1954 (P.L. 83-703) as the tailings or waste products produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content.

[d]Includes TRU mixed wastes. The radioactive characteristics of TRU wastes dictate the methods by which these materials need to be treated, handled, stored, and disposed.

[e]No volume estimates are available.

Table 6.4. UMTRAP site descriptions, status, scheduled duration, and estimated waste volumes[a]

State and site (last operation)	Site area (ha)	Remedial action status and scheduled duration as of Dec. 31, 1991	Estimated waste volume (m^3)
Arizona			
Monument Valley (1968)	11.0;[b] 11.5[c]	Pending (38% complete); project will restart in July 1992/24 months	NA[d]
Tuba City (Sept. 1966)	8.9;[b] 128.3[c]	Completed in 1990	1,260,000
Colorado			
Durango (Mar. 1963)	51	Completed in 1991[e]	2,040,000
Grand Junction (Mar. 1970)	23.9;[b] 26.3[c]		3,580,000
Phase I[f]		Completed	
Phase II[g]		In progress (43% complete)	
Gunnison (Apr. 1962)	14.2;[b] 15[c]	Planned; Apr. 1992/28 months	655,000
Maybell (Nov. 1964)	29.7;[b] 69.2[c]	Planned; Apr. 1993/18 months	2,430,000
Naturita (1963)	h; 20.2[c]	Planned; Apr. 1993/17 months	452,000
New Rifle (Dec. 1972)	12.9;[b] 29.9[c]		3,130,000[i]
Phase I[f]		Completed	
Phase II[g]		Pending; Apr. 1992/38 months	
Old Rifle (1958)	5.5;[b] 18.8[c]		
Phase I[f]		Completed	
Phase II[g]		Pending; Apr. 1992/38 months	
Slick Rock – NC site (1957)	2.4;[b] 7.6[c]	Planned; Apr. 1993/17 months	472,000[j]
Slick Rock – UC site (1961)	7.7;[b] 26.3[c]	Planned; Apr. 1993/17 months	
Idaho			
Lowman (1960)	5.0;[b] 7.0[c]	Completed in 1991	101,000
New Mexico			
Ambrosia Lake (Apr. 1963)	44.9;[b] 230.7[c]		3,500,000
Phase I[f]		Completed	
Phase II[g]		Pending; Aug. 1991/29 months	
Shiprock (Aug. 1968)	29.1[b]	Completed in 1986	2,140,000
North Dakota			
Belfield (Oct. 1965)[k]	k; 14[c]	Planned; Apr. 1993/6 months	121,000[l]
Bowman (Feb. 1967)[k]	k; 26[c]	Planned; Apr. 1993/6 months	
Oregon			
Lakeview (1961)	16.2[b]	Completed in 1987	731,000
Pennsylvania			
Canonsburg (1957)	11.6[b]	Completed in 1985	226,000
South Dakota			
Edgemont[m]	NA[n]	Completed in 1988	34,400
Texas			
Falls City (Aug. 1973)	59.1;[b] 123.4[c]	Planned; Feb. 1992/36 months	4,170,000
Utah			
Green River (Jan. 1961)	3.6;[b] 16.3[c]	Completed in 1989	301,000
Mexican Hat (1965)	28.3;[b] 73.4[c]	Pending; April 1993/24 months	2,780,000[o]
Salt Lake City (Feb. 1964/July 1968)	24.3[b]	Completed in 1987	2,080,000[p]

Table 6.4 (continued)

State and site (last operation)	Site area (ha)	Remedial action status and scheduled duration as of Dec. 31, 1991	Estimated waste volume (m^3)
Wyoming			
Converse County (June 1965)	2.0;[b] 6.3[c]	Completed in 1989	240,000
Riverton (mid-year 1963)	29.1;[b] 56.7[c]	Completed in 1989	1,430,000
Total			31,873,400

[a]Data reported in refs. 7 and 8.
[b]Tailings site area.
[c]Other wastes site area.
[d]Not applicable. Waste volume included with that provided for Mexican Hat, Utah.
[e]Rock cover finalized in summer of 1991.
[f]Preparatory work (road construction and/or structure demolition).
[g]Storage of mill tailings or other waste.
[h]Tailings moved from site during 1977-1979; only contaminated soil remains. Mill area susceptible to flooding.
[i]Includes waste volume for Old Rifle, Colorado.
[j]Includes waste volume for Slick Rock, Colorado (UC site).
[k]No tailings; uraniferous lignite ashing plant; ore roasted and shipped away.
[l]Includes waste volume for Bowman, North Dakota.
[m]Vicinity properties only.
[n]Not applicable. Waste buried in a permanently capped cell repository a few miles south of Edgemont.
[o]Includes waste volume for Monument Valley, Arizona.
[p]Tailings were relocated 80 miles southwest of Salt Lake City near Clive, Utah.

Table 6.5. Projected volume and ^{226}Ra concentration in wastes at uncompleted UMTRAP sites as of December 31, 1991[a]

State and site	Estimated waste volume (m^3)	Radioactivity ^{226}Ra (pCi/g)
Arizona		
Monument Valley	NA[b]	49
Colorado		
Grand Junction	3,580,000	665
Gunnison	655,000	314
Maybell	2,430,000	187
Naturita	452,000[c]	46
Rifle	3,130,000	750
Slick Rock	472,000	200
Subtotal	10,719,000	
New Mexico		
Ambrosia Lake	3,500,000	455
North Dakota		
Belfield/Bowman	121,000[d]	45
Texas		
Falls City	4,170,000	200
Utah		
Mexican Hat	2,780,000	700
Total	21,290,000	

[a]Data reported in refs. 7 and 8.

[b]Not applicable. Waste volume included with that provided for Mexican Hat, Utah.

[c]Contaminated soil only.

[d]No tailings, uraniferous lignite ashing plant; ore roasted and shipped away.

Table 6.6. FUSRAP site descriptions, status, schedule, and volume of stored wastes[a]

State and site	Site area (ha)	Remedial action status and schedule as of Dec. 31, 1991	Volume of stored waste, m^3	
			Permanent	Interim
California				
Gilman Hall, Univ. of California, Berkeley	b	Completed in FY 1982	23	
Connecticut				
Seymour Specialty Wire	b	Planned in FY 1992		
Illinois				
Laboratories at Univ. of Chicago, Chicago	b	Completed in FY 1987	35	
National Guard Armory, Chicago	b	Completed in 1987	15	
Maryland				
W. R. Grace and Company, Curtis Bay	1.6	Planned in FY 2003-2004		
Massachusetts				
Shpack Landfill, Norton	3.2	Planned in FY 1993		
Ventron, Beverly	1.2	Partially completed; to be completed in FY 1994-1995	176	
Missouri				
St. Louis Airport, St. Louis	8.8	Partially completed; to be completed in FY 1997-1998		
St. Louis Airport (Vicinity Properties), St. Louis	b	Planned in FY 1996-1998		
Latty Avenue Properties, Hazelwood	b	Partially completed; to be continued through 2001		24,200[c]
St. Louis Downtown Site, St. Louis	18.2	Planned in FY 1998-2002		
Michigan				
General Motors, Adrian	b	Planned in FY 1998		
New Jersey				
E. I. du Pont de Nemours and Co., Deepwater	283	Planned in FY 2000		
Kellex Research Facility, Jersey City	6.2	Completed in FY 1981	209	
Middlesex Municipal Landfill, Middlesex	1.2	Completed in 1986		23,900[d]
Middlesex Sampling Plant, Middlesex	3.9	Partially completed; to be completed in FY 2003-2005		26,900[e]
W. R. Grace/Sheffield Brook/other properties, Wayne and Pequannock	b	Partially completed; to be continued through FY 2007		29,400[f]
Stepan Chemical Co., Ballod property and private properties on Latham St. and Davidson Ave., Maywood	b	Partially completed; to be continued through FY 2009		26,700[g]
New Brunswick Laboratory, New Brunswick	b	Partially completed; to be completed in FY 2007-2008		
New Mexico				
Acid/Pueblo/Los Alamos Canyons, Los Alamos	51.6	Completed in FY 1982	298	
Bayo Canyon, Los Alamos	137	Completed in FY 1982	1,160[h]	
Chupadera Mesa, White Sands Missile Range	b	None required[i]		

Table 6.6 (continued)

State and site	Site area (ha)	Remedial action status and schedule as of Dec. 31, 1991	Volume of stored waste, m^3	
			Permanent	Interim
New York				
Linde Air Products Div., Tonawanda	22.2	Planned in FY 1995-1996		
Colonie Interim Storage Site, Colonie	b	Partially completed; to be continued through FY 1994		918[j]
Niagara Falls Storage Site (Vicinity Properties), Lewiston	b	Completed in FY 1986		38,200[k]
Niagara Falls Storage Site, Lewiston	77	Partially completed; to be completed in FY 1993-1995		157,000[l]
Ashland Oil Co. (No. 1), Tonawanda	3	Planned in FY 1995		
Ashland Oil Co. (No. 2), Tonawanda	1	Planned in FY 1996		
Seaway Industrial Park, Tonawanda	4.8[m]	Planned in FY 1996-1997		
Baker and Williams Warehouses, New York	b	Partially completed; to be completed in FY 1993	2.5	
Oregon				
Albany Metallurgical Research Center, Albany	b	Completed in FY 1991	2,730	
Pennsylvania				
Aliquippa Forge, Aliquippa	0.34[n]	Partially completed; to be completed in FY 1993		
Tennessee				
Elza Gate, Oak Ridge	8.9	Partially completed; to be completed in FY 1992[o]	6,720	
Total (all sites)			11,368.5	327,218

[a]Data reported in ref. 10.
[b]Not determined.
[c]24,200 m^3 of waste in interim storage on-site.
[d]23,900 m^3 of waste transferred to Middlesex Sampling Plant for interim storage.
[e]26,900 m^3 of waste in interim storage on-site. Does not include 23,900 m^3 of Middlesex Municipal Landfill waste that is also stored on-site.
[f]29,400 m^3 of off-site property waste transferred to interim storage on-site.
[g]26,700 m^3 of waste in interim storage on-site.
[h]Stabilized in situ.
[i]Based on a radiological survey, it was determined that this site does not require any remedial action.
[j]918 m^3 of off-site property waste transferred to interim storage on-site.
[k]38,200 m^3 of off-site property waste transferred to interim storage on-site.
[l]Construction of the final cap is dependent upon final resolution concerning disposal of certain residues currently contained in the waste containment structure.
[m]Existing waste in the Seaway Landfill will remain in place based on pathway analysis findings.
[n]Total floor area that was surveyed; only isolated patches of radioactive contamination were found.
[o]On-site remedial action has been completed. Finalization of documentation to close out remedial action is in progress.

Table 6.7. Projected waste characteristics at uncompleted FUSRAP sites as of December 31, 1991[a]

State and site	Estimated waste volume (m^3)	Principal constituents	Major radioactive contaminants
Connecticut			
Seymour Specialty Wire	19	Rubble, metal	^{238}U
Maryland			
W. R. Grace and Company, Curtis Bay	27,500	Soil	^{232}Th
Massachusetts			
Shpack Landfill, Norton	7,190	Soil, concrete, metal, and rubble	^{238}U, ^{235}U, ^{226}Ra, ^{210}Pb
Ventron, Beverly	5,170	Soil, concrete, rubble, metal, and building material	^{238}U
Subtotal	12,360		
Missouri			
St. Louis Airport	191,000	Soil	^{238}U, ^{230}Th, ^{226}Ra
St. Louis Airport (Vicinity Properties), St. Louis	145,000	Soil	^{238}U, ^{226}Ra
Latty Avenue Properties, Hazelwood	137,000	Soil, rubble	^{238}U, ^{231}Pa, ^{230}Th, ^{227}Ac, ^{226}Ra
St. Louis Downtown Site, St. Louis	188,000	Soil, building material, and rubble	^{238}U, ^{230}Th, ^{226}Ra, ^{210}Pb, ^{222}Rn
Subtotal	661,000		
Michigan			
General Motors, Adrian	153	Soil, building material, and metal	^{238}U
New Jersey			
E. I. du Pont de Nemours and Co., Deepwater	6,320	Soil, building material, rubble, and, road material	^{238}U, ^{232}Th, ^{226}Ra, ^{210}Pb
Middlesex Sampling Plant, Middlesex	16,800	Soil, building material, and rubble	^{238}U, ^{232}Th, ^{226}Ra
W. R. Grace/Sheffield Brook/other properties, Wayne and Pequannock	53,900	Soil, rubble	^{238}U, ^{232}Th, ^{228}Th, ^{226}Ra
Stepan Chemical Co., Ballod property and private properties on Latham St. and Davidson Ave., Maywood	275,000	Soil, rubble	^{235}U, ^{238}U, ^{232}Th, ^{226}Ra, ^{40}K
New Brunswick Laboratory, New Brunswick	3,440	Soil, rubble	^{241}Am, ^{239}Pu, ^{238}U, ^{235}U, ^{226}Ra
Subtotal	355,613		

Table 6.7 (continued)

State and site	Estimated waste volume (m^3)	Principal constituents	Major radioactive contaminants
New York			
Linde Air Products Div., Tonawanda	20,500	Soil, building material, and equipment	^{238}U, ^{232}Th, ^{230}Th, ^{226}Ra
NL Bearings Plant and private properties on Central, Palmer, and Yardboro Avenues, Albany/Colonie	9,940	Soil, building material, equipment, and rubble	^{238}U, ^{226}Ra
Ashland Oil Co. (No. 1), Tonawanda	64,200	Soil	^{238}U, ^{232}Th, ^{226}Ra
Ashland Oil Co. (No. 2), Tonawanda	14,800	Soil	^{238}U, ^{232}Th, ^{226}Ra
Seaway Industrial Park, Tonawanda	89,500	Soil	^{226}Ra
Baker and Williams Warehouses, New York City	61	Building material	^{238}U
Subtotal	199,001		
Pennsylvania			
Aliquippa Forge, Aliquippa	29	Soil, concrete, metal	^{238}U, alpha, beta-gamma
Tennessee			
Elza Gate, Oak Ridge	80	Soil, concrete, building material, and plumbing	^{238}U, ^{226}Ra
Total (all sites)	1,255,602		

[a]Data reported in ref. 10.

ORNL PHOTO 6895-92

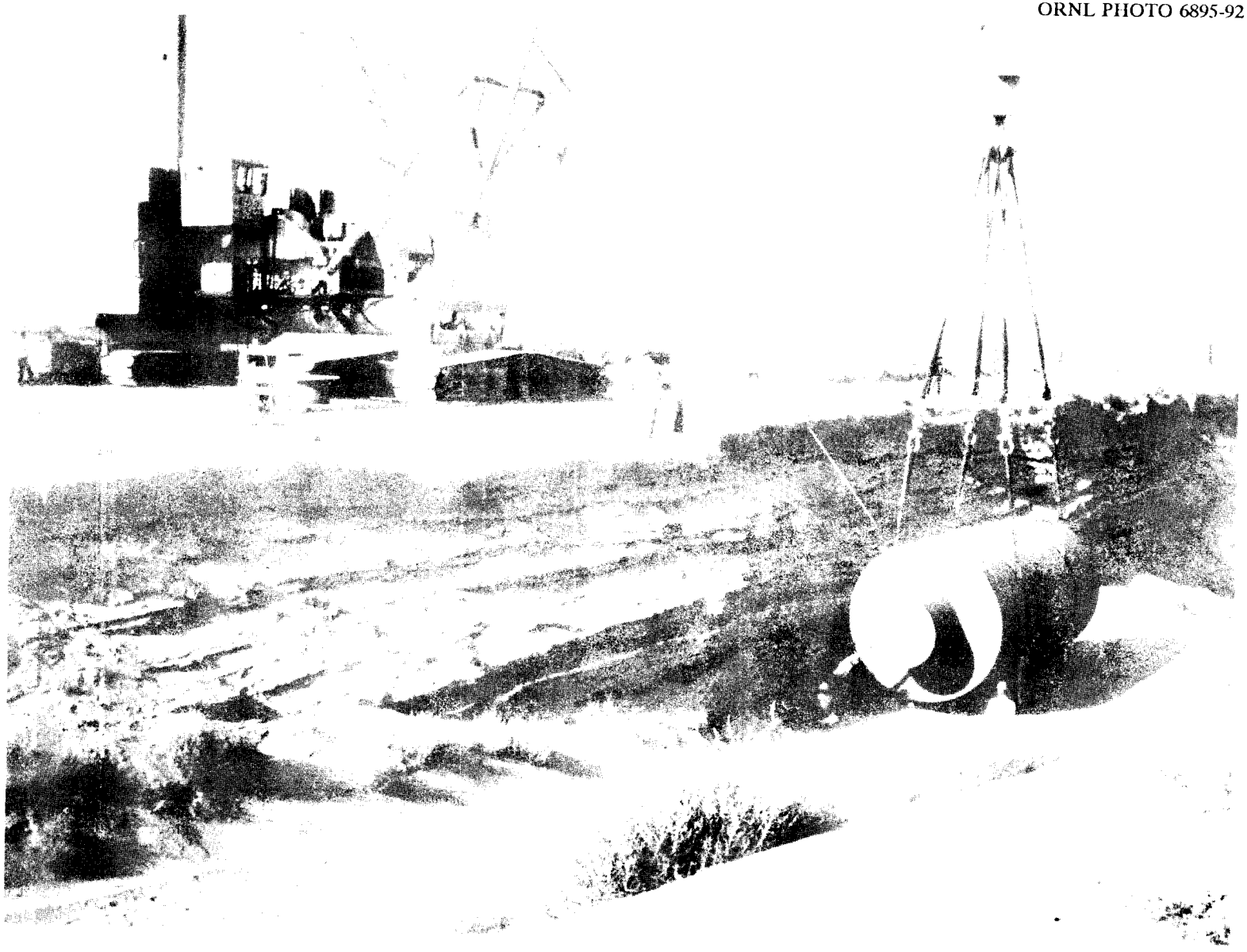


Photo 7.1. Burial of the 290-ton Pathfinder boiling-water reactor vessel at a low-level radioactive waste disposal site on August 27, 1991. (Courtesy of the Northern States Power Company, Minneapolis, Minnesota.)

7. COMMERCIAL DECOMMISSIONING WASTES

7.1 INTRODUCTION

At the end of their useful life, commercial nuclear facilities must be shut down and decommissioned. A schedule of historical and projected commercial LWR shutdowns, based on refs. 1 and 2, is given in Table 7.1. The projected volume, radioactivity, and thermal power of various types of waste generated from future commercial power LWR decommissioning activities are reported in Table 7.2. These waste projections are in addition to those previously reported in Chapter 4 (for LLW) and in Chapter 6 (for environmental restoration activities). This approach is taken mainly because the timing associated with future decontamination and decommissioning (D&D) activities at commercial power reactor sites is uncertain. The projected waste data shown in Table 7.2 are based on the projected LWR shutdown schedule given in Table 7.1 and decommissioning waste source terms developed from refs. 3–9. These projections also assume a 4-year period for decommissioning, beginning 2 years after reactor shutdown to allow sufficient preparation time for D&D operations. It was further assumed that the D&D wastes will be sent to disposal sites in four equal volumes during the 4 years of facility decommissioning. The power reactor shutdown schedule presented in Table 7.1 is based on utility estimates of reactor lifetime. Actual decommissioning schedules may be significantly different from those used herein if any of the following are implemented:

- reactors are upgraded to extend their operating lifetimes,
- significant radioactivity decay time is allowed before decommissioning operations begin, or
- the last core of spent fuel is required to remain on site for a minimum period (possibly several years) prior to shipment.

Estimates of wastes from decommissioning reference commercial LWRs and supporting fuel cycle facilities (for uranium conversion, enrichment, and fuel fabrication) are given in Table 7.3 (data from refs. 3–12). Most of these estimates assume a 40-year facility operating life. (In practice, the operating lifetime can vary significantly, depending on the extent to which facility equipment is periodically upgraded or retrofitted.) Not shown in this table are the radioactive wastes that will result from decommissioning of research, training, and test reactors.[13,14] However, the total volumes of these wastes are not expected to be significant, since such reactors are much smaller than commercial power reactors.

7.2 WASTE CHARACTERIZATION

The LWR decommissioning wastes can be grouped into three major categories:[4,7] (1) neutron-activated wastes, (2) surface-contaminated wastes, and (3) miscellaneous radioactive wastes.

Neutron-activated materials generally include the reactor vessel and its internal components (e.g., core support assemblies, control rod guide tubes) and the inner portion of the biological shield. Contaminated materials include much of the piping and equipment in the reactor containment, fuel, and auxiliary control buildings. In addition, some of the concrete surfaces of these buildings are expected to be radioactive and will require removal. The miscellaneous radioactive waste category consists of a small, but significant, group of materials that includes both "wet" and "dry" solid wastes. Wet radioactive wastes result from the processing of chemical decontamination solutions and contaminated water. These wastes include spent ion-exchange resins, cartridge filters, and evaporator and concentrator bottoms. Dry radioactive wastes include discarded contaminated items, such as rags and wipes, tools, and protective clothing. Many reactor items with surface contamination can be decontaminated,[15] rendering most of the material nonradioactive and producing a smaller, more concentrated volume of waste containing the radioactivity. Waste decontamination requires the appropriate technology and a defined level of radioactivity at which a waste is below an acceptable level of contamination. Establishing such criteria is complicated because there are varying levels of natural radioactivity. Minimum regulatory levels have already been defined in Europe;[16] the EPA, which has responsibility for defining such levels in the United States, began a review of criteria in 1984. Currently, the NRC handles requests to declare a waste below regulatory concern on a case-by-case basis. Depending on the level of technology and the minimum regulatory level definition, actual decommissioning waste volumes could vary somewhat from the estimates reported

in Table 7.3. However, the total radioactivity in the D&D waste from a particular facility is not expected to change significantly from that projected.

A list of the larger commercial power reactors that have undergone some mode of decommissioning to date is provided in Table 7.4 (data from refs. 2 and 17). (A comprehensive listing of all types of domestic reactors that have been shut down or dismantled is given in ref. 2.) As described in ref. 18, the NRC has defined the three major alternative classifications for decommissioning of nuclear facilities:

- DECON. This is defined as ". . . the alternative in which the equipment, structures and portions of a facility and site containing radioactive contaminants are removed or decontaminated to a level that permits the property to be released for unrestricted use shortly after cessation of operations."

- SAFSTOR. This is defined as ". . . the alternative in which the nuclear facility is placed and maintained in such condition that the nuclear facility can be safely stored and subsequently decontaminated (deferred decontamination) to levels that permit release for unrestricted use."

- ENTOMB. This is defined as ". . . the alternative in which radioactive contaminants are encased in a structurally long-lived material, such as concrete. The entombment structure is appropriately maintained, and continued surveillance is carried out until the radioactivity decays to a level permitting unrestricted release of the property." (This alternative would be allowable for nuclear facilities contaminated with relatively short-lived radionuclides such that all contaminants would decay to levels permissible for unrestricted use within a period on the order of 100 years.)

Decommissioning operations collect LLW plus a small volume of high-activity wastes from certain reactor core internal parts. These high-activity wastes are often referred to as "high-activity activation wastes." Under NRC rules, many of these wastes would be classified as greater-than-Class-C (GTCC) LLW. Some GTCC wastes contain significant concentrations of long-lived, nontransuranic radioisotopes, such as ^{59}Ni, ^{63}Ni, and ^{94}Nb. These isotopes are generated by long-term irradiation of stainless steel and some other alloys used for reactor core structural components. Because the method of waste disposal for these reactor internals is different from LLW disposal, GTCC wastes are reported separately. Under current NRC regulations,[19,20] these wastes are considered not generally acceptable for shallow-land disposal. Such wastes must be put into a federal geologic repository unless the NRC approves an alternative disposal in a licensed site. High-activity activation wastes from the immediate decommissioning of LWRs are estimated to make up less than 1% of the total waste volume, but they contain more than 95% of the radioactivity.[4,7] Such reactor wastes are comprised of many long-lived radionuclides. Most of this radioactivity is in a single reactor component, the stainless steel core shroud that surrounds the reactor fuel.

As reported in ref. 21, a study of reactor decommissioning wastes is being made by the Pacific Northwest Laboratory for the NRC. This study includes an analysis of wastes from the Shippingport Station decommissioning and an analysis of neutron-activated metal components (GTCC materials) from the internals of other reactors. Thus far, the waste characterization assessments from this study have indicated the following:

- All reactor decommissioning materials, except the pressure vessel internals, have the potential for being disposed of as Class-A LLW;
- Fission products and TRU radionuclides are absent; and
- Most radioactivity results from neutron-activation products, of which ^{60}Co is the principal contributor.

Additional updated information on the radioactive characteristics of commercial reactor D&D wastes (in particular, spent LWR control rod assemblies) will be documented in future supplements to ref. 21.

7.3 INVENTORIES AND PROJECTIONS

Of the reactors listed in Table 7.4, only three, the Elk River station, the Santa Susana sodium reactor, and the Shippingport station (discussed later), have been completely dismantled. A summary of the wastes from decommissioning the Elk River station is provided in Table 7.5 (data from refs. 22–24). Types and volumes of wastes from decommissioning the Santa Susana reactor are reported in Table 7.6 (data from ref. 25).

For the projections listed in Table 7.2, a 6-year period for decommissioning activities is assumed: 2 years for planning and preparation and 4 for actual decommissioning, with wastes generated equally over the final 4 years. The option does exist, however, to delay decommissioning for 10 to 60 years after reactor shutdown to allow significant radioactive decay.[18] For example, radioactivity levels in PWR piping have been estimated to decrease, in 10 years, to 8.7% and, in 30 years, to 0.63% of the radioactivity levels at the time of reactor shutdown. At PWR shutdown and for about 4 years thereafter, ^{55}Fe and ^{60}Co control the radiation levels; from 4 to about 100 years, ^{60}Co and ^{63}Ni control radiation levels; and well beyond 100 years, ^{59}Ni and ^{94}Nb control radiation levels.[7] The choice between immediate or delayed decommissioning involves cost trade-offs between the costs of storage with delayed decommissioning versus the higher costs resulting from the higher radiation levels associated with rapid decommissioning.[26] Therefore, the start of

actual decommissioning may be much later than the shutdown date (Table 7.1) to allow plant radiation levels to decay to lower levels. Another consideration is that the last core of discharged spent fuel may need to remain at the reactor site for at least 5 years prior to shipment. Table 7.7 shows the effects of various decommissioning alternatives on the volumes and radioactivities of D&D wastes from a reference BWR[3-5] and a reference PWR.[6-8] For cases involving deferred D&D activities, it is evident that both the volumes and activities of wastes significantly decline after a safe storage period of 50 years.

Inventories and projections of wastes from three major DOE decommissioning programs are summarized in Tables 7.8, 7.9, and 7.10 (data from refs. 27-29). The first of these tables lists waste inventory and projection data for completed decommissioning activities at the Shippingport Station Decommissioning Project, site of the first domestic commercial power reactor. The facility was shut down in 1982, and physical dismantling began in September 1985. During April 1989, the decommissioned reactor pressure vessel from the Shippingport Station was received for disposal at the Hanford site after an 8000-mile water journey. The pressure vessel was the last major reactor component to be shipped from the facility. Shippingport decommissioning activities were completed in 1990.[27]

Table 7.9 (data from ref. 28) presents a summary of the West Valley Demonstration Project (WVDP), formerly a commercial fuel reprocessing facility. Since startup of the project in 1982, more than 70% of the original process building's cell surface areas have been decontaminated and released for project reuse.

Inventories and projections of wastes from decontamination activities at the damaged Three Mile Island-Unit 2 reactor are summarized in Table 7.10. Removal of core debris from the damaged reactor started in January 1986 and was completed in April 1990. This resulted in the shipment of 155.9 t of core debris to INEL for R&D testing and storage. TMI-Unit 2 is currently scheduled to have Post Defueling Monitored Storage (PDMS) preparation activities completed by the end of 1993. Imitation of PDMS activities will require NRC approval of a submitted licensing change request.[29]

Decommissioning waste projections are being compiled on several other reactors and a fuel fabrication plant. The reactors include Dresden Unit 1, La Crosse, Saxton, Humboldt Bay Unit 3, Diablo Canyon Units 1 and 2, Rancho Seco, Fort St. Vrain, Peach Bottom (HTGR and BWR units), Pathfinder, and Shoreham.

The Commonwealth Edison Company has issued a decommissioning plan and environmental report[30] for the Dresden Unit 1 nuclear power station. Commonwealth Edison plans to decommission this reactor by first placing the facility in a SAFSTOR condition until Dresden Units 2 and 3 are ready for decommissioning. If an extended life program for Units 2 and 3 is not initiated, all three Dresden units will be decommissioned by dismantling, beginning in 2017. A summary of projected radioactive materials from the SAFSTOR decommissioning of the Dresden Unit 1 station is given in Table 7.11 (data from refs. 30 and 31).

The La Crosse BWR was shut down in 1987 and placed in SAFSTOR in 1988. Current plans are to dismantle the reactor after a SAFSTOR period of 25 years. Projected volumes and associated activities of annual waste shipments from this reactor during this period are given in Table 7.12 (data from ref. 32).

The Saxton Nuclear Experimental Reactor is a 3-MW(e) PWR that was placed in SAFSTOR following its shutdown in 1972. Work on dismantling the reactor site (DECON) started in 1986. To date, decontamination activities have been completed of the control room and radwaste building. The reactor containment building is not scheduled for dismantling until the mid-1990s. A summary of projected waste characteristics from dismantling the Saxton site is provided in Table 7.13 (data from ref. 33).

Projections of decommissioning wastes from reactors owned and operated by the Pacific Gas and Electric Company are provided in Tables 7.14 and 7.15. The waste data reported in these tables are based on decommissioning studies made of the 65-MW(e) Humboldt Bay Unit 3 BWR[34] and the 1100-MW(e) Diablo Canyon PWR Units 1 and 2.[35] Projections for the Humboldt Bay BWR in Table 7.14 include wastes from completely dismantling the reactor following a SAFSTOR period of 30 years (i.e., SAFSTOR with delayed DECON). Projections for the Diablo Canyon units in Table 7.15 reflect wastes from immediate dismantlement (DECON) of these reactors following a 30-year period of operation. Units 1 and 2 were started up in 1985 and 1986, respectively.

The Rancho Seco reactor is a 918-MW(e) PWR that was shut down in 1989. Table 7.16 (data from ref. 36) lists projected volumes of wastes from the dismantlement of this reactor following a SAFSTOR period of about 20 years.

Projections of wastes from DECON (dismantling) of the 330-MW(e) Fort St. Vrain HTGR are reported in Table 7.17 (data from refs. 37 and 38). This reactor was shut down in August 1989.

The 40-MW(e) Peach Bottom HTGR (Unit 1) was shut down in 1974 and placed in SAFSTOR. To put the reactor in this mode of decommissioning, 490 containers of solid radioactive waste were packaged and shipped. This solid waste represented a total volume of nearly 400 m^3 and an activity level of 380 Ci. In addition, about 1.14 m^3 (300 gal) of liquid waste, consisting of contaminated oil, were processed or solidified.[39]

Projections of decommissioning wastes have been made for the 1065-MW(e) Peach Bottom BWRs (Units 2 and 3). These are reported in Table 7.18 (data from ref. 40) for a case involving prompt removal and reactor dismantling (DECON).

The 66-MW(e) Pathfinder BWR was placed in the SAFSTOR mode following its shutdown in 1967. Work on dismantling the reactor (DECON) began in July 1990.

The scope of this phase of decommissioning includes the reactor building, the fuel handling building, the fuel handling area and [illegible] the surrounding areas. By May 1991, most of the piping, pumps, tanks, wiring, ventilation, and miscellaneous systems were removed and disposed of. The reactor vessel was lifted out of [illegible] on May 11, 1991. The decommissioning team shipped the vessel via rail later in 1991. Upon completion of the phase of decommissioning in 1992, only trace [illegible] contamination will remain in the operating, converted fossil plant. Waste inventories and projections from D&D activities at the Pathfinder Reactor [illegible] in Table 7.19 (data from ref. 41).

The 820 MW(e) Shoreham BWR underwent low-power tests in 1989 when the plant's owner, Long Island Lighting Company, agreed to sell the plant to the state of New York for decommissioning. A proposed decommissioning plan (ref. 42) for the Shoreham plant has been prepared and is being reviewed by the NRC. [illegible] of [illegible] waste reported in the Shoreham decommissioning plan are presented in Table 7.20. The volume estimates in this table are conservative because they do not take credit for any volume reduction techniques and, further, because they assume no systems or structures will be decontaminated below the release criteria in place. It is also assumed that even with decontamination of contaminated systems and the reactor pressure vessel, the components will need to be dismantled and disposed of offsite.

Table 7.21 (data from ref. 43) reports projections of wastes from decommissioning the Indian Point Unit 1 reactor. This 265 MW(e) PWR was shut down in 1974 and [illegible] to SAFSTOR. The projections of Table 7.21 [illegible] the case of complete dismantlement (DECON) of the Unit 1 station upon completion of its SAFSTOR phase, which will be when the Unit 2 (PWR) station is finally shut down.

Inventories and projections of wastes from decommissioning activities at the Cimarron (Oklahoma) Fuel Fabrication Facility are provided in Table 7.22 (data from ref. 44). Decontamination work at this fabrication plant is scheduled to be completed during 1993.

Currently, the total impact of wastes from D&D activities at commercial reactor and fuel cycle sites has been small. However, this will become more significant after the year 2000, when more of the older reactors complete their campaign of operation.

In addition to wastes from the decommissioning of commercial reactor and fuel cycle facilities, there will be some resulting from Department of Defense power plant decommissioning operations. During a period spanning 20 to 30 years, approximately 100 nuclear-powered submarines of the U.S. Navy may be taken out of service and consigned to permanent disposal after removal of spent fuel. Current plans are to dispose of the submarine reactor compartments by land burial at government-owned LLW burial sites. Each reactor compartment contains about 1000 t of metal, and it is estimated that 100 reactor compartments can be buried on 4 ha (10 acres) of land.[45] As of the end of 1991, 40 submarines had been taken out of active service. In 20 of these submarines, the reactor compartment was first defueled, then later removed and disposed of at a government burial site. (LLW disposed from these activities is included in the DOE site inventories reported in Chapter 4.) The remaining 20 submarines with reactor compartments were being held in protective storage.[2]

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Table 7.1. Schedule of final shutdown dates for commercial light-water reactors[a,b]

Calendar year of shutdown	BWR		PWR		Total LWR	
	No.	MW(e)	No.	MW(e)	No.	MW(e)
1963	1	5			1	5
1967	1	66	1	17	2	83
1968	2	39			2	39
1972			1	3	1	3
1974			1	265	1	265
1976	1	65			1	65
1978	1	200			1	200
1979			1	926[c]	1	926
1982			1	72	1	72
1987	1	48			1	48
1989	1	820	1	918	2	1,738
Totals through 1991	8	1,243	6	2,201	14	3,444
2000			1	175	1	175
2003	1	72			1	72
2007			2	1,018	2	1,018
2009	2	1,270	1	490	3	1,760
2010	2	1,454	2	1,197	4	2,651
2011	2	1,339	1	805	3	2,144
2012	4	2,747	4	2,803	8	5,550
2013	1	1,065	9	7,314	10	8,379
2014	6	5,288	5	3,620	11	8,908
2015	2	1,642	4	3,875	6	5,517
2016	2	1,886	5	4,590	7	6,476
2017			3	2,560	3	2,560
2018	1	784	3	2,919	4	3,703
2020			2	2,055	2	2,055
2021			4	4,272	4	4,272
2022	2	2,187	2	1,970	4	4,157
2023			3	3,064	3	3,064
2024	4	4,537	2	2,257	6	6,794
2025	3	3,084	6	6,908	9	9,992
2026	2	2,383	3	3,565	5	5,948
2027	2	2,013	6	6,431	8	8,444
2028			2	2,425	2	2,425
2029	1	1,055	2	2,319	3	3,374
2030			2	2,300	2	2,300
Projected totals (1992-2030)	37	32,806	74	68,932	111	101,738

[a]Data from refs. 1 and 2.

[b]Projected reactor shutdown dates are based on the DOE/EIA No New Orders Case. Years in which no reactor shutdown is expected are eliminated.

[c]Shutdown of Three Mile Island-Unit 2 nuclear power plant due to an accident. Upon completion of the present cleanup campaign, the plant will be placed in a monitored storage mode and will be decommissioned when TMI-Unit 1 is dismantled.

Table 7.2. Projections of cumulative volume, radioactivity, and thermal power of wastes from decommissioning commercial light-water reactors shut down during 1992-2030[a,b,c]

Waste type	Volume (m^3)	Activity (Ci)	Thermal power (W)
	Boiling-water reactors		
Class-A LLW	525,805	46,009	352
Class-B LLW	10,595	143,037	1,103
Class-C LLW	1,505	477,399	1,767
Subtotals	537,905	666,445	3,222
Greater-than-Class-C LLW[d]	281	4,733,919	29,450
Totals for D&D of BWRs	538,186	5,400,364	32,672
	Pressurized-water reactors		
Class-A LLW	1,053,693	218,859	1,150
Class-B LLW	12,554	294,567	2,593
Class-C LLW	998	251,453	1,887
Subtotals	1,067,245	764,879	5,630
Greater-than-Class-C LLW[d]	267	45,474,178	266,148
Totals for D&D of PWRs	1,067,512	46,239,057	271,778
	Total light-water reactors		
Total LLW	1,605,150	1,431,324	8,852
Greater-than-Class-C LLW	548	50,208,097	295,598
Totals for D&D of LWRs	1,605,698	51,639,421	304,450

[a]The projections of this table are based on a decommissioning scenario which assumes that upon reactor shutdown, there will be a 2-year planning period followed by a 4-year decontamination campaign, with wastes being collected equally over each of the 4 years. In terms of numerical significance, the number of digits used to report these projections is greater than justified. However, this procedure is used for bookkeeping purposes to ensure consistency in the numerical totals reported. Since these projections are based on the reactor shutdown dates reported in ref. 1 and the source terms developed from refs. 3-9 (see Appendix A), each reported number is significant to no more than three figures.

[b]This table refers only to reactors yet to be decommissioned. Historical reactor D&D wastes are included in the institutional/industrial (I/I) waste inventories reported in Chapter 4.

[c]The projections in this table are cumulative levels for year 2036, the last year in which wastes are collected from reactors shut down in year 2030.

[d]Contribution from the core shroud (see ref. 9).

Table 7.3. Projections of radioactive wastes from decommissioning reference commercial power reactors and fuel cycle facilities[a]

Fuel cycle facility	Capacity	Operation		Decommissioning alternative	Waste volume, m^3	
		Period	Lifetime (years)		LLW[b]	GTCC[c]
Boiling-water reactor	1,155 MW(e)	–	40[d]	DECON	18,938	10[e]
Pressurized-water reactor	1,175 MW(e)	–	40[d]	DECON	18,192	5[e]
Uranium conversion plant (solvent extraction process)	10,000 MTIHM/year	–	40	DECON	1,260	0
Uranium enrichment plants (gaseous diffusion plants)						
• K-25 site	7,700,000 kg SWU/year	1945-1985	40	DECON	910,112	0
• Paducah site	11,300,000 kg SWU/year	1954-2005	51	DECON	662,414	0
• Portsmouth site	8,300,000 kg SWU/year	1956-2005	49	DECON	630,093	0
Fuel fabrication plant	1,000 MTIHM/year	–	40	DECON	1,090	0

[a]Based on information reported in refs. 3-12.
[b]Class-A, Class-B, and Class-C LLW.
[c]Greater-than-Class-C LLW.
[d]Reactor operations assume a 75% capacity factor.
[e]Assumes contributions only from the core shroud. Estimated from information provided in the report DOE/LLW-114 (ref. 9).

Table 7.4. List of U.S. civilian reactors shut down or dismantled as of December 31, 1991[a]

[Reactors of 10-MW(th) capacity or greater]

Reactor facility	Location	Reactor type	Capacity rating		Year of shutdown	Decommissioning alternative selected	Present status of decommissioning alternative
			MW(e)	MW(th)			
Boiling Nuclear Superheater Power Station (BONUS)	Punta Higuera, PR	Boiling-water	17	50	1968	ENTOMB	ENTOMB
Carolinas-Virginia Tube Reactor (CVTR)	Parr, SC	Pressure-tube, heavy-water	17	64	1967	SAFSTOR	SAFSTOR
Dresden Nuclear Power Station, Unit 1	Morris, IL	Boiling-water	200	700	1978	SAFSTOR	SAFSTOR preparation[b]
Elk River Power Station	Elk River, MN	Boiling-water	22	58	1968	DECON	DECON completed[c]
Enrico Fermi, Unit 1	Lagoona Beach, MI	Sodium-cooled, fast	61	200	1972	SAFSTOR	SAFSTOR
ESADA/GE Vallecitos Experimental Superheat Reactor (Empire States Atomic Development Associates and General Electric Company)	Pleasanton, CA	Light-water, moderated	NE[d]	17	1967	SAFSTOR	SAFSTOR
Fort St. Vrain Reactor	Platteville, CO	High-temperature, gas-cooled	330	842	1989	TBD[e]	TBD
General Electric Testing Reactor	Pleasanton, CA	Tank	NE	50	1977	SAFSTOR	SAFSTOR
Hallam Nuclear Power Facility	Hallam, NE	Sodium-cooled, graphite-moderated	75	240	1964	ENTOMB	ENTOMB
Humboldt Bay Power Plant, Unit 3	Eureka, CA	Boiling-water	65	242	1976	SAFSTOR	SAFSTOR[f]
Indian Point Station, Unit 1	Buchanan, NY	Pressurized-water	265	615	1974	SAFSTOR[g]	SAFSTOR
La Crosse Nuclear Generating Station	Genoa, WI	Boiling-water	48	165	1987	SAFSTOR	SAFSTOR[h]
Pathfinder Atomic Plant	Sioux Falls, SD	Boiling-water	66	203	1967	DECON	DECON[i]
Peach Bottom Power Station, Unit 1	Peach Bottom, PA	High-temperature, gas-cooled	40	115	1974	SAFSTOR	SAFSTOR
Piqua Nuclear Power Facility	Piqua, OH	Organic-cooled and moderated	11	46	1966	ENTOMB	ENTOMB

Table 7.4 (continued)

Reactor facility	Location	Reactor type	Capacity rating MW(e)	Capacity rating MW(th)	Year of shutdown	Decommissioning alternative selected	Present status of decommissioning alternative
Plum Brook Reactor	Sandusky, OH	Tank	NE	60	1974	SAFSTOR	SAFSTOR
Rancho Seco	Clay Station, CA	Pressurized-water	918	2,815	1989	SAFSTOR	SAFSTOR preparation[j]
Saxton Nuclear Experimental Reactor Project	Saxton, PA	Pressurized-water	3	24	1972	SAFSTOR	DECON in progress[k]
Shippingport Power Station	Shippingport, PA	Pressurized-water	72	236	1982	DECON	DECON completed[l]
Shoreham Reactor	Brookhaven, NY	Boiling-water	820	2,436	1989	DECON	DECON preparation[m]
Sodium Reactor Experiment	Santa Susana, CA	Sodium-cooled, graphite-moderated	10	30	1964	DECON	DECON completed[n]
Southwest Experimental Fast Oxide Reactor (SEFOR)	Strickler, AR	Sodium-cooled, fast	NE	20	1972	SAFSTOR	SAFSTOR
Three Mile Island-Unit 2 Reactor	Londonderry Township, PA	Pressurized-water	926	2,770	1979	o	o
Vallecitos Boiling-Water Reactor (VBWR)	Pleasanton, CA	Boiling-water	5	33	1963	SAFSTOR	SAFSTOR
Westinghouse Testing Reactor (WTR)	Waltz Mill, PA	Tank	NE	60	1962	SAFSTOR	SAFSTOR
Yankee Rowe, Unit 1	Bolton, MA	Pressurized-water	175	530	1992	TBD	TBD

[a]Based on refs. 2 and 17.
[b]Estimates of decommissioning wastes are reported in Table 7.11.
[c]Decommissioning wastes are reported in Table 7.5.
[d]NE = no electricity generated by reactor before it was shut down.
[e]TBD = to be determined. Decommissioning wastes for the DECON option are reported in Table 7.17.
[f]Estimates of decommissioning wastes are reported in Table 7.14.
[g]Estimates of decommissioning wastes are reported in Table 7.21.
[h]Estimates of decommissioning wastes are reported in Table 7.12.
[i]Estimates of decommissioning wastes are reported in Table 7.19.
[j]Decommissioning wastes are reported in Table 7.16.
[k]DECON of the Saxton facility started in 1986. Estimates of decommissioning wastes are given in Table 7.13.
[l]Decommissioning wastes are reported in Table 7.8.
[m]A proposed decommissioning plan on the Shoreham reactor is undergoing review by the NRC. Estimates of decommissioning wastes are reported in Table 7.20.
[n]Decommissioning wastes are reported in Table 7.6.
[o]TMI-Unit 2 has completed defueling and decontamination in selected areas. The plant will be placed in a long-term monitored storage mode and will be decommissioned when TMI-Unit 1 is dismantled. Inventories of decontamination wastes are reported in Table 7.10.

Table 7.5. Types and quantities of wastes from decommissioning the Elk River reactor site[a,b]

Reactor component or waste type[c]	Volume (m^3)	Mass (t)	Radioactivity[d] (Ci)
Reactor pressure vessel	4.6	36.0	1,110
Reactor internals			
Upper shroud	e	e	770
Lower shroud	e	e	35
Core and shroud plate	e	e	2,370
Core support stand	e	e	100
Inner thermal shield	e	e	3,090
Shadow shields	e	e	2,330
Feedwater distribution ring	e	e	75
Subtotals (internals)	1.1	8.1	8,770
Externals	5.3	54.0	440[f]
Biological shield	5.9	39.0	5.8
Miscellaneous radioactive contaminated materials (excluding concrete)	1,350	1,090	e
Contaminated concrete	2,010	2,680	e
Totals	3,377	3,907	>10,325

[a]Based on information reported in COO-651-93 (ref. 22), BNL-NUREG-29244R (ref. 23), and ref. 24.

[b]The Elk River BWR operated from 1963 to 1968 and generated 58.29 MW(e)-years of (gross) electrical energy. The plant was decommissioned from 1971 to 1974. During this time, the reactor was completely dismantled.

[c]All decommissioning wastes were shipped to Sheffield, Illinois.

[d]Estimated at the start of decommissioning.

[e]Information not available.

[f]Includes 75 Ci estimated for the outer thermal shield of the reactor.

Table 7.6. Types and volumes of wastes from decommissioning the Santa Susana Sodium Reactor Experiment site[a,b]

Type of waste[c]	Shipping container volume, m^3					
	King-Pac[d]	Boxes[e]	Casks	Drums	Unboxed	Totals
Activated vessel components		301	20		18	339
Contaminated components		1,458	49	29	17	1,553
Contaminated soil and concrete	1,752			42		1,794
Absorbed alcohol and other solidified liquids				141		141
Disposed liquid				36		36
Totals	1,752	1,759	69	248	35	3,863

[a]Based on information reported in ESG-DOE-13403 (ref. 25). Activity data were not available.

[b]This sodium-cooled, graphite-moderated reactor operated from 1957 to 1964 and generated 4.244 MW(e)-years of (gross) electrical energy. The plant was decommissioned from 1974 to 1983. During this time, the reactor was completely dismantled.

[c]Initially, these wastes were shipped to Beatty, Nevada. Later in the decommissioning program, they were shipped to Hanford, Washington.

[d]This is a registered trademark for tri-walled cardboard containers used for packaging low-specific-activity nonmetallic wastes (e.g., contaminated soil, bedrock, and concrete rubble).

[e]Wooden boxes used for packaging low-specific-activity wood or steel.

Table 7.7. Estimated volumes and activities of wastes from decommissioning alternatives considered for reference LWRs[a,b,c]

Decommissioning alternative	Totals		Class-A LLW		Class-B LLW		Class-C LLW	
	Volume (m^3)	Activity (10^3 Ci)	Volume (m^3)	Activity (10^3 Ci)	Volume (m^3)	Activity (10^3 Ci)	Volume (m^3)	Activity (10^3 Ci)
Reference boiling-water reactor [1,155 MW(e)]								
Immediate decontamination following shutdown	18,938	295.8	18,512	13.9	373	42.8	53	239.1
Deferred decontamination after a safe storage period of:								
30 years[d]	18,938	9.0	18,652	1.4	233	1.1	53	6.5
50 years[d]	1,736	5.9	1,450	0.2	247	1.0	39	4.7
100 years[d]	1,626	4.0	1,340	0.1	247	0.6	39	3.3
Entombment[e]	8,031	286.6	7,605	4.7	373	42.8	53	239.1
Reference pressurized-water reactor [1,175 MW(e)]								
Immediate decontamination following shutdown	18,192	124.7	17,961	37.3	214	53.1	17	34.3
Deferred decontamination after a safe storage period of:								
30 years[d]	18,195	3.6	18,055	1.5	123	0.6	17	1.5
50 years[d]	1,700	1.6	1,568	0.3	115	0.2	17	1.1
100 years[d]	1,650	1.0	1,533	0.2	100	<0.1	17	0.8
Entombment[e]	3,367	126.5	3,136	39.1	214	53.1	17	34.3

[a]From refs. 3-8. Activities were calculated from data reported in refs. 3-8. Data for each reactor are based on 40 years of operation and a capacity factor of 0.75.

[b]Based on limiting concentration of long- and short-lived radionuclides given in Tables 1 and 2 of 10 CFR 61.55.

[c]Estimates for GTCC wastes from LWR decommissioning (DECON) were recently developed by EG&G Idaho, Inc. and are reported in ref. 9. A summary of all GTCC wastes estimated in ref. 9 for LWR operations and decommissioning activities is presented in Chapter 4.

[d]Includes radioactive wastes from both preparations for safe storage and deferred decontamination.

[e]Involves the removal of reactor spent fuel (shipped to repository) followed by the encasement of the rest of the radioactive portion of the reactor facility.

Table 7.8. Characteristics of wastes from decommissioning activities at the Shippingport Station Decommissioning Project[a,b]

Type of waste	Total waste removed from the Shippingport reactor facility		
	Volume (m^3)	Mass (kg)	Activity (Ci)
Liquid	2,187	c	0.64
Solid[d]			
Reactor pressure vessel package	283	815,560	16,467
Spent resins	101	56,429	40.82
Asbestos	1,072	138,205	2.49
Compacted trash	24	12,412	0.04
Metallic waste	1,801	1,117,113	41.59
Large, one-piece components	326	455,230	24.27
Concrete	52	52,470	0.08
Lead	57	62,302	0.17
Soil	53	31,493	1.44
Solidified sludge	164	198,066	4.30
Other solids	2,123	833,976	26.54
Total solid waste	6,056	3,773,256	16,608.75

[a]Based on ref. 27.

[b]The Shippingport reactor operated from 1957 to 1982, generating 841.8 MW(e)-years of (gross) electrical energy. During its history, the reactor operated with three different cores. Two of these were light-water cooled, seed-blanket, PWR-type cores. The third and last core in the reactor was a seed-blanket LWBR-type. Physical dismantling began in September 1985 and was completed in July 1989.

[c]Information not available.

[d]Solid waste volume and mass include total volume and total mass as packaged.

Table 7.9. Inventories and projections of wastes from various activities at the West Valley Demonstration Project[a,b]

Waste description	Total wastes as of December 31, 1991	Projected total wastes upon completion of the project[c]
Spent fuel remaining[d]		
Mass, MTIHM	27	27
Number of fuel assemblies	125	125
High-level waste generated from reprocessing operations (1966-1972)[e]		
Volume, m^3 (waste form)	1,231 (liquid, sludge, and zeolite)	210 (glass)
Activity, Ci[f]	27,250,000	23,590,000[g]
Transuranic waste generated from presolidification activities and HLW vitrification		
Volume, m^3	42	300
Activity, Ci[f]	66	350
Low-level waste generated from presolidification activities and HLW vitrification		
Buried waste (1982-86) volume, m^3	5,786	15,000
Buried waste (1982-86) activity, Ci[f]	625	58,600
Stored waste volume, m^3	5,400[h]	
Stored waste activity, Ci[f]	433[i]	
Low-level waste incorporated in cement by radwaste treatment system[j]		
Stored waste volume, m^3	3,002	
Stored waste activity, Ci[f]	295	
Low-level waste from postsolidification D&D after HLW vitrification		
Volume, m^3	0	4,300
Activity, Ci[f]	0	1,400
Total low-level summary (buried and stored wastes)		
Volume, m^3	14,188	
Activity, Ci[f]	1,353	

[a]Based on data reported in ref. 28.

[b]At the West Valley Demonstration Project (WVDP) site, Nuclear Fuel Services, Inc., operated a reprocessing plant with a rated capacity of 300 MTIHM/year. During its operation from 1966 to 1972, 640 t of spent fuel were reprocessed.

[c]Wastes generated after 1987 are regarded as stored, not buried or disposed.

[d]At the end of 1990, 125 fuel assemblies (representing 27 t of spent fuel) still remained in storage at the WVDP. These assemblies are owned by DOE. The return shipment of all commercially owned spent fuel (625 fuel assemblies) to the owner utilities was completed by the end of 1986.

[e]Currently, about 2,031 m^3 of HLW is stored at the WVDP site in two underground steel tanks. Eventually, this waste will be vitrified and about 300 canisters of glass will be produced. This assumes each canister contains 0.70 m^3 of glass.

[f]Principal nuclides include ^{241}Am, ^{241}Pu, ^{137}Cs, ^{99}Tc, ^{90}Sr, and ^{63}Ni.

[g]Decayed activity for 1997.

[h]Comprised of Class A (89.5%), Class B (8.5%), and Class C (2.0%) LLW.

[i]Comprised of Class A (24.7%), Class B (64.1%), and Class C (11.2%) LLW.

[j]Comprised of Class A and Class C LLW (see Table A.10 of Appendix A).

Table 7.10. Characteristics of wastes from decontamination activities at the Three Mile Island-Unit 2 reactor site[a,b]

Type of waste	Mass shipped (t)	Total waste shipped from TMI (August 1979 through December 1991)	
		Packaged volume (m^3)	Shipment activity[c] (Ci)
Spent fuel/core debris[d]	155.9	123.9	6,911,513
Low-level and other wastes[e]			
Dry activated waste (DAW)[f]	-	5,880.1	709.94
Wet and solidified waste[g]	-	275.4	7,462.2
Submerged demineralizer system (SDS)[h]	-	58.2	673,877.7
EPICOR II system liners[i]			
First generation	-	125.7	77,750
Second generation	-	808.2	3,804
Defueling water cleanup system (DWCS)[j]	-	8.45	5,886.3
Off-site deconable scrap	-	138.9	4
Totals	155.9	7,418.85	7,681,007.14

[a]Three Mile Island (TMI)-Unit 2 is a PWR reactor with the following characteristics: rated capacity – 926 MW(e); mass of fuel in core before accident – 82 MTIHM; and number of fuel assemblies before accident – 177. The reactor began operation in 1978 and generated 231.6 MW(e)-years of (gross) electrical energy before being permanently shut down by an accident in March 1979.

[b]Based on information reported in ref. 29.

[c]These activities represent the cumulative sum of curies reported at the time of waste shipment. The values reported are not corrected for decay after the time of shipment.

[d]Defueling of the reactor started in January 1986. Fuel debris shipments were completed in April 1990.

[e]Other wastes include those regarded as "abnormal" because their classification is presently uncertain.

[f]Dry activated wastes are dry wastes packaged in drums, boxes, and high-integrity containers.

[g]Includes solidified miscellaneous liquids and miscellaneous resin liners and filters from TMI-Unit 2 systems.

[h]Resin liners and filters from the SDS (for water treatment).

[i]Resin liners and filters from the EPICOR II system that use organic ion-exchange resins and inorganic zeolite media. These include processing high-integrity containers (HICs).

[j]Resin liners and filters from the DWCS that use inorganic zeolite media. These are primarily processing HICs.

Table 7.11. Projected characteristics of radioactive wastes from Dresden Unit 1 decommissioning activities[a,b,c]

Waste category	Reactor component(s)	Volume (m^3)
Radioactive materials	Reactor vessel and internals:[d]	
	Reactor vessel	11
	Bioshield sand and concrete	239
	Thermal shield	2
	Instrumentation support tubes	1
	Bottom core support structure	1
	Other[e]	5
	Subtotal	259
	Solidified decontamination solvents	655
	Reactor station components and materials[f]	6,214
	Total	7,128
Radioactive hazardous materials	Asbestos insulation on contaminated piping and components	409
	Grand total	7,537

[a]Based on refs. 30 and 31.

[b]The 200-MW(e) Dresden BWR began operation in 1960 and generated about 1,800 MW(e)-years of (gross) electrical energy before it was shut down in 1978. The projections of this table pertain to wastes from the dismantlement of the reactor following a SAFSTOR period of about 30 years.

[c]These projections do not include 32 m^3 of LLW from SAFSTOR preparation activities (e.g., materials from cleaning spent fuel pool surfaces, miscellaneous sumps, and other contaminated areas; filters from chemical cleaning system; and miscellaneous dry active trash).

[d]The greatest source of radioactivity in the Dresden containment building is in the reactor vessel and internals. This activity results from neutron activation products in the vessel and shield materials. Reference 28 reports an estimated activity of 4,029,000 Ci for the vessel and internals when the reactor was shut down in 1978. By the year 2017, when dismantling of the reactor is to begin, this activity is projected to drop to a level of about 16,000 Ci.

[e]Other reactor internal components include steam deflector support, top grid assembly, bottom support grid, control rod guide tubes, and reactor vessel cladding.

[f]Reactor station components and materials include piping, valves, pumps, heat exchangers, building concrete, and structural steel.

Table 7.12. Inventories and projections of low-level radioactive wastes from La Crosse BWR decommissioning activities[a,b]

Calendar year(s)	Decommissioning mode	Average annual quantity of waste shipped to burial site[c,d] Volume (m^3/year)	Activity (Ci/year)
1988	SAFSTOR	4.62	70.3
1989[e]	SAFSTOR	6.74	32.12
1990[e]	SAFSTOR	4.59	0.74
1991[e]	SAFSTOR	5.46	0.32
1992[e]	SAFSTOR	35.0	1.2
1993-1996	SAFSTOR	0.0	0.0
1997-1998	SAFSTOR	7.0	23
1999-2003	SAFSTOR	6.5	13
2004-2008	SAFSTOR	4.9	7
2009-2013	SAFSTOR	3.6	5
2014-2018	DECON	103.0	>280

[a]Based on the information reported in ref. 32.

[b]The 48-MW(e) La Crosse BWR began operation in 1968 and generated 462 MW(e)-years of (gross) electrical energy until it was shut down in April 1987. The reactor was placed in SAFSTOR in 1988. The data in this table are based on a SAFSTOR period of 25 years.

[c]During the SAFSTOR period, the principal types of radioactive solid waste which will be processed and shipped to a suitable disposal facility will be low-level radioactive wastes principally with radioactivity content less than Class C (10 CFR 61) wastes. These wastes will include (1) dry active wastes (DAW), normally Class A, unstable; (2) dewatered spent demineralizer resins and filtration media, normally Class A or B, stable; and (3) contaminated or irradiated plant system components, normally Class B or C, stable.

[d]Contributions from activated core components and structural materials are not included. Volume estimates of these materials are currently not available; however, a preliminary activity estimate of 12,620 Ci has been made for these activated materials for year 2014, when the reactor will be ready for dismantlement.

[e]Volume of waste for this year reflects significant reductions due to treatment. Waste shipments for this year contained DAW and contaminated metal, which were either decontaminated, supercompacted, or both by two Oak Ridge waste treatment companies (Quadrex Recycle Center and SEG).

Table 7.13. Projected volumes of wastes from Saxton PWR decommissioning activities[a,b,c]

Reactor component(s)/waste	Volume (m^3)
Reactor vessel, head, and internals	39.64
Pressurizer	3.12
Primary coolant pump	2.83
Steam generator	24.07
Demineralizers	4.25
Shutdown cooling pumps	0.85
Relief valve discharge tank	4.25
Purification system surge tank	9.91
Safety injection pumps	1.42
Cooling heat exchanger	16.99
Containment vessel sump pumps	0.85
Discharge tank drain pumps	0.85
Containment ventilation equipment	16.99
Primary piping	5.66
Auxiliary system piping and valves	28.32
Contaminated and activated concrete of containment vessel	229.37
General valves, controllers, and instrumentation	42.48
Low-level waste from disposal operations	33.98
Westinghouse supercritical test loop	42.48
Total volume	508.31

[a]Based on the information reported in ref. 33.

[b]The 3-MW(e) Saxton PWR was shut down in 1972 and placed in SAFSTOR. Work on dismantling the reactor site started in 1986. This facility operated from 1962 until 1971, generating 10.4 MW(e)-years of (gross) electrical energy.

[c]Activity data are unknown at this time. Saxton reactor decommissioning waste characteristics are still being reviewed, and additional information will be provided in this table in future reports.

Table 7.14. Projected burial volumes of radioactive wastes from SAFSTOR (mothballing/delayed dismantling) of Humboldt Bay Unit 3[a,b,c]

D&D activity/reactor component	Volume (m^3)
Spent fuel racks	63
Nuclear steam supply system removal	
Reactor vessel	71[d]
Reactor vessel internals	24[e]
Other components	17
Removal of major equipment	
Main turbine/generator	353
Main condenser	164
Disposal of contaminated plant systems	
Turbine system	425
Electrical system	153
High-pressure steam and feedwater systems	190
Condensate system	155
Radwaste collection and treatment systems	200
Other systems	248
Decontamination of site buildings	
Refueling	434
Yard piping and soil	160
Other	30
Disposal of contaminated solid waste	152
Process liquid waste[f]	63
Disposal of modified plant and off-gas systems as a result of 1986-1991 capital improvements	100
Total	3,002

[a]Based on the information reported in ref. 34.

[b]The 65-MW(e) Humboldt Bay Unit 3 BWR operated from 1963 until 1976, generating 545 MW(e)-years of (net) electrical energy. The plant was placed in a SAFSTOR mode in 1988. The projections in this table and in ref. 34 assume delayed dismantling (DECON) of the reactor begins in 2015. At this time, the SAFSTOR period will end and the current inventory of spent fuel at the site will have been shipped to a federal repository when the latter is available.

[c]Except where noted, the volumes reported represent estimates for packaged Class A LLW.

[d]Includes 53 m^3 of Class C LLW.

[e]Includes 22 m^3 of Class C LLW and 2 m^3 of GTCC waste.

[f]Class B LLW.

Table 7.15. Projected burial volumes of radioactive wastes from DECON (prompt removal/dismantling) of Diablo Canyon Power Plant PWR Units 1 and 2[a,b,c]

D&D activity/reactor component	Volume, m^3 Unit 1	Volume, m^3 Unit 2
Spent fuel racks	440	440
Nuclear steam supply system removal		
Steam generators	1,911	1,911
Reactor vessel	239[d]	239[d]
Reactor vessel internals	271[e]	242[f]
Other components	416	416
Disposal of plant systems		
Electrical (contaminated) system	908	765
Other systems	1,736	1,411
Decontamination of site buildings		
Fuel handling	96	96
Containment and penetration area	958	958
Other	<<1	158[g]
Disposal of contaminated solid waste	2,787	2,847
Process liquid waste	386	364
Disposal of modified plant systems based on 1986-1991 capital additions	36	108
Total	10,184	9,955

[a]Based on information reported in ref. 35. This reference recommends the DECON option on the basis of technical and financial considerations. Projections for the SAFSTOR decommissioning option are also reported in ref. 35.

[b]Commercial operation of the Diablo Canyon units began in May 1985 for Unit 1 and in March 1986 for Unit 2. Unit 1 has a net capacity rating of 1,131 MW(e), and Unit 2 has a net capacity rating of 1,156 MW(e). For the study of ref. 35, shutdown dates of these reactors are taken as 30 years following their startup dates.

[c]Except where noted, the volumes reported represent estimates for packaged Class A LLW.

[d]Includes 60 m^3 of Class C LLW.

[e]Includes 144 m^3 of Class C LLW and 127 m^3 of GTCC waste.

[f]Includes 128 m^3 of Class C LLW and 114 m^3 of GTCC waste.

[g]Includes wastes from auxiliary and radwaste storage buildings.

Table 7.16. Projected volumes of wastes from Rancho Seco PWR decommissioning activities[a,b,c]

Reactor component(s)/waste	Volume (m^3)
Spent fuel racks	359
Reactor vessel	212
Reactor vessel internals	156
Primary system components and piping	1,336
Total for reactor vessel and components	2,063
Secondary and radwaste systems	2,625
Contaminated structures	468
Processed liquid waste	98
Dry active waste	397
Grand total	5,651

[a]Based on ref. 36 (extracted from a 1991 decommissioning cost study prepared by TLG Engineering, Inc.).

[b]The 918-MW(e) Rancho Seco (Unit 1) PWR was shut down in 1989. The reactor operated from 1974 until 1989, generating 5,277.3 MW(e)-years of (gross) electrical energy.

[c]The projections in this table pertain to wastes from dismantlement of the reactor following a SAFSTOR period of about 20 years.

Table 7.17. Projected characteristics of wastes from DECON (dismantling) of the Fort St. Vrain HTGR[a,b]

Reactor component(s)/waste	Burial volume (m^3)	Activity (Ci)	Projected LLW class
Prestressed concrete reactor vessel (PCRV) system			
PCRV concrete	1,174.94	c	A
Control rod drives (CRDs)	97.81	c	A
CRD absorber strings	18.81	c	C
CRD metal clad reflector	4.04	c	C
Boronated stainless steel rods	845.27	c	B
Top cover plates	1.59	c	A
Top head kaowool[d] and liner	13.32	c	A
Core barrel	21.97	c	A
Core support blocks	41.09	c	A
Core support floor kaowool, plates, and liner	6.94	c	A
Metal clad reflector blocks (non-CRD)	28.67	c	C
Dummy fuel blocks	168.28	c	A
Graphite reflector blocks	237.65	c	A, B
Silica insulation blocks	14.27	c	A
Large permeable reflectors	709.32	c	B
Reflector keys	0.57	c	A
Metal shell for large side reflector	0.58	c	A
Radial cover plate, kaowool, and PCRV liner	55.57	c	A
Region constraint devices	1.42	c	C
Helium purification and regeneration system	30.87	c	A
Helium circulators	4.01	c	A
Steam generators	269.02	c	A, B
PCRV system total	3,746.01	1.30E+6	
Material handling, treatment, and storage (MHTS) systems			
Fuel handling machine	63.33	c	A
Fuel storage wells	28.48	c	A
Equipment storage wells	2.98	c	A
Auxiliary transfer cask	19.52	c	A
Hot service facility	10.98	c	A
MHTS systems total	125.29	3.88E-2	
Decontamination and waste (DW) systems			
Decontamination system	9.57	c	A
Radioactive liquid waste	9.15	c	A
Radioactive gas waste	32.93	c	A
Dry activated and other wastes	153.34	c	A
DW systems total	204.99	1.33E-4	
Fort St. Vrain HTGR total	4,076.29	1.30E+6	

[a]Based on refs. 37 and 38. The case considered involves complete dismantlement of all radioactive systems at the reactor site after defueling of the reactor has been completed.

[b]The 330-MW(e) Fort St. Vrain HTGR operated from 1979 until 1989, generating about 490 MW(e)-years of (gross) electrical energy.

[c]Information is not available.

[d]Kaowool is an insulation material.

Table 7.18. Projected volumes of radioactive wastes from DECON (prompt removal/dismantling) of the Peach Bottom reactors[a]

Reactor [type, net MW(e)] and waste type	Projected LLW class	Disposal volume (m^3)
Peach Bottom, Unit 2 [BWR, 1065]		
LLW	A	23,980
LLW	C	504
LLW	GTCC	169
Subtotal		24,653
Peach Bottom, Unit 3 [BWR, 1065]		
LLW	A	24,913
LLW	C	504
LLW	GTCC	169
Subtotal		25,586
Total		50,239

[a]Peach Bottom data were adapted from ref. 40.

Table 7.19. Characteristics of radioactive wastes associated with decommissioning the Pathfinder reactor[a]

Reactor component(s)/waste	Volume[b] (m^3)	Mass (t)	Activity (Ci)
Reactor vessel[c]	113	280.5	560.92
Bioshield	78	179	0.26
Recirculation pumps and motors (3)	71	56	0.018
Contaminated concrete	50	40	0.065
Dry active waste[d]	567	635.5	0.557
Liquids	0	0	0
Asbestos	97[e]	17	0.0001
Total	976	1,208	561.82

[a]Based on ref. 41. All material is low-specific-activity LLW.

[b]These numbers represent the volume of radioactive waste shipped to processors; the final disposal volumes have not yet been determined.

[c]Includes reactor pressure vessel, internal components, control rod drive blades, gravel, grout, and routine shipping (Type A) packaging components.

[d]Includes piping, valves, conduit, cable, sand, wire, steel, shield blocks, grating, lights, filters, plastic, paper, and wood.

[e]This is the volume of asbestos removed during D&D. Later this material was reduced in volume to 20 m^3.

Table 7.20. Projected characteristics of wastes from Shoreham BWR decommissioning activities[a,b]

(All wastes are projected to be LLW Class A)

Reactor component(s)/waste	Burial volume (m^3)	Activity[c,d] (Ci)
Reactor pressure vessel (RPV) and internals	467	6.01E+2
Reactor recirculation system	170	2.45E-4
Control rod drive system	14[e]	3.00E-4
Residual heat removal system	428	4.30E-4
Core spray system	45	7.19E-4
Reactor water cleanup system	260	6.16E-4
Fuel pool cleanup system	71	7.86E-4
Condensate and demineralizer system	57	2.62E-5
Process sampling system	9	2.29E-5
Spent fuel rack and accessories	235	5.65E-4
Process and dry activated wastes	218	f
Demineralizer system and resins/filters	91	f
Liquid radwaste system	170	1.60E-4
Mirror insulation	11	f
Total	2,246	6.01E+2

[a]Based on the Shoreham Nuclear Power Station Decommissioning Plan (ref. 42).

[b]The 820-MW(e) Shoreham BWR underwent low-power tests until 1989, when the Long Island Lighting Company agreed to sell the plant to the state of New York for decommissioning. A total of 865 MW(e)-hours of (gross) electrical energy were generated during the low power tests.

[c]Activity levels are as of March-April 1990, except for the RPV and internals, which reflect levels as of July 1990.

[d]The isotopic composition of Shoreham's anticipated wastes is assumed to be represented by two radionuclides: ^{60}Co (comprising one-third of the total activity) and ^{55}Fe (comprising the remaining two-thirds of the total activity).

[e]Excludes control blades and control rod drives.

[f]Negligible.

Table 7.21. Projected volumes of wastes from Indian Point Unit 1 PWR decommissioning activities[a,b]

Reactor component(s)	Container (type and number)		
	LSA boxes	Cask liners	Total
Contaminated piping, valves, equipment, and concrete	1,269	0	1,269
Spent fuel racks	9	0	9
Reactor internals	7	13	20
Reactor vessel	52	0	52
Total containers	1,337	13	1,350
External volume (m^3) of each container (box or liner)	4.694	3.341	–
Total container volume (m^3)	6,275	43	6,318

[a]Based on ref. 43.

[b]The 265-MW(e) Indian Point Unit 1 PWR began operation in 1962 and generated about 1,440 MW(e)-years of (gross) electrical energy before it was shut down in 1974. The projections in this table pertain to wastes from the dismantlement of the reactor following a SAFSTOR period of about 35 years.

Table 7.22. Characteristics of wastes from decommissioning activities at the Cimarron Fuel Fabrication Facility[a]

Project area	Type of waste	Total waste removed from Cimarron through December 1991[b]		Projected waste volume remaining[c] (m^3)
		Volume (m^3)	Activity (Ci)	
Burial ground	LLW (LSA)[d]	1,833.10	5.37	0
Mixed-oxide fuel plant	TRU	255.89	10.87	0
	LLW (LSA)	463.88	3.25	0
Uranium fuel plant areas				
a. Uranium fuel plant	LLW (LSA)	2,158.62	3.63	500
b. Northfield area	LLW (LSA)	188.82	.12401	142
Liquid process waste evaporation ponds				
a. Mixed-oxide plant pond	LLW (LSA)	104.30	0.000009	0
b. Uranium plant pond	LLW (LSA)	183.73	0.23	0
Sanitary lagoons	LLW (LSA)	1,559.26	2.93	0
Project totals	TRU	255.89	10.87	0
	LLW (LSA)	6,491.71	15.53	642
Total waste		6,747.60	26.40	642

[a]Based on the information provided in ref. 44.

[b]The LLW inventories are included in the commercial disposal site inventories of Chapter 4.

[c]Decontamination work is scheduled to be completed during 1993. More than 95% of the estimated decontamination requirement has been completed.

[d]LSA = low specific activity waste.

ORNL PHOTO 6896-92

Photo 8.1. Retrieval of mixed low-level waste sludge from a Hanford Site solar evaporation basin. (Courtesy of Westinghouse Hanford Company, Richland, Washington, and the Hazardous Waste Remedial Actions Program, Oak Ridge, Tennessee.)

8. MIXED LOW-LEVEL WASTE

8.1 INTRODUCTION

This chapter reports estimated inventories and generation rates of mixed LLW from DOE site and commercial operations. Mixed LLW includes mixtures of low-level radioactive materials and (chemically and/or physically) hazardous wastes. Mixed high-level and TRU wastes are not included in this chapter but are included in the HLW and TRU waste inventories and projections of Chapters 2 and 3, respectively. This report does not consider the chemically hazardous features of mixed HLW or TRU wastes. Their dominating radioactive characteristics alone dictate the methods by which these materials need to be treated, handled, stored, and disposed. The radioactive components of mixed wastes are subject to the Atomic Energy Act (AEA), as amended,[1] which, for government sources, is administered by DOE, and, for commercial sources, by NRC (unless a state has obtained agreement state status). The hazardous components of all mixed wastes are subject to two federal statutes that are administered by the Environmental Protection Agency (EPA) (unless a state has obtained an authorization status): (1) the Resource Conservation and Recovery Act (RCRA), as amended,[2] and (2) the Toxic Substances Control Act (TSCA).[3] Thus, the treatment, handling, and disposal of mixed wastes are subject to the regulations of the EPA[4] and NRC (or the authorized and agreement states), or DOE. Table 8.1 (data from ref. 5) lists those states and territories designated by EPA as having mixed waste authorization.

In this report, mixed LLW is considered separately from the purely radioactive LLW discussed in Chapter 4. The information provided in the tables of this chapter is preliminary in nature and pertains only to hazardous wastes regulated by RCRA and polychlorinated biphenyls (PCBs) regulated by TSCA. Unless otherwise noted, the inventories and projections reported for mixed LLW are separate from those reported for radioactive LLW in Chapter 4. Inventories of mixed LLW presently stored at DOE sites are in the process of being thoroughly characterized. As a result, the waste at some sites could require reclassification, thereby causing significant changes in the inventories currently reported.

Typically, mixed LLW at DOE sites includes a variety of contaminated materials, including air filters, cleaning materials, engine oils and grease, paint residues, photographic materials, soils, building materials, and decommissioned plant equipment. To support the DOE Office of Environmental Restoration and Waste Management, the Hazardous Waste Remedial Actions Program (HAZWRAP) has developed the Waste Management Information System (WMIS), a data base of treatment, storage, and disposal (T/S/D) unit capabilities and waste stream characteristics at DOE sites. Presently, WMIS contains mixed waste and hazardous, polychlorinated biphenyl (PCB), and radioactive T/S/D unit capabilities and waste stream characterization information.

8.2 WASTE CHARACTERIZATION

Currently, generic characterization of mixed wastes is difficult for several reasons: (1) such wastes have different blends of hazardous (chemical and/or physical) and radioactive components that dictate precautionary measures, (2) several processes may be involved in generating these wastes, (3) various methods are used to prepare these wastes for storage, and (4) EPA has adopted new toxicity characterization leaching procedures. Representative data on the chemical and radionuclide compositions of mixed wastes will be reported as more detailed site information is available.

In this chapter, inventories and annual generation rates of mixed LLW are expressed in terms of physical and hazardous categories. Physical properties are classified in four categories: solid, liquid, gas, and sludge. Chemical properties are classified according to six categories defined by RCRA and TSCA.

8.3 DOE SITE INVENTORIES AND GENERATION RATES

Cumulative mass inventories and generation rates are reported in this chapter for most of the DOE sites listed in Table D.1 of Appendix D. The DOE site inventories and generation rates reported are based on information compiled and processed by HAZWRAP (ref. 6). The levels reported do not reflect any treatment that may take place before interim storage. Thus, some generation rates

may vary from current inventory additions. DOE site inventories and generation rates are given in both mass (kg) and volume (m^3) units. Until recently, many DOE sites tracked and reported their mixed waste streams in mass units. However, for disposal considerations, DOE is requiring these sites to report their mixed waste inventories and generation rates in units of disposal volume. A breakdown of DOE site mixed LLW inventories and generation rates by various physical categories is provided in Tables 8.2–8.5.

Chemically hazardous properties of mixed LLW are described by the following six categories of waste types: PCB, listed, ignitable, reactive, corrosive, and TCLP/EP (toxicity characteristic leaching procedure/extraction procedure) toxic. Table 8.6 (based on refs. 3, 7, and 8) gives a detailed description of the waste characteristics associated with each of the hazard categories. Tables 8.7 through 8.10 report DOE site mixed LLW inventories and generation rates for these categories. The columns in Tables 8.7 through 8.10 are ordered according to the potential hazard presented to humans and the environment, with PCBs accounting for the greatest hazard and TCLP/EP toxic the least hazard. This ordering also reflects considerations given to waste handling. The methodology used in preparing Tables 8.7 through 8.10 assumes that if a waste stream composition falls into more than one category, then its inventory and generation rates are included in the most severe category. (For example, a waste stream containing both PCBs and corrosives would be included in the PCB column.)

A breakdown of the mixed LLW volume inventory by site is graphically described in Fig. 8.1, and a breakdown of the volume generation level by site is shown in Fig. 8.2. The current total volume inventory of mixed LLW at DOE sites is about 101,400 m^3, most of which is located at ten sites (Fernald, ORNL, Paducah, Hanford, INEL, K-25, Portsmouth, Rocky Flats, SRS, and Y-12). During 1991, over 66,000 m^3 of mixed LLW was generated at DOE sites. Tables 8.11 and 8.12 report projected mass and volume generation rates, respectively, of mixed LLW at DOE sites. Data reported in these tables are based on information currently available from WMIS (ref. 6).

8.4 COMMERCIAL MIXED LOW-LEVEL WASTES

Recently, the NRC and EPA cosponsored a survey study to compile a national profile of the volumes, characteristics, and treatability of commercially generated mixed LLW. Such a profile was designed to provide: (1) states and compacts with information to assist in planning and developing adequate disposal capacity for low-level radioactive waste, including mixed waste, as mandated by the Low-Level Radioactive Waste Policy Amendments Act; (2) private developers with a clearer idea of the characteristics and volumes of mixed waste and the technical capability and capacity needed to treat this waste; and (3) a reliable national data base on the volumes, characteristics, and treatability of commercial mixed waste. In addition, the data were collected to provide a basis for possible federal actions that would effectively manage and regulate the treatment and disposal of mixed waste. Results from this investigation are documented in ref. 9 and summarized in this report.

The NRC/EPA study identified the types and volumes of mixed LLW generated from five groups of facilities: nuclear utilities, medical facilities, academic institutions, industrial facilities, and NRC-licensed government facilities. The study selected a random sample of 1,323 facilities out of a total target population of 2,936 facilities. Data from 1,016 completed mixed waste survey questionnaires (77% response rate) received and the use of appropriate weighting factors indicate that approximately 3,950 m^3 of low-level radioactive mixed waste was generated in the United States in 1990 of which 72% was liquid scintillation fluids.

The study divided the low-level radioactive mixed waste into several hazardous stream categories, including the following:

- Liquid scintillation fluids from laboratory counting activities.
- Waste oil from various pumps, equipment, and maintenance activities.
- Chlorinated or fluorinated organics and chlorinated fluorocarbons, including sludges and contaminated filters from dry cleaning, refrigeration, degreasing, and decontamination operations. Chloroform and a number of pesticides are also included.
- Other organics, including miscellaneous solvents, reagents, expired products, and other organic compounds (or materials like rags, wipes, etc., contaminated with such) from research and manufacturing activities, experimental procedures, and laboratory and process equipment cleaning.
- Lead wastes, including lead shielding and lead solutions for research and industrial facilities.
- Mercury wastes, including equipment and debris contaminated with mercury.
- Chromate wastes, including chromium-contaminated solutions for research maintenance and waste treatment (ion exchange) operations.
- Cadmium wastes from decontamination activities.
- Aqueous corrosive wastes, including inorganic acids or, in some cases, bases from cleanup and decontamination activities.
- Other hazardous materials, including materials either not readily assignable to any one of the above categories or containing a number of different hazardous materials.

Summaries of estimated generation rate, amount in storage, and amount treated for each of the five facility

categories and each of the hazardous stream categories are shown in Tables 8.13 and 8.14, respectively (data from ref. 9). Upper and lower bounds were also set on the volume of mixed waste that is untreatable under current technologies by making the simplifying assumption that liquid scintillation fluids, oil, nonhalogenated organics, and corrosive wastes are treatable. Deducting their contributions from the estimated total mixed waste generation rate leaves residues of about 524 m^3. This upper bound for untreatable mixed waste is approximately 13% of the estimated 1990 national generation rate of 3,950 m^3. However, it was noted that the capacity to treat **all** the so-called treatable mixed waste may not be available.

8.5 REFERENCES

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

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

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

4. U.S. Environmental Protection Agency, "Identification and Listing of Hazardous Waste," Code of Federal Regulations, 40 CFR Parts 260–271 (1986).

5. Betty Shackleford, U.S. Department of Energy, Office of Program Support, Office of Waste Operations, Washington, D.C., facsimile to S. N. Storch, Oak Ridge National Laboratory, Oak Ridge, Tennessee, dated Mar. 15, 1992, containing updated EPA mixed waste authorization status for states and U.S. territories as of Dec. 31, 1991.

6. U.S. Department of Energy, Waste Management Information System (WMIS), DOE site mixed LLW inventory and projection data summaries prepared by the Hazardous Waste Remedial Actions Program (HAZWRAP), submitted to the Integrated Data Base Program, May–September 1992.

7. S. M. DePaoli, A. L. Rivera, and B. M. Eisenhower, Hazardous and Mixed Waste Generation at the DOE/ORO Installations Operated by Martin Marietta Energy Systems, Inc., During Calendar Years 1987 and 1988, K/ESH-2, Oak Ridge, Tennessee (September 1990).

8. U.S. Environmental Protection Agency, Code of Federal Regulations, 40 CFR Parts 702-799 (1988).

9. National Profile on Commercially Generated Low-Level Radioactive Mixed Waste — Technical Letter Report for Tasks Five and Six, prepared by Oak Ridge National Laboratory, Oak Ridge, Tennessee, for U.S. Nuclear Regulatory Commission and U.S. Environmental Protection Agency, FIN L-1647-0, June 19, 1992.

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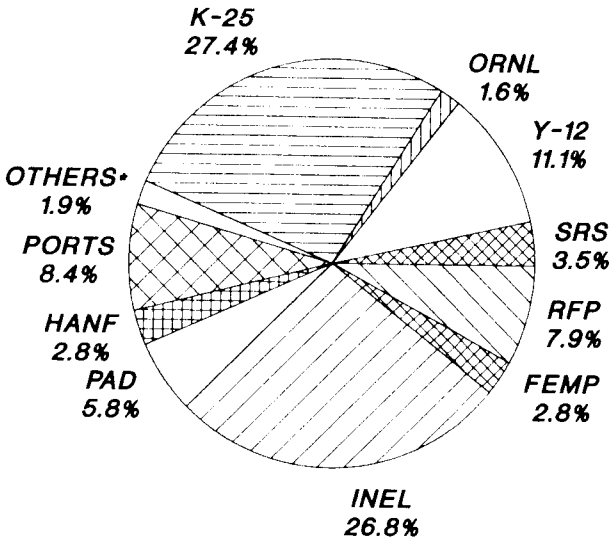
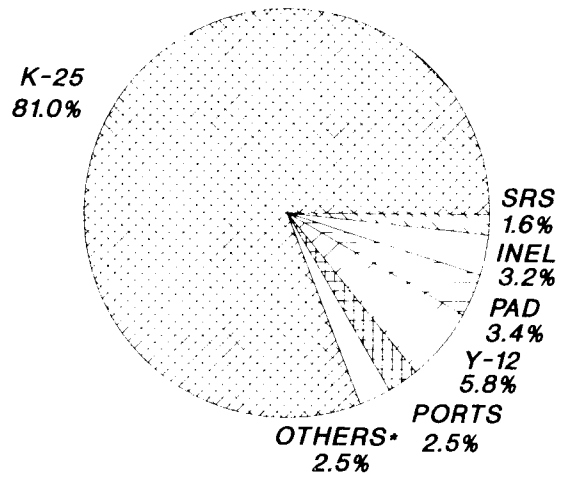


SITE	CUBIC METERS
FEMP	2.824E+03
HANF	2.831E+03
INEL	2.715E+04
K-25	2.778E+04
ORNL	1.598E+03
PAD	5.941E+03
PORTS	8.488E+03
RFP	7.972E+03
SRS	3.568E+03
Y-12	1.131E+04
OTHERS*	1.918E+03
TOTAL	1.014E+05

*Includes contributions from 28 sites.

Fig. 8.1. Total volume inventory of DOE mixed LLW through 1991.

ORNL DWG 92-5853



SITE	CUBIC METERS
INEL	2.093E+03
K-25	5.353E+04
PAD	2.212E+03
PORTS	1.679E+03
SRS	1.072E+03
Y-12	3.803E+03
OTHERS*	1.661E+03
TOTAL	6.605E+04

*Includes contributions from 32 sites.

Fig. 8.2. Volume generation of DOE mixed LLW during 1991.

Table 8.1. States and territories with EPA mixed waste authorization[a]

State/territory	Effective date	State/territory	Effective date
Arkansas	05/29/90	Nebraska	12/03/88
Colorado	11/07/86	New Mexico	07/25/90
Connecticut	12/31/90	New York	05/07/90
Florida	02/12/91	North Carolina	11/21/89
Georgia	09/26/88	North Dakota	08/24/90
Guam	10/10/89	Ohio	06/30/89
Idaho	04/09/90	Oklahoma	11/27/90
Illinois	04/30/90	Oregon	05/29/90
Indiana	09/30/91	South Carolina	09/13/87
Kansas	06/25/90	South Dakota	06/17/91
Kentucky	12/19/88	Tennessee	08/11/87
Louisiana	10/26/91	Texas	03/15/90
Michigan	12/26/89	Washington	11/23/87
Minnesota	06/23/89	Utah	03/07/89
Mississippi	05/28/91		
		(Total = 29 states/territories)	

[a]Based on ref. 5. Information as of December 31, 1991.

Table 8.2. Cumulative mass (kg) inventories of DOE site mixed LLW, by physical category, through 1991[a,b]

Site	Solid	Liquid	Gas[c]	Sludge	Total
AMES	470	0	0	0	470
ANL-E	25,273	47,454	0	32,500	105,227
ANL-W	17,927	177	0	0	18,104
BNL[d]	0	14,930	0	0	14,930
FEMP	80,693,584	401,535	0	1,708,126	82,803,245
FNAL	740	0	0	0	740
HANF	2,728,784	110,200	0	0	2,838,984
INEL	23,267,153	140,738	0	2,613,386	26,021,277
ITRI	0	640	0	0	640
K-25[e]	3,949,958[f]	1,002,576	1,222	36,213,808	41,167,564
KCP	4,260	0	0	0	4,260
LANL	171,382	37,386	0	224,160	432,928
LBL	4,624	8,528	0	0	13,152
LLNL	53,001	134,300	0	0	187,301
MOUND	5,169	45,003	0	0	50,172
NR sites[g]	153	0	0	0	153
NTS	130,500	50,000	0	0	180,500
ORISE	0	0	0	0	0
ORNL	5,500	1,206,135	0	99,182	1,310,817
PAD	1,885,479	246,275	0	2,938,938	5,070,692
PANT	7,110	2,587	0	0	9,697
Pinellas	0	0	0	0	0
PORTS	3,696,300	445,320	0	2,962,780	7,104,400
PPPL	0	76	0	0	76
RAP sites[h]	222,372	55,999	0	9,199	287,570
RFP	8,117,969	23,260	0	363,559	8,504,788
RMI	60,059	5,332	0	5,192	70,583
SLAC	0	0	0	0	0
SNLA[d]	281,744	1,000	0	0	282,744
SNLL	45	321	0	0	366
SRS	206,830	2,449,680	0	16,253	2,672,763
WVDP	16,656	572	0	0	17,228
Y-12	6,212,780	123,400	0	951,850	7,288,030
Total	131,765,822	6,553,424	1,222	48,138,933	186,459,401

[a]Based on ref. 6. Materials may be in interim storage awaiting treatment.
[b]Densities of 1,000 kg/m^3 for liquids and 1,500 kg/m^3 for solids and sludges were assumed to calculate masses when the site did not report mass data.
[c]Stored in cylinders.
[d]Updated information for 1991 was not available from this site.
[e]Inventories reported include only wastes generated at K-25.
[f]Includes 3,635,908 kg of mixed PCB waste stored at K-25.
[g]Includes contributions from Bettis (BAPL) and NRF (INEL).
[h]Includes contributions from Battelle (BCLDP), Colonie (CISS), Grand Junction (GJPO), Santa Susana (SSFL), and Weldon Spring (WSSRAP).

Table 8.3. Cumulative volume (m^3) inventories of DOE site mixed LLW, by physical category, through 1991[a,b]

Site	Solid	Liquid	Gas[c]	Sludge	Total
AMES	0.10	0	0	0	0.10
ANL-E	5.80	46.40	0	41.00	93.20
ANL-W	8.85	0.21	0	0	9.06
BNL[d]	0	14.93	0	0	14.93
FEMP	1,382.09	337.31	0	1,105.08	2,824.48
FNAL	0.18	0	0	0	0.18
HANF	2,720.89	110.20	0	0	2,831.09
INEL	24,010.30	393.47	0	2,742.68	27,146.45
ITRI	0	1.20	0	0	1.20
K-25[e]	2,633.31[f]	1,002.34	2.44	24,142.54	27,780.63
KCP	5.44	0	0	0	5.44
LANL	129.52	65.89	0	239.90	435.31
LBL	3.40	11.03	0	0	14.43
LLNL	35.33	134.33	0	0	169.66
MOUND	7.37	65.22	0	0	72.59
NR sites[g]	0.28	0	0	0	0.28
NTS	87.00	50.00	0	0	137.00
ORISE	0	0	0	0	0
ORNL	6.11	1,214.20	0	377.36	1,597.67
PAD	3,366.04	367.02	0	2,208.10	5,941.16
PANT	19.40	3.95	0	0	23.35
Pinellas	0	0	0	0	0
PORTS	3,913.54	483.43	0	4,090.68	8,487.65
PPPL	0	0.07	0	0	0.07
RAP sites[h]	151.09	270.57	0	8.38	430.04
RFP	7,353.30	132.71	0	486.27	7,972.28
RMI	72.93	6.63	0	7.15	86.71
SLAC	0	0	0	0	0
SNLA[d]	411.10	1.00	0	0	412.10
SNLL	0.22	0.63	0	0	0.85
SRS	542.34	3,010.13	0	15.40	3,567.87
WVDP	11.12	0.57	0	0	11.69
Y-12	3,853.70	123.40	0	7,330.70	11,307.80
Total	50,730.75	7,846.84	2.44	42,795.24	101,375.27

[a]Based on ref. 6. Materials may be in interim storage awaiting treatment.

[b]Densities of 1,000 kg/m^3 for liquids and 1,500 kg/m^3 for solids and sludges were assumed to calculate volumes when the site did not report volume data.

[c]Stored in cylinders.

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

[e]Inventories reported include only wastes generated at K-25.

[f]Includes mixed PCB waste stored at K-25.

[g]Includes contributions from Bettis (BAPL) and NRF (INEL).

[h]Includes contributions from Battelle (BCLDP), Colonie (CISS), Grand Junction (GJPO), Santa Susana (SSFL), and Weldon Spring (WSSRAP).

Table 8.4. Mass generation rates (kg/year) of DOE site mixed LLW, by physical category, for 1991[a,b]

Site	Solid	Liquid	Gas[c]	Sludge	Total
AMES	20	0	0	0	20
ANL-E	86	10,658	0	490	11,234
ANL-W	213	11	0	41	265
BNL[d]	0	1,166	0	0	1,166
FEMP	0	0	0	0	0
FNAL	679	32	0	0	711
HANF	603,204	4,960	0	0	608,164
INEL	21,700	2,543,374	0	684	2,565,758
ITRI	0	750	0	0	750
K-25[e]	124,997	55,465,003[f]	61	187,927	55,777,988
KCP	136	0	0	0	136
LANL	49,005	4,263	0	52,100	105,368
LBL	4,116	4,404	0	0	8,520
LLNL	12,174	59,035	215	7,366	78,790
MOUND	100	0	0	0	100
NR sites[g]	2,506	1,668	0	0	4,174
NTS	45,600	18,000	0	0	63,600
ORISE	0	110	0	0	110
ORNL	338	15,614	0	5,072	21,024
PAD	210,996	129,774	0	2,098,332	2,439,102
PANT	66,559	0	0	0	66,559
Pinellas	0	0	0	0	0
PORTS	1,104,656	117,694	0	34,900	1,257,250
PPPL	0	100	0	0	100
RAP sites[h]	15,048	11,635	0	10,186	36,869
RFP	621,483	1,136	0	7,839	630,458
RMI	46,558	623	0	493	47,674
SLAC	0	0	0	0	0
SNLA[d]	0	0	0	0	0
SNLL	0	161	0	0	161
SRS	22,519	1,043,954	0	0	1,066,473
WVDP	2,646	117	0	0	2,763
Y-12	122,403	3,134,100	0	545,000	3,801,503
Total	3,077,742	62,568,342	276	2,950,430	68,596,790

[a]Based on ref. 6. Values do not reflect any treatment that may, or will, occur prior to interim storage.

[b]Densities of 1,000 kg/m^3 for liquids and 1,500 kg/m^3 for solids and sludges were assumed to calculate masses when the site did not report mass data.

[c]Stored in cylinders.

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

[e]Rates reported include only wastes generated at K-25.

[f]Includes 901,565 kg of mixed PCB waste at K-25. Also includes approximately 45,000,000 kg of water from the TSCA Incinerator and 8,420,000 kg of hydrogen softener blowdown from the steam plant, which were both treated at the Central Neutralization Facility.

[g]Includes contributions from Bettis (BAPL) and NRF (INEL).

[h]Includes contributions from Battelle (BCLDP), Colonie (CISS), Grand Junction (GJPO), Santa Susana (SSFL), and Weldon Spring (WSSRAP).

Table 8.5. Volume generation rates (m^3/year) of DOE site mixed LLW, by physical category, for 1991[a,b]

Site	Solid	Liquid	Gas[c]	Sludge	Total
AMES	0	0	0	0	0
ANL-E	0.01	9.53	0	0.40	9.94
ANL-W	1.02	0.01	0	0.02	1.05
BNL[d]	0	0.99	0	0	0.99
FEMP	0	0	0	0	0
FNAL	0.24	0.02	0	0	0.26
HANF	603.20	4.96	0	0	608.16
INEL	46.24	2,046.88	0	0.21	2,093.33
ITRI	0	1.50	0	0	1.50
K-25[e]	83.33	53,286.97[f]	0.12	155.69	53,526.11
KCP	0.15	0	0	0	0.15
LANL	48.10	10.10	0	54.90	113.10
LBL	2.60	5.91	0	0	8.51
LLNL	12.18	59.05	0.22	7.35	78.80
MOUND	0.14	0	0	0	0.14
NR sites[g]	27.56	2.09	0	0	29.65
NTS	30.40	18.00	0	0	48.40
ORISE	0	0.11	0	0	0.11
ORNL	0.33	15.94	0	5.14	21.41
PAD	477.95	149.76	0	1,584.13	2,211.84
PANT	82.40	0	0	0	82.40
Pinellas	0	0	0	0	0
PORTS	1,371.40	267.93	0	39.30	1,678.63
PPPL	0	0.10	0	0	0.10
RAP sites[h]	10.07	13.37	0	8.49	31.93
RFP	554.62	1.46	0	10.08	566.16
RMI	54.37	0.88	0	0.88	56.13
SLAC	0	0	0	0	0
SNLA[d]	0	0	0	0	0
SNLL	0	0.32	0	0	0.32
SRS	27.93	1,044.47	0	0	1,072.40
WVDP	1.76	0.11	0	0	1.87
Y-12	109.12	3,134.10	0	560	3,803.22
Total	3,545.12	60,074.56	0.34	2,426.59	66,046.61

[a]Based on ref. 6. Values do not reflect any treatment that may, or will, occur prior to interim storage.

[b]Densities of 1,000 kg/m^3 for liquids and 1,500 kg/m^3 for solids and sludges were assumed to calculate volumes when the site did not report volume data.

[c]Stored in cylinders.

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

[e]Rates reported include only wastes generated at K-25.

[f]Includes contributions from mixed PCB waste, water from the TSCA Incinerator, and hydrogen softener blowdown from the steam plant. The incinerator water and hydrogen softener blowdown were treated at the Central Neutralization Facility.

[g]Includes contributions from Bettis (BAPL) and NRF (INEL).

[h]Includes contributions from Battelle (BCLDP), Colonie (CISS), Grand Junction (GJPO), Santa Susana (SSFL), and Weldon Spring (WSSRAP).

Table 8.6. Hazard categories used in this report for characterizing DOE site mixed LLW[a]

Waste category	EPA code(s)	Description
PCB	(none)	PCB wastes[b] contain any form of polychlorinated biphenyl (PCB)-containing wastes (liquid, solid, equipment, etc.)
Listed	F001-F015 F006-F028 P001-P123 U001-U359	A waste is regarded as listed if it is characterized by EPA as hazardous and published in 40 CFR Part 261. Examples: spent solvents (F001-F015), spent sludges (F006-F028), discarded commercial chemicals (P001-P123 and U001-U359), poisons, regulated medical wastes, and combustibles (materials that have a flash point[c] above 60°C)
Ignitable	D001	A waste exhibits ignitability if the waste has a flash point under 60°C, or if, as a solid, it is capable of causing fire through friction at standard temperature and pressure (see 40 CFR Part 261.21). Examples: acetone, toluene, and alcohols
Reactive	D003	A waste exhibits reactivity if it is normally unstable, reacts violently with water, is capable of detonation, or generates toxic gases under certain conditions (see 40 CFR Part 261.23). Examples: poisons and carcinogens
Corrosive	D002	A waste exhibits corrosivity if the pH is <2 or >12.5, or if it corrodes steel at a specified rate (see 40 CFR Part 261.22). Examples: acids, bases, and crystalline solids (e.g., sodium hydroxide)
TCLP/EP toxic	D004-D043	A waste exhibits this toxicity if the leachate contains certain constituents (such as arsenic, lead, mercury, and silver) at concentrations equal to or higher than those given in 40 CFR Part 261.24

[a]Adapted from ref. 7.

[b]PCB wastes with PCB content ≥50 ppm are regulated by the Toxic Substances Control Act (TSCA) (ref. 3) under 40 CFR Parts 702-799 (ref. 8).

[c]The flash point is the lowest temperature at which the vapor of a combustible liquid can be made to ignite momentarily in air.

Table 8.7. Cumulative mass (kg) inventories of DOE site mixed LLW, by hazard category, through 1991[a,b]

Site	PCB	Listed	Ignitable	Reactive	Corrosive	TCLP/EP toxic	Total
AMES	0	0	0	0	0	470	470
ANL-E	0	46,974	0	0	480	57,773	105,227
ANL-W	0	1,101	5,891	0	0	11,112	18,104
BNL[c]	0	14,930	0	0	0	0	14,930
FEMP	0	79,417,517	254,602	0	1,410,000	1,721,126	82,803,245
FNAL	152	0	0	0	0	588	740
HANF[d]	42,910	1,862,824	748,335	132,540	12,340	40,035	2,838,984
INEL	2,315,348	20,797,770	1,965,615	0	3,530	939,014	26,021,277
ITRI	0	640	0	0	0	0	640
K-25[e]	3,635,908	36,408,948	122,067	1	203,141	797,499	41,167,564
KCP	0	2,346	0	0	0	1,914	4,260
LANL	0	264,890	6,000	100	6,294	155,644	432,928
LBL	363	7,591	3,445	0	937	816	13,152
LLNL	120	181,759	600	0	4,822	0	187,301
MOUND	6,315	38,686	2	0	0	5,169	50,172
NR sites[f]	0	0	0	0	0	153	153
NTS	0	131,000	0	0	0	49,500	180,500
ORISE	0	0	0	0	0	0	0
ORNL	4,441	67,032	51,750	0	1,088,502	99,092	1,310,817
PAD	4,932,907	16,391	17,936	0	42,162	61,296	5,070,692
PANT	0	9,697	0	0	0	0	9,697
Pinellas	0	0	0	0	0	0	0
PORTS	6,078,400	761,222	5,000	0	33,328	226,450	7,104,400
PPPL	0	0	76	0	0	0	76
RAP sites[g]	112,779	64,464	10,064	9,079	649	90,535	287,570
RFP	3,944	8,479,411	984	96	0	20,353	8,504,788
RMI	0	5,984	0	0	0	64,599	70,583
SLAC	0	0	0	0	0	0	0
SNLA[c]	10,000	140,500	0	102,900	0	29,344	282,744
SNLL	0	321	0	0	0	45	366
SRS	0	2,418,365	130	79	96,800	157,389	2,672,763
WVDP	2,614	34	120	0	409	14,051	17,228
Y-12	5,289,512	1,718,686	0	0	0	279,832	7,288,030
Total	22,435,713	152,859,083	3,192,617	244,795	2,903,394	4,823,799	186,459,401

[a]Based on ref. 6. Material may be in interim storage awaiting treatment.

[b]Densities of 1,000 kg/m^3 for liquids and 1,500 kg/m^3 for solids and sludges were assumed to calculate masses when the site did not report mass data.

[c]Updated information for 1991 was not available from this site.

[d]Hanford applied a different hazardous ordering scheme for wastes with two or more chemical categories: listed (highest), ignitable, corrosive, TCLP/EP toxic, reactives and other, and PCB (lowest).

[e]Inventories reported include only wastes generated at K-25.

[f]Includes contributions from Bettis (BAPL) and NRF (INEL).

[g]Includes contributions from Battelle (BCLDP), Colonie (CISS), Grand Junction (GJPO), Santa Susana (SSFL), and Weldon Spring (WSSRAP).

Table 8.8. Cumulative volume (m^3) inventories of DOE site mixed LLW, by hazard category, through 1991[a,b]

Site	PCB	Listed	Ignitable	Reactive	Corrosive	TCLP/EP toxic	Total
AMES	0	0	0	0	0	0.10	0.10
ANL-E	0	45.80	0	0	0.60	46.80	93.20
ANL-W	0	0.74	6.41	0	0	1.91	9.06
BNL[c]	0	14.93	0	0	0	0	14.93
FEMP	0	587.26	98.53	0	940.00	1,198.69	2,824.48
FNAL	0.12	0	0	0	0	0.06	0.18
HANF[d]	42.91	1,855.26	748.17	132.54	12.34	39.87	2,831.09
INEL	2,429.55	22,060.77	2,062.59	0	3.61	589.93	27,146.45
ITRI	0	1.20	0	0	0	0	1.20
K-25	3,635.91[e]	23,349.99	78.28	<<1	204.99	511.46	27,780.63
KCP	0	2.82	0	0	0	2.62	5.44
LANL	0	311.74	12.48	0.11	7.88	103.10	435.31
LBL	0.40	10.03	2.60	0	1.00	0.40	14.43
LLNL	0.11	165.82	.40	0	3.33	0	169.66
MOUND	9.14	56.08	0	0	0	7.37	72.59
NR sites[f]	0	0	0	0	0	0.28	0.28
NTS	0	104.00	0	0	0	33.00	137.00
ORISE	0	0	0	0	0	0	0
ORNL	4.47	75.04	51.79	0	1,088.51	377.86	1,597.67
PAD	4,808.68	30.41	21.88	0	73.16	979.02	5,941.16
PANT	0	23.35	0	0	0	0	23.35
Pinellas	0	0	0	0	0	0	0
PORTS	7,368.04	771.68	5.00	0	36.73	286.20	8,487.65
PPPL	0	0	0.07	0	0	0	0.07
RAP sites[g]	100.62	35.94	14.33	6.03	0.63	272.49	430.04
RFP	17.43	7,912.43	1.89	0.42	0	40.11	7,972.28
RMI	0	9.72	0	0	0	76.99	86.71
SLAC	0	0	0	0	0	0	0
SNLA[c]	35.00	94.00	0	268.30	0	14.80	412.10
SNLL	0	0.63	0	0	0	0.22	0.85
SRS	0	3,173.24	0.14	0.82	96.70	296.97	3,567.87
WVDP	1.74	0.03	0.12	0	0.41	9.39	11.69
Y-12	3,323.80	7,809.20	0	0	0	174.80	11,307.80
Total	21,825.93	68,502.11	3,104.68	408.22	2,469.89	5,064.44	101,375.27

[a]Based on ref. 6. Values do not reflect any treatment that may, or will, occur prior to interim storage.

[b]Densities of 1,000 kg/m^3 for liquids and 1,500 kg/m^3 for solids and sludges were assumed to calculate volumes when the site did not report volume data.

[c]Updated information for 1991 was not available from this site.

[d]Hanford applied a different hazardous ordering scheme for wastes with two or more chemical categories: listed (highest), ignitable, corrosive, TCLP/EP toxic, reactives and other, and PCB (lowest).

[e]Inventories reported include only wastes generated at K-25.

[f]Includes contributions from Bettis (BAPL) and NRF (INEL).

[g]Includes contributions from Battelle (BCLDP), Colonie (CISS), Grand Junction (GJPO), Santa Susana (SSFL), and Weldon Spring (WSSRAP).

Table 8.9. Mass generation rates (kg/year) of DOE site mixed LLW, by hazard category, for 1991[a,b]

Site	PCB	Listed	Ignitable	Reactive	Corrosive	TCLP/EP toxic	Total
AMES	0	0	0	0	0	20	20
ANL-E	0	9,704	0	0	954	576	11,234
ANL-W	0	123	0	0	11	131	265
BNL[c]	0	1,166	0	0	0	0	1,166
FEMP	0	0	0	0	0	0	0
FNAL	90	0	32	0	0	589	711
HANF[d]	0	561,484	12,160	15,430	610	18,480	608,164
INEL	0	2,540,754	186	0	0	24,818	2,565,758
ITRI	0	750	0	0	0	0	750
K-25[e]	901,565	45,793,215	55,316	2	8,498,657	529,233	55,777,988
KCP	0	0	0	0	0	136	136
LANL	0	59,863	0	0	500	45,005	105,368
LBL	0	3,804	3,300	0	600	816	8,520
LLNL	0	78,162	311	0	317	0	78,790
MOUND	0	0	0	0	0	100	100
NR sites[f]	0	2,313	0	0	0	1,861	4,174
NTS	0	45,000	0	0	0	18,600	63,600
ORISE	0	110	0	0	0	0	110
ORNL	4,395	10,049	2,094	1	135	4,350	21,024
PAD	2,391,287	8,694	12,204	0	2,156	24,761	2,439,102
PANT	0	66,559	0	0	0	0	66,559
Pinellas	0	0	0	0	0	0	0
PORTS	625,671	600,863	2,880	0	1,600	26,236	1,257,250
PPPL	0	0	100	0	0	0	100
RAP sites[g]	7,703	99	1,415	244	0	27,408	36,869
RFP	0	628,457	0	0	0	2,001	630,458
RMI	0	745	0	0	0	46,929	47,674
SLAC	0	0	0	0	0	0	0
SNLA[c]	0	0	0	0	0	0	0
SNLL	0	161	0	0	0	0	161
SRS	0	5,099	0	0	1,043,200	18,174	1,066,473
WVDP	2,615	20	42	0	49	37	2,763
Y-12	45,000	622,723	30	0	3,120,000	13,750	3,801,503
Total	3,978,326	51,039,917	90,070	15,677	12,668,789	804,011	68,596,790

[a]Based on ref. 6. Values do not reflect any treatment that may, or will, occur prior to interim storage.

[b]Densities of 1,000 kg/m^3 for liquids and 1,500 kg/m^3 for solids and sludges were assumed to calculate masses when the site did not report mass data.

[c]Updated information for 1991 was not available from this site.

[d]Hanford applied a different hazardous ordering scheme for wastes with two or more chemical categories: listed (highest), ignitable, corrosive, TCLP/EP toxic, reactives and other, and PCB (lowest).

[e]Rates reported include only wastes generated at K-25.

[f]Includes contributions from Bettis (BAPL) and NRF (INEL).

[g]Includes contributions from Battelle (BCLDP), Colonie (CISS), Grand Junction (GJPO), Santa Susana (SSFL), and Weldon Spring (WSSRAP).

Table 8.10. Volume generation rates (m^3/year) of DOE site mixed LLW, by hazard category, for 1991[a,b]

Site	PCB	Listed	Ignitable	Reactive	Corrosive	TCLP/EP toxic	Total
AMES	0	0	0	0	0	0	0
ANL-E	0	9.00	0	0	0.53	0.41	9.94
ANL-W	0	0.95	0	0	0.01	0.09	1.05
BNL[c]	0	0.99	0	0	0	0	0.99
FEMP	0	0	0	0	0	0	0
FNAL	0.16	0	0.02	0	0	0.08	0.26
HANF[d]	0	561.48	12.16	15.43	0.61	18.48	608.16
INEL	0	2,032.52	0.42	0	0	60.39	2,093.33
ITRI	0	1.50	0	0	0	0	1.50
K-25[e]	972.62	45,748.11	55.24	<<.01	6,373.99	376.15	53,526.11
KCP	0	0	0	0	0	0.15	0.15
LANL	0	72.00	0	0	1.00	40.10	113.10
LBL	0	5.31	2.20	0	0.60	0.40	8.51
LLNL	0	78.17	.32	0	0.31	0	78.80
MOUND	0	0	0	0	0	0.14	0.14
NR sites[f]	0	6.70	0	0	0	22.95	29.65
NTS	0	36.00	0	0	0	12.40	48.40
ORISE	0	0.11	0	0	0	0	0.11
ORNL	4.60	10.13	2.13	0	0.13	4.42	21.41
PAD	2,143.88	17.97	19.32	0	5.50	25.17	2,211.84
PANT	0	82.40	0	0	0	0	82.40
Pinellas	0	0	0	0	0	0	0
PORTS	908.00	734.73	2.70	0	1.50	31.70	1,678.63
PPPL	0	0	0.10	0	0	0	0.10
RAP sites[g]	7.54	0.11	2.14	0.66	0	21.48	31.93
RFP	0	561.54	0	0	0	4.62	566.16
RMI	0	1.10	0	0	0	55.03	56.13
SLAC	0	0	0	0	0	0	0
SNLA[c]	0	0	0	0	0	0	0
SNLL	0	0.32	0	0	0	0	0.32
SRS	0	9.67	0	0	1,043.20	19.53	1,072.40
WVDP	1.75	0.02	0.04	0	0.04	0.02	1.87
Y-12	40.00	634.00	0.02	0	3,120	9.20	3,803.22
Total	4,078.55	50,604.83	96.81	16.09	10,547.42	702.91	66,046.61

[a]Based on ref. 6. Material may be in interim storage awaiting treatment.

[b]Densities of 1,000 kg/m^3 for liquids and 1,500 kg/m^3 for solids and sludges were assumed to calculate volumes when the site did not report volume data.

[c]Updated information for 1991 was not available from this site.

[d]Hanford applied a different hazardous ordering scheme for wastes with two or more chemical categories: listed (highest), ignitable, corrosive, TCLP/EP toxic, reactives and other, and PCB (lowest).

[e]Rates reported include only wastes generated at K-25.

[f]Includes contributions from Bettis (BAPL) and NRF (INEL).

[g]Includes contributions from Battelle (BCLDP), Colonie (CISS), Grand Junction (GJPO), Santa Susana (SSFL), and Weldon Spring (WSSRAP).

Table 8.11. Projected annual mixed LLW mass generation rates (kg/year) for various DOE sites[a]

Site	Calendar year(s)					
	1992	1993	1994	1995	1996	1997-2030[b]
AMES[c]	2,600	2,700	1,890	1,890	650	540
ANL-E	17,925	16,513	16,513	16,513	16,513	16,513
ANL-W[d]						
BNL[d]						
FEMP	750,000	1,500,000	2,000,000	2,500,000	e	e
FNAL	610	610	610	610	610	610
HANF[f]	7,200,820	1,100,660	1,840,960	1,857,900	1,544,290	2,648,690
INEL[g]	10,000,000	9,600,000	9,600,000	9,600,000	9,600,000	9,600,000
ITRI	0	0	0	0	0	0
K-25[e]						
KCP	90	90	90	90	90	0
LANL	50,000	50,000	50,000	50,000	50,000	50,000
LBL	3,964	3,964	3,964	3,964	3,964	3,964
LLNL	82,000	82,000	82,000	82,000	82,000	82,000
MOUND	1,900	1,700	1,500	1,500	1,500	1,500
NR sites[h]	19,618	2,080	1,280	1,180	980	864
NTS	0	0	0	0	0	0
ORISE	300	300	350	400	400	500
ORNL	13,000	12,500	12,000	12,000	12,000	12,000
PAD	680,884	1,413,095	1,046,990	1,046,990	1,046,990	1,046,990
PANT	4,558	5,014	5,514	6,067	6,674	48,183
Pinellas	0	0	0	0	0	0
PORTS	2,310,000	2,540,000	2,290,000	2,310,000	2,310,000	2,310,000
PPPL[i]	600	600	600	11,900	11,900	555[j]
RAP sites[k]	7,730	7,730	230	2,230	4,230	230
RFP[l]	6,720,000	70,349	70,349	70,349	70,349	70,349
RMI	730	d	d	d	d	d
SLAC	12	12	12	12	12	e
SNLA	23,000	23,500	23,500	23,500	23,500	23,500
SNLL	161	161	161	161	161	<155
SRS[i]	330,000	240,000	270,000	285,000	285,000	285,000
WVDP	1,000	m	m	m	m	m
Y-12	2,872,800	2,514,000	2,199,600	1,924,800	1,683,600	1,440,000
Total	31,094,302	19,187,578	19,518,113	19,809,056	16,755,413	17,642,143

[a]Based on ref. 6.

[b]Annual average for the period indicated.

[c]If a burial site at Ames is excavated in 1993, a potential generation of 80,000 kg/year could result.

[d]Information not reported by site.

[e]Information not available.

[f]Includes contribution from Hanford's receipt of waste in 1992 that is currently being stored by off-site generators.

[g]Projections for INEL do not include contributions from environmental restoration activities planned at the site over the next 30 years. More waste characterization analyses and studies are needed to predict how much mixed LLW will result from these activities.

[h]Includes contributions from Bettis (BAPL), Knolls (KAPL), and NRF (INEL).

[i]Mass generation rates for this site are based on an assumed density of 1,500 kg/m^3.

[j]Average for years 1997-2001. No projections available after 2001.

[k]Includes contributions from Battelle (BCLDP), Colonie (CISS), Grand Junction (GJPO), Santa Susana (SSFL), and Weldon Spring (WSSRAP).

[l]Projections for RFP assume completion of solar pond cleanout and the resumption of plant production by the end of 1992.

[m]Mixed LLW generation data for WVDP cannot be estimated until programmatic and process uncertainties have been resolved in the development of a formal environmental impact statement.

Table 8.12. Projected annual mixed LLW volume generation rates (m^3/year) for various DOE sites[a]

Site	Calendar year(s)					
	1992	1993	1994	1995	1996	1997-2030[b]
AMES[c]	4.6	5.0	3.5	3.5	1.2	1.0
ANL-E	18	17	17	17	17	17
ANL-W[d]						
BNL[a]						
FEMP	1,100	2,500	3,319	4,165	e	e
FNAL	0.13	0.13	0.13	0.13	0.13	0.13
HANF[f]	6,546.2	1,000.6	1,673.6	1,689.0	1,403.9	2,407.9
INEL[g]	10,400	10,000	10,000	10,000	10,000	10,000
ITRI	0	0	0	0	0	0
K-25[c]						
KCP	0.1	0.1	0.1	0.1	0.1	0
LANL	50	50	50	50	50	50
LLNL	7.26	7.26	7.26	7.26	7.26	7.26
Mound	88	88	88	88	88	88
NAONP	2.2	2.0	1.8	1.8	1.8	1.8
NR sites[h]	4.12	3.92	1.92	1.42	1.11	1.09
NTS	0	0	0	0	0	0
OAK-SC	0.30	0.30	0.35	0.40	0.40	0.50
ORNL	13.0	12.5	12.0	12.0	12.0	12.0
PAD	939	1,503	1,221	1,221	1,221	1,221
PANT	7.00	7.70	8.47	9.32	10.25	74.00
Pinellas	0	0	0	0	0	0
PORTS	7,000	7,700	6,800	7,000	7,000	7,000
PPPL	0.40	0.40	0.40	7.93	7.93	0.37[i]
RAP sites[j]	6.5	6.5	0.3	3.3	6.3	0.3
RFP[k]	10,154.4	614.4	614.4	614.4	614.4	614.4
RMI	1.11	d	d	d	d	d
SLAC	0.06	0.06	0.06	0.06	0.06	e
SNLA	147	150	150	150	150	150
SNL	0.32	0.32	0.32	0.32	0.32	<0.22
TIS	220	160	180	190	190	190
WVDP	0.66	1	1	1	1	1
Y-12	2,394	2,095	1,833	1,604	1,403	<1,200
Total	39,104.56	25,924.19	25,982.61	26,835.94	22,186.16	23,036.97

[a]Based on ref. 6.

[b]Annual average for the period indicated.

[c]If a burial site at Ames is excavated in 1993, a potential generation of 50 m^3/year could result.

[d]Information not reported by site.

[e]Information not available.

[f]Includes contribution from Hanford's receipt of waste in 1992 that is currently being stored by off-site generators.

[g]Projections for INEL do not include contributions from environmental restoration activities planned at the site over the next 30 years. More waste characterization analyses and studies are needed to predict how much mixed LLW will result from these activities.

[h]Includes contributions from Bettis (BAPL), Knolls (KAPL), and NRF (INEL).

[i]Average for years 1997-2001. No projections available after 2001.

[j]Includes contributions from Battelle (BCLDP), Colonie (CISS), Grand Junction (GJPO), Santa Susana (SSFL), and Weldon Spring (WSSRAP).

[k]Projections for RFP assume completion of solar pond cleanout and the resumption of plant production by the end of 1992.

[l]Mixed LLW generation data for WVDP cannot be estimated until programmatic and process uncertainties have been resolved in the development of a formal environmental impact statement.

Table 8.13. National commercially generated mixed LLW profile volume summary, by facility category[a]

Facility category	Waste volume, m^3		
	Generated in 1990	Stored as of Dec. 31, 1990[b]	Treated in 1990[c]
Academic	820.7	154.3	1,581.8
Government	750.4	79.0	612.5
Industrial	1,428.0	1,197.2	1,115.1
Medical	563.6	63.1	466.3
Nuclear power plants	385.8	622.5	216.9
Total	3,948.5	2,116.1	3,992.6

[a]Based on ref. 9.
[b]This is not the amount of mixed waste requiring disposal. Some of this waste was being accumulated for treatment.
[c]Treated wastes may include mixed wastes generated in years prior to 1990.

Table 8.14. National commercially generated mixed LLW profile volume summary, by hazardous waste stream[a]

Hazardous stream	Waste volume, m^3		
	Generated in 1990	Stored as of Dec. 31, 1990[b]	Treated in 1990[c]
Organics			
Liquid scintillation fluids	2,837.2	363.4	3,371.8
Waste oil	148.9	178.1	139.4
Chlorinated organics	70.9	27.0	23.2
Fluorinated organics	0	3.5	0
Chlorinated fluorocarbons (CFCs)	113.2	254.7	3.7
Other organics	274.6	117.9	258.9
Total organics	3,444.8	944.6	3,797.0
Metals			
Lead	81.6	138.7	6.1
Mercury	12.5	81.1	1.5
Chromium	28.4	53.3	3.9
Cadmium	0.3	745.2	0.1
Total metals	122.8	1,018.3	11.6
Aqueous corrosives	80.4	12.2	2.6
Other hazardous materials	300.5	141.0	181.4
Total	3,948.5	2,116.1	3,992.6

[a]Based on ref. 9.
[b]This is not the amount of mixed waste requiring disposal. Some of this waste was being accumulated for treatment.
[c]Treated wastes may include mixed wastes generated in years prior to 1990.

APPENDIX A. MISCELLANEOUS RADIOACTIVE MATERIALS

APPENDIX A. MISCELLANEOUS RADIOACTIVE MATERIALS

A.1 INTRODUCTION

This appendix lists most of the remaining spent fuel (not reported in Chapter 1) and other waste materials that may possibly require repository disposal. Current inventories of these wastes are in storage at DOE and commercial sites, and additional inventories will be generated in the future. The miscellaneous materials included are (1) intact spent fuel elements or solids remaining after experimental testing and for which no reprocessing is planned; (2) damaged, irradiated fuel elements and debris; and (3) greater-than-Class-C low-level waste (GTCC LLW), defined as low-level waste generated by licensees of NRC or Agreement States that exceeds the radioactivity limits established in 10 CFR 61.55 for shallow-land disposal. Most of the GTCC LLW currently in inventory is held by licensees of NRC or Agreement States, but some is being stored temporarily by DOE as a convenience (DOE-held GTCC LLW). Data for the following materials are not included because they do not fit in these categories: defense HLW in the tank farms, commercial spent fuel at power reactors, and both the DOE production fuel and U.S. Navy fuel that are scheduled for reprocessing.

Other kinds of miscellaneous radioactive materials (MRM) that might be considered for inclusion in this appendix are special-case wastes, spent fuel disassembly hardware and nonfuel-bearing components, high-activity sources, and radionuclides from the decommissioning of nuclear weapons. These MRM are characterized as follows:

- Special-case wastes are primarily those wastes that have limited or no planned disposal alternatives. Other than the fuel and fuel debris mentioned above, the special-case wastes consist of (a) WIPP noncertifiable defense TRU waste; (b) DOE-held commercial LLW (see DOE Order 5820.2A[1]) that potentially may be designated as GTCC, under the definition given in 10 CFR 61.55, with their disposal justified by a site-specific performance assessment; and (c) low-level wastes that exceed site-specific performance assessment limits. The Radioactive Waste Technical Support Program, managed by EG&G Idaho, Inc., was asked to identify and quantify these special-case wastes.[2,3]

- Spent fuel disassembly hardware is the structural component left after irradiated fuel pins are removed from a fuel assembly, as in consolidation. It consists of end fittings; grid spacers; water rods (BWR, most recent design only); control rod guide tubes (PWR assemblies only); and various nuts, washers, and springs. Nonfuel-bearing components include fuel channels (BWR), control rods, fission chambers, neutron sources, and thimble plugs.[4]

- High-activity sources include sealed sources of ^{14}C, ^{60}Co, ^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239}Pu, and ^{241}Am.

- Radionuclides from the decommissioning of nuclear weapons are primarily plutonium isotopes.

The map of Fig. A.1 shows the current locations of MRM, and Fig. A.2 compares the masses of MRM now stored at the various sites. As seen in Fig. A.3, most of the material is in the form of either intact fuel elements or damaged fuel elements, such as those removed from the TMI-Unit 2 reactor.

A.2 INVENTORIES AND PROJECTIONS

Table A.1 summarizes the current inventory of MRM, exclusive of commercially generated GTCC LLW that may also require repository disposal. Tables A.2 through A.9 describe the separate materials at each site in more detail. The data presented in Tables A.1 through A.9 (derived from refs. 5–15) will be useful in planning for final disposal of these materials in a repository. It should be noted that some quantities of the commercially generated spent fuels reported in Tables A.2–A.9 may already be covered in Chapter 1 of this report. The spent fuel inventories reported in Tables A.2–A.9 will be reviewed to clearly identify any possible overlaps between the inventories in these tables and those reported in Chapter 1.

Any spent fuel inventory overlaps identified from this investigation will be clarified in the 1993 Integrated Data Base document (Rev. 9).

Inventories of special radioactive materials stored at INEL are given in Table A.6. These include materials stored at the Idaho Chemical Processing Plant (ICPP) and the Naval Reactors Facility (NRF). The spent fuels that comprise these inventories are scheduled to be stored indefinitely.[10,11] If required, future special campaigns could reprocess many of these spent fuels.

Data for the unusual spent fuels now being stored at SRS are included in Table A.9. These materials are not presently regarded as reprocessible, due to the lack of defined reprocessing schemes or required facilities. Therefore, this fuel is considered to be in indefinite storage.[15]

Other waste materials that could possibly require geologic disposal include GTCC LLW from commercial sources (including that held by DOE) and DOE spent fuel no longer scheduled for reprocessing. A summary of commercial GTCC LLW volumes and activities reported by the EG&G study of ref. 16 is presented in Table A.10. The major features of this study are described in Chapter 4. The results presented in Table A.10 represent packaged inventories and projections of wastes generated during the period 1985–2035. Recently, DOE made the decision to phase out the reprocessing of spent nuclear fuel for the recovery of highly enriched uranium. Idaho National Engineering Laboratory and the Savannah River Site are preparing phase-out plans. Implications of this decision will be reflected in next year's IDB report. Table A.11 (data from refs. 17–21) gives a mass summary of DOE spent fuel no longer scheduled for reprocessing. The information reported in Table A.11 is based on preliminary surveys and will be revised in future editions of this report.

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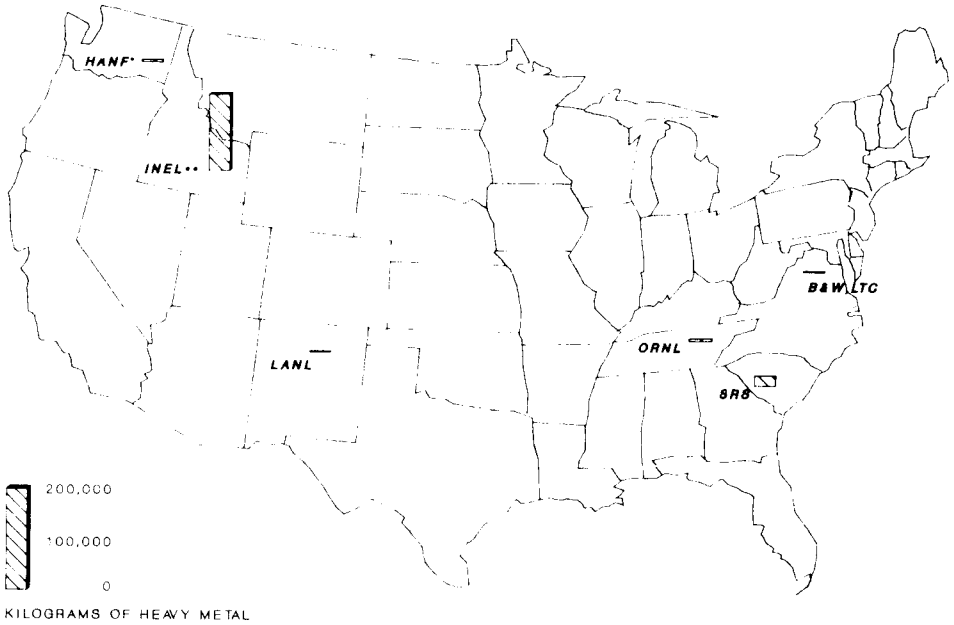
ORNL DWG 92-5863

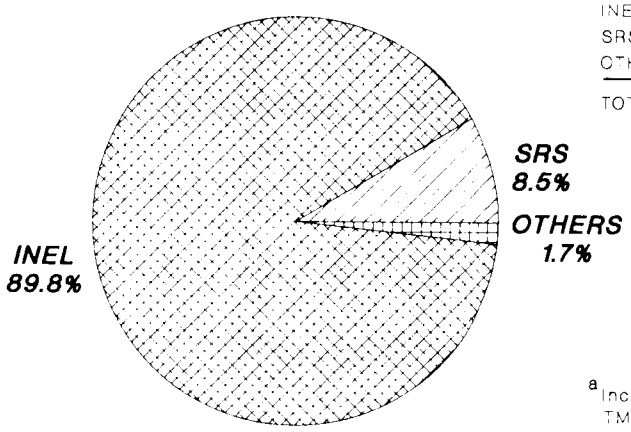


*Includes contribution from both PNL and 200 Area burial grounds.
**Includes contributions from ANL-W, ICPP, NRF, and other facilities. Also, excludes material from TMI-Unit 2.

Fig. A.1. Locations and total masses of miscellaneous radioactive materials through 1991.

ORNL DWG 92-5864

SITE	HEAVY METAL (METRIC TONS)
INEL	230.7[a]
SRS	21.8
OTHERS	4.3
TOTAL	256.8



[a]Includes 82 t from TMI - Unit 2

Fig. A.2. Mass and locations of miscellaneous radioactive materials as of December 31, 1991.

ORNL DWG 92-5865

FUEL TYPE	HEAVY METAL (METRIC TONS)
Intact	165.3
Damaged	80.1
Scrap	10.1
U-233	1.3
TOTAL	256.8

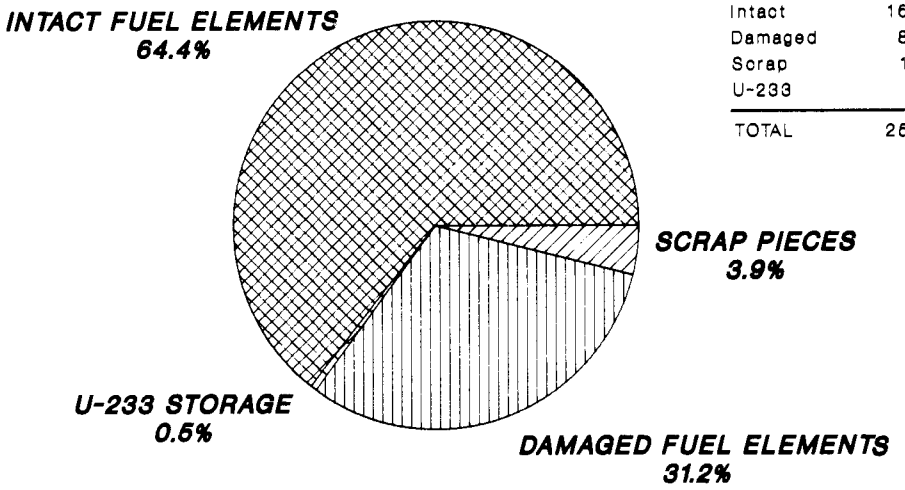


Fig. A.3. Types of miscellaneous radioactive materials in storage through 1991.

Table A.1. Inventory of miscellaneous radioactive materials that may require geologic disposal, as of December 31, 1991

Storage site and location	Total candidate materials (kg)	Uranium content, kg			Total plutonium content (kg)	Total thorium content (kg)
		Total	^{235}U	^{233}U[a]		
Reported potential miscellaneous materials inventory						
Argonne National Laboratory-West; Idaho Falls, ID	311.60	302.65	20.050		8.950	
Babcock & Wilcox, Lynchburg Technology Center; Lynchburg, VA	85.73	84.89	1.317		<0.833	
Battelle Pacific Northwest Laboratory; Richland, WA	2,347.9	2,311.9	21.6		29.3	6.7
Hanford 200-Area burial grounds; Richland, WA	326.73	279.49	76.06		47.24	
Idaho National Engineering Laboratory; Idaho Falls, ID[b]	148,711.81	81,334.46	1,958.59	962.46	273.75	67,103.6
Los Alamos National Laboratory; Los Alamos, NM	4.40	3.03	1.84	0.058	1.31	
Oak Ridge National Laboratory; Oak Ridge, TN	1,253.28	1,252.49	798.7	280.29	0.801	
Savannah River Site, Aiken, SC	21,783.74	13,092.33	762.46	31.16	43.21	8,648.2
Total reported	174,825.20	98,661.30	3,640.62	1,273.97	405.39	75,758.5
Estimated potential miscellaneous materials inventory						
Three Mile Island-Unit 2[c,d]	82,023	82,023	2,064.4			

[a]Some of the ^{233}U waste may be certifiable as TRU waste and would therefore be reported in Chapter 3 in the future.

[b]Many of the fuels at ICPP have a lower uranium enrichment than that of fuels normally processed. These fuels could be reprocessed in a special campaign, if required.

[c]Initial fuel loadings have been provided in order to estimate the potential miscellaneous materials inventory. See ref. 5.

[d]It is estimated that about 158 t of spent fuel and core debris has been removed from the TMI-Unit 2 reactor and transferred to INEL. See Table 7.10 in Chapter 7.

Table A.2. Miscellaneous radioactive materials stored at Argonne National Laboratory-West, as of December 31, 1991[a]

Source of material	Composition	Description[b]	U content, kg		Total Pu content (kg)
			Total	^{235}U	
Radioactive Waste and Scrap Facility[c]					
Basic research – ANL	Scrap	Stored in canister[d]	182.00	12.980	5.052
EBR-2 blanket subassembly	Scrap	Stored in canister[d]	104.80	0.230	0.180
LMFBR test fuel	Scrap	Stored in canister[d]	13.33	5.253	3.026
Postirradiation test on NUMEC LMFBR	Scrap	Stored in canister[d]	0.72	0.345	0.123
Sodium Loop Safety Facility	Scrap	Stored in canister[d]	1.80	1.242	0.569
Total			302.65	20.050	8.950

[a]See ref. 6.

[b]No information regarding the burnup of this scrap is available.

[c]Radioactive Scrap and Waste Facility is located approximately 0.5 miles north of ANL-W site.

[d]Canisters are retrievable and constructed of stainless steel with minimum dimensions of 8-in. OD and 5-ft length. The canister lid is gasketed and tightly screwed on, welded closed, or screwed into a canister fitted with pipe threads.

Table A.3. Miscellaneous radioactive materials stored at Babcock & Wilcox, Lynchburg Technology Center, as of December 31, 1991[a]

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM)	U content, kg		Total Pu content (kg)
				Total	^{235}U	
Arkansas I	UO_2, Zr-clad	Stored in four 4.25-in.-diam × 33-in. Al canisters	47,000	11.762	0.046	0.134
B&W Test Reactor	UO_2, Zr-clad	Stored in fourteen 4.25-in.-diam × 33-in. Al canisters	Unknown[c]	0.015	0.005	<0.0005
Consolidated Edison	UO_2, Zr-clad	Stored in a 4.25-in.-diam × 33-in. Al canister	29,523	10.849	0.060	0.088
Oconee I	UO_2, Zr-clad	Stored in twenty-six 4.25-in.-diam × 33-in. Al canisters	18,686	0.531	0.004	0.003
			24,080	2.159	0.028	0.017
			26,480	6.482	0.033	0.056
			31,160	4.275	0.041	0.037
			39,180	11.000	0.057	0.101
			50,000	8.517	0.030	0.094
Oconee I	UO_2-Gd_2O_3, Zr-clad	Stored in four 4.25-in.-diam × 33-in. Al canisters	15,000	7.911	0.103	0.048
Oconee II	UO_2, Zr-clad	Stored in seven 4.25-in.-diam × 33-in. Al canisters	27,500	10.711	0.105	0.095
			31,000	6.432	0.057	0.056
			36,000	1.999	0.015	0.020
TMI-Unit 2	UO_2 debris	Stored in a 4.25-in.-diam × 33-in. Al canister	Unknown[c]	0.047	0.0307	<0.0005
Various fuel scrap samples	UO_2, Zr-clad	Stored in a 4.25-in.-diam × 33-in. Al canister	Unknown[c]	2.202	0.702	<0.0005
Hot cell solid waste	Miscellaneous[d]	Stored in forty-four 80-gal drums, thirty-four 55-gal drums, and eighty-two 30-gal drums	-	e	e	<0.082[f]
Total				84.892	1.317	<0.833

[a]See ref. 7.
[b]Zr-clad = Zircaloy-clad.
[c]Currently in underground storage tubes.
[d]Miscellaneous materials from periodic hot cell cleanup.
[e]Negligible.
[f]Calculated assuming a contaminated level of <0.5 g of plutonium per drum.

Table A.4. Miscellaneous radioactive materials stored at Battelle Pacific Northwest Laboratory, as of December 31, 1991[a]

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM)	U content, kg		Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U		
Calvert Cliffs	UO_2, Zr-clad	0.440-in. diam x 147 in.					
		(stored as 175 intact rods, 1 cut rod[c])	30,000	370.5	2.6	5.3	
		(stored as 154 intact rods, 1 cut rod[c])	45,000	293.2	1.7	7.7	
Cooper	UO_2, Zr-clad	98 rods[c]	26,000	365.3	2.5	3.1	
Point Beach-1	UO_2, Zr-clad	Stored as three intact fuel assemblies, miscellaneous cut samples	32,000	1,163.6	10.3	10.6	6.7
H. B. Robinson	UO_2, Zr-clad	Stored as 19 cut fuel rod sections[c]	30,000	30.2	2.2	0.2	
Shippingport				3.9	0.1	0.1	
VBWR[d]	UO_2, Zr-clad	Twelve 3-ft fuel rod segments	20,000-30,000	11.1	0.1	0.7	
PNL Lot Numbers:							
ATM-5		Glass mix		0.1	e	<0.1	
ATM-6		Glass mix		0.1	e	<0.1	
Miscellaneous scrap and fuel	Cut pieces, scrap	Stored in hot cells		68.5	2.0	1.5	
Miscellaneous fuel	Cut pieces	Stored in hot cell	Unknown	5.4	0.1	0.1	
Total				2,311.9	21.6	29.3	6.7

[a]See ref. 8.
[b]Zr-clad = Zircaloy-clad.
[c]Stored in a hot cell.
[d]Vallecitos boiling-water reactor.
[e]Negligible.

Table A.5. Miscellaneous radioactive materials stored at the Hanford 200-Area burial grounds, as of December 31, 1991[a]

Source of material	Composition	Description[b]	U content, kg		Total Pu content (kg)
			Total	^{235}U	
EBR II (Experimental Breeder Reactor) From INEL	UO_2/PuO_2, SS-clad	Stored in four 30-in.-diam × 59.5-in. shielded carbon steel casks	45.53	7.64	3.60
From LANL	UO_2/PuO_2, SS-clad	Stored in twenty-four 30-in.-diam × 59.5-in. shielded carbon steel casks	78.34	51.42	28.45
From INEL and FFTF (Fast Flux Test Facility)	UO_2/PuO_2, SS-clad	Stored in five 30-in.-diam × 59.5-in. shielded carbon steel casks	34.65	7.55	9.81
Fast Critical Facility and SEFOR (Southwest Experimental Fast Oxide Reactor) from GE, Vallecitos, CA	UO_2/PuO_2	Stored in twenty-two 75.5-in. × 65.5-in. × 65.5-in. concrete casks	40.49	4.88	4.70
K reactor	Unknown	12 Am target elements stored in one 30-in.-diam × 69-in. Zircaloy container	0.024[c]	0.024	.074
LWRs (GETR,[d] Monticello Reactor, Quad Cities 1 Reactor, and Millstone Reactor)	UO_2 pellets	Stored in six 30-in.-diam × 59.5-in. shielded carbon steel casks	63.26	1.29	0.59
TRIGA (Training Reactor, Isotopes, General Atomic) from Oregon State University	Zr-U hydride (8 wt % U), Al-clad	3.6-cm diam × 72 cm fuel assemblies stored/buried in thirteen 55-gal concrete-filled drums, six to seven assemblies per drum	17.2	3.26	0.013
Total			279.49	76.06	47.24

[a]See ref. 9.
[b]No information regarding the burnup of this fuel is available.
[c]Enrichment of uranium not provided.
[d]General Electric (GE) Testing Reactor.

Table A.6. Miscellaneous radioactive materials stored at the Idaho National Engineering Laboratory, as of December 31, 1991[a]

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
DOE/Defense plus other government agency material stored at ICPP								
GCRE (Gas-Cooled Reactor Experiment)	UO_2-BeO, Hastelloy X clad	Two SS tubes, 2 in. x 44 in.	NA	0.984	0.918			
LWBR (Shippingport Light-Water Breeder Reactor)	Ceramic pellets, Zr-clad, Th blanket	47 units	NA	982.173	10.349	826.016	0.177	56,167.0
Misc. fuels and scrap	Scrap	Stored in 92 SS and Al cans	NA	42.16	31.18			
PWR Core 2 (Shippingport Pressurized-Water Reactor)	UO_2 pellets, Zr-clad	40 units	NA	521.613	395.969			
SM-1A (Stationary Media)	UO_2, SS-clad	Stored in 93 SS cans	Negligible	65.759	56.648			
TORY-IIA	UO_2-BeO cermet crushed to 0.25 in. x 0.06 in.	Stored in 147 Al cans 3.25 in. x 43 in.	0.002[c]	48.645	45.325			
TORY-IIC	UO_2-Y_2O_3-ZrO_2-BeO ceramic	Stored in three Al cans 2.68 in. x 52.5 in.	<1.5[c]	59.065	55.022			
Subtotal				1,720.399	595.561	826.016	0.177	56,167.0
DOE/Civilian Development Programs material stored at ICPP								
BORAX-V (Boiling Reactor Experiment No. 5)	UO_2, SS-clad	35 tube elements, 3.6 in. x 39 in. x 36 in.	NA	20.830	19.420			
EBR Scrap (Experimental Breeder Reactor)	Scrap	Four cans	NA	1.618	0.839			
Fermi 1 Blanket	U-Mo (97% U), sodium-bonded, SS-clad	Stored in 510 SS cans, 0.4-in. diam x 41 in. or 61 in.	<1[c]	34,165.000	120.000		6.522	

Table A.6 (continued)

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
DOE/Civilian Development Programs material stored at ICPP (continued)								
FSVR (Fort St. Vrain Reactor)	U-Th carbide and Th carbide, pyrolytic carbon-coated particles in graphite matrix	750 hexagonal graphite blocks 14.2 in. across flats × 31.2 in.	6,000-26,000	308.330	167.648	90.139	0.752	8,316.6
MURR (University of Missouri)	UAl_x, SS-clad	56 fuel elements, 4 in. × 4.5 in. × 32 in. in Al cans	NA	38.02	33.26			
PARKA (LANL critical assembly)	UC, ZrC	Graphite, ~3-in. diam × 54 in.	NA	147.98	137.84			
Pathfinder	UO_2-B_4C cermet pellets, SS-clad	411 assemblies in 17 SS cans; each can is 9-in. diam × 80 in.	<<1[c]	53.406	49.242			
Peach Bottom	U-Th carbide, pyrolytic carbon-coated particles in graphite matrix	1,603 graphite blocks 3.5-in. diam × 12 ft	>1[c]	332.420	223.540	46.310	0.970	2,620.0
Pulstar, State University of New York at Buffalo	UO_2 pellets in Zr-clad pins	Stored in 24 SS cans, 3 in. × 3 in. × 28.0 in.	<0.01	251.431	12.083		0.793	
TRIGA (Training Reactor, Isotopes, General Atomic)	Al- or SS-clad elements	845 units stored in 177 cans	Varies	160.974	34.680		0.029	
VBWR (Geneva) (Vallecitos Boiling-Water Reactor)	UO_2 and UO_2-TiO_2, SS-clad	142 rods stored in four 6-in.-diam × 36-in. Al cans	8[c]	12.383	2.606			
Subtotal				35,492.392	801.158	136.449	9.066	10,936.6

Table A.6 (continued)

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
		DOE material stored at NRF[d]						
Shippingport PWR Core 1	UO_2 pellets, Zr-clad	Miscellaneous test specimens from blanket fuel assemblies	11,100	568	<0.5		3.4	
Shippingport PWR Core 2	UO_2 wafers, Zr-clad	Three modules and module sections from blanket fuel assemblies	14,273	1,028	2		8.9	
		One seed module		11.09	7.45			
Subtotal				1,607.09	9.45		12.3	
		DOE/Civilian Development Programs material stored at INEL (other than ICPP and NRF)						
CANDU (Canadian Deuterium Reactor)	UO_2 pellets, Zr-clad	8 pins	5,000	2.660	0.261			
Connecticut Yankee	UO_2, Zr-clad	1 assembly (200 pins)	NA	378.485	5.204		3.774	
Dresden	UO_2, Zr-clad	55 pins (depleted U)	NA	165.0	Unknown		1.064	
EMAD[e] (Engine Maintenance Assembly & Disassembly)	UO_2 pellets, Zr-clad	18 assemblies	25,000-30,000	7,831.273	58.103		65.255	
GAP CON (Gap Conductance)	UO_2 pellets, Zr-clad	20 pins	42-115	12.838	1.285			
GE (General Electric)	UO_2 pellets, Zr-clad	Pins	NA	18.644	0.394		0.071	
Halden Assy	UO_2 pellets, Zr-clad	5 pins	4,000	2.313	0.233		0.005	
Halden 226 and 239 Assy	UO_2-PuO_2 pellets, Zr-clad	12 pins	NA	NA			0.324	
IE (Irradiation Effects)	UO_2 pellets, Zr-clad	Pins	27-17,600	7.833	0.867		0.012	

Table A.6 (continued)

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
DOE/Civilian Development Programs material stored at INEL (other than ICPP and NRF) (continued)								
LLR (LOFT Lead Rod)	UO_2 pellets, Zr-clad	7 pins	36-150	3.510	0.327			
LOC (Loss of Coolant)	UO_2 pellets, Zr-clad	60 pins	16-150	7.777	0.816		0.010	
LOFT (Loss of Fluid Test)	UO_2 pellets, Zr-clad	15^+ assemblies	0-1,050	2,201.696	89.371		2.029	
MAPI (Mitsubishi Atomic Power Industries)	UO_2 pellets, Zr-clad	43 pins	2,990-8,770	22.499	1.267		0.032	
Miscellaneous fuel pins	UO_2 pellets, Zr-clad	Pins	Varies	173.354	1.758		2.626	
Miscellaneous rods and scrap	Scrap	Stored in 8 cans	Varies	13.553	1.197			
OPTRAN (Operational Transient)	UO_2 pellets, Zr-clad	Pins	0-15,000	19.669	0.472		0.087	
PBF (Power-Burst Facility)	UO_2-ZrO_2-CaO; Zr sleeves, SS-clad	108 pins	NA	725.690	132.890			
PCM (Power Coolant Mismatch)	UO_2 pellets, Zr-clad	30 pins	<70	18.828	6.557			
Peach Bottom	UO_2 pellets, Zr-clad, Zr-clad assy	1 assembly and pieces (depleted U)	NA	364.1	2.512		1.878	
RIA (Reactivity Initiated Accident)	UO_2 pellets, Zr-clad	23 pins	0-6,090	8.989	0.504		0.013	
H. B. Robinson	UO_2 pellets, Zr-clad	113 pins	28,000	263.916	1.890		2.153	
Saxton	UO_2 pellets, Zr-clad	21 pins	10,400-18,253	7.607	0.660		0.025	
SFD (Severe Fuel Damage)	UO_2 pellets, Zr-clad	143 pins	NA	50.867	2.711		0.150	

Table A.6 (continued)

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
DOE/Civilian Development Programs material stored at INEL (other than ICPP and NRF) (continued)								
TC (Thermocouple)	UO_2 pellets, Zr-clad	Pins	0-<20	6.186	0.683			
TMI-Unit 2	Rubble	360 cans	NA	(Quantities unknown until entire core received)				
VEPCO (Virginia Electric Power Company)		69 assemblies (depleted U)	NA	30,207.295	242.457		172.695	
Subtotal				42,514.582	552.419		252.205	
Total at INEL				81,334.463	1,958.588	962.465	273.748	67,103.6

[a]See refs. 10-11. Many of the fuels at INEL have lower uranium enrichment than is found in those fuels that are normally processed. These fuels could be reprocessed in a special campaign, if required.

[b]Zr-clad = Zircaloy-clad.

[c]Data expressed in percentage.

[d]Based on ref. 11.

[e]Turkey Point Fuel.

NA = not available.

Table A.7. Miscellaneous radioactive materials stored at the Los Alamos National Laboratory, as of December 31, 1991[a]

Source of material	Composition	Description	U content, kg			Total Pu content (kg)
			Total	^{235}U	^{233}U	
EBR-2[b]	U-Pu oxide, carbide, or nitride SS-clad fuel rod segments	0.3-in. diam × 13.5 in.	3.09	1.84	0.058	1.31
Total			3.09	1.84	0.058	1.31

[a]See ref. 12.
[b]Information regarding the burnup of this fuel is not available.

Table A.8. Miscellaneous radioactive materials stored at the Oak Ridge National Laboratory, as of December 31, 1991[a]

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM)	U content, kg			Total Pu content (kg)
				Total	^{235}U	^{233}U	
CEU (Consolidated Edison Uranium)	U_3O_8-CdO solid cake	Stored in 401 3.5-in.-OD x 24-in. SS cans	c	1,044.38	797.70	101.32	
Dresden-1	UO_2, Zr-clad	Sheared fuel pins stored in two 1-qt paint cans	~24,000	5.00	0.024		0.020
		9/16-in.-diam x 8-in. fuel rod sections plus short lengths	20,000	0.930	0.005		0.006
GETR (General Electric Test Reactor)	UO_2, Zr-clad	9/16-in.-diam x 8-in. fuel test capsules	1,000-2,000	0.399	0.022		
Monticello	UO_2, Zr-clad	1/2-in.-diam x 6-in. fuel rod sections plus short lengths	40,000	1.00	0.004		0.008
MSRE[d] (Molten Salt Reactor Experiment)	$LiF-BeF_2-ZrF_4-UF_4$	See ref. 13	~5 x 10^4 Ci total (see ref. 13)	36.95	0.940	31.01	0.743
Oconee-1	UO_2, Zr-clad	1/2-in.-diam x 6-in. fuel rod sections plus short lengths	38,000	1.00	0.005		0.005
Peach Bottom-2	UO_2, Zr-clad	9/16-in.-diam x 8-in. fuel rod sections plus short lengths	10,000	0.324	0.001		0.001
Quad City-1	UO_2, Zr-clad	1/2-in.-diam x 6-in. fuel rod sections plus short lengths	40,000	1.00	0.004		0.008
H. B. Robinson	UO_2, Zr-clad	1/2-in.-diam x 12-in. fuel rod sections plus short lengths	30,000	1.00	0.005		0.004
BR-3 (Belgium)	UO_2, Zr-clad	3/8-in.-diam x 6-in. fuel rod lengths	42,000	0.837	0.020		0.006
ORNL Inventory Item Nos. AUA-67/AUA-70 from LANL	U metal chunks	Stored in two 3.75-in.-OD x 18-in. SS cans	c	6.02		5.89	
CZA-91 from ANL	UO_x powder	Stored in one 3.5-in.-OD x 13-in. SS can	c	0.881		0.856	

Table A.8 (continued)

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM)	U content, kg			Total Pu content (kg)
				Total	^{235}U	^{233}U	
HUA-2A from HEDL	UO_x powder	Stored in five 3.75-in.-OD × 7-in. SS cans	c	0.317		0.307	
LAE-03 from Atomics International (AI)	Metal	Stored in one 3-in.-OD × 10-in. SS can	c	0.01		0.01	
RCP-02 from SRC	UO_2 powder	Stored in thirty-two 3.5-in.-OD × 24-in. SS cans	c	11.14		10.72	
RCP-03 from SRO	UO_2 powder	Stored in 140 3.88-in.-OD × 10-in. SS cans	c	67.41		61.61	
RCP-04 from SRO	UF_4-LiF powder converted from UO_2	Stored in four 3.5-in.-OD × 24-in. SS cans	c	3.19		2.92	
RCP-06	U_3O_8-CdO solid cake	Stored in twenty-seven 3.5-in.-OD × 24-in. SS cans	c	65.55		60.60	
RCP-20/J2BL from LANL	U metal chunks	Stored in six 3.5-in.-OD × 24-in. SS cans	c	5.15		5.05	
Total				1,252.488	798.7	280.29	0.801

[a]See ref. 13.
[b]Zr-clad = Zircaloy-clad.
[c]No information regarding the burnup of this fuel is available.
[d]The Molten Salt Reactor Experiment was concluded in 1969, and the fuel has never been removed from the facility. A surveillance and monitoring program has been in force since shutdown. See ref. 14. Decommissioning of the MSRE facility is an environmental restoration activity discussed earlier in Chapter 6.

Table A.9. Miscellaneous radioactive materials stored at the Savannah River Site, as of December 31, 1991[a]

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
DOE/Civilian Development Programs material stored at SRS								
CANDU (Canadian Deuterium Reactor)	UO_2, Zr-clad	Rods stored in three 5.0-in.-diam x 14-ft cans; pieces stored in three 3.5-in.-diam x 1-ft cans	6,500	50.07	0.231			
Carolinas-Virginia Tube Reactor	UO_2-Zr or SS-clad	One bundle of 34 rods in a 5.0-in.-diam x 14-ft can	Unknown	67.27	0.640		0.200	
Dresden	UO_2-ThO_2, SS-clad	Intact assemblies stored in 4.4-in. x 4.4-in. x 135-in. cans	4,000-10,000	684.00	37.545	15.391	1.879	1,857.0
ERR (Elk River Reactor)	UO_2-ThO_2, SS-clad	Assemblies 3.5 in. x 3.5 in. x 81.62 in.	Max. 50,000	224.29	186.159	14.722		4,818.6
LWR samples (Light-Water Reactors)	UO_2-PuO_2, SS- and Zr-clad	Fuel rod pieces stored in five 3.75-in.-diam x 32.5-in.-long cans	Unknown	12.631	0.192		0.109	
Nereide (a French Experiment using DOE fuel)	UAl-Si_x, Al-clad	Materials Test Reactor plate-type fuel assembly 34.37 in. x 2.98 in. x 3.14 in.	600	35.42	7.015			
H. B. Robinson	UO_2-PuO_2, Zr-clad, SS casing	Four 6- to 8-in.-long fragments in 4.5-in.-diam x 32-in.-long can	6,800-30,000	0.51	0.004		0.003	
Saxton	UO_2-PuO_2, Zr- or SS-clad	567 rods stored in eight 5.0-in.-diam x 14-ft cans and 64 rods stored in one 3.75-in.-diam x 50-in. can	1,000	280.21	1.411		15.408	
	UO_2, Zr-clad	Multiple pins stored in four 5.0-in.-diam x 14-ft cans and one bundle stored in one 12-in.-diam x 14-ft can	1,600	89.19	6.866		0.233	

Table A.9 (continued)

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
DOE/Civilian Development Programs material stored at SRS (continued)								
VBWR (Vallecitos Boiling-Water Reactor)	UO_2, Zr-clad	Stored in four 3.5-in.-diam × 12-in. cans	1,500	11.93	1.243		0.003	
Subtotal				1,455.521	241.306	30.113	17.835	6,675.6
DOE plus other government agencies material stored at SRS								
B&W scrap	UO_2-PuO_2, SS-clad	Stored in 3.5-in.-diam × 32-in. cans	6-54	0.025	0.013		0.048	
EBR-2 (Experimental Breeder Reactor)	UO_2-PuO_2, SS-clad (from ANL)	Eight rods stored in a 3.5-in.-diam × 30-in. can	120 kW total in 1975	0.44	0.376		0.114	
	UO_2-PuO_2, SS-clad (from HEDL)	Rod segments stored in 0.5-in.-diam × 42-in. cans	10,000-34,000	2.04	1.624		0.680	
EBWR (Experimental Boiling-Water Reactor)	UO_2, SS-clad	Assemblies 3.75 in. × 3.75 in. × 62.5 in.	1,600	1.73	1.612			
	UO_2, Zr-clad	Assemblies 3.75 in. × 3.75 in. × 62.5 in.	1,600	1,600.32	95.456			
	UO_2-Zr, Zr-clad	Assemblies 3.75 in. × 3.75 in. × 62.5 in.	1,600	7,482.73	73.967		9.092	
	UO_2-ZrO_2-CaO, Zr-clad	Assemblies 3.75 in. × 3.75 in. × 62.5 in.	1,600	28.93	26.651			
	UO_2-PuO_2, Zr-clad	Assemblies 3.75 in. × 3.75 in. × 62.5 in.	1,600	917.72	2.087		13.940	
EFR-1	PuO_2, SS-clad	Pieces stored in 4.5-in.-diam × 32-in. cans	Unknown				0.022	

Table A.9 (continued)

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
DOE plus other government agencies material stored at SRS (continued)								
GCRE (Gas-Cooled Reactor Experiment)	UO_2 or UO_2-BeO, Hastelloy-clad	Four 2-in.-diam x 32-in. Al cans of scrap pieces; two 1.5-in.-diam Al cans of plates; 66 pin-type assemblies		61.290	56.559			
HWCTR (Heavy-Water Components Test Reactor)	U and UO_2, Zr-clad	Intact assemblies 3 in. diam x 132 in. Pieces of assemblies stored in 3.5-in.-diam x 12-in. cans	6,200	1,051.376	9.470		0.565	
	U-Zr, Zr-clad			37.165	31.590			
HTRE (High-Temperature Reactor Experiment)	UO_2-BeO, Nichrome-clad	Segments and pieces of fuel assemblies and test pieces in thirteen 4-in.-diam x 36-in. Al cans		4.039	3.423			
ML-1 (Mobile Low Power Plant No. 1)	UO_2 and PuO_2-BeO, SS-clad	Sixty-eight 19-pin assemblies		58.575	54.478			
ORNL (Oak Ridge National Laboratory) SIW-1 rods	U, Zr-clad	Rods stored in three 4.5-in.-diam x 9.25-in. Al cans	Unknown but low	0.184	0.171			
ORNL mixed oxide	UO_2-PuO_2, Zr- or SS-clad	Stored in one 3.5-in.-diam x 15.12-in. can	Unknown but low	0.376	0.030		0.094	
Shippingport	UO_2, Zr-clad	Stored in a 10.5-in.-diam x 15-in. container	18,000	16.000	0.023		0.108	
SPERT-3 (Special Power Excursion Reactor Test)	UO_2, Zr-clad	Stored in three 4.0-in.-diam x 12-ft cans	Unknown	9.739	0.603			
SRE (Sodium Reactor Experiment)	U, Th rods, SS-clad	Stored in 3.5-in.-diam x 110.25-in. cans	10,000	154.934	143.410	1.045		1,972.6
	UC, SS-clad			44.324	4.344		0.016	

Table A.9 (continued)

Source of material	Composition[b]	Description	Estimated burnup (MWd/MTIHM)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	^{235}U	^{233}U		
DOE plus other government agencies material stored at SRS (continued)								
SRS (Savannah River Site)	UO_2-PuO_2, Zr-clad	Stored in a 12.0-in.-diam × 14-ft can	Unknown	69.87	0.304		0.161	
ORR-LEU (Oak Ridge Reactor Low Enriched Uranium)	U_3Si_2, Al-clad	Stored in fourteen 3.5-in. × 3.5-in. × 168-in. Al cans	15,600	95.006	14.960	-	0.537	-
Subtotal				11,636.813	521.151	1.045	25.377	1,972.6
Total				13,092.334	762.457	31.158	43.212	8,648.2

[a]See refs. 14 and 15. The spent fuels listed in this table are not reprocessible in existing facilities.
[b]Zr-clad = Zircaloy-clad.

Table A.10. Volume and activity summary of commercial GTCC LLW[a,b]

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

[a]Based on the EG&G Idaho, Inc., study of ref. 16. Data reported represent packaged base case scenario inventories and projections of wastes generated during the period 1985-2035.

[b]These wastes are discussed in Chapter 4; see Table 4.19.

Table A.11. Mass summary of DOE spent fuel no longer scheduled for reprocessing[a]

Site/source	Spent fuel mass
Hanford	
• N Reactor[b]	2,100 MTIHM
• Shippingport PWR[b]	16 MTIHM
• Fast Flux Test Facility[c]	12 MTIHM
Subtotal	2,128 MTIHM
Idaho National Engineering Laboratory[d]	874 t
West Valley[e]	27 MTIHM
Savannah River[f]	0 MTIHM

[a]Compiled from refs. 17-21.

[b]Based on ref. 18.

[c]Based on ref. 19 and includes contributions from fresh fuel (1.9 MTIHM), partially used fuel (5.2 MTIHM), and spent fuel (4.9 MTIHM).

[d]Based on ref. 20. Mass reported is an estimate of total spent fuel mass after burnup. This estimate includes contributions from graphite fuels (including Fort St. Vrain reactor fuel), special fuels (including TMI-Unit 2 fuel), and naval reactor fuels.

[e]Based on ref. 17.

[f]Based on ref. 21. Savannah River currently plans to reprocess all production reactor fuel that has been irradiated.

APPENDIX B. CHARACTERISTICS OF IMPORTANT RADIONUCLIDES

APPENDIX B. CHARACTERISTICS OF IMPORTANT RADIONUCLIDES

B.1 DISCUSSION

The following Table B.1 lists radionuclides whose characteristics are most often referenced in the variety of studies and evaluations discussed in Chapters 1–7. It includes isotopes for HLW, TRU waste, LLW, and uranium mill tailings as defined by EPA,[1] NRC,[2,3] and DOE.[4,5] The data in Table B.1 were obtained from refs. 6–8.

B.2 REFERENCES

1. 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).

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

3. U.S. Nuclear Regulatory Commission, "Biomedical Waste Disposal," Fed. Regist. 46(47), 16230-16234 (Mar. 11, 1981).

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

5. U.S. Department of Energy, Energy Information Administration, Domestic Uranium Mining and Milling Industry 1990 – Viability Assessment, DOE/EIA-0477(90), Washington, D.C. (December 1991).

6. D. C. Kocher, Radioactive Decay Data Tables, DOE/TIC-11026, Washington, D.C. (1981).

7. D. C. Kocher, A Radionuclide Decay Data Base – Index and Summary Table, NUREG/CR-1413, ORNL/NUREG-70, Oak Ridge National Laboratory, Oak Ridge, Tennessee (May 1980).

8. E. Browne and R. B. Firestone, V. S. Shirley, ed., Table of Radioactive Isotopes, John Wiley and Sons, Inc., New York (1986).

Table B.1. Characteristics of important radionuclides[a]

Nuclide	Atomic number	Half-life[b]	Principal mode(s) of decay[c]	Major radiation energies[d] (MeV/dis) α	e	γ(X)	"Q" value[e] (MeV/dis)	(W/Ci)	Specific activity (Ci/g)	Daughter(s)
^{3}H	1	1.233E+01 y	β		0.00568		5.68E-03	3.37E-05	9.650E+03	^{3}He
^{14}C	6	5.730E+03 y	β		0.0495		4.95E-02	2.93E-04	4.457	^{14}N
^{32}P	15	14.282 d	β		0.6947		6.95E-01	4.12E-03	2.853E+05	^{32}S
^{35}S	16	87.51 d	β		0.0486		4.86E-02	2.88E-04	4.263E+04	^{35}Cl
^{36}Cl	17	3.01E+05 y	β (98.1%); EC (1.9%)		0.2460		2.460E-01	1.458E-03	3.299E-02	^{36}Ar; ^{36}S
^{45}Ca	20	163.8 d	β		0.0770		7.70E-02	4.56E-04	1.780E+04	^{45}Sc
^{46}Sc	21	83.83 d	β	0.1120	2.0095		2.122E+00	1.257E-02	3.381E+04	^{46}Ti
^{51}Cr	24	27.704 d	EC		0.0031	0.0325	3.56E-02	2.11E-04	9.240E+04	^{51}V
^{54}Mn	25	312.20 d	EC		0.0034	0.8360	8.394E-01	4.975E-03	7.738E+03	^{54}Cr
^{55}Fe	26	2.73 y	EC		0.0038	0.0016	5.4E-03	3.2E-05	2.500E+03	^{55}Mn
^{59}Fe	26	44.496 d	β		0.1174	1.1882	1.3056	7.741E-03	4.918E+04	^{59}Co
^{57}Co	27	271.77 d	EC		0.0176	0.1252	1.428E-01	8.464E-01	8.456E+03	^{57}Fe
^{58}Co	27	70.92 d	EC		0.0336	0.9758	1.0094	5.99E-03	3.181E+04	^{58}Fe
^{60}Co	27	5.271 y	β		0.0958	2.5058	2.6016	1.541E-02	1.131E+03	^{60}Ni
^{60m}Co	27	10.47 min	IT (99.75%); β (0.25%)		0.0536	0.0066	6.02E-02	3.57E-04	2.993E+08	^{60}Co; ^{60}Ni
^{59}Ni	28	7.5E+04 y	EC		0.0043	0.0024	6.72E-03	3.98E-05	7.574E+04	^{59}Co
^{63}Ni	28	1.001E+02 y	β		0.0171		1.71E-02	1.01E-04	6.168E+01	^{63}Cu
^{65}Zn	30	244.1 d	EC		0.0066	0.5838	5.90E-01	3.51E-03	8.237E+03	^{65}Cu
^{67}Ga	31	3.261 d	EC		0.0333	0.1549	1.882E-01	1.115E-03	5.975E+05	^{67}Zn
^{75}Se	34	119.77 d	EC		0.0134	0.3924	4.06E-01	2.41E-03	1.453E+04	^{75}As
^{79}Se	34	<6.5E+04 y			0.0529		5.29E-02	3.13E-04	6.966E-02	^{79}Br
^{85}Kr	36	1.072E+01 y	β		0.2505	0.0022	2.53E-01	1.50E-03	3.923E+02	^{85}Rb
^{86}Rb	37	18.66 d	β		0.6670	0.0945	7.62E-01	4.52E-03	8.138E+04	^{86}Sr
^{89}Sr	38	50.55 d	β		0.5829	0.0001	5.83E-01	3.46E-03	2.905E+04	^{89}Y
^{90}Sr	38	2.85E+01 y	β		0.1958		1.96E-01	1.16E-03	1.364E+02	^{90}Y

Table B.1 (continued)

Nuclide	Atomic number	Half-life[b]	Principal mode(s) of decay[c]	Major radiation energies[d] (MeV/dis) α	e	γ(X)	"Q" value[e] (MeV/dis)	(W/Ci)	Specific activity (Ci/g)	Daughter(s)
^{90}Y	39	2.671 d	β		0.9332		9.33E-01	5.54E-03	5.441E+05	^{90}Zr
^{91}Y	39	58.51 d	β		0.6039	0.0036	6.07E-01	3.60E-03	2.452E+04	^{91}Zr
^{93}Zr	40	1.53E+06 y	β		0.0471	0.0018	4.89E-02	2.90E-04	2.513E-03	^{93}Nb
^{95}Zr	40	64.02 d	β		0.1200	0.7337	8.54E-01	5.06E-03	2.148E+04	^{95}Nb
^{93m}Nb	41	1.36E+01 y	IT		0.0281	0.0018	2.99E-02	1.77E-04	2.826E+02	^{93}Nb
^{94}Nb	41	2.03E+04 y	β		0.1454	1.5715	1.7169	1.018E-02	1.873E-01	^{94}Mo
^{95}Nb	41	34.97 d	β		0.0435	0.7643	8.078E-01	4.788E-03	3.910E+04	^{95}Mo
^{99}Mo	42	2.748 d	β		0.4076	0.2723	6.799E-01	4.028E-03	4.796E+05	^{99}Tc
^{99}Tc	43	2.13E+05 y	β		0.0846		8.46E-02	5.01E-04	1.695E-02	^{99}Ru
^{99m}Tc	43	6.006 h	IT		0.0142	0.1240	1.382E-01	8.186E-04	5.271E+06	^{99}Tc
^{103}Ru	44	39.254 d	β		0.1105	0.4851	5.96E-01	3.53E-03	3.227E+04	^{103}Rh
^{106}Ru	44	1.020 y	β		0.1004		1.004E-01	5.951E-04	3.346E+03	^{106}Rh
^{103m}Rh	45	56.12 min	IT		0.0375	0.0017	3.92E-02	2.32E-04	3.253E+07	^{103}Rh
^{106}Rh	45	2.17 h	β		0.3144	2.8826	3.197	1.894E-02	3.560E+09	^{106}Pd
^{107}Pd	46	6.5E+06 y	β			0.0093	9.3E-03	5.5E-05	5.143E-04	^{107}Ag
^{110}Ag	47	24.6 s	β (99.70%); EC (0.30%)		1.1842	0.0316	1.216	7.208E-03	4.169E+09	^{110}Cd; ^{110}Pd
^{110m}Ag	47	249.76 d	β (98.64%); IT (1.36%)		0.0755	2.7392	2.815	1.669E-02	4.750E+03	^{110}Cd; ^{110}Ag
^{113m}Cd	48	1.37E+01 y	β (99.9%); IT (0.1%)			0.1834	1.83E-01	1.08E-03	2.168E+02	^{113}In; ^{113}Cd
^{115m}Cd	48	44.6 d	β		0.6029	0.0329	6.36E-01	3.76E-03	2.546E+04	^{115}In
^{111}In	49	2.807 d	EC		0.0340	0.4053	4.393E-01	2.604E-03	4.157E+05	^{111}Cd
^{113m}In	49	1.658 h	IT		0.1340	0.2555	3.89E-01	2.31E-03	1.673E+07	^{113}In
^{114m}In	49	49.51 d	IT (95.7%); EC (4.3%)		0.1431	0.0943	2.37E-01	1.40E-03	2.313E+04	^{114}In; ^{114}Cd
^{113}Sn	50	115.09 d	EC		0.1394	0.2808	4.20E-01	2.48E-03	1.004E+04	^{113}In
^{117m}Sn	50	13.61 d	IT		0.1613	0.1580	3.19E-01	1.89E-03	7.969E+04	^{117}Sn
^{119m}Sn	50	293.0 d	IT		0.0783	0.0114	8.97E-02	5.32E-04	4.478E+03	^{119}Sn
^{121m}Sn	50	5.5E+01 y	IT (77.6%); β (22.4%)		0.0352	0.0050	4.02E-02	2.43E-04	5.912E+01	^{121}Sn; ^{121}Sb
^{123}Sn	50	129.2 d	β		0.5222	0.0069	5.29E-01	3.14E-03	8.219E+03	^{123}Sb
^{125}Sn	50	9.64 d	β		0.8110	0.3124	1.123	6.656E-03	1.084E+05	^{125}Sb
^{126}Sn	50	~1E+05 y	β		0.1249	0.0573	1.82E-01	1.08E-03	2.837E-02	^{126}Sb

Table B.1 (continued)

Nuclide	Atomic number	Half-life[b]	Principal mode(s) of decay[c]	Major radiation energies[d] (MeV/dis) α	e	γ(X)	"Q" value[e] (MeV/dis)	(W/Ci)	Specific activity (Ci/g)	Daughter(s)
^{124}Sb	51	60.20 d	β		0.3897	1.8523	2.242	1.329E-02	1.749E+04	^{124}Te
^{125}Sb	51	2.73 y	β		0.1257	0.4434	5.59E-01	3.37E-03	1.032E+03	^{125}Te
^{126}Sb	51	12.4 d	β		0.3527	2.7496	3.102	1.839E-02	8.360E+04	^{126}Te
^{126m}Sb	51	19.0 min	β (86%); IT (14%)		0.6323	1.5484	2.181	1.292E-02	7.854E+07	^{126}Te; ^{126}Sb
^{123m}Te	52	119.7 d	IT		0.1028	0.1482	2.507E-01	1.482E-03	6.870E+03	^{123}Te
^{125m}Te	52	58 d	IT		0.1136	0.0361	1.467E-01	9.690E-04	1.801E+04	^{125}Te
^{127}Te	52	9.35 h	β		0.2246	0.0043	3.30E-01	1.36E-03	2.633E+06	^{127}I
^{127m}Te	52	109 d	IT (97.5%); β (2.4%)		0.0891	0.0111	9.52E-02	5.52E-04	9.432E+03	^{127}Te; ^{127}I
^{129}Te	52	1.160 h	β		0.5422	0.0624	6.05E-01	3.58E-03	2.094E+07	^{129}I
^{129m}Te	52	33.6 d	IT (64%); β (36%)		0.2663	0.0370	3.33E-01	1.80E-03	3.013E+04	^{129}Te; ^{129}I
^{123}I	53	13.2 h	EC		0.0276	0.1729	2.305E-01	1.188E-03	1.940E+06	^{123}Te
^{125}I	53	60.14 d	EC		0.0179	0.0423	6.92E-02	3.57E-04	1.737E+04	^{125}Te
^{129}I	53	1.57E+07 y	β		0.0556	0.0246	8.34E-02	4.77E-04	1.765E-04	^{129}Xe
^{131}I	53	8.040 d	β		0.1919	0.3826	5.74E-01	3.40E-03	1.240E+05	^{130}Xe
^{133}Xe	54	5.245 d	β		0.1353	0.0459	1.32E-01	1.08E-03	1.872E+05	^{133}Cs
^{134}Cs	55	2.062 y	β		0.1652	1.5555	1.718	1.019E-02	1.294E+03	^{134}Ba
^{135}Cs	55	3.0E+06 y	β		0.0553		5.53E-02	3.32E-04	1.151E-03	^{135}Ba
^{137}Cs	55	3.017E+01 y	β (94.6%); β (5.4%)			0.1708	1.71E-01	1.01E-03	8.698E+01	^{137m}Ba; ^{137}Ba
^{133}Ba	56	1.054E+01 y	EC		0.0547	0.4045	4.592E-01	2.722E-03	2.500E+02	^{133}Cs
^{137m}Ba	56	2.552 min	IT		0.0652	0.5991	6.64E-02	3.94E-03	5.379E+08	^{137}Ba
^{141}Ce	58	32.50 d	β		0.1707	0.0770	2.48E-01	1.47E-03	2.848E+04	^{141}Pr
^{144}Ce	58	284.9 d	β		0.0918	0.0192	1.11E-01	6.58E-04	3.190E+03	^{144}Pr
^{143}Pr	59	13.58 d	β		0.3156		3.16E-01	1.87E-03	6.731E+04	^{143}Nd
^{144}Pr	59	17.28 min	β		1.2091	0.0289	1.238	7.338E-03	7.555E+07	^{144}Nd
^{144m}Pr	59	7.2 min	IT (99.96%); β (0.04%)		0.0464	0.0121	5.85E-02	3.43E-04	1.814E+08	^{144}Pr; ^{144}Nd
^{146}Pm	61	5.53 y	EC (66.1%); β (33.9%)		0.0928	0.7542	8.47E-01	5.02E-03	4.428E+02	^{146}Nd; ^{146}Sm
^{147}Pm	61	2.6234 y	β		0.6196		6.20E-02	3.67E-04	9.270E+02	^{147}Sm
^{148}Pm	61	5.370 d	β		0.7235	0.5747	1.298	7.691E-03	1.643E+05	^{148}Sm
^{148m}Pm	61	41.29 d	β (95.4%); IT (4.6%)		0.1695	1.9861	2.156	1.278E-02	2.136E+04	^{148}Sm; ^{148}Pm

Table B.1 (continued)

Nuclide	Atomic number	Half-life[b]	Principal mode(s) of decay[c]	Major radiation energies[d] (MeV/dis) α	e	γ(X)	"Q" value[e] (MeV/dis)	(W/Ci)	Specific activity (Ci/g)	Daughter(s)
^{151}Sm	62	9.0E+01 y	β		0.1251		1.25E-01	7.41E-04	2.631E+01	^{151}Eu
^{152}Eu	63	1.333E+01 y	EC (72.08%); β (27.92%)		0.1275	1.1628	1.290	7.646E-03	1.729E+02	^{152}Sm; ^{152}Gd
^{154}Eu	63	8.8 y	β		0.2794	1.2531	1.532	9.081E-03	2.699E+02	^{154}Gd
^{155}Eu	63	4.96 y	β		0.0650	0.0633	1.28E-01	7.59E-04	4.651E+02	^{155}Gd
^{153}Gd	64	241.6 d	EC		0.0399	0.1015	1.414E-01	8.381E-04	3.526E+03	^{153}Eu
^{160}Tb	65	72.3 d	β		0.2535	1.1271	1.381	8.186E-03	1.129E+04	^{160}Dy
^{169}Yb	70	32.02 d	EC		0.1117	0.3121	4.238E-01	2.512E-03	2.414E+04	^{169}Tm
^{175}Hf	72	70.0 d	EC		0.0439	0.3646	4.085E-01	2.422E-03	1.066E+04	^{175}Lu
^{182}Ta	73	115.0 d	β		0.2073	1.3011	1.508	8.940E-03	6.253E+03	^{182}W
^{192}Ir	77	73.831 d	β (95.4%); EC (4.6%)		0.2162	0.8137	1.030	6.105E-03	9.211E+03	^{192}Pt; ^{192}Os
^{201}Tl	81	3.046 d	EC		0.0481	0.0924	1.40E-01	8.30E-04	2.132E+05	^{201}Hg
^{207}Tl	81	4.77 min	β		0.4931	0.0022	4.95E-01	2.93E-03	1.904E+08	^{207}Pb
^{208}Tl	81	3.053 min	β		0.5979	3.3742	3.972	2.354E-02	2.945E+08	^{208}Pb
^{209}Pb	82	3.253 h	β		0.1980		1.98E-01	1.17E-03	4.544E+06	^{209}Bi
^{211}Pb	82	36.1 min	β		0.4523	0.0678	5.20E-01	3.083E-03	2.468E+07	^{211}Bi
^{212}Pb	82	10.64 h	β		0.1752	0.1453	3.20E-01	1.90E-03	1.389E+06	^{212}Bi
^{211}Bi	83	2.14 min	α (99.727%); β (0.273%)	6.5505	0.0099	0.0467	6.607	3.916E-02	4.184E+08	^{207}Tl; ^{211}Po
^{212}Bi	83	1.0092 h	α (35.94%); β (64.06%)	2.1740	0.5025	0.1061	2.783	1.649E-02	1.465E+07	^{208}Tl; ^{212}Po
^{213}Bi	83	45.59 min	α (2.16%); β (97.84%)	0.1268	0.4563	0.0825	6.66E-01	3.95E-03	1.934E+07	^{209}Tl; ^{213}Po
^{212}Po	84	2.98E-07 s	α	8.7844			8.784	5.207E-02	1.774E+17	^{208}Pb
^{213}Po	84	4.2E-06 s	α	8.3757			8.375	4.964E-02	1.261E+16	^{209}Pb
^{215}Po	84	1.780E-03 s	α	7.3864			7.386	4.378E-02	2.948E+13	^{211}Pb
^{216}Po	84	1.50E-02 s	α	6.7785			6.779	4.018E-02	3.482E+11	^{212}Pb
^{217}At	85	3.23E-02 s	α	7.0657		0.0002	7.066	4.189E-02	1.610E+12	^{213}Bi
^{219}Rn	86	3.96 s	α	6.8122	0.0064	0.0560	6.875	4.076E-02	1.301E+10	^{215}Po
^{220}Rn	86	55.6 s	α	6.2878		0.0005	6.288	3.727E-02	9.223E+08	^{216}Po
^{222}Rn	86	3.825 d	α	5.4892		0.0004	5.490	3.255E-02	1.538E+05	^{218}Po

Table B.1 (continued)

Nuclide	Atomic number	Half-life[b]	Principal mode(s) of decay[c]	Major radiation energies[d] (MeV/dis) α	e	γ(X)	"Q" value[e] (MeV/dis)	(W/Ci)	Specific activity (Ci/g)	Daughter(s)
^{221}Fr	87	4.9 min	α	6.3571	0.0084	0.0277	6.393	3.789E-02	1.772E+08	^{217}At
^{223}Fr	87	21.8 min	β		0.3805	0.0542	4.35E-01	2.85E-03	3.868E+07	^{223}Ra
^{223}Ra	88	11.43 d	α	5.6972	0.0731	0.1348	5.905	3.500E-02	5.121E+04	^{219}Rn
^{224}Ra	88	3.66 d	α	5.6751	0.0022	0.0103	5.638	3.372E-02	1.593E+05	^{220}Rn
^{225}Ra	88	14.2 d	β		0.1057	0.0137	1.19E-01	7.08E-04	3.920E+04	^{225}Ac
^{226}Ra	88	1.600E+03 y	α	4.7741	0.0035	0.0067	4.784	2.836E-02	9.887E-01	^{222}Rn
^{228}Ra	88	5.75 y	β		0.0116		1.16E-02	6.88E-05	2.340E+02	^{228}Ac
^{225}Ac	89	10.0 d	α	5.7501	0.0257	0.0176	5.793	3.434E-02	5.803E+04	^{221}Fr
^{227}Ac	89	2.177E+01 y	β (98.62%); α (1.38%)	0.0673	0.0125	0.0002	8.00E-02	4.74E-04	7.233E+01	^{227}Th; ^{223}Fr
^{228}Ac	89	6.13 h	β		0.4292	0.9269	1.356	8.038E-03	2.242E+06	^{228}Th
^{227}Th	90	18.718 d	α	5.9022	0.0543	0.1113	6.068	3.597E-02	3.073E+04	^{223}Ra
^{228}Th	90	1.913 y	α	5.3992	0.0201	0.0034	5.423	3.214E-02	8.196E+02	^{224}Ra
^{229}Th	90	7.340E+03 y	α	4.8620		0.0343	4.896	2.902E-02	2.127E-01	^{225}Ra
^{230}Th	90	7.54E+04 y	α	4.6651		0.0004	4.665	2.765E-02	2.109E-02	^{226}Ra
^{231}Th	90	1.0633 d	β	0.1732		0.0295	2.03E-01	1.21E-03	5.316E+05	^{231}Pa
^{232}Th	90	1.405E+10 y	α	4.0056		0.0002	4.006	2.375E-02	1.097E-07	^{228}Ra
^{234}Th	90	24.10 d	β		0.0158	0.0094	2.52E-02	1.49E-04	2.316E+04	^{234}Pa
^{231}Pa	91	3.276E+04 y	α	4.9230	0.0483	0.0399	5.011	2.970E-02	4.723E-02	^{227}Ac
^{233}Pa	91	27.0 d	β		0.1941	0.2042	3.98E-01	2.36E-03	2.075E+04	^{233}U
^{234m}Pa	91	1.17 min	β (99.87%); IT (0.13%)		0.8227	0.0121	8.35E-01	4.95E-03	6.868E+08	^{234}U; ^{234}Pa
^{232}U	92	6.89E+01 y	α	5.3065		0.0002	5.307	3.146E-02	2.140E+01	^{228}Th
^{233}U	92	1.592E+05 y	α	4.8141	0.0055	0.0013	4.821	2.857E-02	9.680E-03	^{229}Th
^{234}U	92	2.454E+05 y	α	4.7732		0.0001	4.773	2.829E-02	6.248E-03	^{230}Th
^{235}U	92	7.037E+08 y	α	4.3785	0.0426	0.1561	4.577	2.713E-02	2.161E-06	^{231}Th
^{236}U	92	2.342E+07 y	α	4.4793	0.0108	0.0015	4.492	2.662E-02	6.469E-05	^{232}Th
^{238}U	92	4.468E+09 y	α	4.1945	0.0095	0.0013	4.205	2.492E-02	3.362E-07	^{234}Th
^{236}Np	93	1.550E+05 y	EC (91%); β (8.9%); α (0.20%)		0.1967	0.1411	3.38E-01	2.00E-03	1.317E-02	^{236}U; ^{236}Pu; ^{232}Pa
^{237}Np	93	2.140E+06 y	α	4.7604	0.0640	0.0327	4.857	2.879E-02	7.049E-04	^{233}Pa
^{239}Np	93	2.355 d	β		0.2521	0.1740	4.26E-01	2.53E-03	2.320E+05	^{239}Pu
^{236}Pu	94	2.851 y	α	5.7521	0.0126	0.0020	5.767	3.418E-02	5.313E+02	^{232}U
^{238}Pu	94	8.774E+01 y	α	5.4871	0.0099	0.0018	5.499	3.2593E-02	1.712E+01	^{234}U
^{239}Pu	94	2.411E+04 y	α	5.1011		0.0001	5.101	3.024E-02	6.216E-02	^{235}U
^{240}Pu	94	6.563E+03 y	α	5.1549			5.155	3.056E-02	2.279E-01	^{236}U
^{241}Pu	94	1.44E+01 y	β	0.0001		0.0052	5.3E-03	3.2E-05	1.030E+02	^{241}Am

Table B.1 (continued)

Nuclide	Atomic number	Half-life[b]	Principal mode(s) of decay[c]	Major radiation energies[d] (MeV/dis)			"Q" value[e]		Specific activity (Ci/g)	Daughter(s)
				α	e	γ(X)	(MeV/dis)	(W/Ci)		
^{242}Pu	94	3.763E+05 y	α	4.8901	0.0081	0.0014	4.900	2.904E-02	3.818E-03	^{238}U
^{244}Pu	94	8.26E+07 y	α (99.875%); SPF (0.125%)	4.5751	0.0007	0.0001	4.576	2.712E-02	1.774E-05	^{240}U; (fission products)
^{241}Am	95	4.327E+02 y	α	5.4801	0.0304	0.0287	5.539	3.283E-02	3.432	^{237}Np
^{242}Am	95	16.01 h	β (82.7%); EC (17.3%)		0.1781	0.0180	1.96E-01	1.16E-03	8.084E+05	^{242}Cm; ^{242}Pu
^{242m}Am	95	1.41E+02 y	IT (99.55%); α (0.45%)	0.0232	0.0403	0.0049	6.84E-02	4.05E-04	9.718	^{242}Am; ^{238}Np
^{243}Am	95	7.380E+03 y	α	5.2656		0.0481	5.3137	3.1496E-02	1.993E-01	^{239}Np
^{242}Cm	96	162.94 d	α	6.0434	0.0090	0.0018	6.0542	3.5886E-02	3.306E+03	^{238}Pu
^{243}Cm	96	2.85E+01 y	α (99.76%); EC (0.24%)	5.8380	0.1129	0.1316	6.083	3.605E-02	5.162E+01	^{239}Pu; ^{243}Am
^{244}Cm	96	1.811E+01 y	α	5.7965		0.0016	5.798	3.437E-02	8.090E+01	^{240}Pu
^{245}Cm	96	8.5E+03 y	α	5.3631	0.1342	0.1178	5.615	3.329E-02	1.717E-01	^{241}Pu
^{246}Cm	96	4.73E+03 y	α	5.3764	0.0072	0.0014	5.385	3.192E-02	3.072E-01	^{242}Pu
^{247}Cm	96	1.56E+07 y	α	4.9475		0.3152	5.263	3.119E-02	9.278E-05	^{243}Pu
^{248}Cm	96	3.40E+05 y	α (91.74%); SPF (8.26%)	4.6524			4.6524	2.7577E-02	4.251E-03	^{244}Pu; (fission products)
^{252}Cf	98	2.645 y	α (96.908%); SPF (3.092%)	5.9308	0.0051	0.0011	5.9370	3.5191E-02	5.378E+02	^{248}Cm; (fission products)

[a]Based on refs. 6-8.

[b]y – years; d – days; h – hours; min – minutes; and s – seconds.

[c]α – alpha decay; β – negative beta decay; EC – electron capture; IT – isomeric transition (radioactive transition from one nuclear isomer to another of lower energy); and SPF – spontaneous fission.

[d]α – alpha decay; e – total electron emissions; and γ(X) – gamma and X-ray photons.

[e]The sum of the average energies per different radiation types in MeV/disintegration or W/Ci (includes alpha and beta particles, discrete electrons, and photons). The "Q" value indicates the amount of energy (heat) that could be deposited in a radioactive material from each decay event if none of the radiation escaped from the material.

APPENDIX C. WASTE FLOWSHEETS, SOURCE TERMS, AND CHARACTERISTICS

APPENDIX C. WASTE FLOWSHEETS, SOURCE TERMS, AND CHARACTERISTICS

C.1 DISCUSSION

In this report, a number of engineering estimates, assumptions, and ground rules are used to determine radioactive waste and spent fuel projections through the year 2030. Many of these involve parameters that characterize certain types of waste (e.g., see Table C.1). In other instances, estimates were made of the waste volume generated per unit of product throughput for each step in the fuel cycle. This appendix is a compilation of generic flowsheets and source terms used for making waste projections. Source terms are used to describe quantitative and qualitative characteristics of radioactive wastes. In general, the source term for a particular waste is comprised of two components unique to that waste: (1) the number of curies of radioactivity expressed either per unit of facility production or per unit of waste volume or mass and (2) a listing of the relative radioactivity contributions of component radioisotopes.

The source terms used in the analysis of this report are based on reported historical data, engineering estimates, calculations, and/or experimental data. Documentation of the source terms and key waste modeling parameters is provided in the following sets of figures and tables (based primarily on refs. 1 through 11). Detailed information on how these source terms and modeling parameters were derived is available, mainly in ref. 1 and its update (ref. 2). Figures C.1 through C.9 were taken from refs. 1 and 2. Figure C.10 was adapted from information presented in ref. 3. Table C.2 lists some basic factors used for estimating waste projections (including HLW estimates reported in ref. 4). Using these requirements, the source terms of Figs. C.1–C.9, and the spent fuel activity levels based on refs. 5 and 6, estimates were made of the spent fuel and waste generation by a 1-GW(e) reference BWR and a 1-GW(e) PWR for a 40-year operating life. The results are reported in Table C.3. 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.

Representative DOE LLW radionuclide compositions are described in Table C.5 (based on ref. 1). Average concentrations for representative radionuclides in LLW disposed of at commercial sites are given in Table C.6, which is based on data available in ref. 1. Table C.7, which gives the radionuclide composition of saltstone at SRS, summarizes information obtained from ref. 3. The data on LLW produced from commercial LWR operations are based on the annual LWR waste shipments to commercial disposal sites (refs. 7 and 8) and the energy generation values reported in Table C.8, which are based on refs. 7, 9, and 10. Table C.9 gives a summary of major sources and estimated characteristics of commercial greater-than-Class-C LLW (data from refs. 11 and 12). Information on the LLW to be incorporated in cement as a result of future operations by the West Valley Demonstration Project Radwaste Treatment System is presented in Table C.10, which is taken from ref. 13.

Compositions (adapted from ref. 2) of I/I wastes are given in Table C.11. These wastes are categorized according to I/I activities (bioresearch, medical, and nonbioresearch).

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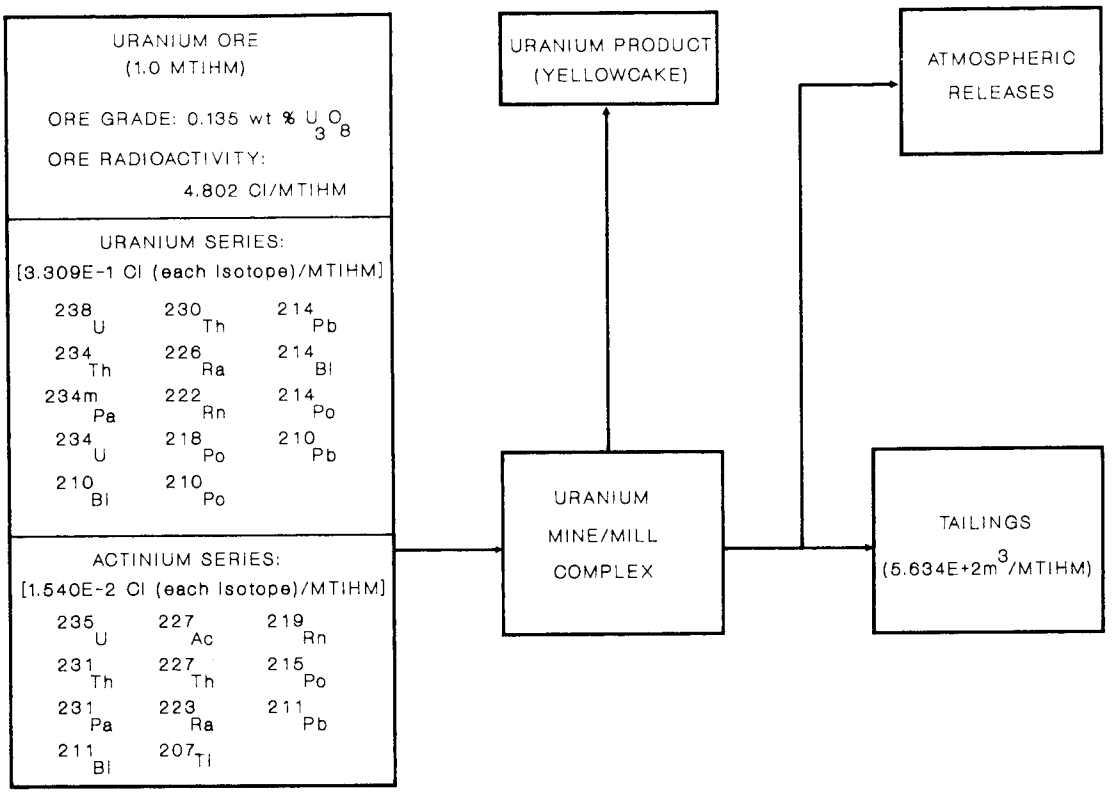
ORNL DWG 89-7803



Fractions of elements from uranium ore in waste and product streams from a uranium mine/mill complex

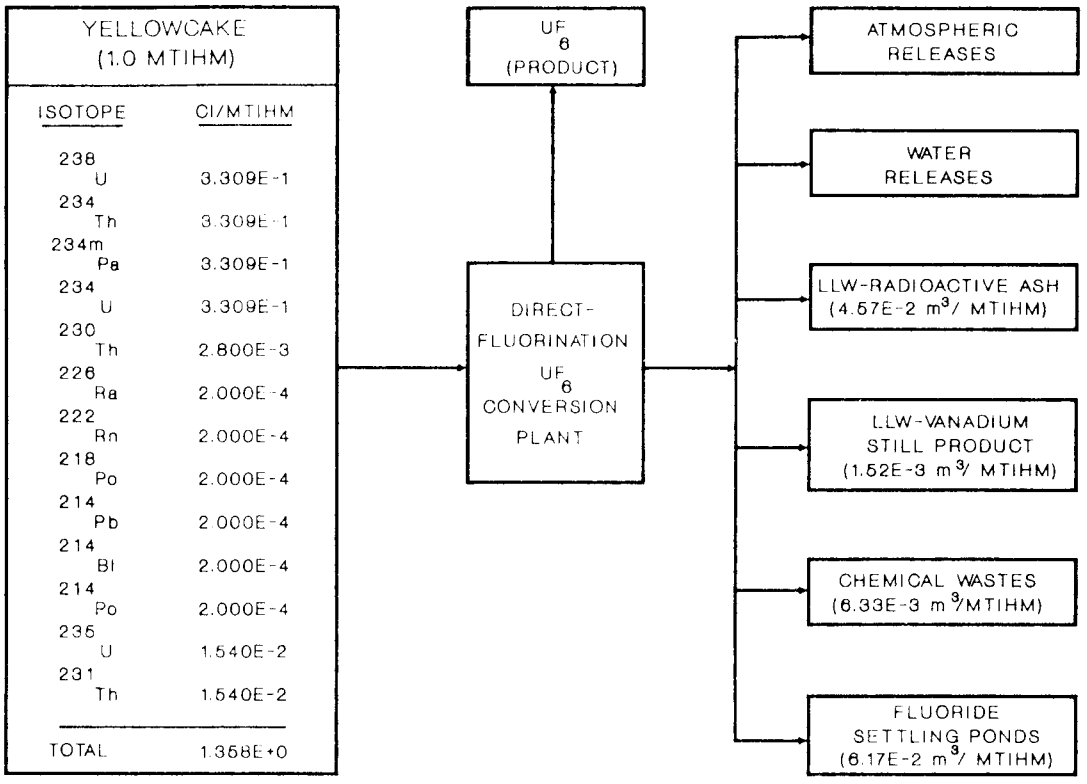
	Waste streams		Product stream[a]
Element	Atmospheric releases	Tailings[b]	Uranium (yellowcake)
Uranium	1.000E-3	6.800E-2	9.310E-1
Protactinium	0.000E+0	1.000E+0	0.000E+0
Thorium	8.000E-6	9.923E-1	7.692E-3
Actinium	0.000E+0	1.000E+0	0.000E+0
Radon	1.000E-1	9.000E-1	0.000E+0
Other	6.000E-7	9.994E-1	5.994E-4

[a] Also includes yellowcake from both solution mining and by-product U_3O_8.

[b] Assumed density = 1.6 t/m^3.

Fig. C.1. Principal waste and product streams from a uranium mine/mill complex.

ORNL DWG 89-7804

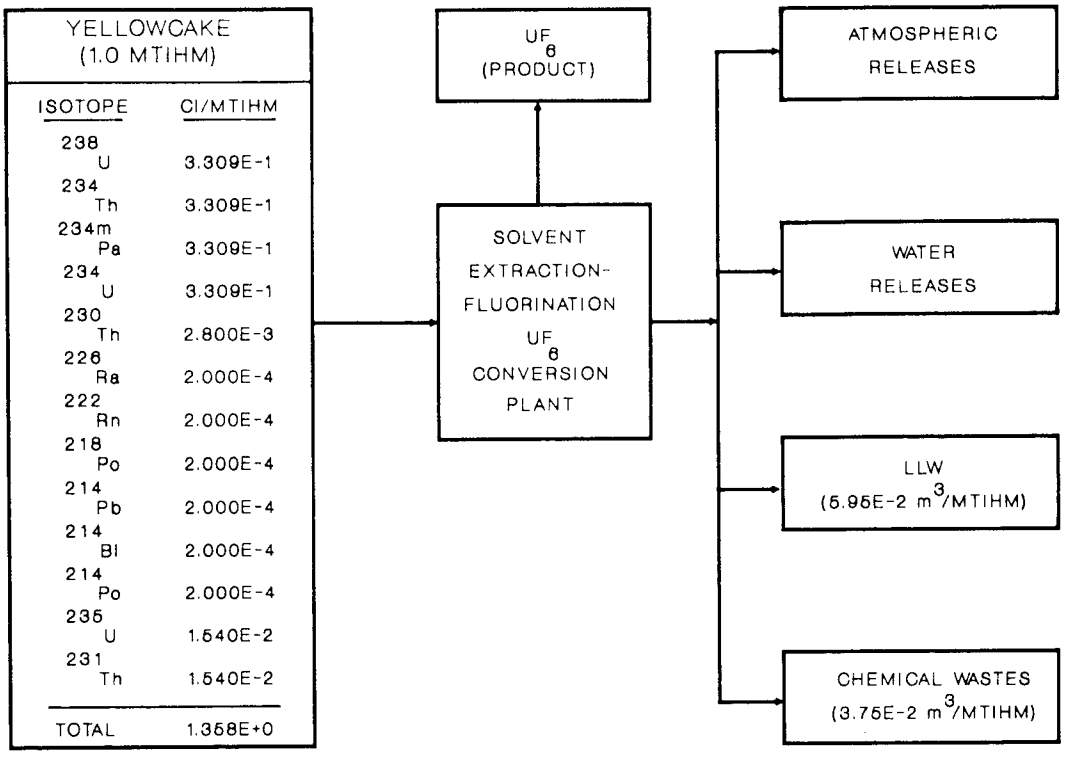


Fractions of elements from yellowcake in waste and product streams from a direct-fluorination UF_6 conversion plant

	Waste streams						
Element	Atmospheric releases	Water releases	Radioactive ash	Vanadium still product	Chemical wastes	Fluoride settling ponds	Product stream (UF_6)
Uranium	2.50E-5	7.65E-5	3.51E-5	5.01E-4	1.00E-6	3.63E-5	9.9932E-1
Thorium	3.22E-5	7.27E-6	1.00E+0	2.67E-5	1.00E-6	8.80E-7	0.00
Radium	3.36E-5	1.14E-3	9.99E-1	2.68E-5	1.00E-6	5.88E-6	0.00
Radon	8.21E-1	0.00	1.79E-1	4.84E-6	0.00	1.06E-6	0.00
Other	3.26E-5	7.25E-6	1.00E+0	2.67E-5	1.00E-6	3.80E-6	0.00

Fig. C.2. Principal waste and product streams from a direct-fluorination UF_6 conversion plant.

ORNL DWG 89-7805

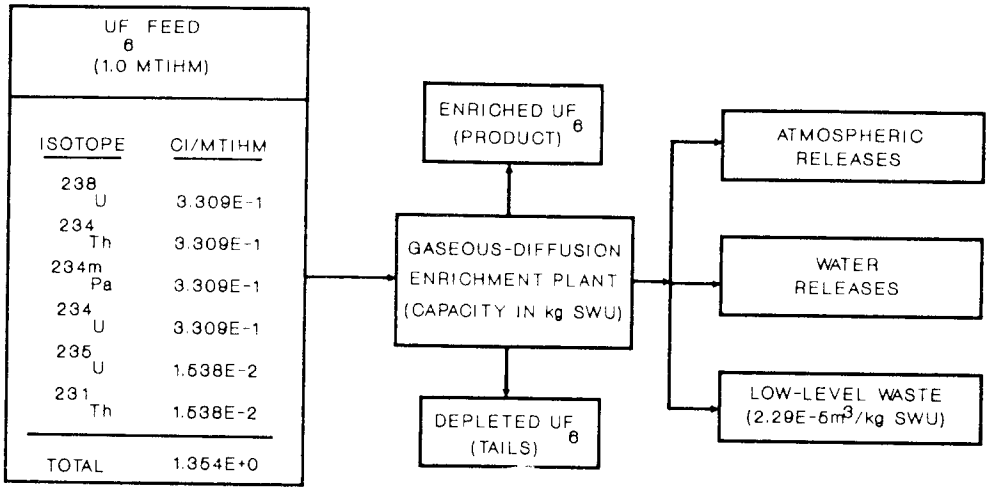


Fractions of elements from yellowcake in waste and product streams from a solvent extraction-fluorination UF_6 conversion plant

	Waste streams				
Element	Atmospheric releases	Water releases	Low-level wastes	Chemical wastes	Product stream (UF_6)
Uranium	1.35E-5	1.13E-9	2.54E-4	2.79E-5	9.997E-1
Protactinium	9.54E-6	6.54E-10	5.01E-1	2.79E-5	4.99E-1
Thorium	1.28E-5	1.15E-9	1.00E+0	2.50E-6	0.00
Other	5.35E-6	1.15E-11	1.00E+0	2.25E-6	0.00

Fig. C.3. Principal waste and product streams from a solvent extraction-fluorination UF_6 conversion plant.

ORNL DWG 92-5867



Separative work units required to produce 1.0 kg of enriched uranium from natural uranium by gaseous diffusion while generating tails containing 0.2 wt % ^{235}U

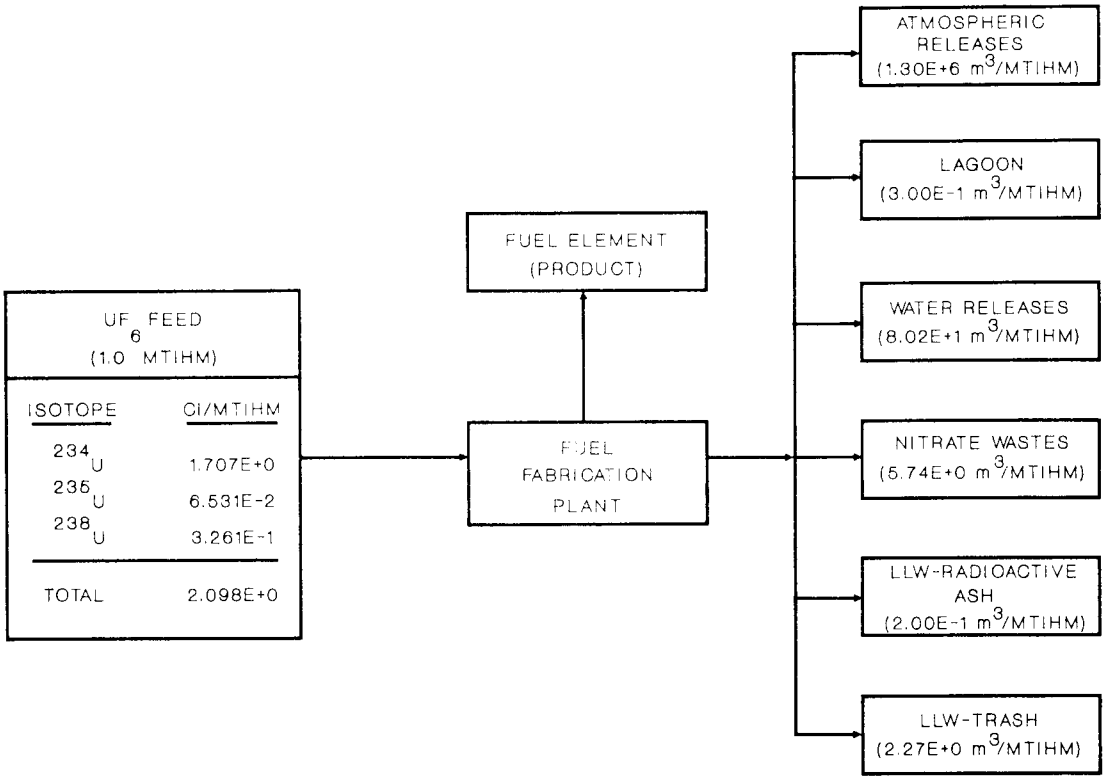
Product desired enrichment (wt % ^{235}U)	Feed natural (0.711 wt % ^{235}U) uranium (kg)	Separative work units (No. of kg SWU)
2	3.523	2.194
3	5.479	4.306
4	7.436	6.544

Fractions of elements from feed in waste and product streams from a gaseous-diffusion uranium enrichment plant

	Waste streams			
Element	Atmospheric releases	Water releases	LLW	Product and tails streams
Uranium	1.4E-6	6.1E-6	4.74E-5	9.9994E-1
Other	1.0E-3	2.0E-3	9.97E-1	0.0

Fig. C.4. Principal waste and product streams from a gaseous diffusion uranium enrichment plant.

ORNL DWG 89-7807

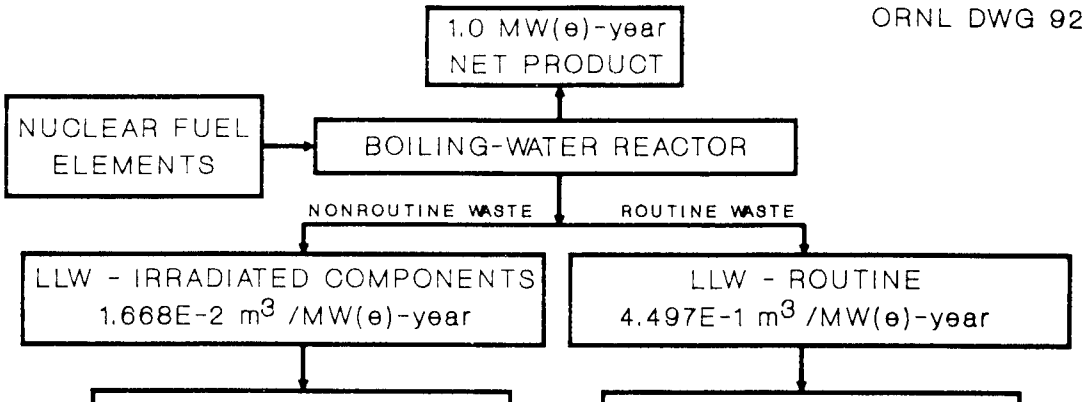


Fractions of uranium from feed in waste and product streams from a fuel fabrication plant

	Waste streams						
Element	Atmospheric releases	Lagoon	Water releases	Nitrate wastes	Radioactive ash	Trash	Product stream (fuel element)
Uranium	1.6E-6	9.6E-4	4.9E-4	1.1E-4	1.0E-6	2.8E-3	9.956E-1

Fig. C.5. Principal waste and product streams from a fuel fabrication plant.

ORNL DWG 92-5859



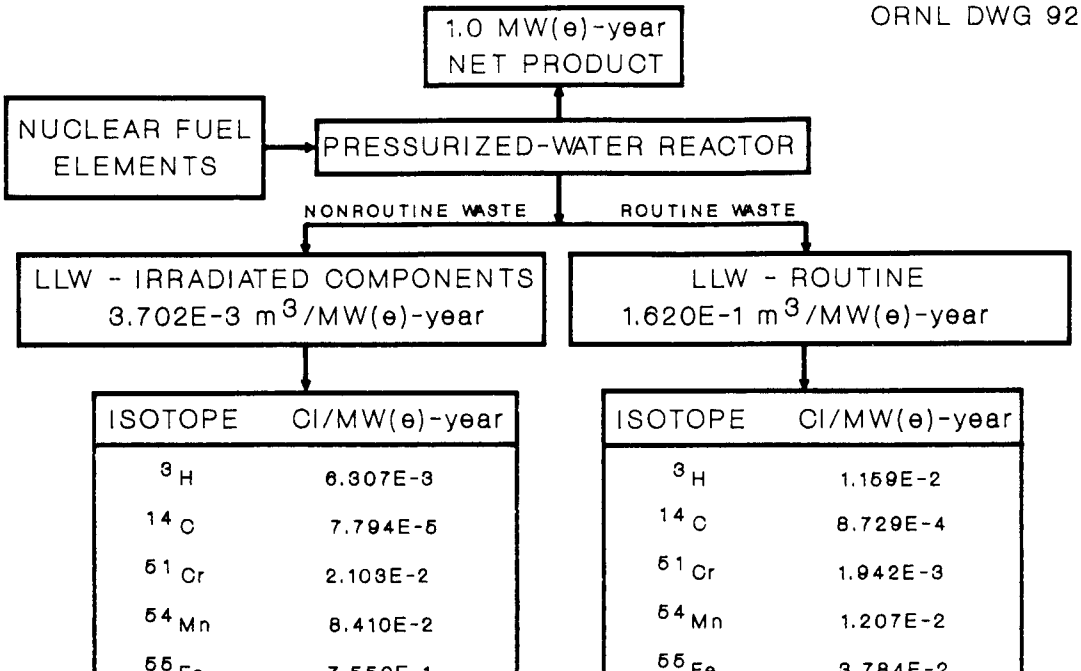
ISOTOPE	Ci/MW(e)-year
^{3}H	1.682E-1
^{14}C	5.340E-4
^{51}Cr	4.818E-2
^{54}Mn	5.182E-1
^{55}Fe	4.839E+0
^{58}Co	1.170E-1
^{59}Fe	8.492E-3
^{59}Ni	3.195E-2
^{60}Co	6.688E+0
^{63}Ni	5.061E-1
^{65}Zn	1.354E-1
^{90}Sr	1.989E-5
^{90}Y	1.989E-5
^{94}Nb	5.246E-6
^{99}Tc	1.081E-4
^{129}I	3.381E-5
^{134}Cs	2.230E-3
^{137}Cs	7.311E-2
^{137m}Ba	6.921E-2
^{241}Pu	1.121E-4
^{242}Cm	1.080E-4
TOTAL	1.321E+1

ISOTOPE	Ci/MW(e)-year
^{3}H	2.819E-3
^{14}C	3.828E-3
^{51}Cr	1.505E-1
^{54}Mn	1.304E-1
^{55}Fe	2.714E-1
^{58}Co	3.312E-2
^{59}Fe	8.218E-3
^{59}Ni	1.052E-4
^{60}Co	5.822E-1
^{63}Ni	1.338E-2
^{65}Zn	1.642E-1
^{90}Sr	6.816E-4
^{90}Y	6.816E-4
^{94}Nb	3.781E-6
^{99}Tc	4.316E-5
^{129}I	4.105E-4
^{134}Cs	7.333E-2
^{137}Cs	8.985E-2
^{137m}Ba	8.498E-2
^{144}Ce	3.664E-4
^{144}Pr	3.664E-4
^{241}Pu	6.751E-4
^{242}Cm	1.232E-5
TOTAL	1.612E+0

NOTE:
NET PRODUCT IS THE ELECTRICAL ENERGY LEAVING THE PLANT FOR DISTRIBUTION

Fig. C.6. Principal waste and product streams from a boiling-water reactor.

ORNL DWG 92-5860



ISOTOPE	Ci/MW(e)-year
^{3}H	6.307E-3
^{14}C	7.794E-5
^{51}Cr	2.103E-2
^{54}Mn	8.410E-2
^{55}Fe	7.550E-1
^{58}Co	1.795E-1
^{59}Fe	1.553E-3
^{59}Ni	5.512E-4
^{60}Co	1.112E-0
^{63}Ni	1.400E-1
^{65}Zn	1.920E-7
^{90}Sr	1.883E-5
^{90}Y	1.883E-5
^{94}Nb	2.463E-8
^{99}Tc	5.649E-8
^{134}Cs	2.462E-2
^{137}Cs	4.225E-2
^{137m}Ba	3.996E-2
^{144}Ce	9.799E-8
^{144}Pr	9.799E-8
^{241}Pu	1.991E-6
TOTAL	2.407E+0

ISOTOPE	Ci/MW(e)-year
^{3}H	1.159E-2
^{14}C	8.729E-4
^{51}Cr	1.942E-3
^{54}Mn	1.207E-2
^{55}Fe	3.784E-2
^{58}Co	9.451E-2
^{59}Fe	2.853E-4
^{59}Ni	1.806E-4
^{60}Co	1.423E-1
^{63}Ni	6.392E-2
^{65}Zn	6.836E-5
^{90}Sr	2.272E-2
^{90}Y	2.272E-2
^{94}Nb	1.240E-6
^{99}Tc	3.935E-5
^{129}I	8.469E-6
^{134}Cs	5.599E-2
^{137}Cs	7.179E-2
^{137m}Ba	6.788E-2
^{144}Ce	3.186E-4
^{144}Pr	3.186E-4
^{241}Pu	3.965E-4
^{242}Cm	6.155E-4
TOTAL	6.084E-1

NOTE:
NET PRODUCT IS THE ELECTRICAL ENERGY LEAVING THE PLANT FOR DISTRIBUTION.

Fig. C.7. Principal waste and product streams from a pressurized-water reactor.

ORNL DWG 92-5861

DECOMMISSIONING OF 1-MW(e) CAPACITY OF BOILING-WATER REACTOR (IMMEDIATE DECOMMISSIONING)

LOW-LEVEL WASTE

PACKAGED WASTE VOLUME = 1.64E+1 m^3/MW(e)

TOTAL ACTIVITY = 2.63E+2 Ci/MW(e)

	WASTE CLASS		
	A	B	C
Volume, m^3/MW(e)	1.60E+1	3.23E-1	4.59E-2
Activity, Ci/MW(e)	1.23E+1	3.88E+1	2.12E+2
Specific Activity, Ci/m^3			
^{14}C	3.97E-6	1.03E-3	1.68E-1
^{59}Ni	1.40E-5	6.31E-3	1.00E+0
^{94}Nb	2.15E-8	1.44E-5	2.39E-3
^{99}Tc	9.34E-8	3.15E-7	5.02E-5
^{60}Co	2.70E-1	4.29E+1	5.37E+2
^{63}Ni	1.97E-3	8.73E-1	1.37E+2
^{90}Sr	5.48E-4	5.07E-2	0.00E+0
^{90}Y	5.48E-4	5.07E-2	0.00E+0
^{137}Cs	2.54E-2	3.44E+0	0.00E+0
^{137m}Ba	2.40E-2	3.25E+0	0.00E+0
Half-Life <5 yr	4.47E-1	6.90E+1	3.93E+3
Total	7.69E-1	1.20E+2	4.61E+3

GREATER THAN CLASS C LOW-LEVEL WASTE

PACKAGED WASTE VOLUME = 8.55E-3 m^3/MW(e)

TOTAL ACTIVITY = 1.11E+3 Ci/MW(e)

	GREATER THAN CLASS C
Volume, m^3/MW(e)	8.55E-3
Activity, Ci/MW(e)	1.11E+3
Specific Activity, Ci/m^3	
^{14}C	1.20E+1
^{54}Mn	1.77E+3
^{55}Fe	7.04E+4
^{60}Co	4.83E+4
^{59}Ni	6.41E+1
^{63}Ni	8.91E+3
^{94}Nb	1.30E-1
Total	1.29E+5

Fig. C.8. Boiling-water reactor decommissioning wastes per 1-MW(e) capacity.

ORNL DWG 92-5862

DECOMMISSIONING OF 1-MW(e) CAPACITY OF PRESSURIZED WATER REACTOR (IMMEDIATE DECOMMISSIONING)

LOW-LEVEL WASTE

PACKAGED WASTE VOLUME = 1.55E+1 m^3/MW(e)

TOTAL ACTIVITY = 1.06E+2 Ci/MW(e)

	WASTE CLASS		
	A	B	C
Volume, m^3/MW(e)	1.53E+1	1.82E-1	1.45E-2
Activity, Ci/MW(e)	3.28E+1	4.40E+1	2.91E+1
Specific Activity, Ci/m^3			
^{14}C	0.00E+0	0.00E+0	0.00E+0
^{59}Ni	4.75E-5	7.23E-3	5.51E-1
^{94}Nb	2.41E-8	5.22E-5	4.06E-3
^{99}Tc	0.00E+0	0.00E+0	0.00E+0
^{60}Co	3.57E-1	7.83E+1	7.39E+2
^{63}Ni	5.66E-3	1.16E+0	8.99E+1
^{90}Sr	4.88E-5	1.73E-3	0.00E+0
^{90}Y	4.88E-5	1.73E-3	0.00E+0
^{137}Cs	5.39E-2	2.06E+0	0.00E+0
^{137m}Ba	5.10E-2	1.95E+0	0.00E+0
Half-Life <5 yr	1.68E+0	1.59E+2	1.18E+3
Total	2.15E+0	2.42E+2	2.01E+3

GREATER THAN CLASS C LOW-LEVEL WASTE

PACKAGED WASTE VOLUME = 3.87E-3 m^3/MW(e)

TOTAL ACTIVITY = 5.05E+3 Ci/MW(e)

	GREATER THAN CLASS C
Volume, m^3/MW(e)	3.87E-3
Activity, Ci/MW(e)	5.05E+3
Specific Activity, Ci/m^3	
^{14}C	1.33E+2
^{54}Mn	7.73E+4
^{55}Fe	7.56E+5
^{60}Co	3.89E+5
^{59}Ni	4.31E+2
^{63}Ni	8.26E+4
^{94}Nb	2.24E+0
Total	1.31E+6

Fig. C.9. Pressurized-water reactor decommissioning wastes per 1-MW(e) capacity.

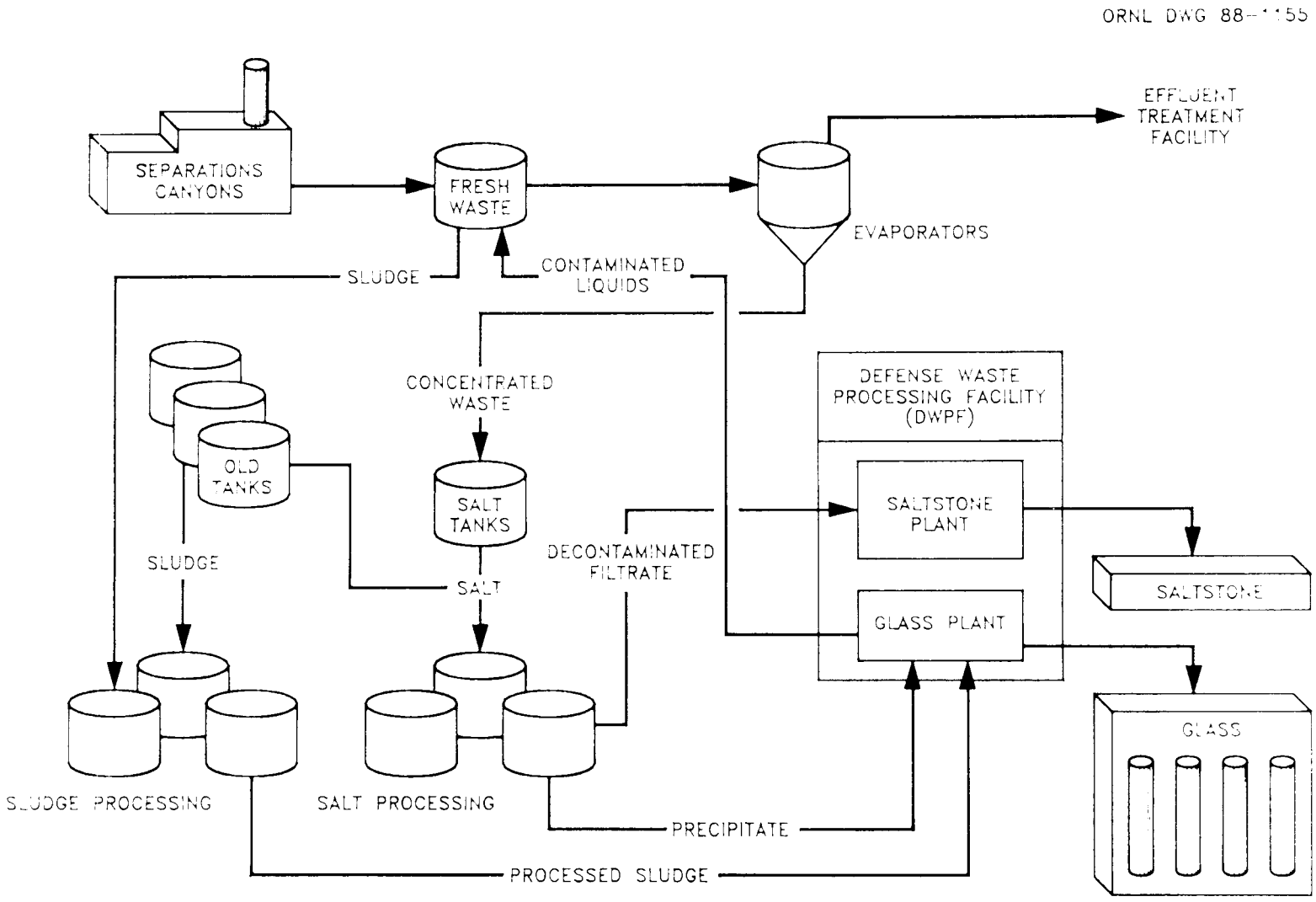


Fig. C.10. Waste flow diagram for the SRS Defense Waste Processing Facility.

Table C.1. Estimated representative unit activity and thermal power characteristics of various types of radioactive materials and wastes

Radioactive material/ waste type	Unit activity (Ci/m^3)	Unit thermal power (W/m^3)
Spent fuel[a]		
BWR	1,000,000-10,000,000	3,500-40,000
PWR	2,000,000-20,000,000	7,500-65,000
High-level waste	1,500-15,000	5-50
Transuranic waste		
Remote handled, stored	1,000	1-2
Contact handled, stored	25-50	0.5-1.5
Buried	0.25-0.50	0.005-0.010
Low-level waste[b]		
DOE sites	9-27	0.012-0.054
Commercial sites[c]	4.6-6.4	0.30-1.60
Class A	0.5-0.7	0.03-0.10
Class B	55-60	14-15
Class C	0.1->7,000[d]	0.003-115[d]
GTCC[e]	>0.1-No limit	>0.003-No limit
Uranium mill tailings	0.010	0.00020

[a]Lower-bound levels are based on cumulative spent fuel discharged; upper-bound levels are based on annual discharges.

[b]Based on 1986-1988 Solid Waste Information Management System (SWIMS) and the national Low-Level Waste Management Program (LLWMP) data access system, both of which were maintained by EG&G, Idaho, Inc., Idaho Falls, Idaho.

[c]Waste classification is defined by the NRC in 10 CFR 61.55 on the basis of concentration of certain long- and short-lived radionuclides. The classification system is designed to minimize potential exposures in both the short and long term. The gross Ci/m^3 shown above are representative of typical LLW shipped to commercial disposal sites. Most medical wastes are Class A. The nuclear power plant wastes account for most of the radioactivity, but some industrial wastes are in the Class B and C categories.

[d]Maximum for ^{63}Ni in activated metal or ^{90}Sr. There is no limit on concentration of ^{3}H, ^{60}Co, or nuclides with half-lives <5 years. The maximum thermal power shown is based on the highest reported gross Ci/m^3 analysis for irradiated core components (1986-1988) and assumes all the activity is due to ^{60}Co, which would yield the greatest heat output. If the activity is due to activation products, such as ^{54}Mn, ^{58}Co, etc., the Ci/m^3 could be much higher for individual shipments and the total W/m^3 could exceed the value shown.

[e]In temporary storage. The concentration of actinides and ^{129}I determine the lower activity boundary. There is no limit on concentration of ^{3}H, ^{60}Co, or nuclides with half-lives <5 years.

Table C.2. Basic factors used for fuel cycle, DOE waste, and I/I waste projections[a]

Activity/facility	Waste type	Annual waste volume generation rate
Electric power generation		Per unit energy generated [m^3/GW(e)-year]
Boiling-water reactor	LLW (routine)	449.7
	LLW (nonroutine)	16.68
Pressurized-water reactor	LLW (routine)	162.0
	LLW (nonroutine)	3.702
Nuclear fuel cycle support[b]		
Uranium mill	Mill tailings	118,000
Uranium conversion[c]	LLW	10.403
Uranium enrichment[d]	LLW	3.52
Fuel fabrication	LLW	87.36
DOE wastes		Annual increase in waste volume inventory during 1991 (m^3/year)
	LLW	53,520
	TRU	1,888
	HLW	-2,500[e]
Industrial/institutional wastes		Annual increase in waste volume inventory during 1991 (m^3/year)
	LLW	8,194

[a]Volumes given are typical for each operation. Many fuel cycle operations occur years before or after electricity from the nuclear reactor is generated.

[b]Waste quantities for the case of no spent fuel recycle and based on a ratio of PWRs to BWRs of 2 to 1.

[c]Assumes one-half of conversion demand is met by direct fluorination and the remaining half of demand is met by solvent extraction-fluorination.

[d]Assumes enrichment demand is met by gaseous diffusion.

[e]This is the difference between the total HLW in storage through 1991 (reported in Table 2.5) and the total HLW in storage through 1990 (reported in Table 2.5 of ref. 4). Such a quantity represents the annual change to all forms of HLW in storage. The negative number listed represents a net annual volume decrease that results from combined changes in both the annual rate of waste generation and waste management operations such as evaporation and calcination.

Table C.3. Lifetime radioactive waste generation by light-water reactors and supporting fuel cycle activities

Waste type	Reference BWR, 1 GW(e)		Reference PWR, 1 GW(e)	
	Volume (m^3)	Radioactivity (undecayed curies)	Volume (m^3)	Radioactivity (undecayed curies)
1. Fuel cycle wastes (no reprocessing)[a]				
A. Mill tailings	3.007E+06	2.353E+04	3.098E+06	2.424E+04
B. LLW from uranium conversion[b]	2.651E+02	2.975E+03	2.732E+02	3.066E+03
C. LLW from uranium enrichment[c]	8.502E+01	3.355E+03	9.479E+01	3.457E+03
D. LLW from fuel fabrication	2.511E+03	5.974E+00	2.151E+03	5.118E+00
2. LLW from reactor power generation[a]				
A. Routine wastes	1.169E+04	4.191E+04	4.212E+03	1.582E+04
B. Nonroutine wastes	4.337E+02	3.435E+05	9.625E+01	6.258E+04
3. Reactor spent fuel[a]	4.792E+02[d]	1.945E+09[e]	3.511E+02[d]	2.188E+09[e]
4. Decommissioning wastes				
A. LLW	1.640E+04	2.631E+05	1.548E+04	1.061E+05
B. Greater-than-Class-C LLW	8.553E+00	1.107E+06	3.870E+00	5.051E+06
Totals	3.039E+06	1.947E+09	3.121E+06	2.193E+09

[a]Waste generated from 40 years of reactor operation and 26 GW(e)-years of electric energy production.

[b]Assumes one-half of conversion demand will be met by direct fluorination and the remaining half by solvent extraction-fluorination.

[c]Applies to the gaseous diffusion process.

[d]Includes spacing between the stacked fuel rods of each assembly.

[e]Based on activity levels measured 1 year after reactor discharge, as reported in ref. 5 from using the ORIGEN2 code (ref. 6). Activity levels reported for the BWR are based on a burnup of 27,500 MWd/MTIHM. For the PWR, these levels are based on a burnup of 33,000 MWd/MTIHM.

Table C.4. Mass, radioactivity, and thermal power of nuclides in domestic commercial LWR spent fuel at the end of calendar year 1991[a]

Atomic number	Element	Mass number of nuclide	Mass, g		Radioactivity, Ci		Thermal power, W	
			Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1	Hydrogen	Stable[b]	8.74E+03	1.13E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Hydrogen	3	1.57E+02	1.22E+03	1.52E+06	1.18E+07	5.11E+01	3.98E+02
2	Helium	Stable	5.10E+03	5.33E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3	Lithium	Stable	2.09E+03	2.59E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	Beryllium	Stable	1.96E+00	2.08E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5	Boron	Stable	1.92E+03	2.36E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6	Carbon	Stable	3.41E+05	4.25E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Carbon	14	8.37E+02	6.82E+03	3.73E+03	3.93E+04	1.09E+00	1.15E+01
7	Nitrogen	Stable	2.34E+05	2.93E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
8	Oxygen	Stable	2.58E+08	3.19E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00
9	Fluorine	Stable	2.05E+04	2.53E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
10	Neon	Stable	8.19E-01	8.75E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
11	Sodium	Stable	2.86E+04	3.54E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Sodium	24	1.69E-04	1.69E-04	1.47E+03	1.47E+03	4.08E+01	4.08E+01
12	Magnesium	Stable	3.90E+03	4.81E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
13	Aluminum	Stable	1.61E+05	1.92E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
14	Silicon	Stable	9.11E+05	1.13E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
15	Phosphorus	Stable	4.55E+05	5.28E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Phosphorus	32	3.07E-01	3.07E-01	8.77E+04	8.77E+04	8.89E+02	8.89E+02
16	Sulfur	Stable	5.00E+04	6.36E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
17	Chlorine	Stable	9.43E+03	1.18E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
18	Argon	Stable	7.81E+02	8.44E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
19	Potassium	Stable	3.37E+00	3.62E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
20	Calcium	Stable	3.82E+03	4.73E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
21	Scandium	Stable	2.29E-01	2.36E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
22	Titanium	Stable	1.66E+05	1.96E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
23	Vanadium	Stable	3.40E+04	3.95E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Vanadium	50	1.03E+02	1.22E+03	1.94E-11	2.19E-10	2.14E-13	2.41E-12
24	Chromium	Stable	2.09E+07	2.59E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Chromium	51	7.64E+01	7.64E+01	7.06E+06	7.07E+06	1.51E+03	1.51E+03
25	Manganese	Stable	1.73E+06	2.17E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Manganese	54	1.68E+02	3.06E+02	1.30E+06	2.37E+06	6.47E+03	1.18E+04
26	Iron	Stable	6.33E+07	7.39E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Iron	55	4.53E+03	1.66E+04	1.13E+07	4.15E+07	3.82E+02	1.40E+03
	Iron	59	2.85E+00	2.86E+00	1.40E+05	1.41E+05	1.09E+03	1.09E+03
27	Cobalt	Stable	1.53E+05	1.87E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Cobalt	58	8.85E+01	9.14E+01	2.82E+06	2.91E+06	1.69E+04	1.74E+04
	Cobalt	60	1.29E+04	7.00E+04	1.46E+07	7.92E+07	2.25E+05	1.22E+06
28	Nickel	Stable	1.99E+07	2.39E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Nickel	59	1.20E+05	1.21E+06	9.10E+03	9.20E+04	3.61E-01	3.65E+00
	Nickel	63	2.08E+04	1.99E+05	1.29E+06	1.23E+07	1.30E+02	1.24E+03
29	Copper	Stable	3.41E+04	4.17E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
30	Zinc	Stable	7.71E+04	9.53E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Zinc	65	2.02E+01	3.21E+01	1.67E+05	2.65E+05	5.83E+02	9.26E+02

Table C.4 (continued)

Atomic number	Element	Mass number of nuclide	Mass, g		Radioactivity, Ci		Thermal power, W	
			Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
31	Gallium	Stable	6.46E+01	6.94E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
32	Germanium	Stable	1.19E+03	1.23E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
33	Arsenic	Stable	3.73E+02	3.87E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
34	Selenium	Stable	9.26E+04	9.50E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Selenium	79	1.11E+04	1.14E+05	7.72E+02	7.94E+03	1.92E-01	1.98E+00
35	Bromine	Stable	4.03E+04	4.15E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
36	Krypton	Stable	6.33E+05	6.48E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Krypton	81	4.38E-02	4.34E-01	9.21E-04	9.13E-03	1.13E-07	1.13E-06
	Krypton	85	4.35E+04	3.14E+05	1.71E+07	1.23E+08	2.56E+04	1.85E+05
37	Rubidium	Stable	1.85E+05	1.88E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Rubidium	86	3.10E+00	3.10E+00	2.52E+05	2.52E+05	1.14E+03	1.14E+03
	Rubidium	87	4.58E+05	4.69E+06	4.01E-02	4.10E-01	3.35E-05	3.43E-04
38	Strontium	Stable	6.57E+05	6.71E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Strontium	89	9.75E+03	9.83E+03	2.84E+08	2.86E+08	9.80E+05	9.88E+05
	Strontium	90	9.93E+05	8.84E+06	1.35E+08	1.21E+09	1.57E+05	1.40E+06
39	Yttrium	Stable	8.08E+05	8.14E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Yttrium	90	2.52E+02	2.22E+03	1.37E+08	1.21E+09	7.60E+05	6.69E+06
	Yttrium	91	1.77E+04	1.80E+04	4.34E+08	4.41E+08	1.56E+06	1.58E+06
40	Zirconium	Stable	6.40E+08	8.33E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Zirconium	93	1.56E+06	1.61E+07	3.91E+03	4.04E+04	4.54E-01	4.69E+00
	Zirconium	95	3.32E+04	3.39E+04	7.13E+08	7.29E+08	3.61E+06	3.69E+06
41	Niobium	Stable	1.03E+06	1.20E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Niobium	93m	1.24E+00	4.31E+01	3.50E+02	1.22E+04	6.19E-02	2.16E+00
	Niobium	94	1.25E+04	1.25E+05	2.34E+03	2.34E+04	2.38E+01	2.38E+02
	Niobium	95	2.83E+04	2.92E+04	1.11E+09	1.14E+09	5.30E+06	5.47E+06
	Niobium	95m	1.44E+01	1.47E+01	5.49E+06	5.61E+06	7.63E+03	7.79E+03
42	Molybdenum	Stable	6.78E+06	7.01E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
43	Technetium	99	1.46E+06	1.52E+07	2.48E+04	2.57E+05	1.24E+01	1.29E+02
44	Ruthenium	Stable	4.11E+06	4.21E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Ruthenium	103	1.32E+04	1.32E+04	4.27E+08	4.27E+08	1.43E+06	1.43E+06
	Ruthenium	106	2.29E+05	4.59E+05	7.67E+08	1.54E+09	4.56E+04	9.14E+04
45	Rhodium	Stable	7.95E+05	8.42E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Rhodium	103m	1.18E+01	1.18E+01	3.85E+08	3.86E+08	8.86E+04	8.87E+04
	Rhodium	106	2.15E-01	4.32E-01	7.67E+08	1.54E+09	7.36E+06	1.47E+07
46	Palladium	Stable	1.93E+06	1.93E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Palladium	107	4.23E+05	4.36E+06	2.18E+02	2.24E+03	1.29E-02	1.33E-01
47	Silver	Stable	1.46E+05	1.53E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Silver	108	1.50E-09	1.62E-08	1.10E+00	1.19E+01	4.10E-03	4.43E-02
	Silver	108m	4.74E-01	5.13E+00	1.24E+01	1.34E+02	1.20E-01	1.30E+00
	Silver	110	1.66E-05	2.60E-05	6.91E+04	1.09E+05	4.96E+02	7.80E+02
	Silver	110m	1.09E+03	1.72E+03	5.19E+06	8.17E+06	8.67E+04	1.36E+05
	Silver	111	2.50E+01	2.50E+01	3.95E+06	3.95E+06	8.85E+03	8.85E+03
48	Cadmium	Stable	2.54E+05	2.68E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Cadmium	109	7.06E-01	1.67E+00	1.82E+03	4.32E+03	2.12E-01	5.01E-01
	Cadmium	113m	4.81E+02	3.77E+03	1.04E+05	8.19E+05	1.76E+02	1.38E+03

Table C.4 (continued)

Atomic number	Element	Mass number of nuclide	Mass, g		Radioactivity, Ci		Thermal power, W	
			Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
	Cadmium	115m	2.24E+01	2.25E+01	5.72E+05	5.74E+05	2.13E+03	2.14E+03
49	Indium	Stable	2.21E+03	2.47E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Indium	114	6.67E-05	6.72E-05	9.19E+04	9.25E+04	4.38E+02	4.40E+02
	Indium	114m	4.15E+00	4.18E+00	9.60E+04	9.66E+04	1.35E+02	1.36E+02
	Indium	115	4.41E+03	5.30E+04	2.75E-08	3.30E-07	3.94E-11	4.73E-10
	Indium	115m	4.47E-02	4.47E-02	2.83E+05	2.83E+05	5.65E+02	5.65E+02
50	Tin	Stable	1.05E+07	1.37E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Tin	117m	1.44E+01	1.44E+01	1.15E+06	1.15E+06	2.13E+03	2.13E+03
	Tin	119m	2.91E+03	4.60E+03	1.30E+07	2.06E+07	6.74E+03	1.07E+04
	Tin	121m	4.35E+01	4.29E+02	2.57E+03	2.54E+04	5.16E+00	5.08E+01
	Tin	123	4.07E+02	4.82E+02	3.35E+06	3.96E+06	1.05E+04	1.24E+04
	Tin	125	1.06E+01	1.06E+01	1.15E+06	1.15E+06	7.62E+03	7.62E+03
	Tin	126	5.17E+04	5.37E+05	1.47E+03	1.52E+04	1.83E+00	1.90E+01
51	Antimony	Stable	3.96E+04	4.18E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Antimony	124	3.36E+01	3.42E+01	5.89E+05	5.98E+05	7.82E+03	7.95E+03
	Antimony	125	2.83E+04	1.09E+05	2.93E+07	1.13E+08	9.14E+04	3.52E+05
	Antimony	126	1.30E+00	1.30E+00	1.09E+05	1.09E+05	2.01E+03	2.01E+03
	Antimony	127	1.11E+01	1.11E+01	2.95E+06	2.95E+06	1.75E+04	1.75E+04
52	Tellurium	Stable	8.84E+05	9.09E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Tellurium	123	2.12E+01	2.12E+02	6.18E-09	6.17E-08	6.26E-13	6.25E-12
	Tellurium	123m	2.06E+00	2.35E+00	1.83E+04	2.08E+04	2.66E+01	3.03E+01
	Tellurium	125m	3.82E+02	1.51E+03	6.89E+06	2.72E+07	5.79E+03	2.29E+04
	Tellurium	127	4.99E+00	5.47E+00	1.32E+07	1.44E+07	1.78E+04	1.95E+04
	Tellurium	127m	1.12E+03	1.26E+03	1.05E+07	1.18E+07	5.67E+03	6.37E+03
	Tellurium	129	3.57E-01	3.57E-01	7.47E+06	7.48E+06	2.67E+04	2.67E+04
	Tellurium	129m	3.67E+02	3.67E+02	1.11E+07	1.11E+07	1.94E+04	1.94E+04
	Tellurium	132	9.97E+01	9.97E+01	3.03E+07	3.03E+07	6.00E+04	6.00E+04
53	Iodine	Stable	1.02E+05	1.05E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Iodine	129	3.40E+05	3.53E+06	6.00E+01	6.23E+02	2.78E-02	2.88E-01
	Iodine	131	4.41E+02	4.41E+02	5.47E+07	5.47E+07	1.86E+05	1.86E+05
54	Xenon	Stable	9.85E+06	1.01E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Xenon	129m	3.06E-03	3.06E-03	3.87E+02	3.87E+02	5.42E-01	5.42E-01
	Xenon	131m	1.78E+01	1.78E+01	1.49E+06	1.49E+06	1.43E+03	1.43E+03
	Xenon	133	4.37E+02	4.37E+02	8.18E+07	8.18E+07	8.76E+04	8.76E+04
55	Cesium	Stable	2.11E+06	2.19E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Cesium	134	1.92E+05	5.83E+05	2.49E+08	7.55E+08	2.53E+06	7.68E+06
	Cesium	135	6.13E+05	6.08E+06	7.06E+02	7.00E+03	2.36E-01	2.34E+00
	Cesium	136	6.19E+01	6.19E+01	4.54E+06	4.54E+06	6.19E+04	6.19E+04
	Cesium	137	2.24E+06	2.01E+07	1.95E+08	1.75E+09	2.16E+05	1.93E+06
56	Barium	Stable	2.59E+06	2.62E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Barium	136m	2.78E-06	2.78E-06	7.48E+05	7.48E+05	9.04E+03	9.04E+03
	Barium	137m	3.43E-01	3.07E+00	1.85E+08	1.65E+09	7.25E+05	6.49E+06
	Barium	140	1.96E+03	1.96E+03	1.43E+08	1.43E+08	4.00E+05	4.00E+05
57	Lanthanum	Stable	2.30E+06	2.36E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Lanthanum	138	1.05E+01	1.11E+02	2.02E-07	2.13E-06	1.48E-09	1.56E-08

Table C.4 (continued)

Atomic number	Element	Mass number of nuclide	Mass, g		Radioactivity, Ci		Thermal power, W	
			Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
	Lanthanum	140	2.98E+02	2.98E+02	1.66E+08	1.66E+08	2.78E+06	2.78E+06
58	Cerium	Stable	2.29E+06	2.34E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Cerium	141	1.22E+04	1.22E+04	3.49E+08	3.49E+08	5.10E+05	5.11E+05
	Cerium	142	2.13E+06	2.18E+07	5.12E-02	5.24E-01	0.00E+00	0.00E+00
	Cerium	144	4.54E+05	7.84E+05	1.45E+09	2.50E+09	9.62E+05	1.66E+06
59	Praseodymium	Stable	2.04E+06	2.08E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Praseodymium	143	2.13E+03	2.13E+03	1.44E+08	1.44E+08	2.68E+05	2.68E+05
	Praseodymium	144	1.92E+01	3.31E+01	1.45E+09	2.50E+09	1.07E+07	1.84E+07
	Praseodymium	144m	9.59E-02	1.66E-01	1.74E+07	3.00E+07	5.96E+03	1.03E+04
60	Neodymium	Stable	5.05E+06	5.21E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Neodymium	144	2.06E+06	2.44E+07	2.44E-06	2.89E-05	0.00E+00	0.00E+00
	Neodymium	147	5.88E+02	5.88E+02	4.72E+07	4.72E+07	1.14E+05	1.14E+05
61	Promethium	147	2.37E+05	9.09E+05	2.20E+08	8.43E+08	7.89E+04	3.02E+05
	Promethium	148	6.27E+01	6.27E+01	1.03E+07	1.03E+07	7.94E+04	7.94E+04
	Promethium	148m	3.95E+02	3.96E+02	8.44E+06	8.46E+06	1.07E+05	1.07E+05
62	Samarium	Stable	8.13E+05	8.50E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Samarium	147	1.44E+05	3.30E+06	3.28E-03	7.50E-02	4.49E-05	1.03E-03
	Samarium	148	3.24E+05	3.12E+06	9.79E-08	9.41E-07	1.17E-09	1.12E-08
	Samarium	149	5.35E+03	6.50E+04	1.28E-09	1.56E-08	0.00E+00	0.00E+00
	Samarium	151	2.44E+04	2.63E+05	6.41E+05	6.92E+06	7.51E+01	8.12E+02
63	Europium	Stable	2.05E+05	2.08E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Europium	152	6.12E+01	4.92E+02	1.06E+04	8.52E+04	8.01E+01	6.44E+02
	Europium	154	7.27E+04	4.64E+05	1.96E+07	1.25E+08	1.76E+05	1.12E+06
	Europium	155	2.53E+04	1.30E+05	1.18E+07	6.04E+07	8.58E+03	4.39E+04
	Europium	156	4.16E+02	4.16E+02	2.29E+07	2.29E+07	2.37E+05	2.37E+05
64	Gadolinium	Stable	1.10E+06	1.52E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Gadolinium	152	6.51E+01	2.30E+03	1.42E-09	5.02E-08	1.85E-11	6.54E-10
	Gadolinium	153	1.69E+02	2.99E+02	5.96E+05	1.05E+06	5.39E+02	9.53E+02
65	Terbium	Stable	1.90E+04	2.21E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Terbium	160	1.57E+02	1.62E+02	1.78E+06	1.83E+06	1.45E+04	1.49E+04
	Terbium	161	1.28E+00	1.28E+00	1.50E+05	1.50E+05	3.01E+02	3.01E+02
81	Thallium	Stable	1.87E-09	1.79E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Thallium	206	6.21E-22	6.21E-22	1.35E-13	1.35E-13	1.22E-15	1.22E-15
	Thallium	207	5.02E-12	2.94E-10	9.56E-04	5.60E-02	2.81E-06	1.64E-04
	Thallium	208	7.43E-09	3.53E-07	2.19E+00	1.04E+02	5.15E-02	2.44E+00
	Thallium	209	1.37E-14	9.99E-14	5.59E-06	4.09E-05	9.29E-08	6.79E-07
82	Lead	Stable	1.89E+03	2.33E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Lead	204	2.63E+01	3.26E+02	3.30E-13	4.08E-12	5.08E-15	6.29E-14
	Lead	205	6.32E-02	6.78E-01	3.67E-06	3.95E-05	1.07E-10	1.15E-09
	Lead	209	1.78E-10	5.38E-10	8.11E-04	2.45E-03	9.33E-07	2.81E-06
	Lead	210	7.25E-08	9.76E-06	5.54E-06	7.45E-04	1.28E-09	1.73E-07
	Lead	211	3.88E-11	2.27E-09	9.58E-04	5.61E-02	2.87E-06	1.68E-04
	Lead	212	4.38E-06	2.08E-04	6.09E+00	2.89E+02	1.16E-02	5.50E-01
	Lead	214	1.29E-12	1.68E-10	4.24E-05	5.50E-03	1.35E-07	1.75E-05

Table [illegible] (continued)

[illegible]	Element	Mass number	Mass, g		Radioactivity, Ci		Thermal power, W	
			Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Polonium	211	2.81E-17	1.65E-15	2.66E-06	1.57E-04	1.21E-07	7.07E-06
	Polonium	212	2.20E-17	1.04E-15	3.80E+00	1.83E-02	2.[illegible]E-01	9.82E-01
	Polonium	213	2.01E-20	1.47E-19	3.33E-04	1.83E-03	1.26E-05	9.37E-05
	Polonium	214	1.73E-19	1.72E-17	5.51E-04	5.51E-03	2.57E-06	2.56E-04
	Polonium	215	3.25E-17	1.30E-15	6.58E-04	5.61E-02	4.26E-05	2.51E-03
	Polonium	216	1.75E-11	8.30E-10	6.08E+00	2.89E+02	2.48E-01	1.18E+01
	Polonium	218	1.50E-13	1.94E-11	4.24E-05	5.50E-03	1.53E-06	1.99E-04
85	Astatine	217	1.61E-18	1.18E-15	2.59E-04	1.89E-03	1.10E-05	8.08E-05
86	Radon	218	8.86E-18	8.86E-18	1.31E-05	1.31E-05	5.64E-07	5.64E-07
	Radon	219	7.36E-14	4.31E-12	9.58E-04	5.61E-02	3.98E-05	2.33E-03
	Radon	220	6.59E-09	3.13E-07	6.08E+00	2.89E+02	2.31E-01	1.10E+01
	Radon	222	2.75E-10	3.57E-08	4.24E-05	5.50E-03	1.40E-06	1.82E-04
87	Francium	221	1.46E-12	1.07E-11	2.59E-04	1.89E-03	9.99E-06	7.31E-05
	Francium	223	3.71E-13	2.03E-11	1.44E-05	7.87E-04	3.73E-08	2.04E-06
88	Radium	222	9.80E-15	9.80E-15	1.31E-05	1.31E-05	5.19E-07	5.19E-07
	Radium	223	1.87E-08	1.10E-06	9.58E-04	5.61E-02	3.41E-05	2.00E-03
	Radium	224	3.82E-05	1.81E-03	6.08E+00	2.89E+02	2.09E-01	9.92E+00
	Radium	225	6.03E-09	4.77E-08	2.36E-04	1.87E-03	1.66E-07	1.31E-06
	Radium	226	4.32E-05	5.57E-03	4.27E-05	5.51E-03	1.23E-06	1.59E-04
	Radium	228	2.42E-11	3.28E-09	5.66E-09	7.68E-07	4.36E-13	5.92E-11
89	Actinium	225	4.46E-09	3.26E-08	2.59E-04	1.89E-03	9.04E-06	6.61E-05
	Actinium	227	1.44E-05	7.88E-04	1.04E-03	5.70E-02	5.04E-07	2.76E-05
	Actinium	228	4.17E-12	4.51E-12	9.36E-06	1.01E-05	8.09E-08	8.75E-08
90	Thorium	226	4.88E-13	4.88E-13	1.31E-05	1.31E-05	5.01E-07	5.01E-07
	Thorium	227	3.17E-08	1.81E-06	9.75E-04	5.57E-02	3.56E-05	2.03E-03
	Thorium	228	7.32E-03	3.50E-01	6.01E+00	2.87E+02	1.96E-01	9.40E+00
	Thorium	229	9.56E-04	8.65E-03	2.03E-04	1.84E-03	6.22E-06	5.63E-05
	Thorium	230	2.78E+00	1.04E+02	5.61E-02	2.10E+00	1.59E-03	5.95E-02
	Thorium	231	6.93E-05	8.21E-04	3.69E+01	4.37E+02	2.07E-02	2.45E-01
	Thorium	232	4.51E-01	1.81E+01	4.95E-08	1.99E-06	1.20E-09	4.81E-08
	Thorium	233	9.07E-12	9.07E-12	3.31E-04	3.31E-04	8.39E-07	8.39E-07
	Thorium	234	2.63E-02	3.27E-01	6.09E+02	7.58E+03	2.47E-01	3.07E+00
91	Protactinium	231	5.39E-01	6.46E+00	2.55E-02	3.05E-01	7.67E-04	9.19E-03
	Protactinium	232	9.86E-06	9.86E-06	4.24E+00	4.24E+00	2.77E-02	2.77E-02
	Protactinium	233	2.83E-02	2.77E-01	5.88E+02	5.74E+03	1.34E+00	1.30E+01
	Protactinium	234	4.00E-07	4.93E-06	8.00E-01	9.86E+00	1.15E-02	1.42E-01

Table C.4 (continued)

Atomic number	Element	Mass number of nuclide	Mass, g		Radioactivity, Ci		Thermal power, W	
			Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
	Protactinium	234m	8.86E-07	1.10E-05	6.09E+02	7.58E+03	3.01E+00	3.75E+01
	Protactinium	235	5.99E-17	5.99E-17	1.99E-09	1.99E-09	5.55E-12	5.55E-12
92	Uranium	230	4.79E-10	4.79E-10	1.31E-05	1.31E-05	4.65E-07	4.65E-07
	Uranium	231	4.44E-09	4.44E-09	5.97E-04	5.97E-04	4.94E-07	4.94E-07
	Uranium	232	1.01E+00	1.81E+01	2.16E+01	3.87E+02	6.93E-01	1.24E+01
	Uranium	233	2.51E+00	4.16E+01	2.43E-02	4.03E-01	7.06E-04	1.17E-02
	Uranium	234	3.31E+05	3.99E+06	2.07E+03	2.50E+04	5.96E+01	7.19E+02
	Uranium	235	1.46E+07	1.99E+08	3.15E+01	4.31E+02	8.24E-01	1.13E+01
	Uranium	236	7.37E+06	7.59E+07	4.77E+02	4.91E+03	1.29E+01	1.33E+02
	Uranium	237	4.87E+02	4.88E+02	3.98E+07	3.98E+07	7.53E+04	7.54E+04
	Uranium	238	1.81E+09	2.25E+10	6.08E+02	7.58E+03	1.54E+01	1.92E+02
	Uranium	239	1.72E-02	1.72E-02	5.75E+05	5.75E+05	1.55E+03	1.55E+03
	Uranium	240	2.27E-04	2.27E-04	2.11E+02	2.11E+02	1.73E-01	1.73E-01
93	Neptunium	235	5.83E-03	1.18E-02	8.18E+00	1.66E+01	4.75E-04	9.62E-04
	Neptunium	236	7.31E-01	6.82E+00	9.64E-03	8.98E-02	1.94E-05	1.81E-04
	Neptunium	236m	8.69E-05	8.69E-05	5.13E+01	5.13E+01	4.06E-02	4.06E-02
	Neptunium	237	8.35E+05	8.14E+06	5.89E+02	5.74E+03	1.80E+01	1.76E+02
	Neptunium	238	1.97E+01	1.97E+01	5.11E+06	5.11E+06	2.45E+04	2.45E+04
	Neptunium	239	1.47E+03	1.47E+03	3.41E+08	3.41E+08	8.24E+05	8.25E+05
	Neptunium	240	3.66E-04	3.66E-04	4.42E+03	4.42E+03	4.68E+01	4.68E+01
	Neptunium	240m	2.03E-06	2.03E-06	2.15E+02	2.15E+02	1.25E+00	1.25E+00
	Neptunium	241	1.45E-13	1.45E-13	7.08E-06	7.08E-06	1.98E-08	1.98E-08
94	Plutonium	236	1.90E+00	6.86E+00	1.01E+03	3.65E+03	3.51E+01	1.27E+02
	Plutonium	237	1.67E-02	1.68E-02	2.02E+02	2.03E+02	7.45E-02	7.48E-02
	Plutonium	238	2.65E+05	2.39E+06	4.53E+06	4.10E+07	1.50E+05	1.36E+06
	Plutonium	239	9.52E+06	1.14E+08	5.92E+05	7.08E+06	1.83E+04	2.18E+05
	Plutonium	240	4.32E+06	4.67E+07	9.86E+05	1.06E+07	3.07E+04	3.31E+05
	Plutonium	241	2.32E+06	1.92E+07	2.39E+08	1.98E+09	7.42E+03	6.14E+04
	Plutonium	242	9.02E+05	8.96E+06	3.44E+03	3.42E+04	1.02E+02	1.01E+03
	Plutonium	243	1.82E-01	1.82E-01	4.75E+05	4.75E+05	5.48E+02	5.48E+02
	Plutonium	244	4.99E+01	4.62E+02	8.86E-04	8.19E-03	2.57E-05	2.38E-04
	Plutonium	245	1.91E-06	1.91E-06	2.31E+00	2.31E+00	5.48E-03	5.48E-03
	Plutonium	246	4.19E-07	4.19E-07	2.05E-02	2.05E-02	1.73E-05	1.73E-05
95	Americium	239	3.35E-09	3.35E-09	3.70E-03	3.70E-03	8.94E-06	8.94E-06
	Americium	240	1.45E-05	1.45E-05	3.73E+00	3.73E+00	2.44E-02	2.44E-02
	Americium	241	1.19E+05	7.43E+06	4.07E+05	2.55E+07	1.35E+04	8.48E+05
	Americium	242	4.90E-01	6.28E-01	3.96E+05	5.08E+05	4.50E+02	5.76E+02
	Americium	242m	1.34E+03	1.29E+04	1.31E+04	1.25E+05	5.16E+00	4.94E+01
	Americium	243	1.78E+05	1.68E+06	3.56E+04	3.35E+05	1.14E+03	1.08E+04
	Americium	244	1.27E-02	1.27E-02	1.62E+04	1.62E+04	8.50E+01	8.50E+01
	Americium	244m	1.31E-04	1.31E-04	3.88E+03	3.88E+03	1.17E+01	1.17E+01
	Americium	245	4.50E-07	4.50E-07	2.78E+00	2.78E+00	5.16E-03	5.16E-03
	Americium	246	6.72E-10	6.72E-10	2.06E-02	2.06E-02	1.66E-04	1.66E-04

Table C.4 (continued)

Atomic number	Element	Mass number of nuclide	Mass, g		Radioactivity, Ci		Thermal power, W	
			Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
96	Curium	242	1.24E+04	1.59E+04	4.11E+07	5.25E+07	1.51E+06	1.93E+06
	Curium	243	6.87E+02	5.47E+03	3.55E+04	2.83E+05	1.30E+03	1.04E+04
	Curium	244	5.21E+04	3.83E+05	4.22E+06	3.10E+07	1.48E+05	1.08E+06
	Curium	245	1.99E+03	1.74E+04	3.41E+02	2.99E+03	1.13E+01	9.93E+01
	Curium	246	2.66E+02	2.21E+03	8.16E+01	6.79E+02	2.67E+00	2.22E+01
	Curium	247	2.68E+00	2.12E+01	2.49E-04	1.97E-03	7.94E-06	6.29E-05
	Curium	248	1.53E-01	1.13E+00	6.49E-04	4.83E-03	8.08E-05	6.01E-04
	Totals		2.93E+09	3.66E+10	1.09E+10	2.32E+10	4.50E+07	8.76E+07

[a]Includes contributions from nuclides in the fuel, cladding, and fuel assembly structural material.
[b]The term "stable" represents a group of nonradioactive nuclides of a particular element.

Table C.5. Representative DOE LLW radionuclide composition by percent activity[a]

Uranium/thorium		Fission product		Induced activity		Alpha, <100 nCi/g		"Other"	
Nuclide	Composition	Nuclide	Composition	Nuclide	Composition	Nuclide	Composition	Nuclide	Composition
^{208}Tl	0.0017	^{60}Co	0.08	^{51}Cr	4.95	^{238}Pu	2.62	^{3}H	1.22
^{212}Pb	0.0045	^{90}Sr	7.77	^{54}Mn	38.10	^{239}Pu	0.20	^{14}C	0.06
^{212}Bi	0.0045	^{90}Y	7.77	^{58}Co	55.40	^{240}Pu	0.70	^{54}Mn	6.76
^{212}Po	0.0029	^{95}Zr	1.27	^{59}Fe	0.49	^{241}Pu	96.4	^{58}Co	6.24
^{216}Po	0.0045	^{95}Nb	2.83	^{60}Co	0.87	^{241}Am	0.004	^{60}Co	18.03
^{224}Ra	0.0045	^{99}Tc	0.02	^{65}Zn	0.19	^{242}Cm	0.056	^{90}Sr	8.48
^{228}Ra	0.0269	^{125}Sb	2.93			^{244}Cm	0.020	^{90}Y	8.48
^{228}Ac	0.0269	^{125m}Te	0.73		100.00			^{99}Tc	0.12
^{228}Th	0.0045	^{106}Ru	6.39				100.000	^{134}Cs	13.98
^{231}Th	0.0259	^{106}Rh	6.39					^{137}Cs	18.45
^{232}Th	0.273	^{134}Cs	0.38					^{137m}Ba	17.45
^{234}Th	33.197	^{137}Cs	17.31					^{238}U	0.73
^{234m}Pa	33.197	^{137m}Ba	16.38						
^{234}Pa	0.0034	^{144}Ce	14.67						100.00
^{235}U	0.0258	^{144}Pr	14.67						
^{238}U	33.197	^{147}Pm	0.06						
		^{151}Sm	0.11						
	100.0000	^{152}Eu	0.09						
		^{154}Eu	0.09						
		^{155}Eu	0.06						
			100.00						

[a]Based on ref. 1.

Table C.6. Average concentrations for representative radionuclides in LLW at commercial disposal sites[a]

Radionuclide	Half-life[b]	Concentration (Ci/m^3)
^{3}H	1.228E+01 y	1.083E+00
^{14}C	5.730E+03 y	5.079E-03
^{26}Al	7.300E+05 y	2.980E-10
^{32}Si	1.000E+02 y	3.725E-11
^{32}P	1.428E+01 d	9.292E-04
^{35}S	8.751E+01 d	2.208E-03
^{36}Cl	3.010E+05 y	6.143E-06
^{40}K	1.280E+09 y	1.766E-07
^{51}Cr	2.770E+01 d	7.137E-02
^{54}Mn	3.122E+02 d	3.895E-01
^{55}Fe	2.730E+00 y	3.112E+00
^{59}Fe	4.445E+01 d	5.081E-03
^{58}Co	7.092E+01 d	2.047E-01
^{60}Co	5.271E+00 y	2.242E+00
^{59}Ni	7.500E+04 y	1.364E-03
^{63}Ni	1.001E+02 y	2.692E-01
^{65}Zn	2.441E+02 d	1.174E-01
^{85}Kr	1.072E+01 y	8.147E-04
^{89}Sr	5.055E+01 d	6.032E-03
^{90}Sr	2.850E+01 y	6.987E-02
^{90}Y	2.671E+01 d	6.987E-02
^{91}Y	5.851E+01 d	8.859E-03
^{95}Zr	6.402E+01 d	1.036E-02
^{94}Nb	2.030E+04 y	1.659E-05
^{95}Nb	3.497E+01 d	1.916E-02
^{93}Mo	3.500E+03 y	9.273E-12
^{99}Tc	2.130E+05 y	1.949E-04
^{103}Ru	3.925E+01 d	5.900E-04
^{108m}Ag	1.300E+02 y	5.534E-06
^{110m}Ag	2.498E+02 d	3.600E-02
^{113}Cd	9.000E+15 y	4.223E-12
^{124}Sb	6.020E+00 d	2.621E-03
^{125}Sb	2.730E+00 y	1.901E-02
^{123}Te	1.300E+13 y	5.710E-07
^{125}I	6.014E+00 d	4.570E-04
^{129}I	1.570E+07 y	2.101E-05
^{131}I	8.040E+00 d	5.299E-03
^{134}Cs	2.062E+00 y	8.661E-02
^{135}Cs	3.000E+06 y	1.105E-05
^{137}Cs	3.017E+01 y	2.431E-01
^{137m}Ba	2.552E+00 min	2.300E-01
^{141}Ce	3.250E+01 d	1.649E-03
^{144}Ce	2.849E+02 d	1.463E-02
^{144}Pr	1.728E+01 min	1.463E-02
^{144}Nd	2.100E+15 y	1.689E-10
^{147}Pm	2.623E+00 y	1.317E-02
^{157}Tb	1.100E+02 y	1.012E-10
^{158}Tb	1.800E+02 y	3.768E-10
^{175}Hf	7.000E+01 d	1.427E-03
^{181}Hf	4.240E+01 d	3.235E-03
^{187}Re	4.100E+10 y	1.772E-11

Table C.6 (continued)

Radionuclide	Half-life[b]	Concentration (Ci/m^3)
^{209}Po	3.253E+00 h	1.284E-10
^{226}Ra	1.600E+03 y	2.852E-04
^{229}Th	7.340E+03 y	1.310E-10
^{230}Th	7.540E+04 y	1.721E-08
^{232}Th	1.405E+10 y	8.171E-03
^{231}Pa	3.276E+04 y	1.016E-10
^{233}U	1.592E+05 y	2.308E-07
^{234}U	2.454E+05 y	5.368E-05
^{235}U	7.037E+08 y	2.541E-05
^{236}U	2.432E+07 y	7.886E-07
^{238}U	4.468E+09 y	6.992E-03
^{237}Np	2.140E+06 y	1.670E-07
^{239}Pu	2.413E+04 y	7.714E-06[c]
^{240}Pu	6.563E+03 y	1.892E-06[c]
^{242}Pu	3.763E+05 y	4.652E-07[c]
^{241}Am	4.322E+02 y	3.063E-05
^{243}Am	7.380E+03 y	1.056E-08
^{248}Cm	3.400E+05 y	4.700E-07
Others[d]	–	3.308E-03
Total		8.379E+00

[a]Taken from the report by G. W. Roles, Characteristics of Low-Level Radioactive Waste Disposed During 1987 Through 1989, NUREG-1418, December 1990.

[b]y = years; d = days; h = hours; min = minutes; and s = seconds.

[c]The commercial disposal site at Barnwell, South Carolina, has not permitted disposal of plutonium; thus, its isotopes are omitted when this list is applied to waste disposed at Barnwell.

[d]Includes contributions from radionuclides in natural thorium, natural and depleted uranium, and other actinides.

Table C.7. Projected chemical and radionuclide composition of saltstone at SRS[a,b]

End of calendar year	Fraction of radionuclide[c]										
	^{3}H	^{90}Sr	^{90}Y	^{99}Tc	^{106}Ru	^{106}Rh	^{125}Sb	^{137}Cs	^{137m}Ba	^{147}Pm	Total
1992	0.029	0.138	0.138	0.014	0.000	0.000	0.008	0.036	0.033	0.603	1.00
1993	0.026	0.115	0.115	0.020	0.001	0.001	0.021	0.030	0.027	0.644	1.00
1994	0.026	0.116	0.116	0.019	0.001	0.001	0.015	0.029	0.027	0.649	1.00
1995	0.029	0.127	0.127	0.020	0.001	0.001	0.012	0.032	0.030	0.622	1.00
1996	0.035	0.140	0.140	0.023	0.000	0.000	0.011	0.037	0.034	0.580	1.00
1997	0.041	0.153	0.153	0.025	0.001	0.001	0.010	0.040	0.036	0.541	1.00
1998	0.045	0.163	0.163	0.030	0.001	0.001	0.009	0.042	0.039	0.507	1.00
1999	0.050	0.175	0.175	0.032	0.000	0.000	0.008	0.042	0.039	0.477	1.00
2000	0.057	0.191	0.191	0.034	0.000	0.000	0.008	0.042	0.039	0.437	1.00
2001	0.063	0.209	0.209	0.036	0.000	0.000	0.008	0.043	0.040	0.391	1.00
2002	0.068	0.228	0.228	0.038	0.000	0.000	0.007	0.044	0.040	0.344	1.00
2003	0.074	0.247	0.247	0.041	0.000	0.000	0.007	0.045	0.041	0.298	1.00
2004	0.079	0.265	0.265	0.043	0.001	0.001	0.006	0.045	0.042	0.255	1.00
2005	0.083	0.281	0.281	0.044	0.001	0.001	0.006	0.046	0.042	0.215	1.00
2006	0.088	0.295	0.295	0.045	0.001	0.001	0.006	0.046	0.042	0.181	1.00
2007	0.091	0.308	0.308	0.047	0.001	0.001	0.006	0.045	0.042	0.152	1.00
2008	0.094	0.320	0.320	0.048	0.001	0.001	0.006	0.045	0.041	0.124	1.00
2009	0.097	0.331	0.331	0.049	0.001	0.001	0.005	0.044	0.041	0.101	1.00
2010	0.097	0.335	0.335	0.051	0.001	0.001	0.006	0.046	0.042	0.086	1.00
2011	0.100	0.343	0.343	0.054	0.000	0.000	0.004	0.047	0.043	0.065	1.00
2012	0.102	0.348	0.348	0.056	0.000	0.000	0.004	0.047	0.044	0.051	1.00
2013	0.103	0.351	0.351	0.057	0.000	0.000	0.003	0.048	0.044	0.041	1.00
2014	0.105	0.354	0.354	0.060	0.000	0.000	0.002	0.048	0.044	0.032	1.00
2015	0.108	0.355	0.355	0.061	0.000	0.000	0.002	0.048	0.045	0.025	1.00
2016	0.109	0.355	0.355	0.062	0.000	0.000	0.003	0.048	0.044	0.024	1.00
2017	0.111	0.355	0.355	0.063	0.000	0.000	0.003	0.047	0.044	0.022	1.00
2018	0.112	0.355	0.355	0.063	0.000	0.000	0.003	0.047	0.043	0.021	1.00
2019	0.113	0.355	0.355	0.064	0.000	0.000	0.004	0.046	0.043	0.020	1.00
2020	0.114	0.355	0.355	0.065	0.000	0.000	0.004	0.046	0.042	0.018	1.00
2021	0.116	0.355	0.355	0.066	0.000	0.000	0.004	0.045	0.042	0.017	1.00
2022	0.117	0.355	0.355	0.066	0.000	0.000	0.004	0.045	0.041	0.017	1.00
2023	0.118	0.354	0.354	0.067	0.000	0.000	0.004	0.044	0.041	0.016	1.00
2024	0.119	0.354	0.354	0.068	0.000	0.000	0.004	0.044	0.040	0.015	1.00
2025	0.121	0.354	0.354	0.069	0.000	0.000	0.004	0.043	0.040	0.014	1.00
2026	0.122	0.354	0.354	0.070	0.000	0.000	0.003	0.043	0.040	0.014	1.00
2027	0.123	0.354	0.354	0.071	0.000	0.000	0.003	0.043	0.039	0.013	1.00
2028	0.124	0.354	0.354	0.072	0.000	0.000	0.003	0.042	0.039	0.012	1.00
2029	0.126	0.353	0.353	0.073	0.000	0.000	0.003	0.042	0.038	0.012	1.00
2030	0.127	0.353	0.353	0.073	0.000	0.000	0.003	0.041	0.038	0.011	1.00

[a]Taken from ref. 3.

[b]Chemical composition (wt %): fly ash, 46.0; water, 30.2; cement, 11.5; $NaNO_3$, 6.0; NaOH, 1.9; $NaNO_2$, 1.5; $NaAl(OH)_4$, 1.3; Na_2SO_4, 0.7; and other, 0.9.

[c]The radionuclide composition at the end of a year is expressed in terms of the fraction of each significant nuclide making up an average unit of radioactivity in all the saltstone collected from the beginning of the operation of the saltstone plant to the end of the year indicated.

Table C.8. Historical and projected DOE/EIA No New Orders Case commercial LWR net annual electrical generation[a,b]

End of calendar year	Historical generation [MW(e)-years]			End of calendar year	No New Orders Case projected generation [MW(e)-years]		
	BWR	PWR	Total		BWR	PWR	Total
1960	29	4	33	1992	21,264	48,351	69,615
1961	60	97	157	1993	21,178	48,687	69,865
1962	137	96	233	1994	21,178	49,306	70,484
1963	136	208	344	1995	21,195	49,966	71,161
1964	164	198	362	1996	21,178	50,563	71,741
1965	164	212	376	1997	21,178	50,808	71,986
1966	221	334	556	1998	21,178	50,890	72,068
1967	184	419	603	1999	21,143	51,035	72,178
1968	205	781	986	2000	21,143	51,035	72,178
1969	238	1,049	1,287	2001	21,143	51,035	72,178
1970	1,011	1,192	2,203	2002	21,124	51,035	72,159
1971	1,969	2,103	4,075	2003	21,093	51,035	72,128
1972	3,188	2,450	5,641	2004	21,093	51,035	72,128
1973	4,446	4,620	9,073	2005	21,093	51,035	72,128
1974	5,298	6,650	11,955	2006	21,093	51,035	72,128
1975	6,309	12,089	17,395	2007	21,093	51,035	72,128
1976	8,044	13,113	21,343	2008	21,093	51,035	72,128
1977	9,636	17,737	27,388	2009	20,792	50,956	71,748
1978	11,353	19,596	31,142	2010	20,200	50,724	70,924
1979	11,390	17,332	28,662	2011	18,909	50,264	69,173
1980	10,416	17,848	28,343	2012	18,621	49,658	68,279
1981	10,187	20,310	30,517	2013	17,280	46,808	64,088
1982	10,201	20,716	30,938	2014	14,585	42,304	56,889
1983	9,363	22,494	31,883	2015	12,366	40,196	52,562
1984	9,766	26,427	35,072	2016	12,109	38,792	50,901
1985	12,151	30,413	41,382	2017	11,296	36,803	48,099
1986	12,737	33,726	46,495	2018	11,005	35,949	46,954
1987	14,810	36,465	51,275	2019	10,746	35,312	46,058
1988	16,722	41,639	58,361	2020	10,746	35,107	45,853
1989	16,845	43,489	60,334	2021	10,746	33,917	44,663
1990	20,861	44,947	65,808	2022	10,370	32,747	43,117
1991	23,060	46,819	69,879	2023	9,236	32,048	41,284
				2024	7,750	31,185	38,935
				2025	5,881	27,978	33,859
				2026	4,927	25,902	30,829
				2027	4,252	24,259	28,511
				2028	3,736	22,177	25,913
				2029	3,423	20,504	23,927
				2030	2,960	18,713	21,673

[a]Historical data for 1960-1990 are based on refs. 7 and 9 and for 1991 on ref. 10.
[b]Projected data for 1992-2030 are based on ref. 10.

Table C.9. Estimated sources and characteristics of commercial greater-than-Class-C LLW[a]

Waste source	Physical form	Primary isotopes of concern for disposal
Utilities		
Operations	Activated metals, instruments, filters, ion-exchange resins, sludges	^{59}Ni, ^{63}Ni, ^{94}Nb, and TRU isotopes
Decommissioning	Activated metals	^{59}Ni, ^{63}Ni, and ^{94}Nb
Fuel testing labs		
Burnup lab operation	Solidified liquids, metal cuttings, glassware, equipment, ion-exchange resins	^{90}Sr and TRU isotopes
Burnup lab decommissioning	Solidified liquids, metals, glassware, equipment	^{90}Sr and TRU isotopes
Sealed sources		
Manufacturer operations	Trash, metal, foils	^{14}C, ^{90}Sr, ^{137}Cs, ^{241}Am, and Pu isotopes
Manufacturer decommissioning	Trash, metal, foils	^{14}C, ^{90}Sr, ^{137}Cs, ^{241}Am, and Pu isotopes
Sources designated as waste	Sealed sources	^{137}Cs, ^{238}Pu, ^{239}Pu, and ^{241}Am
Other		
Carbon-14 users	Solidified process liquids	^{14}C
Test and research reactors	Activated metals	^{59}Ni, ^{94}Nb, and TRU isotopes
Other	Soil, trash	^{241}Am

[a]Gleaned from information given in refs. 11 and 12.

Table C.10. Projected number and volume of drums and classes of LLW incorporated in cement to be generated in the WVDP Low-Level Radwaste Treatment System[a,b,c,d]

End of calendar year	Number of drums			Total volume of drums (m^3)
	Class A[e]	Class B	Class C[f]	
1987	726	g	-	196
1988	-	g	2,024	546
1989	-	g	4,508	1,217
1990[h]	-	g	3,863	1,043
1991[i]	-	g	0	0
1992[j]	-	g	4,545	1,227
Total number	726	g	14,940	
Total volume, m^3	196	g	4,034	4,229

[a]The so-called square drums used are parallelopipeds of square cross section (~0.6 m x 0.6 m x 0.8 m) with a volume of 71 gal (0.27 m^3).

[b]The classes are in accordance with the Classes (A, B, or C) as set by requirements of the NRC in 10 CFR 61.55.

[c]Taken from ref. 13.

[d]Alkaline HLW liquid is processed (see Sect. 2) to yield a loaded ion-exchange material (zeolite), which is HLW, and an effluent, which is LLW. This effluent is solidified with cement.

[e]Generated in 1987 during equipment testing campaigns.

[f]Stored in a shielded drum cell.

[g]No Class B waste is expected to be generated with the effluent mentioned in footnote d.

[h]Processing of alkaline HLW liquid was completed in November 1990, leaving a 1,090-m^3 heel of liquid in the alkaline HLW waste (liquid plus sludge) storage tank.

[i]Processing of liquids from washing of HLW sludge is scheduled to begin in October 1991.

[j]The drums projected to be filled in 1992 will contain the liquids mentioned in footnotes h and i after treatment by ion exchange (see footnote d).

Table C.11. Composition of industrial and institutional waste by category[a]

	Composition,[b] %				
		Institutional			
Radionuclide	Industrial	Bioresearch	Medical	Nonbioresearch	Total
^{3}H	6.453E+01	5.286E+01	8.341E+00	8.824E+01	6.319E+01
^{14}C	3.815E-01	2.738E+01	6.107E+00	6.549E+00	4.454E+00
^{22}Na		1.652E-01			2.279E-02
^{32}P	6.340E+00	4.416E+00	7.367E+00		5.816E+00
^{36}Cl		3.239E-02			4.469E-03
^{35}S	5.519E+00	4.294E+00	8.735E-01		5.042E+00
^{45}Ca	8.671E-04	2.242E-02			3.791E-03
^{46}Sc			1.911E-02		2.571E-04
^{51}Cr	1.394E-01	2.775E-01	3.417E-01		1.550E-01
^{54}Mn	8.052E-02			3.987E-02	6.654E-02
^{55}Fe	2.336E-03	2.092E-03		6.577E-01	3.102E-02
^{57}Co	4.584E-03		6.575E-01		1.252E-02
^{58}Co	2.228E-03	2.318E-02			4.992E-03
^{59}Fe	9.859E-04			1.551E-02	1.473E-03
^{60}Co	3.366E+00			9.230E-01	2.748E+00
^{63}Ni	9.752E-03			5.037E-02	1.006E-02
^{65}Zn	1.196E-03	5.929E-02		1.398E-01	1.482E-02
^{67}Ga			7.758E-02		1.043E-03
^{75}Se	1.341E-02		2.419E-02		1.112E-02
^{85}Kr	4.061E-02				3.267E-02
^{90}Sr	3.310E-01				2.663E-01
^{90}Y	3.310E-01				2.663E-01
^{90}Mo			2.317E+00		3.114E-02
^{99m}Tc			7.023E-01		9.349E-03
^{109}Cd	8.790E-02				7.071E-02
^{111}In	6.475E-04		2.800E-02		8.969E-04
^{113}Sn			2.410E-02		3.240E-04
^{123}I	5.063E-04		2.190E-02		7.016E-04
^{125}I	1.703E+00	9.902E+00	7.064E+01		3.686E+00
^{131}I	1.465E-02	5.453E-01	5.652E-02		8.778E-02
^{133}Ba	2.674E-02				2.151E-02
^{133}Xe			3.828E-02		5.146E-04
^{134}Cs	2.605E-02				2.096E-02
^{137}Cs	6.008E+00	1.230E-02		1.250E+00	4.892E+00
^{137m}Ba	5.687E+00	1.164E-02		1.183E+00	4.625E+00
^{147}Pm	1.015E-01				8.167E-02
^{151}Sm	6.166E-03				4.960E-03
^{153}Gd			5.288E-03		7.107E-05
^{169}Yb	8.637E-02				6.948E-02
^{175}Hf	1.234E-02				9.924E-03
^{182}Ta	7.939E-01				6.387E-01
^{192}Ir	3.347E-01		1.995E+00		2.961E-01
^{201}Tl			2.585E-01		3.476E-03
^{210}Po	1.424E-01				1.146E-01
^{226}Ra			1.071E-01		1.439E-03
^{230}Th	7.489E-04				6.047E-03
^{232}Th	1.665E+00				1.341E+00
^{235}U	1.356E-02				1.091E-02
^{238}U	2.172E+00			9.484E-01	1.807E+00
^{241}Pu	1.806E-02				1.453E-02
Total	1.000E+02	1.000E+02	1.000E+02	1.000E+02	1.000E+02

[a]The volumetric composition of I/I is considered to be as follows: 70.3% industrial, 21.9% bioresearch, 2.3% medical, and 5.5% nonbioresearch. The radioactivity composition of I/I waste is considered to be 80.5% industrial, 13.8% bioresearch, 1.3% medical, and 4.4% nonbioresearch.

[b]The composition is presented as percent of total curies in each individual category of I/I waste and as percent of the total in all I/I waste combined. This information is adapted from ref. 2.

APPENDIX D. REFERENCE SITES AND FACILITIES

APPENDIX D. REFERENCE SITES AND FACILITIES

D.1 DISCUSSION

This appendix provides a listing of major DOE and commercial sites and facilities discussed in this report. Table D.1 lists major DOE sites and facilities. Major commercial radioactive waste disposal sites are given in Table D.2. For each site or facility listed in these tables, additional information is provided, including reference symbol or label, location, operations contractor, and, for DOE sites, the supervisory DOE field office.

Table D.1. Major DOE sites and facilities referred to in this report

Site/facility	Symbol/label	Location	Principal contractor(s) for site operations (Phone number)[a]	DOE field office (Phone number)[a]
Ames Laboratory	AMES	Ames, IA	Iowa State University (515/294-2680)	Chicago (708/252-2001)
Argonne National Laboratory-East	ANL-E	Argonne, IL	University of Chicago (708/252-2000)	Chicago (708/252-2001)
Argonne National Laboratory-West[b]	ANL-W	Idaho Falls, ID	University of Chicago (208/533-7000)	Idaho (208/526-0111)
Battelle Columbus Laboratories Decommissioning Project	BCLDP	Columbus, OH	Battelle Memorial Institute (614/424-3989)	Chicago (708/252-2001)
Brookhaven National Laboratory	BNL	Upton, NY	Associated Universities, Inc. (516/282-2123)	Chicago (708/252-2001)
Colonie Interim Storage Site	CISS	Colonie, NY	Bechtel National, Inc. (615/220-2000)	Oak Ridge (615/576-5454)
Fermi National Accelerator Laboratory	FNAL	Batavia, IL	University Research Association (708/840-3000)	Chicago (708/252-2001)
Fernald Environmental Management Project	FEMP	Fernald, OH	Westinghouse Environmental Management Company of Ohio, Inc. (513/738-6200)	Fernald Field Office (513/738-6319)
Grand Junction Projects Office	GJPO	Grand Junction, CO	DOE Grand Junction Projects Office (303/248-6000)	Idaho (208/526-0111)
Hanford Site	HANF	Hanford, WA	Westinghouse Hanford Company, Inc. (509/376-7511)	Richland (509/376-7411)
Idaho National Engineering Laboratory	INEL	Idaho Falls, ID	EG&G Idaho, Inc. (208/526-0111)	Idaho (208/526-0111)
Inhalation Toxicology Research Institute	ITRI	Albuquerque, NM	Lovelace Biomedical and Environmental Research Institute, Inc. (505/845-1037)	Albuquerque (505/845-4154)
Kansas City Plant	KCP	Kansas City, MO	Allied-Signal Aerospace Company Kansas City Division (816/997-2000)	Albuquerque Kansas City Area Office (816/997-3348)

Table D.1 (continued)

Site/facility	Symbol/label	Location	Principal contractor(s) for site operations (Phone number)[a]	DOE field office (Phone number)[a]
Lawrence Berkeley Laboratory	LBL	Berkeley, CA	University of California (510/486-4000)	San Francisco Lawrence Berkeley Laboratory Site Office (510/486-4363)
Lawrence Livermore National Laboratory	LLNL	Livermore, CA	University of California (510/422-1100)	San Francisco (510/273-6383)
Los Alamos National Laboratory	LANL	Los Alamos, NM	University of California (505/667-5061)	Albuquerque Los Alamos Area Office (505/667-5061)
Mound Plant	MOUND	Miamisburg, OH	EG&G Mound Applied Technologies (513/865-4020)	Albuquerque Dayton Area Office (513/865-3271)
Naval Reactors Program Facilities Bettis Atomic Power Laboratory	BAPL	West Mifflin, PA	Westinghouse Electric Corporation (412/476-5000)	DOE/HQ Office of Naval Reactors (NE-60) Pittsburgh Naval Reactors Area Office (412/476-5000)
Knolls Atomic Power Laboratory	KAPL	Schenectady, NY	General Electric Company (518/395-4000)	DOE/HQ Office of Naval Reactors (NE-60) Schenectady Naval Reactors Area Office (518/395-4000)
Naval Reactors Facility (INEL)	NRF	Idaho Falls, ID	Westinghouse Electric Corporation (208/526-0111)	DOE/HQ Office of Naval Reactors (NE-60) Pittsburgh Naval Reactors Area Office (412/476-5000)
Nevada Test Site	NTS	Mercury, NV	Reynolds Electrical & Engineering Company, Inc. (702/295-9060)	Nevada (702/295-1212)
Oak Ridge Institute for Science and Education	ORISE	Oak Ridge, TN	Oak Ridge Associated Universities (615/576-3000)	Oak Ridge (615/576-5454)
Oak Ridge K-25 Site	K-25	Oak Ridge, TN	Martin Marietta Energy Systems, Inc. (615/574-1000)	Oak Ridge (615/576-5454)

Table D.1 (continued)

Site/facility	Symbol/label	Location	Principal contractor(s) for site operations (Phone number)[a]	DOE field office (Phone number)[a]
Oak Ridge National Laboratory	ORNL	Oak Ridge, TN	Martin Marietta Energy Systems, Inc. (615/574-1000)	Oak Ridge (615/576-5454)
Oak Ridge Y-12 Plant	Y-12	Oak Ridge, TN	Martin Marietta Energy Systems, Inc. (615/574-1000)	Oak Ridge (615/576-5454)
Pacific Northwest Laboratory[c]	PNL	Richland, WA	Battelle Memorial Institute (509/375-2121)	Richland (509/376-7411)
Paducah Gaseous Diffusion Plant	PAD	Paducah, KY	Martin Marietta Energy Systems, Inc. (502/441-6000)	Oak Ridge Paducah Site Office (502/441-6800)
Pantex Plant	PANT	Amarillo, TX	Mason & Hanger — Silas Mason Company, Inc. (806/477-3000)	Albuquerque Amarillo Area Office (806/477-3000)
Pinellas Plant	Pinellas	Largo, FL	Martin Marietta Specialty Components, Inc. (813/541-8001)	Albuquerque Pinellas Area Office (813/541-8196)
Portsmouth Gaseous Diffusion Plant	PORTS	Portsmouth, OH	Martin Marietta Energy Systems, Inc. (614/897-2331)	Oak Ridge Portsmouth Area Office (614/897-2331)
Princeton Plasma Physics Laboratory	PPPL	Princeton, NJ	Princeton University (609/243-2000)	Chicago Princeton Area Office (609/243-3700)
Reactive Metals, Incorporated Extrusion Plant	RMI	Astabula, OH	RMI Titanium Company (216/992-7442)	Albuquerque Astabula Area Office (216/992-7442)
Rocky Flats Plant	RFP	Golden, CO	EG&G Rocky Flats, Inc. (303/966-7000)	Albuquerque Rocky Flats Office (303/966-7000)
Sandia National Laboratories Albuquerque	SNLA	Albuquerque, NM	AT&T Technologies, Inc. (505/844-5678)	Albuquerque (505/845-4154)
Livermore	SNLL	Livermore, CA	AT&T Technologies, Inc. (510/294-3000)	Albuquerque (505/845-4154)

Table D.1 (continued)

Site/facility	Symbol/label	Location	Principal contractor(s) for site operations (Phone number)[a]	DOE field office (Phone number)[a]
Santa Susana Field Laboratory (Energy Technology Engineering Center)	SSFL (ETEC)	Canoga Park, CA	Rockwell International Rocketdyne Division (818/586-5326)	San Francisco (510/273-6383)
Savannah River Site	SRS	Aiken, SC	Westinghouse Savannah River Company (803/725-6211)	Savannah River (803/725-6211)
Stanford Linear Accelerator Center	SLAC	Palo Alto, CA	Stanford University (415/926-3300)	San Francisco Stanford Site Office (415/926-3208)
Three Mile Island-Unit 2 Reactor	TMI-Unit 2	Middletown, PA	General Public Utilities (717/944-7621)	Idaho Three Mile Island Site Office (717/944-7621)
Waste Isolation Pilot Plant	WIPP	Carlsbad, NM	Westinghouse Electric Corporation WIPP Project Office (505/885-7500)	Albuquerque WIPP Project Office (505/887-8115)
Weldon Spring Site Remedial Action Project	WSSRAP	Weldon Spring, MO	Jacobs Engineering Group, Inc. MK-Ferguson Company (314/441-8978)	Oak Ridge Weldon Spring Site (314/441-8978)
West Valley Demonstration Project	WVDP	West Valley, NY	Westinghouse Electric Corporation West Valley Nuclear Services (716/942-3235)	Idaho West Valley Project Office (716/942-4313)

[a]Phone number for access to main organizations.
[b]Part of the Idaho National Engineering Laboratory.
[c]Part of the Hanford Site.

Table D.2. Major commercial radioactive waste disposal sites included in this report[a]

Site	Symbol/label	Location	Principal contractor for site operations (Phone number)[b]
Barnwell	BARN	Barnwell, SC	Chem-Nuclear Systems, Inc. (803/256-0450)
Beatty	BETY	Beatty, NV	US Ecology, Nuclear (702/553-2203)
Maxey Flats	MFKY	Hillsboro, KY	Westinghouse Electric Corporation Environmental Technology Division (606/784-6612)
Richland	RICH	Richland, WA	US Ecology, Nuclear (509/377-2411)
Sheffield	SHEF	Sheffield, IL	US Ecology, Nuclear (815/454-2077)
West Valley	WVNY	West Valley, NY	Westinghouse Electric Corporation West Valley Nuclear Fuel Services Company, Inc. (716/942-3235) New York State Energy Research and Development Authority (518/465-6251)

[a]Does not include uranium mill tailings sites. See Table 5.2.
[b]Phone number for access to main organizations.

GLOSSARY OF TERMS

Actinides: Elements with atomic numbers from 90 to 103 inclusive. (Note that actinium is not part of this group.)

Activation product: A radioactive material produced by bombardment with neutrons, protons, or other nuclear particles.

Agreement State: A state that has entered into an agreement with the Nuclear Regulatory Commission (as specified by the 1954 Atomic Energy Act) and has authority to regulate the disposal of low-level radioactive waste under such an agreement. This term is used in the Low-Level Radioactive Waste Policy Act (Public Law 99-240).

Alpha decay: Radioactive decay in which an alpha particle (^{4}He nucleus) is emitted.

Beta decay: Radioactive decay in which a negative electron (beta particle) is emitted.

Borosilicate glass: A type of glass containing at least 5% boric oxide. It is used in glassware that resists heat and is a leading candidate for use in high-level waste immobilization and disposal.

Branching ratio: The fraction of nuclei that disintegrates in a specific way. (It is usually expressed as a percentage.)

Burnup, specific: The total energy released per initial unit mass of reactor fuel as a result of fission. The unit commonly used for specific burnup is megawatt-days per metric ton of initial heavy metal, MWd/MTIHM.

By-product material: (1) Any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material; (2) the tailings or waste products produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content.

Calcine: A form of high-level waste produced from defense reactor fuel reprocessing waste (at the Idaho Chemical Processing Plant) by heating to a temperature below the melting point to bring about loss of moisture and oxidation to a chemically stable form.

Canister: A metal container used for the storage or disposal of heat-producing solid radioactive waste.

Capacity factor, plant: The ratio of the electrical energy actually supplied by a power plant in a given time interval to the electrical energy that could have been produced at continuous full-power operation during the same time period.

Capsules: Encapsulated strontium and cesium high-level wastes produced from defense reactor fuel reprocessing at the Hanford site.

Cladding: A corrosion-resistant tube, commonly made of zirconium alloy or stainless steel, surrounding the reactor fuel pellets which provides protection from a chemically reactive environment and containment of fission products.

Code of Federal Regulations: A documentation of the general rules by the executive departments of the federal government. The code is divided into 50 titles that represent broad areas subject to federal regulation. Each title is divided into chapters that usually bear the name of the issuing agency. Each chapter is further subdivided into parts covering specific regulatory areas.

Control rod: A movable part of a reactor used to regulate the degree of fuel fissioning in the core.

Conversion, fuel: Chemical treatment of yellowcake (U_3O_8) to uranium hexafluoride (UF_6) in preparation for enrichment.

Core, nuclear reactor: That part of the reactor which contains the nuclear fuel and in which most or all of the nuclear fissions occur.

Daughter product(s): The nuclide(s) formed by the radioactive disintegration of a first radionuclide (parent).

Decay, radioactive: The transition of a nucleus from one energy state to a lower one, usually involving the emission of a photon, electron, or neutron.

Decay chain, radioactive: A series of nuclides in which each member transforms into the next through radioactive decay until a stable nuclide has been formed.

Decommissioning: Preparations taken for retirement of a nuclear facility from active service, accompanied by the execution of a program to reduce or stabilize radioactive contamination.

Decommissioning wastes: Wastes (generally low-level) collected or resulting from facility decommissioning activities.

Decontamination: Those activities employed to reduce radiation levels or to remove radioactive contamination in or on structures, equipment, and materials.

Deep bed plant: A BWR facility using a demineralizer vessel for water purification which contains an ion-exchange resin that is 3 or more feet deep.

Disintegration energy (Q): The amount of energy released in a particular nuclear disintegration. This is usually expressed in MeV per disintegration.

DOE waste: Radioactive waste produced from activities supported by the Department of Energy and/or U.S. government defense programs.

Double-shell tank wastes: High-level wastes, generated from defense reactor fuel reprocessing at Hanford, which are stored in double-shelled tanks. These wastes consist of a mixture of liquid and suspended solids referred to as slurry. See also "single-shell tank wastes."

Electron capture: Radioactive decay in which an orbital electron is captured by the nucleus.

Enrichment, fuel: A nuclear fuel cycle process in which the concentration of fissionable uranium (i.e., ^{235}U) is increased above its natural level of 0.71%. (The method currently utilized in the United States is gaseous diffusion.)

Environmental Impact Statement: A report that documents the information required to evaluate the environmental impact of a project. Such a report informs decision-makers and the public of the reasonable alternatives which would avoid or minimize adverse impacts or enhance the quality of the environment.

Environmental restoration project: A group of activities initiated to access a DOE facility or radioactive waste site that may require restoration to acceptable radiation levels.

Equilibrium cycle: An assumed nuclear fuel cycle condition in which the feed and waste materials of a facility have constant compositions. In a reactor this condition typically results after the third or fourth fuel loading schedule.

Fabrication, fuel: Conversion of enriched UF_6 into pellets of ceramic uranium dioxide (UO_2). These pellets are then sealed into corrosion-resistant tubes of zirconium alloy or stainless steel. The loaded tubes, called fuel elements or rods, are then mounted into special assemblies for loading into the reactor core.

Fertile nuclide: A nuclide capable of being transformed into a fissile nuclide by neutron capture at specific neutron energies.

Filter/demineralizer plant: A facility that combines filtration and ion-exchange processing using nonregenerable powered resins.

Fissile nuclide: A nuclide capable of undergoing nuclear fission with neutrons.

Fission, nuclear: The division of a heavy atomic nucleus into two (or, rarely, more) parts with similar masses, usually accompanied by the emission of neutrons and gamma radiation.

Fission products: Nuclides produced either by fission or by the subsequent decay of the nuclides thus formed.

Fission, spontaneous: Nuclear fission that occurs without the addition of particles or energy to the nucleus.

Formerly utilized site: A site contaminated with radioactive wastes which was previously used for supporting nuclear activities of the DOE's predecessor agencies, the Manhattan Engineer District (Manhattan Project) and the Atomic Energy Commission.

Fuel assembly: A grouping of nuclear fuel rods that remains integral during the charging and discharging of a reactor core.

Fuel cycle, nuclear: The complete series of steps involved in supplying fuel for nuclear reactors. It includes mining, refining, enrichment, fabrication of fuel elements, use in a reactor, chemical processing to recover the fissionable material remaining in the spent fuel, reenrichment of the fuel material, refabrication of new fuel elements, and management of radioactive waste.

Generation (electricity): The process of producing electric energy from other forms of energy; also, the amount of electric energy produced, commonly expressed in kilowatt-hours (kWh) or megawatt-years [MW(e)-years].

Generation (gross): The total amount of electric energy produced by the generating units in a generating station or stations, measured at the generator terminals.

Generation (net): Gross generation less the electric energy consumed at the generating station for station use.

Glass frit: A fusible ceramic mixture used to make glass for use in the immobilization and disposal of high-level wastes.

Greater-than-Class-C low-level waste: Waste from commercial sources containing radionuclide concentrations that exceed Nuclear Regulatory Commission limits for Class C low-level radioactive waste as defined in 10 CFR Part 61.55.

Grout: A mortar or cement mixture used to immobilize radioactive wastes.

Half-life, radioactive: For a single radioactive decay process, the time required for the activity to decrease to half its initial value by that process.

Hazardous waste: Nonradioactive waste containing concentrations of either toxic, corrosive, flammable, or reactive chemicals above maximum permissible levels as defined by the Environmental Protection Agency in 40 CFR Part 261 or polychlorinated biphenyls (PCBs) above maximum permissible levels as defined by the EPA in 40 CFR Parts 702–799.

High-level waste: As defined by the Nuclear Waste Policy Act, high-level waste is (1) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including the liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations; and (2) other highly radioactive material that the Nuclear Regulatory Commission, consistent with existing law, determines by rule to require permanent isolation.

Hydrofracture: A process formerly used for permanent disposal of low-level (approximately 0.25 Ci/L) liquid waste at the Oak Ridge National Laboratory. The process involved mixing the waste with a blend of cement and other additives with the resulting grout being injected into shale at a depth of 200 to 300 m. The injected grout hardened into thin, horizontal sheets several hundred meters wide.

Industrial waste: Commercial low-level waste resulting from non-nuclear fuel cycle sources. These include the commercial producers of radiochemicals and radiopharmaceuticals, luminous dial manufacturers, and instruments that incorporate sealed source components (e.g., smoke detectors).

Institutional waste: Commercial low-level waste resulting from bioresearch, medical, and certain nonbioresearch sources. Bioresearch wastes include wastes from animal studies at universities. Medical wastes include those generated from diagnostic and therapeutic procedures on humans at hospitals. Nonbioresearch wastes include research reactor wastes; small-volume, sealed radiation sources; and accelerator targets.

Leaching: The process of removal or separation of soluble components from a solid by percolating water or other liquids through the solid.

Low-level waste: As specified in the Low-Level Radioactive Waste Policy Amendments Act of 1985 (Public Law 99-240), radioactive waste not classified as high-level waste, spent nuclear fuel, or by-product material specified as uranium or thorium tailings and waste.

Mill tailings, uranium: Earthen residues that remain after the extraction of uranium from ores. Tailings may also contain other minerals or metals not extracted in the process.

Mixed low-level waste: Waste that satisfies the definition of low-level radioactive waste (LLW) in the Low-Level Radioactive Waste Policy Amendments Act of 1985 and contains hazardous waste that has at least one of the following characteristics: (1) is listed as a hazardous waste in Subpart D of 40 CFR Part 261, (2) exhibits any of the hazardous waste characteristics identified in Subpart C of 40 CFR Part 261, or (3) contains PCB-containing wastes subject to regulation under the Toxic Substances Control Act and 40 CFR Parts 702–799.

Mixed waste: Waste that includes concentrations of both radionuclides and hazardous chemicals.

Moderator: A material used to reduce neutron energy (for fissioning if in a reactor) by elastic scattering.

MRS facility: A proposed facility for the monitored retrievable storage of spent fuel from commercial power plants. Such a facility would permit continuous monitoring, management, and maintenance of these wastes and provide for their ready retrieval for further processing or disposal.

Neutron activation: The process of irradiating a material with neutrons so that the material itself is transformed into a radioactive nuclide.

Nonfuel components: Nuclear reactor core parts and hardware, excluding the nuclear fuel itself. Such components include shrouds, control rods, fuel channels, in-core chambers, support tubes, and dummy fuel rods.

Parent: A radionuclide that upon decay yields a specified nuclide (the daughter) either directly or as a later member of a radioactive decay series.

Pressure vessel, reactor: A strong-walled container housing the core of most types of power reactors. It usually also contains other core components such as the moderator and control rods.

PUREX process: A solvent extraction process that may be employed in the reprocessing of uranium/plutonium-based nuclear fuels.

Radioactivity: The number of spontaneous nuclear disintegrations occurring in a given quantity of material during a suitably small period of time. A unit of activity commonly used is the curie (Ci), which is 3.7×10^{10} disintegrations per second.

Reactor, boiling-water: A light-water reactor in which water, used as both coolant and moderator, is allowed to boil in the core. The resulting steam is used directly to drive a turbine.

Reactor, breeder: A reactor that produces more fissionable fuel than it consumes. The new fissionable material is created by a process (breeding) in which fission neutrons are captured in fertile materials.

Reactor, fast flux: A reactor in which fission is induced predominantly by fast neutrons.

Reactor, high-temperature, gas-cooled: A nuclear reactor that uses an inert gas (helium) as the primary coolant and a graphite moderator.

Reactor, light-water: A nuclear reactor that uses light water (H_2O) as the primary coolant and moderator, with slightly enriched uranium as the fuel. There are two types of commercial light-water reactors: boiling-water and pressurized-water.

Reactor, naval propulsion: A reactor used to power a vessel or submarine of the U.S. Navy.

Reactor, pressurized-water: A light-water reactor in which heat is transferred from the core to a heat exchanger via water kept under high pressure, so that high temperatures can be maintained in the primary system without boiling the water. Steam is generated in a secondary circuit.

Reactor, production: A reactor whose primary purpose is to produce fissile or other materials or to perform irradiations on an industrial scale. Unless otherwise specified, the term usually refers to either a tritium- or plutonium-production facility used to produce materials for nuclear weapons.

Reactor, research: A reactor whose nuclear radiations are used primarily as a tool for basic or applied research. Typically, it has a thermal power of 10 MW(t) or less and may include facilities for testing reactor materials.

Reactor, test: A reactor associated with an engineering-scale test program conducted for the purpose of developing basic design information or demonstrating safety characteristics of nuclear reactor systems.

Reinserted fuel: Irradiated reactor fuel that is discharged in one cycle and inserted in the same reactor during a subsequent refueling. In a few cases, fuel discharged from one reactor has been used to fuel a different reactor.

Repository, geologic: A facility that has an excavated subsurface system for the permanent disposal of spent fuel and high-level waste.

Reprocessing, fuel: The chemical/mechanical processing of irradiated nuclear reactor fuel to remove fission products and recover fissile and fertile material.

Salt cake: A salt form of high-level waste stored in tanks which is produced from neutralizing acidic liquid waste from defense reactor fuel reprocessing with an alkaline agent (caustic soda).

Saltstone: A low-level waste by-product from the solidification of high-level waste at the Savannah River Site. Saltstone is retained in trenches at Savannah River.

Sea-bed disposal: Placement of waste packages in deep ocean sediments.

Sea dumping (disposal): The practice of periodically dumping shiploads of drummed, solidified waste at specified locations in the ocean.

Separative work unit: The standard measure of enrichment services. The separative work unit (SWU) is expressed as a unit of mass. For example, one kilogram of separative work is expressed as 1 kg SWU.

Single-shell tank wastes: High-level wastes, generated from defense reactor fuel reprocessing at Hanford, which are stored in single-shelled tanks. These tanks contain inventories of liquid, sludge, and salt cake. See also "double-shell tank wastes."

Slurry, high-level waste: A watery mixture of highly radioactive, insoluble matter.

Solvent extraction: The separation of materials of different chemical types and solubilities by selective solvent action; used to recover and separate uranium and plutonium in reprocessing spent nuclear fuel.

Source term (IDB Program usage): A set of qualitative and quantitative features used to describe the origin and concentration of radioactive waste. The qualitative features include a flowchart of waste streams generated by a facility or an activity. Quantitative features include (1) the number of curies of radioactivity expressed either per unit of facility production or per unit of waste volume or mass; and (2) a listing of the relative concentrations of component radioisotopes per curie of waste activity.

Special nuclear material: Plutonium or uranium enriched to a higher than natural assay.

Spent fuel: Nuclear fuel that has been permanently discharged from a reactor after it has been irradiated. Typically, spent fuel is measured in terms of either the number of discharged fuel assemblies or the quantity of discharged fuel mass. The latter is measured either in metric tons of heavy metal (i.e., only the heavy metal content of the spent fuel is considered) or in metric tons of initial heavy metal (essentially, the initial mass of the fuel before irradiation). The difference between these two quantities is the weight of the fission products.

Thermal power: A measure of the rate of heat energy emission that results from the radioactive decay of a material. A unit of thermal power commonly used is the watt (W).

THOREX process: A solvent extraction process developed for the reprocessing of thorium-based nuclear fuels.

Transuranic waste: As defined and used by the Department of Energy (DOE Order 5820.2A), radioactive waste that, at the time of assay, contains more than 100 nCi/g of alpha-emitting isotopes with atomic numbers greater than 92 and half-lives greater than 20 years.

Transuranic waste acceptance criteria: A set of conditions established for permitting transuranic wastes to be disposed at the Waste Isolation Pilot Plant.

Transuranic waste certification: The process for verifying that a suspect radioactive waste is transuranic.

Transuranic waste, contact-handled: Transuranic waste with a surface dose rate of less than 200 mrem/h and minimal heat generation to permit handling by contact methods.

Transuranic waste nondestructive assay/nondestructive examination: Nondestructive test procedures performed on suspect transuranic wastes to determine their transuranic isotope concentration. From these tests such wastes can be properly classified (certified) as transuranic or low-level.

Transuranic waste, remote-handled: Transuranic waste with a surface dose rate of greater than 200 mrem/h and/or heat generation to require remote handling and/or shielding.

Vitrification: The conversion of high-level waste materials into a glassy or noncrystalline solid for subsequent disposal.

Waste Isolation Pilot Plant: A research and development facility, located near Carlsbad, New Mexico, to be used for demonstrating the safe disposal of wastes from DOE activities.

Yellowcake: A uranium oxide concentrate that results from milling (concentrating) uranium ore. It typically contains 80 to 90% U_3O_8.

INDEX

Agreement State, 111, 209, 229
Ames Laboratory (AMES), 298
  LLW at, 127–30
  mixed LLW at, 214–17, 219–24
Argonne National Laboratory
  Argonne, Illinois (ANL-E), 298
    LLW at, 127–30
    mixed LLW at, 214–17, 219–24
    TRU waste at, 89–92, 96, 98, 100, 102, 104–8
  Idaho Falls, Idaho (ANL-W), 298
    LLW at, 127–30
    miscellaneous radioactive materials at, 230, 232, 234, 239–43
    mixed LLW at, 214–17, 219–24
Atomic Energy Act (AEA), 7, 158, 209

Barnwell (South Carolina) commercial waste site, 302
  LLW at, 114, 117, 120, 132, 136–37, 289
Beatty (Nevada) commercial waste site, 302
  LLW at, 114, 117, 120, 132, 136–37
Boiling-water reactor (BWR), 17–18, 23–24, 26, 29, 32–35, 112–13, 265, 272, 274, 277–79, 291
Borosilicate glass (see **High-level waste**)
Brookhaven National Laboratory (BNL), 298
  LLW at, 127–30
  mixed LLW at, 214–17, 219–24
Burnup, spent fuel, 13, 17
  distribution in BWRs, 35
  distribution in PWRS, 36
  of miscellaneous materials, 236–37, 239–43, 245–50
By-product material, 3, 111, 147

Calcine (see **High-level waste**)
Cape Henry (HEN) LLW, 119, 131
Ceramic (see **High-level waste**)
Classification of LLW, 112–13
Code of Federal Regulations (CFR)
  10 CFR Part 61, 3, 7, 113
  40 CFR Part 61, 148
  40 CFR Part 191, 7
  40 CFR Parts 260–271, 201
  40 CFR Parts 702–799, 202
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 157–58

Decommissioning of reactors, 6, 179–82, 186–94, 196–206
  NRC alternatives, 180
  reactor shutdown dates, 186, 189–90
  waste volumes from alternatives, 193
Decommissioning wastes, commercial, 4, 6, 179–206
  characteristics of, 187, 193, 274–75, 279
  from specific facilities and sites
    Cimarron Fuel Fabrication Facility, 182, 206
    Diablo Canyon Units 1 & 2 Reactors, 181, 201
    Dresden Unit 1 Reactor, 181, 197
    Elk River Reactor, 180, 191
    Fort St. Vrain Reactor, 181, 203
    Humboldt Bay-Unit 3 Reactor, 181, 200
    Indian Point-Unit 1 Reactor, 182, 206
    La Crosse Reactor, 181, 198
    Pathfinder Reactor, 181, 204
    Peach Bottom Reactors
      Unit 1 (HTGR), 181
      Units 2 and 3 (BWRs), 181, 204
    Rancho Seco Reactor, 181, 202
    Santa Susana Sodium Reactor Experiment, 180, 192
    Saxton Reactor, 181, 199
    Shippingport Station Decommissioning Project, 180–81, 194
    Shoreham Reactor, 181, 205
    Three Mile Island-Unit 2 Reactor, 181, 196
    West Valley Demonstration Project, 181, 195
Defense Waste Processing Facility (DWPF), 5, 13, 41, 276
Department of Energy (DOE), 1–2, 255
  Energy Information Administration (EIA), 4–5
  Environmental Restoration and Waste Management Five-Year Plan, 6, 157–61
  Order 5820.2A, 77, 229
  Transuranic Waste Program, 77–79
  waste program offices, 2
Disintegration energy (see **Q-value**)
Double-shell tank waste (see **High-level waste**)

Environmental Impact Statement (EIS)
Hanford defense waste, 41
West Valley, 112
Environmental Protection Agency (EPA), 148, 179, 209–10
Environmental restoration (ER) wastes, 6, 157–77, 179
ER projects, 6, 157–61, 163, 165–66
locations of, 163, 165–66
site status, 157–61
wastes from, 164–77
FUSRAP activities, 160–61
characteristics of wastes from, 167–68
locations of, 166
site descriptions and status, 174–77
UMTRAP activities, 158–59
characteristics of wastes from, 167–68, 170–72
locations of, 165
site status, 171–72

Fabrication (nuclear fuel), 114, 145, 271, 278–79
Farallon Islands (FIS) LLW, 119, 131
Fast Flux Test Facility (FFTF), 238
Fermi National Accelerator Laboratory (FNAL), 298
LLW at, 127–30
mixed LLW at, 214–17, 219–24
Fernald Environmental Management Project (FEMP), 298
LLW at, 127–30
mixed LLW at, 214–17, 219–24
Fort St. Vrain Reactor (FSVR), 18
decommissioning of, 181, 203
spent fuel from, 34, 240
Formerly Utilized Site Remedial Action Program (FUSRAP), 157, 160–61, 167–68, 174–77
Fuel assemblies, 17–18
projected for LWRs, 32–33
reference characteristics of, 34

Generation, commercial nuclear electrical, 291
Glass frit, 45
Grand Junction Remedial Action Project (GJRAP), 159, 168, 171
Greater-than-Class-C (GTCC) low-level waste, 3, 113, 139, 229
from LWR decommissioning, 15, 180, 187, 193
sources and characteristics, 113–14, 292

Hanford Site (HANF), 298
HLW at, 39–41, 43–44
canisters, 53
chemical composition of, 69
radionuclide composition of, 70–71
treatment methods for, 46
LLW at, 117, 119, 124, 127–30, 132
environmental restoration wastes at, 169–70
miscellaneous radioactive materials at, 232, 234, 238, 251
mixed LLW at, 212, 214–17, 219–24
TRU wastes at, 77–79, 81–83, 87–92, 95–96, 98, 100, 102, 104–8
Hanford Waste Vitrification Plant (HWVP), 13, 41
Hazardous waste, 7, 209
Hazardous Waste Remedial Actions Program (HAZWRAP), 3, 111, 209–10
High-level waste (HLW), 1–2, 5, 9–15, 39–75
acid liquid, 39–40, 44, 55–62
alkaline liquid, 39–40, 44, 55–62
calcine, 39–40, 44, 55–62, 67–68
canisters, 41, 46, 50–54
capsules, 40, 44, 55–63, 70–71
ceramic, 39, 41, 53
double-shell tank, 39, 46, 54
glass, 39, 57–62, 64–65
inventory, significant revisions of, 63
liquid, 39–40, 44–46, 55–66, 68–72, 74–75
locations of, 44
precipitate, 40, 44, 55–65
salt cake, 40, 44, 55–65, 69–71
single-shell tank, 46, 54
sludge, 40, 44, 45, 54–65, 69–71, 73, 75
slurry, 40, 44, 46, 55–63, 69–71, 75
zeolite, 39–40, 44, 55–63, 75
Hydrofracture, 111–12, 131

Idaho Chemical Processing Plant (ICPP), 39, 230
HLW at, 39–41, 43–44, 50, 53–57, 59, 61, 66–68
calcine, chemical composition of, 67
canisters, 41, 53–54
liquid, chemical composition of, 66
radionuclide composition of, 68
treatment methods for, 45
miscellaneous radioactive materials at, 232, 234, 239–40
Idaho National Engineering Laboratory (INEL) [includes **Idaho Chemical Processing Plant (ICPP)**], 298
HLW at, 39–41, 43–44, 50, 53–57, 59, 61, 66–68
radionuclide composition of, 68
treatment methods for, 45
LLW at, 117, 119, 124, 127–30, 132
environmental restoration wastes at, 163, 169–70
miscellaneous radioactive materials at, 230, 232, 234, 239–43
mixed LLW at, 212, 214–17, 219–24
TRU wastes at, 77–79, 81–83, 87, 89–92, 95–96, 98, 100, 102, 104–8
Industrial and institutional (I/I) wastes, 5–6, 13, 111, 113–15, 117, 121, 140, 265, 278, 294
source term for, 294

Inhalation Toxicology Research Institute (ITRI), 298
LLW at, 127-30
mixed LLW at, 214-17, 219-24
Integrated Data Base (IDB) Program, 1-2, 7, 12
Sources of information, 12

Kansas City Plant (KCP), 298
LLW at, 127-30
mixed LLW at, 214-17, 219-24
Knolls Atomic Power Laboratory (KAPL), 299

Lawrence Berkeley Laboratory (LBL), 299
LLW at, 127-30
mixed LLW at, 214-17, 219-24
Lawrence Livermore National Laboratory (LLNL), 299
LLW at, 127-30
mixed LLW at, 214-17, 219-24
TRU wastes at, 81, 89-91, 96, 98, 104, 106-8
Light-water reactor (LWR)
lifetime waste generation, 279
LLW (see **Low-level waste**)
radionuclide characteristics of spent fuel, 280-86
Los Alamos National Laboratory (LANL), 299
LLW at, 119, 124, 127-30, 132
miscellaneous radioactive materials at, 232, 234, 244
mixed LLW at, 214-17, 219-24
TRU wastes at, 79, 81-83, 87-92, 95-96, 98, 100, 102, 104-8
Low-Level Radioactive Waste Policy Act (LLRWPA), 114
Low-Level Radioactive Waste Policy Amendments Act (LLRWPAA), 113-15
Low-level waste (LLW)
commercial, 112-15, 117-18, 121, 123, 136-45, 288-89
fuel fabrication for LWRs, 114, 121, 145, 271
greater-than-Class-C (GTCC) wastes, 3, 113-14, 139, 229
I/I waste, 5-6, 13, 111, 113-15, 117, 121, 140, 265, 278, 294
locations of disposal sites, 120, 132
nonroutine LWR operations, 143, 272-73
routine BWR operations, 141, 272
routine PWR operations, 142, 273
state shipments to disposal sites, 138
UF_6 conversion for LWRs, 114, 121, 144, 268-69
DOE, 111-12, 117-19, 121-22, 124-35
locations of disposal sites, 119
physical characteristics of, 126
radionuclide characteristics of, 125, 127-28, 287
saltstone (at SRS), 135, 290
sea disposal of, 111, 131
inventory, significant revisions of, 133
land usage status, 132

Low-Level Waste Management Program (LLWMP), 138, 277

Manifest Information Management System (MIMS), 112
Massachusetts Bay wastes, 119, 131
Maxey Flats (Kentucky) commercial waste site, 302
LLW at, 120, 132, 136-37
Midwest Fuel Recovery Plant (MFRP) spent fuel, 2, 17
Miscellaneous radioactive materials (MRM), 6-7, 227-51
characteristics of, 6-7, 229
inventories of, 234-51
locations of, 232
Mixed LLW, 3, 7, 209-25
commercial, 210-11, 225
characteristics of, 210-11
generation, 225
LWR-generated, 225
DOE, 209-10
characteristics of, 214-24
generation, 216-17, 221-24
inventories, 214-15, 219-20
Mound Plant (MOUND), 299
LLW at, 127-30
mixed LLW at, 214-17, 219-24
TRU wastes at, 78-79, 81, 83, 88-91, 93, 96, 98, 104, 106-8

Naturally occurring radioactive materials (NORM), 111
Naval Nuclear Fuel Division (Babcock & Wilcox) — Research Laboratory (NNFD-RL), 232, 234, 236
Naval Reactors Program Facilities (DOE/HQ, NE-60), 299
LLW at, 127-30
mixed LLW at, 214-17, 219-24
Neutron activation products, 179-80, 292
Nevada Test Site, 299
LLW at, 117, 119, 124, 127-30, 132
mixed LLW at, 214-17, 219-24
TRU wastes at, 79, 81, 83, 89-91, 97, 99, 104, 106-8
Nonfuel LWR core components, 113, 143
Nuclear accelerator-generated radioactive materials (NARM), 111
Nuclear power reactors in U.S., 2, 4-5, 13-15, 17-18, 112-14, 179-82, 265, 272-75, 279
locations of, 20
Nuclear Regulatory Commission (NRC), 3, 111-13, 179-82, 209-10, 255

Oak Ridge Institute for Science and Education (ORISE), 299
mixed LLW at, 214-17, 219-24
Oak Ridge K-25 Site (K-25), 299
LLW at, 117, 119, 124, 127-30, 132
mixed LLW at, 212, 214-17, 219-24

Oak Ridge National Laboratory (ORNL), 300
environmental restoration wastes at, 163, 169–70
LLW at, 117, 119, 124, 127–30, 132
miscellaneous radioactive materials at, 232, 234, 245–246
mixed LLW at, 214–17, 219–24
TRU wastes at, 81–83, 87–91, 93, 95, 97, 99, 101, 103–8
ORIGEN2 computer code, 4, 78–79, 279

Pacific Northwest Laboratory (PNL), 300
miscellaneous radioactive materials at, 232, 234, 237
Paducah (PAD) Gaseous Diffusion Plant, 300
LLW at, 119, 127–30
mixed LLW at, 212, 214–17, 219–24
Pantex (PANT) Plant, 300
LLW at, 119, 127–30
mixed LLW at, 214–17, 219–24
Pinellas Plant, 300
LLW at, 127–30
mixed LLW at, 214–17, 219–24
Portsmouth (PORTS) Gaseous Diffusion Plant, 300
LLW at, 119, 127–30
mixed LLW at, 212, 214–17, 219–24
Pressurized-water reactor (PWR), 17–18, 23–24, 27, 30, 32–34, 36, 113, 273, 275, 277–79, 291
Princeton Plasma Physics Laboratory (PPPL), 300
LLW at, 127–30
mixed LLW at, 214–17, 219–24
Projection scenarios (DOE/EIA), commercial LWR, 4–5, 17–18, 21–22, 24–33, 114, 148, 291
Lower Reference Case
for electric power generating capacity, 24
for discharged spent fuel, 21–22, 25, 29–31, 33
No New Orders Case
for electric power generating capacity, 13, 24
for electrical generation, 291
for discharged spent fuel, 21–22, 25–28, 32
PUREX process waste, 40, 72–73, 75

Q-value, 256–61

Radionuclide characteristics, 255–61
Reactive Metals, Incorporated (RMI), Extrusion Plant, 300
LLW at, 127–30
mixed LLW at, 214–17, 219–24
Remedial action projects, 6, 157–61
mixed LLW from, 214–17, 219–24
Repository, geologic, 2, 3, 18, 39, 54, 229–30
Reprocessing, fuel, 2, 4–5, 13, 17–18, 39–41, 54, 72–74, 77, 229–30, 251
Resource Conservation and Recovery Act (RCRA)
wastes regulated by, 3, 157, 209, 218

Richland (Washington) commercial waste site, 302
LLW at, 117, 120, 132, 136–37
Rocky Flats Plant (RFP), 300
mixed LLW at, 210, 212, 214–17, 219–24
TRU wastes at, 78–79, 81, 83, 89–91, 93, 97, 99, 104, 106–8

Salt cake (see **High-level waste**)
Saltstone (see **Low-level waste**)
Sandia National Laboratory, Albuquerque (SNLA), 300
LLW at, 117, 119, 124, 127–30, 132
mixed LLW at, 214–17, 219–24
TRU wastes at, 78–79, 81–83, 89–91, 93, 97, 99, 104, 106
Sandia National Laboratory, Livermore (SNLL), 300
LLW at, 127–30, 132
mixed LLW at, 214–17, 219–24
San Diego (SDG) LLW, 119, 131
Santa Cruz Basin (SCB) LLW, 119, 131
Santa Susana Field Laboratory (SSFL), 159, 301
Savannah River Site (SRS), 301
Defense Waste Processing Facility (DWPF), 5, 13, 41, 276
HLW at, 13–15, 39–41, 43–45, 53, 55–57, 59, 61, 63–65
canisters, 53–54
chemical composition of, 64
radionuclide composition of, 65
treatment methods for, 45
LLW at, 112, 117, 119, 124, 127–30, 132, 135
saltstone, 112, 135
environmental restoration wastes at, 157, 160, 163, 169–79
miscellaneous radioactive materials at, 232, 234, 239, 247–51
mixed LLW at, 210, 212, 214–17, 219–24
TRU wastes at, 78–79, 81–83, 87, 89–91, 94–95, 97, 99, 104, 106–8
Sea-bed disposal, 111–12, 119, 131
Sheffield (Illinois) commercial waste site, 302
LLW at, 117, 120, 132, 136–37
Single-shell tank waste (see **High-level waste**)
Slurry (see **High-level waste**)
Source terms, waste, 7, 265, 267–75, 287–90, 294
for commercial LLW disposal sites, 288–89
for DOE LLW disposal sites, 287
for fuel fabrication wastes, 271
for I/I wastes, 294
for LLW from LWR operations, 272–73
for saltstone at SRS, 290
for UF_6 conversion wastes, 268–69
for uranium enrichment wastes, 270
for uranium mill tailings, 267
for wastes from D&D of LWRs, 274–75
Special-case wastes, 229
Special nuclear material, 111

Specific activity, 256-61, 274-75
Spent fuel, 2, 5, 9-11, 13-15, 17-36, 229-30, 234
disposal of, 2, 18, 229-30
radioactivity and thermal power as a function of burnup, 23
radionuclide inventory, 280-86
reference LWR characteristics, 34
Stanford Linear Accelerator Center (SLAC), 301
LLW at, 127-30
mixed LLW at, 214-17, 219-24

Tailings (see **Uranium or Thorium mill tailings**)
THOREX process waste, 74-75
Thorium mill tailings, 111
Three Mile Island-Unit 2 Reactor, 301
wastes from, 196, 229, 232, 234, 243
Toxic Substances Control Act (TSCA)
wastes regulated by, 3, 7, 209, 218
Transuranic (TRU) waste, 3, 5, 9-11, 14-15, 77-108
buried, 5, 14-15, 77-79, 81-82, 84, 87, 92-95, 106-7
contact-handled (CH), 3, 77-79, 84, 89-90, 92-94, 96-99, 104, 106-8
generated, 92-94, 96-105, 108
inventory, significant revisions of, 90-91
isotopic composition of, 95-103
locations of, 81
physical composition of, 92-94
points of origin, 81
remote-handled (RH), 3, 77-79, 85, 89, 91, 92-94, 100-103, 105-8
soil contaminated by, 87-88
storage in WIPP, 77-79

Uranium hexafluoride, 268-71
Uranium mill tailings, 3, 6, 14-15, 111, 147-55, 267
characteristics of, 147-48, 155, 267
generated, 154
historical and projected volume of, 151
locations of active sites, 150
site status, 152-53
Uranium Mill Tailings Remedial Action Program (UMTRAP), 15, 157-59, 163, 165, 167-73
wastes from, 15, 167-73

Vitrification, 5, 13, 39-41, 45-46, 50-54, 57-62, 64-65

Waste Isolation Pilot Plant (WIPP), 301
TRU wastes to be placed in, 77-79, 81
Waste Management Information System (WMIS), 3, 111, 209
Waste sites, 297-302
Weldon Spring Site Remedial Action Project (WSSRAP), 301
wastes at, 169-70
West Valley Demonstration Project (WVDP), 301
HLW at, 13-15, 39-41, 43-44, 46-51, 53, 55-56, 58, 60, 62, 72-75, 195
acid liquid, chemical composition of, 74
alkaline liquid, chemical composition of, 72
alkaline sludge, chemical composition of, 73
canisters, 53
inventory, significant revisions of, 63
radionuclide composition of, 75
treatment methods for, 46
zeolite resin, 39-40, 55-56, 58, 60, 62, 75
LLW at, 136-37, 195, 293
mixed LLW at, 214-17, 219-24
Radwaste Treatment System, 46, 265, 293
spent fuel at, 2, 17, 195, 251
TRU wastes at, 195
West Valley (New York) commercial waste site, 302
LLW at, 114, 117, 120, 132, 136-37

Yellowcake, 5, 267-69
Yucca Mountain, Nevada
potential repository site characterization, 18
Y-12 Plant (Oak Ridge), 300
LLW at, 117, 119, 124, 127-30
mixed LLW at, 210, 212, 214-17, 219-24

Zeolite (see **High-level waste**)

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[illegible]-West, P.O. Box 2528, Idaho Falls, ID 83401

[illegible] P.O. Box 1625, Idaho Falls, ID 83415-4201

[illegible] Plant, Westinghouse Idaho Nuclear Company, Inc., P.O. Box 4000, [illegible]

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General Electric Company, Largo, FL 33700

Portsmouth Gaseous Diffusion Plant, P.O. Box 628, Piketon, OH 45661

Princeton Plasma Physics Laboratory, Princeton University, P.O. Box 451, Princeton, NJ 08544

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EG&G Rocky Flats Inc., P.O. Box 464, Golden, CO 80401-0464

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Santa Susana Field Laboratory, Canoga Park, CA 91303

Savannah River Site, Westinghouse Savannah River Company, P.O. Box 616, Aiken, SC 29802

Stanford Linear Accelerator Center, P.O. Box 4349, Palo Alto, CA 94309

Waste Isolation Pilot Plant (WIPP):
Department of Energy, WIPP Project Office, P.O. Box 3090, Carlsbad, NM 88221

Westinghouse Electric Corporation, WIPP Project Office, P.O. Box 2078, Carlsbad, NM 88221

DOE Environmental Restoration Program/Project Offices and Contractors

DOE Environmental Restoration Projects:
Department of Energy, Office of Environmental Restoration, EM-40, Germantown, MD 20874

Office of Technical Services, 12800 Middlebrook Road, Suite 207, Germantown, MD 20874

DOE Three Mile Island Site Office, P.O. Box 88, Middletown, PA 17057

Formerly Utilized Sites Remedial Action Program (FUSRAP):
Bechtel National, Inc., 151 Lafayette Drive, P.O. Box 350, Oak Ridge, TN 37831-0350

DOE Field Office, Oak Ridge, P.O. Box 2001, Oak Ridge, TN 37831-8723

Grand Junction Remedial Action Project (GJRAP):
Department of Energy, Grand Junction Projects Office, P.O. Box 2567, Grand Junction, CO 81502

Hazardous Waste Remedial Actions Program, Tri-County Mall, P.O. Box 2003, Oak Ridge, TN 37831-7606

Uranium Mill Tailings Remedial Action Program (UMTRAP):
DOE Field Office, Albuquerque, UMTRA Project Office, P.O. Box 5400, Albuquerque, NM 87115

Jacobs Engineering Group, Inc., Suite 1700, 5301 Central Ave., N.E., Albuquerque, NM 87108

West Valley Project Office, DOE Field Office, Idaho, P.O. Box 191, West Valley, NY 14171

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Congressional Office of Technology Assessment, 600 Pennsylvania Ave., S.E., Washington, DC 20510-8025

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