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INVENTORY AND SOURCES OF TRANSURANIC SOLID WASTE

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TERA ADVANCED SERVICES CORPORATION

INVENTORY AND SOURCES OF TRANSURANIC SOLID WASTE

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PREFACE

This report was prepared for Lawrence Livermore Laboratory (LLL) under LLL Purchase Order 9101903. This report provides an overview of the inventory and sources of transuranic (TRU) solid radioactive wastes. The information data base has been updated through calendar year 1977 where possible. This data base is being continually updated and will be revised by TERA Advanced Services Corporation as necessary during the duration of the LLL waste management program.

It is the purpose of this report to serve as a working document which will be used throughout the TRU waste management program. This report, and those following, will be compatible not only in format but also in content, reference material and direction. Comments, clarifications or improved data should be directed to B. G. Kniazewycz at TERA's Berkeley office.

1.0 SUMMARY

In the early days of the Manhattan Project, little thought was devoted to disposal of contaminated material since it was secondary to the main task at hand. Later, as it became apparent that the laboratories would become permanent federally supported activities, increasing attention was given to waste disposal problems, especially land burial. As the research, development and production programs were expanded and modified, the waste materials and used equipment to be buried became much more varied and more difficult to manage.

Solid radioactive waste had often been buried in the most accessible and convenient vacant place, without a great deal of thought for the long-term consequences. Fortunately, the amount of radioactive material was not large at that time. The transuranium (TRU) elements were very strictly conserved and, at first, solid waste containing separated fission products was not a serious land burial problem. Wartime pressures for production and lack of knowledge or understanding led to siting and operational practices that, in many situations, are unsatisfactory by present day standards.

The purpose of the report is to support the development of standards and criteria which will specifically address the problem of TRU contaminated waste--generated by Department of Energy (DOE) nuclear programs and commercial application of nuclear technology.

Section 2.0 of this report presents an overview and introduction to the generation, sources and past practices dealing with TRU contaminated waste. In Section 3.0 the DOE facilities are discussed and supported in more detail in Appendices B through E. Section 4.0 and Appendix F address commercial disposal sites, while Section 5.0 addresses the commercial nuclear industry. The waste inventory is presented in Section 6.0, and waste projections are discussed in Section 7.0. Section 8.0 presents an extensive list of references and related bibliography.

Appendix A presents a glossary of terms and list of metric conversions. A DOE facility survey questionnaire and results of that survey are presented in Appendix G. Appendix H presents a list of potential TRU waste sources (special nuclear material licensees).

The generation of transuranic-contaminated waste material is associated with the light-water reactor fuel cycle if the spent fuel is recycled. In addition, TRU waste may also be generated as a result of handling the spent fuel, either during interim storage or final repackaging and disposal. For the military TRU waste, i.e., those associated with the various national labs and facilities operated for the defense sector of the government, TRU material is generated as a result of weapons program R&D and production. In addition, the use of nuclear power for naval ships will also generate such waste when the fuel is processed and recycled.

To adequately define the sources of TRU waste in the U.S. it is necessary to identify all present inventories of such wastes, as well as the facilities which generate or may generate such wastes in the future. In many cases, it is difficult to clearly define the TRU component generated at a facility without identifying the overall waste generation rates as well as characteristics of the waste handled at each particular facility. Thus, this report identifies the overall waste management programs and generation rates at the various government facilities, along with the TRU components. This is especially important when other aspects of the LLL TRU waste management program are considered. In particular, the waste form and characteristics work requires that the various forms of TRU-contaminated material be identified and quantified to such an extent that meaningful waste forms can be defined and technology to process this waste be identified.

TRU waste has been disposed of at five of the six commercial burial sites which have supported the commercial LWR industry as well as Department of Energy (DOE)*-generated waste. The sites containing TRU waste are given in Table 6-4 of this report. These sites have accepted wastes generated in the fuel cycle;

* DOE and its predecessors AEC and ERDA.

primarily fuel fabrication and spent-fuel reprocessing, as well as numerous miscellaneous R&D activities and small commercial uses of TRU radioisotopes. At present there is no commercial reprocessing of spent fuel and what high-level waste exists is limited to the nuclear fuel services at the West Valley Facility. The present inventory of TRU-contaminated waste is limited primarily to DOE-generated waste (shipments now terminated) and R&D fuel fabrication activities involving plutonium. The best available information indicates that the cumulative DOE-generated TRU waste (through 1976) shipped to commercial burial grounds contained about 7.6 kg of TRU isotopes. The cumulative TRU material buried through 1976 was 123.4 kg which is broken down by commercial burial site in Table 6-4.

The TRU solid waste inventory that is located at seven different DOE sites is approximately 0.41 million cubic meters. Only about 10 percent of this is in retrievable storage.** By 1986 it is anticipated that the retrievable storage inventory might increase by a factor of 2.5 while the waste in burial sites remains virtually unchanged. The present TRU inventory of contaminated wastes, soils and sediment is as follows:

Retrievably stored	374 kg TRU
Previously buried	760 kg TRU
Contaminated soils and sediments	190 kg TRU

** 0.37 million m³ are in land burial sites and 0.04 million m³ retrievably stored.

2.0 INTRODUCTION

All operations that produce or use nuclear materials generate radioactive wastes. The wastes vary widely in volume, composition, and amount and type of radioactivity, depending on the materials and nature of the originating operations. Most of the radioactive wastes generated today in the United States are from Department of Energy (DOE) site operations and from commercial nuclear reactors and supporting nuclear fuel cycle activities.

The radioactive wastes are generally classified as either "high-level" wastes or "other" wastes. High-level wastes (HLW) are defined as those aqueous wastes resulting from the operation of the first cycle solvent extraction system, or equivalent, and the concentrated waste from subsequent extraction cycles, or equivalent, in a facility for reprocessing irradiated reactor fuels,⁶⁶ during the initial step in the chemical reprocessing of spent fuel. Other waste classification schemes have been proposed and utilized. The classification of TRU waste will be the subject of a separate report. However, for the purpose of the present report the NRC classification scheme will be used.

The current NRC definition of Class A wastes is as follows:⁶⁵

Class A radioactive wastes (CARW) are those radioactive wastes which, due to their radiotoxicity and radioactive half-life, could reasonably be expected to contribute to radiation exposures in excess of those permitted by applicable Federal radiation standards through the use of state-of-the-art disposal methods other than disposal in a Class A radioactive waste repository.

From a literal reading, it would appear that no wastes are classifiable as Class A radioactive wastes, since state-of-the-art disposal methods eliminate radiation exposures that exceed those permitted by applicable standards. However, it is understood that at issue here is the geologic isolation of certain classes of radioactive wastes, especially the high-level fission product wastes. Therefore, in this report all wastes that appear to have characteristics that similarly justify geologic isolation will be considered as potential Class A wastes.

Pending numerical definitions currently under development by the NRC, the potential sources of Class A radioactive wastes are noted below.⁵³

(1) Reprocessing of fuel discharged from light water power reactors:

- Solidified fission products and actinides from first-cycle raffinate in Purex extraction, referred to as high-level wastes.
- Fuel-element structural materials, including zircaloy cladding hulls, stainless steel components and fittings, and inconel spacers.
- Intermediate-level and low-level actinide (transuranic (TRU)) wastes from Purex reprocessing.
- Kr-85 recovered from dissolver off-gas, as now required by EPA.
- I-129 recovered from dissolver off-gas, as now required by EPA.
- C-14 recovered from dissolver off-gas and from process ventilation. Although C-14 recovery is not yet required, atmospheric releases of C-14 offer a greater potential environmental hazard than do releases of Kr-85 and I-129.^{67,68}
- H-3 recovered from discharge fuel. Although H-3 recovery is not yet required, recovery processes are being developed.

(2) Fabrication of mixed-oxide fuel: low-level transuranium (TRU) wastes are produced when reactor fuel is fabricated from uranium and recycled plutonium.

(3) Unreprocessed fuel discharged from light water power reactors.

(4) High-level radioactive wastes and other wastes generated at the West Valley, N. Y. reprocessing plant.³⁴ These wastes are exempted from 10 CFR 50 Appendix F which requires that high-level wastes from licensed fuel reprocessing plants be solidified and ultimately transferred to a Federal repository.⁵³ However, these wastes are subject to a later rule-making decision, and it is logical that they be considered as potential Class A wastes for a Federal repository.

- (5) Radioactive wastes from decommissioning reactors, independent spent-fuel storage basins, fuel-reprocessing plants and mixed-oxide fuel-fabrication plants.
- (6) High-level and transuranic radioactive wastes generated by the operation of the Department of Energy (DOE) facilities at Hanford, Savannah River, Rocky Flats, the Idaho National Engineering Laboratory and other sites are referred to herein as "military wastes."²² Although no decision has been announced that these wastes are to be emplaced in a geologic isolation facility, the properties of these wastes are such that they should be considered as potential Class A wastes.

The source of the largest potential radiological hazard associated with wastes from the nuclear fuel cycle is the HLW stream from fuel reprocessing, or the spent fuel assemblies in the absence of reprocessing (see Figure 2-1). A second category of solid wastes (See Figure 2-2), which includes a wide variety of materials such as cladding hulls and miscellaneous wastes from fuel reprocessing and refabrication steps, and which are referred to as transuranic (TRU) wastes, represents a problem comparable in importance to that posed by isolation of the actinide component of the HLW. The viability of a nuclear energy industry depends upon the ability to dispose of this material reliably and safely.

This report presents estimates of sources of transuranium solid wastes in the United States and an evaluation of the quantities of these wastes. It is assumed that transuranium solid waste has transuranium alpha radioactivity of greater than 10 nCi/g (nanocuries per gram). This assumption has the effect of excluding most of the very large volume of waste that is generated within the normally occupied work areas of transuranium processing and fabrication plants. It is assumed that wastes containing less than 10 nCi/g of transuranium nuclides will continue to be buried on site or shipped, generally as Low Specific Activity (LSA) or Type A Quantity material, to burial grounds (either commercial or DOE sites).

Up to the present time, commercially generated solid waste contaminated with transuranium (TRU) nuclides has been disposed of at commercial burial grounds. These are sites carefully selected and monitored to provide reasonable assurance that buried radioactivity is retained there and is unlikely to migrate from the

FIGURE 2-1
NUCLEAR FUEL CYCLE

FIGURE 2-2

FATE OF TRANSURANICS IN LWR PLUTONIUM
RECYCLE FLOWSHEET (NORMALIZED)⁷⁰

vicinity. In these analyses, no credit is given to containment provided by the packaging. There are six licensed burial grounds which have operated or continue to operate and accept commercially generated low-level radioactive waste and, at present, have TRU-contaminated waste at levels below 10 nCi/g. However, in the past four years some controversy has arisen concerning the probable migration of transuranic activity from the commercial burial site at Maxey Flats, Kentucky.

2.1 BACKGROUND ON TRANSURANIUM (TRU) - CONTAMINATED WASTE

Land burial has been used for the disposal of radioactive wastes since the inception of nuclear weapons research in the 1940's. The term "burial", as used in this report, refers to the placement of waste at relatively shallow depths in earth materials, with no intent or provision for ready retrievability at a later date. As such, it is distinguished from geologic disposal and storage techniques by the proximity of the waste to the surface of the earth and the surrounding biosphere. The migration or dispersal of the radioactive and other toxic materials in the waste must be kept to some minimum or acceptable level.

Initially, burial grounds operated by the U.S. Atomic Energy Commission (AEC) handled and disposed of wastes generated by AEC facilities as well as wastes from private industry. However, during the 1950's much of the waste generated within private industry was delivered to several private companies for sea disposal. Growing pressures against this technique caused the AEC to encourage the use of burial facilities at the Oak Ridge National Laboratory at Oak Ridge, Tennessee, and the National Reactor Testing Station in Idaho Falls, Idaho, until private burial grounds could be established. In 1962 a commercial burial ground was opened at Beatty, Nevada, and in 1963 a similar site was opened at Morehead, Kentucky. In May 1963 the AEC discontinued its policy of accepting wastes from private industry. By 1971, six commercial sites were licensed for the handling and disposal of radioactive waste.

At present, radioactive wastes in all categories other than "high-level waste" (produced during the first stage of fuel reprocessing) are buried at both DOE and commercial burial sites.

In 1969 a controversy arose concerning the safety of the burial activities involving plutonium contaminated soil at the then National Reactor Testing Station (NRTS) near Idaho Falls, Idaho (since renamed the Idaho National Engineering Laboratory (INEL)). The controversy primarily involved the concern for Pu-239 (a long half-life material) and its high toxicity per unit weight. As a result of this concern and the concern of Idaho officials over the long-term status of the aquifer beneath the project, the AEC made a commitment that the waste in question would be directed or transferred to a Federal repository in salt (then being planned) when it became available. It is noted that a U.S. Public Health Service review of the waste management practices in question led to the conclusion that the land burial techniques then in use met the Federal Radiation Council criteria for protection of the public, and that it was very unlikely that the radioactivity would migrate from the burial grounds in the future if the then current practices were continued.

A commitment was made in 1970 by the commissioners of the AEC that all future transuranium waste would be stored temporarily in a readily accessible manner so that it would remain retrievable for a minimum of 20 years.⁶¹ This policy has recently been taken by operators to mean surface storage on specially constructed concrete or asphalt pads or in underground vaults of waste containing more than 10 nanocuries of transuranium nuclides per gram of waste. Waste contaminated with transuranium nuclides buried below the surface in previous years may be exhumed in the future.¹

A background discussion and rationale for considering the special problems of managing transuranium waste follows.

The letter of commitment written by Chairman Glenn T. Seaborg to Senator Frank T. Church of Idaho on June 9, 1970 was aimed solely at the National Reactor Testing Station. It stated, "... AEC plans to store not only currently generated alpha waste, but also to excavate, process and ship such wastes that are being temporarily stored at NRTS. A number of years will be required to complete the transfer of such waste from NRTS, which we hope to start within the decade." Since nearly the whole decade has passed and neither a method of finally processing such wastes, nor a site for final disposal have been identified, it does not seem likely that the decade will see the initiation of that very large and potentially costly project. That general decision, however, has now been accepted by some as a commitment, and has contributed to the dilemma of the operators of commercial land burial sites when they are presented with waste containing transuranium elements.¹

On September 12, 1974 the AEC (now the NRC) published an intention to modify its regulations so as to require all commercial sources of transuranium wastes to ship it to selected AEC (now DOE) sites for retrievable storage.⁷¹ Should this regulation be issued, the contribution from the nuclear power field will add to the size of those waste storage facilities at DOE sites, and most certainly it will extend the period of subsequent handling and treatment of low-level transuranium-contaminated waste well into the foreseeable future. Unless there are suitable sites for the final disposal of such waste, a substantial increase in the amount of radioactive material would necessarily be placed at surface or near surface storage at some yet undesignated DOE sites.

Notably with the management of transuranium waste, the overlap between present practice and older practices makes it difficult to clearly identify the problems. There is some concern about the radiological health similarities of seepage pits and land burial sites, particularly with respect to migration of radioactive elements in the soil.

It is assumed that transuranium wastes that have excessive unit size or radiation level for receipt at the Federal repository will be stored or buried on-site in a potentially retrievable form separate from nontransuranium wastes. These types of transuranium wastes are generated predominantly at DOE or commercial plants* for reprocessing spent fuel and, as generated, are primarily a hazard because of their fission product content.

2.2 TRANSURANICS (TRU) AND LONG-LIVED FISSION PRODUCT WASTES

TRU and some fission product wastes are especially significant because they have long half-lives and some are rather radiotoxic. Some transuranic radionuclides exhibit both of these properties and are primarily produced by single or multiple neutron capture by U-238 in LWR fuel during the operation of a nuclear reactor. Reprocessing of spent fuel attempts to remove plutonium, but since the separation is not complete, the resulting high-activity liquids will contain some plutonium as well as other transuranics. Likewise, transuranic contamination of low-activity wastes also occurs when the transuranic materials are handled or processed, which is primarily at DOE facilities involved in nuclear weapons production.

Transuranics are persistent in the environment, and as a general rule are strongly retained by soils. They are not easily transported through most food chains, although some reconcentration does take place in the aquatic food chain. They pose only a slight biological hazard to humans upon ingestion because they are weakly absorbed from the gastrointestinal tract. A greater hazard results from

* Presently, no commercial reprocessing of spent fuel is allowed by the Federal government.

inhalation since they behave like normal dust, and fractionate accordingly. Production of an adverse health effect in the lung, or elsewhere, depends on the particle size and solubility of the inhaled contaminated dust. Upon entry into the bloodstream (either by ingestion or inhalation), TRUs will then readily accumulate in bone and liver tissues, and can significantly increase the risk of cancer.⁵⁶

Prior to 1970 TRU-contaminated wastes were not segregated from other low-activity wastes. Current DOE policy is to retrieve and store wastes containing greater than 10 nanocuries of TRU alpha-emitting radionuclides per gram.^{61,71} Transuranium-contaminated wastes being produced by private commercial activities, however, are still being buried at one (Richland) of the six operating commercial burial grounds. Burial at the remaining five commercial sites is currently limited to those wastes containing less than 10 nanocuries of TRU alpha-emitting radionuclides per gram.

2.3 MANAGEMENT OF MILITARY HIGH-LEVEL WASTE

During the early years of the Government's nuclear weapon program, little attention was devoted to developing technologies for long-term storage or disposal of high-level waste. Priorities were placed on producing nuclear weapons materials; waste management decisions were based on short-term expediency rather than long-term implications. As a result, 270 million liters of high-level defense waste are "temporarily" stored in field tanks at the DOE Hanford Works and Savannah River Plant.^{12,15,24} Additionally, 11.4 million liters are stored at Idaho National Engineering Laboratory (INEL).²¹ The waste stored at Hanford and Savannah River make up about 94 percent of the total volume of DOE waste.

Most high-level waste from reprocessing operations is produced in an acidic chemical form. Stainless steel must be used for temporary storage tanks for acid waste. In the early years of the Government's nuclear weapons program, however, stainless steel was scarce and expensive, so the AEC decided to neutralize the waste produced at Hanford to allow storage in tanks constructed

from cheaper and more readily available carbon steel. Tanks designed at the Savannah River facilities, constructed in the early 1950's, were modeled after the Hanford facilities, incorporating improvements from Hanford operating experience. As a result, acidic waste to Savannah River is also neutralized before storage in carbon steel tanks. Numerous disadvantages to such neutralization are evident. These include the fact that injecting the neutralizing agent more than doubles the volume of high-level waste which must be stored and eventually disposed of. Further, plutonium and Sr-90 are insoluble in neutralized waste and eventually settle in a sludge at the bottom of the storage tanks. Removing the sludge from storage tanks is a very difficult technological problem. Further, while the technology necessary to convert this neutralized waste to a suitable form for long-term storage or disposal has been demonstrated on the laboratory scale, a full scale operation is still questionable.

Section 3.0 discusses DOE facilities and is supplemented by more detailed information in Appendices B through E.

2.4 COMMERCIAL NUCLEAR INDUSTRY

Solid wastes containing small amounts of alpha radioactivity are routinely produced during normal commercial operations at nuclear fuel fabrication and spent fuel reprocessing plants. Although these wastes ordinarily have a very low actinide content, their heterogeneous nature, combined with the very long-lived alpha content, may impose a safety hazard for many decades. To properly assess the magnitude of the alpha waste disposal problem, it is necessary to characterize the nature and quantities of wastes produced to date and, to the extent possible, to predict future waste production rates from the commercial nuclear industry operations. Detailed discussion is provided in Section 5.0.

2.4.1 FUEL FABRICATION INDUSTRY

The fuel fabrication industry includes both the plutonium fuel preparation plants and fuel fabrication plants.

The function of the plutonium fuel preparation plants is to prepare mixed $\text{UO}_2\text{-PuO}_2$ that is used to fabricate fuel elements for plutonium-fueled light water reactors or LMFBR's. The feed materials are purified $\text{Pu}(\text{NO}_3)_4$ solutions received from spent fuel processing plants and natural or depleted uranium as UO_3 , UO_2 , or $\text{UO}_2(\text{NO}_3)_2$ solutions.

These plants will probably be physically located on the same site as a fabrication or spent fuel processing plant but, in either case, the plant will generate a characteristic low radiation level, transuranium waste. The fuel fabrication plant will fabricate mixed $\text{UO}_2\text{-PuO}_2$ fuel for either light water reactors or the LMFBR. This plant generates a low radiation TRU waste of which 60-80 percent by volume is combustible and subject to incineration or other means of volume reduction.⁵⁹

Most of the wastes are generated inside glove boxes, but a significant amount of waste is also generated external to the boxes in contamination control measures. In larger scale facilities, wastes contaminated with recoverable amounts of actinides are separated from the wastes that are candidates for burial. The most common burial vessel is the standard 208-liter steel drum (DOT 17C or 17H). Plutonium-contaminated wastes have been usually buried off-site, by a disposal contractor, in approved commercial burial sites. Uranium contaminated wastes are buried at approved commercial sites.

2.4.2 SPENT FUEL REPROCESSING INDUSTRY

Solid wastes from reprocessing plants can be classified into five categories: cladding hulls, intermediate- and low-level (ILW/LLW), general trash, failed equipment and dry chemicals. The volume of cladding hulls, ILW/LLW and dry chemical wastes are proportional to the amount of spent fuel reprocessed, while the volumes of general trash and failed equipment are approximately independent of plants throughout and are produced at approximately a constant annual rate per plant.

Of the total volume of solid waste produced in the reprocessing industry, about 70 percent of the volume will originate from general trash, while the other 30 percent will be about equally divided among the other four categories. The distribution of the plutonium in the waste will remain fairly constant through the years at 32 percent in the cladding hulls, 42 percent in the ILL/LLW, 21 percent in the general trash, four percent in the dry chemicals and less than one percent in the failed equipment.⁵⁹

Most of the low radiation level, transuranium solid waste generated in a spent fuel processing plant originates in the sections of the plant that are used for final purification, storage, and shipping of the plutonium product.

2.4.3 OTHER SOURCES

Radionuclides used in the practice of nuclear medicine constitute the largest fraction of the non-fuel cycle uses of radioactivity. Other radioisotopes are finding extensive applications in well-logging, in industrial radiography, as large-curie teletherapy and irradiator sources, in some consumer products (such as smoke detectors), and in the manufacture of certain types of gauges. These, together with relatively small amounts of radioactive material used in research, constitute the primary applications of radioisotopes and potential waste sources.⁴⁸

Other TRU waste is possibly generated due to industrial and medical application of transuranic radioisotopes. Such uses will generate miniscule levels of waste compared to DOE and nuclear fuel cycle wastes.

3.0 DEPARTMENT OF ENERGY (DOE) FACILITIES

The purpose of this section is to provide a brief overview of the major DOE facilities. More extensive information is provided in Appendices B through E.

3.1 INTRODUCTION

DOE contractors operate large land burial operations at five principal DOE facilities. Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee; Los Alamos Scientific Laboratory (LASL), Los Alamos, New Mexico; Idaho National Engineering Laboratory (INEL), Idaho Falls, Idaho; Hanford Works, Richland, Washington and Savannah River Plant (SRP), Aiken, South Carolina. Smaller land burial sites are at other DOE facilities including Sandia, Albuquerque, New Mexico; Pantex, Amarillo, Texas; Nevada Test Site, Las Vegas, Nevada; Feed Materials Production Center, Fernald, Ohio; and the gaseous diffusion plants at Oak Ridge, Tennessee, Paducah, Kentucky, and Portsmouth, Ohio. A list of major DOE waste generating/burial sites is given in Table 3-1.¹

In 1970 AEC (DOE) established a policy that transuranic waste in concentrations exceeding 10 nanocuries per gram be stored above ground and be retrievable.³ At the five principal facilities an estimated one million cubic meters of waste have been buried containing 18 million curies. The waste includes approximately 952 kilograms of transuranium nuclides, mainly at INEL and Hanford, of which 740 kilograms are buried and 212 kilograms are retrievably stored (1975). The current annual volume of DOE generated waste is approximately 65,000 m³. The volume is expected to decrease gradually in the future with the use of improved waste management techniques including volume reduction technology.¹¹

DOE facilities at Oak Ridge, Los Alamos, Savannah River, Idaho and Hanford, have also used cribs for disposal of some liquid waste which contained levels of radioactivity unacceptable for release to uncontrolled areas. Through 1974 over 525 billion liters of liquid waste, containing five million curies, have been discharged into the ground at Savannah River, Idaho and Hanford with the intention that the radioactivity would be tracked as it moved through the soil beyond the point of release and that the extent of migration would be limited by removing the driving force of further liquid releases.¹¹

TABLE 3-1

MAJOR GENERATING STORAGE AND DISPOSAL SITES
FOR SOLID LOW-LEVEL RADIOACTIVE WASTE, JUNE 1976¹

Amarillo, Texas -- DOE generating site; DOE storage and disposal site, (uranium-contaminated waste, and transuranic-contaminated waste).

Argonne, Illinois -- DOE generating site.

Fernald, Ohio -- DOE generating site, DOE disposal and storage site (uranium-contaminated waste).

Hanford, Washington -- DOE generating site; DOE storage and disposal site (fission product/induced activity contaminated waste, uranium-contaminated waste, transuranic - contaminated waste).

Idaho Falls, Idaho -- DOE generating site; DOE storage and disposal site (fission product/induced activity-contaminated waste, uranium-contaminated waste, and transuranic-contaminated waste).

Livermore, California -- DOE waste generating site; DOE storage and disposal site (uranium- and thorium-contaminated waste).

Los Alamos, New Mexico -- DOE generating site; DOE storage and disposal site (fission product/induced activity-contaminated waste, uranium-contaminated waste, and transuranic-contaminated waste).

Miamisburg, Ohio -- DOE generating site.

Las Vegas, Nevada -- DOE generating site; DOE storage and disposal sites (fission product/induced activity-contaminated waste, transuranic-contaminated waste).

Paducah, Kentucky -- DOE generating site; DOE storage and disposal site (uranium-contaminated waste).

Piketon, Ohio -- DOE generating site, DOE disposal and storage site (uranium-contaminated waste).

Oak Ridge, Tennessee -- DOE generating site; DOE storage and disposal site (fission product/induced activity-contaminated waste, uranium-contaminated waste, and transuranic-contaminated waste).

Rocky Flats, Colorado -- DOE generating site.

Albuquerque, New Mexico -- DOE generating site; DOE storage and disposal site, (uranium-contaminated waste, and transuranic-contaminated waste).

Aiken, South Carolina -- DOE generating site; DOE storage and disposal site (uranium-contaminated waste, fission product/induced activity-contaminated waste, and transuranic-contaminated waste).

3.2 ARGONNE NATIONAL LABORATORY (ANL)

There is no active burial ground at ANL but at the time of decommissioning of the original laboratory in the city of Chicago, building rubble was buried in the Cook County Forest Reserve. The site is known and kept under surveillance. Other ANL-generated wastes and building rubble were also buried at this location. ANL produces a wide variety of solid radioactive wastes suitable for burial. Some solid waste arises from the treatment of liquid waste streams by evaporation of the liquid waste to a high solids content and a dense self-solidification with vermiculite in 208-liter drums. The total annual solid waste produced is about 845 cubic meters.¹ At Argonne, all waste suitable for burial has been shipped to Sheffield, Illinois, a commercial burial site.

3.3 HANFORD RESERVE

Past land burial practices at this site are of interest because they give historical insight to the attitudes prevailing at various periods. From 1944 to 1954 there was no serious segregation of different types of low-level radioactive waste. Combustibles and noncombustibles were buried in the same trench. Burial records were incomplete and there was a minimal amount of information as to the quantity or type of radioactive material. From 1955 to 1965 there was an increased interest in developing an alternate disposal method. Recordkeeping was improved and more faithfully maintained. From 1966 to 1974 a program of centralization of the burial grounds in the 200 Area was started and completed. The measurements of the kinds and amounts of radioactivity in the buried wastes improved. Sites were marked with informative semipermanent markers. Recordkeeping was further improved as segregation of radioactive waste by categories was initiated. Since 1970, in keeping with the modified policy of DOE, transuranium waste has been kept separately in a retrievable form.¹⁶

A detailed discussion of the Hanford Reserve is presented in Appendix B.

3.4 IDAHO NATIONAL ENGINEERING LABORATORY (INEL)

At Idaho Falls, the AEC built reprocessing facilities in the early 1950's to reprocess spent fuel from its research reactors. INEL is also the site for reprocessing spent fuel from the Navy's nuclear program. The amount of fuel reprocessed there, however, is quite small in comparison to Hanford and Savannah River. Only 11.4 million liters of high-level waste are now stored at INEL after more than 20 years of reprocessing. The waste has been retained in its acidic form unlike the waste at Hanford and Savannah River. Acid wastes from INEL processing operations are transferred to stainless steel holding tanks. There are currently 15 of these tanks. Eleven tanks are contained in the underground concrete vault. The four 11,000 liter tanks are buried on a concrete pad but are not surrounded with a vault. These tanks are used to store waste from early reprocessing operations and are presently empty. No tank failures have been recorded at INEL. At INEL, DOE constructed a calcining facility and began operations in 1963. In this process, the liquid acid waste in the holding tanks is converted to a dry granular solid. Calcination also results in a 9:1 volume reduction in waste. The granules are stored in stainless steel bins which are placed in buried concrete vaults. About 6,000 cubic meters of transuranium-contaminated solid waste is shipped annually to the INEL for storage, primarily from Rocky Flats operations. This material was formerly buried in pits, but waste above the 10 nanocuries per gram level is now stored on asphalt pads under sheets of plastic and plywood with a compacted earthen cover. The waste is contained in plastic-lined 208-liter drums or special fiberglass reinforced plastic covered boxes. This facility provides retrievable storage for alpha emitting wastes. A similar pad is used for disposal of radioactive waste with high salt content and low plutonium content which is not currently to be retrieved.^{1, 21}

A detailed discussion of INEL is presented in Appendix C.

3.5 LOS ALAMOS SCIENTIFIC LABORATORY (LASL)

LASL acts as a burial site for solid waste. LASL produces a large variety of contaminated solid waste of which the principal contaminant of concern is Pu-239. Non-TRU waste is usually packaged in plastic bags and fiber containers only

strong enough to provide contamination control enroute to and at the burial site prior to emplacement in large pits to be covered with soil. Fission product wastes with high gamma radiation readings are handled separately, shielded during transport and at the burial grounds, then placed in specifically drilled shafts in the burial area.

About 80 percent of all radioactive waste that has been buried is contaminated with transuranium elements and includes a large amount of Am-241. In 1974 the annual burial was 32,020 Ci and 4,071 m³ of solids including the binding or encasing materials. Plutonium, primarily Pu-239, in the solid waste amounts to about 150 grams per year and about five kilograms accumulated prior to the time retrievable storage of TRU-contaminated waste was instituted.¹ Appendix E provides a more detailed discussion of LASL.

3.6 MOUND FACILITY

No waste is at present buried on-site. Some building rubble contaminated with plutonium was buried in the past and the burial site is well identified and frequently monitored. All current waste is shipped off-site for burial at a commercial burial site or for burial/storage at a DOE site.

The Mound Facility generates a miscellaneous kind of solid waste which results from the treatment of liquid waste streams. The principal contaminant is Pu-238 with some Pu-239. The usual amount shipped each year is about 2,350 m³ and of this about 75 percent is plutonium-contaminated. About 10 percent of the solid waste is a result of treatment of 23,000 m³ of a liquid stream.¹ A detailed discussion of the Mound Facility is presented in Appendix E.

3.7 OAK RIDGE NATIONAL LABORATORIES (ORNL)

Historically, a variety of systems have been used for the land burial of solid low-level radioactive waste. Early in the operations of ORNL the solid waste storage areas were small and were located at the main ORNL site. Wastes were dumped into trenches and backfilled. No records were kept of the quantity or kind of

solid waste. In fact, it is quite possible that fluid combustibles were also buried. It is also likely that little fissionable material is in the waste because an extreme effort was made at the time to conserve it.

During the period of 1955-1963 ORNL was the southern region storage area for solid wastes. About 28,000 m³ of solid radioactive waste were derived from the numerous sources of research and operation waste sent to ORNL burial. The variety, character and even the amount of radioactive wastes acquired in this way are unknown.¹

At ORNL the solid radioactive waste is generated in a number of ways and forms. The most bulky and least contaminated is laboratory refuse. It consists of animal carcasses, animal wastes, glassware, rubber and synthetic rubber goods, paper, rags and a miscellany of items either known or suspected to be contaminated with radioactive material. Another source of lesser volume comes from the variety of chemical and physical research and development activities. There is also the usual array of discarded equipment, machinery, tools, tanks, valves and pipes that are no longer needed or are so radioactive as to preclude successful economic decontamination. Finally, there is soil, concrete flooring, and building materials contaminated by spills and leaks. It is anticipated that there will be need for the burial of about 3,000 m³ per annum for the next 10 years at ORNL.¹ A detailed discussion of all Oak Ridge facilities is provided in Appendix E.

3.8 ROCKY FLATS PLANT (RFP)

At present no radioactive waste is being buried at Rocky Flats. In the past, some burials occurred locally, but most of the plutonium contained in the waste has been retrieved and shipped to the Idaho National Engineering Laboratory (INEL). The small remainder is in a known location and is under surveillance. The wastes currently shipped to INEL are stored in a retrievable transuranium storage area if the contamination level exceeds 10 nanocuries of transuranium nuclides per gram of waste. About 50 percent of the radioactive solid wastes presently produced by the Rocky Flats Plant result from the treatment of liquid

streams.^{1, 64} The rest is produced by a variety of chemical plants and laboratory operations.

Shipments of alpha-emitting wastes are made in 208-liter drums or plywood boxes coated with a glass fiber impregnated polyester. Rigid polyethylene liners in the drums and the box coating provide the integrity needed for 20 year retrievable storage. Wastes not requiring retrievable storage are packaged only to meet transportation requirements, not to provide control after burial. Alpha-emitting waste comprises about 90 percent of the total generated. About 7,000 m³ of alpha-emitting waste is currently generated each year containing about 20 kilograms of plutonium of various isotopic compositions. The 15,500 m³ of liquid wastes when treated produce 3,700 m³ of solids, a reduction to 24 percent of the original volume.¹

Low specific activity (LSA) waste consists of non-line generated waste and evaporated salts. Non-LSA waste consists of line-generated waste, first-stage sludge, second-stage sludge, cemented liquids and organic liquids mixed with calcium silicate to form a putty-like mass called "grease." Now employed, however, is a more useful operation of classification developed in 1970 at INEL when it became necessary to establish the retrievable storage operation. Category one includes paper rags, miscellaneous filters, glass, gloves and general garbage. Category two includes all metallic waste. Category three includes the sludges, the cemented liquids and "grease." Category four consists of undefined waste. Fortunately, the volume of the last category is small and creates no problem of waste management.

Currently, the Rocky Flats operation generates about 20 kilograms of waste plutonium annually. The accumulated Rocky Flats-generated plutonium in the INEL burial site through FY 1975 amounts to about 500 kilograms of which 120 kilograms are in the retrievable storage.^{1, 64}

3.9 SAVANNAH RIVER PLANT (SRP)

Savannah River has replaced Hanford as a major production facility for the Government's nuclear defense program, with three production reactors now in operation.¹ Presently, about 80 million liters of high-level waste are stored in carbon steel tanks. DOE is processing high-level waste at Savannah River into saltcake as at Hanford. DOE is presently using 31 tanks for high-level liquid waste storage, ranging in capacity from 3.7 million liters to five million liters. All tanks are constructed of carbon steel and sit in reinforced concrete vaults. Eight have single steel walls and the others have double steel walls. Another 24 of the largest of the tanks are under construction or planned.^{23, 24}

The major radionuclides that are buried or stored in many forms at the SRP include the following: H-3 - 2.9 million curies; Co-60 - 150,000 curies; Sr-90 - 4,000 curies; Cs-137 - 4,000 curies; Pu-238 - 309,000 curies; Pu-239 - 1,000 curies; Cm-244 - 40,000 curies.¹ About 11,300 m³ of alpha-emitting waste were buried before 1965 and about an equal volume since then. The earlier burials were not encapsulated in concrete. They contained a total of about 200 curies of Pu-239. Since 1965, there have been some low-level alpha disposals without encapsulation. However, the location of these burials is well known and trial exhumations have been undertaken.

At the Savannah River Plant 19,000 curies of Pu-238 waste, 1,000 curies of Pu-239 waste from finishing operations, and 40,000 curies of Cm-244 waste from SRP production operations are stored along with 290,000 curies of Pu-238 waste from the Mound Facility and LASL in an array of concrete containers designed for ease of monitoring and retrieval.¹

A detailed discussion of SRP is presented in Appendix D.

3.10 OTHER DOE FACILITIES

Table 3-2 provides a listing of DOE waste generating facilities with burial sites and Table 3-3 provides a listing of DOE and subcontractors facilities without burial grounds.

TABLE 3-2
DOE FACILITIES GENERATING SOLID WASTES
WITH BURIAL GROUNDS (1976)¹

<u>Site</u>	<u>Location</u>
Feed Materials Production Center	Fernald, Ohio
Hanford Reserve	Hanford, Washington
Idaho National Engineering Laboratory	Idaho Falls, Idaho
Lawrence Livermore Laboratory (Site 300)	Livermore, California
Los Alamos Scientific Laboratory	Los Alamos, New Mexico
National Lead Company of Ohio	Niagara Falls, New York
Nevada Test Site	Las Vegas, Nevada
Oak Ridge Gaseous Diffusion Plant (K-25 plant)	Oak Ridge, Tennessee
Oak Ridge National Laboratory (X-10 plant)	Oak Ridge, Tennessee
Oak Ridge Y-12 Plant	Oak Ridge, Tennessee
Paducah Gaseous Diffusion Plant	Paducah, Kentucky
Pantex Plant	Amarillo, Texas
Portsmouth Gaseous Diffusion Plant	Piketon, Ohio
Sandia Laboratory (Kirkland AFB(East))	Albuquerque, New Mexico
Savannah River Plant	Aiken, South Carolina
Weldon Springs	St. Charles County, Missouri

TABLE 3-3
DOE FACILITIES GENERATING SOLID WASTES
BUT WITHOUT BURIAL GROUNDS (1976)¹

<u>Site</u>	<u>Location</u>
Ames Laboratory	Ames, Iowa
Argonne/West	Idaho Falls, Idaho
Atomics International	Santa Susana, California
Bendix Plant	Kansas City, Missouri
Bettis Atomic Power Laboratory	West Mifflin, Pennsylvania
Brookhaven National Laboratory	Upton, L.I., New York
Burlington DOE Plant	Burlington, Iowa
Fermi National Accelerator Laboratory	Weston, Illinois
Lawrence Berkeley Laboratory	Berkeley, California
Lovelace Foundation Laboratory	Albuquerque, New Mexico
Mound Facility	Miamisburg, Ohio
Naval Reactors Facility	Idaho Falls, Idaho
Pinellas Plant	Clearwater, Florida
Rocky Flats Plant	Golden, Colorado
Shippingsport Atomic Power Station	Shippingsport, Pennsylvania

4.0 COMMERCIAL DISPOSAL SITES

Since TRU-contaminated solid waste generated at various points in the commercial nuclear fuel cycle has historically been disposed of at commercial burial grounds, a description of these grounds is appropriate as part of the background concerning the handling of TRU waste. The purpose of this section is to provide a brief overview of the commercial disposal sites, while Appendix F presents more detailed information.

4.1 INTRODUCTION

Three private companies currently operate, or have operated, the six licensed commercial burial grounds. The disposal site location and year when licensed are presented in Table 4-1.

All commercial disposal sites were licensed to handle by-product, source and special nuclear materials. All sites are on federally- or State-owned land. At five sites the State owns the land and leases it to the burial ground operators. At the Richland site the Federal government leases the land to Washington, which then leases it to the burial ground operator. All of the sites except Sheffield are licensed for burial by the State in which they are located under a Federal agreement giving states this licensing authority. An "Agreement State" is a State that has entered into an agreement with the NRC, which allows the State to control the receipt, possession, use, and transfer of by-product material and quantities of source and special nuclear material not sufficient to form a critical mass. The scope of the agreement allows the State to license the disposal sites for burial of radioactive wastes, except those wastes resulting from irradiated fuel separation. Since Illinois is not an Agreement State, the Sheffield site is licensed by the NRC, but it also has a State permit to bury waste. The Beatty site, in addition, has an NRC license to bury special nuclear material in quantities exceeding State licensable quantities. At Beatty and Richland, the NRC regulates the handling of special nuclear material since large quantities are authorized to be handled by these facilities. The Barnwell site is pursuing a similar license with the NRC. The State regulates the handling of by-product and source materials at these sites.^{3, 8}

TABLE 4-1
BURIAL AND STORAGE SITE IDENTIFICATION

Name	Operated By	Location	Year Licensed
Beatty	Nuclear Engineering Co., Inc.	About 17 km south of Beatty, NV	1962
West Valley ^(a)	Nuclear Fuel Services, Inc.	About 50 km southwest of Buffalo, NY	1963
Morehead ^(b)	Nuclear Engineering Co., Inc.	About 20 km northwest of Morehead, KY	1963
Richland	Nuclear Engineering Co., Inc.	About 16 km northwest Richland, WA	1965
Sheffield ^(c)	Nuclear Engineering Co., Inc.	About 8 km southwest of Sheffield, IL	1967
Barnwell	Chem-Nuclear Systems	About 8 km northwest of Barnwell, SC	1971

(a) West Valley closed March 1975.

(b) Morehead (Maxey Flats) closed December 1977.

(c) Sheffield's burial trenches are filled.

A proposed amendment to the NRC regulations will ban commercial burial of waste contaminated with transuranic (TRU) nuclides.⁷¹ Since the initial licensing of the Barnwell disposal site in 1971, South Carolina has prohibited the burial of transuranic contaminated waste except Am-241. Since October 1973 the New York site has not been allowed to receive for burial more than trace quantities of plutonium. In 1974 Kentucky announced that it was limiting the concentration of transuranics to be buried to ten (10) nanocuries per gram and the licensee placed the ten (10) nanocurie limit on waste at the Sheffield site. In September 1975 Nevada placed the same limitation on transuranic materials.⁸

The total volume of solid radioactive wastes buried at commercial sites (Table 4-2) from 1962 through 1977 was about 506,000 cubic meters. This waste was estimated to contain about 4.2 million curies of radioactivity uncorrected for decay. About 1,800 kilograms of special nuclear material containing about 123.4 kilograms of plutonium are buried at commercial sites. Of the total waste volume buried at commercial sites, Morehead and Barnwell have received the greatest amount; about 27 percent and 28 percent, respectively (through 1977). Before 1962 commercially generated solid waste was usually disposed of at sea or at the AEC burial sites.³

4.2 COMMERCIAL BURIAL PRACTICES

The commercial burial sites at Beatty, Nevada; Richland, Washington; Sheffield, Illinois (presently all trenches have been filled); and Morehead, Kentucky (no longer in operation), are operated by the Nuclear Engineering Company. The West Valley, New York (no longer in operation), site was operated by Nuclear Fuel Services, Inc., and the Barnwell, South Carolina (limited monthly burial rate), site is operated by Chem-Nuclear Systems.

In physical form a great deal of the bulk of waste buried consists of material which is not radioactive itself, but which has small amounts of radioactive material on its outer or inner surfaces. Examples of this are paper trash, packing material, plastic sheeting and tubing, broken glassware, defective or obsolete equipment, protective clothing, rags, mops and other cleaning equipment and

TABLE 4-2
COMMERCIAL SOLID RADIOACTIVE WASTE GENERATED ANNUALLY
IN THE UNITED STATES¹⁹

<u>CALENDAR YEAR</u>	<u>VOLUME ($\times 10^3 \text{ m}^3$)</u>
1962	1.86
1963	6.24
1964	13.10
1965	13.30
1966	16.19
1967	19.38
1968	19.65
1969	21.41
1970	24.98
1971	29.35
1972	37.33
1973	47.08
1974	53.25
1975	57.01
1976	74.22
1977	(71.36) ^a
1978	(80?)

^a Preliminary information.

building rubble. Another type of contaminated waste in which radioactive contaminants are much less likely to become physically separated from the non-radioactive bulk of the material include ion exchange resins or filters which have been used to treat radioactive or potentially radioactive water and air effluents, solidified salts resulting from evaporation processes, etc. Other physical forms of solid radioactive waste in which the radioactivity is an inherent or inseparable part of the structure or the material in which it is contained consists of discarded shielding, instrumentation, control rods, and other nuclear reactor equipment in which activation of materials has resulted in the radioactivity.^{6, 38}

In general, the intermediate-level wastes result from liquid-waste treatment or from the removal of equipment or materials from reactors. Wastes are not accepted for burial if they present a significant nonradioactive hazard such as explosion or fire.

Waste packaging is provided to meet Department of Transportation (DOT) requirements and in some cases to permit above ground storage of the waste package for short time periods. However, no credit is taken for the containment capability of the package after burial, as the soil material is considered to provide the primary containment barrier.

All sites use open trenches or pits as the primary disposal facility. The trenches are about six meters deep but vary considerably in length and width. An average burial trench at a commercial burial site is about 100 m long, 10 m wide and 6 m deep, with a volume of approximately 5,100 cubic meters. This volume is not completely filled with waste packages because of space between packages of different shapes and because of the filling technique and requirements for earth fill. Waste is placed in the trench in a sequential fashion, usually starting at one end, and covered with earth at intervals dependent on the waste type and climate. Trenches containing dry wells or specialized casks are used for the disposal of some higher activity wastes. Trenches at the humid eastern sites are commonly sloped to one end and may contain water-collection facilities at the low end for use during or after trench filling. When the entrenched waste accumulates to within a yard or so of the surface, a backfill of uncontaminated

earth is placed over the waste and mounded a few feet above the original land surface to encourage precipitation runoff.⁶

The radioactive materials contained in buried waste range from those with very short half-lives, such as radiopharmaceuticals and some fission products, to long-lived materials, such as uranium and plutonium. As shown in Table 4-3, present policies restrict the burial of plutonium at concentrations above 10 nCi/g of waste at all but the Richland site, but some such materials remain in place from previous years.

Radionuclides presently buried at commercial sites are divided into the three categories. These are special nuclear materials (SNM), which are fissionable materials such as U-235 or Pu-239; source materials, such as natural uranium, which can be converted to special nuclear materials in a reactor; and by-product materials, which include all other radionuclides.³⁸

The NRC has jurisdiction over the licensing of commercial burial sites, except as it has relinquished that authority to its Agreement States. At present, only the Sheffield site is licensed directly by the NRC, but some activities, such as the handling of specified quantities of special nuclear materials, are regulated by the NRC at all sites. Federal regulations require that the title to the land used for burial reside with a State or Federal agency. Thus commercial burial operators have generally purchased the land and deeded the portions required for burial to the State, which then leases the land to the site operator. Long-term care of the site after termination of operation rests with the landowner, be it a State or the Federal Government. To provide funds for such care, the States collect fees from the burial ground operators.

TABLE 4-3

BURIAL REQUIREMENTS AT THE SIX COMMERCIAL BURIAL SITES^{8, 6}

Requirement	Beatty, Nevada	West Valley, New York ^(a)	Morehead, Kentucky	Richland, Washington	Sheffield, Illinois	Barnwell, South Carolina
Acceptance of waste types:						
Dewatered resins	Yes	No	Yes	Yes	No	Yes
Dewatered Powdex	Yes	No	Yes	Yes	?	Yes
Diatomaceous earth	?	?	Yes	Yes	?	Yes
Dewatered sludges	Yes	No	?	Yes	No	Yes
Free liquids	No	No	No	Yes	No	No
Solidification agents:						
All types of cement	Yes	Yes	Yes	Yes	Yes	Yes
Urea-formaldehyde systems	Yes	?	?	Yes	Yes	Yes
Other organic polymers	(b)	(b)	?	?	?	?
Asphalt/bitumen	(b)	(b)	?	?	?	?
Selected requirements:						
Retrievability	No	No	No	No	No	No
Plutonium limitations	Yes	Yes	Yes	No	Yes	Yes

- (a) Prior to its closing in March 1975.
 (b) Uncertain about acceptance.

4.3 CRITERIA FOR DISPOSAL OR STORAGE

The requirements for burial of solid radioactive wastes at each of the six commercial sites are discussed in Appendix F. It also shows possession limits and permissible concentrations that might affect packaging and shipment of wastes to that particular burial site.

The latest burial requirements at each of the six sites are also given in Appendix F. The criteria for West Valley are those used when the site was accepting waste for burial. More stringent requirements will be enforced when, and if, the burial site is reopened. Although the requirements for the site are similar, there are certain differences of interest, as follows:⁶

- The West Valley site requires that the contents of any package of waste with loose radioactive material and a contact radiation level >200 mR/hr on the package be solidified in cement in a metallic container, or in other packaging approved by the site.
- Liquids must be solidified before burial at all sites except West Valley, where they may be absorbed if package contact radiation levels are <200 mR/hr.
- West Valley does not have a curie limit on the amount of non-transuranic by-product material that may be possessed unburied; the other sites have an unburied possession limit.
- West Valley has a self-imposed limit of one gram per 28.3 m³ for materials containing transuranic radionuclides in general and Pu-239 in particular.
- The Sheffield, Richland, Beatty, and Barnwell sites accept bulk shipments of liquids and have the authority and capability for solidification prior to burial.
- A state-imposed restriction at the West Valley site, not given in Appendix F, was an average trench concentration after burial of 7.1 Ci/m³.
- Sheffield has a state-imposed concentration limit of 35.3 Ci/m³ package. This limit may be exceeded with special permission.

Currently, one commercial burial site (Richland) accepts TRU wastes, with the exception of plutonium, in quantities up to its possession limit for any other by-product material. This will soon change, however, as the regulatory agency in Washington is also considering adoption of a TRU limit of 10 nCi/g.

5.0 COMMERCIAL NUCLEAR INDUSTRY

The commercial nuclear industry typically is understood to include all nuclear fuel cycle activities. For the purpose of this report other non-fuel cycle waste sources or potential sources will also be briefly reviewed. Figure 2-1 shows the nuclear fuel cycle. It is reasonably well accepted that transuranic contaminated wastes are primarily generated by the back end of the fuel cycle. The sources of these transuranic wastes include the fuel fabrication industry and spent fuel reprocessing industry.

5.1 FUEL FABRICATION INDUSTRY

The commercial nuclear power industry is presently supported in the U.S. by seven major uranium fuel fabricators processing low enriched uranium hexafluoride (UF_6) into finished fuel assemblies of uranium oxide pellets clad in zircaloy tubing.³⁵ In addition, there are three pilot facilities capable of producing uranium-plutonium mixed oxide (MOX) fuel rods for use in fuel assemblies. One additional MOX fuel rod plant of commercial production capacity is in the planning stage.

The extracted plutonium from the chemical reprocessing step of spent fuel is combined with natural uranium at the mixed oxide fuel fabrication plant to form mixed uranium dioxide-plutonium dioxide fuel pins for recycle to the LWR. This material will contain trace amounts of radioactive impurities after decontamination at fuel reprocessing.⁷⁶ In the conventional process, plutonium dioxide powder is blended with ceramic grade uranium dioxide powder, followed by the pelletizing, sintering and mechanical steps employed in the uranium fuel fabrication steps. Residual plutonium is recycled into the main process through a scrap recovery cycle. The fuel assemblies themselves may be fabricated from the loaded fuel rods at the uranium fuel fabrication plant. The finished pellets are loaded into zircaloy tubes and the completed fuel rods are assembled in fixed arrays. Residual uranium and plutonium are recycled into the main process through a scrap recovery cycle.

However, UF_6 product from chemical reprocessing will contain small quantities of fission products and transuranium isotopes. Specifications have been published which indicate the maximum acceptable limits for radioactivity resulting from these impurities.⁷⁶ These are: gross alpha due to transuranium isotopes - 1,500 dis/min/(g of U); gross beta due to fission products and transuranium isotopes - 10 percent of the beta activity of aged normal uranium; and gross gamma due to fission products and transuranium isotopes - 20 percent of the gamma activity of aged normal uranium.³⁷ Such processed uranium may then be sent to the enriching plant.

5.1.1 WASTE GENERATION AND HANDLING PRACTICES

Most of the wastes from processing or fabrication operations and the associated analytical work are generated inside glove boxes. However, a significant amount of waste is generated outside the boxes from contamination control measures. Usually, liquid wastes are segregated from solid wastes and the solid wastes are bagged in plastic. In addition, plutonium-contaminated wastes are often sorted by enrichment level. In plants that can be termed production rather than development facilities, wastes are separated from the wastes that are candidates for disposal by burial.

In general, the solid wastes are the conglomerates arising from the processing and contamination control efforts and consist primarily of paper (wipes and cartons) and plastic (bags). The radioactive constituent is often initially a fine powder. The degree of segregation of paper and plastic depends primarily on the type and extent of scrap recovery. It is estimated that the solid waste stream is about half plastic and half paper, but numerous other constituents are discarded into this stream including cloth, rubber (gloves), glassware, unusable equipment and tools, metal cans, graphite, spent ion-exchange resin, asbestos paper fiber filters, and even small amounts of treated or solidified liquid (usually organics or oil). This solid waste stream is bagged in plastic and then placed in the plastic lined 208-liter drums. Larger items are crated for burial.⁵⁹

Each fuel fabricator has at least four types of wastes: solids from the main process line which are small enough to fit into 208-liter drums, larger sized solid

waste such as failed equipment, slightly contaminated solids generated in cleanup of small spills outside the main process line and laboratory liquid wastes. Most fabricators also generate liquid wastes from plutonium processing, scrap recovery or other sources.

5.1.1.1 SOLIDS FROM MAIN PROCESS LINE⁵⁹

Most fuel fabrication operations are performed in dry glove boxes. Solid waste includes wipes, neoprene gloves, small failed equipment and small air filters. Most of the waste from glove boxes results from cleanup operations. Major spills are usually recovered by using a paint brush and dust pan. Some processors use vacuum cleaners for more complete removal of dry powders which accumulate in the glove box. Occasional cleanup of the residual powders is necessary to provide proper contamination and exposure control. Cleanup is usually by wipes or cheesecloth. Thus, most of the solid waste from glove boxes is initially cellulose materials. The waste is removed from the box by bagging in PVC and a second PVC bag is often added for additional safety as soon as the first bag is cut from the box. This introduces an appreciable amount of plastic into the waste. Neoprene gloves have to be changed regularly and contribute additional plastic similar to the PVC. If sphincter containers are used, they also contribute either cardboard or aluminum to the wastes. Some plastic bottles or cardboard containers are often used within glove boxes. Glassware is less common, but might be used by some fabricators.

Under special conditions cleanup might be accompanied with liquids for more exhaustive cleaning. Usually these are chemically relatively mild, innocuous liquids. Many processors use cheesecloth and nitric acid for cleaning stubborn residues of plutonium. Cloth or papers soaked with nitric acid are rinsed with water before being discarded, and often they are neutralized with caustic substances. Since nitric acid solutions are used only in the final stages of cleaning, these materials usually contain only small amounts of plutonium.

Other small items from the glove box are included in this type of waste. Examples are marking pens, tools, prefilters and small failed equipment. If the

item is small enough to fit into a 208-liter drum, or can be reduced to this size easily, it is usually treated the same as other small waste items.

Waste is usually not sorted into various types (e.g., cloth, paper, plastic, tools and equipment) unless one or more types may contain enough plutonium to make recovery economically attractive. If recovery is contemplated, material is usually sorted into three classes: cellulose, plastic and other. Cellulosic material is incinerated or oxidized and the residue is leached to recover plutonium. Plastics may be treated similarly to cellulosic materials, or may be leached for plutonium recovery. Leaching of plastics is reported to be much more efficient if shredding is done before leaching. Plutonium may be recovered from other wastes by leaching. Most of the waste reprocessing is only in the planning states or limited to batches of waste which have unusually large amounts of plutonium.

5.1.1.2 LARGE FAILED EQUIPMENT⁵⁹

Some equipment items are not easily reducible in size. Such equipment is cleaned as much as practicable, enclosed in plastic for contamination control and placed in a shipping container. Since large equipment does not fail often, each is treated as a special case at present. Disposal containers are built to fit the particular needs for each shipment. Special pretreatment can also be used to minimize the potential for spread of contamination.

Large air filters are considered and handled as large equipment, even though they are replaced routinely. If they contain appreciable amounts of plutonium, some recovery may be performed. Filters are typically about the size of a 0.6 m on a side cube consisting of fire resistant filter media in a wooden frame. Prefilters are often used on each individual glove box to reduce the amount of plutonium which can reach the large filters.

5.1.1.3 SLIGHTLY CONTAMINATED SOLIDS⁵⁹

Small occurrences of contamination outside the glove boxes must be cleaned thoroughly. This generates a large volume of waste with very little plutonium

content. Most of the waste is cellulose and rubber gloves. Cloths or papers soaked with liquids are treated the same as those used in glove boxes. This type of waste could most easily be compacted since the plutonium content is very low and it is the least suitable for scrap recovery. Waste is usually collected in plastic bags (mostly polyethylene) and deposited in 208-liter drums. All plutonium fabricators use extreme caution to maintain a very clean work area outside of the glove boxes so that normal materials used outside the boxes do not become contaminated.

5.1.1.4 CHEMICAL PROCESSING LIQUIDS⁵⁹

Chemical processing liquids for waste disposal originate primarily as aqueous, often acidic, streams that include effluents such as process filtrates, pickling liquids and decontamination liquids. Conventional water treatment steps convert the major radioactive components into a sludge which is then often solidified by incorporation into a second medium, e.g., cement.

5.1.1.5 MISCELLANEOUS LIQUIDS

In addition to processing liquids, small and poorly defined quantities of plutonium-containing organic solutions and vacuum pump oils are generated. The organic solutions include solvents as well as complex chemicals associated with laboratory studies. Some solvents specifically identified are kerosene (used as a lubricant in metallography), trichloroethylene and carbon tetrachloride. In general, current methods of treating or fixing these liquids are the same as those described above for the processing liquids. The treated miscellaneous liquids are often disposed of along with solids from the main process line, since the incorporation or adsorption step is usually conducted in small vessels inside glove boxes.

5.1.1.6 OTHER SOLIDS⁵⁹

A few types of solid waste do not fit appropriately in any of the above categories since they are not routinely generated, and they may contain significant amounts

of plutonium. One such waste is spent ion exchange resins. Usually these are sulfonic acid types which are used in scrap recovery operations. Before disposal they are washed with water or diluted caustic substances to remove nitric acid. They may be blended with concrete or air dried and treated as dry solid waste.

Casting compounds are used in metallographic or ceramographic examination of fuels and components. Polishing results in finely divided organic materials mixed with alpha-emitters. The scale of operations determines the advisability of recovering the plutonium. Also, the mounted specimen after examination may be discarded if the plutonium content does not warrant recovery. Some of the mounting material becomes waste by spillage or deterioration before use. Although the volume is small, this type of waste introduces components not otherwise present in the waste.

Quality control processes often use special chemicals which are introduced in excess of the amount required. Virtually any chemical may be used for special analyses or for testing new analytical procedures. Usually these are introduced as solutions and eventually become laboratory liquid waste.

5.1.1.7 MOX FUEL FABRICATION WASTE QUANTITIES

From the above discussion, it is understood that the wastes of concern in this study are the liquid and solids generated during MOX fuel fabrication. The liquids include: salt solutions, organic liquids and surfactant/detergent solutions.

The solid wastes are comprised of wet particulate solids, dry particulate solids and combustible and noncombustible solids.⁵⁰ Table 5-1 presents the sources of the non-high-level fabrication wastes which are anticipated to be TRU or potentially TRU-contaminated.

5.2 WASTE FROM THE SPENT FUEL REPROCESSING INDUSTRY

Following a cycle of exposure in the LWR, the spent fuel can be chemically processed to recover the unburned uranium and plutonium and separate the

TABLE 5-1
SOURCES AND QUANTITIES OF NON-HIGH LEVEL
MOX FUEL FABRICATION TRU-WASTES

<u>Waste Category</u>	<u>Estimated Waste Volume m³/MTHM^(a)</u>	<u>Waste Description</u>
1. Salt Solutions	0.08	Concentrated scrap recovery, decontamination, and off-gas scrub liquids.
2. Surfactants/Detergent Solutions	~0.01	Laundry wastes, personnel decontamination solutions.
3. Organic Liquids	0.0015	Pneumatic fluids, oils, laboratory solvents.
4. Wet Particulates	0.0003	Bead ion exchange resins used for liquid effluent treatment.
5. Dry Particulates	—	Floor sweepings, etc. Volume not identified.
6. Combustible Solids	0.5	General trash (cellulosics, plastics, rubber - uncompacted).
	0.06	Ventilation (HEPA) filters (up to 60 wt% combustible).
7. Noncombustible Solids	0.2	General trash, PuO ₂ cans, etc. (uncompacted)
	<u>0.2</u>	Failed equipment, furnace brick.
TOTAL	1.05	

(a) MTHM - Metric Tons Heavy Metal. Volumes are based on annual throughput at a large (~400 MTHM/yr) mixed oxide fuel fabrication plant. Amounts are representative of typical facilities, but not all facilities will have the full spectrum of wastes.

fission products for storage or ultimate disposal. The generic spent fuel reprocessing plant is located on a relatively large site and utilizes the Purex process to separate fissile material from the fission products. In this process, the fuel elements are chopped into short pieces, and the metal oxides are leached by hot nitric acid, leaving behind the chopped tubing. The nitric acid solution, containing uranium, transuranics and fission products, is adjusted chemically and processed through solvent extraction and ion exchange systems. These process steps separate the fission products, uranium and plutonium from each other. The purified uranium product is converted to uranium hexafluoride and is shipped to the gaseous diffusion plant for re-enrichment. The purified plutonium product is converted to PuO_2 for recycle to the mixed oxide fabrication plant. The high-level liquid wastes are stored temporarily on-site in a water-cooled storage basin and ultimately converted to solid form for shipment to the Federal waste repository.^{50, 36}

5.2.1 TYPES OF WASTES^{59, 58, 60}

Solid wastes from reprocessing plants can be classified functionally into the following general categories: cladding hulls, intermediate- and low-level waste, general trash, equipment and dry chemicals.

- Cladding Hulls - This category is simply the residual fuel element cladding and hardware from the dismantling, shearing, and dissolving operations. Although in many instances other equipment hardware is added with the hulls, the equipment hardware is included in the equipment category for the purposes of this survey.
- Intermediate- and Low-Level Wastes (ILW/LLW) - A liquid effluent is generated which is first highly concentrated and then placed in tanks for storage. The liquid is principally from washing of solvent, decontamination of equipment and chemical digestion (e.g., ion exchange disposal). Another solid which is added to ILW/LLW is metal fines from shearing and sawing.
- General Trash - All solid material which leaves the plant for disposal is termed general trash if it is not specifically included in another category. For example, off-gas ventilation filters are included as general trash. Also, if plutonium scrap recovery operations are conducted, the waste is included as general trash.

- Equipment - Obsolete equipment, or failed equipment which is removed from service is included in the equipment category.
- Dry Chemicals - Since some of the plant operations include uranium conversion to UF_6 , the solids originating from this operation are identified as dry chemicals.

5.2.2 SOURCES OF WASTE IN THE SPENT FUEL REPROCESSING INDUSTRY

For the fuel reprocessing plant, the waste identification is best clarified by discussing each source of waste which potentially contains plutonium.

5.2.2.1 FUEL RECEIVING⁵⁹

The water basin for receipt and storage of fuels contains a cleanup system which from time to time requires replacement of the ion exchange resin. The plutonium content is generally unknown but is considered TRU-contaminated.⁹ Up to 7 m³ of resin are expected to be disposed of each year from larger basins. Disposal concepts and practices vary. For purposes of this review, the waste from fuel receiving is included as general trash and wet particulates.

5.2.2.2 HEAD END TREATMENT⁵⁹

The treatment for removal of iodine varies from aqueous scrubbing to silver reactors and silver zeolites. Replacement of the zeolites is anticipated to produce an overall average of 0.002 cubic meter per metric ton of fuel processed. For disposal, the zeolites are placed in 208-liter drums. However, the plutonium content in this general trash is expected to be negligible. HEPA filters on the dissolver off-gas are replaced periodically except in those plants which use permanently installed filters (e.g., sand). The volume of filter replacement varies; the volume of used filters is somewhat independent of throughput. No measurements or estimates of the amount of plutonium on the filters are available. The quantity of filters is included as general trash.

Cladding hulls and pieces of fuel hardware are produced from a chop leach head end in all plants and are included as a separate category. Although there has been some stainless steel cladding and stainless steel parts as well as zirconium, it is anticipated that about 95 percent by weight of all future cladding hulls and hardware will be zirconium until fast reactor fuels are reprocessed. As shown in Figure 2-2, the amount of plutonium in the hulls is nominally 0.1 percent of the total plutonium in the fuel processed. This is expected to be somewhat lower with longer fuels (because fewer pieces exist with only one end open). Thus, in general the plutonium content is estimated to be about 0.02 percent to 0.1 percent of throughput. The volume of the hulls and hardware ranges from 0.3 to 0.55 cubic meter per metric ton.

5.2.2.3 GENERAL TRASH⁵⁹

Most of the material accumulated throughout a reprocessing plant is handled in the form it is collected. Some classification of the waste occurs because it is accumulated at a specific location in the plant or because of its high beta-gamma activity. Typically, this general trash is composed of electrical cords, lights, wire cables, small equipment, glass, rags, paper and cotton wipes, clothing, floor sweepings, tape, rubbers, lead, filters, manipulator boots and sleeves and all forms of plastic. Estimates of the amount of combustible material vary from 50 to 70 weight percent if the plastics are considered noncombustible. In some cases the noncombustible was estimated at 10 percent with up to another 10 percent being moisture. The volume of general trash (including TRU-contaminated material) ranges from 1 to 9 cubic meters per metric ton of fuel processed. Where filters are routinely replaced in the plant, the volume of filters will average from 0.02 to 0.2 cubic meter of filters per metric ton.

5.2.2.4 EQUIPMENT DISPOSAL^{59, 73}

Periodic failure of equipment requires the disposal of all sizes and shapes of equipment. Smaller pieces can be handled in the same manner as the cladding hulls. For example, pipe jumpers, valves, pumps, etc., can be sawed into small

pieces and stored with the cladding hulls. Larger pieces of equipment require special handling in plywood or concrete boxes. Each situation is considered special.

The amount of equipment disposal varies and, of course, peaks during a maintenance period and/or a process change. No equipment may be sent to burial for one to two years, but a considerable amount another year. The size may range from 2 to 4 square meters and up to 12 m long. In terms of equipment volume per metric ton, about 0.03 to 0.3 m^3 per metric ton is expected.

The amount of plutonium contained on or in a piece of equipment is not measured directly. Analysis of decontaminating solutions indicates a low level of contamination. From typical surface dose readings, not more than about a gram of plutonium is expected to be on a rather large piece of equipment if plutonium is not held up in sludges or cakes.

5.2.2.5 DRY CHEMICALS⁵⁹

If the conversion of the uranium to UF_6 occurs at the reprocessing facility dry chemicals require disposal. In one instance this waste is about 85 percent AlF_3 , 10 percent Al_2O_3 , and five (5) percent NaF and MgF_2 . The total volume is expected to be about $0.3 \text{ m}^3/\text{MT}$. In another approach the volume is expected to be about $0.1 \text{ m}^3/\text{MT}$ and be principally Ca(OH)_2 , CaF_2 and Al_2O_3 . The plutonium content is quite small since the partitioning during solvent extraction is expected to be good. Less than 0.1 percent of the plutonium throughput is lost to the uranium and eventually to dry chemical waste.

5.2.3 QUANTITY OF WASTE PRODUCED⁵⁹

The quantity of waste produced in the spent fuel reprocessing industry can best be reported by using the classifications of waste type discussed previously. The amount of plutonium in each type of waste is shown as a function of plutonium throughput in Table 5-2. The values given for the probable average are for the situation where the reprocessing plants are operating at near capacity levels.

TABLE 5-2
PLUTONIUM IN SOLID WASTE⁵⁹

<u>Waste Type</u>	<u>Pu in Solid Waste Percent in Pu Throughput</u>	
	<u>Range</u>	<u>Probable Average</u>
Cladding Hulls	0.02 to 0.1	0.07
ILW/LLW	0.01 to 0.2	0.1
General Trash	0.001 to 0.3	0.05
Equipment	-----	0.0002 ^(a)
Dry Chemicals	0.01 to 0.1	0.01
Total	0.04 to 0.7	0.23

^(a)Surfaces assumed to be decontaminated thoroughly, with no residual sludge.
About one gram of Pu expected for each large piece of equipment.

Table 5-3 lists the solid waste volume for each type of waste. The numbers in the table represent actual waste volume as a function of fuel reprocessing rate. Additional space will be required for storage due to the irregular shapes of packages and for shielding. The volume of general trash is somewhat independent of throughput and is estimated to be $1,200 \text{ m}^3$ per year per plant. Likewise, the volume of waste occupied by failed equipment is estimated to be 150 m^3 per year per plant.

5.2.4 ACTINIDE CONTENT⁵⁹

Reliable information on the amount of plutonium in the solid waste is lacking because, in general, measurements are not made to verify the quantities. Little is known about the composition of other isotopes in the waste. Only assumptions can be made, based on the fission spectra and the source of waste in the process. For example, neptunium is expected to average about 1/20 of the plutonium content. Table 5-4 presents some assumed characteristics at the presently closed NFS facility at West Valley, New York. These values compare favorably with the information provided above.

The relative proportion of each type of waste is shown in Table 5-5 for plutonium content. The distribution of plutonium is expected to remain fairly constant through the years, with about 75 percent of the plutonium being associated with the cladding hulls and the ILL/LLW categories.

Prediction of waste production becomes tenuous due to the numerous uncertainties involved in future nuclear capacity as well as waste and residual management practices. For example, the size of a plant, the extent of residual recovery, changes in regulations, the cost of waste disposal, and the value of plutonium are important and interrelated factors in determining the fraction of plutonium throughput which will be lost as waste. A recent analysis of the TRU-contaminated waste sources and quantities, presented in Table 5-6, generally supports earlier evaluations discussed above.

The fraction of plutonium lost during processing is expected to decrease as the throughput increases. This trend assumes that the fractional loss will decrease

TABLE 5-3
ESTIMATED VOLUMES OF SOLID TRU-WASTE⁵⁹

<u>Waste Type</u>	<u>Cubic Meter per Metric Ton</u> ^(a)	
	<u>Range</u>	<u>Probable Average</u>
Cladding Hulls	0.3 to 0.55	0.4
ILW/LLW	0.06 to 0.4	0.2
General Trash	0.03 to 10	(b)
Equipment	0.03 to 0.3	(c)
Dry Chemicals	0.1 to 0.3	0.15

-
- (a) Volume of actual waste. Packaging, shielding and the irregular shape of packages may increase the space required for storage by a factor of up to 3.
- (b) Volume of general trash is independent of processing rate. Assumed to be 1,200 m³ per year per plant.
- (c) Volume of equipment waste category is independent of processing rate. Assumed to be 150 m³ per year per plant.

TABLE 5-4
RADIOACTIVE WASTES GENERATED ANNUALLY AT NFS DESIGN RATE (750 TONNES/YEAR)⁷³

	Intermediate Level Waste						HEPA Filters
	High Level Waste	Leached Hulls	Salts	Slurry	Resin	Equipment	
Original quantity (m ³)	40	260	135	46	21	300	57
Percent of total	1.3	8.3	4.3	1.5	0.6	9.3	1.8
Physical form	Solid	Solid	Slurry	Slurry	Solid	Solid	Solid
Chemical form	Calcine oxide of MPF and added inerts	Zr alloy or stain-less steel	Sodium nitrate 40% solution + mercuric iodate	Filter aid	Organic and mineral resins	Metal	General dust on glass filter
Radio-activity (m ³ /final volume)	99.95% of activity in fuel. $\sim 3.5 \times 10^6$ Ci of MFP/m ³	0.05% of activity in fuel. 17,500 Ci Co-60/m ³	20-40 Ci of MFP. 0.01 Ci 1-129 <3.5 g Pu/m ³	35-350 Ci/m ³ MFP. <10 nCi Pu/g.	35-350 Ci/m ³ MFP. <10 nCi Pu/g.	1,000 mr/hr. <10 nCi Pu/g.	1-500 mr/hr. <17.5 Ci B/m ³ , 75% 10 nCi, 25% ~ 5 mCi Pu/g.
Process	Calcine	---	Dry	Wry	Concrete	Decon-crete as necessary	Compaction
Shipping container	0.5m x 5m canisters	Steel canisters	Steel caniste.	208-l drums	208-l drums	Special container as required	Special container or drum
Final volumes (m ³)	80	260	122	---	42	440	14
Percent of total	3.9	12.8	6.0	2.0	2.0	21.6	0.7
MFP - mixed fission products							

TABLE 5-4
(CONT.)

	Solvent	Low Specific Activity Waste				Total Volume
		Alpha Waste Combustible	Combustible	Slurry	Salts	
Original quantity (m ³)	6	480	1,000	660	160	3,150
Percent of total	0.2	15.3	31.5	21.0	4.9	
Physical form	Liquid	Solid	Solid	Slurry	Slurry	
Chemical form	Diluent TEP	Paper, cloth, rubber, plastic, miscellaneous	Same	Water treatment, sludge, CaF ₂	Sodium nitrate 40% solution	
Radio-activity (m ³ /final volume)	> 3,535 Ci m ³ MFP. < 10 nCi Pu/g.	< 500 mr/hr. < 106g Pu/m ³	< 200 mr/hr. < 10 nCi Pu/g.	< 200 mr/hr. < 10 nCi Pu/g.	< 200 mr/liter < 10 nCi Pu/g.	
Process	Burn or distill	Compaction	Compaction or incineration	---	Dry or absorb	
Shipping container	Mix with ILW waste	208-1 drums	208-1 drums	208-1 drums	208-1 drums	
Final volumes (m ³)	0.3	100	200	585	140	2,030
Percent of total	0.01	5.2	9.8	28.9	7.0	

MFP - mixed fission products

TABLE 5-5

PERCENTAGE DISTRIBUTION OF PLUTONIUM IN SOLID WASTE⁵⁹

	<u>Percent of Total Pu In All Wastes</u>
Cladding Hulls	32
ILL/LLW	42
General Trash	21
Failed Equipment	1
Dry Chemicals	4
	<hr/>
Total	100

TABLE 5-6
SOURCES AND QUANTITIES OF NON-HIGH LEVEL FUEL
REPROCESSING PLANT TRU-WASTES^a

<u>Waste Category</u>	<u>Estimated Waste Volume m³/MTHM^(a)</u>	<u>Waste Description</u>
1. Salt Solutions	0.3 0.03	Composited, concentrated decontaminations and miscellaneous liquids. Iodine scrub solutions.
2. Precipitates and Slurries	0.8 0.07	Water treatment slurry (iron hydroxides, clays, miscellaneous precipitates). Slurry from UF ₆ off-gas treatment.
3. Surfactant/Detergent Solutions	—	Miscellaneous surfactant-containing decontamination solutions. (Volume included in 1, above.) Laundry wastes may also be included in this category.
4. Organic Liquids	0.008 0.005	Degraded TBP solvent. Miscellaneous lubricants, oils, hydraulic fluids, lab solvents, etc.
5. Wet Particulates	0.01 0.005-0.01	Bead ion exchange resins used to purify solvent and process condensates. Adsorbents/ion exchange minerals used for condensate and UNH purification.
6. Dry Particulates	0.0002-0.006 0.002 0.034 0.038	Iodine removal adsorbents, zeolites Ruthenium adsorbent beds. UF ₆ adsorbent beds. UF ₆ fluorinator beds and fines.
7. Combustible Solids	0.2 0.9 0.16	Miscellaneous combustible trash (uncompacted). Miscellaneous combustible trash (uncompacted) Ventilation filters (up to 60 wt% combustible).
8. Noncombustible Solids	0.03 0.02-0.4	General trash. Failed equipment, packaged deep bed filters.
TOTAL	2.6 - 3.0	

(a) MTHM - Metric Tons Heavy Metal. Volumes are based on annual throughput of MTHM at a large (~1500 MTHM/yr) reprocessing plant. Amounts are representative of typical facilities, but not all facilities will have the full spectrum of wastes.

linearly from the value of 0.007 (early 1980's) to 0.0025 in 1990's, after which it remains constant. The steady-state value of 0.0025 was estimated for large-scale production.⁵⁹

The volume of solid alpha-containing waste which will be generated in the future is likewise uncertain and depends on such factors as changes in regulations and incentive for volume reduction.

5.3 ENRICHMENT PLANT OPERATIONS³⁷

While laser enrichment and gas centrifugation offer alternatives for future enrichment, the present discussion is limited to the gaseous diffusion plants.

Gaseous diffusion operating experience has been very limited in terms of large throughputs of power reactor returns. Although there has been considerable production reactor material returned to the cascade, irradiation exposure of that material has been ten- to twenty-fold less than that for power reactors. Experience to date has indicated the following:

- A significant quantity of all non-uranium radioactivity (neptunium, plutonium, and fission products) is retained in the feed cylinder (UF_6 tank) and will be removed when and where the returned cylinder is washed.
- PuF_6 and NpF_6 are easily reduced and therefore removed by trapping with CoF_2 , MgF_2 , NaF , cryolite, etc.
- Technetium, compared to other fission or alpha emission products, is less likely to be removed by any process. Experience at Oak Ridge Gaseous Diffusion Plant indicates that technetium release to the environment would be 10 percent of feed to the liquid effluent and one percent of feed to the gaseous effluent.
- Experience also indicates that other fission products and alpha radioactivity release fractions should be no more than one-tenth of that for technetium. Measurements of gaseous and liquid effluents have failed to identify any other fission products. However release fractions of one percent to the liquid effluent and 0.1 percent to the gaseous effluent for other fission products will be used below to estimate environmental releases.

- Cobaltous fluoride traps exhibit decontamination factors of 400 for neptunium and 10^3 for plutonium prior to feeding to the cascade or conversion facility.
- A large portion of the radioactivity entering a settling pond will be entrained in the sludge of the pond.

The bulk of the radioactivity will be released as solids, either entrained on adsorbate or equipment removed from service for disposal. Liquid waste will be generated by rinsing (decontamination) of recycled equipment. The first rinse solution, which contains the bulk of the radioactivity, is saved to be used as the dilute acid wash solution. Subsequent rinses are sent to the primary holding pond.

Gaseous wastes can result from purge system venting, venting of evaporator overheads at the uranium recovery facility, and venting of decontamination hoods in the recycle facility. However, the exact breakdown for retention and release factors for each step is not known. One can only make assumptions based on experience with gaseous diffusion. The limited experience available was used to arrive at the estimates in Table 5-7 about gaseous, liquid, and solid discharges for non-uranium radioactivity.

5.4 OTHER POTENTIAL SOURCES

5.4.1 MEDICAL APPLICATIONS⁷⁵

During the past 25 years, clinical applications of radioactive materials have become a major branch of medicine. In particular, gamma-ray-emitting isotopes are now commonly used for the purpose of imaging specific areas or organs in the body. The normal technique used in a scanning procedure is to give the patient an injection of the isotope in the appropriate chemical form to localize it in the desired organ or system, and collect the emitted gamma radiation on an imaging device. In 1972, some 6,355,000 procedures were performed in 3,300 hospitals in 1,500 cities in the United States using radiopharmaceuticals.⁷⁴ Radioisotopes of iodine were among the first such materials used. Their use in the study of thyroid physiology and in the diagnosis and treatment of thyroid disorders

TABLE 5-7

ASSUMED DISTRIBUTION OF FISSION PRODUCTS
AND TRANSURANIUM ISOTOPES TO ATMOSPHERE,
PRIMARY HOLDING POND, AND BURIAL GROUND

<u>Isotope</u>	<u>Fraction Released to Atmosphere</u>	<u>Fraction Released to Primary Holding Pond</u>	<u>Fraction Input to Burial Ground</u>
NP-237	2×10^{-7}	4×10^{-6}	~1.0
Other Transuranium	8×10^{-10}	1.6×10^{-8}	~1.0
Tc-99	0.01	0.10	0.89
Fission Products	0.001	0.01	0.989

(300,000 to 540,000 administrations/year) still make them an important part of the current practice of nuclear medicine.

An example of the rapid growth of the use of organ-imaging techniques is the increased application of Tc-99m, an unstable daughter of Mo-99. Tc-99m is not, in itself, a natural component of any biological system, but its desirable properties (a six-hour half-life and 140-kev gamma ray which is well-matched to existing monitoring instruments) make it ideal for imaging. Because of these properties, relatively large amounts of Tc-99m can be administered with little radiation dose. It is estimated that nearly 5.5 million examinations were performed in 1972 using technetium. At present, one of the most useful forms is a pertechnetate used for brain scanning (1,000,000 administrations/year in 1972). Many other isotopes are now used in scanning procedures: Au-198 or I-131 for the liver (380,000 administrations/year in 1972), I-131 for the lungs (246,000 administrations/year in 1972), Hg-203 for the kidneys (67,000 in 1972), etc.⁴⁸

Isotopes with more energetic emissions, such as Co-60 and Cs-137, are used in therapeutic situations where the radiation is used to destroy localized malignancies. No TRU radioisotopes are presently utilized in these applications. However, the current generation of heart pacemakers does utilize plutonium as an energy source and as such does make this part of the medical industry a source of TRU-contaminated waste.

5.4.2 THE WELL-LOGGING INDUSTRY

Well-logging firms use radioisotopes in down-hole measurements to provide information on the underground strata and to assess a well's capability for secondary and tertiary recovery. In a typical logging operation, a neutron source and a gamma source are placed in an instrumentation package and lowered by means of a cable to the bottom of the bore hole. The package is then withdrawn slowly while the instrumentation detects the neutrons and gamma rays backscattered from the surrounding strata, and the detected signals are displayed on a chart recorder. The results yield information about the properties of rock formations as a function of depth.

Typically, an americium-beryllium neutron source of five to 20 curies and a Cs-137 gamma-ray source of several curies are used.⁴⁸ Each source is enclosed inside two small, stainless-steel cylinders, one inside the other, with welded end caps. Sources are fabricated in a hot cell by a service company, which purchases the radioisotopes from a company having access to a production reactor. Some logging firms and some oil companies also use radioactive tracers, usually I-131, Kr-85, or tritiated water, that are injected into a well to monitor its flow properties. Thus the americium-beryllium source is a TRU waste source.

5.4.3 THE RADIOGRAPHY INDUSTRY

Radiography sources are made primarily from one of two isotopes, Ir-192 or Co-60, both of which emit relatively high energy gamma rays. The radiation is used to examine the structural integrity of welded joints, principally in large pipes, frames, and pressure vessels, or to determine the thickness of a material. No TRU material is utilized.

5.4.4 LARGE CURIE SOURCES

Teletherapy sources containing large quantities of Co-60 (up to 10,000 curies) are fabricated and shipped to cancer treatment centers both in the United States and abroad. Irradiator sources, usually Co-60 or Cs-137, are used for research or in large-scale food sterilization operations and contain hundreds of thousands of curies.

5.4.5 RADIOACTIVE GAUGING SOURCES

A number of different gauging techniques use radioactive materials fabricated in sealed-source form. Material thickness is measured by detecting the variation in beta or gamma radiation that is transmitted through the material. Examples are thickness measurements of paper, rubber, plastic sheet, metal foil, and pipe wall. The material level of solids or liquids is measured by detecting a change in transmitted radiation through tanks, bins, boxes, bottles, cans, or other containers. Fluid densities and bulk densities of solids are measured by detecting

transmitted radiation. Coating thicknesses of adhesives, paints, or anticorrosives are measured by detecting transmitted or backscattered radiation. Moisture content is measured by detecting the degree of neutron thermalization.

A number of different isotopes, usually in sealed source form and including Ra-226, Cs-137, Co-60, Kr-85, Sr-90, Am-241, Pm-147, and Th-204, are used in the individual sources, which contain from a few millicuries up to several curies of activity. The radioactive materials used by the source manufacturers are obtained from suppliers of by-product material.⁴⁸

5.4.6 RADIOISOTOPE THERMOELECTRIC GENERATORS

Cm-244 is a potentially economic fuel material in heat sources for radioisotope thermoelectric generators, when recovered from LWR spent fuel. Requirements for the curium include 97 percent minimum product purity.

5.4.7 OTHER NUCLEAR POWER APPLICATIONS

The Naval Nuclear Propulsion Program uses highly enriched uranium (>90 percent U-235) in a PWR system. Like other reactor types, uranium is enriched as UF_6 by gaseous diffusion for fabrication into fuel elements. Because very little U-238 is present in the fuel, only very small quantities of plutonium are produced by neutron irradiation in the reactor. The recovered U-235 is re-enriched for reapplication to the fuel cycle.

6.0 TRU-CONTAMINATED WASTE INVENTORY

This section discusses the present TRU-contaminated waste inventory from both DOE facilities and commercial operations. The information is presented from best available data. Some discrepancies are noticed but these reflect differences in reporting periods, accuracy of measurements and differences between generation rates and buried quantities (due to volume reduction and packaging).

6.1 DOE FACILITIES

The TRU waste inventory from the DOE facilities, discussed in Section 3.0, includes a diverse number of waste materials and a wide range of radioactivity levels and isotopic composition. It is important to note that the TRU-contaminated waste, i.e., above 10nCi/g TRU, only makes up about 20 percent of the present annual DOE facilities' waste generation rate.¹⁷ Individual characterization of the DOE generated waste is provided in Appendices B through E.

The TRU waste is currently separated into waste containing greater than 10 nCi of TRU radioisotopes per gram and those containing less.⁶¹ These TRU wastes are also designated as retrievably or non-retrievably stored. The estimated total volumes of TRU waste buried or stored each fiscal year from 1973 to 1976 at DOE sites, show a factor of nearly 2 decrease from 4,695 m³ to 2,240 m³ in non-retrievable storage while the average annual volume in retrievable form remained roughly constant at 9,600 m³, with a volume range of 7,630 m³ to 11,800 m³, over the same period.⁶³

At present, among the DOE installations, the Savannah River Plant (SRP), as shown in Table 6-1, produces the largest annual volume of non-retrievable waste (2,560 m³ or 54.6 percent of the non-retrievable TRU waste stored/buried in FY 1973) with an expected decrease to 2,000-2,300 m³ accounting for 94-99 percent of the total non-retrievable TRU waste anticipated in FY 1976.⁶³ Rocky Flats produced the largest total volumes of TRU waste over this time frame (3,775 to 6,170 m³ annually), 17 to 23 percent of which is <10 nCi/g and is normally stored

TABLE 6-1

**CUMULATIVE VOLUME OF DOE-GENERATED RADIOACTIVE SOLID WASTE BURIED AND/OR STORED
AT DOE SITES OR COMMERCIAL BURIAL GROUNDS^{63,17}
(REPORTED OR PROJECTED VOLUMES)**

<u>Site for Burial/Storage</u>	Cumulative Volume (m ³) TRU Through FY 1972		TRU (m ³) FY 1973		TRU (m ³) FY 1974		TRU (m ³) FY 1975		TRU (m ³) FY 1976	
	Retrievable	Non- Retrievable	Retrievable	Non- Retrievable	Retrievable	Non- Retrievable	Retrievable	Non- Retrievable	Retrievable	Non- Retrievable
Hanford	2,025	151,515	449.2	0	658.7	0	647.8	0	515.4	0
INEL	11,727.6	50,399.3	6,420.3	824.3	4,024.4	803.3	4,704	2,463.9	4,248	1,048
LASL	123.2 ^b	4,384 ^c	629.3 ^b	4,597 ^c	564.3 ^b	2,405.4 ^c	708 ^b	2,407 ^c	736 ^b	2,379
Nuclear Engineering Co.	0	14,203.8	0	1,569.1	0	1,097.4	56.6	29.58	28.3	23.8
Nuclear Fuel Services	a	a	0	a	a	a	0	0	0	0
ORNL	483.9	5,664.1	119.3	0	195.4	0	240.8	0	226.6	0
Sandia	64.7	0.57	56.6	0.28	78.4	0	108.5	0	114.5	0
SRP	785.9	23,492	110.5	2,577.2	174.2	2,648	849.6	1,982.4	1,132.8	2,407
a Unknown b >10 nCi/g c All LASL Waste <10 nCi/g assumed to be buried non-retrievably TB Terminated Burial/Storage

non-retrievably. Only in FY 1975, when a special "sludge clearing" operation was scheduled, did the estimate of this type of non-retrievable waste approach 40 percent. All Rocky Flats TRU waste is shipped to the Idaho National Engineering Laboratory (INEL) for disposal.

An increase in waste Pu stored or buried from a cumulative total of 820 kg in FY 1972 to 1,030 kg in FY 1975 and to about 1,135 kg in FY 1977 is shown in Figure 6-1. The Mound Facility, which usually discards 0.5 to 1 kg of Pu per year, began in FY 1975 to ship such waste to INEL for disposal rather than to commercial burial grounds. The Pu contained in DOE-generated TRU waste shipped to commercial burial grounds was expected to total 7.2 kg by the end of FY 1976. The total Pu buried in commercial burial grounds, however, was estimated at 80 kg at the end of FY 1974, at 113 kg at the end of FY 1975, and 124.3 kg at end of FY 1976.⁶³ The difference between these values and the ones reported here from DOE sites are due to commercially generated Pu wastes (e.g., from fuel reprocessing and fuel fabrication) that are shipped to commercial burial grounds for disposal. The TRU waste volumes buried or stored at DOE sites and their TRU contents are given in Tables 6-2 and 6-3.

The total volume of waste generated annually is always larger than the annual volume buried and stored because several sites use compaction as a means of volume reduction. Volume reduction factors in the order of 4:1 or 5:1 are commonly obtained by hydraulic compaction of most ordinary radioactive wastes, and incineration of combustible wastes can provide volume reduction factors of 20 or greater. Shredding or chopping of waste materials is not as effective in reducing volume as compaction but a 2:1 decrease can be readily achieved.⁶³

6.2 COMMERCIALY GENERATED TRU WASTE

As indicated in Sections 4.0 and 5.0, the commercially-generated TRU waste includes the waste generated in the nuclear fuel cycle—fuel fabrication and spent fuel reprocessing—as well as numerous miscellaneous R&D activities and small commercial use of TRU radioisotopes such as Am-241 and Cm-244. At present there is no commercial reprocessing of spent fuel and what high-level waste exists is limited to the Nuclear Fuel Services' West Valley facility.

FIGURE 6-1
CUMULATIVE AMOUNT OF DOE PLUTONIUM
BURIED AND/OR STORED AS WASTE
AS A FUNCTION OF TIME ^{63, 17}

TABLE 6-2

SOLID RADIOACTIVE WASTE GENERATED AT DOE FACILITIES WITHOUT BURIAL GROUNDS¹

Site	Cumulative Quantities through 1974			FY 1974 Quantities				
	Total (m ³)	Total (kilocuries)	TRU Volume (m ³)	TRU (kilograms)	Total (m ³)	Total (kilocuries)	TRU Volume (m ³)	TRU (kilograms)
Ames Laboratory (Ames, Iowa)	100	<1	---	---	10	---	---	1
Argonne/West (Idaho Falls, Idaho)	23,000	7	70	5	900	1	---	---
Atomics International (Santa Susana, California)	900	1	5	---	300	---	---	---
Bendix Plant (Kansas City, Missouri)	800	---	---	---	5	---	---	---
Bettis Atomic Power Lab- oratory (West Mifflin, Pennsylvania)	7,500	2	---	---	1,600	1	---	---
Brookhaven National Lab- oratory (Upton, L.I., New York)	300	45	---	---	200	45	---	---
Burlington DOE Plant (Burlington, Iowa)	5	---	---	---	---	---	---	---
Fermi National Accelerator Laboratory (Weston, Illinois)	100	---	---	---	50	---	---	---
Lawrence Berkeley Laboratory (Berkeley, California)	200	1	40	---	40	1	---	---
Lovelace Foundation Lab- oratory (Albuquerque, New Mexico)	400	<1	1	---	110	---	---	---
Mound Facility	24,000	85	17,000	5	1,500	12	1,000	1
Naval Reactors Facility (Idaho Falls, Idaho)	17,000	3,200	1	---	900	10	---	---
Pinellas Plant (Clearwater, Florida)	700	110	---	---	60	12	---	---
Rocky Flats Plant (Golden, Colorado)	88,000	310	70,000	440	7,000	16	6,000	22
Shippingport Atomic Power Station (Ship- pingport, Pennsylvania)	700	---	---	---	300	---	---	---
TOTAL	163,705	3,760	---	450	12,995	---	7,000	---

TABLE 6-3
SOLID RADIOACTIVE WASTE STORED AND BURIED AT DOE SITES

Site	Hectares	Cumulative Quantities ^{17,63}		Annual Rate (m ³)	Retrieval Storage (1977) ¹⁷	
		Total Volume m ³ - (year)	Kilocuries Buried		Volume (m ³)	TRU (kg)
Feed Materials Production Center	7.6	324,311 (1977)	0.10	175	---	---
Hanford Reservation	98.4	187,596 (1977)	2,039	6,170	7,732	67.4
Idaho National Engineering Laboratory	21.0	156,150 (1977)	3,571	6,800	32,250	266
Lawrence Livermore Laboratory	2.3	700 (1974)	NA	---	---	---
Los Alamos Scientific Laboratory	23.1	246,350 (1977)	2,665	4,000	1,704	27.7
National Lead Co. of Ohio	0.4	6,939 (1977)	< 0.10	0	---	---
Nevada Test Site	64.8	7,723 (1977)	5.01	125	90	1.3
Oak Ridge Gaseous Diffusion Plant	0.4	1,076 (1977)	<< 1	---	---	---
Oak Ridge National Laboratory	23.8	18,540 (1977)	62.65	3,170	1,319	17.8
Oak Ridge Y-12 Plant	2.1	32,800 (1977)	NA	1,460	---	---
Paducah Gaseous Diffusion Plant	0.7	6,515 (1977)	1.05	90	---	---
Pantex Plant	0.4	137.7 (1977)	<< 1	1.4	0.13	2.4
Portsmouth Gaseous Diffusion Plant	0.4	279 (1977)	<< 1	4	---	---
Sandia Laboratory	0.57	1,322 (1977)	2.4	68	0	0
Savannah River Plant	37.6	273,348 (1977)	4,270	10,735	1,563	52
Weldon Springs	3.0	43,047 (1977)	<< 1	0	---	---
TOTAL	279	1,306,834		32,799	46,658	434.6

TABLE 6-3

(CONT.)

Site	FY 1974 Quantities ⁶³		Retrievable Storage ⁶³		Annual Rate ¹⁷		Quantity Disposed of Prior to Storage	
	Total Quantities (m ³)	Kilocuries	Volume (m ³)	TRU (kg)	Volume (m ³)	TRU (kg)	Volume (m ³)	TRU (kg)
Feed Materials Production Center (Fernald, Ohio)	400	---	---	---	---	---	---	---
Hanford Works	6,500	375	700	10	1,105	14.0	---	354.6
Idaho National Engineering Laboratory	7,100	57	3,800	36	4,700	31.0	---	332.0
Lawrence Livermore Laboratory	---	---	---	---	---	---	---	---
Los Alamos Scientific Laboratory	3,900	35	370	7	510	6.3	---	4.2
National Lead Co. of Ohio (Niagara Falls, New York)	---	---	---	---	---	---	---	---
Nevada Test Site	580	---	---	---	28	0.4	---	0.23
Oak Ridge Gaseous Diffusion Plant	10	---	---	---	---	---	---	---
Oak Ridge National Laboratory	3,600	1	200	2	113	2.1	---	(a)
Oak Ridge Y-12 Plant	90	NA	---	---	---	---	---	---
Paducah Gaseous Diffusion Plant	90	NA	---	---	---	---	---	---
Pantex Plant	2	---	---	---	0	0	---	0
Pittsboro Gaseous Diffusion Plant	7	---	---	---	---	---	---	---
Sandia Laboratory	80	1	---	---	0	0	0.2	0.0001
Savannah River Plant	14,100	175	80	2	170	4.0	---	1.4
Weldon Springs	---	---	---	---	---	---	---	---
TOTAL	36,459	---	5,150	57	6,626	57.8	---	692.42

(a) not available - classified

The present inventory of TRU and TRU-contaminated waste is limited primarily to DOE-generated waste (shipments now terminated) and R&D fuel fabrication activities involving plutonium. These include some R&D activities in several LWRs as well as the Fast Flux Test Facility project.

Currently about 80,000 m³ of low-level solid wastes are buried each year at the five operating commercial burial sites. The total volume of solid radioactive waste buried at the six commercial burial sites through 1976 is 422,607 m³ (500,000 m³ -1977 est.). This waste has about 3.8 million curies (1976) of radioactivity, uncorrected for decay. About 1,676 kg of special nuclear material (SNM) is buried at the sites (1976).

The best available information indicates that the cumulative DOE-generated TRU waste (through 1976) shipped to commercial burial grounds contained about 7.6 kg of TRU isotopes. The total plutonium buried in commercial burial grounds was estimated at 80 kg at the end of FY 1974. At the end of FY 1975 an estimated 113 kg of Pu was buried at the sites or an increase of 33 kg. The cumulative TRU material through 1976 was 123.4 kg. Table 6-4 presents the breakdown of buried waste at the commercial sites.

TABLE 6-4

CUMULATIVE WASTE INVENTORY AT COMMERCIAL BURIAL SITES (1977)³, 9-14

Site	Total Volume Buried	SNM	1974	
	(10 ³ m ³)		TRU (kg)	TRU (kg)
Beatty	58.054	688.247	14.3	14.3
West Valley ^(a)	66.726	56.003	3.6	3.6
Morehead	135.016	31.260	69.1	69.1
Richland	16.238	83.235	12.7	23
Sheffield	86.634	53.962	13.4	13.4
Barnwell	142.873	456.863*	--	--

(a) West Valley was closed March 1975

* Cumulative through 1976

7.0 TRU-CONTAMINATED WASTE PROJECTIONS

Besides an inventory of presently buried/stored TRU-contaminated waste it is important to project future waste generation rates and radioactivity levels to allow policy makers an assessment vehicle to determine the impact of a proposed rulemaking change. The purpose of this section is to briefly review past projections and provide an assessment of future TRU generation rates, radioactivity levels and cumulative totals. This section discusses both DOE and commercial waste projections.

7.1 DOE WASTE PROJECTIONS

While DOE solid radwaste includes fission products and induced activity, uranium, and transuranium (TRU) waste categories, only the TRU will be discussed. The TRU waste is separated into wastes containing greater than 10 nCi/g and those containing less. These TRU wastes are also designated as retrievable and non-retrievably stored.

As discussed in Section 6.0, the DOE-generated TRU waste has shown a minor decrease since 1973 with a factor of nearly two decrease in non-retrievable storage while the average volume in retrievable form remained roughly constant. Table 7-1 presents an estimate of future TRU waste burial volumes. These values are somewhat different from the generation rates and reflect the use of volume reduction technology. Several techniques for volume reduction are now under consideration. Included are efforts to recover uranium and transurium elements by waste-partitioning methods, that is, by separation of waste streams according to their probable isotopic content. Besides this sorting activity, various technologies to compress, shred, incinerate, etc., the generated waste are being utilized. It is apparent that the most burdensome aspect of future DOE waste management is the control of the quantity and the wide and diverse range of waste materials. Present DOE waste management programs are designed to control the quantity of waste generated and, as such, while future waste generation rates may increase, the total waste buried should decrease.¹

TABLE 7-1

ESTIMATES OF FUTURE ANNUAL TRANSURANIUM SOLID WASTE
BURIED VOLUME FROM DOE FACILITIES^{17, 18, 63}

<u>Site</u>	<u>Transuranium Waste (m³)</u>
Hanford Reservation	1,105
LASL	510
INEL*	4,700
ORNL	113
Savannah River Plant	170
Other DOE Facilities	28
TOTAL	6,626

* Includes Rocky Flats generated wastes.

While the annual TRU waste generation rate is about 12,000 m³ (about 6,600 m³ buried) it is expected that this may decrease in the future due to improved waste management practices and the increased use of volume reduction technology--compaction, shredding, incineration, etc. The corresponding TRU inventory should be less than 30 kg per year. 1, 63, 17

7.2 COMMERCIAL TRU-CONTAMINATED WASTE PROJECTIONS

The projection of commercial TRU-contaminated waste from fuel cycle activities is typically performed by utilizing fuel cycle computer models such as NUFUEL, ENFORM, ORSAC, KWIPLAN, FLYER, and ALPS. These models have been designed to evaluate the nuclear fuel cycle with emphasis typically on such items as: material and process flow; isotopic composition; mass; volume and composition of process waste streams; economics, etc. For the purpose of this report a number of projections have been reviewed and the projecting basis is presented which most closely reflects the present nuclear and energy policy of the U.S. It is understood that the NRC is presently developing a modularized, integrated computer model for projecting the quantities, physical characteristics and associated storage/disposal costs of commercial nuclear wastes generated on a regional basis through the year 2000.

7.2.1 WASTE GENERATION RATE

The following discussion presents the generation of various TRU-contaminated waste streams. These rates are presented per unit throughput or electrical generation level thus allowing easy computation of cumulative volumes depending upon the nuclear energy generating capacity scenarios utilized.

7.2.1.1 CLADDING WASTE

Cladding waste consists of solid fragments of zircaloy and stainless steel cladding and other structural components of the fuel assemblies that remain after the fuel cores have been dissolved. In addition to neutron induced radioactivity, the cladding waste contains 0.05 percent of actinides and 0.05 percent of the

non-volatile fission products of the spent fuel. It is estimated that after compaction to 70 percent of theoretical density, the final volumes will be 0.07, 0.08 and 0.25 cubic meter per metric ton of PWR, BWR and LMFBR fuel, respectively. The compacted cladding is packaged in canisters containing 0.1 cubic meter of waste.^{49, 60}

Tables 7-2 and 7-3 present typical TRU-isotopic composition for cladding waste.

7.2.1.2 LOW-LEVEL TRANSURANIC WASTE

Low-level TRU wastes are defined for this report as those solid materials that contain plutonium and other transuranic long-lived alpha emitters in concentrations greater than 10 nCi per gram yet have sufficiently low external radiation levels that they can be handled safely without shielding. Low-level TRU wastes arise principally at fuel preparation and fabrication plants and enrichment facilities and to lesser extents at fuel reprocessing plants. They consist of a wide variety of solid materials, including those items made of paper, cloth, wood, plastic, rubber, glass, ceramic and metals, as well as immobilized salt and sludges that arise in the treatment of liquid waste streams and filters from cleanup of off-gas. The transuranic element content of these wastes ranges from trace amounts to several grams per cubic meter and averages about nine (9) grams per cubic meter. The densities of the uncompacted waste vary from 35 kg per cubic meter to as much as 3,500 kg per cubic meter; about 1/2 to 2/3 of these wastes by volume are combustible and can be reduced via incineration by factors of 20 and 10 in volume and weight respectively; about 1/2 to 3/4 of the waste by volume can be reduced by factors of two to 10 through compaction.⁴⁹

A survey of operations at DOE laboratories and production facilities indicates that future large plants will generate about 283, 566, and 113 cubic meters of uncompacted low-level TRU waste per ton of plutonium processed for fuel preparation, fabrication, and reprocessing respectively. An average plutonium concentration in the waste is nine (9) grams per cubic meter representing fuel losses of 0.25 percent in preparation, 0.5 percent in fabrication, and 0.1 percent in reprocessing. The isotopic composition of the plutonium is: one (1) percent

TABLE 7-2

CURIES OF TRU RADIOISOTOPES IN THE CLADDING WASTE
FROM ONE METRIC TON OF URANIUM-ENRICHED FUEL⁴⁹

	<u>PWR</u> ^(a)		
	DISCHARGE	10 Years	100 Years
Np-239	8.67E-03	8.66E-03	8.59E-03
Pu-238	2.50E-01	2.63E-01	1.32E-01
Pu-239	1.62E-01	1.62E-01	1.62E-01
Pu-240	2.41E-01	2.42E-01	2.41E-01
Pu-241	6.18E-01	3.85E-01	5.36E-01
Am-241	1.19E-01	8.99E-01	1.92E-01
Am-242M	3.62E-03	3.46E-03	2.30E-03
Am-242	3.62E-03	3.46E-03	2.30E-03
Am-243	8.67E-03	8.66E-03	8.59E-03
Cm-242	6.84E-00	2.84E-03	1.88E-03
Cm-243	1.46E-03	1.18E-03	1.68E-04
Cm-244	9.86E-01	6.73E-01	2.14E-02
Total	7.05E01	4.07E01	3.04E00

	<u>BWR</u>		
	DISCHARGE	10 Years	100 Years
Np-239	6.81E-03	6.81E-03	6.75E-03
Pu-238	1.00E-00	9.49E-01	4.73E-01
Pu-239	1.52E-01	1.52E-01	1.52E-01
Pu-240	2.33E-01	2.34E-01	2.33E-01
Pu-241	5.38E-01	3.34E-01	4.67E-01
Am-241	1.30E-01	8.08E-01	1.69E-00
Am-242M	5.95E-03	5.68E-03	3.77E-03
Am-242	5.95E-03	5.68E-03	3.77E-03
Am-243	6.81E-03	6.81E-03	6.75E-03
Cm-242	5.08E-00	4.66E-03	3.09E-03
Cm-244	7.54E-01	5.14E-01	1.64E-02
Total	6.11E01	3.61E01	3.06E00

(a) 8.67E-03Ci is equivalent to 8.67×10^{-3} Ci

TABLE 7-3

CURIES OF TRU RADIOISOTOPES IN THE CLADDING WASTE
FROM ONE METRIC TON OF PLUTONIUM-ENRICHED FUEL⁴⁹

	<u>PWR</u> ^(a)			
	CHARGE	DISCHARGE	10 Years	100 Years
Np-239	0.0	1.36E-01	1.36E-01	1.35E-01
Pu-238	1.71E04	8.91E00	8.64E-00	4.35E00
Pu-239	1.37E03	3.37E-01	3.37E-01	3.36E-01
Pu-240	2.55E03	1.00E00	1.03E00	1.06E00
Pu-241	6.76E05	2.98E02	1.86E-02	2.60E00
Pu-242	1.48E01	9.29E-03	9.30E-03	9.30E-03
Am-241	0.0	1.00E00	4.76E-00	9.64E00
Am-242M	0.0	1.84E-01	1.76E-01	1.17E-01
Am-242	0.0	1.84E-01	1.76E-01	1.17E-01
Am-243	0.0	1.36E-01	1.36E-01	1.35E-01
Cm-242	0.0	8.48E-01	1.44E-01	9.58E-02
Cm-243	0.0	1.35E-02	1.09E-02	1.55E-03
Cm-244	0.0	2.72E01	1.85E-01	5.90E-01
Cm-245	0.0	7.82E-03	7.81E-03	7.73E-03
Cm-246	0.0	1.50E-03	1.50E-03	1.48E-03

Total	6.97E05	4.22E02	2.20E02	1.92E01
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	<u>BWR</u>			
	CHARGE	DISCHARGE	10 Year	100 Year
Np-239	0.0	1.09E-01	1.08E-01	1.08E-01
Pu-238	1.75E04	9.47E00	9.04E-00	4.52E-00
Pu-239	1.17E03	2.92E-01	2.92E-01	2.92E-01
Pu-240	2.37E03	9.44E-01	9.60E-01	2.92E-01
Pu-241	5.30E05	2.49E02	1.55E-02	2.17E-00
Pu-242	1.23E01	7.49E-03	7.49E-03	7.49E-03
Am-241	0.0	1.12E00	4.25E-00	8.28E-00
Am-242M	0.0	1.16E-01	1.10E-01	7.32E-02
Am-242	0.0	1.16E-01	1.10E-01	7.32E-02
Am-243	0.0	1.09E-01	1.08E-01	1.08E-01
Cm-242	0.0	5.79E01	9.06E-02	6.01E-02
Cm-243	0.0	8.72E-03	7.02E-03	1.00E-03
Cm-244	0.0	1.96E01	1.34E-01	4.26E-01
Cm-245	0.0	9.05E-03	9.04E-03	8.98E-03
Cm-246	0.0	1.66E-03	1.66E-03	1.63E-03

Total	5.51E05	3.39E02	1.83E-02	1.71E-01
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(a) 1.36E-01 Ci is equivalent to 1.36×10^{-1} Ci

TABLE 7-3

(CONT.)

	<u>LMFBR</u>			
	CHARGE	DISCHARGE	10 Years	100 Years
Np-239	0.0	2.71E-02	2.70E-02	2.68E-02
Pu-238	2.73E04	9.40E00	8.83E00	4.40E00
Pu-239	3.21E03	1.93E00	1.93E00	1.92E00
Pu-240	4.66E03	2.62E00	2.62E00	2.62E00
Pu-241	1.00E06	2.96E02	1.84E02	2.57E00
Pu-242	1.32E01	7.17E-03	7.17E-03	7.17E-03
Am-241	0.0	1.13E00	4.85E00	9.67E00
Am-242M	0.0	5.64E-02	5.39E-02	3.58E-02
Am-242	0.0	5.64E-02	5.39E-02	3.58E-02
Am-243	0.0	2.71E-02	2.70E-02	2.68E-02
Cm-242	0.0	2.77E01	4.42E-02	2.93E-02
Cm-243	0.0	2.26E-02	1.82E-02	2.60E-03
Cm-244	0.0	7.39E-01	5.04E-01	1.60E-02
Total	1.03E06	3.40E02	2.03E02	2.13E01

Pu-238, 59 percent Pu-239, 24 percent Pu-240, 12 percent Pu-241 and four (4) percent Pu-242. It is assumed that the wastes are compacted or otherwise reduced in volume by factors of three to 10 before burial.⁴⁹

7.2.1.3 INTERMEDIATE-LEVEL TRANSURANIC WASTE

Intermediate-level transuranic waste is defined for the purposes of this report as those solids or solidified materials other than high-level and cladding waste that contain long-lived transuranic alpha particle emitters in concentrations greater than 10 nanocuries per gram and have after packaging typical surface dose rates between 10 and 1,000 mrem/hour due to fission product contamination. About 283 cubic meters of this type of waste containing an average of one gram per cubic meter of plutonium and other actinides are generated at reprocessing plants per ton of plutonium processed. This corresponds to a plutonium loss of about 0.025 percent. Like low-level transuranic waste, this waste is assumed to be reduced in volume before buried by a factor of three to 10.⁴⁹

7.2.1.4 NON-TRANSURANIC WASTE

Non-transuranic waste is composed of those diverse materials that are contaminated with low levels of beta- and gamma-emitting isotopes, but contain less than 10 nCi of long-lived alpha activity per gram. This waste, which is common to all nuclear facilities, generally has a radioactivity level in the range of 0.035 to 35 curies per cubic meter. About 566, 1,132 and 227 cubic meters of non-transuranic waste per ton of plutonium will be generated at plutonium conversion, fuel fabrication and fuel reprocessing plants respectively.⁴⁹ This waste is reduced in volume as will be the low- and intermediate-level TRU waste. The average composition before volume reduction is 35 microcuries per cubic meter of LWR fission products.

7.2.2 OTHER CONTAMINATED WASTES

As discussed in Section 5.0, there are other potential TRU-contaminated waste sources. Future projections will be based upon past experience as such data is made available.

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APPENDICES

APPENDIX A
GLOSSARY¹
AND
METRIC TO ENGLISH CONVERSION FACTORS

TERA CORPORATION

Actinide Series: The series of elements beginning with actinium, element No. 89, and continuing through lawrencium, element No. 103, which together occupy one position in the periodic table. The series includes uranium, element No. 92, and all the manmade transuranium elements. The group is also referred to as the "actinides."

Activations: The process of making a material radioactive by bombardment with neutrons, protons, or other nuclear particles. Also called radio-activation. The resultant radioactive materials are commonly called activation products.

Activity: A measure of the rate at which a material is emitting nuclear radiations; usually given in terms of the number of nuclear disintegrations occurring in a given quantity of material over a unit of time; the standard unit of activity is the curie (Ci).

Alpha Waste: Waste material that is contaminated by radionuclides that emit alpha particles, particularly (in this text) the transuranium elements.

Cladding Waste (hulls): Fuel rods in most nuclear reactors today are made up of fissionable materials clad in a protective alloy sheathing that is relatively resistant to radiation and the physical and chemical conditions that prevail in a reactor core. The spent fuel rods, after removal from the reactor and storage to permit radioactive decay of the short-lived fission products, are removed and in certain fuel cycle processing systems are chopped up, and the residues of the fissionable materials are leached out chemically. The remaining residues, principally the now radioactivated cladding material (zirconium alloys, stainless steel, etc.) and insoluble residues of nuclear fuel, fission products, activation products and transuranium nuclides, are left behind as cladding waste, which is a special category of transuranium radioactive waste.

Crib: A back-filled burial trench into which intermediate-level liquid waste is distributed through a perforated pipe.

Critical: The condition in which a material is undergoing nuclear fission at a self-sustaining rate; the critical mass of a material is the amount that will self-sustain nuclear fission when placed in an optimum arrangement in its present form.

Curie (Ci): A unit of radioactivity defined as the amount of a radioactive material that has an activity of 3.7×10^{10} disintegrations per second (d/s); millicurie (mCi) = 10^{-3} curie; microcurie (μ Ci) = 10^{-6} curie; nanocurie (nC) = 10^{-9} curie; picocurie (pCi) = 10^{-12} curie; femtocurie (fCi) = 10^{-15} curie.

Decommissioning: The process of removing a facility or area from operation and decontaminating and/or disposing of it or placing it in a condition of standby with appropriate administrative and physical controls and safeguards.

Decontamination: The selective removal of radioactive material from a surface or from within another material.

Disposal: The planned release or placement of waste in a manner that precludes recovery.

Engineered Storage: The storage of radioactive wastes, usually in suitable sealed containers, into any of a variety of structures especially designed to protect them from water and weather and to help keep them from leaking to the biosphere by accident or sabotage.

Fertile Material: A material, not itself fissionable by thermal neutrons, that can be converted into a fissile material by irradiation in a reactor. There are two basic fertile materials, uranium-238 and thorium-232. When these fertile materials capture neutrons, they are partially converted into fissile plutonium-239 and uranium-233, respectively.

Fissile Materials: While sometimes used as a synonym for fissionable material, this term has also acquired a more restricted meaning, namely, any material fissionable by neutrons of all energies, including (and especially) thermal (slow) neutrons as well as fast neutrons; for example, uranium-235 and plutonium-239.

Fission: The splitting of a heavy nucleus into two approximately equal parts (which are nuclei of lighter elements), accompanied by the release of a relatively large amount of energy and generally one or more neutrons. fission can occur spontaneously, but usually is caused by nuclear absorption of gamma rays, neutrons, or other particles.

Fissionable Material: Commonly used as a synonym for fissile material. The meaning of this term also has been extended to include material that can be fissioned by fast neutrons only, such as uranium-238. Used in reactor operations to mean fuel.

Fission Products (F.P.): The nuclei (fission fragments) formed by the fission of heavy elements, plus the nuclides formed by the fission fragments' radioactive decay.

Fuel (nuclear, reactor): Fissionable material used as the source of power when placed in a critical arrangement in a nuclear reactor.

Fuel Cycle: The complete series of steps involved in supplying fuel for nuclear power reactors. It includes mining, refining, the original fabrication of fuel elements, their use in a reactor, chemical processing to recover the fissionable material remaining in the spent fuel, reenrichment of the fuel material, refabrication into new fuel elements, and management of radioactive waste.

Fuel Separation (fuel reprocessing): Processing of irradiated (spent) nuclear reactor fuel to recover useful materials as separate products, usually separation into plutonium, uranium, and fission products.

Half-life (T_{1/2}): The time in which half the atoms of a particular radioactive substance disintegrate to another nuclear form. Measured half-lives vary from millionths of a second to billions of years.

Health Physics: The science concerned with recognition, evaluation, and control of health hazards from ionizing and nuclear radiations.

High-level Liquid Waste (HLLW): The aqueous waste resulting from the operation of the first-cycle extraction system (Purex Process), equivalent concentrated wastes from subsequent extraction cycles, or equivalent wastes from a process not using solvent extraction, in a facility for processing irradiated reactor fuels.

Ion Exchange: A chemical process involving the reversible interchange of various ions between a solution and a solid material, usually a resin. It is used to separate and purify chemicals, such as fission products, rare earths, in solution.

Ionizing Radiation: Any radiation displacing electrons from atoms or molecules, thereby producing ions. Examples: alpha, beta, and gamma radiation.

Isotope: One of two or more atoms with the same atomic number (the same chemical element) but with different atomic weights. An equivalent statement is that the nuclei of isotopes have the same number of protons but different numbers of neutrons. Isotopes usually have very nearly the same chemical properties, but somewhat different physical properties.

Licensed Material: Source material, special nuclear material, or by-product material received, possessed, used, or transferred under a general or special license issued by the U.S. Nuclear Regulatory Commission or an Agreement State.

Long-lived Isotope: A radioactive nuclide that decays at such a slow rate that a quantity of it will exist for an extended period.

Man-rem: A unit in health physics to compare the effects of different amounts of radiation on groups of people. It is obtained by multiplying the average dose equivalent to a given organ or tissue (measured in rems, which see) by the number of persons in that population.

Nuclide: A species of atom having a specific mass, atomic number, and nuclear energy state. These factors determine the other properties of the element, including its radioactivity.

Plutonium (Pu): A heavy, radioactive, manmade, metallic element with atomic number 94. Its most important isotope is fissionable plutonium-239, produced by neutron irradiation of uranium-238. It is used for reactor fuel and in weapons.

Rad (acronym for radiation absorbed dose): The basic unit of absorbed dose of ionizing radiation.

Radiation: The emission and propagation of energy through matter or space by means of electromagnetic disturbances, which display both wave-like and particle-like behavior; in this context the "particles" are known as photons. Also, the energy so propagated. The term has been extended to include streams of fast-moving particles (alpha and beta particles, neutrons, cosmic radiation, etc.). Nuclear radiation is that emitted from atomic nuclei in various nuclear reactions, including alpha, beta, and gamma radiation and neutrons.

Radioactive Contamination: Deposition of radioactive material in any place where it may harm persons, spoil experiments, or make products or equipment unsuitable or unsafe for some specific use. The presence of unwanted radioactive matter. Also radioactive material found on the walls of vessels in used-fuel processing plants, or radioactive material that has leaked into a reactor coolant. Often referred to only as contamination.

Radioactivity (often shortened to "activity"): The spontaneous decay or disintegration of an unstable atomic nucleus, usually accompanied by the emission of ionizing radiation. The word radioactivity is often used to refer to radioactive materials or radioactive nuclides, but this usage is not, strictly speaking, correct. Radioactivity is a process, not a substance.

Radioisotopes: A radioactive isotope. An unstable isotope of an element that decays or disintegrates spontaneously, emitting radiation. More than 1,300 natural and artificial radioisotopes have been identified.

Radwaste: Waste materials that are contaminated with radioactive materials.

Rem: A unit of measure for the dose of ionizing radiation that gives the same biological effect as 1 roentgen of x rays; 1 rem equals approximately 1 rad for X, gamma, or beta radiation.

Roentgen (abbreviation r): A unit of exposure to ionizing radiation. It is that amount of gamma or X rays required to produce ions carrying one (1) electrostatic unit of electrical charge (either positive or negative) in one (1) cubic centimeter of dry air under standard conditions. Named after Wilhelm Roentgen, German scientist who discovered X rays in 1895.

Short-lived Isotopes: A radioactive nuclide that decays so rapidly that a given quantity is transformed into its daughter products within a short period (usually those with a half-life of days or less).

Solid wastes (radioactive): Either solid radioactive material or solid objects that contain radioactive material or bear radioactive surface contamination.

Special Nuclear Material (SNM): Plutonium, uranium-233, uranium-235, or uranium enriched to a higher percentage than normal of the 233 or 235 isotopes.

Tanks: A large metal container located above ground or underground for storage of liquid wastes.

Tank Farm: An installation of interconnected underground containers (tanks) for storage of high-level waste.

Transuranium: Nuclides having an atomic number greater than that of uranium (i.e., greater than 92). The principal transuranic radionuclides of concern in radioactive waste management are tabulated below with their half-lives:

<u>Nuclide</u>	<u>Half-Life (Years)</u>	<u>Principal Decay Modes</u>
neptunium-237	2,140,000	alpha
plutonium-238	86	alpha, spontaneous fission
plutonium-239	24,390	alpha, spontaneous fission
plutonium-240	6,580	alpha, spontaneous fission
plutonium-242	379,000	alpha
americium-241	458	alpha
americium-243	7,950	alpha
curium-245	9,300	alpha
curium-246	5,500	alpha, spontaneous fission

The transuranium nuclide produced in largest amounts is plutonium-239; americium-241 is also produced in significant amounts. One system of classification used at Oak Ridge includes U-235 (162,000 year half-life, alpha decay) among the transuranium isotopes, although, strictly speaking this is not accurate.

Uranium: A radioactive element with the atomic number 92 and, as found in natural ores, an average atomic weight of approximately 238. The two principal natural isotopes are U-235 (0.7 percent of natural uranium), which is fissionable, and U-238 (99.3 percent of natural uranium), which is fertile. Natural uranium also includes a minute amount of U-234.

METRIC TO ENGLISH CONVERSION FACTORS

<u>To Obtain</u>	<u>Multiply</u>	<u>By</u>
Acres	Hectares	2.471
Cubic Feet	Cubic Meters	35.314
Feet	Meters	3.281
Gallons	Liters	0.2642
Inches	Centimeters	0.3937
Miles	Kilometers	0.6214
Pounds	Kilograms	2.2046
Square Feet	Square Meters	10.764
Tons (Short)	Tons (Metric)	1.1023
Temperature ($^{\circ}\text{F}$)	($^{\circ}\text{C} + 17.78$)	1.8

APPENDIX B

HANFORD RESERVATION

TERA CORPORATION

1.0 BACKGROUND ON HANFORD HIGH-LEVEL WASTE MANAGEMENT

The semiarid Hanford Reservation site occupies about 1,480 square kilometers of the southeastern part of the State of Washington. The reactor facilities are located along the Columbia River in what is known as the 100 Area. The reactor fuel processing and waste management facilities are in the 200 Area which is on a plateau about 11 kilometers from the river. The 300 Area, just north of Richland, contains the reactor fuel manufacturing facilities and the research and development laboratories.

In early 1943, the United States Army Corps of Engineers selected the Hanford site as the location for reactor and chemical separation facilities for the production and purification of plutonium for possible use in nuclear weapons (Manhattan Project). A total of eight graphite-moderated reactors using the Columbia River water for once-through cooling, and a new type of dual purpose reactor (N-Reactor) using a recirculating water coolant and producing both plutonium and steam for electricity, were eventually built along the Columbia River. Today, only the N-Reactor remains in operation.¹⁶

Defense high-level radioactive waste resulting from the chemical processing of spent nuclear fuel for recovery of plutonium, uranium and neptunium has been accumulated at the Hanford Reservation since 1944. The waste containing most of the fission products and comparatively small quantities of uranium, plutonium and other actinides was originally stored as liquid in 149 underground single-shell storage tanks.¹⁵ This liquid contains significant quantities of solids in the form of precipitated sludge. Beginning in 1958, problems were experienced with liquid leaking from some of these tanks. As a result, waste management activities since the 1960's have been primarily in the area of reduction of the volume of liquid waste by evaporation of the water to form an immobile solid (salt) and residual liquor. Residual liquor is the liquid formed from the currently used evaporated-crystallizer systems which upon additional concentration would form a hygroscopic solid unsuitable for storage in single-shell tanks. The majority of the high-heat emitting radioisotopes, Sr-90 and Cs-137, is removed from the waste by means of a fractionization process which converts these isotopes to

solid strontium fluoride and cesium chloride compounds which are then placed in double-walled capsules for storage in water basins. In addition to this activity, an additional waste-management program has been initiated to construct double-shell tanks. All pumpable liquids will be stored in these high-integrity tanks by the early 1980's. No reactor-fuel reprocessing waste has been accumulated since 1972 when the Purex Chemical Processing facility was last in operation. However this facility was scheduled to start up again in 1978 to process accumulated and future N-Reactor fuel. This has recently been indefinitely delayed.

Upon completion of the current fractionization and solidification program in the early 1980's, defense high-level waste inventory will consist of approximately:

- 95 million liters (bulk) of damp salt cake
- 41.6 million liters (bulk) of damp sludge
- 11.4 million liters of liquid waste awaiting solidification
- 41.6 million liters of residual liquor
- 2900 capsules of Sr-90 and Cs-137

2.0 DESCRIPTION OF FACILITIES AND RADIOACTIVE WASTE INVENTORIES

The DOE facilities at the Hanford Reservation include nuclear reactors for plutonium production (100 Area); fuels and plutonium processing and high- and low-activity radioactive waste management (200 Area); fuel fabrication (300 Area); laboratory complex (300 Area); the Fast Flux Test Facility (400 Area); central service facility (1100 Area); on-site construction services (3000 Area); and administrative services (700 Area).

Solid wastes contaminated with mixed fission and activation products have been disposed of by shallow land burial at the Hanford site since the beginning of operations in 1944. A total of 26 sites in the 100 Area (26 ha), 28 sites in the 200 Area (68 ha), and 11 sites in the 300 and 600 Area (26 ha) have been used for the storage and disposal of solid radioactive waste.¹⁷ Various facilities are discussed below.

2.1 100 AREA - REACTOR FACILITIES¹⁶

The 100 Area contains:

- One operating reactor (N-Reactor)
- Eight retired or standby reactors
- Cribs and burial grounds

All current wastes are shipped to the 200 Area for disposal, however, 1.6×10^4 m³ of solid waste was buried in the past as well as current N-Reactor primary coolant release to the 100-N crib.

Detailed records were not kept in the past; however, total estimated input inventories at the reactor facilities through 1972 are:

<u>Radionuclide</u>	<u>Ci</u>
Sr-90, Cs-137 and Pu-239	160
Eu-152 and Pu-239	650
Co-60	76,100
Fe-59	150,000

Total estimated input inventories for crib and burial grounds through 1972 (except for 100-N Crib) are:

<u>Radionuclide</u>	<u>Ci</u>
Co-60	25,900
Sr-90	34
Pu-239	0.38
Zn-65	1,000
Mn-54 and Zr-95	3,500

Total estimated input inventories for the 100-N Crib through 1972 are:

<u>Radionuclide</u>	<u>Ci</u>
Co-60	2,000
Sr-90	50
Mn-54 and Zr-95	950
Cs-137	350
All others	350
Total	3,700

A detailed discussion of the 100 Area is found in Reference 16.

2.2 200-AREA REACTOR FUEL PROCESSING AND WASTE MANAGEMENT FACILITIES¹⁶

In addition to the fuel processing facilities the following waste disposal facilities receive waste from all other Hanford areas, as well as outside agencies.

2.2.1 TANKS (FOR HIGH-LEVEL WASTES)

- 153 tanks (capacities from 1.89×10^5 liters to 3.79×10^6 liters each)

- 3 tanks (under construction) for concentrated high temperature wastes

Table B-1 lists the total tank waste inventory. Table B-2 gives the average chemical composition of the high-level waste. Table B-3 gives the major fission products inventory and Table B-4 gives the major actinides inventory.

Figures B-1 and B-2 show the radionuclide content after 1990 of in-tank and encapsulated waste, respectively.

2.2.2 CRIBS (FOR INTERMEDIATE LEVEL WASTES)¹⁵

- 144 deactivated
- 8 not used
- 10 standby
- 15 currently in use

177 Total

Table B-5 gives the estimated inventories discharged to 200 Area cribs and ponds while Table B-6 gives the estimated inventory of plutonium at these sites.

2.2.3 PONDS (FOR AUXILIARY PROCESS WATER)¹⁶

- 30 ponds with total surface area of 145 hectares.
- 73 hectares in current use.

2.2.4 SOLID RADIOACTIVE WASTE BURIAL GROUNDS¹⁶

More than $1.42 \times 10^5 \text{ m}^3$ of contaminated solids have been buried on the 200 Area plateau since the start of chemical processing operations. These wastes consist of so-called "dry waste" (soiled clothing, laboratory supplies, tools, etc., packed in cardboard, wood or metal containers) and industrial waste (primarily items of failed process equipment packaged in heavy metal or concrete boxes).

TABLE B-1
ESTIMATED HANFORD TANK WASTE INVENTORY¹⁵
(In Millions of Liters)

	<u>New Tanks</u>	<u>Old Tanks</u>	<u>Total</u>
<u>1968</u>			
Liquid	181.7	49.2	230.9
Solid	56.8	3.8	60.6
<u>1972</u>			
Liquid	177.9	3.8	181.7
Solid	79.5	2.6	82.1
<u>1976</u>			
Liquid	49.2	3.8	53
Solid	140	0	140
<u>1980</u>			
Liquid	9.5	3.8	13.3
Solid	177.9	0	177.9

TABLE B-2

AVERAGE CHEMICAL COMPOSITION OF
HANFORD HIGH-LEVEL WASTE¹³

<u>Chemical</u>	<u>Salt Cake Wt. %</u>	<u>Sludge Wt. %</u>	<u>Residual Liquor Wt. %</u>	<u>Total Wt. %</u>
NaNO ₃	84.5	17.2	12.1	50.9
H ₂ O	10.3	35.8	47.1	25.1
Na ₃ PO ₄	0.1	22.6	--	5.9
NaOH	1.5	3.2	14.3	4.8
NaNO ₂	1.7	3.7	12.3	4.6
NaAlO ₂	1.4	3.1	11.7	4.1
Na ₂ CO ₃	0.5	2.2	0.8	1.0
Na ₂ SiO ₃	--	2.9	--	0.7
Al ₂ O ₃	--	2.3	--	0.6
Fe(OH) ₃	--	1.8	--	0.5
Na ₂ SO ₄	--	1.1	0.5	0.4
Other	<u>--</u>	<u>4.1</u>	<u>1.2</u>	<u>1.4</u>
TOTALS	100.0	100.0	100.0	100.0

TABLE B-3

INVENTORY OF MAJOR FISSION PRODUCTS IN
HANFORD HIGH-LEVEL WASTE DECAYED TO 1990
(FROM REACTOR PRODUCTION - 1944-1971)¹⁵

(Curies)

Radionuclide ^(a)	Salt Cake ^(b)	Sludge ^(b)	Residual Liquor ^(b)	Capsules	Total
H-3	*	*	1.1×10^4	--	1.1×10^4
C-14	*	*	*	--	1.6×10^4
Se-79	*	8.2×10^2	*	--	8.2×10^2
Sr-90	2.0×10^6	4.5×10^7	6.0×10^5	5.8×10^7	1.1×10^8
Zr-93	*	6.9×10^3	*	--	6.9×10^3
Tc-99	*	*	3.1×10^4	--	3.1×10^4
Ru-106	*	3.7×10^1	3.7×10^1	--	7.4×10^1
Pd-107	*	5.7×10^1	*	--	5.7×10^1
Cd-113m	*	5.0×10^3	*	--	5.0×10^3
Sn-121m	*	1.1×10^2	*	--	1.1×10^2
Sn-126	*	6.8×10^1	*	--	6.8×10^1
Sb-125	*	2.0×10^4	*	--	2.0×10^4
I-129	*	*	4.7×10^1	--	4.7×10^1
Cs-134	1.2×10^2	1.2×10^2	4.3×10^2	2.5×10^3	3.2×10^3
Cs-135	4.4×10^1	4.4×10^1	1.6×10^2	9.0×10^2	1.1×10^3
Cs-137	5.0×10^6	5.0×10^6	1.8×10^7	1.0×10^8	1.3×10^8
Ce-144	*	9.9×10^0	*	--	9.9×10^0
Pm-147	*	1.0×10^6	*	--	1.0×10^6
Sm-151	*	1.4×10^6	*	--	1.4×10^6
Eu-152	*	1.5×10^3	*	--	1.5×10^3
Eu-154	*	7.3×10^4	*	--	7.3×10^4
Eu-155	*	7.4×10^4	*	--	7.4×10^4

(a) Daughter nuclides in decay chains are not listed.
Curie values are for parent nuclide only.

(b) Radionuclides present in trace quantities are indicated by an asterisk.

TABLE B-4

INVENTORY OF MAJOR ACTINIDES IN
HANFORD HIGH-LEVEL WASTE DECAYED TO 1990
(FROM REACTOR PRODUCTION - 1944-1971)¹⁵
(Curies)

<u>Radionuclide</u> ^(a)	<u>Sludge</u>
U-233	4.0×10^2
U-235	1.3×10^1
U-238	3.0×10^2
Np-237	1.0×10^2
Pu-238	4.0×10^2
Pu-239	2.1×10^4
Pu-240	5.2×10^3
Pu-241	6.0×10^4
Am-241	5.0×10^4

- a. Salt cake and residual liquor contain trace quantities of these isotopes (see Table B-3).

FIGURE B-1

RADIONUCLIDE CONTENT OF HANFORD IN-TANK WASTE¹⁵

TERA CORPORATION

TABLE B-5
ESTIMATED INVENTORIES^(a) RADIOACTIVE LIQUID WASTE
TO GROUND 200 AREAS¹⁶

	<u>Units</u>	<u>To Ponds and Ditches</u>	<u>To Cribs</u>	<u>To Specific Retention Sites</u>	<u>Total^(b)</u>
Decay Through 1972 (From Startup) 200 East					
Volume	(l)	3.0×10^{11}	2.0×10^{10}	1.0×10^8	3.0×10^{11}
Pu	(g)	$< 7.0 \times 10^2$	1.0×10^4	4.0×10^2	1.0×10^4
Beta	(Ci)	6.0×10^3	6.0×10^4	4.0×10^4	1.0×10^5
Sr-90	(Ci)	1.0×10^3	1.0×10^4	8.0×10^3	2.0×10^4
Ru-106	(Ci)	$< 3.0 \times 10^1$	2.0×10^3	3.0×10^2	3.0×10^3
Cs-137	(Ci)	4.0×10^2	8.0×10^3	1.0×10^4	2.0×10^4
Co-60	(Ci)	$< 3.0 \times 10^1$	1.0×10^2	2.0×10^1	$< 2.0 \times 10^2$
U	(kg)	$< 1.0 \times 10^4$	3.0×10^4	5.0×10^4	8.0×10^4
U-233	(g)	$< 5.0 \times 10^2$	5.0×10^2		$< 1.0 \times 10^4$
Decayed Through 1972 (From Startup) 200 West					
Volume	(l)	2.0×10^{11}	1.0×10^{10}	8.0×10^7	2.0×10^{11}
Pu	(g)	8.0×10^3	8.0×10^4	9.0×10^4	2.0×10^5
Beta	(Ci)	4.0×10^2	3.0×10^4	2.0×10^4	5.0×10^4
Sr-90	(Ci)	$< 1.0 \times 10^2$	6.0×10^3	2.0×10^2	7.0×10^3
Ru-106	(Ci)	$< 2.0 \times 10^0$	9.0×10^1	2.0×10^0	9.0×10^1
Cs-137	(Ci)	$< 9.0 \times 10^1$	5.0×10^3	1.0×10^4	2.0×10^4
Co-60	(Ci)	$< 9.0 \times 10^0$	3.0×10^1	3.0×10^0	$< 4.0 \times 10^1$
U	(kg)	$< 6.0 \times 10^3$	4.0×10^4	1.0×10^3	4.0×10^4

(a) The estimated inventories (or concentrations) of radionuclides are reported to one significant figure to reflect the uncertainty in the data. Where the estimated inventories are noted as less than ($<$), the recorded inventory is based on the analytical limit of detection.

(b) Totals do not necessarily equal the sum of individual contributions because of rounding of the data.

TABLE B-5

(CONT.)

	<u>Units</u>	<u>To Ponds and Ditches</u>	<u>To Cribs</u>	<u>To Specific Retention Sites</u>	<u>Total^(b)</u>
Decayed Through 1972 (From Startup)			Total 200-E + 200-W		
Volume	(l)	5.0×10^{11}	3.0×10^{11}	2.0×10^8	5.0×10^{11}
Pu	(g)	9.0×10^4	9.0×10^4	9.0×10^4	2.0×10^5
Beta	(Ci)	7.0×10^3	9.0×10^4	6.0×10^4	2.0×10^5
Sr-90	(Ci)	2.0×10^3	2.0×10^4	8.0×10^3	3.0×10^4
Ru-106	(Ci)	$< 3.0 \times 10^1$	2.0×10^3	3.0×10^2	3.0×10^3
Cs-137	(Ci)	5.0×10^2	1.0×10^4	2.0×10^4	4.0×10^4
Co-60	(Ci)	$< 4.0 \times 10^1$	$< 2.0 \times 10^2$	2.0×10^1	$< 2.0 \times 10^2$
U	(kg)	$< 7.0 \times 10^3$	6.0×10^4	5.0×10^4	1.0×10^5
U-233	(g)	$< 5.0 \times 10^2$	5.0×10^2		$< 1.0 \times 10^3$

(a) The estimated inventories (or concentrations) of radionuclides are reported to one significant figure to reflect the uncertainty in the data. Where the estimated inventories are noted as less than (<), the recorded inventory is based on the analytical limit of detection.

(b) Totals do not necessarily equal the sum of individual contributions because of rounding of the data.

TABLE B-6

ESTIMATED INVENTORIES OF PLUTONIUM IN DISPOSAL SITES¹⁶

<u>Disposal Site</u>	<u>Plutonium (kg)</u>	<u>Disposal Site</u>	<u>Plutonium (kg)</u>
216-U-10		216-Z-3	5.7
U Pond and Ditches	8.3	216-Z-4	0.002
216-B-7		216-Z-5	0.34
224-B, 221-B, 5-6 Cell and Construction Waste	4.3	216-Z-6	0.005
216-S-1 and -2		216-Z-7	2.0
Redox Process Condensate	1.2	216-Z-8	0.05
216-T-32		216-Z-9 ^(a)	38. ^(b)
224-T Waste	3.2		
216-Z-1AA	30.	216-Z-10	0.05
216-Z-1AB	17.	216-Z-12	25.
216-Z-1AC	11.	216-Z-16	0.07
216-Z-1 and 2	7.0	216-Z-17	0.05
		216-Z-18	22.

(a) "Z-9" Crib.

(b) Other estimates indicate that the system to contain between 25 and 70 kilograms of plutonium.

Transuranic bearing waste has been packaged in sealed metal containers and segregated in the burial trenches since May 1970. Contaminated solid waste is buried in 19 sites on the 200 Area plateau using 63 hectares. Some failed equipment from the Purex Facility is stored in tunnels on flat cars.

Prior to 1968, essentially all of the waste buried was generated by the 200 Area operating facilities. Since 1968, waste generated by 300 Area operations also has been buried in the 200 Area sites. Beginning in December 1973, waste from reactor operations in the 100 Area was being sent to the 200 Area for burial. Small volumes of solid waste, generated by offsite DOE operations, have been and will continue to be buried here. During 1973, approximately 60 m^3 containing less than 4 Ci of mixed radioactive materials were received from offsite.

Tables B-7 and B-8 give the estimated inventories of the burial grounds and Purex storage tunnels, respectively.

The dry wastes listed in Table B-7 have been characterized and are presented in Table B-9.

2.3 300 AREA - REACTOR FUEL MANUFACTURING FACILITIES AND RESEARCH AND DEVELOPMENT LABORATORIES

There is a 2.84×10^5 liter capacity temporary storage facility in the 300 Area; however, all liquid wastes are currently transferred to the 200 Area for ultimate disposal.

Currently generated solid waste is sent to the 200 Area burial ground; however between 1944 and 1967 approximately $2.1 \times 10^4 \text{ m}^3$ were buried in the 300 Area. It is estimated that this buried waste contained 10 Ci of uranium contamination and 0.5 Ci of thorium contamination.

Three contractors are conducting research and development studies in the area: Westinghouse-Hanford, Battelle-Northwest, and United Nuclear Industries.¹⁹

TABLE B-7
ESTIMATED DECAYED STATUS OF SOLID WASTE^(a) BURIAL GROUNDS IN THE 200 AREAS THROUGH 1972¹⁶

	Volume (m ³)	Uranium (G)	Plutonium (G)	Total (Ci)	Sr-90 (Ci)	Cs-137 (Ci)	Ru-106 (Ci)	Other Radioactive (Ci)
Burial Ground - 200 East Area								
Dry Waste No. 001	3.1×10^3	4×10^5	9×10^2	5×10^0	1×10^0	1×10^0	9×10^{-7}	
Dry Waste No. 12A	1.5×10^4	1×10^6	9×10^3	7×10^1	1×10^1	2×10^1	3×10^{-1}	
Dry Waste No. 12B	7.4×10^3	7×10^3	1×10^3	2×10^3	2×10^2	2×10^2	6×10^{-1}	
Minor Construction No. 4	1.6×10^3	1×10^3	1×10^1	5×10^{-1}	1×10^{-1}	1×10^{-1}	2×10^{-6}	
Construction (No Number)	2.3×10^3	2×10^3	2×10^1	6×10^{-1}	1×10^{-1}	2×10^{-1}	3×10^{-5}	
222 Vaults	1.7×10^2	1×10^3	1×10^0	3×10^1	7×10^0	8×10^0	4×10^{-6}	
Industrial Waste No. 002	9.1×10^3	3×10^5	8×10^2	1×10^3	3×10^2	3×10^2	6×10^{-4}	
Industrial Waste No. 005	3.1×10^3	1×10^5	6×10^2	4×10^2	1×10^2	1×10^2	2×10^{-3}	
Industrial Waste No. 05Z	6.2×10^3	1×10^5	1×10^3	1×10^3	2×10^2	2×10^2	3×10^{-2}	
Industrial Waste No. 010	1.5×10^4	8×10^5	5×10^3	5×10^4	4×10^3	5×10^3	2×10^3	
TOTAL 200-E(b)	6.2×10^4	3×10^6	2×10^4	6×10^4	5×10^3	6×10^3	2×10^3	
Burial Ground - 200 West Area								
Dry Waste No. 001	7.1×10^3	7×10^5	9×10^4	9×10^0	2×10^0	2×10^0	2×10^{-6}	
Dry Waste No. 002	8.5×10^3	1×10^6	1×10^5	3×10^1	6×10^0	7×10^0	1×10^{-6}	
Dry Waste No. 003	1.1×10^4	7×10^7	7×10^4	5×10^1	1×10^1	1×10^1	3×10^{-3}	
222-T Vaults	6.8×10^1	3×10^2	3×10^{-1}	4×10^1	9×10^0	1×10^1	9×10^{-6}	
222-S Vaults	1.8×10^2	7×10^2	7×10^{-1}	2×10^2	5×10^1	6×10^1	6×10^{-3}	
Industrial Waste No. 001	1.4×10^4	9×10^5	2×10^3	2×10^3	6×10^2	6×10^2	1×10^{-3}	
Industrial Waste No. 002	1.9×10^4	2×10^6	6×10^3	2×10^4	3×10^3	4×10^3	1×10^2	
Dry Waste No. 03A	5.1×10^3	9×10^6	4×10^3	1×10^5	3×10^2	3×10^2	1×10^2	1×10^5
Dry Waste No. 04A	1.8×10^4	5×10^8	4×10^4	3×10^2	5×10^1	5×10^1	2×10^0	
Dry Waste No. 04B	8.5×10^3	4×10^6	2×10^4	2×10^5	3×10^2	3×10^2	9×10^1	2×10^5
Colson - No. 1	6.2×10^0	2×10^5	5×10^2	1×10^2	1×10^1	2×10^1	2×10^0	
Colson - No. 2	2.3×10^0		5×10^{-1}	3×10^0	4×10^{-1}	4×10^{-1}	8×10^{-2}	
Colson - No. 3	4.8×10^0	1×10^5	5×10^2	3×10^3	3×10^2	4×10^2	8×10^1	
Colson - No. 4	1.5×10^1	5×10^4	7×10^2	1×10^4	1×10^3	1×10^3	4×10^2	
Colson - Alpha 1	5.7×10^0	4×10^4	1×10^3	4×10^4	7×10^2	7×10^2	4×10^2	1×10^4
TOTAL 200-W(b)	9.1×10^5	6×10^8	4×10^5	4×10^5	7×10^3	7×10^3	1×10^3	3×10^5
TOTAL 200 AREAS(b)	1.5×10^6	6×10^8	4×10^5	5×10^5	1×10^4	1×10^4	3×10^3	3×10^5

(a) The estimated inventories or concentration of radionuclides are reported to one significant figure to reflect the uncertainty in the data.

(b) Totals do not necessarily equal the sum of individual contributions because of rounding of the data.

TABLE B-8
PUREX EQUIPMENT STORAGE TUNNELS^(a) INVENTORY^(b)
SEPTEMBER 30, 1973¹⁶

	<u>Tunnel No. 1</u>	<u>Tunnel No. 2</u>	<u>Total</u> ^(c,d)
Volume, m ³	566	566	1,133
Total MFP, Ci ^(d)	6,000	20,000	30,000
Sr-90, Ci	1,000	40	1,000
Ru-106, Ci	1	7	8
Cs-137, Ci	1,000	40	1,000
Co-60, Ci	--	20,000	20,000
Pu-239, g	--	500	500

-
- (a) Currently the distribution of waste plutonium stored on the Hanford site is 40 percent in tanks, 39 percent in solid disposal sites and 21 percent in liquid disposal sites. The total amount of plutonium in these sites is estimated to be 940 kg $\pm$ 30 percent.
- (b) The estimated inventories (or concentrations) of radionuclides are reported to one significant figure to reflect the uncertainty in the data.
- (c) Totals do not necessarily equal the sum of individual contributions because of rounding of the data.
- (d) Curies shown are decayed to September 30, 1973.

TABLE B-9
CHARACTERISTICS OF DRY WASTE BURIED¹⁶
ON AN AVERAGE DAY (MAXIMUM)*⁵

<u>Source</u>	<u>No.</u>	<u>Container</u>	<u>Volume (ft³)</u>	<u>Activity, Ci</u>
222-S Bldg. (Hot cell)	4(5)	30-gal	30(38)	20. (70) F.P. (a)
	9(22)	Cardboard boxes	40(100)	0.6(3) F.P.
221-T	14(22)	Cardboard boxes	60(100)	0.1(2) F.P.
Laundry	9(22)	Cardboard boxes	40(100)	
Misc.	5(22)	Cardboard boxes	20(100)	
BNW	70(150)	Cardboard boxes	300(700)	< 5 (< 10) F.P.
HEDL	45(75)	Cardboard boxes	200(300)	

(a) Fission Products

* () designate maximum daily volume.

The TRU waste shipments during the first half of CY-1976 are presented in Table B-10. The volumes and their TRU content are reported for combustible and noncombustible wastes. For the first half of CY-1976, 16.1 m³ of combustible waste and 7.4 m³ of noncombustible waste were shipped for disposal. This compares with the first half CY-1975 shipments of 40.7 m³ containing 1,344 grams of plutonium.

2.4 400 AREA - FAST FLUX TEST FACILITY (FFTF)

This is a construction area and no radioactive wastes are presently being generated.

2.5 600 AREA¹⁶

The 600 Area is all other Hanford Reservation areas not included in the 100, 200, 300 or 400 Areas. In the past miscellaneous low-level solid radioactive wastes may have been buried in this area; however, accurate records were not kept and volumes and composition are not known.

TABLE B-10
TRU WASTE SHIPMENTS
FROM 300 AREA TO 200 AREA (1/76-6/76)

<u>Function</u>	<u>No. of Drums^(a)</u>	<u>Average Weight kg</u>	<u>Total Volume m³</u>	<u>Pu Content g</u>
Combustible Waste				
Quality Control	25	59	5.30	203
Fuel Fabrication	22	54	4.66	167
Post Irradiation Testing	27	54	5.73	N.A. ^(c)
Maintenance and Miscellaneous	2	80	0.42	2.6
Subtotal	76	57	16.11	373
Noncombustible Waste ^(b)	2 Steel boxes	N.A. ^(c)	7.36	N.A. ^(c)
Total			23.5	373

(a) 0.2 m³ drums

(b) Packages waste - obsolete equipment, concreted drum waste, etc.

(c) Not assayed due to high β - γ activity.

3.0 LIQUID WASTES ¹⁶

Approximately 1.44×10^8 liters of liquid waste and 9.46×10^7 liters of solidified waste (as of March 1975) are currently stored in underground tanks at Hanford. This waste was generated during the period 1944 to 1974 and represents more than 95 percent of the total high-level waste expected to be generated during the operation period of the Hanford plutonium production facilities through 1978. Based on current production plans, the operation of N-Reactor and the Purex Processing Plant results in the generation of approximately 3.8 million liters of high-level waste each year. Operation of these facilities through 1983 or 1990 will generate about 1.9×10^7 or 4.5×10^7 liters of additional high-level liquid waste, respectively. This liquid would be converted to 3.8×10^6 to 1.1×10^7 liters of solidified waste.

The thrust of the current waste management program for high-level waste is to convert stored and currently generated high-level waste from a liquid to a salt cake form. The existing evaporators, along with one evaporator currently under construction (1972), will solidify most of the stored and currently generated liquid waste to salt cake. A residuum of highly caustic liquid will remain which cannot be further evaporated with these evaporators. The residuum will be treated to produce a solid either by chemical addition or a special type evaporator, alternatives which are now under development. If a satisfactory solidified waste (immobile but removable) cannot be developed for interim storage at a reasonable cost, then the residuum could continue to be stored in double-wall tanks until an ultimate disposal method is in place. Replacement tanks could be built from time to time as needed to continue storage of this liquid. Since any leakage from the primary tank can be collected, detected and removed by pumping from the secondary tank, leakage of liquid waste to the soil would be effectively eliminated.

The solidification of the liquid waste, along with the construction of additional double-wall tanks to contain the liquids in interim periods, is considered to be the current program for management of the high-level waste.

4.0 SOLID WASTES

4.1 OVERVIEW

More than $1.42 \times 10^5 \text{ m}^3$ of contaminated solids have been buried on the 200 Area plateau since the start of chemical processing operations. These wastes consist of so-called "dry waste" (soiled clothing, laboratory supplies, tools, etc., packed in cardboard, wood or metal containers) and industrial waste (primarily items of failed process equipment packaged in sealed metal containers) and segregated in the burial trenches since May 1970. Contaminated solid waste is buried in 19 sites on the 200 Area plateau using 63 hectares. Some failed equipment from the Purex Facility is stored in tunnels on flat cars. A summary of all solid waste volume is given in Table B-11.

A review of the distribution of waste by categories defined based on plutonium concentration and general radiation levels, indicates that the waste in the 200 Area is generally low radiation level boxed dry waste. Tables B-12 and B-13 present this information based upon Reference 18. It would appear that similar ratios would be appropriate for the present inventory of the 200 Area.

Solid radioactive waste buried in the ground is considered to be in long-term storage. An exception is that waste buried after April 30, 1970, which is suspected of containing transuranium nuclides; this is considered to be in interim storage (20 years). Large items of solid waste, such as failed equipment from locations where the presence of transuranium nuclides can be safely ruled out, are packaged in concrete boxes and buried in industrial waste burial trenches. Small items of failed equipment and trash-type contaminated waste, from locations where the presence of transuranium nuclides can be safely ruled out, are packaged in cardboard cartons, wood boxes, or steel or fiber drums and buried in the so-called "dry waste" trenches.

The various waste containers used provide containment of nontransuranic radioactive contamination and minimize radiation exposure to personnel during temporary storage, handling, shipment, and burial operations. Once buried, no reliability is placed on the containers for confinement or retrievability of these

TABLE B-11

SUMMARY SOLID RADIOACTIVE WASTE RELEASES TO THE GROUND¹⁶

Waste Generation Location	Composition	Quantity		Current Disposition Location
		Currently Stored (m ³)	Future Storage (m ³ /yr) ^(a)	
100 Area	Miscellaneous solid waste	1.6×10^4	1,130	200 Areas
200 Area	Miscellaneous solid waste	1.6×10^5	2,600	200 Areas
300 Area	Miscellaneous solid waste from fuel element manufacturing containing uranium and thorium and from research and development	2.1×10^4	1,590	200 Areas
600 Area	Miscellaneous solid waste	(b)	0	200 Areas

(a) All future solid waste sent to the 200 Area.

(b) Volume not known.

TABLE B-12

ESTIMATED VOLUMES OF BURIED TRANSURANIUM SOLID WASTE
AT HANFORD 200 AREA BURIAL GROUNDS THROUGH 1969¹⁸

Type	Surface Dose Rate (mrem/hr)	Pu ^a Content (kg)	Beta Activity As Charged (Ci)	Volume As Charged (m ³)
1. Low radiation level, boxed dry waste	< 10	298	2,000	48,100
2. High radiation level, boxed dry waste	> 10	34	8,000	19,800
3. Failed metal equip- ment (boxed or bagged)	> 10	<u>23</u>	<u>620,000</u>	<u>70,750</u>
Total		355	630,000	158,650
Boxed large equipment in Purex rail tunnels	> 1,000	> 1	> 10,000	1,550
Cribs and surrounding soil with Pu ≤ 20 μ Ci/kg	< 10	260	3,100,000	

- a Plutonium in use at Hanford typically is 94% Pu-239 and 6% Pu-240 and has specific alpha activity of 0.07 Ci/g of the element.

TABLE B-13
ESTIMATED SOLID WASTE BURIALS IN HANFORD 200 AREAS DURING CY 1969¹⁸

	<u>Percent Burnable</u>	<u>Surface Dose Rate (mrem/hr)</u>	<u>Total Pu (g)</u>	<u>Non-Pu Beta- Gamma Activity (Ci)</u>	<u>Total Volume (m³)</u>
1. Pu contaminated, low radiation level, boxed dry waste ^a	75	< 2	4,000	-	790 ^c
2. Pu contaminated, intermediate radiation level, boxed dry waste ^a	75	10-100	500	130	630
3. Pu contaminated, high radiation level, boxed dry waste ^a	50	> 100	400	28,000 ^b	1,130
4. Failed metal equipment, high radiation level (boxed or bagged) ^b	10	> 10	200	65,000	540
5. Low transuranic, low radiation level, boxed dry waste ^a	50	< 10	-	34,000	680 ^d
6. Low transuranic, high radiation level, boxed dry waste ^a	10	> 10	-	40,000	1,700
Total			5,000	168,000	5,470 ^e

^a Waste in cardboard boxes, wood boxes, and metal drums consists of cloth, paper, plastic, tools, glass filters, dirt, and miscellaneous small hardware.

^b Consists primarily of failed metal equipment in wood or concrete boxes.

^c Includes 70 m³ from Rocky Flats.

^d Includes 42 m³ from Lawrence Radiation Laboratory.

^e Total volumes were 4,300 m³ in 1967 and 4,950 m³ in 1968.

materials. Although burial of the waste containers by backfilling the trench is normally done at the close of the day's receipt of solid waste, waste trenches are immediately backfilled whenever the dose rate at the edge of the trench reaches 100 mR/hr. Solid waste is normally covered with three to six meters of earth to prevent uptake of radionuclides by plant life or disturbance by burrowing animals. An exception, waste contained in concrete boxes or small drums, may have a minimum dirt cover of four feet provided that radiation levels at grade are less than 1 mR/hr. Periodic routine surveillance of filled burial trenches is provided to assure that the burial grounds are maintained to meet existing standards.

Solid waste, containing or suspected of containing transuranium nuclides above 10nCi/g buried after April 30, 1970, is packaged and buried in compliance with DOE-M-0511. This directive states that "such wastes shall be segregated from other solid wastes and shall be packaged and buried so that they can be readily retrievable, as contamination-free packages, within an interim period of 20 years."

Formerly, the waste was packaged in steel drums and steel or concrete boxes and buried in special trenches. Subsequent evaluation of steel drums directly buried in Hanford soils indicated that failures could occur in less than 20 years and retrieval, as contamination-free packages, might not be possible. Two alternatives to direct burial were implemented on a test basis, either of which will protect the containers from direct contact with the soil and will permit ease of retrieval. One method consists of stacking steel drums on a pad and covering with plywood and nylon sheeting prior to covering with four feet of earth. The other method is placing the drums in a concrete "vee" trench, placing a metal cover over the top and covering with earth.

Small items of transuranic-bearing solid waste, containing fission products capable of generating high dose rate gamma emissions, are packaged and shipped in shielded casks. This waste is discharged from the casks to caissons, which can be retrieved.

Some of the Purex processing equipment is so large and becomes so contaminated in service, that its transport to a burial ground would require abnormally high exposure of operating personnel. Such equipment is placed on flatcars and pushed into the solid waste storage tunnels appended to the Purex Plant.

4.2 TRU BURIAL FACILITIES^{16,18}

Asphalt pads are currently being used for the retrievable storage of low-activity TRU wastes. The wastes are packaged in 208-l drums or in steel boxes and stacked on the pad in 7.3-m wide x 7.3 m-high modules. Flame-retardant plywood is placed between the layers, and plywood is placed on top of the modules. The completed module is covered with PVC laminated nylon sheet and 1.3 m of soil overburden. TRU waste generated between June 1972 and March 1973 was placed in 208-l drums and stored in a concrete "vee" trench. Waste drums were placed at a 45° angle inside the trench. A steel cover was then placed over the trench and covered with 1.2 m of soil as an overburden.

Underground caissons are used for storage of small packages of high-activity TRU waste. The waste is packaged in 3.8-l or 18.9-l paint cans with clips or resin to hold the lids in place. The caissons are reinforced concrete cylinders buried 4.0 m below the surface. The caissons have 0.9-m-diameter chutes, offset or convoluted to reduce surface radiation exposure.

Extremely large, heavy, or highly contaminated waste equipment is stored on railroad flat cars in two railroad tunnels. The contamination may be TRU or non-TRU and is usually associated with activation products. One tunnel is filled with eight flat cars and is now inactive. The second tunnel is 515 m long and can store about 42 flat cars. At present (1977), nine cars of waste are stored in this tunnel.¹⁸

TRU waste unsuitable for pad or caisson storage due to size, security requirements, or surface radiation is stored in alpha trenches. This waste is packaged in fiberglass-reinforced polyester-covered plywood boxes, reinforced concrete boxes, metal boxes, or 208-l drums. Once placed in the trench, the waste is

covered with 1 meter of soil. These trenches are also used for storage of TRU and non-TRU classified waste in 208-l drums. The drums are stacked vertically and covered with a plywood cover. Completely filled trenches are covered with a PVC laminated nylon sheet and 1.2 m of soil. Classified wastes are covered on the day they are placed in the trenches.

Currently used packaging for radioactive wastes ranges from cardboard boxes sealed with tape to flanged steel containers with reinforced concrete shielding.

The fissile content of each container accepted for burial is measured before or subsequent to packaging, and the amount of fissile material is recorded on the shipping papers. All of the wastes are monitored for surface contamination at their point of origin. Dose rates at the surface of a package are determined and recorded. All packages must be free from external contamination. Generally, radiation rates at the surface of a package are less than 10 mR/hr. High-activity wastes are transported in shielded metal containers.

The accumulated volume of radioactive waste at Hanford is approximately 188,000 m³, which contains 2,039 KCi of radioactivity.

APPENDIX C

IDAHO NATIONAL ENGINEERING LABORATORIES (INEL)

TERA CORPORATION

1.0 BACKGROUND^{22, 21}

The Idaho National Engineering Laboratory (INEL), formerly named the National Reactor Testing Station, was established in 1949 as an area where nuclear reactors, support plants, and equipment could be constructed, tested, and operated. The INEL covers an area of about 2,300 km² on the central edge of the semiarid Snake River Plain. Since 1949, 51 nuclear facilities, mostly reactors, have been built, or are under construction or design at the INEL. These facilities include the Idaho Chemical Processing Plant (ICPP), which reprocesses irradiated spent nuclear fuel.

The ICPP is in a fenced security area of about 0.4 km² located within the INEL. The ICPP facilities are designed to recover unused fissionable uranium from irradiated nuclear fuels. Usually the fuels come from the research and test reactors and from military reactors.

In the recovery process the unused uranium is separated from the other fuel components and purified for future reuse. The other fuel components (jacketing materials and fission products) are separated and retained as acidic high-level liquid waste (HLLW) in underground stainless steel tanks. At the ICPP Waste Calcining Facility (WCF) this HLLW is converted to granular solid (calcine), which is placed in stainless steel bins in underground reinforced-concrete vaults at the ICPP.

Solid contaminated waste, except for the calcined solids, is transported to the INEL Radioactive Waste Management Complex (RWMC); uncontaminated solid waste is deposited in a sanitary land fill.

2.0 DESCRIPTION OF FACILITIES²¹

INEL is comprised of the following:

1. Argonne National Laboratory - West (ANL-W)
2. Naval Reactors Facility (NRF)
3. Idaho Chemical Processing Plant (ICPP)
4. Test Area North Support Facility (TAN)
5. Loss of Fluid Test Facility (LOFT)
6. Power Burst Facility (PBF)
7. Test Reactor Area (TRA)
8. Central Facilities Area (CFA)
9. INEL Solid Radioactive Waste Management Areas
10. Auxiliary Reactor Area
11. Low Power Test and Experimental Beryllium Oxide Reactor Facilities
12. Idle Facilities

2.1 LIQUID WASTE STORAGE FACILITIES

Of the facilities listed above only ICPP has interim storage of high-level liquid waste (prior to calcining). At all facilities low-level liquid wastes are processed prior to discharge to the environment.

2.2 SOLID RADIOACTIVE WASTE FACILITIES

The solid radioactive waste facilities at the INEL are the Radioactive Waste Management Complex (RWMC), SL-1 Burial Ground, ANL Solid Waste Storage Area, and the ICPP Calcined Waste Storage Area.

At the RWMC and SL-I Burial Grounds, fission and activation product wastes are buried directly in the soil below ground level. Uranic and transuranic wastes are currently stored above the land surface in fire-resistant and watertight containers at the Transuranic Storage Area (TSA). These containers are placed on an asphalt pavement and covered with plywood-plastic and soil. At the ANL Solid Waste Storage Area and the ICPP Calcined Waste Storage Area, radioactive wastes are stored in watertight steel containers and concrete vaults placed below the ground. Table C-1 lists the total amounts of wastes located in each of these areas as of the end of December 1974.

The estimated curie amounts apply at the time of deposition, or, in the case of the ICPP, at the time of calcination. Radioactive decay has further reduced the amount of activity.

The following individual areas are enclosed within fences:

(1) RWMC Subsurface Disposal Area (SDA)	35.6 hectares
(2) TSA	23.5 hectares
(3) SL-I Burial Ground	1.6 hectares
(4) ANL-W Solid Waste Storage Area	2.0 hectares
(5) ICPP Calcined Waste Storage Area	<u>1.2</u> hectares
Total	63.9 hectares

TABLE C-1

TOTAL AMOUNTS OF SOLID RADIOACTIVE WASTES BY AREA 1952-1974²¹

<u>Area</u>	<u>Volume (m³)</u>	<u>Curies</u>
RWMC Subsurface Disposal	139,000	5,978,000
Transuranic Storage Area	24,478	93,525
SL-I Burial Ground	2,320	600
ANL Solid Waste Storage Area ^(a)	62	9,490,171
ICPP Calcined Waste Storage ^(a,b)	<u>1,222</u>	<u>52,862,000</u>
Total	157,082	58,423,696

(a) Storage

(b) Represents 1.06×10^7 liters of liquid waste

3.0 HIGH-LEVEL LIQUID RADIOACTIVE WASTE

The HLLW at the ICPP is stored on an interim basis at the tank farm. All HLLW eventually is solidified in the WCF and placed in retrievable storage.

The tank farm contains eleven (11) 1.14-million liter and four (4) 114,000-liter stainless steel tanks for interim storage of HLLW²². The 1.14-million liter tanks are located in concrete vaults.

4.0 SOLID RADIOACTIVE WASTE

There are several areas at the INEL dedicated to the storage or disposal by burial of solid radioactive waste material. These areas are: (a) INEL Radioactive Waste Management Complex and associated Transuranic Storage Area (TSA), (b) SL-1 Burial Ground, (c) High-Level Waste Storage Facility at ANL-W, and (d) Calcined Solids Storage Facilities at ICPP for storage of solid calciner product. 21

4.1 INEL RADIOACTIVE WASTE MANAGEMENT COMPLEX (RWMC)^{21, 17}

The RWMC was established in 1952 to accommodate the radioactive wastes generated by Laboratory operations. In addition to wastes generated at the INEL, the RWMC has also received wastes from the DOE's Rocky Flats Plant since 1954. Most of these wastes are contaminated with uranic and transuranic nuclides. Lesser quantities of waste have also been received over the years from other DOE-associated facilities.

The RWMC is located in the southwestern part of INEL and is enclosed by fences and surrounded by dikes and drainage channels.

In terms of area, RWMC constitutes 70 percent of all INEL waste facilities, including seepage ponds and storage areas for high-level waste. Four major on-site contractors ship their waste to RWMC. Also, other DOE facilities throughout the country send TRU waste to RWMC for storage.

Waste received for storage or disposal must comply with DOT shipping requirements, DOE-ID Manual 0529, and RWMC documents such as waste packaging guidelines, standard practices, and operating procedures.

RWMC is divided in two fenced sections: the subsurface disposal area (SDA), which is 35.6 ha, and the transuranic storage area (TSA), which is 22.3 ha. Approximately 8.1 ha remains for future disposal at SDA and 17.8 ha remains for future disposal at TSA. These are described below.

4.1.1 SUBSURFACE DISPOSAL AREA (SDA)^{21, 17}

Underground and above-ground disposal activities are carried out in the 35.6 ha SDA. Facilities include trenches, pits and soil vaults or shafts.

4.1.1.1 TRENCHES

These disposal trenches are between 150 and 300 m in length x 6 m in width x 4.5 m in diameter. They are used for the disposal of compactible solid radioactive waste such as paper, rags, etc., and also for most high-radiation-level (beta-gamma) waste.

The majority of on-site solid low-level radioactive waste, until January 1974, was received at the RWMC in cardboard boxes sealed with tape. The waste was compacted to about half its volume, and a three-foot soil cover was applied. Since 1971 compactible waste generated at Naval Reactor Facilities has been compacted and sent to the RWMC in bales. Since January 1974, all other compactible waste received at the RWMC is being compacted. Use of a bale-type unit that utilizes a hydraulic press to achieve a 10-to-1 reduction in waste volume has been implemented. The 270 kg bales are placed in specially designed fiberboard boxes with plastic liners that provide a protective container and aid stacking in the pits or trenches. Presently, most of the on-site wastes are transported to the RWMC in plastic bags to accommodate the new compaction operation. Larger noncompactible wastes arrive in wooden boxes and are stacked in the trenches along with the compacted bales.

Wastes with high gamma radiation levels are handled remotely, utilizing special shielded containers and boom cranes. When the trenches are full, they are covered with a minimum of three feet of soil.

Facilities for the TRU waste retrieval projects (Initial Drum Retrieval and Early Waste Retrieval (EWR) projects) are also located within the SDA. These retrieval activities are contained within two structures known as the air support weather shields. The EWR is double contained, with the operating area enclosed

in a second structure within the weather shield. The waste retrieved by these projects is repackaged and placed in a 20-year retrieval storage on the TSA-R pad.

4.1.1.2 PITS

The disposal pits range in size from 30 to 45 m in width, 150 to 300 m in length, and 2 to 7.3 m in depth. Bulky, irregular sized wastes such as tanks, drums, piping, etc., are transported to a pit in trunks, deposited therein, and covered with soil when enough area has been filled to allow earthmoving equipment to travel across the face of the pit. Low-activity beta-gamma wastes are disposed of in these pits.

4.1.1.3 VAULTS

Soil vaults or shafts (0.4 m in diameter x 3 m deep) are also used for disposal of high-activity beta-gamma wastes. These structures are expected to replace the trench concept in the disposal of bulky items such as reactor heads.

4.1.2 TRANSURANIC DISPOSAL AREA (TDA)

Waste containing less than 10 n Ci/g of TRU elements is disposed of above ground on the Transuranic Disposal Area. The TDA consists of asphalt pads having level surfaces of about 1,900 m², enclosed on three sides by an earth berm. The 7.6 cm asphalt surface rests upon a 10 cm gravel base and is sloped toward the center and the open end for drainage of moisture. One such pad is presently in use (which is designated as Transuranic Disposal Area-TDA) at the RWMC. Drums and crates of uranic and transuranic waste containing less than 10 nCi of transuranic activity per gram of waste, are stacked on the pad in a horizontal geometric configuration to a height of about 5.5 m. Once a section of the pad is filled with containers, earth is moved over the top and sides of the stack to provide a moisture barrier over the waste. This storage concept allows for greater container integrity, an all-weather working surface, and maximum utilization of surface area within the RWMC.

4.1.3 TRANSURANIC STORAGE AREA (TSA)

The construction of the TSA is similar to that of the TDA and affords the same advantages. Transuranic wastes containing more than 10 nCi/g of TRU elements are stored on an interim basis on this pad, which measures 45.7 m x 228.6 m. The pads are constructed of 7.6 cm of asphalt over a base of 10.2 cm of compacted gravel. The waste is packaged in containers designed for 20-year integrity. The bulk of the wastes stored on the TSA pad arrives at the INEL by rail from the Rocky Flats Plant. Some U-233 wastes from Bettis Atomic Power Laboratory (BAPL), which is associated with the DOE's Pittsburgh Naval Reactor Office, and other potential sources, such as the DOE's Mound Facility at Miamisburg, Ohio, are also received --along with any INEL-generated transuranic wastes. The containers must meet 20-year integrity requirements for storage on the TSA pad, along with other safety and administrative imposed requirements.

The TSA is filled in 25 x 46-m sections called "cells." The drums are stacked five drums high in a close-pitched triangular array with a layer of fire-retardant plywood and plastic sheeting separating each level. The sides of the cells are lined with 1.2 x 1.2 x 2.1-m fiberglass-coated wooden boxes that contain waste too bulky for the drums. The boxes define the cells and provide end support for the drum array. Each cell in the 228.6 m length of the pad is separated by a 0.9 m-thick soil firewall as the cell is completed. The entire array is covered with fire-retardant plywood and nylon-reinforced polyvinyl before the final 0.6 to 0.9 m-thick soil cover is placed.

Waste containing more than 10 nCi/g of TRU elements, plus activation and/or fission products in concentrations requiring special handling, is stored in the Intermediate-Level Transuranic Storage Facility (ILTSF). This facility consists of 26 concrete-filled carbon steel storage vaults constructed from 7.9 m vertical pipes, 61 and 40.1-cm in diameter. The pipes are enclosed in a 1.5-m-high earth embankment. A removable concrete plug in each vault provides shielding. Sixteen additional vaults were scheduled for construction near the end of FY -1977.

4.1.4 SOLID RADIOACTIVE WASTE DATA²¹

Solid radioactive waste enters the SDA and TSA in the following containers:

- (1) Special shielded cask inserts (SDA)
- (2) 208- and 114-liter steel drums mostly from off-site shippers (TSA)
- (3) 1.2 x 1.2 x 2.1 m wooden boxes (TSA)
- (4) Compacted 0.4 m³ bales (SDA)
- (5) Fiber barrels (SDA)
- (6) Other special containers, such as the 0.02 mm yellow plastic bags used for compactible waste (SDA)

Special administrative forms contain information on waste volume and nuclide content and activity which is used as input to the DOE quarterly computerized radioactive waste reporting system (called SWIMS). Waste currently placed in the SDA is considered disposed of, whereas that stacked in the TSA is considered stored. From 1954 through November 1970, waste containing approximately 2×10^5 Ci of plutonium-contaminated waste was disposed of at the INEL Subsurface Disposal Area. Pu-241 comprised about 87 percent of this activity with lesser amounts of Pu-238, -239, -240, and -242. The transuranic wastes that were buried at the Radioactive Waste Management Complex prior to November 1970 are presently being retrieved. An air-support building, is being used to avoid potential contamination of the environment during the retrieval program. The air-support building is positioned over the work site, the soil overburden is removed, the disposed 208-liter drums are recovered and then repackaged in 314-liter steel drums or wood and fiberglass boxes. After the drums have been removed from the area under the air-support building, the excavated area is backfilled with soil, smoothed, and graded to comply with drainage requirements. The air-support building is then moved to another location and the work sequence repeated. The repackaged drums from this retrieval program are being stored on the TSA. Ultimate disposal will be at a Federal repository.

A summary of solid radioactive wastes stored or disposed of at the TSA and SDA during 1974 is given in Table C-2.

Table C-3 is a list of the radioactive nuclides disposed of at the INEL in 1974. The radioactive nuclides stored at the TSA during 1974 are listed in Table C-4. Table C-5 shows a 21-year summary of wastes disposed of at the SDA or stored at the TSA.

Figures C-1 and C-2 show graphically the total volume and activity of solid wastes handled from 1952 through 1974 while Figures C-3 and C-4 present the cumulative waste generations.

4.2 SL-1 BURIAL GROUND²¹

SL-1 experienced an accidental nuclear excursion on January 3, 1961, which destroyed the reactor and contaminated the reactor building. The reactor and reactor building were dismantled. Most of the dismantled building, contaminated equipment, and the decontamination waste were interred directly in a burial ground established a short distance from the facility.

Only about five percent of the fission products from the excursion (about 130 MW-sec) escaped from the pressure vessel during the accident. The uranium was all reclaimed except for a little less than one kg. Measurements of waste going into the SL-1 Burial Ground indicate that about 600 Ci were interred owing to the accident. Since the SL-1 disposal area was only for waste from the one incident, this amount constitutes the total material buried in the area. No wastes have been buried there since 1962.

The total area within the exclusion fence around the disposal area is about 1.7 hectares.

TABLE C-2
SOLID RADIOACTIVE WASTE STORED OR DISPOSED
OF AT INEL SDA OR TSA DURING 1974²¹

<u>DISPOSED-OF WASTES</u>		
<u>Originating Facility</u>	<u>Volume (m³)</u>	<u>Curies</u>
ANL	269	708
ARA	23	1
CFA	218	16
CPP	963	5,739
NRF	275	5,822
SPERT	28	1
TAN	201	6,736
TRA	215	736
Rocky Flats	<u>1,526</u>	<u>10</u>
Total	3,718	19,770

<u>STORED WASTE</u>		
TSA	4,135	23,530

TABLE C-3

SOLID RADIONUCLIDES DISPOSED OF AT INEL SDA DURING 1974²¹

<u>Nuclide</u>	<u>Curies</u>
Antimony-125	107
Cerium-141	2
Cerium-144	805
Cesium-134	66
Cesium-137	1,424
Chromium-51	82
Cobalt-58	2
Cobalt-60	7,662
Europium-154	42
Europium-155	24
Iron-59	1,440
Manganese-54	72
Mixed activation products	92
Mixed fission products	761
Nickel-59	3,200
Plutonium-238	1
Plutonium-239	1
Plutonium-240	1
Plutonium-241	5
Plutonium-242	1
Praseodymium-144	324
Radium-226	1
Rhodium-106	48
Rubidium-86	63
Ruthenium-106	338
Strontium-90	1,579
Thorium-232	1
Uranium-233	1
Uranium-235	1
Uranium-238	5
Unidentified alpha	1
Unidentified beta and gamma	29
Yttrium-90	1,081
Zinc-65	361
Zirconium/niobium-95	154
Total	19,770

TABLE C-4

TSA NUCLIDE SUMMARY IN CURIES FOR 1974²¹

<u>Nuclide</u>	<u>Curies</u>
Americium-241	4,453
Mixed fission products	22
Plutonium-238	58
Plutonium-239	1,921
Plutonium-240	472
Plutonium-241	16,390
Plutonium-242	1
Uranium-232	3
Uranium-233	204
Uranium-238	<u>1</u>
Total	23,530

TABLE C-5
SOLID RADIOACTIVE WASTE DISPOSED OF
OR STORED AT RWMC 1952-1974²¹

<u>Year(s)</u>	<u>Disposed</u>		<u>Stored</u>	
	<u>Volume (m³)</u>	<u>Curies</u>	<u>Volume (m³)</u>	<u>Curies</u>
1952-1964	61,738	771,300		
1965	7,533	702,900		
1966	9,487	924,300		
1967	9,657	877,800		
1968	13,735	301,500		
1969	11,498	971,000		
1970	12,517	504,400	1,416	4,225
1971	4,022	350,900	7,108	12,670
1972	3,540	214,700	5,919	28,500
1973	3,880	339,800	5,891	24,600
1974	<u>3,718</u>	<u>19,700</u>	<u>4,135</u>	<u>23,530</u>
Total	141,325	5,978,000	24,469	93,525

FIGURE C-1
VOLUME OF RADIOACTIVE SOLID WASTES
HANDLED AT INEL SDA AND TSA BY YEAR²¹

FIGURE C-2
ACTIVITY OF RADIOACTIVE SOLID WASTES
HANDLED AT INEL SDA AND TSA BY YEAR²¹

FIGURE C-3

CUMULATIVE ACTIVITY OF RADIOACTIVE SOLID WASTES
HANDLED AT INEL SDA AND TSA BY YEAR²¹

FIGURE C-4

CUMULATIVE VOLUME OF RADIOACTIVE SOLID WASTES
HANDLED AT INEL SDA AND TSA BY YEAR²¹

4.3 ICPP CALCINED SOLID STORAGE FACILITIES^{21, 22}

The ICPP calciner storage bins area is considered a solid waste management location. These underground engineered receiving bins store the solid calciner product. These storage bins were first put into service in 1963 and through 1974 approximately 53 million Ci of radioactivity representing 12,255 m³ of total volume have been stored within them. Almost 100 percent of this radioactivity is composed of Sr-90 and Cs-137. Table C-6 gives the quantity of calcined solid waste. Calcined solid waste is expected to continue at a rate of 140 m³ per year until approximately 1980 when a new calciner will be available. Solid calcine waste generation will then be 450 m³ per year. Table C-7 presents typical properties of the calcined solids which are generated at ICPP.²²

Other solid radioactive wastes generated and handled at the ICPP include filter cartridges, WCF off-gas filters, ion-exchange resins, sediment from settling basins, and hot waste boxes containing low-level contaminated wastes. Approximately 600 to 700 m³ of solid waste typically are sent to the RWMC annually. The waste is packaged in cardboard boxes, wooden boxes, and metal drums. All solid wastes from the ICPP are monitored for volume, radioactivity, and major nuclides prior to disposal.

4.4 ANL RADIOACTIVE SCRAP AND WASTE FACILITY²¹

The ANL Radioactive Scrap and Waste Facility is a controlled access, fenced 1.6 hectare area. The facility is 120 m wide by 137 m long. The storage site utilizes storage holes with steel liners which are fabricated of Schedule 10 pipe (3.7 m long and 0.4 m outside diameter with a 0.64 cm-thick wall). They are welded closed at the bottom end and provided with a top closure plate. The top plate is welded on after the material has been deposited in the liner and has been shielded with a concrete plug. Gravel shielding was used in some cases prior to 1974.

The facility was designed for 27 rows on 3.7 m centers with approximately 40 holes per row on 1.8 m centers allowing space for approximately 1,080 holes.

TABLE C-6
RADIOACTIVE LIQUID WASTE SOLIDIFIED
BY FLUIDIZED BED CALCINATION²²

Campaign	Liquid Volume Calcined ^(a) (liters)	Solid Waste Produced ^(b) (m ³)	Radioactivity ^(c) (Ci)
H-1	1,934,000	215	10.0 x 10 ⁶
H-2	3,744,000	413	19.7 x 10 ⁶
H-3	1,245,000	159	3.2 x 10 ⁶
H-4	851,000	130	1.2 x 10 ⁶
H-5	1,136,000	150	6.6 x 10 ⁶
H-6	1,175,000	185	5.1 x 10 ⁶
H-7 ^(d)	<u>1,514,000</u>	<u>228</u>	<u>6.0 x 10⁶</u>
TOTALS	11,600,000	1,480	51.8 x 10 ⁶

- (a) Nonradioactive liquid wastes used for startup checkout are not included, and WCF decontamination wastes are not subtracted.
- (b) Solids include radioactive and nonradioactive calcine and the starting-bed material.
- (c) Activities are computed at time of calcination.
- (d) Projection for the part of H-7 in FY 1976 transition quarter (to October 1, 1976).

TABLE C-7
TYPICAL PROPERTIES OF CALCINED SOLIDS²²

	<u>Fluoride Waste</u>	<u>Nonfluoride Waste</u>
Bulk Density, kg/m ³ (lb/ft ³)	1600 (100)	1120 (70)
Heat Generation Rate, W/kg	0.065-0.13	0.26
<u>Chemical Properties</u>		
Metallic Oxides (wt %)	43.3	89.2
Nitrogen as N ₂ O ₅ (wt %)	<1.0	4.0
Water as H ₂ O (wt %)	<1.0	<2.0
Calcium as CaF ₂ (wt %)	54.2	0
Fission Product and Other Oxides or Fluorides (wt %)	0.5	4.8
<u>Radiochemical Properties</u>		
Cs-137, Ci/kg (Ci/lb)	2.86 (1.30)	17.6 (8.00)
Sr-90, Ci/kg (Ci/lb)	3.52 (1.60)	13.2 (6.00)
Pu, Ci/kg (Ci/lb)	0.01 (0.0045)	0.02 (0.009)

The facility was first used in 1965 and through 1974 has received 56.6 m³ of waste totaling 10 million Ci of radioactivity, all of which originated at ANL. The material consists primarily of waste metal from fuel handling and refabrication operations. The waste is remotely loaded into a steel waste can which is then sealed and placed in a top-loading, bottom-unloading waste handling cask. The cask provides adequate shielding for personnel protection and when loaded is removed from the loading cell and transported on a special truck to the storage site. The special truck allows the cask to be positioned directly over an empty hole for easy placement of the steel waste can. Table C-8 shows the nuclide summary for 1974, and Table C-9 gives the summary of waste stored in the facility from 1965 through 1974.

If in the future it should become desirable to do so, the storage liners (complete with contained waste) could be retrieved. A detailed surface and structural examination of an empty underground storage tube was conducted after 5-1/2 years of use. The examination included a visual observation of the surface, microstructural, and micrometer measurements. The storage containers received only slight corrosion on the outer surfaces. The small deviations observed from the "as-specified" wall thickness of the container indicate that the integrity of the container is well preserved and prolonged life can be expected under identical exposure conditions.

4.5 ACCUMULATED WASTE

The total volume of waste that has been disposed of at INEL (through 1976) is 156,150 m³ of primarily mixed fission and activation products. Also, 266 kg of TRU elements have been stored, and 332 kg were buried prior to the retrievability requirement.¹⁷

TABLE C-8

ANLW STORAGE AREA NUCLIDE SUMMARY FOR 1974²¹

<u>Nuclide</u>	<u>Curies</u>
Chromium-51	19,090
Cobalt-58	8,354
Cobalt-60	47,920
Manganese-54	9,802
Mixed activation products	5,744
Mixed fission products	603
Plutonium-239	23
Uranium-235	1
Uranium-238	<u>1</u>
Total	91,536

TABLE C-9
SOLID RADIOACTIVE WASTE STORED AT ANLW 1965-1974²¹

<u>Year</u>	<u>Volume (m³)</u>	<u>Curies</u>
1965	7	760,797
1966	16	2,454,465
1967	13	1,492,504
1968	9	1,878,902
1969	5	950,961
1970	2	671,900
1971	3	476,733
1972	4	274,073
1973	2	438,300
1974	<u>1</u>	<u>91,536</u>
Total	62	9,490,171

APPENDIX D

SAVANNAH RIVER PLANT (SRP)

TERA CORPORATION

1.0 BACKGROUND^{23, 24}

Since 1953, the Savannah River Plant (SRP), near Aiken, South Carolina, has been producing special nuclear materials, primarily plutonium and tritium, for defense purposes. The SRP facilities were constructed and initially operated for the Atomic Energy Commission. Operation since 1975 has continued under the direction of the Energy Research and Development Administration (ERDA) and presently the Department of Energy (DOE).

The SRP operations produce high-level radioactive waste in the chemical processing of fuel and target elements after irradiation in the SRP nuclear reactors. This waste is stored as an alkaline liquid with a precipitated sludge until the decay heating has abated appreciably. Then the supernatant liquid is converted to salt cake to reduce volume and mobility. The storage facilities are large underground tanks that are engineered to provide reliable isolation of waste from the environment.

At SRP, solid wastes contaminated with transuranium nuclides are generated primarily in the final purification areas (B lines) of the two separations plants. Wastes from the B line of the F plant contain principally Pu-239 while those from the B line of the H plant contain principally Pu-238. All wastes are buried in a local on-site burial ground. Through calendar year 1965, most waste was in cardboard cartons with relatively little provision for confinement and retrievability. Since that time, coincident with large scale processing of Pu-238, most wastes containing > 0.1 curie of Pu-239 or Pu-238 per package have been encapsulated in concrete before burial to immobilize the waste and to facilitate possible future retrieval.

2.0 LIQUID WASTE STORAGE FACILITIES²³

2.1 HIGH-LEVEL LIQUID WASTES

Liquid radioactive wastes are produced at SRP primarily from nuclear fuel reprocessing operations in the F and H Areas. These wastes are stored in large underground tanks in these areas by methods that do not preclude any of the possible options for long-range management of the wastes.

Recovery processes in the hot (heavily shielded) and warm (moderately shielded) canyons generate aqueous waste streams that contain most of the fission products. These waste streams that come from the warm canyon are referred to as low-heat waste (LHW) and those from the hot canyon are high-heat waste (HHW). This terminology is used to identify the source of the waste and to indicate that LHW will not require auxiliary heat removal, as does HHW. The term "high-level liquid waste" includes both HHW and LHW. The wastes are made alkaline and flow by gravity from the processing buildings to the waste storage tank farm.

Fresh waste is aged for one to two years to permit settling and the decay of short-lived fission products. During this period insoluble materials settle to form a layer of sludge at the bottom of the tank. The sludge is a mixture of oxides and hydroxides of manganese, iron, and some aluminum; small amounts of uranium, plutonium, and mercury; and essentially all of the fission products originally in the irradiated fuel except cesium. After aging, the supernate, containing dissolved salts and radioactive cesium, is transferred to a continuous evaporator. The concentrate from the evaporator is transferred to a cooled waste tank where the suspended salts settle. After cooling, additional salt crystallizes. The supernate is returned to the evaporator for further concentration. This process continues until the liquid has been converted to a crystallized salt cake. The low-heat waste is handled similarly to high-heat waste. Low-heat salts are now being accumulated in uncooled waste tanks.

Ranges of chemical compositions, principal long-lived radioactive constituents and other properties of high-level liquid wastes (LHW and HHW) are presented in Table D-1.

At present, SRP has 30 large subsurface tanks for the storage of aqueous radioactive wastes, as sludge, supernatant liquid of various salt concentrations, and salt cake. Sixteen of these tanks are adjacent to one separations plant (H Area) and 14 are adjacent to the other (F Area). Three additional tanks are nearing completion in H Area, and four tanks are under construction in F Area. All of the waste tanks are below ground, and are built of carbon steel and reinforced concrete, but they are of four somewhat different designs. Three designs have double steel walls and bottoms and forced water cooling systems and are used primarily for high-heat waste and waste concentrate; the fourth design has a single steel wall directly supported by the encasing reinforced concrete, has no forced cooling, and is used primarily for low-heat waste and concentrate.²³

Table D-2 summarizes the volumes of total waste, sludge, and salt in the tanks as of December 1975.

Net accumulation of stored waste from current fresh waste receipts and tank farm evaporator operation is expected to continue at no more than an average rate of 3.8 million liters per year. The volume of liquid supernate stored in the waste tanks will vary with time as waste management operations are carried out to relocate existing and new wastes. Transfer of existing salt cake and sludge to new or improved tanks will temporarily increase the total volume of waste because of the water added to accomplish the transfers. Addition of new evaporators and improved in-tank coolers will reduce the liquid volume.

Spare volume is maintained in sound double-wall tanks in each of the two waste tank areas (F and H). This volume is equivalent to the largest volume of waste stored in any one tank. New waste tanks that are now under construction or planned will enable the replacement of all single-wall tanks and those double-wall tanks that have leaked waste liquid and salt into the annulus between the primary and secondary steel container.

TABLE D-1
RANGE OF CHEMICAL COMPOSITIONS OF
SRP HIGH-LEVEL LIQUID WASTES²³

<u>Constituent</u>	<u>Concentration</u>
Supernate	
NaNO ₃ , NaNO ₂	3 to 6M
Na ₂ CO ₃	0.1 to 0.3M
Na ₂ SO ₄	0.02 to 0.2M
NaOH	1 to 6M
NaAl (OH) ₄	0.4 to 1.0M
Sludges ^(a)	
MnO ₂	Principal constituents of sludge
Fe(OH) ₃	
Radioisotopes	
Sr-90	0.3 to 180 Ci/l
Cs-137	0.3 to 6 Ci/l
Pu-238	0.0003 to 0.3 Ci/l
Pu-239	0.03 to 6m Ci/l

(a) Settled volume ~ 10% of supernate volume.

TABLE D-2
 CONTENTS OF HIGH-LEVEL LIQUID WASTE TANKS
 DECEMBER 1975²³

	<u>Millions of liters</u>
Total volume of waste, F and H Areas	77.3
Volume of sludge	9.0
Volume of salt cake	25.5
Volume of liquid supernate	42.8
Total unoccupied storage space	33.7 ^(a)

(a) Includes working volume and emergency spare volume.

All of the new tanks will be of the latest type, with the primary container fully stress-relieved and a full height secondary container.

By the mid-1980's, all of the high-level liquid waste is estimated to be stored in tanks completed in 1970 or later. Evaporators will be constructed as needed so that waste evaporation capacity will not limit the tank replacement program.

Current waste management practices, including the construction of new double-wall waste tanks to replace the older single-wall and leaking double-wall tanks, do not preclude any of the possible options for long-term management of SRP wastes. These options include improvement in current practices based on continued surveillance and maintenance and, at the other extreme, complete removal of the wastes from tank storage and conversion to an inert solid form for ultimate storage. It has been demonstrated at SRP that the waste salt can be redissolved and that the settled sludge can be removed by a combination of hydraulic and chemical cleaning.

3.0 SOLID RADIOACTIVE WASTE STORAGE SITE (BURIAL GROUND)

3.1 FACILITY DESCRIPTION^{23, 17}

One centrally located solid radioactive waste storage site is used to store all radioactive solid waste produced at the Savannah River Plant as well as occasional special DOE shipments from off-site. This storage site occupies 78.9 hectares approximately 10 km from the nearest plant boundary. The original area of 31 hectares, which began to receive waste in 1953, was filled in 1972, and operations were shifted to a 48-hectare site contiguous to the original area. A paved road to its entrance and many unpaved roads inside the fenced area provide access for trucks, the usual transportation mode for solid waste. Three railroad spurs permit shipments of large pieces of contaminated process equipment from the plant's operating areas.

The solid waste storage site is divided into sections for accommodating various levels and types of radioactivity in waste materials: transuranium (TRU) alpha waste, low beta-gamma waste, and high beta-gamma waste (high beta-gamma and low beta-gamma solid radioactive wastes are those containing primarily beta-gamma emitters which are segregated according to radiation measurement). Examples of the materials in storage include:

- Contaminated equipment - obsolete or failed tanks, pipes, jumpers, and other process equipment from the fuel separations plants.
- Reactor and reactor fuel hardware - fuel components and housings not containing irradiated fuel and spent deionizer resins.
- Spent lithium-aluminum targets - the waste target alloy after tritium has been extracted.
- Oil from gas displacement pumps in the tritium facilities - before burial, oil is placed in drums containing an absorbent material.

- Mercury from gas pumps in tritium facilities - before initiation of recycling in 1968, deteriorated and contaminated mercury was buried with primary containment by one-liter polyethylene bottles.
- Incidental waste from laboratory and production operations - small equipment, spent air filters, clothes, analytical waste, decontamination residues, plastic sheeting, and gloves.
- Occasional shipments from offsite - tritiated waste from the Mound Facility, Pu-238 process waste from Los Alamos Scientific Laboratory (LASL) and the Mound Facility, and debris from two U.S. military airplane accidents in foreign countries.

Accurate records are kept of the contents, radiation level, and storage location of each load of waste. Shipments are described and recorded, and permanent computerized records are maintained on magnetic tape. The exact location of the burial trenches is defined by use of a 30.5-m grid system laid out in 1962. The 30.5-m grids are further divided into twenty-five 6.1-m squares.

3.2 STORAGE MODES^{23, 17}

There are two types of facility storage modes at SRP: pads and trenches. Waste emplacements are covered promptly with soil to reduce radiation exposures and the potential of fire and wind-blown contamination. When a trench is nearly filled with waste, it is backfilled with soil. The minimum soil cover is 1.2 m, but it must be sufficient to reduce surface radiation to 6 mR/hr or less.

3.2.1 TRU WASTE²³

Transuranic waste was originally buried in plastic bags and cardboard boxes in earthen trenches designated specifically for this waste. At Savannah River beginning in 1965, TRU waste was segregated according to TRU content into two categories, retrievable and nonretrievable, and additional containment was added for retrievable waste. Waste containing greater than 0.1 Ci per package was placed in prefabricated concrete containers and then buried. These retrievable

containers were 1.8 meters in diameter by 2 meters high. Waste that did not fit into the prefabricated concrete containers was encapsulated in concrete. Transuranium waste from the Savannah River Laboratory was buried in cubical concrete containers. Waste containing less than 0.1 Ci per package was buried unencapsulated in alpha trenches. A total of 242,900 m³ was buried under these practices.¹⁷

In 1974, the storage procedures were modified to reflect new DOE criteria governing retrievable storage of solid transuranic waste. Transuranium wastes contaminated to greater than 10nCi/g are now stored, protected from contact with water-saturated soil, in containers that can be retrieved intact and free of external contamination for at least twenty years from the time of storage. Combustible and noncombustible wastes are stored in separate containers. Polyethylene-lined galvanized drums are used as the primary container; waste packages containing more than 0.1 Ci are additionally protected by closure in concrete cylinders. Containers are stored on a steel-bar-reinforced concrete pad (18 m in width by 46 m in length by 0.3 m in thickness) and covered with 1.2 m of earth. The top layer is covered with asphalt and soil and then seeded. In accordance with DOE Manual 0511, canyon equipment and other bulky wastes contaminated with transuranium nuclides to greater than 10 nCi/g and also intensely contaminated with gamma emitters are stored directly in earthen trenches protected from contact with water-saturated soil. Waste is placed in the trench and covered with soil soon after its placement. The minimum soil cover is 1.2 m or as deep as is needed to reduce surface radiation to at least 6 mR/hr.

3.2.2 BETA-GAMMA WASTE

Waste contaminated with beta-gamma emitters is separated into two categories for burial: low beta-gamma and high beta-gamma. Low beta-gamma waste is defined as waste measuring less than 50 mR/hr at 7.6 cm from an unshielded package and less than 50 mR/hr at 3 m from the truck load. This waste is disposed of in low beta-gamma waste trenches. Scrap unirradiated uranium is

also classified as low beta-gamma waste, but it is buried in separate trenches. Irradiated reactor fuel housing components, tritium waste (classified as high beta-gamma waste because of induced activity associated with the Li-Al melts from the process facility), and miscellaneous waste in cardboard boxes are segregated and buried in separate trenches.

Trenches are 6 m wide x 6 m deep and up to 215 m long. The total trench length that had been utilized from the beginning of SRP operations through 1976 was 25 km in an area of 14.6 ha.

3.2.3 SOLVENT

Degraded solvent from the chemical separations areas is stored in underground tanks at the burial ground. The present inventory of 562,000 liters contains about 45 Ci of TRU nuclides (Pu-238, Pu-239, Cm-244) and about 50 Ci of fission product nuclides. The solvent storage facility consists of six bitumastic-coated, mild steel tanks of 94,000-liter capacity, which were installed in 1975. Each tank has a sump with liquid level monitored weekly for leaks. In addition, two older 94,000-liter mild steel tanks are used to store solvent with the lowest level of radioactivity. The liquid level in all eight tanks is measured weekly to detect leaks. The expected rate of waste solvent generation is about 19,000 liters per year.

3.3 QUANTITY OF WASTE^{23, 17}

The estimated volume and curie content of waste buried in 1975 is listed in Table D-3. The total estimated volume and curies of waste in storage are summarized in Table D-4. Table D-5 presents the maximum quantities of radionuclides stored at a single location.

A total of 273,348 m³ of waste, which contains 4270 KCi of radioactivity, has been disposed of at SRP. The TRU wastes which are stored occupy a volume of 1563 m³ and contain 52 kg of transuranic nuclides.¹⁷

TABLE D-3
SOLID WASTE BURIED IN 1975 FROM SRP OPERATIONS ^{(a)23}

Radio-nuclide	Earthen Trenches		Retrievable Storage		Total	
	Volume, m ³	Curies	Volume, m ³	Curies	Volume, m ³	Curies
Cf-252	4	--	40	1.5	44	1.5
Cm-244	400	--	10	50	410	50
Pu-238 ^(c)	420 ^(b)	(b)	40	4,190	483	4,330
Pu-239 ^(d)	770		80	160	850	160
	--					
Np-237	50	--	10	0.4	60	0.
U-238	540	1.2	1	--	541	1.2
U-235	220	0.002	3	--	223	0.002
H-3	1,000	59,500	--	--	1,000	59,500
Fission Products	6,470	65,500	2	90	6,470	65,600
Activa-tion Products	320	71,500	10	400	330	71,900
Totals	10,200 ^(b)	197,000 ^(b)	200	4,900	10,400	202,000

(a) Volumes and curies rounded to no more than 3 significant figures.

(b) These totals do not include a process vessel vent filter in a 23 m³ steel tank estimated to contain less than 140 Ci Pu-238 which is buried in an earthen trench. This filter also contains an estimated 6,000 Ci of fission products. Such equipment is excluded from surface storage by DOE Manual Chapter 0511.

(c) The Pu-238 waste typically contains 81 percent Pu-238, 15 percent Pu-239, three percent Pu-240 and one percent Pu-241.

(d) The Pu-239 waste typically contains about 94 percent Pu-239 and six percent Pu-240.

TABLE D-4
SOLID RADIOACTIVE WASTE STORED IN BURIAL GROUND (a)23
(THROUGH 1975)

Radio-nuclide	Earthen Trenches		Retrievable Storage		Total		Corrected for Decay, Ci ^(b)
	Volume, m ³	Curies	Volume, m ³	Curies	Volume, m ³	Curies	
Cf-252	400	0	170	12	570	12	7
Cm-244	6,000	1,670	800	40,600	6,800	42,300	33,300
Pu-238	4,600	3,380	560	257,000 ^(c)	5,160	260,000	251,000
Pu-239	12,600	510	600	1,700 ^(d)	13,200	2,210	2,210
Np-237	500	0.2	30	2.8	530	3	3
U-238	25,600	25	1	0	25,600	25	25
U-235	2,600	0.2	10	0	2,600	0.2	0.2
H-3	10,300	3,540,000 ^(e)	10	146,000	10,300	3,690,000	2,550,000
Fission Products	164,000	678,000 ^(f)	50	25,400	164,000	703,000	58,000 ^(f)
Activation Products	22,900	3,250,000 ^(g)	10	450	22,900	3,250,000	970,000
Totals	250,000	7,470,000	2,240	471,000	252,000	7,950,000	3,860,000

(a) Volumes and curies rounded to no more than 3 significant figures.

(b) Corrected for decay through 1975.

(c) Includes 230,000 curies in DOE waste received from off-site.

(d) Includes 150 curies in DOE waste received from off-site.

(e) Includes 1,470,000 curies in DOE waste received from off-site.

(f) Cs-137 and Sr-90 are estimated at 2% each of the total before decay and 40% each after decay.

(g) Co-60 is estimated to be 98% of this total.

TABLE D-5
MAXIMUM QUANTITIES OF BURIAL GROUND RADIONUCLIDES
STORED AT SINGLE LOCATIONS²³

<u>Isotope</u>	<u>Condition</u>	<u>Maximum Quantity, Ci</u>
Pu-238	High-level transuranium cabinet waste in lined, steel drums. Fourteen drums are placed in a concrete container. Container is open prior to sealing.	2000 per concrete concrete container (550 per drum)
Pu-239	Same as above	23 per concrete container (12 per drum)
Cm-244	High-level transuranium waste from SRL in lined steel drums. Fourteen drums are placed in a concrete container. Container is open prior to sealing.	1800 per concrete concrete container (500 per drum)

3.4 WASTE CHARACTERISTICS²³

The solid wastes at SRP can be divided into six categories. These will be individually discussed to provide insight into SRP solid waste characteristics.

3.4.1 CARDBOARD BOXES BURIED IN TRENCHES

These wastes generally originate in gloved enclosures and their associated laboratories. They are characterized by relatively high combustible content and relatively low external radiation level. Through 1965 a total of about 2 kg of Pu-239 was buried in this manner. Since that time these wastes have been limited to no more than 0.1 curie per package on the basis of a passive gamma analysis. The most common cardboard box is a 38 cm cube. Other sizes that are used include 61- and 76-cm cubes. Approximately 70 percent of all waste buried through 1970 consisted of cardboard boxes. It is estimated that if this waste were retrieved the volume of the restored waste would be triple the original volume.

3.4.2 BOXED OR DRUMMED WASTE IN CONCRETE CULVERTS

Since 1965 cardboard cartons or metal drums containing < 0.1 curie per package (principally combustible waste having low external radiation level) have been placed in large concrete containers before burial. These containers have inside dimensions of 1.8 m diameter x 1.8 m tall and outer dimensions of 2.1 m diameter 2.1 m tall. These containers are made by pouring a concrete bottom in a standard culvert section. After the container is filled the top is sealed in place using epoxy resin. These concrete containers weigh about 7,000 kg. This waste form makes up 2.6 percent of the total waste buried through 1970.

3.4.3 LARGE EQUIPMENT IN MONOLITHIC POURS

Large items of equipment significantly contaminated with transuranium nuclides - encased in wooden or metal boxes to promote safe transport to the burial

ground - are further encased in concrete using the earth as a form. After a concrete footing is poured in an earth excavation of suitable size, the boxed waste is placed on the footing and concrete is poured all around and on top. A total of about 200 such burials have been made through 1970 (approximately 3.3 percent of total waste buried). Outer dimensions of the concrete pours have varied from about 1.2 m cubes to about 6-m cubes.

3.4.4 SRL TRANSPLUTONIUM WASTES

Wastes from the Savannah River Laboratory (containing principally americium, curium, and californium) are placed in 0.6 m square by 1 to 1.2 m long concrete boxes before burial. These boxes weigh about 450 kg. The wastes originate primarily in glove boxes and process cells. Most of the waste is combustible and the radiation level at the surface of the concrete box is generally in the range of 10-1000 mrem/hr. This waste makes up about seven percent of the waste material buried.

3.4.5 LARGE EQUIPMENT DIRECTLY BURIED IN TRENCHES

Prior to 1966 large items of process equipment having significant transuranium contamination were enclosed in wooden or metal boxes and buried directly in trenches without concrete encapsulation. At present this practice is permitted only for those items of process equipment that have been substantially decontaminated of transuranium materials before burial. In general, this equipment has a relatively high external radiation level from fission product contamination. This waste makes up about five to six percent of all the waste buried through 1970.

3.4.6 RETRIEVABLE 208-LITER DRUMS

Drummed wastes received from off-site are presently stored in the Savannah River burial ground. These waste containers (approximately 11.2 percent of the waste buried through 1970) are in relatively good physical condition and may be considered retrievable for a period of at least several years.

3.5 MISCELLANEOUS RADIOACTIVE WASTE²³

In addition to the waste sources discussed above, certain miscellaneous radioactive waste sources exist at SRP. Most of the locations of miscellaneous waste disposal are marked or are within controlled areas. These include locations containing radioactivity from spills, equipment failure, etc., but not locations containing activity from ongoing operations. Table D-6 presents those areas which are TRU-contaminated.

3.6 FUTURE WASTE GENERATION²³

The estimated annual generation rate of transuranium solid waste under the present and proposed policies are summarized in Table D-7. The waste forms generally reflect use of the retrievable criteria for waste with TRU control greater than 10 nCi/g.

TABLE D-6
MISCELLANEOUS RADIOACTIVE WASTE IN SOIL²³

<u>Date</u>	<u>Location & Brief Description</u>	<u>Disposal Area (ft²)</u>	<u>Treatment of Area After Release</u>	Remaining		
				<u>Volume (ft³)</u>	<u>Curie Content</u>	<u>Type Waste</u>
2/54	Plutonium solution released thru the F-Area sanitary sewer system from Building 221-FB Line	2X10 ³ outside F Area fence	Residue from treated sewage (Building 607-1F) deposited in trench and covered	10 ³	< 0.02	Pu
6/69	Curium-244 aerosol released from Building 773-A cell #12 exhaust stack of the High Level Caves	1X10 ⁵	None	-	0.02	α, primarily Cm-244
12/71	Curium-244 released from the High Level Caves separator pit to the ground area underneath E-Wing Building 773-A.	1X10 ³	None	-	6	α, γ, primarily Cm-244

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TERA CORPORATION

TABLE D-7
ESTIMATED ANNUAL GENERATION RATE
OF TRANSURANIUM SOLID WASTE AT SRP²³

Waste Category	Radioactivity (Ci)			Volume (m ³)
	Pu-239	Pu-238	Cm-244	
1. Cardboard boxes for direct trench burial	10 ⁻⁴	10 ⁻⁴	--	500
2. Burial of drummed waste in concrete culverts	180 (3000 g)	1,400 (85 g)	-- --	650
3. Large equipment in monolithic concrete pours	40	180	--	65
4. SRL 0.6 x 0.6 x 1 m concrete boxes	20	--	12,000	300
TOTAL	240 (4000 g)	1,600 (100 g)	12,000	1,515

APPENDIX E

**OTHER DEPARTMENT OF ENERGY (DOE)
FACILITIES**

TERA CORPORATION

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1.0 INTRODUCTION

The purpose of this Appendix is to present the best available information on other Department of Energy (DOE) facilities which generate and/or bury/store TRU-contaminated or potentially TRU-contaminated waste. The information presented is somewhat sketchy and possibly outdated, but represents the best available data taken from literature available to the researchers and personal conversation by investigators.

2.0 LOS ALAMOS SCIENTIFIC LABORATORY (LASL)

2.1 INTRODUCTION

The Los Alamos Scientific Laboratory is located in north-central New Mexico on the Pajarito Plateau, west of the Rio Grande, on the eastern slopes of the Jemez Mountains. LASL has used shallow land burial for disposal of solid radioactive waste since the mid-1940s. The bulk of the material consists of room-generated trash. A variety of special disposal operations has been performed, ranging from the shaft burial of a cylinder containing a few grams of tritium-contaminated solution to the demolition and burial of entire buildings. Currently, there are three active locations (areas A, G, and T) for disposal at LASL.¹⁷ All solids contaminated with radioactivity are buried on-site at LASL. Contaminated aqueous liquids are treated to produce solids for on-site storage. Contaminated organic liquids are either burned (low-activity level) or jellied (high-activity level) to form a "solid" for on-site storage.

Waste generated at LASL is packaged to provide safe handling and transport to the disposal site. With the exception of tritium wastes, the packaging is not intended to provide containment after burial. Most of the low-activity trash-type waste is compacted and baled prior to burial.

"Room-trash"-type wastes generated at the LASL DP-West plutonium facility are tested for radioactivity and properly segregated for burial or storage. This same practice is followed for similar types of waste generated at the LASL R&D facilities where transuranic material is worked with. Distinctively hazardous and radioactive wastes, such as contaminated laboratory chemicals and reactive metals, are properly packaged and disposed of in shafts and are immediately covered. The solids are categorized below according to how they are buried.¹⁸

LASL utilizes both storage facilities and disposal facilities. There are four types of storage facilities - storage shed, storage trench, cask storage trench and a corrugated metal pipe storage trench - which are located in area G and area T. Disposal facilities include both disposal trenches and shafts.

2.1.1 STORAGE FACILITIES¹⁷

The storage shed located in area G is a metal building (12.2 m in length x 4.6 m in width x 3.7 m in height) which serves as a temporary aboveground storage area for drums and fiberglass-coated crates containing retrievable TRU wastes. Maximum storage space available is for about 250 (208-liter) drums or 25 (1.2 m in length x 1.2 m in width x 2.1 m in height) fiberglass crates. Once a sufficient number of drums and crates have been accumulated in this shed, the drums are coated with a corrosion inhibitor and the crates are sealed with fiberglass and then all are placed into the retrievable storage trench.

Also located in area G, the retrievable storage trench is 9.1 m wide, 122 m long, and 7.6 m deep with a 1:4 slope entrance ramp and an asphalt-lined floor. Sumps at the low point in the trench collect all water entering the trench as a result of rain or snowmelt. Waste packages are stacked in the trench to within 1-2 m from the surface, and the stack is then covered with 1.9 cm plywood and completely encased with a reinforced vinyl material. Finally, the waste stack is covered with 1.2 m of backfill.

Wastes placed in the trench are limited to 1 g Pu-238 per 208-liter drum, 100 g of other TRU per 114-liter drum, 200 g of other TRU per 208-liter drum, or 175 g per m³ to a maximum of 350 g per crate.

Wastes contaminated with Pu-238 in excess of 1 g per drum or with U-233 with high gamma radiation are stored in concrete casks and placed into shallow trenches (40-80 m long by 2.8 m deep). The outside of each cask is coated by the manufacturer with a bitumin epoxy material and is coated a second time with an asphalt roofing compound. The casks are placed vertically in a trench, and the trench is backfilled almost to the top of the cask.

Two 114-liter drums of waste each containing up to a maximum of 40 g each of Pu-238 or 200 g U-233 are placed inside each cask. The cask lids are sealed with roofing tar. When a portion of a trench is filled, corrugated galvanized sheet metal is used to cover the trench over the tops of the casks, and the trench is backfilled to ground level and mounded 0.5 to 1.0 m above ground level.

Two trenches containing 120 casks have been filled to date (1977), and a third trench has been started. Room is available for five additional trenches.

The corrugated metal pipe (CMP) storage trench located in area T is used for the disposal of retrievable cement paste containing plutonium and americium. This paste is pumped into 0.75-m-diameter by 6.1-m-long corrugated metal pipe sections. Prior to filling, these pipes are placed in a trench approximately 6 m deep by 70 m long by 7.3 m wide. An uncontaminated cement plug 0.3 m thick seals the bottom of each pipe. Once filled, the pipes are sealed with another 0.3-m-thick cement plug. After the filling and sealing, the pipes are covered with backfill. The trench is about 33 percent full. However, the generation of retrievable cement paste is expected to end by mid-1978.¹⁷

2.1.2 SOLIDS IN WASTE TRENCHES

Most small solid articles contaminated with radioactivity are put into 0.03 m³ steel foot-operated rubbish bins with polyethylene bag liners. If a slightly larger volume is needed 0.06 m³, corrugated cardboard cartons lined with plastic bags are used. When these plastic liners are full, they are sealed and collected either in 0.34 m³ plastic bags or in the cardboard boxes which are also sealed. Other containers, such as 3.8-liter, 19-liter, 114-liter, and 208-liter steel cans or drums, are used for special situations. The large bags, boxes, and other containers are placed in steel transportable waste bins. The bins are picked up by special trucks and taken to the contaminated waste disposal area for discharge. Large contaminated solid items are covered as necessary to prevent spread of contamination during shipment and transported separately to the disposal area. This miscellaneous bagged and boxed waste makes up about two-thirds, currently, of the waste buried at LASL. Over 90 percent is contaminated with plutonium. Dewatered sludge from the low-level liquid waste treatment plant is put into 208-liter steel drums and hauled to the disposal area.

Disposal trenches are used for the disposal of low-activity nonretrievable radioactive wastes. These wastes include contaminated trash from laboratory areas, failed equipment, and solid residues from liquid waste treatment. Wastes are packaged in plastic bags, cardboard boxes, or wooden crates.

In the disposal area, trenches about 9 m deep, 30 m wide, and 150 m long with an excavated volume of about $3.4 \times 10^4 \text{ m}^3$ are dug. The ends are sloped for ease of access by vehicles. Wastes are carried by truck into the pit where they are dumped or set into place. Penetrating radiation readings on the package surfaces range from essentially zero to about 0.6 mrem/hr with an average of about 0.1 mrem/hr. When the waste has accumulated to a depth of about one meter, it is covered with about 0.3 m of dirt and compacted. Layers are continued until the pit is filled to within one meter of the surface, then dirt is placed on top, compacted and leveled.

2.1.3 SOLIDS IN WASTE SHAFTS

Deep shafts, augered into the volcanic tuff, are used for the disposal of high beta-gamma waste, tritium waste, contaminated animal tissue, cement paste, and classified contaminated waste.

Small items that are known to contain somewhat larger amounts of radioactivity, particularly beta-gamma radiation, are put into vertical shafts or holes in the ground and covered at 0.9 m intervals. These shafts are 0.9 m in diameter and 9 m deep. In some cases the shaft is lined with 0.15 m of concrete and the waste is covered with concrete or asphalt. Since 1956, any waste containing a significant quantity (milligram) of plutonium has been buried separately in special shafts or holes.

Since mid-1968, the dewatered sludge from one liquid waste disposal facility and an americium raffinate (approximately 6,050 liter/month containing about 1.06 mg Am-241/liter and 2.12 mg Pu-239/liter) are fixed in cement in a continuous process and pumped through an underground pipeline to deep holes located in an abandoned waste disposal area about 46 m away from the cementing facility. These holes or wells are 1.8 to 2.4 m in diameter and 7.6 to 20 m deep at both areas G and T. They are filled with waste up to 1 m from ground surface or up to where the allowable level is reached. No more than 500 g of fissile material may be disposed of in a shaft, and radiation doses at the shaft surface cannot exceed 100 mR/hr. Whenever doses are exceeded, backfill is

added to reduce the dose. When the shaft is filled with waste, excavated turf is added to fill void spaces, a final 1 m concrete plug is poured, and the concrete is mounded above the shaft surface to provide a final seal with proper drainage. Before mid-1968, the americium raffinate was fixed in cement by a batch process in 208-liter drums which were hauled by truck to the waste pits. Most of the americium discarded is in this cemented product.

2.1.4 WASTE GENERATION

Reductions of 20-25 percent in the volume of wastes have been accomplished through a combination of required generator-site waste management standard operating procedures, as well as through control of materials entering radioactive work areas. Similarly, a large reduction in the volume of wastes placed in retrievable storage has resulted from better assay and segregation techniques. Rough estimates of the solid wastes contaminated with transuranics expected to be generated annually at LASL are shown in Table E-1. The current and expected annual rate of waste disposal at LASL is about 4000 m³/year, which contains 8 KCi of mixed fission and activation products and 8000 kg of uranium. The rate of TRU storage is 510 m³/year, which contains 6.3 kg of transuranic elements. This compares favorably to the 1974 data which indicated an annual burial of 32,020 curies in 4071 m³ of solids including binding agent.¹ Plutonium (primarily Pu-239) amounted to about 150 g and about 5 kg prior to provisions for retrievable storage.

TABLE E-1
ESTIMATES OF FUTURE ANNUAL GENERATION
OF TRU-CONTAMINATED SOLID WASTE AT LASL¹⁸

Type	Percent Combustible (Volume %)	Annual Rate		
		Pu (g)	Am (g)	Volume (m ³)
Bagged and boxed miscellaneous solid articles	60	20	trace	3,239
Dewatered sludge from water treatment	0	30	trace	255
Cemented sludge and americium raffinate	0	150	75	340
TOTAL		200	75	4,125

3.0 MOUND FACILITY

3.1 WASTE GENERATION, CHARACTERISTICS, AND AMOUNTS

Unclassified contaminated solid wastes generated by the Mound Facility are shipped to commercial burial sites at West Valley, New York (presently closed), or Morehead, Kentucky, for burial, while classified wastes were shipped to Oak Ridge, Tennessee (ORNL). All TRU waste has been shipped to INEL since FY 1975.^{1,63} The polonium (an alpha emitter) and plutonium contaminated solid wastes generated at Mound can be put into five categories: Pu-238 low-level waste (LSA), Pu-238 high-level waste (non-LSA), solidified-clariflocculator-sludge (non-LSA), absorbed Pu-238 acid and caustic wastes (non-LSA), Po-210 low-level waste (LSA), and Po-210 high-level waste (non-LSA). The discard limits for Pu-238 are shown in Table E-2. The quantity of plutonium discarded ranged from 45 g in FY 1966 to 1120 g in FY 1970 (Table E-3).¹⁸

3.1.1 PU-238 LOW-LEVEL WASTE¹⁸

The Pu-238 low-level waste is composed of contaminated equipment, floor sweepings, used plastic shoe covers, discarded clothing, paper towels, swipes, cleaning rags, blotter paper, etc., from rooms in which glove box and hot cell operations are conducted. Less than 0.35 mCi Pu-238 per m³ is associated with this class of waste. About 60 vol % is collected and shipped in crates and about 40 vol % in drums. Drums are the preferred containers for all waste types. Crates are used only for items that are too large for drums.

3.1.2 PU-238 HIGH-LEVEL WASTE¹⁸

The Pu-238 high-level waste consists of miscellaneous burnable and nonburnable solids (metal, plastic, glass, etc.) from glove boxes and hot cells used in plutonium production. As shown in Table E-2, burnables have less than 0.110 g of Pu-238 per 3.78-liter carton, nonburnables less than 0.511 g per 3.78-liter carton, and glass filters less than 0.613 g per one 25.4 cm filter. Generally, this waste is collected in 3.78-liter cardboard cartons with a plastic coating on the inside

TABLE E-2
DISCARD LEVELS OF PU-238 AT MOUND FACILITY (1970)¹⁸

<u>Residue</u>	<u>Pu-238 Discard Level^(a)</u>
Burnables	0.110 g per 3.78 liter can
Nonburnables	0.511 g per 3.78 liter can
Ion exchange raffinate	0.006 g/liter
Evaporator condensate	0.006 g/liter
Caustic bubbler and scrubber solution	0.012 g/liter
Wash solution	0.006 g/liter
Filtrate solution	0.013 g/liter
Spent resin	0.358 g per 3.78-liter can
Glass filters	0.613 g per one 25.4 cm filter
In-line filters	0.461 g per one 25.4 cm filter
Drummed residues	1.85 g per 208-liter drum

a. A typical isotopic composition of the Pu-238 is:

Pu-238	80.94%
Pu-239	15.26%
Pu-240	2.88%
Pu-241	0.79%
Pu-242	0.12%
Pu-236	1.2 ppm

TABLE E-3

QUANTITIES OF TRU-CONTAMINATED
SOLID WASTE GENERATED IN FY 1970 AND EXPECTED
TO BE GENERATED THROUGH FY 1975 AT MOUND FACILITY^{1, 18}

Category	FY 1970 Generation	Expected Generation Through FY 1975	
	Volume (m ³)	Volume (m ³)	Annual Average (m ³)
Pu-238 low-level waste ^(a)	1,398	8,500	1,700
Pu-238 high-level waste ^(b)	299.7	1,700	340
Solidified-clariflocculator-sludge ^(c)	287.1	1,700	340
Absorbed Pu-238 acid and caustic ^(c)	381	700	140

- a. About 90 vol % combustibles.
- b. About 75 vol % combustibles.
- c. Noncombustibles.

surface. Three cartons are sealed in a PVC bag as they are removed from the production line. Four of these sealed units, i.e., 12 cartons, are placed in a 114-liter steel drum. However, 208-liter drums and plywood crates are used for larger items such as contaminated equipment and glove boxes. Large items usually are filled with self-foaming plastic and placed in a crate which is lined with a polyethylene sheet. The open space in the crate is then filled with the self-foaming plastic.

3.1.3 SOLIDIFIED-CLARIFLOCCULATOR-SLUDGE¹⁸

The class of waste called solidified-clariflocculator-sludge is generated when sludge from the contaminated wastewater treatment facility is mixed with cement. The sludge contains the barium, calcium, and iron salts formed as well as the flocculating agent and activated charcoal added during the scavenging-precipitation treatment of the contaminated wastewater from drains, sinks, showers, the laundry, etc. The sludge containing 30 to 35 wt % solids is mixed with 11 to 22 kg of Portland cement in a 114-liter steel drum. Less than 3.53 Ci Pu-238 per m³ is associated with this waste.

3.1.4 ABSORBED PU-238 ACID AND CAUSTIC WASTE¹⁸

Absorbed Pu-238 acid and caustic waste are generated when acidic and caustic solutions from the Pu-238 production lines are reacted with and absorbed by a pulverized clay. In the treatment process, 45 liters of acidic or caustic solution are mixed with 110 liters of ground dried clay in a 110-liter polyethylene jug (DOT Specification 2S) which is held within a 125-liter steel drum (DOT Specification 17H). The jug is outgassed for 24 hours with acidic solutions and eight hours with the caustic solutions before sealing. The radioactivity associated with this waste is less than 700 mCi per m³.

3.1.5 PO-210 LOW-LEVEL WASTE¹⁸

The Po-210 low-level waste category consists of contaminated equipment, floor sweepings, used plastic shoe covers, discarded clothing, paper towels, swipes,

cleaning rags, etc., from rooms in which glove box and hot cell operations for polonium production are carried out. The Po-210 content of this waste is less than 0.35 mCi per m³. The waste is collected and shipped in 114-liter steel drums (DOT 17H); 208-liter steel drums (DOT 17C); and plywood crates (DOT 19A or 19B).

3.1.6 PO-210 HIGH-LEVEL WASTE¹⁸

The Po-210 high-level waste is generated in the glove boxes and hot cells used in polonium production. It consists of the contaminated metal, glass, plastic, cloth, paper, etc., removed from the boxes and cells. The polonium associated with these materials amounts to less than 1,765 Ci/m³. The waste is collected in 114-liter steel drums. This drum is shipped in a 208-liter steel drum used as an overpack.

The volume of TRU-contaminated solid waste generated in 1970 and estimated through FY 1975 is given in Table E-3.

4.0 OAK RIDGE RESERVATION

4.1 INTRODUCTION

Located in the west central portion of eastern Tennessee, the Oak Ridge Reservation is bounded on the northeast, southeast, and southwest by the Clinch River and on the northwest by Black Oak Ridge.

The 92-square-mile Oak Ridge Reservation was originally acquired by the Manhattan Project, U. S. Army Corps of Engineers, as a site for production facilities and nuclear research, and a security buffer and safety zone were established around each plant within the Reservation. The original 23,877 hectares acquired in 1942 have since been reduced to approximately 14,959 hectares through land transfers to the municipal government of Oak Ridge and to state and Federal agencies.²⁵

The allocation of land among the DOE users is as follows:

<u>Administrative Unit</u>	<u>Hectares</u>
Multiple Use	7,068
ORNL (X-10)	3,550
Y-12	1,384
K-25	1,910
CARL (UT-DOE)	1,047

Four separate production and research facilities are operated within the reservation. They are Oak Ridge National Laboratory (X-10), the Y-12 Plant, the Oak Ridge Gaseous Diffusion Plant (K-25), and the Comparative Animal Research Laboratory (CARL). Buffer zones are designated around each of the four facilities for health, safety, and future expansion. Access to the reservation is limited primarily to public roads and visitor centers for reasons of health, safety, and national security.²⁵

4.2 OAK RIDGE NATIONAL LABORATORY (ORNL)

Normal operations at ORNL generate up to 7.6 million liters per year of intermediate-level waste (ILW) solution having an average activity concentration of a few hundredths of a curie per liter. This ILW solution is routinely neutralized with sodium hydroxide which precipitates those constituents of the waste solution that are insoluble in alkaline solution. These solids, which contain the bulk of the Sr-90 and the actinides that have been discharged to the waste system, settle and accumulate in the waste storage tanks. The remaining liquid (supernate) is concentrated by evaporation and since 1966 has been periodically disposed of by shale fracturing (a process for the fixation of the waste in an impermeable bedded shale formation at a depth of approximately 300 meters). Approximately 300,000 liters of concentrated waste solution are disposed of annually. The current generation rate for sludge is about 40,000 liters per year. About 1,500,000 liters of sludge have accumulated from the operations of previous years and are presently held in various waste storage tanks.²⁵

The concentrated waste solution is alkaline, the major chemical constituent is sodium nitrate and the predominant radionuclide is Cs-137 (about 0.3 Ci/l). This solution is one of three components of the ILW to be processed in the proposed processing facility. The anticipated concentration of radionuclides in each of the three ILW streams is given in Table E-4. The second ILW component is the sludge which would be diluted to a 12-percent-by-weight slurry to make it pumpable. The predominant radionuclide would be Sr-90. The third component of the ILW to be processed is an assumed waste from future operations at ORNL which is designated as "pilot plant waste."

4.2.1 LIQUID WASTE STREAMS²⁵

Radioactive liquid wastes are produced by a number of different research, development, and production programs at ORNL. These include such things as basic radiochemistry studies, development of reactor fuel reprocessing methods, production of radioisotopes for medical, industrial and research uses, production of transuranium isotopes for research, operation of research reactors, etc. The

TABLE E-4
DESIGN BASIS WASTE STREAMS FOR ORNL PROCESSING FACILITY²⁵

Waste	Nuclide	Specific Activity (Ci/liter)	Estimated Annual Volume (liter/year)	Estimated Annual Curies (Ci/year)	Estimated Total Volume (liters)	Estimated Total Curies (Ci)
<u>Routine Wastes</u>						
Concentrate	Cs-137	0.26	300,000	8×10^4		
	Ba-137M	0.24		7.4×10^4		
	Sr-90	0.026		8,000		
	Y-90	0.026		8,000		
	Ru-106	0.009		2,800		
	Rh-106	0.009		2,800		
	Pu-239	2.6×10^{-7}				
		to				
		2.6×10^{-6}		0.08 to 0.8		
		2.6×10^{-4}		80		
Pilot-Plant Wastes	Cm-244		19,000			
	Cs-137	1.3		2.5×10^4		
	Ba-137M	1.2		2.3×10^4		
	Sr-90	1.3		2.5×10^4		
	Y-90	1.3		2.5×10^4		
	Ce-144	0.7		1.4×10^4		
	Pr-144	0.7		1.4×10^4		
	Pm-147	1.8		3.5×10^4		
	Pu-239	2.6×10^{-5}		0.5		
	Cm-244	0.066		125		
Sludge	Cs-137	0.01	150,000*	1,600		
	Ba-137M	0.01		1,490		
	Sr-90	0.1		16,000		
	Y-90	0.1		16,000		
	Pu-239	4.2×10^{-5}		6.4		
	Cm-244	1.6×10^{-3}		240		
<u>Stored Wastes</u>						
Sludge	Cs-137	0.014		5.7×10^6 *		8×10^4
	Ba-137M	0.013				7.4×10^4
	Sr-90	0.14				8×10^5
	Y-90	0.14				8×10^5
	Pu-239	5.3×10^{-5}				300
	Cm-244	2.1×10^{-3}				1.2×10^4

*Volume after dilution for transfer.

liquid radioactive wastes from these and similar activities are collected in underground stainless steel tanks ranging in size from a few hundred liters to several thousand liters and located near the individual facilities producing the waste. The wastes are made alkaline in the collection tanks by the addition of sodium hydroxide to reduce the corrosiveness. The collection tanks are periodically emptied by pumping the contents to one of six 645,000-liter underground concrete central collection tanks. These tanks are frequently referred to as the "gunite" tanks because of the method that was used to construct them. The addition of sodium hydroxide to the raw waste causes some of the dissolved materials to precipitate from the solution and this precipitate settles to the bottom of the gunite tanks as a sludge. The sludge contains essentially all (99%) of the uranium and transuranium nuclides that might have been in the liquid as well as some of the radioactive fission products such as Sr-90. The sludge is one component of the ILW that is to be processed by the proposed solidification facility. The liquid above the sludge is fed to an evaporator where it is concentrated by a factor of 20 to 30 and the concentrate is temporarily stored in one or more of the remaining gunite tanks. About 300,000 liters per year of concentrated waste solution is generated at ORNL. Periodically, the accumulated concentrate is pumped to the shale fracturing facility in an adjacent valley, mixed with cement, and injected into a shale formation at an approximate depth of 300 meters.

At the present time there is a construction program in progress at ORNL to modify the waste processing system described above. These modifications include the installation of a second ILW evaporator in parallel with the existing evaporator, installation of two 190,000-liter stainless steel tanks in a stainless steel lined underground vault to receive raw waste and feed it to the evaporator, installation of a 190,000-liter stainless steel tank to collect the ILW concentrate from the evaporators, installation of a new doubly contained central waste collection header, the installation of eight 190,000-liter stainless steel tanks for temporary storage of concentrate in an underground vault located adjacent to the proposed site for a new solidification facility and the installation of a doubly contained waste transfer line between the evaporator and the new waste storage tanks.

When the construction currently in progress is complete, operation of the ILW collection and concentration system will be essentially the same as it is now except that the six gunite tanks will no longer be used. However, before these tanks can be put into a condition requiring minimal future surveillance, the sludge which has been accumulating since 1943 (≈1,500,000 liters) must be removed and immobilized in the proposed new processing facility. This represents a "one time only" task for the new facility since it is planned, once the proposed facility is built, to process sludge routinely rather than let it accumulate as it has in the past.

The proposed processing facility will be designed to handle three types of intermediate level radioactive wastes. This ILW consists of:

1. Currently generated waste solution concentrate, which totals about 300,000 liters per year. This waste will be an alkaline salt solution (1 M NaNO_3 and other minor constituents). Generally, the major radionuclide (about 0.3 Ci/liter) is Cs-137, while only 0.3 Ci/liter or less is Sr-90. The major alpha activity is Cm-244 from the heavy element production program; its concentration is about 0.3 m Ci/liter. The long lived (greater than 30 years) alpha content of the waste concentrate, including the decay products from short lived parent nuclides is less than 10 n Ci/gram.
2. The sludges produced by the processing and handling operations of the last three decades that are currently stored in the gunite waste tanks. There are about 1,500,000 liters of these sludges. Analyses indicate that these sludges contain between 500,000 and 800,000 Ci of Sr-90, between 60,000 and 90,000 Ci of Cs-137, 12,000 Ci of Cm-244 and 250 to 310 Ci of Pu-239. Current planning anticipates that within the next few years these sludges will be resuspended and pumped to a processing facility. This waste stream, after resuspension and dilution for pumping, will have a specific activity of about 13 Ci/liter of Sr-90. About 40,000 liter/year of currently generated sludge will also be processed. Its composition is expected to be similar to that of the sludge now in storage.
3. Future pilot plant wastes - Several pilot plant programs that have been proposed for ORNL have the potential for generating waste solutions with a higher specific activity than the ORNL intermediate level waste has had in the

past. Some of these programs, such as the LMFBR spent fuel reprocessing plant, propose to include processes that will immobilize all waste streams that are generated. If the quantity and concentration of radionuclides are high, however, the wastes would be stored in existing doubly contained waste storage tanks until the isotopes with short half-lives had decayed (at least five years) and the specific activity of the residual isotopes would be low enough so that only moderately thick shielding would be needed in the processing facility. After this time these wastes or some part of them could be processed by the ORNL ILW system.

4.2.2 OPERATIONAL HISTORY²⁵

The existing disposal facility was built in 1963 and a series of experimental waste injections was made in 1964 and 1965 to demonstrate the feasibility of the process. After the end of these experimental injections the facility was converted into an operational facility for the routine disposal of concentrated intermediate level waste solution. This solution is an alkaline solution that is approximately 1M in NaNO_3 . The predominant radionuclide is Cs-137; its specific activity is about 0.3 Ci/liter. About 300,000 liters/year is produced.

A number of modifications and improvements were made at this time to improve various phases of the plant operation. Two additional waste storage tanks with a combined capacity of 180,000 liters were installed. This increased the total on-site waste storage capacity to 340,000 liters. A dry solids weigh tank was installed to improve the dry solids blending system.

From 1966 to 1970, this modified facility was used for a series of seven injections that disposed of 3,750,000 liters of waste grout containing 350,600 Ci of Cs-137 and 26,500 Ci of Sr-90. Some of the parameters of these injections are given in Table E-5.

4.2.3 TRU WASTE OPERATIONS^{18, 63}

Solid radioactive waste generated at this site is collected in suitable containers and transported to one of the burial grounds, where they are stored or disposed of. There are six burial grounds at ORNL. Three of these are inactive, and two

TABLE E-5

INJECTION PARAMETERS FOR ROUTINE ORNL DISPOSAL OF WASTE SOLUTION²⁵

Injection No.	Date	Depth (m)	Waste Volume (liter)	Sr-90 (Ci)	Cs-137 (Ci)	Cm-244 (Ci)	Pu-239 (Ci)
<u>Experimental Injections</u>							
I-7	1964 to 1965	285 to 264		1,436	5,237	--	--
<u>Operational Injections</u>							
ILW1A	1966	264	136,300	3	19,750	NA*	NA
ILW1B	1966	264	98,400				
ILW2A	1967	261	325,500	1,050	58,500	NA	NA
ILW2B	1967	261	234,700				
ILW3A	1967	261	117,300	9,000	17,000	NA	NA
ILW3B	1967	261	196,800				
Water Test	1967	258	--				
ILW4A	1968	258	90,900	4,300	51,900	NA	1.10
ILW4B	1968	258	235,350				
ILW5	1968	254	306,600	500	69,400	NA	1.15
ILW6	1969	254	300,400	8,900	89,000	NA	0.24
ILW7	1970	254	314,200	2,747	44,833	19.2	1.77
ILW8	1972	251	275,200	45	28,000	0.20	0.13
ILW9	1972	251	258,500	231	23,400	6.51	None
ILW10	1972	251	320,800	1,330	18,800	26.67	0.37
ILW11	1972	251	286,750	1,100	23,500	155.74	None
ILW12	1975	248	97,300	1,324	12,752	1.02	None
ILW13	1975	248	306,600	3,368	35,750	17.83	0.03
ILW14	1975	248	<u>314,000</u>	<u>2,874</u>	<u>30,592</u>	3.58	None
Total ILW			4,218,600	36,766	523,377		

NA = not analyzed

(burial grounds 5 and 6) are currently in use. Burial ground 3 is now only used for above-ground storage of contaminated equipment that may be reusable.

Estimated sources of transuranium-solid waste at ORNL are summarized in Table E-6. Approximately $1.76 \times 10^5 \text{ m}^3$ of radioactive solid waste were buried in ORNL burial grounds through 1972. About 60 percent of this waste was generated at ORNL while the remainder was shipped from off-site (including Argonne National Laboratory). Most of the ORNL waste was transported to the burial ground using only temporary containment such as plastic and sprayed coatings. Wastes from off-site were generally shipped in steel drums and wooden crates. In general, wastes were not segregated with respect to waste type.

At present, ORNL burial grounds are used almost exclusively for ORNL wastes, which are generated at the rate of about $4,250 \text{ m}^3/\text{year}$. Wastes containing negligible quantities of transuranium nuclides continue to be buried in a relatively unretrievable fashion. Low radiation level, transuranium solid waste is packaged in either 208-liter steel (or stainless steel) drums or steel boxes and stored either in a building or a roofed, rock-filled trench to facilitate retrievability. High radiation level transplutonium wastes from the Transuranium Facility are collected and stored in the rock-filled trench as potentially retrievable, sealed concrete containers. Other high radiation level transuranium wastes are packaged in stainless steel containers and stored in marked, steel-lined auger holes.

ORNL classified locally generated radioactive waste intended for burial as follows:

- The fissile-alpha waste corresponding to transuranium waste is defined by DOE 0511-21 as the solid waste that exceeds the concentration of 10 microcuries of alpha particle activity per kilogram of waste associated with fissionable isotopes. This category includes, primarily, americium, curium, and plutonium, as well as some U-235. This material must be handled so as to permit retrieval within 20 years. These materials originated primarily in the transuranium-processing facilities and in fuel reprocessing research and development operations. Beta-gamma emitting nuclides are often included with these

TABLE E-6
ESTIMATED SOURCES OF TRANSURANIUM SOLID WASTE AT ORNL^{a, 18}

Type	Percent Burnable	Quantity in Storage		Annual Generation Rate	
		Volume (m ³)	Alpha Radioactivity (Ci)	Volume (m ³)	Alpha Radioactivity (Ci)
Retrieval Steel Drums ^(a)					
Low radiation level	50			169 ^(d)	30 (Pu-239)
Retrieval Steel Boxes ^(a)					
Low radiation level	20	0	0	42 ^(d)	6 (Pu-239)
Steel Drums and Boxes ^(a)					
High radiation level	50	0	0	28 ^(d)	5 (Pu-239)
Concrete Casks ^(a)	50	280	200 (Cm-244)	100 ^(d)	80 (Cm-244)
Solid Waste for Burial					
Low radiation level	50	113,300 ^(b) (283,300) ^(c)	300 (Pu)	3,335	<1
Solid Waste for Burial					
High radiation level	50	18,300 ^(b)	100 (Pu)	835 (84,500) ^(c)	<0.03
Tank Farm Sludges	0	1,275 ^(b) (7,300) ^(c)	300 (Pu-239)		

- a. Waste from contamination zones or known to contain $> 3531 \mu\text{Ci}/\text{m}^3$ of transuranium nuclides.
b. Quantity as charged.
c. Estimated volume if the waste were prepared for off-site shipment.
d. Since 1970, these packages are stored to facilitate retrievability.

nuclides and in very heavy elements spontaneous fission often occurs with production of neutrons. Certain beryllium isotopes or deuterium will emit photoneutrons. These special situations all create unique problems and demand special methods for handling of the fissile alpha wastes.

- The fissile non-alpha waste is a solid waste that contains one gram or more of non-alpha particle emitting fissionable materials regardless of concentration, or more than 35.7 grams per cubic meter (one gram per cubic foot) of the same material regardless of quantity. Sources of these wastes include various metallurgical operations and other analytical and research and development operations. The objective of handling this waste is to prevent the criticality during or after burial. It is not a direct radiation hazard.

The volume of waste buried at ORNL since the fire of 1961 is about $87,500\text{ m}^3$ in the area of 7.5 hectares. Transuranium- and uranium-contaminated wastes buried at ORNL before 1974 amount to about 685 m^3 and fissionable material and contaminated waste about 200 m^3 . Not all of the transuranium waste can be considered reasonably retrievable.¹

Fissile alpha-particle emitting wastes (TRU wastes) have an alpha particle radioactivity in excess of 10 microcuries per kilogram (10 nanocuries per gram) originating from fissionable isotopes. This kind of waste, when accompanied by a high level of beta, gamma, or neutron emission, is packaged at the point of origin in reinforced concrete casks. Records are kept of the location and content of each of the trenches containing this material.

4.2.3.1 STORAGE FACILITIES¹⁷

TRU wastes are stored in a variety of ORNL facilities ranging from trenches in which material is placed and covered with soil, to stainless-steel-lined shafts, to 85 percent below-ground buildings for 208- or 114-liter metal drums. The selection of the facility depends on the intensity of the radiation involved.

TRU waste containing high levels of beta-gamma or neutron emissions is placed in reinforced concrete casks and stored in unlined trenches. Casks are

segregated by trench according to their flammable and non-flammable waste content. Once filled, the trenches are backfilled with soil. TRU waste containing less than 200 mR/hr is stored in stainless steel drums and held in a staging area until a sufficient number of them is available for storage at the Retrievable Waste Storage Facility, Building 7826. Building 7826 is a one-story reinforced concrete and concrete-block structure approximately 11.5 m x 17.4 m x 4 m high. There are 24 pits or cells which can each accommodate 64, 208-liter drums. About 85 percent of the structure is below grade.

TRU waste with high background readings is stored in stainless-steel-lined shafts of various diameters (ranging from 20.3 to 50.8 cm). The liners are provided with concrete collars and stainless steel caps. Spacing between shafts is not less than 0.9 m, and the transuranic isotope content is limited to 200 g per shaft. The shafts are filled with stainless steel containers of waste and then are capped with a removable concrete plug. The contents of each shaft are recorded.

Facilities 7827 and 7829 contain stainless steel wells which are used for the storage of TRU waste containing high beta-gamma activity. Facility 7829 contains 30 wells; 15 of them are 4.5 m deep, and the other 15 are 3 m deep. The diameter of these wells ranges from 20.3 to 76.2 cm.

4.2.3.2 DISPOSAL FACILITIES

Non-TRU waste and general radioactive waste are generally disposed of in unlined trenches and/or shafts. Trenches are approximately 15 m in length, 3 m wide, and 3-4.5 m deep. They are graded to slope toward one end. A corrugated metal casing, 15.2 cm in diameter, is inserted vertically into the trench and is used as a monitoring well. Once filled to within 0.9 m of grade, the trench is backfilled with soil.

Shafts vary in diameter (0.6 to 1.0 m) and depth (less than 6 m). A minimum spacing of 0.9 m in between shafts is maintained, and the radioactive content is limited to 200 g per shaft. Once filled, the shafts are capped with concrete.

Three settling basins have been used in past operations at ORNL. These basins are waste pond no. 1, waste pond no. 2, and the homogeneous reactor test settling basin. Only waste pond no. 1 is still used and serves as an equalization basin for laboratory process waste prior to treatment in the ion-exchange facility.

From 1957 to 1976, waste pond no. 2 served as a settling basin for the effluent from the lime-soda-clay treatment plant. Sediment samples taken after its decommissioning indicated that bottom sediments at this pond contain approximately 5 Ci of Pu-239 and Pu-240 and various fission products. The concentration of radionuclides in the bottom sediments of waste pond no. 1 is expected to be higher than that in waste pond no. 2. However, the bottom sediments in this pond have not been sampled, and consequently no estimate of their radioactive content is available.

The settling basin was used for disposal of low-activity liquid waste generated in the 7500 area. The basin is no longer in service and has been filled and covered with asphalt. No records of its contents are available.

Pits and trenches were used for the disposal of intermediate-level liquid waste. A total of four pits and three trenches was used in this operation until 1965. Radionuclide seepage from one trench and one pit was detected in the earlier days of this operation, and both trench and pit were closed. Approximately $181,680 \text{ m}^3$ of liquid waste containing 1 million curies was disposed of in these pits and trenches.

Burial grounds 1 and 2 cover an area of about 2 ha and were closed in 1946. These areas were used primarily for the disposal of contaminated trash, laboratory equipment, and other items that were discarded. Burial ground 3 was opened in 1946 and used until 1951 for underground disposal of waste. Burial ground 4 covers a total area of 9.3 ha and was used until 1959 for the disposal of alpha-and beta-gamma-contaminated waste.

Burial ground 5 has been used for the disposal of all types of wastes including TRU waste; however, most of the material that has been disposed of in this

burial ground is considered as general radioactive waste such as mixed fission products, depleted uranium, filter media, and equipment that could not be economically decontaminated. The 27.5-ha burial ground 6 was opened in 1969 and is used for disposal of waste in trenches and shafts.

For TRU waste, an Authorization for Storage of Radioactive-Contaminated Solid Waste and a Record of Transactions of Source and Special Nuclear Materials are required before the material is transported to the storage site. The three types of containers used for the packaging of this waste are concrete casks, stainless steel drums, and stainless steel capsules. Concrete casks are placed in trenches, and shielded drums and capsules are placed in shafts. Casks containing flammable waste are separated from those containing nonflammable waste. Once filled, the trenches are backfilled with 0.9 m of soil.¹⁷

Low-activity waste is stored in drums and does not require shielding. The drums are shipped by truck and stacked in building 7823 until a sufficient number of them is accumulated. Then they are transferred to building 7826 for final storage. Non-TRU waste is disposed of in unlined shafts and covered with 0.9 m of soil. Unpackaged bulk material containing less than 1 g/ft^3 of fissionable isotopes is disposed of in unlined trenches. General radioactive waste disposal is accomplished by depositing the waste in trenches or shafts. Once the trench is filled to within 0.9 m of the surface, it is backfilled with soil.

High-activity general radioactive waste with a surface radiation in excess of 200 mR/hr is packaged in stainless steel drums and transported in shielded casks for disposal in shafts. A total of $18,540 \text{ m}^3$ of this radioactive contaminated waste containing 62.6 KCi of radioactivity has been disposed of at ORNL. The current rate of disposal is approximately $3000 \text{ m}^3/\text{year}$.¹⁷

4.3 OAK RIDGE Y-12 PLANT¹⁷

The Oak Ridge Y-12 Plant (427-ha plant area) is located in Bear Creek Valley about 4.8 km from Oak Ridge, Tennessee. The low-activity radioactive waste disposal sites are also located in Bear Creek Valley about 2.9 km west of the main plant site. The classified disposal area is located within the main plant site.

Low-activity radioactive waste is disposed of in trenches (5.5 m deep x 7.9 m wide) at burial grounds 1-A and 2-C. Filled trenches are covered with soil, leveled, and grass-seeded. Burial ground 1-A is used primarily for the disposal of depleted uranium-contaminated materials such as particulate filters, metal drums, and mixed-metal machine turnings. About 9.0×10^6 kg of these materials is disposed of in this burial ground annually. Waste disposal, compaction, and sealing processes presently require the use of land at a rate of 0.04 ha per year.

Materials contaminated with enriched uranium and natural thorium are disposed of in burial ground 2-C at a rate of 4.5×10^5 kg per year. The current land use for this waste disposal operation is 0.04 ha per year. Burial ground 2-B is used for the storage of pure, depleted uranium. About 7.3×10^5 kg of uranium is buried in trenches (4.5 m deep by 4.0 m wide) at this site.

Classified materials such as forms made from uranium and thorium are disposed of in trenches (5.8 m deep x 2.4 m wide) at the classified disposal area. For security reasons, the materials are covered with soil the same day they are placed in the trench. A total of 2.3×10^5 kg of these contaminated materials is buried annually at this site.

Records and descriptions are maintained on each disposal operation; they include the volume, radionuclide content, type of containers, location, and personnel safety measures taken. No further information is presently available concerning these waste materials.

4.4 OAK RIDGE GASEOUS DIFFUSION PLANT (K-25)

The Oak Ridge Gaseous Diffusion Plant is situated on a 259-ha area in eastern Tennessee. Its primary purpose is the enrichment of uranium hexafluoride in the uranium-235 isotope. No high-level radioactive waste is stored or disposed of at K-25. The majority of the low-activity waste buried or stored at this site is material contaminated with uranium and with traces of Np-237, Pu-239, and Tc-99.

4.4.1 BURIAL FACILITIES¹⁷

There are five low-activity radioactive waste sites at K-25: the old classified burial ground, new classified burial ground, K-33 contaminated waste burial ground, K-722 scrap metal yard, and K-1407-C retention basin. Three of the five sites are land burial grounds, but only one is still active. The fourth site is an active above-ground storage area where noncontaminated and contaminated scrap metal is stored. The fifth site is an active retention basin for radioactive and nonradioactive sludges.

The old classified burial ground covers 1.5 ha and has an average depth of about 9.1 m. Due to the lack of accurate records, no good estimate of the radioactivity of the materials disposed of at this site can be made. However, it can be deduced that most of the material buried is uranium-contaminated with only trace quantities of transuranics and/or fission products.¹⁷

The new classified burial ground was built in 1975 to dispose of classified radioactive and nonradioactive material and covers an area of 8.9 ha. Waste is buried in trenches 4.5 m deep and 30.5 m long. Each trench is completely filled, covered with soil, and grass-seeded before excavating another trench. At the present time, only 0.1 Ci of uranium is buried at this site, along with trace quantities of TRU and/or fission products.

The K-33 contaminated waste burial ground was utilized for the disposal of unclassified solid radioactive waste. The area occupied by the buried materials is only 0.08 ha of the 1.1 ha initially committed for this site. As of July 1975, this area contains about 1007.5 m³ of uranium-contaminated materials and 68.8 m³ of thorium-contaminated materials.¹⁷ Small amounts of other uranium compounds, thorium compounds, contaminated uranium hexafluoride cylinders, beryllium chips, boron, etc., are also buried at this site. The use of this burial ground was discontinued, effective March 1976. The total predicted radioactivity of all these materials is approximately 14.1 Ci. The K-33 burial ground contains a total of 62 graves, ranging from trenches (3.4 m wide x 0.9 m in diameter x 36.9 m in length) to shafts (3.7 m deep x 0.9 m in diameter).

The K-722 scrap metal yard covers 8.9 ha of land for the storage of scrap metal. The scrap metals consist of steel, stainless steel, aluminum, copper, nickel, and alloys. Two of the 8.9 ha are set aside for the storage of metal that has been exposed to uranium materials or shows alpha or beta-gamma activity on the surface. It is estimated that 2.7×10^6 to 4.5×10^6 kg of contaminated scrap metal are stored in this site. No estimated quantity of radionuclides associated with these materials is available.

The K-1407-C retention basin (213.4 m x 15.2 m x 1.8 in diameter) is primarily used in the disposal of radioactive and nonradioactive sludges, such as dredgings from various holding ponds. Since its construction in 1973, this basin has accumulated a volume of about 1146.9 m^3 of dewatered sludge. The total radioactivity of the material contained in this basin is estimated to be about 18 Ci, primarily consisting of uranium compounds and TC-99. Currently the use of this basin is restricted to the periodic storage of lime sludges. Radioactive wastes are not routinely deposited in this basin.

In addition to the retention basin, K-25 has three holding ponds: K-1407-B, K-901-A, and K-1007-B. The K-1407-B holding pond (118.9 m x 45.7 m x 1.8 m in diameter) is mainly used for the settling of uranium compounds discharged from the decontamination and recovery facility. As of April, 1977, 3 Ci of radioactivity was estimated to be in this pond, mainly consisting of low-activity uranium and technetium compounds. The K-901-A holding pond has a length of approximately 426.7 m, a width ranging from 1 m to nearly 137.2 m, and a depth ranging from a few centimeters to about 3 m. Its primary purpose is the settling of lime solids from the water treatment facility. In the past, this pond was used for the disposal of radioactive and nonradioactive waste from an intermittent cylinder-puncturing operation. No estimate of the radioactivity of this pond is available. Some uranium and trace quantities of TC-99 have been detected.

The K-1007-B pond (548.6 m x 137.2 m x 1.5 m in diameter) is mainly used for pH control, through dilution, of small quantities of acidic and caustic wastes discharged from the laboratories and for the settling of solids from chemical operations and storm drains. Although the estimated radioactivity of the pond is

not available, bottom sediment samples have been analyzed to contain minor amounts of uranium and technetium compounds.

4.4.2 OPERATING PRACTICES

Since the old classified burial ground and the K-33 contaminated waste burial ground are no longer used for waste disposal, there are no operating practices associated with their use, except for routine landscaping maintenance.

Material disposed of in the new classified burial ground is properly surveyed for radiation contents. Accurate records of the radiation contents and disposal locations for specific radioactive items are kept. Material disposed of at the K-722 scrap yard is classified as clean or contaminated by health physics personnel and stored in a designated area of the yard according to its classification. The current use of the K-1407-C retention basin is restricted to radioactive and nonradioactive sludge disposal.

5.0 ROCKY FLATS PLANT (RFP)

5.1 INTRODUCTION

The Rocky Flats Plant, which is operated for the Department of Energy by Atomics International, is a key producer of plutonium parts for nuclear weapons. It is located approximately 10 miles south of Boulder, Colorado, and 16 miles northwest of Denver. Construction of the present plant complex consisting of some 75 buildings and structures, was started in 1951, and the plant was put into operation during 1953.⁶⁴

RFP handles many kilograms of plutonium each year. The work, which is performed in glove boxes, currently generates, annually, more than 5,230 m³ of solid waste contaminated with plutonium.

5.1.1 LIQUID WASTES⁶⁴

Liquids contaminated with plutonium are transferred to a process waste treatment plant. There the plutonium and other chemical contaminants are removed by carrier precipitation as solids for transfer to DOE-approved storage at INEL.

Most liquids are treated at least three times by neutralization and the addition of ferric hydroxide to form a carrier precipitate. This precipitate is collected on drum filters, removed as a sludge, mixed with dry cement to absorb free liquids, and placed in 208-liter drums. Liquids containing hydrochloric acid or complexing agents are processed separately by mixing the liquids with portland cement to form a solid in 208-liter drums. Liquids containing acids are neutralized prior to mixing. Organic solutions and oils are also blended with an absorbent to form a solid in the 208-liter drums.

Effluent from treated liquid, which is low in radioactivity but high in soluble chemical contaminants, is evaporated in solar ponds or by forced evaporation. Salts from the evaporation are packaged in 208-liter drums. The previously released processed aqueous waste is now being retained in a holding pond until construction of a new waste treatment facility is completed.

5.1.2 RADIOACTIVE SOLID WASTE¹⁸

In its handling of plutonium and other radionuclides, the Rocky Flats Plant generates radioactive scrap, or residue, and radioactive waste. Scrap is material that can be recycled for productive use; radioactive scrap contains plutonium or enriched uranium that is economically desirable to recover. Waste, on the other hand, has no recoverable value. Radioactive waste is not economically worth treating to recover the plutonium or uranium in it.

A total of about 5,230 cubic meters of plutonium contaminated waste is currently generated annually. Nearly 3,270 cubic meters of this total is packaged and shipped to an off-site retrievable storage location. This is considered TRU waste, which is waste with more than 10 nanocuries per gram (nCi/g). Approximately 1,960 cubic meters is packaged and shipped to an off-site non-retrievable location; this is non-TRU (NTRU) waste that has less than 10 nanocuries of plutonium per gram.⁶⁴

Currently¹, the Rocky Flats operation generates about 20 kg of waste plutonium annually. The accumulated (through 1975) plutonium in the INEL burial site amounts to about 500 kg of which about 120 kg is retrievable storage.

5.1.2.1 WASTE COLLECTION¹⁸

Removing solid waste from glove boxes involves transferring the waste through a glove-box opening into a plastic bag or sleeve clamped to the opening. The bag is then twisted, taped closed, and cut away. If the bag is left out for even a short period, it is placed in a second bag for added protection. These procedures are

supplemented by forced, down-draft ventilation; individually fitted respiratory protection for all personnel; close radiation monitoring surveillance; and protection from external radiation sources. Because of its origin, all waste of this type is considered by the Department of Transportation (DOT) to be of NOS (Not Otherwise Specified) activity (formerly HSA or High Specific Activity). LSA (Low Specific Activity) waste has less than 0.1 microcurie of plutonium per gram of waste; NOS waste contains more than 0.1 μ Ci/g.

Other contaminated solid wastes result from materials such as clothing, paper used by employees in process - controlled areas (but outside glove boxes), and surgeons' gloves; they are designated low specific activity (LSA) if no significant X- or gamma radiation is noted by radiation monitoring surveys and if no measurable plutonium is indicated by drum-counting techniques. These techniques involve detectors that identify and quantify the radioactive elements in each drum containing contaminated waste.

5.1.2.2 WASTE PACKAGING¹⁸

Most radioactive wastes are sorted and packaged in 208-liter steel drums manufactured under a quality control program to ensure compliance with DOT specifications. A thick-walled polyethylene drum liner is used to contain TRU wastes inside the drum for retrievable storage. The polyethylene liner provides added resistance to corrosion from the contents, increases resistance to tear or puncture, and is a means of containment even if the steel drum corrodes. The plutonium content of each drum is determined by counting neutrons and gamma radiation.

Some wastes such as glove boxes, large equipment, and construction materials are too large to fit into a 208-liter drum. These items are disassembled to reduce the volume, cleaned to remove plutonium, and packaged into 1.9 cm thick plywood boxes. For retrievable storage, the boxes are coated with fire-retardant

and fiberglass-reinforced polyester. These boxes are manufactured under a quality control program to ensure compliance with DOT specifications. Each item placed into a plywood box is monitored with a calibrated, portable, sodium iodide detector to detect any significant residual plutonium.

All primary containment packaging for contaminated waste is controlled by Quality Control Procedure Q-2000, "Radioactive Material Packaging Quality Assurance."⁶⁴

5.1.2.3 WASTE SHIPPING¹⁸

Rocky Flats uses rail cars and truck trailers to ship wastes at the present time to INEL (Idaho National Engineering Laboratory). Drums and uncoated boxes containing non-TRU waste, such as evaporator salts, sewage sludge, and material contaminated with depleted uranium and beryllium are trucked directly to INEL. All other drums have TRU waste; they are placed in cargo containers that are loaded into ATMX rail cars, which are specially designed cars owned by DOE. All rail shipments go to the Transuranic Storage Area where the cargo containers are unloaded. All coated boxes are also shipped by ATMX rail car.

5.1.3 GENERAL

Rocky Flats' operating policy places the responsibility for all wastes on the department that generates the waste. The policy enforces a philosophy of eliminating and controlling waste where the waste originates. Since 1970, the volume of solid, radioactive waste generated at Rocky Flats has been reduced from a rate in excess of $8,400 \text{ m}^3$ per year to the present rate of slightly more than $5,200 \text{ m}^3$ per year ($6,000 \text{ m}^3$ in 1975¹).¹⁸

Rocky Flats is actively pursuing additional programs and facilities to further reduce the volume of solid, radioactive waste being generated and the amount of plutonium contained in wastes. Major reductions are expected when new scheduled chemical recovery and waste treatment facilities become operational.

These facilities will remove more plutonium from the waste streams, provide for incineration of all combustibles, recover nitric acid for reuse, remove more water from the waste treatment sludges, and increase the density of evaporator salts.

5.2 WASTE TYPES, CHARACTERISTICS, AND AMOUNTS¹⁸

Unclassified contaminated solid wastes generated by RFP are shipped to INEL for burial while classified wastes are shipped to Richland, Washington. The volume of solid waste (contaminated with uranium or plutonium and americium) shipped doubled from about 3,700 m³ in FY-1964 to about 7,650 m³ in FY-1969 (see Table E-7) and nearly doubled again to about 11,350 m³, shipped in FY-1970 because of the waste generated in cleaning up after the fire in a plutonium production line in May 1969. The annual volume shipped has decreased to about 5,230 m³ (1976). The activity shipped to INEL in these wastes varies depending upon programs being carried out (Table E-8). The plutonium (and americium) contaminated solid waste generated at RFP can be put into eight categories: first stage sludge (non-LSA), second stage sludge (non-LSA), evaporator salts (LSA), cemented liquids (non-LSA), grease (non-LSA), line-generated waste (non-LSA), nonline-generated waste (LSA), and crated waste (non-LSA). Sorting or segregation of contaminated waste at RFP is done mainly to facilitate measurement of radioactive content and to aid in the processing of the material.

5.2.1 SOLIDS FROM THE WASTE TREATMENT PLANT^{64, 18}

First stage sludge, second stage sludge, evaporator salts, cemented liquids, and grease are generated in the waste treatment plant for radioactive liquids. Aqueous liquids of low radioactivity but high chemical content are sent either to the waste evaporator in the treatment plant or to solar evaporation ponds and then to the evaporator. The evaporator bottoms are sent to a double-drum dryer where the remaining water is removed. Water vapor from the evaporator and drum dryer go up the evaporator stack. The dried salts are drummed for shipment. Aqueous liquids of high radioactivity and high chemical content are

TABLE E-7
CONTAMINATED^(a) SOLID WASTE
SHIPPED BY ROCKY FLATS FROM FY-64 TO FY-69¹⁸

FY	Shipped to INEL	Shipped to Richland
	Volume (m ³)	Volume (m ³)
64	3,571.4	10.5
65	3,727.3	10.3
66	3,843.4	21.4
67	5,350.1	22.2
68	7,607.9	32.9
69	<u>7,522.7</u>	<u>22.2</u>
Total shipped to INEL	31,622.8	
Total shipped to Richland (classified material)		129.5
Total shipped FY 64-69		31,752.3

a. Plutonium and nonplutonium contaminated.

TABLE E-8

ESTIMATE OF TRU ACTIVITY SHIPPED BY ROCKY FLATS PLANT
TO INEL FOR STORAGE¹⁸

Year	Pu-239 (g)	Am-241 (g)
67	50,031	2,129
68	46,486	1,778
69	38,046	4,876

Year	(Ci) ^(b)	(Ci) ^(a)
67	4,622	6,813
68	3,579	5,690
69	2,930	15,603

a. Based on: Am-241 at 3.2 Ci/g

b. Plutonium Isotopic Composition and Alpha Radioactivity

Isotope	Wt. %	Ci/g Pu
Pu-238	0.009	0.0015
Pu-239	93.750	0.0575
Pu-240	5.857	0.0133
Pu-241	0.368	--
Pu-242	<u>0.016</u>	<u>0.0000006</u>
	100.000	0.0723

processed through two stages of decontamination in the treatment plant using a ferric hydroxide carrier precipitation process. The decontaminated aqueous waste is combined with the low radioactivity--high chemical content waste and is processed in the waste evaporator mentioned above. The precipitate is removed from the supernatant liquid by vacuum filtration. The filter cakes are drummed for shipment as first and second stage sludges. Aqueous liquids of high radioactivity but low chemical content are decontaminated in the second stage of the waste treatment plant. The precipitate is filtered and drummed for shipment as second stage sludge. Aqueous wastes containing complexing agents are not amenable to the above precipitation process. They are discharged into lined drums filled with magnesia and cement to set up before shipment. These solids form the category called cemented liquids. (Ion exchange resins are also cemented.) Organic liquids, primarily cutting oil plus carbon tetrachloride, are shipped to the waste treatment plant where they are mixed with calcium silicate to form a putty-like mass called grease. About 140 liters of organic waste is converted to grease per 208-liter drum used for shipment.

5.2.2 LINE-GENERATED WASTES¹⁸

Line-generated waste contains the bulk of the plutonium discarded and shipped for burial. This waste category is segregated at the point of generation according to type of waste material (Table E-9). The residues are segregated by type to aid in assaying for nuclear materials accounting and to facilitate processing, including incineration when necessary, to recover plutonium. The type of matrix has to be known to obtain a valid determination of plutonium content by the drum counter. Residues which contain more than the discard concentration of plutonium are processed as scrap to recover the plutonium. Residues which contain less than the discard concentration are discarded as line-generated wastes.

5.2.3 NONLINE-GENERATED WASTES¹⁸

Wastes removed from a radioactive material processing area (other than a processing line) are considered as contaminated and are collected in drums as

TABLE E-9
CATEGORIES AND DISCARD LIMITS AT THE
ROCKY FLATS PLANT LINE-GENERATED WASTE¹⁸

Category	Discard Limit (g Pu/g)
Sweepings	0.007
Sludge	0.007
MgO Sand	0.007
ion Exchange Resin	0.007
Incinerator Ash	0.007
Sweepings Heels	0.007
Ash Heels	0.007
Glass and Ceramics	0.0005
Scarfed Molds	0.00035
Graphite Flow Residue	0.002
CWS Filter (0.6 x 0.6 x 0.3 m)	24 g/filter
Dry Box Filters (3.1 x 3.1 x 1.6 cm)	3 g/filter
Washables	0.0006
Combustibles	0.0007
Miscellaneous Scrap Metal	0.0003

nonline-generated solid waste. Drums indicating greater than 0.5 mr/hr at the surface are sent to the drum counter for assaying and possible plutonium recovery. Nonline-generated waste which shows less than 0.5 mr/hr at the surface of the drum is considered LSA waste and shipped as such.

5.2.4 CRATED WASTES

Items that are too large to be put into a drum are put into plastic lined plywood boxes or crates. These constitute the category called crated wastes.

Nonline-generated plutonium wastes are segregated from nonline-generated uranium wastes since they are generated in separate buildings. However, until 1970 they were not kept separate in shipment or burial. Drums of all categories of non-LSA plutonium wastes are mixed in shipment and burial. A comprehensive breakdown of RFP waste discards for first stage sludge, second stage sludge, evaporator salts, and cemented liquids are given in Table E-10; for grease in Table E-11; for line-generated waste in Table E-12; for nonline-generated waste in Table E-13; and for crated Pu-contaminated waste in Table E-14 (based on 1967 evaluation).

TABLE E-10

FIRST STAGE SLUDGE, SECOND STAGE SLUDGE, CEMENTED LIQUIDS,
AND EVAPORATOR SALTS SHIPPED BY THE ROCKY FLATS PLANT
IN CY 1967^(a), 18

Date (Quarter CY 67)	First Stage Sludge	Second Stage	
	Volume (m ³)	Sludge Volume (m ³)	Miscellaneous ^(b) Volume (m ³)
1st	70.6	46	22.9
2nd	48.9	72.4	6.9
3rd	46.8	71	7.5
4th	<u>49.8</u>	<u>62.2</u>	<u>3.7</u>
Total	216.1	251.6	41.0

Date (Quarter CY67)	Cementing Facility		Evaporator Salts
	Cemented Liquid Volume (m ³)	Miscellaneous ^(b) Volume (m ³)	Volume (m ³)
1st	33.5	10	1.2
2nd	22.3	6.9	3.3
3rd	5.6	6.2	72.8
4th	<u>16.7</u>	<u>7.7</u>	<u>175.3</u>
Total	78.1	30.8	262.6

- a. Total plutonium charged off in these four waste categories was 8.125 kg.
- b. Contaminated empty bottles used as containers for transporting solutions to the waste treatment building.

TABLE E-11
GREASE SHIPPED BY THE ROCKY FLATS PLANT IN 1967¹⁸

Date (Quarter 1967)	CCL ₄ -Oil Generated		Shipped ^(a)	Empty Contaminated Drums	
	Volume (liter)	Pu (g)	Volume (m ³)	Drums (No.)	Volume (m ³)
1st	19,190	263	20.4	627	130.5
2nd	21,725	199	338.3	440	91.6
3rd	10,600	75	320.1	547	113.8
4th	<u>12,225</u>	<u>292</u>	<u>286.4</u>	<u>334</u>	<u>69.5</u>
Total	63,740	829	965.2	1,948	405.4

a. The amount of grease shipped is much larger than the CCL₄-oil waste generated because of back-log material.

TABLE E-12
LINE-GENERATED WASTE SHIPPED BY THE
ROCKY FLATS PLANT IN 1967¹⁸

Material	Volume (m ³)	Pu (g)
Graphite	88.5	21,211
Sand, Slag, and Crucible	47.7	6,948
Insulation	65.8	13,012
Fire Brick	0.6	355
Resin	5.0	1,207
Scrap Metal	56.8	1,773
Glass	21.0	1,235
Washables	66.2	4,699
Combustibles	23.5	648
Line-Generated	9.0	344
Filters	6.0	592
Tantalum	1.9	169
Miscellaneous	17.1	2,164
Am-241 Waste	8.6	408
Am-244 Waste	<u>1.8</u>	<u>113</u>
Total	376.2	54,878

TABLE E-13
 NONLINE-GENERATED WASTE (FROM PU PRODUCTION AREAS)
 SHIPPED BY THE ROCKY FLATS PLANT IN 1967¹⁸

Date (Quarter 1967)	Volume (m ³)
1st	309.1
2nd	280.8
3rd	282.5
4th	<u>325.8</u>
Total	1,198.2

TABLE E-14

CRATED PU-CONTAMINATED SOLID WASTE SHIPPED BY THE
ROCKY FLATS PLANT IN 1967¹⁸

Date (Quarter 1967)	Incinerator Filters		Miscellaneous Pu-Contaminated Wastes		Total Crated Pu-Contaminated Wastes	
	Volume (m ³)	Pu (g)	Volume (m ³)	Pu (g)	Volume (m ³)	Pu (g)
1st	23.4	510	93.5	313	116.9	823
2nd	66.3	482	77.4	264	143.7	746
3rd	62.4	671	81.3	230	143.7	901
4th	<u>38.9</u>	<u>988</u>	<u>175.4</u>	<u>298</u>	<u>214.3</u>	<u>1,286</u>
Total	191.0	2,651	427.6	1,105	618.6	3,756

6.0 PADUCAH GASEOUS DIFFUSION PLANT

The current burial of low-level radioactive waste at Paducah is within the 303-ha main plant site, which is located near Paducah, Kentucky.

6.1 BURIAL FACILITIES¹⁷

The primary radioactive waste burial area, C-404, is a converted holding pond. The holding pond was constructed with an on-grade tamped clay bottom and tamped clay lined dikes (1.8 m high) enclosing an area of 0.5 ha. The pond was used in the disposal of uranium-contaminated magnesium fluoride slag and rejected uranium tetrafluoride.

This area is now covered with silty clay and is slightly mounded to facilitate runoff. Drummed uranium wastes are currently being placed on top of the backfilled pond. Once a sufficient number of drums are assembled, a clay cover will be placed over the drums.

The uranium burial ground, C-749, comprises an area of 0.3 ha and was used for the disposal of uranium-bearing scrap metal deemed undesirable for burial in the old holding pond area (primarily pyrophoric uranium metal in the form of sawdust, shavings, and turnings). Approximately 74 percent of this area has been utilized since the first burial on December, 1975. Scrap metal is placed inside an excavated pit and covered with a 1.2-m soil cover.

The classified scrap burial yard, C-746F, is a fenced 0.7-ha plot. Disposal in this area has utilized an area of 0.1 ha. Items disposed of consist of nonrecoverable weapon components. These are placed in a pit 2.4 m deep and then covered with a 1.2 m cover of soil. The only radioactivity associated with this facility is a very small amount of tritium (less than 10 Ci).

Area A (20.7 m in width x 83.8 m in length x 3-3.7 in diameter) is used for the disposal of miscellaneous noncombustible trash (excluding uranium scrap and

contaminated materials or equipment). Aluminum and steel shavings from the machine shop and a limited amount of contaminated bulky equipment items have been buried here in the past. Approximately 85 percent of this area has been used. The used areas are covered with a 1.2-m layer of compacted clay and gravel.

During the period of 1958 to 1962, areas B, C, and G were used to dispose of noncombustible trash and contaminated noncombustible material (except uranium scrap) and equipment. These areas comprise a total of 0.2 ha and were dug to a depth of 1.8 to 2.1 m. Each pit was filled to about 0.9-1.2 m with waste and covered with 0.9-1.2 m of soil.

The concrete burial sites, areas D and E, comprise an area of 0.03 ha, and small burial pits were excavated to a depth of 1.8-2.1 m. Each pit contains about 9070 kg of concrete pieces resulting from the removal of the concrete bases of the vibrating reactor trays during May and June of 1960. The uranium-contaminated material buried in these pits was covered with about 0.9 m of soil.

The 0.06 ha which comprises area F-C-340 has been utilized for disposal of miscellaneous contaminated material and equipment and contaminated scrap metal. Material buried was covered with about 0.9 m of soil.

The contaminated aluminum burial site, area J, has an area of about 0.04 ha. A pit was excavated to a depth of about 1.8 m, and the contaminated scrap metal buried in this pit consisted of about 100 to 150 drums of aluminum scrap metal in the form of nuts, bolts, etc. The contamination was primarily natural, depleted, and slightly enriched uranium corrosion products with trace quantities of neptunium and plutonium. The concentration of TRU nuclides is estimated to be orders of magnitude below the level that requires retrievable storage.¹⁷ The pit was covered with 0.9 m of soil.

Area L (55.2 m²) contains a single contaminated iodine cold trap (UF₆ condenser) buried in 1968 at a depth of 1.8 m. Area M consists of two pits comprising an

area of about 0.08 ha and excavated to a depth of about 4.6 m. The larger pit was used from the beginning of plant operation until 1958 to dispose of all types of trash and equipment, contaminated and noncontaminated. The smaller pit was excavated for disposal of all the scrap metal remaining in the yard (primarily contaminated) which was not soluble at the time this yard was cleaned up and closed. Both pits were covered with 0.6-0.9 m of soil. The contamination involved primarily natural or slightly depleted uranium.

The contaminated scrap yard, C-746E, contains contaminated scrap metal from plant operations and comprises an area of 0.3 ha. As of April 1977, the yard was 90 percent full.

6.2 OPERATING PRACTICES

Scrap uranium is generated by precipitation with lime from equipment decontamination and cylinder wash solutions. The filter sludge is collected in plastic-lined drums. When a number of drums are accumulated, personnel load them on a truck and unload them at area C-404. These drums are covered with clay soil up to within a few rows of the end of the current stack. Depleted uranium tetrafluoride is also drummed and transported to area C-404 for burial.

Lime sludges are analyzed for Np-237, Pu-239, Th-230, and Tc-99. Batches containing Np-237 and Pu-239 in excess of 10 $\mu\text{Ci/kg}$ are stored retrievably in plastic-lined steel drums in warehouse C-7465.

7.0 PORTSMOUTH GASEOUS DIFFUSION PLANT

The Portsmouth Gaseous Diffusion Plant is located on a 1618.8-ha reservation in Pike County, Ohio.

7.1 BURIAL FACILITIES¹⁷

There are three storage facilities at the Portsmouth site for low-activity radioactive wastes: the X-206-D storage area, the X-744G facility, and the classified waste area.

The X-206-D storage area measures 76.2 m x 41.5 m, and all storage is on the ground. This area is used to store small scrap metal items which have small amounts of radioactive contamination and a high scrap resale value. The metals include copper, monel, stainless steel, nickel, brass, etc. All metal items are decontaminated prior to storage in this area.

The X-744G facility is a warehouse covering 0.8 ha. It is used primarily for storage of UF_6 contained in cylinders and for storage of nonfluorinated materials such as U_3O_8 , UO_3 , UNH, uranium solutions, and radioactive plant waste. The low-activity radioactive wastes stored in this facility include the solid residues from the uranium recovery operation, contaminated alumina, magnesium fluoride, sodium fluoride, and various classified contaminated wastes and materials. Contaminated wastes are stored temporarily until a sufficient amount has been accumulated for burial. The classified waste area is capable of retrievably storing several tons of classified wastes such as barrier tube sheets, steel parts, and certain floor sweepings. All these materials are decontaminated before storage.

The X-749 burial ground is a 2-ha site used for aboveground storage and disposal of unclassified contaminated waste. The stored materials are, for the most part, large pieces of metal or equipment having fixed surface contamination which are stored in 208-liter drums. All materials are decontaminated prior to storage.

Buried items in the X-749 trenches fall under two categories. Category 1 (chemical trap waste) includes uranium-bearing solids such as alumina, sodium fluoride, magnesium fluoride, incinerator ash, and filter cake, whose uranium content is not economically recoverable. Category 2 consists of scrap metal that is potentially or slightly contaminated and cannot be sold or placed in a sanitary landfill. Scrap metal is decontaminated before burial.

7.2 OPERATING PRACTICES¹⁷

Before 1976, no special packaging procedures were used in preparing contaminated wastes for burial. Category 1 wastes in the X-749 trenches were buried in metal containers. During 1976, much of the wastes were found to contain TC-99, which is water soluble. To avoid further contamination, operating practices were changed; each package of chemical trap waste was sealed in plastic, and each trench was also covered with plastic. This precaution is now a standard procedure used in all burials.

Contaminated materials considered nonrecoverable are segregated and labeled for proper identification and disposal. Other contaminated wastes with no value, but with TRU concentration above allowable limits, are shipped to other facilities.

The individual trenches used for waste burial are excavated in the clay soil and have surface areas ranging from $9.3\text{--}167.2\text{ m}^2$. Classified burial trenches are about 4 m deep, and waste is covered with soil to a depth of 3.0 m. In the unclassified burial grounds, trenches are only 2.4 m deep and are covered with 1.2 m of soil.

7.3 WASTE GENERATION

The accumulated volume of waste at Portsmouth is 279 m^3 , which contains approximately 2700 kg of uranium.

8.0 FEED MATERIALS PRODUCTION CENTER (FMPC)

8.1 INTRODUCTION

The Feed Materials Production Center is located near Fernald, Ohio, on a 424-ha site about 16.1 km northwest of Cincinnati. The primary work at FMPC is the production of purified uranium metal and compounds for use at other DOE sites. A small amount of thorium work is also done. The recycling of uranium and thorium has introduced minimal amounts of transuranic and fission products into the waste storage areas.¹⁷

Most of the solid waste generated at FMPC results from the neutralization of acidic waste solutions. Filter cake and sludges collected from the neutralized wastes are deposited in chemical waste pits.

8.2 STORAGE FACILITIES¹⁷

There are three long-term storage facilities at FMPC: K-65 tanks, metal oxide tanks, and chemical waste pits. Five pits are identified by number, based on the chronological order of their construction. They are further identified as "dry" or "wet" pits, based on the physical state of the material placed in the pit.

There are two K-65 tanks and two metal oxide tanks which are each 24.4 m in diameter and 8.2 m high. The tank walls are made out of concrete, 20.3 cm thick, and were post-stressed with high-tensile steel wire protected by a 1.9-cm grout coating. These were also protected by a soil embankment. The K-65 tanks were used for the storage of refinery residues that resulted from the processing of pitchblende ores, which was discontinued in 1959. These tanks are the property of the African Metals Corporation and are stored at FMPC under a lease contract that expires in 1983. Only one of the two metal oxide tanks contains wastes, and both are owned by DOE. These wastes are residues resulting from the processing of ore concentrates and contain only a trace of radium.

Pits 1, 2, and 4 are essentially inground facilities which were constructed by digging a large hole and then lining it with a 46-61 cm of impervious clay. Maximum depths of pits 1 and 2 are 5.2 and 4.0 m, respectively. Both pits have been backfilled, covered with clean soil, and graded to provide surface drainage away from the pits. Pit 4 is partially filled and is used for the disposal of dry solids. Maximum depth of the pit is 7.3 m. Pit 3 was constructed to receive neutralized waste slurries. The solids settled, and the supernatant flowed into an adjacent clearwell. The capacity of the pit was $174,110 \text{ m}^3$. The pit has been filled to its capacity to function as a settling basin and partially covered with clean soil. The remaining capacity is being used for the disposal of filter cake. Once the pit has been completely filled, it will be covered, graded, and seeded to control runoff and erosion.

Pit 5 is a rubber-lined settling basin with a capacity of $87,929 \text{ m}^3$ and a surface area of 1.5 ha. The pit is 7.6 m deep and is used for the disposal of neutralized liquid wastes from uranium and thorium processing.

8.3 OPERATING PRACTICES

There are no facilities at FMPC for the treatment of solid radioactive wastes. Uranium and thorium-contaminated solid wastes are disposed of in pit 4 without treatment.

Contaminated combustible residues, sewage sludge, graphite, and oils are incinerated in various facilities. The uranium values are recovered from the generated ash.

In general, liquid wastes from uranium and thorium processing are first neutralized and then may follow one of two routes. In one route, the neutralized wastes are sent to pit 5, where the solids settle out and the supernatant overflows to a clearwell. In the other route, the neutralized wastes are filtered and the filter cake is deposited in pit 3.

8.4 WASTE GENERATION

As of February, 1977, approximately 3,135,990 kg of normal and enriched uranium have been placed in pits 1 through 5.¹⁷

9.0 NIAGARA FALLS SITE

9.1 INTRODUCTION

The DOE-Niagara Falls site located in Niagara County, New York, is dormant and in caretaking status. Placement of additional radioactive wastes in storage or disposal at the site is not contemplated.¹⁷

Radioactive wastes at this site are either disposed of on the surface or stored in buildings. These wastes are primarily residues that were generated in the processing of pitchblende concentrates bought from the African Metals Corporation in the Belgian Congo to obtain pure U_3O_8 during the early years of the atomic energy program.

The contract with the African Metals Corporation stipulated that, with certain specific exceptions, only the uranium content was sold to the United States, with all other minerals to remain as property of the vendor. As a result of this, about 60 percent of the wastes at this site belong to the African Metals Corporation and are stored in buildings leased from DOE until 1983.¹⁷

9.2 OPEN-LAND DISPOSAL FACILITIES¹⁷

All of the radioactive wastes disposed of aboveground are the property of DOE. These wastes consist of R-10 residues, R-10 iron cake, and contaminated soil removed from surrounding areas in a decontamination operation that took place in 1972.

The R-10 residues were generated from a 3 percent U_3O_8 pitchblende, which was given a cyanide treatment for removal of precious metals. These residues amount to 7.5×10^6 kg, containing 0.1 percent U_3O_8 and having a radioactivity of 3.75 mR/hr at the surface. To eliminate a potential dust hazard, R-10 residues were covered with topsoil and grass-seeded in 1964. The R-10 iron cake is a by-product residue from 3 percent U_3O_8 pitchblende and contains no radium. The material is primarily lead vanadate. A total of 1.4×10^5 kg containing 0.4

percent U_3O_8 and having a radioactivity of 2.24 mR/hr at the surface was disposed of adjacent to the R-10 residues.

The 11,469 m³ of soil and buried debris removed in a decontamination operation in 1972 was piled up to a height of 4.5 m, occupying an area of 0.4 ha. A radiation survey indicated a maximum reading of 3.5 mR/hr at 0.9 m above the surface of the pile. Soil samples indicated contamination due to uranium and/or radium.

9.3 OTHER FACILITIES

Of the radioactive waste stored inside buildings, only the F-32 and Middlesex Sand wastes are owned by DOE. Both wastes are stored in the same building. There are 1.3×10^5 kg of F-32 and 1815 kg of sands in storage containing 1 percent and 4 percent of U_3O_8 , respectively.

The radioactive wastes owned by the African Metals Corporation and stored at DOE-Niagara Falls consist of 1.6×10^6 kg of K-65 residues, 7.5×10^6 kg of L-30 filter cake, and 1.7×10^6 kg of L-50 sludges. K-65 residues are stored in a 50.3-m-high reinforced concrete tower. These residues contain 0.3 percent U_3O_8 and have a radioactivity of 5 mR/hr at 1.8 m above the surface. The L-30 filter cake contains 0.2 percent U_3O_8 and has a radioactivity of 13 mR/hr at the surface. The L-50 sludge originated from a 6 percent U_3O_8 pitchblende processed in 1944. This sludge contains 0.1 percent U_3O_8 and a radioactivity of 8 mR/hr.

10.0 WELDON SPRING SITE

10.1 INTRODUCTION

The Weldon Spring operation, located in St. Charles County, Missouri, has two separate disposal sites approximately 6.4 km apart: the raffinate pits area and the quarry. Since no radioactive wastes are generated at the present time at Weldon Spring, activities at these sites are limited to the caretaking and management of waste burial facilities.

10.2 DISPOSAL FACILITIES¹⁷

The two disposal sites mentioned above comprise a total area of 24.7 ha.

The raffinate pits consists of four pits having a total capacity of approximately 492,700 m³. The radioactive wastes disposed of in these pits are primarily raffinates from the refinery operation and magnesium fluoride slurry from the uranium recovery processes performed by the Weldon Spring Production Center.

Approximately 70 percent of the residues disposed of in pits 1, 2, and 3 are neutralized raffinates from refinery operations. The wastes were pumped as slurry into the pits, the solids settled out and remained, and the supernatant overflowed into the plant sewer. The remaining 30 percent of the residues are washed slag residues from the uranium metal production operation. In addition to some uranium residues similar to those in pits 1-3, pit 4 contains raffinate solids from the processing of thorium recycle materials in the refinery.

A total waste volume of 168,102 m³ has been disposed of in these pits. It is estimated that 75,802 m³ of free water is retained atop the sludges in the residue pits.

The quarry site consists of an open pit primarily used for disposal of chemical and radioactive contaminated waste. Prior to its acquisition by the Atomic Energy Commission, the Department of the Army used the quarry for the

disposal of TNT-contaminated scrap metal. No data are available about how much of this material was disposed of in the quarry. The Atomic Energy Commission first used the quarry in 1959 for the disposal of drummed residues containing approximately 3.8 percent thorium.

In 1963-1964, approximately 38,211 m³ of uranium- and radium-contaminated scrap metal was disposed of in the quarry. This material consisted of contaminated process equipment, building scrap, and soil. Additional drummed thorium residues containing 3.8 percent thorium- and TNT-contaminated wastes were disposed of in the quarry during 1966. During 1967-1968, an estimated volume ranging from 3818 to 7636 m³ of contaminated equipment and scrap metal was disposed of in the quarry by the Army in its decontamination operations of the Weldon Spring Plant.

11.0 PANTEX PLANT

11.1 INTRODUCTION

The 1.4-ha burial site is centrally located on the Llano Estacado within the 3683-ha Pantex Plant, which is located 29 km northeast of Amarillo, Texas. All radioactive waste buried at this site is considered retrievable over a period of 20 years.

11.2 BURIAL FACILITIES¹⁷

Radioactive waste is packaged for burial in the generating area in plastic bags and overpacked in 18.9-liter cans or in fibreglassed wood boxes.

Waste is stored in vertical concrete cylinders (6.1 m deep x 1.8 m in diameter) or in trenches (30.5 m long x 4.3 m wide x 4.0 m deep). Once filled with waste, the cylinders are capped with a concrete plug and covered with 1.8 m of compacted soil. Waste stored in trenches is also covered with 1.8 m of compacted soil.

11.3 WASTE GENERATION¹⁷

No TRU wastes are routinely generated at Pantex, and the small amount of TRU waste from nonroutine sources is segregated from the other wastes and buried in a separate trench in fibreglassed boxes. The current annual rate of waste burial is 1.4 m³/year, which contains 134 kg of uranium, which is the primary component of the wastes.

12.0 SANDIA LABORATORIES (SL)

12.1 INTRODUCTION

Sandia Laboratories is located at the foothills of the Manzano Mountains near Albuquerque, New Mexico. The current 0.6-ha radioactive disposal site is located in an environmental test area, Tech Area III, of Sandia Laboratories. An old burial ground (closed in 1960), consisting of an area of 0.11 ha, is located in an explosive test area, Tech Area II.

12.2 BURIAL FACILITIES¹⁷

The active disposal site is divided into three areas: one for the disposal of classified nuclear weapon components, another for the disposal of bulky debris, and the last for future expansion. Open trenches and burial shafts are the two methods of disposal employed at SL.

The form of the waste determines the packaging used for burial. All liquids are solidified and packaged. All decontamination waste is sealed inside plastic bags. For large equipment, removable contamination is either fixed or contained. Radioactive components are bagged. An instrument survey is performed at this time to determine if radiation levels or removable contamination precludes normal handling.

Open trenches (55 m in length x 11 m in width x 4 m in diameter) are used for very low activity or suspect radioactive waste. This includes decontamination debris, HEPA filters, surplus contaminated equipment, experimental structures used in contaminated areas, solidified liquids, etc.

Open trenches are periodically backfilled to prevent any possible escape of loose contamination and to reduce fire hazard.

Burial shafts (3 m in length x 3 m in width x 8 m in diameter) are used to dispose of all radioactive devices with security classification, radioactive sources

than $10\mu\text{Ci}$, and uranium machining waste, as well as any other uranium waste that is a potential fire hazard.

Each active shaft is covered by a steel platform containing a locked door. The shafts are used until the level of waste is within 2 m of the surface, at which time they are backfilled and the soil is allowed to settle. After approximately 1 year of settling, the shafts are capped with concrete.

Before retrievable storage of TRU waste became a DOE requirement, plutonium-contaminated debris from nuclear weapons tests was placed in one trench in the disposal area. This waste is not considered retrievable. Subsequent TRU waste generated at SL and requiring retrievable storage has been transported to an off-site DOE storage facility. Currently (1977), no TRU wastes are being generated at SL.

12.3 WASTE GENERATION¹⁷

The current cumulative inventory indicates that a total volume of 1322 m^3 of radioactive waste has been disposed of at this site since operations started. This total includes primarily fission product/induced-activation products, 152.8 m^3 of uranium-contaminated wastes, 15.7 m^3 of TRU-contaminated wastes containing less than 10 nCi/g , and 0.2 m^3 of TRU-contaminated wastes containing more than 10 nCi/g (which were buried prior to the retrievable storage requirement). The cumulative decayed activity is 2.4 KCi .

13.0 NEVADA TEST SITE (NTS)

13.1 INTRODUCTION

The Nevada Test Site is located in Nye County, Nevada, and comprises an area of 371,158 ha. Of this area, 155,404 ha are used for nuclear testing programs and the remaining area provides a variety of possible radioactive waste management locations. At present, less than 81 ha are being used for waste management operations at NTS. Seven sites are used at NTS for the storage and disposal of radioactive waste: area 5 RWMS, R-MAD RWMS, U3ax crater, U3fi drillhole, Horn Silver mineshaft, U2bu crater, and U8d postshot drillhole.

13.2 STORAGE FACILITIES¹⁷

Area 5 RWMS is used for both storage and disposal of radioactive waste and comprises an area of 15.7 ha. Pads are used for the storage of tritium-contaminated waste, low-activity TRU waste, and potentially reusable activated or contaminated hardware and equipment.

The R-MAD (reactor-maintenance, assembly, and disassembly) facility is used for the storage of reactor hardware remaining after the preparation of expended fuel elements and covers an area of 22.3 ha. This site was used in the past for both disposal and surface storage of radioactive hardware and waste from the nuclear rocket development program.

Twenty-six additional radioactive waste sites are used for surface storage at NTS. These are considered retired or inactive because no wastes are being added to the sites. Most of the waste stored at these sites consists of contaminated parts from a large exhaust deflector, reactor cores, and nuclear test wastes. Current plans are to remove the waste stored at these sites and consolidate it in a disposal site.

13.3 DISPOSAL FACILITIES¹⁷

Area 5 RWMS is used for the disposal of classified wastes. The wastes are disposed of in trenches having a width and depth of about 3.2 m and a length of 90-180 m. Excavations are filled with radioactive waste to near surface level. Then a final soil cover at least 0.9-m thick is placed on top of the waste. TRU waste is restricted to area 5 RWMS, where it is stored on the surface in closely spaced, sealed drums. However, a storage pad is being constructed in FY-1978.

The U3ax crater is a crater from a past underground nuclear test which originally was 129.5 m in diameter and 18.3 m deep. The crater is now used for the disposal of large unpackaged waste items. There are 46,000 m³ of burial capacity still available (1977) for disposal at this site. Land burial at the U3ax crater consists of cut-and-fill operations. Layers of low-activity contaminated waste are covered with layers of soil from the crater sides.

The U3fi drillhole, originally intended for emplacement of a nuclear test device, is about 1.8 m in diameter and was plugged with concrete at a depth of about 240 m before abandonment. Now the hole is used for disposal of classified waste consisting of drilling core samples containing radioactive debris from weapon tests.

The Horn Silver mineshaft is an abandoned mineshaft used for the disposal of classified radioactive waste. Most of the waste already deposited there was generated during Project Pluto, a past nuclear ramjet engine test series. A concrete plug has been poured over the wastes at a depth of about 128 m, and a concrete collar pad with a steel cover and lid has been installed on the shaft. The remaining unused volume is about 700 m³.

The U2bu crater was used for disposal of low-activity contaminated drilling mud and liquid. The crater was originally about 230 m in diameter and 31 m deep, but now is nearly full of drilling mud. The U8d postshot drillhole is used for the disposal of low-activity contaminated liquid waste. This is accomplished by attaching the drain hose of the tanker transporting the wastes to a valve

connector and hose permanently installed in a flange over the U8d casing. There are 10 seepage basins at NTS which were used for the collection of low-activity contaminated water and other liquids generated by mining and decontamination operations.

13.4 WASTE GENERATION

The total accumulated amount of waste is 5.07 KCi and the current disposal rate is 125 m³/year. The total volume of TRU waste stored is 90 m³, which contains 1.3 kg of transuranics.

14.0 ARGONNE NATIONAL LABORATORY (ANL)

The Argonne National Laboratory (ANL) is located in Argonne, Illinois, and is operated by the University of Chicago for DOE.

14.1 BURIAL FACILITIES¹

There is no active burial ground at ANL; however, during the decommissioning of the original laboratory (in Chicago proper) building rubble was buried in the Cook County Forest Preserve. Other ANL-generated waste and building rubble were also buried at this surveillance site.

14.2 WASTE GENERATION¹

ANL produces a wide variety of solid radioactive waste suitable for land burial. About 40 m^3 per year of solid waste results from liquid radwaste treatment. The solid waste produced annually is about 845 m^3 . In the past, waste was shipped to Sheffield, Illinois, for burial. Present shipping activities are unknown.

ANL also operates one facility at INEL where on-site burial is practiced.

15.0 OTHER DOE SITES

15.1 WASTE QUANTITIES AND PRESENT DISPOSAL METHODS¹⁸

The quantity of solid waste contaminated with transuranics expected to be generated annually at other DOE sites varies from about one cubic meter at Sandia Laboratory, to about 230 m³ for Argonne National Laboratory (Table E-15). Sites in favorable geographic locations (remote, dry, etc.) bury solid waste on site while those in less favorable locations ship to commercial burial grounds. Based on the experience of the larger national laboratories and production sites, about 10 percent of the total solid waste generated annually by these sites is expected to be non-LSA waste. About 60 percent of this would be expected to be shipped to a TRU waste repository in steel drums and about 40 percent in steel boxes or bins.

TABLE E-15

**QUANTITIES OF SOLID WASTE CONTAMINATED WITH TRANSURANICS
EXPECTED TO BE GENERATED AT OTHER DOE SITES¹⁸**

Site	Volume (m ³ /yr)	Burial (for transport and burial)	Containers	Combustible (Volume %)	Alpha Activity ^(a) (as shown) ^(b)
Sandia Laboratory	1.1	on-site	0.06m ³ plastic bags and 0.6 to 0.9m cardboard boxes	100	range: 0.01 to 0.1 Ci avg.: 0.01 Ci
Brookhaven National Laboratory	5.7	off-site	1.2m x 1.8m x 2.4m steel bins	90	range: 1 μ Ci to 1m Ci avg.: 10 μ Ci
Battelle Memorial Institute	15.9	off-site	208-liter steel drums	75	range: unknown avg.: unknown
Lawrence Radiation Laboratory (Berkeley)	32.4	off-site	114- and 208-liter steel drums	90	range: 1 μ Ci to 1 Ci avg.: 100 μ Ci
Lawrence Livermore Laboratory	132.5	off-site	208-liter steel drums	75	range: 1 to 10 Ci avg.: 0.25 Ci

a. Alpha activity includes Pu-238, Pu-239, Am-241 and/or Cm-244.

b. Activity content of packages; not of a unit volume or weight.

APPENDIX F

COMMERCIAL BURIAL SITES

TERA CORPORATION

1.0 INTRODUCTION

The term "burial," as used in this report, refers to the placement of waste at relatively shallow depths in earth materials, with no intent or provision for ready retrievability at a later date. Buried wastes are subject, in some degree, to the influence of water, infiltration and movement, erosion, plant uptake, animal penetration, and human activity.² The consequent migration or dispersal of radioactive and other toxic materials must be kept to some minimum or acceptable level. The physical and chemical form of the waste, engineered containment mechanisms, and the surrounding earth materials can be used to attain the desired level of containment.

Shallow earth burial has been used for the disposal of radioactive waste since the inception of nuclear weapons research in the 1940's. Initially, only the Atomic Energy Commission's national laboratories and contractor facilities handled and disposed of radioactive waste. Burial grounds were operated at each facility for the disposal of waste generated by weapons development and other nuclear research programs. Radioactive wastes generated by private industry were initially disposed of at the AEC-operated burial grounds.

The volume of radioactive wastes generated by private industry increased dramatically during the 1950's. Burial grounds operated by the AEC at Oak Ridge National Laboratory (ORNL) and at the National Reactor Testing Station (NRTS) in Idaho received some of this waste. However, the majority of the radioactive waste generated by private industry was managed by sea disposal services offered by private companies.

Growing pressures against sea disposal led to the AEC in January 1960 designating regional land disposal sites which would accept waste for burial from private industry and from AEC contractors without burial facilities.³ Under this interim policy (May 1960), suitably packaged wastes were accepted for burial at ORNL and NRTS until such time as commercial burial sites became available. In February 1961, the AEC established regulations to permit commercial operation of low-level burial grounds on Federal or state owned land.

In September 1962, a commercial burial facility was opened in Beatty, Nevada. This burial ground, licensed by the regulatory branch of the AEC, provided an alternative to both sea disposal and the AEC facilities. A similar site was opened shortly thereafter in Morehead, Kentucky, and in 1963, the AEC discontinued its policy of accepting radioactive waste from private industry. In the following years additional commercial sites were opened in other states and by 1971 six commercial burial grounds were licensed for the handling and disposal of radioactive waste (see Figure F-1). The last disposal of radioactive waste at sea was conducted in June 1970.

Wastes presently buried at both commercial and Department of Energy (DOE) facilities contain a large variety of radioactive materials, ranging from low activity radiopharmaceuticals to high activity fission products and trace quantities of transuranic isotopes. The hazards these wastes pose to man and his environment are primarily dependent on their radioactive properties, rather than on their chemical toxicity. The time frame of the hazard is dependent on the half-life of the specific radionuclide. The bulk of the radioactive materials at existing sites exhibit half-lives on the order of tens of years or less, and at typical concentrations will thus decay to innocuous levels in periods of less than a few hundred years. In the human time frame, the hazard period of other materials, such as Pu-239 with a 24,000-year half-life, differs little from that of toxic stable elements like chromium.

In 1970, the AEC implemented policies limiting the burial of long-lived transuranic radionuclides at AEC operated sites. Such waste containing greater than 10 nanocuries per gram were sent to retrievable storage facilities. The AEC issued a proposed rule on September 12, 1974 which would have limited burial of transuranic wastes at commercial sites also. Following creation of the NRC and ERDA, ERDA withdrew the draft environmental statement needed to fulfill NEPA requirements for the rule. Although the rule has not been implemented, all the commercial burial sites except the Richland site presently limit the burial of transuranium nuclides.³

Disposal operations at commercial burial facilities are similar to conventional sanitary landfill operations, with the additional handling precautions requisite to radioactive materials. Burial in open, unlined trenches is the common practice, with each trench containing a mixture of radionuclides and waste forms. Water is the principal medium by which the radioactive materials can migrate away from the burial trench, either by dissolution in subsurface water, or by erosive processes. Thus, site investigation and selection procedures involve extensive studies of the hydrogeology of prospective sites. Similarly, efforts are made to exclude water from the waste following burial. Less than half of the existing burial sites have detected the movement of radioactive materials away from the buried waste and none of these releases have posed any hazard to public health and safety.

FIGURE F-1
BURIAL SITE LOCATIONS

2.0 BURIAL SITE DESIGN OBJECTIVES

The containment capability of a burial ground is dependent on the physical and chemical form of the emplaced waste, the retaining ability of the natural system surrounding the waste, and any engineering modifications to the system. In general, migration of radionuclides from buried waste to man's environment involves two separate phenomena: dissolution of radionuclides in the waste by water in contact with it, and movement of the liquid containing the radionuclides away from the burial emplacement at a sufficient velocity that they enter man's environment during their hazardous lifetime. Most physical and biological processes that mobilize and transport radionuclides can be described in these general terms. Thus, measures that impeded either of these phenomena will increase the containment ability of a burial site.

Commercial burial grounds have been located on the basis of regional requirements for waste disposal facilities. Site selection involved the survey of several prospective sites, with the final decision based on hydrogeologic and economic factors.

The single most important factor affecting the containment capability of a burial ground is the degree to which ground and surface water can contact the waste and subsequently cause migration of the radionuclides. As a result, a hydrologic assessment is required as a portion of the licensing procedure for each site. In effect, these studies provide an estimate, prior to use of the burial ground, of the degree to which ground and surface water will contact the waste following burial, the pathway of the water away from the burial site, the ion-exchange or adsorptive capability of the materials along that path, and the extent to which the radionuclide content of off-site ground and surface waters will be effected by the burial grounds.

The important characteristics related to the containment capability of each of the six commercial sites are presented in Table F-1. Earth materials tend to be both non-homogeneous and anisotropic. Solid waste burials are universally

TABLE F-1
COMMERCIAL BURIAL SITE CHARACTERISTICS²

	<u>Beatty</u>	<u>Marehead</u>	<u>West Valley</u>	<u>Richland</u>	<u>Sheffield</u>	<u>Barnwell</u>
Mean annual precipitation (mm)	100	1200	1000	200	900	1100
Surficial material type	Alluvial sand and gravel	Weathered shales, clay and sand	Glacial drift, silty clay/interbedded sand and gravel	Clay, sand and gravel	Glacial drift; sand, silt and gravel	Sand and clay sand
Thickness (meters)	Over 200	3-5	20-30	Over 150	20-30	0-10
Interstitial permeability to water (cm/day)	Variable (0.02-0.1)	Very low (0.02)	Low (0.5)	Variable	Variable (0.04-40.)	0-10
Bedrock material type	Metamorphic and sedimentary	Shale	Shale	Volcanic	Shale, claystone and coal	Clay, sand and sandstone
Structure	Folded	Flat-lying	Flat-lying	Flat-lying	Flat-lying	Flat-lying
Ground water depth to shallowest saturated zone (meters)	80-90	1-2	Variable, 1-20	100	4-20	10-20
Depth of continuous groundwater zone (meters)	80-90	1-2	20	100	5-20	10-20
Depth to regional aquifer (meters)	80-90	None present	None present	100	100	200
Surface water proximity	3 km	500 m	On-site	10 km	At site boundaries	At site boundaries
Flow characteristics	Ephemeral, following storms	Small, perennial	Small, perennial	Large, perennial (Columbia River)	Lake to north; small, perennial to south	Small, perennial
Absorptive or ion exchange capacity of material surrounding burial (a)	Moderate	High	High	Moderate	Low	Moderate
Principal flow paths away from burial	Unsaturated flow in pores	Shale fractures	Shale fractures and lens in drift	Unsaturated flow in pores	Pore spaces in till	Pore spaces in sand

located at shallow depths, in the transition zone between soil materials and subsurface geology. The numerical values provided in Table F-1 are either estimates of a range of values, or approximate mid-range values. Some values vary from point to point and on a seasonal and annual basis at each burial site.

3.0 CURRENT PRACTICES AND EXPERIENCE

The purpose of this section is to describe existing commercial (and DOE-operated) radioactive waste burial facilities and technology.

3.1 COMMERCIAL TECHNOLOGY

Three companies operate the six commercial burial facilities (see Figure F-1): Chem-Nuclear Systems, Inc., (CNS) operates a site at Barnwell, South Carolina; Nuclear Fuel Services (NFS) operates a site at West Valley, New York; and Nuclear Engineering Company (NECO) operates the sites at Sheffield, Illinois; Beatty, Nevada; Richland, Washington; and Morehead, Kentucky (also referred to as the Maxey Flats facility).

There is considerable similarity in the overall operations at the six commercial waste disposal sites. Small differences are found in wastes accepted, surface water control provisions, and other site-specific regulations.

3.2 WASTES ACCEPTED FOR BURIAL

Wastes buried at the commercial facilities originate not only from the nuclear fuel cycle, but also from sources such as educational institutions, hospitals, government installations, industrial research and production facilities, pharmaceutical manufacturers, and waste disposal and decontamination companies. Table F-2 shows the historical use of the West Valley site. Waste commonly referred to as low-level is characterized as mostly paper trash with varying other items such as packing materials, protective clothing, broken glassware, plastic sheeting and tubing, radioactive carcasses of experimental animals, obsolete contaminated equipment, and building rubble. Higher activity wastes typically originate from the nuclear fuel cycle. Common wastes in this category include spent ion exchange resins, filters, filter sludges, evaporator bottoms, shielding, piping, instrumentation, control rods, and equipment and materials with induced radioactivity. Radioactive wastes not accepted for burial generally include

TABLE F-2

HISTORICAL USE OF THE WEST VALLEY COMMERCIAL BURIAL SITE⁴

Type of Facility	Total no.	New York based	Waste volume (%)
Nuclear power plants	8	3	22.6
Institutional, educational, and hospitals	30	21	1.8
Federal government	7	4	12.0
Industrial and pharmaceutical manufacturing and research and development	70	38	21.5
Waste disposal and decontamination companies	9	5	19.2
Nuclear Fuel Services, Inc.	1	1	23.0
	<hr/> 125	<hr/> 72	<hr/> 100.0

materials whose inherent chemical toxic or hazardous properties are judged to be greater than their radioactive hazard. Materials that have pyrophoric or explosive characteristics, free liquids, and compressed gases above one atmosphere are excluded from burial at all sites. Some sites accept liquids, but effect solidification prior to burial.

Limitations on package external radiation and radionuclide content also exist, but specific values vary.⁸ Generally, limitations on the quantities of radioactive materials that can be stored above ground prior to burial are applied to three categories of waste. By-product material includes "any radioactive materials (except special nuclear materials) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material."⁵ Special Nuclear Materials (SNM) refer to fissile radionuclides such as U-235, U-233, or Pu-239. Source materials are those which can be converted in a reactor to SNM, and include materials such as natural uranium and thorium. State-regulated site-specific restrictions for the on-site possession (unburied) of these are given in Table F-3. Wastes with transuranic alpha-emitting contamination above 10 nCi/g are only accepted for burial at the Richland site. Specific restrictions on acceptable wastes appear to be the most restrictive at the West Valley, New York site (no longer in operation). In addition to those materials already listed, other excluded materials include infectious materials, poisons, insecticides, rodenticides, herbicides, fungicides, and other such materials.

3.3 WASTE PACKAGING

No Federal or state standards have been developed for the burial of radioactive waste. In lieu of such standards, waste packagings are determined primarily by Department of Transportation (DOT) regulations for the shipment of radioactive materials. Most waste packaging methods presently in use are not intended to provide containment following burial since the soil is considered to be the primary container.

TABLE F-3
BURIAL SITE CRITERIA AND RESTRICTIONS

West Valley	Maxey Flats	Barnwell	Sheffield	Richland	Beatty
<u>SOLID</u>	<u>SOLID</u>	<u>SOLID</u>	<u>SOLID</u>	<u>SOLID</u>	<u>SOLID</u>
Must be packaged.	Must be packaged, except that objects with induced radioactivity and no removable contamination are exempt from packaging.	Must be packaged, except that objects with induced radioactivity and no removable contamination are exempt from packaging.	Must be packaged.	Must be packaged.	Must be packaged except that solids with induced radioactivity and no removable contamination are exempt from packaging.
	Dewatered resins in strong, tight containers and dewatered are acceptable.	Dewatered resins are acceptable.	Resins solidified with chemicals or cement are acceptable.	Dewatered resins are acceptable.	Dewatered resins are acceptable.
Filter aids are acceptable without absorption or solidification, provided there is no free liquid in the container and the container contact radiation levels are ≤ 200 mR/hr. If the contact radiation levels are > 200 mR/hr, the filter aids must be solidified in cement in a metallic container, or conform to other packaging standards approved in writing by the site.	Filter aids must be solidified.	Filter aids must be solidified.	Filter aids must be solidified.	Filter aids must be solidified.	Filter aids must be solidified.
Spent filter cartridges must be solidified in cement in metallic containers if contact radiation levels are > 200 mR/hr or must conform to other packaging standards approved in writing by the site.	Spent filter cartridges in a disposable container are acceptable without solidification.	Spent filter cartridges in a disposable container are acceptable without solidification.	Spent filter cartridges in a disposable container are acceptable without solidification.	Spent filter cartridges in a disposable container are acceptable without solidification.	Spent filter cartridges in a disposable container are acceptable without solidification.

$>$ greater than
 $\leq$ less than or equal to
 $\neq$ not greater than

TABLE F-3
(CONT.)

West Valley	Maxey Flats	Barnwell	Sheffield	Richland	Beatty
<p>If package contact radiation levels are >200 mR/hr and it contains loose radioactive material, the contents must be solidified in cement in a sealed metallic container or conform to other packaging standards approved in writing.</p> <p>Resins must be solidified in cement or equivalent.</p>					
<u>POSSESSION LIMITS</u>	<u>POSSESSION LIMITS</u>	<u>POSSESSION LIMITS</u>	<u>POSSESSION LIMITS</u>	<u>POSSESSION LIMITS</u>	<u>POSSESSION LIMITS</u>
Non-TRU byproduct material. No limit.	Non-TRU byproduct material (except Ra-226: 15,000 curies Ra-226: 500 millicuries)	Non-TRU byproduct material: 5,000 curies.	Non-TRU byproduct material: 5,000 curies.	Non-TRU byproduct material: 60,000 curies.	Non-TRU byproduct material: 50,000 curies.
	Source material: 4,545 kg	Source material: 27,273 kg	Source material: 18,182 kg	Source material: 1,818 kg	Source material: 11,364 kg
Special nuclear material:	Special nuclear material:	Special nuclear material:	Special nuclear material:	Special nuclear material:	Special nuclear material:
U-235: 350 grams U-233: 200 grams	U-235: 350 grams U-233: 200 grams	U-235: 350 grams U-233: 200 grams	U-235: 500 grams (≥ 100 g/package) U-233: 300 grams (≥ 60 g/package) Pu: 300 grams (≥ 60 g/package)	U-235: 350 grams (≥ 100 g/package) U-233: 200 grams (≥ 60 g/package) Pu: 200 grams (≥ 60 g/package)	U-235: 500 grams (≥ 10 g/package) U-233: 300 grams (≥ 60 g/package) Pu: 300 grams (≥ 60 g/package)
For Pu-239, site imposes a 1 gram/shipment limit.	20 grams/package		≥ 20 grams/package ≥ 530 grams/m ³ /package in combination.	≥ 530 grams/m ³ /package in combination.	≥ 530 grams/m ³ /package in combination.
$>$ greater than $\leq$ less than or equal to $\geq$ not greater than

TABLE F-3
(CONT.)

West Valley	Maxey Flats	Barnwell	Sheffield	Richland	Beatty
<p>Transuranic materials:</p> <p>Site imposes limit that the concentration of plutonium in waste shall not exceed 0.1 gram/package or $\frac{1}{2}$ gram per 28.32 m³ of waste.</p>	<p>Transuranic materials:</p> <p>≤ 10 nanocuries/gram</p>	<p>Transuranic materials:</p> <p>Except for Am-241, transuranic materials are accepted at this site with the limit of ≤ 10 nanocuries/gram.</p>	<p>Transuranic materials:</p> <p>≥ 10 nanocuries/gm.</p>	<p>Transuranic materials:</p> <p>At present no specific limit is added to the special nuclear material limitations.</p>	<p>Transuranic materials:</p> <p>≥ 10 nanocuries/gram.</p>
<p><u>MISCELLANEOUS</u></p> <p>No explosive or pyrophoric materials in packages.</p> <p>No free water in packages.</p> <p>Shipments must be made in self-supporting, disposable containers.</p> <p>Toxic wastes are not accepted.</p> <p>$>$ greater than $\leq$ less than or equal to $\geq$ not greater than</p>	<p><u>MISCELLANEOUS</u></p> <p>Radioactive wastes with associated chemically toxic wastes may not be buried if the chemical toxicity exceeds the radiological hazard.</p>	<p><u>MISCELLANEOUS</u></p> <p>Radioactive wastes with associated chemically toxic wastes may not be buried if the chemical toxicity exceeds the radiological hazard.</p>	<p><u>MISCELLANEOUS</u></p> <p>Radioactive wastes with associated chemically toxic wastes may not be buried if the chemical toxicity exceeds the radiological hazard.</p> <p>Any or all of the above requirements not withstanding, the concentration per package must not exceed 35.3 Ci/m³ (may be exceeded with special permission).</p>	<p><u>MISCELLANEOUS</u></p> <p>Toxic wastes are not accepted</p>	<p><u>MISCELLANEOUS</u></p> <p>Currently, combinations of radioactive and chemical wastes are not accepted for burial.</p>

The bulk of the waste materials are packaged in 208-liter DOT-approved mild-steel drums.⁴ Very low-level wastes (generally microcurie quantities) may be shipped and buried in wood or fiberboard boxes. Current practice at all sites is to bury waste materials in the same containers in which they are received with the exception of material which requires transportation in an expensive reusable shielded cask. This waste is packaged in a container or liner which can be safely removed from the cask and placed in a trench.

3.4 BURIAL PROCEDURES

Open trenches are used at all sites as the primary burial facility.⁷ Trench design is similar at all facilities, ranging in physical dimensions, from 60 to 260 m long, eight to 20 m wide at ground surface, and five to eight m deep. For all the burial sites it has been specified that the bottom of the trench shall be above the maximum ground water elevation.

Techniques to cover and seal waste in trenches vary with the local climate, soil, and ground water conditions. One to three meters of soil is mounded and graded over the top of the waste, the mound being one to two meters high over the centerline of the trench. at the more arid western sites no special attempts are made to further compact the fill or seal the trenches. Efforts at the other four sites involve more impermeable soils such as clay in constructing the cover, reseeding the mound, and construction of drainage fields around the mounded trenches.

3.5 BURIAL SITE INVENTORY

Existing buried waste inventories at the six sites, through 1977, are given in Tables F-1 through F-7. All of this material is low-level solid waste in the sense that it has not originated from the first stage of a nuclear fuel reprocessing operation.

TABLE F-4
COMMERCIAL SITES LOW-LEVEL WASTE BURIAL HISTORY^{3, 9-14}
WASTE VOLUME BURIED (m³)

YEAR	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977*	TOTAL
Beatty	1,860	3,510	2,840	1,989	3,530	3,210	3,580	4,280	4,130	3,590	4,300	4,080	4,100	4,179	3,864	5,012	58,054
Morehead		2,210	3,870	5,750	5,560	7,820	8,180	10,400	12,500	13,200	15,600	10,100	8,520	17,098	13,783	425	135,016
West Valley		522	6,390	4,720	4,700	4,950	4,510	4,280	5,098	6,370	7,057	7,500	8,580	2,049	0 ^(a)	0 ^(a)	66,726
Richland				569	2,403	870	669	438	423	584	654	1,033	1,410	1,500	2,867	2,718	16,238
Sheffield						2,530	2,710	2,010	2,830	4,430	5,960	8,530	12,400	14,112	13,480	17,642	86,634
Barnwell										1,171	3,757	15,839	18,244	18,072	40,227	45,563	142,873
TOTAL	1,860	6,240	13,100	13,130	16,190	19,380	19,650	21,410	24,980	29,350	37,330	47,080	53,250	57,010	74,220	71,360	505,541

(a) West Valley closed March 1975

* Preliminary values obtained from private communication with each burial site.

TABLE F-5
COMMERCIAL SITES LOW-LEVEL WASTE BURIAL HISTORY^{3, 9-14}
BY-PRODUCT MATERIAL BURIED
(CURIES)

YEAR	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977*	TOTAL
Beatty	NA	5,690	6,477	6,377	11,974	10,894	6,808	9,761	12,304	4,316	5,228	5,704	23,904	18,389	4,493	23,000	155,119
Morehead		22,716	148,322	63,828	52,729	42,280	45,578	31,028	46,968	720,146	217,350	118,274	143,656	289,571	211,356	267,000	2,420,802
West Valley ^(a)		1,372	11,355	21,515	41,056	51,230	51,675	23,264	36,291	42,458	61,208	170,552	55,505	10,273 ^(a)	0 ^(b)	0 ^(b)	557,754
Richland				144	1,006	5,378	10,330	55,964	52,820	23,916	31,809	57,037	12,173	113,341	104,306	7,000	475,224
Sheffield						3,850	2,381	2,192	5,427	7,895	4,857	2,834	3,299	6,104	7,744	11,000	57,513
Barnwell										4,118	997	42,500	329,043	17,420	90,205	NA	484,283 ^(c)
TOTAL	NA	29,778	116,154	91,874	106,765	113,772	116,772	122,209	153,849	802,849	321,449	396,901	567,510	455,098	418,104	--	--

(a) Pu-238 subtracted from figures, West Valley reports Pu-238 as by-product material instead of SNM

(b) West Valley was closed March 1975.

(c) Through 1976

NA Not Available

* Preliminary values obtained from private communication with each burial site.

TABLE F-6
COMMERICAL SITES SPECIAL NUCLEAR MATERIALS* BURIAL HISTORY³, 9-14
SNM BURIED (kg)

YEAR	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977*	TOTAL
Beatty	0.319	41,304	172,030	334,762	5,872	22,644	8,602	5,005	7,708	0,757	21,177	15,164	16,954	29,276	2,096	4,577	688,247
West Valley ^(a)		0.952	3,273	2,433	4,999	3,446	2,045	7,301	8,273	4,816	7,321	7,710	2,984	0 ^(c)	0 ^(b)	0 ^(b)	56,003
Morehead		0.059	11,889	4,261	7,462	14,842	17,771	31,506	47,562	72,770	71,443	46,244	23,832	25,690	27,474	27,555	431,260
Sheffield						< 0.001	< 0.001	3,843	5,649	9,934	5,898	6,126	6,198	5,285	1,738	6,299	53,962
Richland				0.003	1,418	Trace	Trace	0.032	0.200	0.015	0.832	6,558	4,884	18,978	24,378	25,937	83,235
Barnwell										13,220	46,718	99,800	100,444	64,425	122,256	NA	456,863 ^(d)
TOTAL	0.319	43,215	187,192	341,459	19,751	42,170	30,172	47,687	69,392	101,512	153,389	181,107	166,296	143,654	177,942	--	--

* Fissile materials

(a) Pu-238 added to West Valley figure

(b) West Valley was closed March 1975

(c) No available data

(d) Through 1976

* Preliminary values obtained from private communication with each burial site.

TABLE F-7
COMMERCIAL SITE SOURCE MATERIAL BURIAL HISTORY^{3, 9-14}
SOURCE MATERIAL* BURIED (kg)

YEAR	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977*	TOTAL
Beatty	296	472	331	236	91	346	1,040	290	322	NA	9,340	11,500	9,710	1,438	5,000	22,175	62,587
Morehead		5,210	5,590	568	690	5,680	6,250	2,550	7,220	5,730	8,260	9,340	13,100	82,416	75,944	655	229,203
West Valley		7,580	10,100	22,200	38,300	20,300	6,460	80,000	31,700	51,400	72,500	44,200	61,700	NA ^(a)	0 ^(a)	0 ^(a)	446,440
Richland				0.9	253	0.9	2.7	88.4	31.3	606	3,112.5	2,250	20.3	215	5,011	2,753	14,345
Sheffield						3,930	8,703	6,330	2,000	212	3,600	2,410	13,900	35,950	3,854	216,000	296,889
Barnwell										12,546	1,606	45,305	26,961	46,005	24,367	NA	154,790 ^(b)
TOTAL	296	13,300	16,000	23,070	39,400	30,224	22,500	89,300	41,300	70,546	98,373	115,195	125,161	166,024	114,176	--	---

* Non-fissile uranium and thorium

(a) West Valley was closed March 1975

(b) Through 1976

NA Not available

* Preliminary values obtained from private communication with each burial site.

One difficulty encountered in analysis of existing commercial site inventories arises from the past use of terms like "by-product material" and "mixed fission product" rather than identifying specific radionuclide contents of buried wastes.

A second difficulty involves the variation in values from independent inventories at each site. There are several causes, including the lack of specific radionuclide information as discussed above, and differing interpretations of those unspecific data. In addition, the values for radionuclide content of the buried wastes have been determined largely by estimates provided by the waste generator.

4.0 INSTITUTIONAL ASPECTS

Handling and burial of solid radioactive waste by the private sector is regulated in several ways. At the national level, the Nuclear Regulatory Commission (NRC) has responsibility for licensing waste burial sites except where its authority has been relinquished to "Agreement States." The ownership and licensing of commercial sites is summarized in Table F-8. Illinois, the only nonagreement state with a commercial radwaste burial site is presently in the process of negotiating such an agreement. The NRC also licenses the handling and burial of special nuclear materials at the commercial sites in Nevada and Washington, as the quantities of these materials handled are greater than permitted under "Agreement State" provisions.

The license for operation of a burial site continuously undergoes modification.^{2, 8} This results from special petitions from the site operator to the regulating agency requesting authority to handle waste forms or quantities not previously encountered. As a result, the license is in effect an accumulation of correspondence between the site operator and the various regulating agencies which may occupy more than a meter of shelf space. Licenses are issued for a fixed time period, at the end of which the operator must reapply. The license is automatically extended during the application review period.

The renewal procedure is greatly complicated by the complexity of the license and its amendments, and by continually changing state and Federal regulations. For example, several states have restricted the burial of plutonium (TRU) in concentrations greater than 10 nCi/g of waste. This restriction resulted primarily from a similar restriction imposed by DOE on its own burial site operators. A proposed 10 CFR 20 rule change would prohibit all shallow land burial of wastes containing more than a specific level of transuranic nuclides. Such waste would be transferred to Federal custody for ultimate disposal. The present non-uniformity of regulations, and pending changes in those regulations produces considerable difficulty in the license renewal.

TABLE F-8
LICENSING OF COMMERCIAL SITES²

	<u>Beatty</u>	<u>West Valley</u>	<u>Morehead</u>	<u>Richland</u>	<u>Sheffield</u>	<u>Barnwell</u>
Site Operator	NECO	Nuclear Fuel Service (NFS)	Nuclear Engineering Co. (NECO)	NECO	NECO	Chem-Nuclear (CNS) Systems
Site Ownership	State, leased to NECO	State, leased to NFS	State, leased to NECO	Federal, leased to state, leased	State, leased to NECO	State, leased to CNS
Agreement State	Yes	Yes	Yes	Yes	No, (pending)	Yes
Activities licensed directly by NRC	Handling and burial of SNM	None	None	Handling and burial of SNM	All burial	Handling and burial of SNM
Activities licensed by State	All other	All	All	All other	None	All other
Burial of TRU (Pu) >10 nCi/g	Restricted since 1975	Restricted since 1974	Restricted since 1974	Pending restriction	Permitted, but not practiced	Never permitted
Operational Status	Open	Closed since March 1975	Closed since December 1975	Open	No burial activities	Open with limited monthly burial rate

APPENDIX G

**DOE FACILITY SURVEY
QUESTIONNAIRE AND RESULTS**

TERA CORPORATION

The survey questionnaire and results will be included in a future update of this report based on LLL input.

APPENDIX H

POTENTIAL TRU WASTE SOURCES

TERA CORPORATION

This Appendix will list all NRC holders of SNM licenses who might generate TRU contaminated waste (TRU levels above 0 nCi/g).