FIFTY YEARS OF FEDERAL RADIOACTIVE WASTE MANAGEMENT

POLICIES AND PRACTICES

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Fifty Years of Federal Radioactive Waste Management Policies and Practices

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OVERVIEW

This report provides a chronological history of policies and practices relating to the management of radioactive waste for which the U.S. Atomic Energy Commission and its successor agencies, the Energy Research and Development Administration and the Department of Energy, have been responsible since the enactment of the Atomic Energy Act in 1946. The defense programs and capabilities that the Commission inherited in 1947 are briefly described. This legacy came from the Manhattan Engineering District of the Army Corps of Engineers, who had the responsibility during World War II for developing the Nation's nuclear weapons capability.

The focus of the Commission's program remained until the mid-1950's exclusively on its assigned goals in the nuclear defense program. To achieve these goals that were expanding as a result of the Cold War, the Commission undertook a dramatic expansion nationwide of its physical facilities and program capabilities over the five years beginning in 1947.

While the nuclear defense activities continued to be a major portion of the Atomic Energy Commission's program, there was added in 1955 the Atoms for Peace program that spawned a multiplicity of "peaceful use" applications for nuclear energy, e.g., the civilian nuclear power program and its associated nuclear fuel cycle; a variety of industrial applications; and medical research, diagnostic, and therapeutic applications.

All of these nuclear programs and activities generated large volumes of radioactive waste that had to be managed in a manner that was safe for the workers, the public, and the environment. The management of these materials, which varied significantly in their physical, chemical, and radiological characteristics, involved to varying degrees the following phases of the waste management system life cycle: waste characterization, storage, treatment, and disposal, with appropriate transportation linkages.

In the early years there were uncertainties about the effects of many of the radioactive species on humans and the environment and how these materials would interact with their host environment over time. As a result, what was felt to be a conservative approach was used in managing the wastes. The high-activity waste was, and still is, stored in large-capacity shielded storage facilities, pending the availability of capabilities for appropriate treatment/stabilization of the waste and for disposal. The low-activity waste was generally managed and disposed in accordance with then prevailing practices employed for nonradioactive hazardous waste. The solid low-activity waste was disposed in shallow land burial facilities. Most of the liquid low-activity materials were either further diluted and dispersed to the environment; disposed directly to ground in cribs, settling basins, or deep injection wells; or, to a limited degree, packaged in metal containers with concrete ballast and disposed in the ocean. In those cases where disposal of liquid or solid waste was made in shallow land disposal facilities, it was expected that the radionuclides would be retained in the underlying

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soil columns and above the fresh- water aquifer. All of these activities were monitored with respect to containment of the waste over time.

As an increased body of research results and performance-monitoring data became available, there were changes in the "regulatory" requirements and policies and practices for managing the various categories of radioactive waste. The gradual reduction in secrecy constraints on the Commission's programs and the resulting increase in interactions and communications among the waste management personnel at the sites and in headquarters contributed significantly to the aforementioned changes. The evolution of these changes for each of the classes of waste is chronicled in the report.

One of the benefits of reviewing the history of the waste management program policies and practices is the opportunity it provides for identifying the lessons learned over the years. Examples are summarized at the end of the report and are listed in no particular order of importance.

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1.0 Objective

The objective of this report is to identify, document as appropriate, and review the Federal radioactive waste management policies and practices that have evolved from the initial atomic energy programs undertaken by the Manhattan Engineering District, Corps of Engineers, U.S. Army (MED), to those of the Atomic Energy Commission (AEC), the Energy Research and Development Administration (ERDA), and the Department of Energy (DOE).

The scope of the policies and practices includes only those of the aforementioned Federal agencies with operational responsibility for managing the radioactive waste generated by their programs or that have been transferred to them under various arrangements for management and disposal. Reference to policies and practices by other Federal agencies, such as the Nuclear Regulatory Commission (NRC) and the Environmental Protection Agency (EPA), will be included only when helpful in discussing the AEC/ERDA/DOE policies and practices.

The classes of radioactive waste addressed in the paper are high-level waste (HLW), low-level waste (LLW), Greater-Than-Class C (GTCC) commercial LLW, transuranic waste (TRUW), mixed low-level waste (MLLW), and special-case waste (SCW). Wastes in a gaseous or airborne state are not addressed in this paper. The bulk of the radioactive constituents in the gaseous by-products of the nuclear programs are assumed to be captured in the systems designed to discharge these effluents to the environment by flowing through appropriate control systems that allow only the release of radionuclide concentrations in compliance with established regulatory standards. The control systems, in removing radionuclides from the gaseous effluents by scrubbing, filters, or other technologies, generate secondary liquid or solid wastes that are managed under one of the appropriate non-HLW management systems discussed herein.

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2.0 Introduction

The AEC was established in 1946 thereby providing civilian responsibility and control over the U.S. atomic energy programs that were initiated by the Manhattan Engineering District (MED) during World War II to carry out a military national security mission. The primary capabilities inherited by the AEC for the conduct of its programs included uranium separation and enriching facilities and a pilot plutonium production reactor and plutonium separation facilities (Oak Ridge, Tennessee); three plutonium production reactors and associated plutonium separation facilities (Hanford, Washington); Los Alamos Scientific Laboratory for design and fabrication of atomic bombs (New Mexico); and University of Chicago's Metallurgical Laboratory to provide research support for the complex.

The defense production capabilities were more than doubled over the period of 1947-52 and included additional gaseous diffusion plants for enriching uranium at Paducah, Kentucky, and Portsmouth, Ohio, with expansion of the plant at Oak Ridge; five additional plutonium production reactors at Hanford; five tritium and plutonium production reactors at the Savannah River Site (South Carolina); feed material center (Fernald, Ohio); component production and assembly plants (Rocky Flats, Colorado, and Amarillo, Texas); a second weapons research and development laboratory (Livermore, California); the Nevada Test Site; and the National Reactor Testing Station (now the Idaho National Engineering Laboratory).

Included in the AEC's responsibilities was the management of the relatively large volumes of radioactive waste being generated by the various Commission programs at sites across the country. The basic principle guiding efforts to discharge this responsibility required that the waste be managed in a way that ensures effective control over the radiation hazard thereby providing an acceptable level of protection for human health and the environment—a principle that has applied throughout the history of the U.S. waste management programs.

Understandably, in the early years of these programs there was considerable uncertainty about what would constitute an acceptable level of protection. The wartime programs initiated by the MED had short-term goals for producing special nuclear materials (plutonium and highly enriched uranium) considered vital to the national security and did not allow time for the purpose of solving issues related to the cradle-to-grave management of the wastes generated by these programs.

The Manhattan Project officials did understand, at least theoretically, the environmental, health, and safety implications of nuclear technology. Concern of a major accident, as well as secrecy considerations, encouraged the remote siting of facilities. The project officials made a significant effort to promote health and safety. There were extensive programs throughout the MED complex (Hanford, Oak Ridge, the Metallurgical Laboratory at the University of Chicago, and Los Alamos Laboratory) concerning routine industrial safety. In addition, the Metallurgical Lab established in July 1942 the Chicago Health Division, whose primary task was to institute a health physics program

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to monitor radiation hazards.¹ A need was also recognized at Hanford for a team of onsite experts in the new science of health physics for the purpose of defining and measuring radiological hazards, establishing safety procedures for plutonium production workers, and developing and calibrating new and unique environmental monitoring instruments. Both area-and personnel-monitoring devices were used from the earliest days at Hanford. The health physicists, on the basis of prewar research and standards derived from experience with X-rays, radium, and radon, took a conservative approach, viewing almost any radiation exposure as being harmful, as if no threshold existed, and that any body burden might cause adverse health effects.²

The MED provided little, if any, central direction relating to the management of waste other than the health and safety assistance provided by the Medical Section of the University of Chicago's Health Division. Sites and contractors developed waste management programs largely in isolation both from each other and from Headquarters control. Self-auditing of waste practices was the rule throughout the complex.³

The Hanford health physics capability was set up independent of the Met Lab in Chicago. Los Alamos also established and conducted its own health physics program. Tight security hampered cooperation and data exchange among the Laboratories' health physicists.⁴ The insights resulting from the experiences of these multiple health and safety programs were useful to the Commission's early efforts to establish health and safety standards and criteria for managing radioactive materials and waste products. However, it was recognized by the AEC that the knowledge and experience available were limited concerning the short-and long-term effects on human health for many of the radionuclides contained in the waste products of the emerging nuclear age. A similar lack of knowledge prevailed with respect to how the radionuclides in their various physical and chemical states would react with and impact upon the diverse environments at the atomic energy installations.

The health and safety protection programs the AEC inherited from the MED were judged by the Commission to be excellent; however, it felt the need, for independent evaluations and recommendations due to the physical deterioration of facilities and equipment and difficulties in transitioning to a civilian agency. In response to this need, the Commission established in August 1947 a Safety and Industrial Health Advisory Board to examine the health, safety, and fire protection throughout the complex. The Board consisted primarily of outside experts from various health and safety fields. The National Academy of Sciences became concerned that the Commission was not giving adequate attention to sanitary engineering issues, such as water supply and waste disposal. The Academy was largely responsible for getting its committee chairman on sanitary engineering, Abel Wolman of Johns Hopkins University, on the Commission's Advisory Board.⁵

The Board delivered its final report to the Commission in April 1948. The Board found that the health and safety program for the employees was, in general, quite good, with some exceptions that usually involved programs and installations for which universities were responsible. Los Alamos was the target for the strongest criticism. However, the Board was quite critical of protection for the public against radiation and other hazards. In particular, the Board viewed the management of waste

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disposal to be negligent. It noted that continued disposal of waste "in present quantities and by present methods" would in the long-term present "the gravest of problems." It was concluded in a supplementary report on environmental sanitation that the "disposal of both toxic and radioactive wastes required immediate laboratory and field study."⁶

The report on environmental sanitation provided detailed criticism of AEC waste-disposal practices at specific sites and concluded with a list of problems prevalent across the complex that in the Board's opinion required immediate attention, including:

- the extent of migration toward underground water supplies of radioactive and toxic wastes disposed in wells, cribs, and pits;
- the extent of travel in rivers and streams of wastes and their deposits in banks or beds;
- the extent of dispersion of gaseous wastes from vents or stacks;
- waste disposal support studies with respect to an area's biology, geology, meteorology, and hydrology; and
- provision for equipment and sampling techniques necessary to monitor air, soil, and water.

The Board's report dealt extensively with recommendations for upgrading the environmental, safety, and health (ES&H) effort as a priority matter. Organization and management was highlighted as the key factor; diffused responsibility for ES&H matters was highlighted as a major problem. Cited as an example was the fact that throughout the complex officials focused considerable attention on radiation hazards and ignored the release of chemically toxic wastes. While the Board endorsed an earlier Commission decision for general decentralization of program management and responsibility, it urged that "detailed" central control for ES&H matters be withdrawn gradually, with provision for maximum interchange of information among Headquarters, field offices, and operating contractors.

Many of the Advisory Board's recommendations were adopted and implemented promptly by the Commission and its contractors; however, the advice concerning organizational changes and waste management considerations was largely ignored. The latter was not viewed as a priority matter. The Commission was generally content to let waste management be handled locally, a view that the field generally endorsed. A month after the Board submitted its report, a group representing all Commission laboratories voted in favor of letting each laboratory solve its own waste management problems.⁷

There were exceptions to this position within the ranks of the AEC and contractor officials. Walter Zinn, director of the new Argonne National Laboratory (ANL), opposed the move to let laboratories handle their own waste problems since it would dilute efforts to establish effective, complex-wide

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standards. He told his staff in 1948 that disposal of radioactive waste constitutes one of the greatest and most important problems being faced by ANL.⁸

In its efforts to maintain safe and effective control over the radiation hazard associated with the long-term management of radioactive wastes, the AEC adopted early in its existence two basic disposal concepts:⁹

- 1) Concentrate and contain: This concept pertained principally to the highly radioactive liquid waste generated from the chemical reprocessing of irradiated reactor fuels that must be "reduced to a suitable concentrated form and contained indefinitely in this way;" and
- 2) Dilute and disperse: In the employment of this basic concept for management of liquid, low-activity waste streams, "the radioactivity may be reduced to tolerable levels by dilution in nature-in air or water."

In implementing these concepts, the Commission identified three pieces of information necessary to determine the methods that must be applied to managing radioactive wastes:¹⁰

- 1) The maximum quantity of specific radioisotopes that research and experience indicate humans can tolerate, either in the total body or in various organs, which translate into maximum concentrations of specific radionuclides that can be safely allowed in water and air (determining these limits was a major effort);
- 2) The specific radioactive and chemical nature of the waste under consideration; and
- 3) The physical, chemical, and biological characteristics of the environment in which the waste would be managed (i.e., treated, stored, or disposed).

Having established these basic general Commission policies and concepts, the Operations Offices and their contractors were given responsibility for developing the detailed waste management policies and practices applicable to their respective waste streams and sites. It was (and still is) incumbent upon the field organizations to evaluate for each facility the factors affecting the management of waste streams generated by the facility and to make certain that the waste management operations comply with the established standards and criteria. The AEC, as noted in its 1959 annual report to Congress, did not establish detailed regulations and standards for disposal of radioactive waste due to the "varied and complex technical problems which arise" in these operations. Instead, according to the report, the Commission "establishes permissible concentrations of radioactivity in effluents to public or unrestricted areas, and permits the disposal on a routine basis of only extremely low quantities of radioactive waste by release into sanitary sewer systems or by burial at sea or in soil." Performance criteria were determined for waste disposal

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operations for each nuclear installation consistent with two principles: keep the discharge as low as practicable, and check continuously on results.

In this same report to Congress, the AEC recognized that the standards of protection were based on the best available biological and medical experience and knowledge, and on specific research. The Commission also acknowledged that understanding was still not complete and new problems would continue to arise as atomic energy programs developed and expanded; consequently, standards would be revised as more and better knowledge was gained. (An example is AEC Manual Chapter 0524, "Standards For Radiation Protection," approved in Nov. 1968 and provided more extensive health and safety requirements for the overall AEC complex.)

In light of these considerations, it is not surprising that:

- 1) The waste management policies, practices, and regulations, have undergone significant changes over the years; and
- 2) Large quantities of the more hazardous wastes generated over the past half-century (e.g., high-level liquid wastes) are still in storage, pending an acceptable disposal capability.

As noted earlier, this report provides a review of the evolution of policies and regulations governing the practices for managing radioactive waste for which DOE and its predecessor agencies have had responsibility. The scope of the review includes the management of commercial high-level waste and spent nuclear fuel following the establishment of the Office of Civilian Radioactive Waste Management in 1982 only to the extent it is necessary to the coverage of other DOE radioactive waste management programs. The format for the review is by waste type (i.e., high-level waste (HLW), low-level waste (LLW), transuranic waste (TRUW), Greater-Than-Class-C (GTCC) commercial LLW, special-case waste (SCW), and mixed low-level waste (MLLW). It should be noted, however, that some discussion in the LLW section about developments in Federal policies in the late 1980's (Section 4.4) and in this decade (Section 4.5) is broader in scope than implications only for managing LLW. Inclusion of the material in these sections provides the most convenient and least confusing way of maintaining a chronological historical perspective.

High-Level Waste

3.0 High-Level Waste

3.1 Definition - Classification Considerations

The definition of high-level waste (HLW) has been debated and applied in various forms and for various purposes over the entire history of the U.S. atomic energy program. The time span has been long enough so that some of the management objectives have changed, institutional memories of intent have been lost, technologies have changed, new legislation has been enacted, and environmental expectations and regulations have been modified. Based on current projections for having an operational disposal facility and for the rate and order for accepting waste at the facility, disposal of some of the Department's HLW may occur more than a century after the waste was generated.

Early developments moved in the direction of a waste classification system based on the radiologic hazard to man and associated radionuclide concentrations even though complete quantitative criteria did not exist at that time. The initial waste management systems were influenced more by ensuring safe operational considerations rather than disposal requirements. However, there was recognition from the beginning that the high-activity waste generated in the chemical processing of irradiated reactor fuels and containing the bulk of the fission product inventory would require long-term isolation from the human environment. These wastes were, therefore, put in interim storage in underground tanks pending later development of an appropriate disposal capability. This unique, high-activity waste stream became known as "high-level waste," a class of radioactive waste that was defined by its source of generation.

Over the years, various methods for defining or classifying radioactive wastes have been employed. However, the high-activity waste generated from reprocessing irradiated reactor fuel has consistently been classified as HLW. On the other hand, concentrations of the more toxic radionuclides contained in the waste have provided the basis for classifying other categories of radioactive waste, e.g., defense waste contaminated with specific concentrations of long-lived transuranic nuclides is classified as transuranic waste (see Section 5). In addition, all radioactive waste that did not qualify as HLW, spent nuclear fuel, TRUW, or mill tailings has been classified by exception as LLW. Subsequently, LLW was subdivided into several additional categories of waste based on concentrations of selected radionuclides (see Section 4).

Due largely to the confusion resulting from this mixed bag of criteria for classifying the waste streams plus the existence of some anomalies in the potential risks of managing some categories of waste under existing classification criteria, NRC, with DOE and EPA encouragement, decided to consider in the mid-1980's the possible extension of concentration-based classification standards to cover all categories of radioactive waste. In effect, the Commission proposed to define HLW in a manner that would apply the term "high-level radioactive waste" to materials in amounts and concentrations exceeding numerical values that would be stated explicitly in the form of a table.

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(NOTE: This approach to waste classification is similar to those proposed by the United States of America Standards Institute in 1967 and the International Atomic Energy Agency in 1969.) HLW would, therefore, be characterized by the kind of hazard that would require disposal in a geologic repository, or a facility providing equivalent isolation of the waste. Other waste would be classified as non-HLW. Under this arrangement, there would be an upper concentration limit for the LLW.

This decision by NRC was reflected in its Advanced Notice of Proposed Rulemaking (ANPRM) published in the *Federal Register* in February 1987. The Commission proposed to classify wastes as HLW or non-HLW by evaluating the disposal capability of hypothetical, "intermediate" disposal facilities providing less isolation than a deep geologic repository. Wastes that could not be safely disposed of in such facilities would be classified as HLW.

The external comments on the ANPRM covered a broad range of opinion. For example, there were those that promoted a policy for requiring the disposal of the more radioactive LLW (i.e., Class C and GTCC) in the geologic repository. Others criticized the ANPRM as an attempt to reclassify some defense waste derived from reprocessing irradiated fuel as non-HLW and, therefore, eligible for disposal in the underground tanks in which they are currently stored. In the face of such criticism and the magnitude and complexity of the problem of evaluating the long-term performance of hypothetical disposal systems for a large inventory of source terms, NRC abandoned the proposal to develop nuclide concentration limits for classifying the HLW, a decision that was announced on May 18, 1988.¹¹

The current authorities for defining or providing criteria for classifying high-level radioactive waste are the Nuclear Waste Policy Act of 1982 (NWPA), Sec. 2 (12) and 10 CFR Part 60.2 (1981) of the NRC regulations. The definition in the NWPA is:

- (A) the highly radioactive material from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations; and
- (B) other highly radioactive material that the Commission [NRC], consistent with existing law, determines by rule requires permanent isolation.*

This definition also appears in DOE Order 5820.2A, Attachment 2, Definition 18, and in the EPA regulation 40CFR191.

The NRC noted in its 1987 ANPRM that clause (A) refers to waste that contains fission products in sufficient concentrations and pointed out that long-lived transuranic radionuclides are also present

* Permanent isolation, as used in the NWPA, denotes disposal in a deep geologic repository or by other means providing comparable isolation from human environment.

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in the liquid reprocessing wastes and represent the predominant long-term hazard of these wastes and, therefore, must be considered in defining reprocessing wastes that should be regarded as HLW.

The NRC definition, while stated somewhat differently from that of the NWPA, is intended to be consistent with the definition in the Act. NRC specified the waste streams from the spent-fuel processing operations that would be classified as HLW, i.e., the liquid waste resulting from the operation of the first cycle solvent extraction system, or equivalent, and the concentrated waste from subsequent extraction cycles, or equivalent. (The extraction process removes the produced plutonium and residual uranium from other constituents, principally the fission products, of the irradiated reactor fuel). It should be noted that NRC utilizes this definition, which is consistent with its 10CFR50 Appendix F definition of HLW, when determining what defense HLW is subject to its licensing authority.

The NRC definition in 10CFR60 also identifies as HLW any irradiated reactor fuel that is to be disposed without having been chemically reprocessed to recover the contained special nuclear material. Irradiated fuel elements, if discarded without reprocessing, were also included in the AEC definition of HLW for the first time in the Commission's 1973 "Plan for the Management of AEC - Generated Radioactive Wastes;" it was also included in the HLW definition appearing in AEC Manual Chapter 0511, "Radioactive Waste Management," issued in 1973.

3.2 Liquid HLW Generation and Interim Storage

The generation of significant quantities of HLW in the United States began with the war-time program of the Manhattan Engineering Project when irradiated reactor fuels were chemically processed to separate and recover plutonium from the fission products by the bismuth phosphate precipitation process. Development and operation of the REDOX process, beginning in 1952, provided the first continuous process (solvent extraction) and the first process to recover both plutonium and uranium. While a number of different processes have been used over the years (see Table 3.1), depending on the type of fuel element processed, the basic approach has been the same. The solid irradiated fuel elements, after a minimum storage of 90 to 120 days, were dissolved in nitric acid and the solution fed to solvent extraction columns that selectively extracted the plutonium and the uranium. Fission products were scrubbed from the solvent extract by an aqueous salt solution before the extract left the column. The solution contained more than 99.9 percent of the dissolved fission products (in the Purex process) as well as the inert materials in the feed and scrub solutions, all of which were collected for treatment and storage as HLW pending further treatment (stabilization) and disposal.

It should be noted that over the years there have been somewhat different meanings assigned to the terms "storage" and "disposal" when used in connection with the management of Federal radioactive waste. In the 1972 "Plan for Management of AEC-Generated Radioactive Wastes,"¹² disposal is defined as the planned release of radioactive materials in a manner that precludes recovery. If recovery is possible, even though not planned, the terms "burial" or "storage" are sometimes used

TABLE 3.1

**AVERAGE GALLONS OF WASTE PER TON OF URANIUM PROCESSED
FOR AEC PRODUCTION FUELS**

<u>PROCESS & PERIOD</u>	<u>RAFFINATES</u>	<u>COATING WASTE</u>	<u>TOTAL STORED*</u>
***** CHEMICAL DECLADDING - ALKALINE WASTE *****			
BISMUTH PHOSPHATE, 1944-1955			10,000-5,000
REDOX, 1952-1967	400	400	800
PUREX, 1956-	150	400	550
ZIRCONIUM CLAD	250	600	850
ALUMINUM CLAD	145	400	545
***** IMPROVED PUREX PROCESSES** *****			
CHOP LEACH	150		150
PLUS ACID WASTE	50		50
PLUS U-IV	30		30
OPTIMUM PROCESS	10		10

* EXCLUDES 400 TO 600 GALLONS PER TON OF ORGANIC WASH, PLANT DRAINS, AND DECONTAMINATION WASTES WHICH ARE EVAPORATED TO FROM 20 TO 50 GALLONS OF INTERMEDIATE LEVEL WASTES.

** FOR CIVILIAN POWER REACTOR FUELS.

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in place of disposal. This is in contrast to the meanings generally assigned to these terms for at least the last 15 years. For example, NRC's 10 CFR Part 60, which was promulgated in 1981, defines disposal as the isolation of radioactive wastes from the accessible environment with no intent to recover the waste even if such a course of action were possible. Because of the historical precedent, it is not uncommon today to encounter the use of "storage" or "long-term storage" when referring to the final disposition of any class of radioactive waste.

The high-activity liquid wastes that contain the bulk of the fission products from the processed irradiated fuel elements were generated as highly acidic liquid solutions (no precipitates) and must be handled and stored in corrosion-resistant vessels, normally stainless steel. However, when the program was initiated during World War II at Hanford, there was a shortage of stainless steel; therefore, the HLW was neutralized and stored as alkaline slurries in underground tanks constructed of reinforced concrete and lined with carbon steel. All DOE-generated HLW is stored on DOE owned and secured reservations in underground tanks or bins, pending conversion to a solid form suitable for disposal in a permanent isolation facility, in accordance with current management strategy.

The neutralization of the liquid HLW resulted in precipitated fission product metal oxides and hydroxides that collected as sludge on the storage tank floor. In-tank and external evaporation has removed significant amounts of water, leading to a viscous high sodium hydroxide content residual liquor with elevated salt content and crystallized salts, commonly referred to as "salt cake."¹³

The practice of neutralizing the liquid HLW for storage was continued in later chemical reprocessing facilities at the AEC Savannah River Plant and the commercial chemical reprocessing plant at West Valley, New York. However, the acidic liquid HLW generated at the Idaho Chemical Processing Plant at the National Reactor Testing Station (now the Idaho National Engineering Laboratory) was stored in underground stainless steel tanks, pending calcination in a fluidized bed calciner to a granular form. The calcined product is stored in underground stainless steel bins in concrete vaults (500-year design life). Current management strategy prescribes further processing of the calcined product to a final waste form for disposal in a deep geologic repository. Heat from the radionuclide decay in the calcined product is removed by air flowing past the outer walls of the storage bins.¹⁴

While the search for an appropriate disposal capability proceeded (see Section 3.3.2), the increasing volumes of liquid defense HLW at the three chemical reprocessing sites - Hanford, Savannah River Site, and the Idaho National Engineering Laboratory - had to be managed in appropriate "interim" storage facilities, and an appropriate waste form for disposal had to be developed. The liquid HLW storage facilities and their contents, both for defense and commercial programs, are described in Table 3.2. The number and types of tanks deployed at the four HLW interim storage sites reflect the situation in the early 1990's. The tanks at Hanford and Savannah River range in capacity from about 500,000 to 1.3 million gallons except for a few smaller tanks constructed initially at Hanford. The liquid waste tanks at INEL have a capacity of about 300,000 gallons, and the waste generated

Table 3.2

Inventory of High-Level Waste by Volume and Radioactivity (12/31/93)

Based on Information Table 2.6 and Table 2.7, Integrated Data Base for 1993 (December 1994)

VOLUME, THOUSANDS OF CUBIC METERS

	HANF	INEL	SRS	WVDP	TOTAL
Liquid	24.9	6.8	61.4	1.80	94.9
Sludge	46.0	--	13.9	0.03	59.9
Salt Cake	93.0	--	53.8	--	146.8
Slurry	97.8	--	--	--	97.8
Calcine	--	3.7	--	--	3.7
Precipitate	--	--	0.2	--	0.2
Zeolite	--	--	--	0.16	0.16
Capsules	.0035	--	--	--	0.0035
	261.7	10.5	129.3	1.99	403.5

NUMBER OF TANKS

Double Shell	28	11	51	4	94
Single Shell	149	--	--	--	149
Calcine	--	7	--	--	7

RADIOACTIVITY, MILLIONS OF CURIES

HANF	INEL	SRS	WVDP	TOTAL
15.5	2.6	83.9	3.60	105.6
101.3	--	412.0	11.3	524.6
7.3	--	110.0	--	117.3
84.3	--	--	--	84.3
--	49.9	--	--	49.9
--	--	0.1	--	0.1
--	--	--	10.4	10.4
153.0	--	--	--	153.0
361.4	52.5	606.0	25.3	1045.2

SRS: SAVANNAH RIVER

INEL: IDAHO NATIONAL ENGINEERING
LABORATORY

HANF: HANFORD SITE

WVDP: WEST VALLEY DEMONSTRATION PROJECT

--: WASTE FORM NOT GENERATED AT THIS TIME

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by the PUREX process at the West Valley Plant was stored in a 600,000 gallon tank. It is interesting to note that in a final report in 1948 to the AEC by its Safety and Industrial Health Advisory Board, the Board stated that Hanford was spending "hundreds of thousands of dollars" for holding tanks of high-level liquid waste, a condition that "certainly provides no solution to a continuing and overwhelming problem. The business of constructing more and more containers for more and more objectionable material has already reached the point both of extravagance and of concern in most of the areas."¹⁵

Until about 1970, the HLW storage facilities generally consisted of two types of underground tanks: 1) concrete tanks, usually lined with carbon steel and called single-shell tanks; and 2) free-standing carbon steel or stainless steel tanks in underground concrete vaults. If the vault was lined, the storage was doubly contained. Over the period of 1943 to 1973, there were 149 single-shell tanks and 4 double-shell tanks constructed at Hanford, while at Savannah River there were 22 "cup and saucer" and double-shell tanks and 8 single-shell tanks put into service.* Those tanks built during and after 1967 at both sites were an improved double-shell design consisting of a stress-relieved free-standing carbon steel tank inside a fully steel lined concrete vault. It is obvious from Table 3.2 that a number of these double-shell tanks were put into service at both the Hanford and Savannah River sites, and in the case of the latter, replaced all of the single-shell tanks that represented a higher risk for breach of containment of the stored waste.

In addition to the management challenge posed by the radiological characteristics of the HLW during interim storage, there are the problems associated with the heat-generating characteristics of the waste. This only became a problem after several years when higher heat generation rates were experienced in the waste. This change resulted from increased fission product concentrations due to increased irradiation of the fuel elements, improved processing method (flowsheets), and a desire to put as much waste as possible in each tank. Moreover, over time both Hanford and Savannah River installed evaporators in the storage systems to reduce the liquid volumes and concentrate the HLW. Eventually the concentration of fission products in some of the tanks increased to the point that boiling occurred.

At Hanford, such wastes stored in single-shell tanks were allowed to boil, which served as a heat-transfer mechanism to control the temperature of the waste. Air circulators were also installed in some tanks to improve the heat transfer from the insoluble sludge layers that had settled to the bottom of the tanks. This was necessary to avoid conversion of the liquid near the bottom of the tank into steam, which could result in a sudden and sometimes violent release of steam.

*The cup and saucer-type tank consisted of a free-standing carbon steel tank located inside a concrete vault. The bottom of the vault is covered with a carbon steel liner which extends 5 feet up the vault wall.

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The low-heat HLW at Savannah River was evaporated to almost entirely salt crystals. The evaporator concentrates from the high-heat wastes were returned to the double-shell tanks for storage. These tanks were equipped with cooling coils capable of dissipating the higher heat loads. The Hanford tanks did not have the cooling coils; however, the high-heat wastes at Hanford were processed to remove the fission products cesium-137 and strontium-90, which were significant contributors to the heat generation. The cesium and strontium were subsequently doubly encapsulated in stainless steel for long-term storage. Several hundred of these capsules were used as sources for various irradiator applications. With the removal of these radionuclides, the processed waste, after several years of aging for decay of the shorter-lived fission products, could be evaporated along with other stored low-heat wastes to salt cake.

Over the years, 73 of the HLW storage tanks have either leaked or been assumed to have leaked due to structural stresses and pitting and stress corrosion. The leakers have involved single-shell tanks at Hanford and six of the "cup and saucer" type of tanks at Savannah River. Of the latter, only one leaked to ground; in the case of the other five, the leakage was retained in the saucer (i.e., the partially steel-lined concrete vault). There is now sufficient data to suggest that waste from leaking tanks at Hanford may have already reached the groundwater. Hanford plans to collect additional data to confirm the source(s) of the contamination, the depth the contamination has traveled in the vadose zone, and contribution to groundwater contamination.

Spare or reserve tankage was provided for interim storage of HLW to ensure:

- A) emergency storage capacity in case of leaking tanks or unplanned waste generation; and
- B) operational continuity by providing operating surge capacity. The "Plan for the Management of AEC-Generated Radioactive Wastes" (WASH1202, Jan.1972) required that each tank farm or interconnected system of tank farms containing high-heat wastes have available, in tanks empty except for a residual heel, space equivalent to the largest volume of liquid wastes stored in any one tank. The Plan had a similar requirement for each tank farm or interconnected system of tank farms storing low-heat HLW.

The acidic HLW generated at the Idaho Chemical Processing Plant was stored in stainless steel tanks in underground concrete vaults, except for 4 small (30,000 gallon) direct-buried stainless steel tanks that were originally provided for waste from processing early submarine reactor cores and were subsequently emptied and not reused. A fluidized-bed waste-calcining facility began operation in late 1963 to convert the Idaho liquid HLW to a granular solid that was stored in stainless steel bins within concrete vaults. The calcination process resulted in volume reduction for the liquid HLW by a factor of 10.

Most HLW transfer lines at Savannah River and Idaho are encased, thereby providing double containment. The transfer lines at Hanford were originally buried directly underground, resulting in some failures with leakage of radioactivity into the soil that is currently estimated at

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approximately 100,000 gallons. Replacement of the direct buried lines with encased lines was undertaken in the early 1970's.¹⁶ However, some direct buried lines are still in use at Hanford for pumping residual liquids from single-shell tanks.

Monitoring systems are employed at all three sites to detect any breach in the integrity of the storage containment. As noted above, there have been leaks in the past from several single-shell tanks at Hanford, some of which were highly publicized by the news media. The leaked material has been largely retained in the soil overburden to the deep aquifer. There is now sufficient data to suggest that waste from leaking tanks at Hanford may have already reached the groundwater. Hanford plans to collect additional data to confirm the sources(s) of the contamination, the depth the contamination has traveled in the vadose zone, and contribution to groundwater contamination.

In summary, the Department's high-level waste that has been generated as a result of chemical processing of spent-fuel elements over the past 50 years is being subjected to interim storage in underground steel/concrete tanks at various DOE facilities in a number of physical and chemical forms: acidic liquid; caustic liquid, with or without sludge; salt cake; slurry; or as dry granular calcine. Current management plans require that all of these wastes be subjected to further treatment for conversion to acceptable waste forms for permanent isolation in a geologic repository.

3.3 High-Level Waste Solidification and Disposal

From the beginning of the program for the production of plutonium at Hanford, it was recognized that the large volumes of highly radioactive waste generated by this program would require long-term isolation from the human environment due to the presence of significant quantities of long-lived radionuclides (e.g., plutonium with a half-life of about 24,000 years). The AEC advised Congress in its 1959 annual report that the tank storage of HLW does not represent disposal and that containment of these materials will be required for hundreds of years.¹⁷ The Commission described an on-going research program to develop and evaluate methods relating to HLW disposal that included: a) the conversion of liquid waste to solids and the development of methods for disposal of the produced solids, b) direct disposal of high-level liquid waste into the earth at great depths, and c) removal of specific toxic and long-lived isotopes to reduce the total waste problem.

3.3.1 Waste Solidification

The principal driver in the 1950's for finding a stable waste form for permanent isolation of the HLW was the need to develop the inventory of technologies necessary to establish an economic commercial nuclear fuel cycle. The Atomic Energy Act had been amended in 1954 and President Eisenhower had announced the creation of the Atoms for Peace program in 1955, both of which set the stage for the emergence of the civilian nuclear power stations and their supporting fuel cycles.

The Commission was convinced at that time that the "low-activity" wastes were essentially under control and attention should be focused on the problems of HLW disposal. Moreover, the AEC

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decided to make the civilian HLW disposal a priority program even though there was no civilian HLW prior to 1966 when the first commercial reprocessing facility opened at West Valley, New York. (It operated until 1972 and was the only such commercial facility to become operational in the United States before the Federal Government adopted a policy in 1977 that deferred indefinitely such commercial operations in the United States).

Initially, civilian plants for chemical reprocessing irradiated fuel assemblies from powerplants could only be built on Federal or State-owned land, as was the case for the Nuclear Fuel Services plant at West Valley, New York and the partially completed General Electric and Allied-Gulf plants at Morris, Illinois, and Barnwell, South Carolina, respectively. This requirement was terminated with the issuance of Appendix F of 10 CFR Part 50 in 1970, which allowed such plants to be located on privately owned property. This regulation also required that the commercial HLW be solidified within 5 years and the solidified product to be delivered to a Federal Repository within 10 years after the generation of the liquid HLW. In anticipation of this requirement, the AEC decided the most manageable and cost-effective strategy for disposal of the commercial HLW would be to establish a central Federal repository for these wastes.¹⁸

The initial backend of the commercial nuclear fuel cycle (pre-1977) was based on the AEC defense program basic technology for chemical reprocessing of irradiated fuel. Both fuel cycles, however, needed a capability for stabilizing and disposing of the high-activity waste resulting from the reprocessing operations. Responding to this challenge, AEC's Division of Reactor Development and Technology convened a meeting at Johns Hopkins University in 1957 for a wide-ranging exchange of views about options for fixation of waste on stable solid media. A follow-on meeting was held in Idaho in 1960.

The options covered at the 1957 meeting, which were under study and development at that time, for stabilizing the liquid HLW are listed in Table 3.3. The AEC-sponsored activities in this area remained preoccupied with these alternatives and variations thereof through the 1960's and beyond as they winnowed down the list and focused on the more promising ones for use in the commercial fuel cycle, as well as for potential use in the defense program.

To facilitate this process, the Commission approved the Waste Solidification Engineering Prototype (WSEP) for Hanford in 1962. The WSEP was to provide the technical, economic, and safety evaluations for multiple candidate solidification processes through pilot plant studies and demonstrations. The WSEP started operations in 1966 and operated four years demonstrating pot calcination, spray calcination, and waste fixation in phosphate and borosilicate glass. The fluidized bed calcination process was demonstrated in a pilot plant at Argonne National Laboratory, and an engineering-scale demonstration unit was constructed and operated at the Commission's Idaho Chemical Processing Plant. This processing unit converted liquid HLW to the solid calcine product for about 20 years, beginning in 1963, until replaced with a production-scale calciner.

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In 1968, the Government Accounting Office (GAO) issued a report on the Commission's waste management programs, and the AEC also convened that year a waste management task force to evaluate its waste management programs. Both developments had implications for the HLW solidification and disposal programs. The GAO report recommended the establishment of an organizational unit responsible for policy formulation and program oversight. It also recommended a more vigorous program for the long-term management of the radioactive waste and the solidification of the defense HLW or its emplacement in a geologic formation. The task force report included conclusions consistent with GAO's recommendation for a more aggressive approach to the long-term phase of the waste management program. In 1970, AEC established a Division of Waste and Scrap Management (renamed Waste Management and Transportation in 1971) that adopted a priority goal of developing a plan for the long-term management of the Commission's radioactive waste. Such a plan was promulgated in January 1972.¹⁹

Over time the vitrification process employing a joule-heated ceramic melter for producing a borosilicate glass became the preferred HLW solidification option for providing the disposal waste form for emplacement in a geologic repository. There have been challenges over the years to the use of this waste form for stabilizing liquid HLW, usually in terms of promoting a ceramic material as a more stable waste form. While a decision has not yet been made concerning the waste form to be used in disposing of the Idaho calcined HLW, conversion of the material to a ceramic product has considerable support. Converting the calcined HLW to glass logs, as is planned for the HLW at the other production sites, significantly increases the volume of waste to be disposed and has, therefore, fallen into disfavor for the INEL portion of the HLW inventory.

Pursuant to an agreement with the State of New York and enabling legislation by the Congress (the West Valley Demonstration Project Act of 1980), the Department assumed a qualified responsibility for managing the HLW stored in underground tanks at the commercial plant at West Valley, New York. It had chemically reprocessed spent nuclear fuel from 1966 to 1972, generating about 2,000 cubic meters of neutralized HLW. The Department's primary responsibility under this project is to demonstrate the solidification of HLW into a form suitable for disposal and to transport the waste to a Federal repository for disposal. DOE selected borosilicate glass as the disposal waste form and the use of the ceramic melter to produce the solidified product, following a similar solidification strategy that had been selected at Savannah River once it was decided that the Savannah River HLW was to be disposed of offsite.

It was decided in the late 1980's that the HLW removed from the storage tanks at Savannah River and Hanford should undergo pretreatment before vitrification occurs to reduce the volumes of solidified HLW for repository disposal. It was felt this approach could result in significant cost reductions. The pretreatment will result in generating a high-activity waste stream and a low-activity waste stream. The latter, once appropriately solidified, can be disposed of as LLW.

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Table 3.3

HLW Solidification Processes Under Study: 1950's -1960's

<u>Process</u>	<u>Location</u>
1. Ion exchange process in which radioactive ions are absorbed on minerals of extruded natural clay, with fixation accomplished by heating the clay to 1700° F.	1. Laboratory tests at Brookhaven National Laboratory (BNL).**
2. Convert liquid wastes to solids by fluid-bed calcination.	2. Studies began at Argonne National Laboratory in 1955. This work led to construction of the Waste Calcining Facility at the Chemical Processing Plant at the National Reactor Testing Station in Idaho (now INEL).*
3. Pot calcination: evaporation of wastes to dryness followed by calcination of residues at temperatures of 700-900° C.	3. Process developed at ORNL in the early 1960's; to be demonstrated in the Waste Solidification Engineering Prototype (WSEP) installation at Hanford beginning early 1966.*
4. Spray calcination: converting liquid wastes to solid by spray calcination in a heated tower.	4. Process developed at the Pacific Northwest Laboratory; also to be demonstrated at the WSEP in the late 1960's.*
5. Phosphate-glass fixation: a continuous process for incorporating waste fission products into phosphate glass. The glass melt from the platinum-lined crucible was to be discharged into a disposal container.	5. Process developed at BNL. Based on results of early 1960's, equipment was developed and shipped to Hanford for tests in the mid to late 1960's.*

* "Radioactive Wastes", U.S. AEC, Nov. 1965.

** "Management of Radioactive Wastes," reprint from U.S. AEC's Annual Report to Congress for 1959, January 1960.

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Facilities for solidifying HLW have been constructed at Savannah River (the Defense Waste Processing Facility) and West Valley. Both have been subjected to testing programs and both began production of vitrified product (glass logs cast in stainless steel containers) in 1996. At the Hanford and Idaho sites, specific technical options are being evaluated for pre-treatment and solidification of the HLW, and decisions about those processes and facilities (including the possibility of privatization) are expected in the next few years.

3.3.2 Disposal

The objective of disposal (sometimes referred to as terminal storage) is the isolation of radioactive wastes from human environment until they no longer pose a threat to public health and safety, and to do so in a manner that places minimum reliance on future maintenance and surveillance of the disposal system.

In parallel with the research on selecting a suitable waste form (s) for disposal of HLW, efforts were initiated in the late 1950's to select and develop a capability for the long-term isolation of the solidified HLW by emplacement in suitable geologic formations. Rock salt was the leading candidate at that time. R&D on direct disposal of HLW into deep wells was also initiated at the end of that decade, but had a short life span. There was general agreement in 1960 that removal of specific fission products from the wastes would not significantly change the waste disposal picture. However, variations on this alternative (i.e., partitioning of the long-lived nuclides for subsequent transmutation) were recycled under somewhat different circumstances two different times in later years, once in the 1970's and again in the late 1980's, and rejected both times.

There were strong interests from 1955 on to develop suitable waste forms and disposal capability for permanent isolation of HLW generated in both the defense and civilian programs. However, as noted above, the latter became the more compelling consideration driving these programs. This was due principally to the fact that a) in-tank solidification and disposal or onsite bedrock disposal of HLW slurries were the preferred options at that time for AEC-generated HLW (see Fig. 3.1); and b) the commercial HLW was to be solidified and shipped off the site of generation for disposal. Moreover, as noted earlier, there was a growing body of opinion that the commercial waste should be converted within five years to a chemically, thermally, and radiolytically stable solid form for shipment to the offsite Federal-Government-controlled disposal facility within 10 years. These requirements were ultimately promulgated in Appendix F of 10 CFR 50 in 1970.

In 1955, the National Academy of Sciences - National Research Council (NAS-NRC) was retained by the AEC to provide independent advice and assessment on geohydrological considerations pertaining to HLW disposal. The Academy, under AEC sponsorship, convened a conference on "The Disposal of Radioactive Waste in Land" at Princeton University in September 1955 that provided the first comprehensive discussion of underground disposal of HLW. One approach that received considerable attention was disposal in underground facilities, either naturally occurring or manmade. Disposal at comparatively shallow depths using surface excavations such as quarries,

Figure 3.1

PRODUCTION SITE HIGH-LEVEL WASTE MANAGEMENT PLAN (1971)¹

¹ REF: Frank Baronowski (U.S. AEC) Statement to Joint Committee on Atomic Energy, March 16, 1971.

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underground caverns, and shallow mines was deemed unreliable because such openings are rarely watertight. Use of deep mines below the shallow fresh water table was examined with the conclusion that openings in salt domes or salt beds or space in abandoned salt mines were the most promising.

Laboratory studies on the behavior of salt in relation to nuclear waste led to the initiation in mid-1958 of a series of tests in a Carey Salt Company mine in Kansas. This work led Oak Ridge National Laboratory to carry out in the mid-1960's an experimental program in a salt mine in the Lyons, Kansas, area for the purpose of developing technology for the disposal of HLW in bedded salt formations.

Another HLW disposal option that received modest attention in the late 1950's was the injection of liquid waste into deep wells. Since the petroleum industry had developed extensive technology for injecting fluids into deep wells, the American Petroleum Institute was requested to appoint a committee of experts to consider the feasibility of disposing of radioactive liquids in this way. The group identified major problems with the development and use of a system for disposing of radioactive materials in abandoned deep oil wells.

While a modest level of effort continued on studies, for alternatives to the deep geologic repository for disposal of HLW - principally the deep seabed disposal option - the work of the 1950's and 60's had in large measure focused the HLW disposal program on efforts to find a site with acceptable geohydrologic characteristics for establishing a deep geologic repository and to develop an appropriate stable waste form for disposal of the radioactive materials in such a facility.

In the course of its studies, an NAS-NRC committee included an examination of the AEC plans for managing its defense high-level and low-level waste. In June 1960, the committee informed AEC chairman John McCone that no existing site generating high-or intermediate-level wastes possessed suitable geological conditions for the safe disposal of these wastes. The committee further recommended "as urgent" that the AEC establish waste disposal facilities at separate and suitable geological sites. The AEC rejected the recommendations due to the high costs and practical difficulties associated with relocating its waste management/disposal activities, especially those relating to HLW.²⁰

In 1971, the AEC asked Congress to authorize construction of a repository for disposal of commercial HLW and defense transuranic (TRU) waste, with the Lyons mine as a tentative site, subject to the satisfactory completion of certain additional tests and studies. Congress only authorized the additional studies. Two site-specific safety questions, including unacceptable borehole penetrations, and increasing political opposition to the project convinced AEC to abandon work at Lyons in mid-1972 and begin evaluation of possible replacement sites.

To comply with the then existing regulatory limits on the amount of time a private sector-generator may retain custody of solidified HLW (5 years), the AEC simultaneously began an evaluation of

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Retrievable Surface Storage Facilities (RSSFs) to provide a Federal capability for long-term storage of commercial HLW.

WASH-1539, "Draft Environmental Statement-Management of Commercial High-Level and Transuranic-Contaminated Radioactive Waste," was issued for comment in September 1974 and meetings were held for public comment during October and November 1974. The principal comments reflected concern that:

- Too much emphasis was given to retrievable storage and insufficient attention given to disposal in a geologic repository, reflecting a fear that the Federal Government might leave the high-level waste in retrievable storage indefinitely.
- A number of issues that were being transferred to the newly created NRC by the Energy Reorganization Act of that year received no discussion in the draft environmental statement (such as the impact of waste management activities at commercial facilities).²¹

Following the formation of ERDA as a result of the Energy Reorganization Act, (Oct. 11, 1974), the waste management program was promptly reevaluated. One of the first actions of the new Administrator was to review the comments on WASH-1539 that led to his decision to withdraw WASH-1539 and to commit the Administration to provide an expanded Environmental Impact Statement (EIS) with NRC as a participant. These analyses led to the conclusion that for both the civilian and defense programs, early demonstration of permanent disposal technology was essential.²² Moreover, due to delays in the buildup of commercial nuclear power and fuel reprocessing, ERDA concluded that a deep geological disposal facility could be available in time to satisfy the Nation's needs and an RSSF would not be required. Pursuant to recommendations by ERDA, President Ford directed ERDA in October 1976 to demonstrate a high-level waste repository by 1985.²³

Throughout this period, these efforts were viewed as being principally in support of the management of commercial HLW. There was recognition in the 1972 AEC waste management plan that due to the expense associated with the packaging and shipment offsite of solidified HLW, "a thorough study of promising potential methods for acceptable onsite long-term storage [read disposal] has first priority." The options under consideration at the time for the long-term management of AEC's HLW are presented in Fig. 3.1.

Onsite disposal options being considered at that time included disposal of Hanford HLW in near-surface engineered facilities or emplacement of slurries (or other appropriate waste forms) in deep-mined basalt caverns. Disposal in near-surface engineered facilities was viewed as insitu disposal of the HLW in the underground storage tanks appropriately stabilized for the necessary long-term containment for the waste. At Savannah River, the efforts concentrated on disposal of the HLW as a slurry in deep-mined caverns in the bedrock underlying the site. At both Hanford and Savannah River, the backup disposal option was emplacement of the waste in an acceptable form in an offsite Federal deep geologic repository.²⁴ In 1977, Savannah River, Idaho, and Richland evaluated their

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options in documents entitled "Alternatives for Long-Term Management of Defense High-Level Waste" (ERDA 77-41, 77-42, and 77-43). Each document evaluated the risk and cost of multiple alternatives.

The program for identifying a suitable site (s) for establishing a deep geologic repository for disposal of commercial and possibly defense HLW and/or TRU waste progressed from the early 1960's through many time-consuming programmatic and institutional perturbations until the enactment of the Nuclear Waste Policy Act of 1982 (NWPAA) that established a new office within DOE, the Office of Civilian Radioactive Waste Management (OCRWM), to concentrate on the disposal of commercial HLW and unprocessed irradiated spent fuel (SNF).^{*} Highlights of these developments are listed in Table 3.4. OCRWM would also be responsible for providing a capability for disposal of the defense HLW if the President of the United States determined such a course of action to be appropriate (which President Reagan did in 1985).

The NWPAA provided a mechanism for funding the OCRWM HLW/SNF disposal program by assessing a charge on the generators of the waste (i.e., the utilities having nuclear power reactors). The Act also provided a timetable for achieving a HLW repository by the mid-1990's. To accomplish this objective, DOE was to study five potential sites and recommend three of those sites to the President by January 1, 1985. The five candidate sites included bedded salt deposits in Texas and Utah, a salt dome in Mississippi, basalt on the Hanford reservation, and volcanic tuff at Yucca Mountain in Nevada.

DOE narrowed these candidate sites to three in May 1986, selecting the Hanford, Nevada, and Texas sites for further characterization. The three candidate host States promptly filed lawsuits challenging the decisions and how they were reached. This opposition and the threat to the detailed process prescribed in the 1982 legislation led Congress to amend the NWPAA in 1987 and to designate the Nevada Yucca Mountain site as the only candidate site for characterization and evaluation for hosting the first Federal geologic repository. The OCRWM program is still in the process of accomplishing this objective.

3.4 Regulatory Considerations

In parallel with the aforescribed efforts to provide an operational capability for the long-term management of HLW, there was a growing realization of the need for more extensive and specific standards and criteria for the long-term performance of a HLW disposal system, including the waste form to be emplaced in the system. Organizational and institutional changes in the early 1970's had

^{*}President Carter had discontinued the chemical processing of irradiated fuel assemblies from commercial power reactors in 1977 for non-proliferation reasons. Thereafter irradiated reactor fuel was added to the list of products for disposal in a deep geologic repository.

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implications for efforts to address these regulatory issues associated with the management of radioactive waste.

The year 1970 saw the birth of the National Environmental Policy Act that established the Council of Environmental Quality and the environmental assessment/impact statement (EA/EIS) process. In the same period the Environmental Protection Agency (EPA) was being formed. The mandate for the EPA provided for the development and promulgation of general environmental standards that, among other things, serve as a basis for development and promulgation of regulations governing the management of all classes of radioactive wastes. The Energy Reorganization Act of 1974 terminated the AEC and assigned its atomic energy responsibilities to a new agency, the Energy Research and Development Administration (ERDA), except for those activities relating to the regulatory functions pertaining to the atomic energy programs of the private sector. These regulatory responsibilities were transferred to the new agency, the Nuclear Regulatory Commission (NRC). While ERDA retained the responsibility for regulating its own programs (both defense and non-defense), the regulations promulgated by the NRC would also serve as a guide for and an influence upon ERDA's internal environmental, health, and safety regulations and requirements.

The Energy Reorganization Act (Section 202) identified what activities would require NRC licensing and regulation and also formalized the requirement that any disposal facility for HLW would be owned and operated by the Federal Government, as well as being licensed and regulated by the NRC. One of the early actions by NRC was initiation of the development of regulations for licensing a mined geologic repository for disposal of HLW, an effort that resulted in promulgation of 10 CFR Part 60 in 1981. Among other requirements, Part 60 prescribes specific performance standards for the stability of the waste packages emplaced in the geologic repository.

The statutory requirement that NRC license and regulate the disposal of HLW has on occasion inspired external challenges and requests for NRC rulings about aspects of DOE's HLW management program. Additional and improved HLW storage tanks were planned in the 1970's for Hanford. The Natural Resources Defense Council (NRDC) raised the issue of whether these tanks should be licensed by NRC since NRDC felt they were intended for long-term storage of the waste. The plans at that time contemplated storage in the new tanks would not exceed 20 years; therefore, it was decided that storage would not be long-term and NRC licensing would not be required.

In the late 1980's, DOE revealed plans to pretreat the HLW thereby generating a high-activity stream for vitrification and disposal in a repository and a low-activity stream to be classified as LLW that would, therefore, qualify for onsite shallow land disposal without NRC licensing. NRC was petitioned by an external group to rule on whether disposal of the low-activity stream required NRC licensing. The Commission endorsed the Department's conclusion that NRC licensing would not be necessary. There have also been questions raised over the years as to:

- A) whether the high-activity sources produced from cesium and strontium extracted from the Hanford HLW should be classified and managed as HLW; and

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TABLE 3.4
MAJOR STEPS IN EVOLUTION OF HLW DISPOSAL
PROGRAM/PRE-NUCLEAR WASTE POLICY ACT (1982)**

1957	National Academy of Sciences Panel Recommends Salt Deposits as Possible Repository Sites.
1963-1967	Project Salt Vault at Lyons, Kansas.
1968	Evaluation of Hanford Basalts Begins in Washington State.
1970	Proposed Pilot Facility at Lyons, Kansas.
1972	Withdrawal from Lyons, Kansas. Search Continues in Kansas, Expanded to New Mexico. U.S. Geological Survey (USGS) Begins Reconnaissance of Gulf Coast Salt Domes, USGS Begins Reconnaissance in Paradox Basin in Utah and Colorado.
1974	Waste Isolation Pilot Plant (WIPP) Facility Proposed for Site in New Mexico. Evaluation of Salt Domes Begin.
1976	National Waste Terminal Storage (NWTS) Program Announced. Evaluation of Geologic Formations at Nevada Test Site (NTS) Begins. Evaluation Begins of Permian Basin in Texas, Excluding Delaware Subbasin.
1977	Evaluation Begins of Salina Salt Basin in Michigan, New York, and Ohio. Evaluation of Palo Duro Subbasin (Permian Basin) Begins.
1978	Study Areas Recommended in Gulf Coast and Salina Salt Regions. Office of Nuclear Waste Isolation (ONWI) Formed at Battelle Memorial Institute.
1979	Interagency Review Group.
1980	Final Environmental Impact Statement - Management of Commercially Generated Radioactive Wastes (FEIS) is issued. Preliminary Surveys Completed of Existing Data in National Files on Crystalline Rocks. Department of Energy Files Statement of Position on NRC's Proposed Waste Confidence Rulemaking Proceeding.
1981	Program Policy Modified to Further Define Immediate Goals: Intensive Site Investigations at Three Locations, Leading to Design and Construction of a Test and Evaluation Facility. Broad National Survey of Geologic Environments and Geohydrological Provinces in Cooperation with USGS.

***"Answers to Your Questions About High-Level Nuclear Waste Isolation," Office of Nuclear Waste Isolation, Battelle Memorial Institute, Oct. 1981.

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- B) whether the interim storage of liquid HLW in the underground tanks at Hanford and Savannah River has been sufficiently long-term to require NRC licensing.

High-level waste is considered to be a mixed waste* until demonstrated to the contrary. Liquid HLW is a characteristic mixed waste because it is either highly acidic or highly alkaline (i.e., it exhibits the characteristics of corrosivity). This waste also contains heavy metals such as lead, chromium, and barium and, therefore, exhibits the characteristics of toxicity. Moreover, the HLW may contain a substance specifically listed as a hazardous material under the EPA regulations and would, therefore, be classed as a listed mixed waste. EPA has declared vitrification as best demonstrated available technology (BDAT) for treating characteristic mixed HLW. There are uncertainties concerning the BDAT for treating listed mixed HLW.⁵¹

*Mixed waste contains both radioactive and non-radioactive hazardous components as defined by the Atomic Energy Act and the Resource Conservation and Recovery Act, respectively.

Low-Level Waste

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4.0 Low-Level Waste

DOE has generated and is currently generating LLW at more than 35 sites; however, 80 percent of the LLW is generated at 7 sites: Hanford, INEL, LANL, ORR, SRS, Fernald, and Portsmouth Gaseous Diffusion Plant. DOE generated about 38,000 cubic meters of LLW in 1994, which contained about 0.9×10^6 Ci of radioactivity. The Department had in onsite storage at the end of 1994 about 126,000 cubic meters of LLW containing approximately 4 million curies of radioactivity, and the total inventory of buried LLW was about 3 million cubic meters containing about 13 million curies of radioactivity.*

Since the end of the Cold War and the reduction in DOE's defense programs there has been elimination or significant reductions in many of the waste streams resulting from these programs in the past. However, these developments have provided greater impetus to programs for decontamination and decommissioning of obsolete facilities and sites with significant contributions of LLW. The emergence of increased field operations in the Department of Energy's environmental management programs responsible for the cleanup and restoration of contaminated sites will also result in the generation of large volumes of low-level and other types of waste.

4.1 Definition - Classification Considerations

While the category of HLW has been specifically and clearly defined on the basis of its source of generation over the history of radioactive waste management, there has been considerable confusion and misunderstandings about definitions and classification criteria for categories of waste within the large inventory and from the multiple sources of generation of non-HLW which, with noted exceptions, will be referred to as low-level waste (LLW).

This confusion has resulted in large measure from the fact that, unlike HLW, there is significant diversity in the physical and chemical state and the radiological characteristics of the LLW streams. Therefore, different systems for managing and disposing of the waste streams have been employed. Moreover, there can be and usually have been variations among the sites of generation in the storage, treatment, and disposal (STD) system used for similar non-HLW streams due largely to the different environmental characteristics of the sites and the lack of interaction among the sites during the early years as a result of security considerations.

Until well into the 1970's there was a tendency to develop strategies and programs for managing the non-HLW on the basis of whether it was generated as a liquid or a solid and on the specific activity associated with each waste stream. In addition, the disposal option selected was tempered by the environmental characteristics of the host site. For example, the disposal of liquid waste at Hanford,

*Integrated Data Base Project Report-1994; U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics, DOE/RW-0006, Rev. 11, Sept. 1995.

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with its semi-arid climate and deep ground-water table, would likely be different from disposal of similar waste at Savannah River, a humid site with near-surface ground water.

As a result of these considerations, there existed at the major sites during this early period the following non-HLW categories: intermediate-level (activity) liquid and solid wastes and low-level (activity) liquid and solid wastes. The intermediate and low-level waste categories may or may not have been defined by site-established classification criteria, such as concentration limits for specific radionuclides.

At a production site, such as Hanford, with a reasonably consistent inventory of waste streams of reasonably stable isotope concentration ranges, the non-HLW streams were normally categorized as intermediate or low-level. However, at a predominately R&D site, such as Brookhaven National Lab, there were "hot" laboratory operations that generated wastes with a wide-ranging and an ever-changing mix and concentrations of radionuclides. In such cases, quantitative criteria were generally established for classifying the laboratory waste (i.e., concentration limits for specific radionuclides) as intermediate or low-level.

It follows that while there was similar waste classification nomenclature used throughout the AEC complex, there could be considerable variation from site to site in the characteristics of the waste for the same class or category. These differences existed because each site had responsibility for characterizing and classifying its waste streams and developing the strategies and implementing programs for managing these wastes. In discharging these responsibilities, the various sites had to contend with waste streams with different characteristics and with host environments that had different climatic, geohydrologic, and geographic characteristics. Moreover, the security at this time restricted inter-site communication and collaboration and the development of more uniform waste classification and management practices.

In March 1970, the AEC issued an Immediate Action Directive²⁵ (IAD) that required any solid wastes with known or detectable contamination of transuranic nuclides be segregated, packaged, and buried in such a fashion that they could be readily retrieved as contamination-free packages within an interim period of 20 years. There was no threshold transuranic concentration limit specified in the Directive; however, it was recognized that definitive criteria were required for clarification of intent in this area. A task group on sorting of contaminated from uncontaminated materials was charged with developing a proposed "good definition of alpha waste."²⁶

After a great deal of internal AEC discussion and debate on the subject, the Manual Chapter 0511, "Radioactive Waste Management," established in September 1973 the requirement that radioactive solid waste, other than that generated by solidification of high-level liquid waste, containing "significant" U-233 or transuranic nuclide contamination shall be stored at AEC sites, segregated from other radioactive solid waste. The Manual Chapter went on to clarify "significant" contamination in its definition of "Transuranic Contaminated Solid Waste." It is waste that is contaminated with certain alpha-emitting radionuclides of long half-life (includes U-233 and its

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daughter products, plutonium and transplutonium nuclides, excluding Pu-238 and 241, except under certain conditions) and with specific radiotoxicity to greater than 10 nanocuries per gram of waste. The value of 10 nanocuries per gram was derived from the upper range of concentrations of radium-226 in the earth and was considered to be subject to modification if justified on the basis of studies of long-term nuclide migration in soil.

These developments had the effect of discontinuing in the early 1970's the practice of disposal in shallow land-burial facilities of solid non-HLW contaminated with transuranic radionuclides in excess of 10 nanocuries per gram. (This threshold concentration was later increased to 100 nanocuries per gram; see Section 5.1) At the same time, a new class of AEC-generated radioactive waste was created, transuranic (TRU) waste (see Section 5).

AEC Manual Chapter (AECM) 0511 also established a basis for categorizing non-HLW liquid waste streams and the operational criteria for managing each category. Those liquid radioactive wastes not meeting the definition of HLW were viewed to be either:

- 1) liquids that can be discharged to the environment in compliance with the requirement of AECM 0524 (i.e., persons in uncontrolled areas will not be exposed to concentrations in excess of those prescribed in Table II, annex A, Appendix 0524); or
- 2) liquids that are either:
 - A) high-activity liquid waste that would be managed in accordance with the policies for HLW; or
 - B) liquid wastes that are to be converted to solids and managed in accordance with the operational criteria for radioactive solid waste (other than solidified HLW) set forth in AECM 0511.

After over three decades of experience in managing and disposing of non-HLW and in monitoring the performance of these operations, it became apparent to the Federal waste managers that to achieve with a reasonable degree of assurance compliance with the health and safety performance objectives there must be a more disciplined and structured approach to managing the waste as an integrated system involving generation, characterization, reduction/treatment, packaging, storage, and disposal. It was recognized that disposal and the performance assessment of the disposal system should drive the overall management system as reflected in DOE Order 5820.2A issued in 1988. These conditions will be discussed more fully later in this section. It suffices to note at this time in connection with LLW classification that DOE Order 5820.2A recognized that the application of the performance assessment methodology facilitates the development of site-specific waste classification limits if they are operationally useful in determining how specific wastes should be stabilized and packaged for safe onsite disposal.

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4.2 Policies and Practices for First 25 Years

During these early years, there was little concern evidenced on the part of the AEC Headquarters management about the safety and effectiveness of the LLW management programs. Responsibility for waste management was delegated to the Field Offices whose programs were in large measure following a philosophy practiced for management and disposal of other industrial hazardous wastes. The low-activity, relatively short-lived liquid waste was being diluted and dispersed into the environment at very low concentrations or solidified, packaged, and disposed either in shallow land burial facilities or at great depths in the ocean, while the low-activity wastes generated as solids were disposed in shallow land burial facilities. Those non-HLW streams with higher levels of radioactivity and/or long-lived radionuclides were nominally stored pending the availability of a disposal capability with appropriate long-term isolation from human environment.

Even though there were uncertainties during this period about the impact on biological systems as a result of their uptake and exposure to radionuclides and about the interactions of these nuclides with host disposal environments, it was felt these considerations were adequately compensated by what was then viewed as a conservative approach used in the employment of the traditional hazardous waste management practices. Moreover, the level of comfort with these practices was enhanced by the use of systems for the monitoring of the performance of the disposal systems that were for the most part deployed on large, relatively isolated government-owned and controlled reservations.

In those instances where low-activity liquid wastes were discharged to surface waters, such as the Clinch River at Oak Ridge and the Columbia River at Hanford, extensive sampling and monitoring programs were deployed for surveillance of the elements in the ecosystems associated with these waters. Over the years, the results of these programs helped fashion improvements in the waste management operations and in the regulatory requirements with which the operations must comply.

President Eisenhower's introduction of the Atoms-For-Peace Program in the mid -1950's and the enactment of the Atomic Energy Act of 1954 effectively ended the government monopoly of the atom and made possible its use in numerous medical, agricultural, and industrial applications, including the private development of nuclear power. Low-level waste, according to Commission officials, would be the responsibility of companies engaged in nuclear activities. The AEC announced in 1960 that it would license LLW land disposal facilities and would phase out the use of AEC facilities for disposal of LLW generated by non-AEC programs as commercial capabilities became available. Involvement of the government in the management of this class of waste as generated in the private sector would be limited to promulgating standards and licensing. The first commercial LLW disposal facility was established in 1962 at Beatty, Nevada, followed by five additional disposal facilities over the period of 1963 to 1971. Only two of these facilities continue to operate today-one at Richland, Washington, and one at Barnwell, South Carolina.

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With these developments came increased external scrutiny of the AEC waste management programs, and in 1959 the Congressional Joint Committee on Atomic Energy held public hearings on radioactive waste disposal. Experts from the Commission and its major sites gave testimony on a variety of subjects, including techniques for land disposal of radioactive waste, methods for liquid low-activity waste dispersion into streams and rivers at Oak Ridge, and direct discharge by injection wells of low-activity liquid wastes into the water table at Idaho. Both low- and high-level waste management practices were discussed in depth. Testimony was provided by industry spokesmen, officials of other Federal agencies such as the Public Health Service, and State regulators, as well as scientific and technical experts. The general conclusion of the hearings was that waste disposal practices had not yet resulted in any harmful effects.²⁷ The AEC waste management officials, convinced that management of LLW was essentially under control, decided to focus attention on the problems associated with HLW disposal.

The AEC allowed only solid low-level waste appropriately packaged (usually in steel drums) to be disposed in the ocean. A large percentage of the package consisted of concrete ballast. This option was only used by laboratories with minimal or no onsite land disposal capability and were located at sufficient distances from established AEC LLW land disposal facilities to make ocean disposal more cost-effective. The Commission sponsored research in connection with ocean disposal on such matters as the processes of uptake of various components of the waste by suspended silt and bottom sediment and the concentration of waste components by marine life, including phytoplankton, the first stage of the food chain. These and related R & D projects involved many organizations including the Chesapeake Bay Institute; the Fish and Wildlife Service Laboratory at Beaufort, N.C.; U.S. Coast and Geodetic Survey; the U.S. Public Health Service; and the Committee on Oceanography of the National Academy of Sciences.

In the late 1950's, some non-AEC low-activity waste was disposed in the ocean by commercial firms operating under Commission license and control. However, a change in AEC policy at that time permitting licensed disposal firms to utilize the Commission's land-burial sites had some effect on limiting the commercial ocean disposal practices depending on the convenience and economic trade-offs between the two options.

Ocean disposal of AEC LLW was discontinued in 1970 after more than 100,000 containers had been disposed of by this method, each containing an average of approximately a half curie of activity at the time of disposal. This development resulted in large measure due to concerns expressed by the fishing and seafood processing industries and certain of their congressional representatives. Economics also had a role in the decision.

The intermediate-level liquid waste was discharged into the ground by seepage from structures known as cribs, trenches, or settling basins in those environments, such as Hanford, with "appropriate" climate (semi-arid) and favorable geohydrological characteristics (e.g., soil columns that inhibit migration of the radionuclides to the relatively deep underlying aquifers). The cribs were placed underground to minimize radiation levels and surface contamination. At those sites with less

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favorable environmental conditions, and fortunately, generally smaller volumes of this type of waste, such as Brookhaven National Laboratory (BNL), the intermediate-level liquid wastes would normally go into holding tanks, which may be followed by volume reduction, solidification in concrete (usually in 55-gallon drums), and disposal in the ocean.

It should be noted that the so-called intermediate-level liquid wastes generated at the production sites at Hanford, INEL, and Savannah River that were discharged to ground normally contained relatively low concentrations of radionuclides. Hanford's intermediate liquid waste included streams from decontamination in late steps of the plutonium separations process, spent solutions used to absorb or scrub gases, condensed vapors from self-boiling tanks, and various other condensates from process equipment. Behavior in the soil of each major type of waste was evaluated in the laboratory before disposal operations started. Any process waste stream that was not adequately retained in the soil was stored in tanks as HLW.⁹

Toward the end of this period, there was increasing concern about the ion-exchange/adsorptive capacity of the host soils for the continued disposal of the intermediate-level liquid wastes to ground, particularly when the pH, the presence of solvents, and other characteristics of the waste stream were not carefully monitored and controlled. These concerns were ventilated as early as 1957 during a working meeting on fixation of radioactivity in stable, solid media at Johns Hopkins University.²⁸ D.W. Rhodes of Hanford Atomic Products Operation reported on research concerning the fixation of radioisotopes in "low-level" and "intermediate-level" waste streams on soils at Hanford. He found that a number of factors, including those noted above, influence the equilibrium uptake on soils of most of the isotopes studied.

"Intermediate" waste is no longer used in the United States as a waste classification; however, it is widely used abroad. This class of waste in the United States was applied only to radioactive liquid materials. Once the discharge of these liquid waste streams to ground was discontinued in favor of solidifying the waste for management and disposal as solid waste, the intermediate waste classification was phased out. ORNL was the last site to use the intermediate waste classification and that was employed in connection with relatively high-activity liquid waste generated in various fuel cycle R & D programs. These wastes were stored in underground tanks prior to onsite disposal using deep well injection and hydrofracture techniques. This practice was discontinued in 1983.

As noted earlier in the HLW's discussion, a NAS-NRC committee, which had been retained by the AEC to provide advice and analysis of matters pertaining to disposal of HLW, also examined AEC's non-HLW management practices. The committee in 1960 noted that no existing AEC site generating HLW or intermediate-level waste possessed suitable geological conditions for the safe disposal of these wastes. The committee recommended that the AEC establish disposal facilities for these wastes at separate and suitable geological sites.²⁹ The AEC rejected the recommendation because of high costs and practical difficulties associated with such a course of action, and the fact that there was no evidence of an undue risk to the health and safety of the public, the workers, or the environment.

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In general, the non-HLW categories and associated management strategies for the first 25 years can be summarized as shown in Fig.4.1.

4.3 Policies and Practices: The 1970's

As the waste management programs advanced through the 1970's, there evolved a more structured and disciplined approach, as well as a greater degree of involvement by the AEC Headquarters in directing and overseeing the management of the radioactive waste generated across the complex. The Commission, due in part to the external interest in and attention to the AEC waste management programs and practices, took steps to elevate the organizational stature, the technical credibility, and resource availability for waste management programs and activities. This trend was reflected in a variety of developments, including:

- 1) An AEC General Manager's (GM) Task Force on AEC Operational Radioactive Waste Management undertook in 1968 a study of the adequacy of policies and practices regarding radioactive waste management activities at AEC installations,³² including shallow land disposal of solid radioactive waste at AEC operational sites. As early as 1957, a report by a waste management committee of the National Academy of Science-National Research Council, "Disposal of Radioactive Waste on Land," concluded that "continuing disposal of certain [large volume] low-level waste in the vadose zone, above the water table, is of limited application and probably involves unacceptable long-term risks." The NAS/NRC committee, however, noted that this and other findings in the report were educated opinions, not supported by research. It was assumed that research on this issue would be undertaken before final conclusions were made.

The GM task force concluded that in appropriate locations and using appropriate procedures, ground burial of low-level solid wastes and contaminated materials and equipment appears to be an acceptable method of long-term storage and probably of disposal. However, since such burial grounds will require long-term land use restrictions and perhaps surveillance, they should be restricted to as few sites as practicable. Adequate records of burial locations and other pertinent data should be maintained.

The task force also recommended that radioactive liquid wastes routinely discharged to the environment should be decontaminated to significantly reduce the long-lived nuclide content, and the total amount of radioactivity in such wastes should be minimized to the extent practicable.

The recommendations of the task force on waste management policies and principles, which were approved by the Commission on August 30, 1968, served as a basis for R&D and revisions of waste management practices at the AEC sites throughout the 1970's.

FIGURE 4.1

**AEC NON-HLW CATEGORIES AND MANAGEMENT STRATEGIES
FOR FIRST 25 YEARS***

*Includes waste streams contaminated with transuranics

2) In May 1970, there was established the Division of Waste and Scrap Management (DWSM) that evolved into the Division of Waste Management and Transportation (DWMT) in August 1971. The primary responsibilities assigned to DWMT included:³⁰

- Develop and direct an AEC program for "long-term storage" (read disposal) of radioactive waste;
- Provide programmatic and fiscal control and direction of AEC waste burial grounds;
- Establish AEC waste management plans;
- Establish AEC waste management policy;

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- Develop and coordinate AEC's decontamination and decommissioning program for obsolete facilities; and
- Prepare and maintain AEC Manual Chapter on Waste Management, AECM 0511.

It should be noted, however, that the lines of authority, as reduced to practice, were somewhat fuzzy. The Division responsible for producing the special nuclear materials for the defense program continued to provide Headquarters programmatic and fiscal responsibility for operations relating to management of wastes generated in its production programs, particularly the high-level waste. The promulgation of complex-wide environmental, health, and safety standards and criteria applicable to waste management operations was the responsibility of a Headquarters staff organization, the Division of Operational Safety.

- 3) The Director of the new Division of Waste and Scrap Management sent a memorandum in February 1971 to the Managers of the AEC Field Offices noting that his Division was established in response to a need for a coordinated approach to solving radioactive waste and scrap management problems. He further stated that in this connection, DWSM is developing an AEC-wide waste management program that will assure consistent practices with regard to planning, operations, and cost accounting. The memorandum also transmitted several "essential policy statements applicable to waste management" that had evolved from recent studies. For the most part, these statements were explicit and, if implemented, were expected to lead to more consistent and uniform waste management practices across the AEC complex.³¹
- 4) One of the priority considerations in the early 1970's was the reduction in volume of LLW being generated and to develop appropriate waste segregation practices, particularly with respect to waste contaminated with plutonium or other long-lived isotopes. Three working groups were convened for the purpose of reviewing and recommending near-term technology for use in the areas of waste: a) compaction, b) incineration, and c) sorting (or segregation). All three working groups issued reports^{33,34,35} that were widely employed in modifying LLW management operations at AEC sites.
- 5) Consistent with one of the recommendations of the General Manager's task force, in early 1972 the first long-term plan for the management of AEC-generated radioactive waste was promulgated.³⁶ It was updated in 1973.
- 6) The AEC issued in 1973 the Manual Chapter 0511, "Radioactive Waste Management." Responsibilities assigned to DWMT included:
 - (A) the requirement to develop, recommend, and promulgate policies, guides, and requirements for treatment and interim and terminal storage of liquid, solid, and gaseous wastes at the AEC facilities, including the definition of categories of waste and to assist the Division of Operational Safety in the development of safety policies,

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guides, standards, and requirements for the release of radioactive effluents to the environment; and

- (B) the requirement that it determine and approve criteria and specifications for wastes that are to be "stored" (read disposed) in near-surface land burial grounds.
- 7) As noted in Section 4.1, an Immediate Action Directive in 1970 followed by Manual Chapter 0511 in 1973 had the effect of segregating LLW streams contaminated with transuranics from other LLW for management and disposal pursuant to more stringent long-term containment criteria.

These developments resulted in initiatives to develop and deploy technologies designed to reduce the volumes of LLW, to devise separate strategies for managing waste contaminated with long-lived transuranics, and to provide more effective control and assurance for the long-term containment of the land-disposal LLW. There was a transition from random dumping in shallow land trenches to a systematic/recorded emplacement of stabilized waste packages in engineered, near-surface land disposal systems, with more extensive area monitoring systems to track the performance of the disposal facilities in isolating the waste from the human environment.

In October 1979, DOE instructed its sites sending LLW to commercial disposal facilities to discontinue the practice due to concern about the depletion of commercial disposal capacity. This directive reversed an AEC decision in May 1963 allowing the use of commercial LLW disposal facilities for those sites that did not have onsite disposal capability.

4.4 Policies and Practices: The 1980's

The trend of the 1970's for increased attention and improvement in the management of non-HLW continued in the 1980's. This trend was reflected in the increased research and development in treatment and disposal technologies, development of short-and long-term waste management plans at the Headquarters and field-level, increased resource availability, the development of performance criteria and standards for the waste management systems, the emergence of more meaningful waste acceptance criteria for disposal systems, improved records and tracking of disposal waste packages, and the deployment of a more effective capability for monitoring the performance of the disposal systems for containing the waste.

More specifically, developments in this decade that had significant influence on the management of LLW included:

- 1) President Carter, in a message sent to Congress on February 12, 1980, outlined a comprehensive national radioactive waste management program.³⁷

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- (A) The message was based on a report published the previous year by the Interagency Review Group on Nuclear Waste Management³⁸ that had undertaken a comprehensive review of the entire waste management program at the request of the President.
 - (B) The program included the following actions to be taken in connection with the management of defense LLW:
 - DOE will review by 1981 alternative LLW disposal techniques and determine whether any changes should be adopted in the future;
 - DOE will accelerate R&D on improved methods for disposing of LLW;
 - DOE will continue the existing land burial technology program presently designed to upgrade all DOE LLW disposal operations by 1988; and
 - DOE will take action to ensure that adequate attention is given to the hydrologic characteristics of proposed locations for the future siting of LLW disposal facilities.
- 2) The development and promulgation by NRC in 1982 of regulations covering land disposal of licensee-generated LLW (10CFR61), which resulted in considerable internal DOE scrutiny and discussion of, and ultimately changes to, the Department's requirements concerning disposal of LLW.
- 3) The Low-Level Radioactive Waste Policy Act of 1980 (Public Law 96-573) and the amendments thereto in 1985 (Public Law 99-240, enacted Jan. 15, 1986) delineated the responsibilities of the States and the Federal Government in managing the defense and commercial LLW generated in the United States and thereby focused widespread attention upon the DOE and private sector programs for the management and disposal of LLW:
- (A) The State administrations and their regulatory authorities that hosted DOE LLW disposal facilities became much better informed and interested in radioactive waste management operations and expanded their technical capabilities in this area and their interactions with the waste management programs;
 - (B) The 1985 amendments made the Federal Government responsible for disposing of the licensee-generated LLW that exceeds the concentration limits for Class C LLW, i.e., those LLW's that are most radioactive and/or have concentrations of the long-lived transuranic nuclides greater than 100 nanocuries per gram of waste (now classified as greater-than-Class C LLW, which is discussed in section 4.6)

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- (C) The Act mandated DOE to provide technical and financial assistance to the States in discharging their responsibilities to establish a capability for disposing of LLW generated by licensees of NRC and the Agreement States.
- 4) During this decade, DOE waste streams became subject to the requirements of the Resource Conservation and Recovery Act of 1976 (RCRA) that establishes safe and environmentally acceptable management practices for solid wastes. The implementing Federal regulations that identified those wastes subject to regulation as hazardous material and the national standards defining how those wastes could be acceptably managed were set forth by EPA in 1980 in 40 CFR 261 and 264, respectively. The fact that DOE waste became subject to RCRA requirements through a court decision in 1984 ultimately led to those waste streams contaminated with both radioactive and chemical hazardous constituents (known as "mixed waste") being subject to both EPA's 40 Part 264 requirements and DOE's regulations for radioactive waste, based on the Atomic Energy Act. (See section 7.)
- 5) A new DOE Order 5820.2A establishing requirements for managing all classes of radioactive waste was promulgated in 1988; it was more extensive in scope and performance criteria than previous Orders on this subject.

Developments of the late 1970's and early 1980's were such that LLW disposal practices in the private sector started down a somewhat different pathway from those employed for defense LLW. The events leading to the divergence started with the "revolution" by the Governors of three States hosting the three LLW disposal facilities licensed to receive and dispose of commercial waste-South Carolina, Nevada, and Washington. They threatened to close the disposal facilities, at least to out-of-State waste, unless arrangements evolved for other States to share in the responsibility for the safe management and disposal of the Nation's radioactive wastes.

Largely as a result of this "crisis" created by the three Governors:

- 1) President Carter in his 1980 national radioactive waste management program created a State Planning Council to advise the Executive Branch and to work with Congress on key radioactive waste management and disposal issues (South Carolina's Governor Riley served as chairman); and
- 2) The Low-Level Radioactive Waste Policy Act of 1980 was enacted, thereby providing a framework for the States to establish regional LLW disposal facilities.

These developments triggered extensive discussions and debates about what would constitute acceptable siting and disposal technology to use for the establishment of each of the proposed regional facilities. Despite the views of NRC officials and other waste management experts touting the adequacy of the LLW disposal technology then being employed by the licensed disposal facilities and by the defense programs, the States generally opted for a new generation of disposal

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technologies involving greater reliance on manmade barriers for long-term containment of the disposed waste than was currently used in the United States. It was felt by advocates for this approach that the added costs of the enhanced engineered containment of the system were justified to minimize reliance on the somewhat uncertain long-term performance of the natural barriers of the site to migration of the waste. More stable waste forms, high-integrity containers, and above-grade or below-grade concrete vaults became common-place design requirements for the proposed new regional disposal facilities.

Another requisite to the establishment of new commercial disposal facilities that received considerable attention during this decade was the modeling and analytical methodology used in assessing long-term performance of LLW disposal facilities. Such a performance assessment (PA) is required as part of a license application for a new commercial disposal system. It is a significant element in determining whether a proposed disposal facility is licensable and what conditions are to be imposed by the license. The PA also serves as guidance to the facility operator in developing waste acceptance criteria that, in turn, assists the waste generator in determining the waste characterization and certification information required.

These developments in the private sector had some rub-off effect on the management/disposal of the defense waste. For example, PA's, based on modeling of the disposal system and the mathematical analysis of the fate of the source-term inventory as it interacts with its host environment (manmade and naturally occurring) over the long term, had not been performed for the defense LLW facilities prior to their becoming operational.

DOE Order 5820.2A "Radioactive Waste Management," which was issued in 1988, required that field organizations with waste disposal facilities prepare and maintain a site-specific radiological performance assessment for these facilities for the purpose of providing reasonable assurance that the facilities comply with established long-term performance objectives. However, the assessment was required to take into account only waste disposed after the date of issuance of this Order. (NOTE: The subject of taking into account the waste that was disposed prior to 1988 will be revisited in Section 4.5.) This Order also required that monitoring measurements be made within and outside each disposal facility and its host site as a means of evaluating actual and prospective performance of the disposal system.

Waste disposal operations began to adopt more extensive and prescriptive waste acceptance criteria with respect to waste forms, packaging, and data characterizing the waste packages. The latter contributed to the development and maintenance of more complete records concerning the types and amounts of radioactivity disposed, as well as better records for the tracking of waste packages. This information facilitated the development of long-term performance assessments of the disposal system.

Unfortunately, these more stringent disposal requirements were not consistently evolving in lock-step with capabilities to provide the necessary waste characterization data or stabilized waste forms.

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There were gaps in the laboratory analytical capabilities and in the availability of accessible waste treatment facilities. As a result, large volumes of waste were diverted into storage at some DOE sites, where significant amounts remain today, awaiting characterization and appropriate treatment and packaging for disposal. In some cases, waste classification is uncertain. The provision for and maintenance of safe storage for the large volumes of waste that, for one reason or another, has not been transitioned to disposal consumes a significant portion of the Department's annual waste management budget.

This decade saw the States become much more involved in and knowledgeable about the management of hazardous wastes due to their efforts to establish new regional licensed LLW disposal facilities and their participation with the U.S. EPA in implementing the requirements for managing hazardous materials under the RCRA and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) statutes. The latter resulted in an increased presence on DOE sites and involvement in the Department's waste management programs of external regulatory authorities since many of the radioactive waste streams were also contaminated with the non-radioactive hazardous constituents covered by the RCRA regulations. It was only natural that the conditioning acquired in experience with the "commercial" LLW disposal activities would influence the host State positions on DOE LLW disposal activities. An example of the implications of these developments on the DOE programs was the opposition by the State of Tennessee to Oak Ridge's intent early in the 1980's to establish new LLW disposal capacity by constructing a new shallow land burial facility. The State urged DOE to consider the new generation of engineered LLW disposal concepts being proposed for the regional disposal facilities to serve the private sector. Oak Ridge reinitiated the process of evaluating disposal technologies and after some considerable slippage in schedule selected an earth-mounded above-grade concrete bunker concept employing concrete canisters for emplacement of the LLW packages.

The last couple of years in this decade found DOE under considerable criticism from environmental groups and elements of Congress concerning nuclear facility safety and environmental problems in the nuclear weapons complex. The Department's environmental cleanup obligations under CERCLA (or "Superfund") and RCRA had been clarified. The amendments to CERCLA in the Superfund Amendment and Reauthorization Act (SARA) in late 1986 provided exact procedures to be followed on a specific time table. In May 1987, the Department accepted the application of RCRA regulations for its mixed waste, thereby committing DOE to adhere to the cleanup provisions of the Act.

The Department took a number of actions in response to these developments including a detailed study of environmental conditions at DOE facilities, the results of which were promised to Congress in 1988.³⁹ In presenting the results of the study to Congress in mid-1988, DOE said the resolution of the environmental issues would require a significant investment over a long period of time. It was estimated that cleanup and compliance costs could range from \$66 billion through fiscal year 2025 to as high as \$110 billion through fiscal year 2045. A Government Accounting Office report at the

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same time supported the high funding estimate and recommended the Department request between \$5 and \$8 billion for fiscal year 1990 to begin the job.⁴⁰

A new Administration under President Bush and Energy Secretary Admiral Watkins reflected the view that widespread safety and environmental problems in DOE's nuclear weapons complex required immediate attention; numerous sites needed to be cleaned up because of past processing and waste practices. The new Secretary advised Congress at his confirmation hearing in February 1989 that there is an urgent need to effect a significant change in the deeply imbedded DOE/Defense Programs "culture" of 35 years that has "evolved from such heavy emphasis on achieving production goals, made within an atmosphere of collegial secrecy, that problems relating to safety, health and the environment have not only been backlogged to intolerable levels but, in effect, hidden from public view until recently." He went on to note that the management of radioactive waste presented nearly the same challenges as those encountered in the overall weapons complex. The Secretary noted that the 1990 budget proposal included much-needed provisions to both implement the safety, health, and environmental standards at waste facilities and to upgrade the facilities themselves. However, to assure that waste will be handled, processed, and finally stored in compliance with those safety standards to which Federal, State, and responsible local authorities are full partners will require a "strong, common culture." (Culture was described as the set of values permeating the work atmosphere within which operations take place.)

The Secretary appointed Leo Duffy in March 1989 as his special assistant for coordination of DOE defense waste management. A principal responsibility of the new assistant was to develop a five-year plan by the end of July, consistent with a promise to Congress. The plan would take a consolidated look at DOE waste and cleanup activities and provide the basis for fiscal year 1991 budget requests. This first five-year plan was released to the public by the Secretary in August 1989 and was represented as the cornerstone of DOE's long-term strategy in achieving the "minimization, cleanup, and management" of DOE's waste materials in compliance with the goal of ensuring that risks to human health and safety and to the environment were either eliminated or reduced to prescribed safe levels. Given the possible budget constraints, DOE recognized the need for prioritizing the plan's activities. The prioritizing methodology would be based on "risk concepts" and would be designed to "promote the greatest reduction in overall health and safety risk" as well as the "greatest degree of regulatory compliance." Duffy felt that centralized planning, Department-wide priorities, and consolidated budgeting were necessary to meet the five-year plan's goals.⁴¹

The plan's approach to solving the Department's environmental restoration and waste management problems was predicated largely on two basic principles: technology development and waste minimization. The plan was updated annually, with the latest version issued in January 1993.

Other developments in 1989 that resulted in significant implications for waste management policies, operations, and resources included:

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- Ten Governors, who are members of the Western Governor's Association and are from States that host or border States that host DOE sites, wrote Secretary Watkins criticizing the Department for deferring too long the cleanup and disposal of defense wastes and provided specific recommendations for Federal actions to provide defense waste cleanup.⁴²
- DOE entered into a tripartite agreement with EPA and the State of Washington that addressed Hanford's waste management and contamination problems, providing among other things the cleanup commitments undertaken, the applicable regulations, and the assigned responsibilities with enforceable milestones to achieve cleanup and regulatory compliance. This agreement, which EPA undertook pursuant to authority under Section 120 of SARA, provided a blueprint that influenced subsequent negotiations in other host States.⁴³
- In June 1989, the Secretary announced a 10-point plan to strengthen the environment, safety, and health activities at the Department's production, research, and testing facilities. The plan included:
 - Contractor award fees would be modified so that at least 51 percent would be based on compliance with environmental, safety, and health requirements.
 - Formation of environmental "tiger teams" that would review "operations, documentation, agreements, planning, and facility's performance in meeting environmentally-regulated schedules." The teams would perform followup compliance assessments at DOE's 35 major facilities by mid-1991.
- In October 1989, the Secretary approved the establishment of the Office of Environmental Restoration and Waste Management (EM) with Leo Duffy as office director. At the same time, he announced his intention to submit legislation elevating the office to an assistant secretary level. EM would integrate under a single line organization the responsibilities and accountability for environmental cleanup, waste management, and compliance formerly assigned to the Offices of Defense Programs, Nuclear Energy, and Energy Research. It was argued that for these programs to have success in the long term, they would require first priority of a single Headquarters organization, not a second-level priority of an organization responsible for achieving production goals or for performing energy-related research.⁴⁴

4.5 Policies and Practices: 1990-1996

In spite of the major changes during the 1980's in the scope of the programs responsible for environmental cleanup and waste management, in the regulatory requirements with which these programs must comply, and in the institutional framework within which the programs must function, DOE moved into the 1990's feeling that the requirements for the waste management programs were fairly well defined and straight forward. While there existed some complex problems in the waste management programs, including some that required new or improved technologies, there was little

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controversy over what problems needed to be solved, especially following the Tiger Team visits. Waste management was an ongoing operation, providing tangible results, even though the results were not as extensive or as rapid in some areas as had been projected. There were uncertainties remaining about the priorities to be assigned to the problems for resolution even though there was general agreement that the priorities should be based on ES&H risks associated with the problems.

As DOE moved into the 1990's, it was expected that once the environmental restoration projects become operational the radioactive waste that has to be removed from these cleanup sites, rather than stabilized in place, would be transferred to the waste management element of EM for storage, treatment, and/or disposal, as appropriate. The bulk of the waste generated from these operations was expected to be LLW, TRU waste, or mixed low-level waste (MLLW). One of the principal uncertainties then (and now) is the volume of waste that must be removed from the restoration sites and the resulting impact on the DOE LLW disposal capacity and operations.

The LLW management operations were ongoing, normally proceeding through steps of characterization, processing, packaging, storage (as necessary), and disposal. As noted earlier, these operations were subject since 1988 to the requirements of DOE Order 5820.2A, which reflected significant elaboration and improvement over prior regulations. In theory, these more stringent requirements on each component of the system operations were designed to maintain the overall performance of the system within the envelope of established performance standards. For example, the waste characterization and certification facilitated determinations about compliance of waste with established criteria and specifications for acceptance at the storage, treatment, or disposal facility; the processing or treatment reduced the waste volumes and provided a more stable waste form for disposal; and disposal was to involve emplacement of waste packages having minimum void space to minimize subsidence when disposed in shallow land burial facilities and with liquids representing no more than 0.5-1.0 percent of the waste volume.

In this same time period, those sites with LLW disposal facilities were in the process of conducting long-term performance assessments for their operating LLW disposal systems. The results of these efforts have led to the incorporation of more stringent waste acceptance criteria at some of the disposal facilities to ensure compliance with the systems long-term performance standards. In some cases, these changes in acceptance criteria and specifications have eliminated the opportunity for onsite disposal of portions of the LLW. The site, then, must seek offsite disposal options for this "orphaned" waste or develop onsite disposal capability with enhanced containment characteristics. In either case, rather long-term storage is likely for the orphaned waste.

Both options, disposal offsite or improved onsite disposal, have been employed to some degree. As noted earlier, Oak Ridge discontinued a mature project to establish a new onsite shallow land burial facility for disposal of LLW as a result of the State of Tennessee strongly suggesting DOE/OR consider the new technologies employing enhanced engineered containment that were emerging as preferred options for new regional disposal facilities for commercial waste. Oak Ridge ultimately selected and developed the tumulus facility, a variation on the earth-mounded concrete bunker

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technology. INEL, SRS, and Oak Ridge elected to continue using 10 nanocuries of transuranic contamination per gram of waste as the maximum allowable concentration for disposal in their shallow land burial facilities even though the regulations had been amended to increase this limit to 100 nanocuries per gram. Oak Ridge and INEL decided to pursue offsite disposal opportunities for their 10-100 nanocuries per gram waste, while SRS opted to provide an onsite disposal capability with enhanced containment.

There have been four new developments in the early 1990's that will undoubtedly have significant implications for the management of the Department's low-level radioactive waste:

- 1) The Defense Nuclear Facilities Safety Board (DNFSB) issued in 1994 Recommendation 94-2, "Conformance with Safety Standards at DOE Low-Level Nuclear Waste and Disposal Sites." (NOTE: The DNFSB is a five-member independent Board established by Congress in 1988 to review safety and environmental conditions at DOE's defense nuclear facilities and to make recommendations to the Secretary of Energy.)
- 2) Legislation was introduced in Congress proposing DOE's nuclear activities be subjected to external regulation;
- 3) Congress tightened the purse strings on funding for EM programs early in the Clinton Administration; and
- 4) Contrary to earlier expectations, EM's restoration program decided to conduct its own LLW management and disposal operations pursuant to requirements. (CERCLA)

The DNFSB's Recommendation 94-2 stated that the long-term performance assessment for a LLW disposal facility should not limit the analysis to waste disposed after September 26, 1988, as required in Order 5820.2A, but "... insure that PA's are based upon the total inventories (past, present, and future) emplaced or planned for the burial site(s)." In addition, the Board and DOE subsequently agreed that the PA's would include all source terms that add to the dose caused by the LLW disposal facility. This development will send all sites with LLW disposal facilities back to the "drawing board" to revise their PA's. This task could be somewhat confused by the development 4 cited above. It will be necessary for the 94-2 LLW management tasks and requirements, including the all source-term analysis, to be applied also to the planned EM-40 CERCLA-regulated, LLW disposal activities.⁴⁵

Continued congressional pressure to bring all of DOE's nuclear operations under external regulation resulted in proposed legislation and hearings in the Spring of 1994. In the course of these hearings, DOE endorsed the concept of outside regulation but recommended a more thorough examination of the issue by affected Federal agencies and their stakeholders before Congress took further action. For the purpose of performing this examination, DOE established the Advisory Committee on External Regulation of Department of Energy Nuclear Safety and gave it a charter to recommend

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whether and how DOE nuclear facilities and operations should be externally regulated to best protect human health and safety and the environment (excludes the naval reactor program). The Committee published its final report with the requested recommendations in December 1995.⁴⁶ The fundamental recommendations were:

- Essentially all aspects of safety at DOE's nuclear facilities and sites should be externally regulated;
- Existing agencies rather than a new one should be responsible for external regulation; and
- Under any regulatory scheme, DOE should maintain a strong internal safety management system.

This matter is still under consideration by the Department.

During the first two or three years of EM's existence, it suffered from a lack of qualified personnel, both at Headquarters and in the field, an inadequate organizational infrastructure, and was provided annual levels of funding greater than the program could effectively digest.⁴⁷ However, the funding situation was reversed shortly thereafter as Congress and the Administration became more concerned about bringing government spending and the rate of increase in the national deficit under tighter control. A GAO report of April 1992 criticized the EM program for not doing enough to control costs, and for insufficient management oversight that had led to poor contractor performance and cost growth.⁴⁸

Senator Bennett Johnston, Chairman of the Senate Energy Committee, was becoming increasingly critical of the costs associated with the EM programs in light of the modest returns for this investment that he felt was further penalized by increasingly stringent EPA regulations. These considerations set the stage for the change in Administration in 1993 and Thomas Grumbly's confirmation hearing as Assistant Secretary for Environmental Management before the Senate Energy and Natural Resources Committee. He listed five priorities that required immediate attention, three of which directly addressed major concerns reflected in recent GAO reports and criticisms by Senator Johnston:

- 1) Address the "truly urgent risks" in the system;
- 2) Improve EM's management and financial practices; and
- 3) EM must identify the risks at DOE facilities and show progress "in the near-term" (i.e., become more "outcome-oriented" and to do so in a manner that is obvious to the public). Grumbly subsequently added an additional priority action: establishing a cost baseline to estimate a cumulative long-term cost for EM's programs.⁴⁹

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These commitments were again summarized by Grumbly when testifying before the Senate Energy and Natural Resources Committee on July 29, 1993. The Senate confirmed that understanding by establishing a statutory requirement that DOE would provide the Congress with an EM program baseline accompanied with appropriate milestone commitments to be annually updated with schedule/cost variance reports. An outgrowth of these developments has been the ongoing efforts within EM to assess the ES&H risks associated with each of its program elements, which can then be used to prioritize or rank them in their competition for funding.

Before the program/budget baseline process achieved full implementation, a new Assistant Secretary for Environmental Management, Alvin Alm, took office in early 1996 and promptly introduced a 10-Year Plan concept for the EM program. This plan is to be developed for the entire EM program in conjunction with similar plans for each of the sites or Operations Offices.

These plans, which are currently scheduled for completion by the end of fiscal year 1997, are intended to guide the achievement of a 10-year vision for the EM program (i.e., the complete cleanup of most DOE sites within a decade, with treatment for a few remaining waste streams continuing at a small number of sites beyond the decade). Achievement of the vision is to be guided by the following principles:

- Eliminate the most urgent risks;
- Reduce mortgage and support costs to free up funds for further risk reduction;
- Protect worker health and safety;
- Reduce the generation of waste;
- Create a collaborate relationship between DOE and its regulators and stakeholders;
- Focus technology development on cost and risk reduction; and
- Integrate waste treatment and disposal across sites.

Each site plan is to be developed on the basis of the following assumptions:

- Assume level budgets over the 10-year period 1997-2006;
- Reflect completion of cleanup by 2006 or earlier if practicable;
- Assume optimum regulatory flexibility;
- Define the status of the site in 2006;
- Make maximum use of information already developed for the Baseline Environmental Management Plan (BEMR), strategic plans, etc.;
- Reduce immediate risks first;
- Optimize integration across programs and sites;
- Make continuous improvements in efficiency;
- Make continuous reallocation of resources from support to mission-direct activities;
- Recognize strong stakeholder values;
- Use innovative technology to reduce costs and improve effectiveness;
- Maximize the use of privatization where cost-effective; and

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- Optimize sequencing of work within and among sites.

It is not anticipated that the backlog of stored TRUW and HLW will be disposed of within the 10 years.

Secretary Watkins announced on January 12, 1991, that DOE would prepare a Program Environmental Impact Statement (PEIS) for the overall EM program. This scope was subsequently reduced to include only the waste management program. The initiative was a bit surprising since waste management operations had been in progress for almost 50 years. The major sites had developed EIS's for their respective waste management program after the National Environmental Policy Act (NEPA) had introduced the EIS process in 1970 and each of the major sites had waste management program plans. Moreover, each new capital project serving the waste management program since 1970 had an EIS prepared as part of the project authorizing process. In any case, after approximately 6 years and \$59 million, a draft PEIS was released for public review and comment in August 1995.⁵⁰

The waste management PEIS is a nationwide study examining the environmental impacts of managing five types of radioactive and hazardous wastes. The five waste types are: high-level waste (HLW); low-level waste; mixed low-level waste; transuranic waste; and non-wastewater hazardous waste.

The PEIS describes the positive and negative environmental effects of several alternative actions, including taking no action, for accomplishing a particular waste management function. The Statement, therefore, informs both decisionmakers and the public of reasonable alternatives to be evaluated in terms of adverse impacts and environmental quality and of the results of these evaluations. The product of this effort is intended to assist DOE in determining the sites at which it should either continue to operate certain waste management facilities or locate new waste management facilities.

A PEIS examines a program in its entirety as opposed to discrete program functions, projects, or activities. As in the past, subsequent project-level EIS's will be prepared once the sites for new waste management facilities have been determined. The exercise has resulted in the compilation of an extensive amount of data that has been useful to numerous EM programs. About \$34 million of the project cost represented payments to DOE labs to compile these data.

4.6 Greater-Than-Class C (GTCC) Low-Level Waste

When the NRC promulgated 10CFR61, "Licensing Requirements for Land Disposal of Radioactive Waste," in 1982, it established a new subcategory of licensee-generated LLW, the GTCC LLW. These were the wastes that contained concentrations of either short-lived and/or long-lived radionuclides that exceed those listed in Tables 1 or 2 in Section 61.55.

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It was further noted in Section 61.55 that the GTCC LLW is not generally acceptable for near-surface land disposal; however, the Commission agreed to consider on a case-by-case basis proposals for near-surface land disposal of such waste, taking into account the specific characteristics of the waste, disposal site, and method of disposal. Approval of such proposals would be based on a finding of reasonable assurance of compliance with the performance objectives in Subpart C of Part 61.

A number of waste packages containing GTCC LLW were approved for disposal in licensed LLW disposal facilities over the next several years following issuance of 10CFR61. This practice was generally discontinued after the Congress amended the Low-Level Waste Policy Act in 1985, which assigned responsibility to the Federal Government (read DOE) for accepting and disposing of licensee-generated GTCC LLW in an NRC-licensed disposal facility. In 1989, the NRC, under pressure to identify an option for disposal of GTCC LLW, amended Section 61.55 of Part 61 to note that this category of LLW is not generally acceptable for near-surface land disposal and must be disposed of in a geologic repository (as defined in Part 60) unless a proposal for an alternative mode of disposal in a facility licensed under Part 61 is approved by NRC.

DOE has not received from licensees any GTCC LLW under the authority mandated by Congress in the 1985 Amendments Act. There have been no terms and conditions established by DOE covering such transactions. To do so would require issuance of a schedule of charges based on recovery of reasonable costs for DOE waste management services, as required under the Amendments Act. This information, which would be based on costs associated with a specific disposal regime (and storage/treatment operations, if appropriate), is not currently available.

Until DOE is able to receive waste under the GTCC LLW program, licensees will have no disposal options available to them since case-by-case consideration of disposal of GTCC LLW at licensed LLW disposal facilities is no longer feasible. In the early 1990's, DOE stated that it would accept, under authority of the Atomic Energy Act, GTCC LLW from licensees pursuant to requests from NRC, based on a Commission determination that continued possession of the materials by the licensees represented an unacceptable public health and safety risk. Such transactions have generally occurred at no cost to the licensee.

The types of wastes included in the GTCC LLW inventory are sealed sources, irradiated structural materials, residuals from manufacturing processes involving radioactive materials, and materials from various nuclear fuel cycle D&D projects. The projected volume of these wastes to be transferred to the DOE GTCC LLW program is approximately 2000m³. There are, however, uncertainties associated with these projections, including questions about the quantities of GTCC LLW to be generated by D&D projects and which non-fuel reactor components the OCRWM program will accept from the utilities under their standard contracts to provide HLW/SNF disposal services. The relatively small volume of waste projected for the GTCC LLW program and the diversity of radiological characteristics associated with the various types of GTCC LLW are largely responsible for delays in establishing terms and conditions for DOE acceptance of the GTCC LLW.

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These circumstances have frustrated the selection of a preferred disposal option(s) for the GTCC LLW. These considerations have been cited as principal justification for co-disposal with HLW/SNF in the geologic repository as a prime candidate for disposal of the GTCC LLW, recognizing that a disposal facility dedicated to GTCC LLW would not likely be economically feasible. Co-disposal of GTCC LLW with DOE - generated waste with similar radiological characteristics (i.e., elements of the special case waste) has not been seriously considered to date since the law requires that the GTCC LLW be disposed of in NRC-licensed facilities.

The DOE draft PEIS for managing the storage, treatment, and disposal (STD) of radioactive and hazardous waste (DOE/EIS-0200-D, Vol. I, Aug. 1995) did not provide alternatives for the STD of the GTCC LLW, but simply noted that the Department is currently developing strategies for managing this class of waste.

Transuranic Waste

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5.0 Transuranic Waste

5.1 Introduction

Radioactive waste containing transuranic radionuclides has been generated since the early 1940's. The sources of generation have been primarily in connection with plutonium production and recovery operations, the manufacture of nuclear weapons, and research and development activities. As a result of these activities, there were at the end of 1993 approximately 106,000 cubic meters of transuranic-contaminated waste (TRUW) in retrievable storage at DOE sites and an estimated 204,000 cubic meters that had been buried or nonretrievably stored in shallow land disposal facilities prior to 1970.⁵¹ The aforementioned draft PEIS states that the buried TRUW will be managed in accordance with the provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

With the end of the Cold War and the phase-down of the DOE nuclear defense program in the early 1990's, the future generation of TRU waste is expected to come from the cleanup of contaminated sites; the decontamination and decommissioning (D&D) of defense program facilities and devices; the research, development, and testing programs at several national laboratories; and the possible future reclassification of some special nuclear materials as waste. There may also be TRU waste transferred from the private sector to DOE for management and disposal as a result of D&D projects at licensed nuclear fuel cycle facilities. (This would be classified as GTCC LLW by NRC and the licensees.)

Prior to 1970, the disposal of non-high level liquid and solid waste containing transuranic radionuclides was accomplished in much the same way as for other low-activity waste streams. The bulk of the liquid wastes had very low concentrations of transuranics resulting from contamination of large volumes of liquids used in various processing unit operations. These wastes were commonly discharged to ground in such structures as seepage basins, cribs, and injection wells. In the case of surface or near-surface discharges, the radioactive contaminants would become fixed on the clay in the underlying soil columns.

The solid waste contaminated with transuranics were packaged and emplaced, along with the other solid non-HLW, in shallow land disposal facilities. If such capabilities did not exist onsite, the waste packages would be transferred to another site for shallow land disposal. An exception to this practice was the management of solid LLW, including that contaminated with transuranics, at the Brookhaven and Lawrence Livermore National Laboratories where it was more cost-effective to use ocean disposal, a practice that was discontinued in 1970.

A number of developments in the 1960's generated concern about the practices used in the disposal of waste containing the toxic, long-lived transuranic radionuclides. Significant quantities of plutonium were accumulating in the soil columns underlying the cribs and trenches used to dispose

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of large volumes of dilute liquid wastes. There was even concern that a criticality incident may occur at one crib at Hanford. When increased levels of contamination were experienced in the liquid wastes at Hanford, they were diverted to the underground HLW storage tanks.

With respect to the solid wastes containing transuranic nuclides, the event normally given credit for discontinuing their disposal with other LLW in shallow land burial facilities was the fire at the Rocky Flats site in May 1969. The public attention and exposure generated in the aftermath of the fire, including the revelation through monitoring of the site that there had been onsite and offsite plutonium contamination from a previous fire in 1957, inspired pressure from external sources for additional information.⁵²

It became public knowledge that solid waste from Rocky Flats containing transuranic nuclides had been buried in INEL shallow land disposal facilities and that AEC planned to send an additional estimated 330,000 cubic feet of plutonium-contaminated waste from the Rocky Flats fire to Idaho for disposal. The State of Idaho, the local press, and Senator Frank Church brought considerable pressure on AEC concerning the issue. Four separate Federal agencies were requested by the Senator to assess the long-range implications of the waste disposal on the large aquifer underlying the INEL, an aquifer that ultimately empties into the Snake River in the Thousand Springs area. The findings of these assessments were generally critical of the AEC waste management activities in Idaho. These results plus pressure from Senator Church led to an AEC decision to discontinue the shallow land disposal of solid transuranic contaminated waste in favor of retrievable storage of such waste, pending the availability of a disposal facility with greater long-term containment capability.

This policy decision was reflected in an Immediate Action Direction (IAD No. 0511-21) on March 20, 1970. The decision was followed by a letter from the AEC chairman to Senator Church in June 1970 noting that the AEC would place the transuranic-contaminated waste in retrievable storage at the Idaho site and subsequently retrieve the material, process it as necessary, and ship the waste to a salt mine near Lyons, Kansas, for disposal with the HLW from the civilian program. The Chairman stated that the transfer of the waste should start by the end of the decade and recognized that a number of years would be required to complete the transfer.⁵³

While discontinuance of land burial of solid waste contaminated with transuranics became effective after April 30, 1970, there was a delay until 1973 when a concentration limit was established for this new class of defense waste. DOE Order 0511, "Radioactive Waste Management," required that solid waste containing greater than 10 nanocuries of alpha activity, per gram of waste, attributable to transuranic radionuclides with half-lives greater than 20 years would be placed in retrievable storage pending the availability of an appropriate disposal capability. As noted earlier, this concentration limit was based on the upper range of concentrations of radium-226 in the earth. DOE, after consultation with other Federal agencies, increased in 1984 the threshold concentration limit for TRU waste from 10 to 100 nanocuries per gram of waste.

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When the TRU waste classification criterion was established, there were actions taken at Hanford to divert to the HLW storage tanks the plutonium-contaminated liquid wastes coming from the Plutonium Finishing Plant that had been discharged to ground in the past.

5.2 Waste Management Policies and Practices

A major portion of the solid TRU waste was generated at the Rocky Flats defense site and shipped to INEL for retrievable storage. The waste was packaged in steel 55-gallon drums or fiberglass, wooden, and metal boxes. These packages, which could contain no more than 200 mg. of plutonium, were stacked in the Interim TRU Waste Storage Area (ITSA) on asphalt pads and covered with a synthetic cover and 3 feet of earth. Berms were constructed around the ITSA pads. Somewhat different retrievable storage facilities were used at other sites. Hanford used several storage configurations, including storage on asphalt pads with covers of plywood, plastic, and dirt. In addition to INEL, six other DOE sites have significant quantities of TRUW buried or in retrievable storage: Hanford, ORNL, LANL, RFP, NTS, and SRS.

When initiated, the retrievable storage requirement was predicated on a need for no more than 20 years. The salt mine in Kansas was expected to be available relatively soon for disposal of TRU waste packages. The AEC, therefore, felt that there should be no problem in honoring the commitment to the State of Idaho to initiate the transfer of the stored TRU waste from the INEL site by the end of the 1970's. The Lyons, Kansas, project, however, encountered both technical problems and strong political and public opposition. As a result, the AEC stopped work on the project in September 1971 and began looking for alternate geologic repository sites.⁵⁴

During the early 1970's, those elements of the Federal program concerned with the management of the defense TRU waste focused on establishing a disposal capability providing sufficiently long-term containment and on the technologies that would reduce the volumes and provide more stable waste forms for disposal. The latter involved several research, development, and demonstration projects on treating combustible TRU waste by incineration and chemical processing. Various methods were studied for stabilizing the residuals from the volume-reduction processes into candidate waste forms.

Studies relating to the disposal phase of managing the TRU waste not only involved the multi-faceted program to find an acceptable site for the deep geologic repository, but there were also efforts in progress to develop conceptual designs for such a repository based on bedded salt as the host geologic medium. These initial designs assumed the emplacement of canisters of vitrified HLW on one horizon and of pallets of 55-gallon drums of TRU waste on another horizon.

5.3 Waste Isolation Pilot Plant (WIPP)

The search for a suitable site for a deep geologic repository for disposal of defense TRU waste narrowed to a preferred site in New Mexico. ERDA officials decided in early 1976 to construct a waste isolation pilot plant (WIPP) in a bedded salt deposit at the Los Mochos site near Carlsbad,

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New Mexico. The plan was to initiate construction of the facility in 1979 and for WIPP to become operational in 1985.⁵⁵

The 15 years that followed this decision and the accompanying plan to have WIPP operational by the mid-1980's was a period of confusion, indecisiveness, and frustration for the WIPP project. These problems stemmed partially from technical issues, but to a larger extent from political and public understanding and acceptance considerations. The frequent turnover in senior program management and administrations at both the Federal and State levels, as well as the changing regulations applicable to the TRU waste management system, contributed significantly to changes in the program requirements and schedule for this long-term project.

Shortly after the decision to construct WIPP, ERDA officials decided it would be prudent to enhance the credibility of the undertaking through independent analysis of the proposed TRU waste disposal system and to engage public participation in the project. Some senior officials felt the best way to accomplish this would be to subject WIPP to the NRC licensing process, even though there was no legal requirement to do so. At the same time, they suggested expanding the scope of the project to allow acceptance of defense HLW, an elaboration that would legally require NRC licensing. The proposed expanded scope would also permit the emplacement of some commercial spent-fuel assemblies in WIPP for the purpose of generating data about the interaction of the assemblies with the repository environment.⁵⁶ President Carter had discontinued in April 1977 chemical reprocessing of irradiated power reactor fuel for reasons based on non-proliferation considerations; therefore, it was felt that spent nuclear fuel may be disposed in a geologic repository.

Others in ERDA preferred an approach that simply involved the participation of NRC personnel in all phases of the WIPP project without invoking the formal licensing process. It was felt that this close association with the project would benefit NRC in the development and fine tuning of the technical and procedural requirements for licensing the first commercial geologic repository. The Commission did not reflect any particular enthusiasm for this type of association with the WIPP project. In any case, ERDA was replaced by the DOE before a decision was made, and still another task force was assembled to assess then-current waste management programs. The emphasis for this task force's study was on commercial wastes since, according to one Department official, DOE did not have institutional problems with its own defense wastes.⁵⁷

The task force completed its report in February 1978. It supported disposal of commercial high-level waste/spent fuel in a geologic repository. However, it concluded that realization of such a facility required further research and development in bedded salt and a test program involving emplacement of spent nuclear fuel in an instrumented geologic facility. The task force noted that the planned WIPP facility would satisfy these requirements and recommended that it be used for this purpose even though it would require licensing by NRC and removal of the limitation on accepting only defense waste. It was also observed that legislation would be required to permit withdrawal of the land on which WIPP was to be constructed.

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In response to the task force conclusion that a national nuclear waste management policy was needed, President Carter established in March 1978 an Interagency Review Group (IRG) to make recommendations on the long-term management of nuclear wastes. The group had representation from 14 Federal agencies, with provision for participation by the public.⁵⁸

The President, after receiving the IRG report in March 1979, unveiled his comprehensive waste management program in February 1980, which included his decision to cancel the WIPP project and that the defense TRU waste planned for disposal at this facility should be placed instead in the first commercial geologic repository. He felt that all geologic repositories, whether for disposal of defense or civilian radioactive waste, should be licensed by NRC and should accept waste from both programs. He advocated a program of geologic investigations in a variety of geologic media and projected a decision on a site for the first repository in the mid-1980's with an operational facility a decade later.^{59,60}

The IRG report triggered an intense debate among the Department, the White House, and elements of Congress concerning issuance of the report and the announcement of the President's program. DOE disagreed with the recommendations concerning WIPP and the search for alternate sites. The Senate and House Armed Services committees, as well as the State of New Mexico, opposed any plans involving acceptance of commercial waste at WIPP and indicated the project would not be funded if it had to be licensed.

As a result of these developments, no funding was requested in fiscal year 1981 for construction of WIPP; however, provision was made for operating funds under the commercial nuclear waste management program to ensure retention of the New Mexico site and the continuation of site characterization work. The intent was to compare this site with other qualified candidate sites before making a final selection of the site to host the licensed disposal facility for defense and commercial wastes.⁶¹ The Congress did not concur in the Administration's plans and stated that WIPP should go forward as planned, taking the position that cancellation of WIPP would adversely impact defense program activities and that WIPP should accept only defense wastes. With a new Administration in 1981, President Reagan reversed his predecessor's decision on WIPP, and DOE promptly announced a decision that WIPP construction should be initiated as soon as possible as a facility for disposal of defense TRU waste.⁶²

After 7 years of construction and \$700 million in expenditures, WIPP was ready by the end of 1988 to begin receiving waste packages. DOE planned to conduct a 5 year test program, involving up to 150,000 drums of TRU waste, before certifying the facility as a qualified disposal system. (Its design capacity was about 800,000 drums of TRU waste.) Even at this advanced stage of the project, it was still plagued by environmental and political uncertainties, e.g:

- The characteristic for salt formations to creep with time posed a concern that retrieval of waste packages, should that be necessary, may be quite difficult;

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- After more than 10 years of effort, the waste acceptance criteria and specifications had not been completed; concerns remained about such technical issues as the potential for hydrogen generation within the waste packages and the fact that any gas generation could lead to possible new radionuclide and hazardous constituent transport pathways.
- The risk of human intrusion during the postclosure period due to the potential for future exploration for oil, gas, and potash deposits;
- Whether the Department can bring the disposal facility within compliance to EPA's regulations for disposal of hazardous materials, a requirement that evolved well into the construction phase of the facility; and
- Permanent land withdrawal legislation was needed before DOE could initiate disposal operations.

These issues continued to delay the initiation of even the test program for WIPP. In late 1989, DOE announced a restructured program that called for acceptance of experimental amounts of TRU waste in WIPP by mid-1990, with full startup scheduled for 1994 or 1995. The repeated delays in putting WIPP into operation triggered reactions from some western governors. In 1989, Governor Andrus of Idaho suspended TRU waste shipments from Rocky Flats to INEL; shortly thereafter, essentially all intersite shipments were suspended. Colorado negotiated with DOE an agreement that specified an upper limit (1601 cubic yards) on the amount of hazardous waste stored at Rocky Flats, as specified in a State permit. In late 1991, the Secretary of Energy received an administrative land withdrawal from the Department of Interior and announced that shipments of TRU waste to conduct in-situ tests at WIPP would begin. This action led to litigation designed to prevent the opening of WIPP until it met all applicable environmental regulations (NEPA and RCRA).⁶³

The WIPP Land Withdrawal Act (Public Law 102-759) was passed by Congress on October 30, 1992, thereby transferring control of the land on which WIPP is located from the Department of Interior to DOE. The Act required EPA to establish disposal standards for the TRU waste. It also imposed a series of regulatory requirements with which DOE must comply before initiating the test phase with waste at WIPP and before disposal of TRUW could begin.⁶⁴ The Act was subsequently amended by Congress in late 1996.

In late 1993, given the new regulatory requirements in P.L. 102-579, DOE decided that safe disposal of TRU waste in WIPP could be adequately demonstrated without resorting to the emplacement of waste in the WIPP facility, and the previously proposed Test Phase Plan was modified accordingly. This decision was based, in part, upon an independent evaluation and recommendations by the National Academy of Sciences and other stakeholders. According to the Department's draft PEIS for its waste management program, before making a decision of whether or not to proceed to the WIPP disposal phase, which is projected to begin with contact-handled waste in late 1997 per the

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amended Land Withdrawl Act, DOE will prepare a WIPP supplemental EIS. The current draft PEIS, therefore, addresses only the treatment and storage of TRUW.

One of the more troublesome uncertainties about obtaining approvals for WIPP operations has been achieving compliance with EPA's requirements for disposal of those TRU wastes containing RCRA-regulated constituents. It has been estimated that 50-60 percent of the TRU waste inventory is mixed waste (i.e., it contains both radioactive and hazardous constituents regulated in accordance with the RCRA requirements). DOE proposed that WIPP's compliance with these regulations be achieved pursuant to a No-Migration Variance, as provided in the RCRA regulations. However, the amended Land Withdrawl Act eliminated the requirement to obtain the variance.

TRU waste accepted by WIPP must comply with WIPP's waste acceptance criteria and specifications (WAC). Since the No-Migration Variance petition requirement has been eliminated for WIPP, DOE plans to treat the TRU waste only to the extent necessary to meet the WAC.

The development of the WAC for WIPP was initiated in the late 1970's by Sandia National Laboratory (SNL). The early work was undertaken in a "sterile" environment by project personnel focusing only on an ideal waste package for the proposed geologic repository. There was virtually no SNL interaction at that time with the sites managing the stored TRU waste; therefore, there was minimum appreciation of the challenge the evolving WAC would represent in terms of retrieval, treatment, and repackaging of the waste to be acceptable for receipt at WIPP. It was observed by one of the INEL waste managers after receiving the initial draft of the criteria and specifications that not a single drum of the stored TRU waste at INEL would qualify for acceptance at WIPP. This came as a shock to DOE, since it had been anticipated that the bulk of the stored waste could be emplaced in WIPP without further treatment and packaging. After some 2 to 3 years, DOE Headquarters established a standing committee to address the development of the WAC. The group had representation from the WIPP project office in New Mexico and those sites with significant inventories of stored TRU waste.

The waste acceptance criteria for WIPP will ultimately be established on the basis of a performance assessment of the repository and in consultation with EPA and the State of New Mexico. The WAC have not yet received final approval; therefore some uncertainty exists about the extent of waste treatment necessary as a prerequisite to disposal in WIPP.

In parallel with work on WIPP, considerable effort has been expended by DOE on the development and testing of an appropriate transportation capability for linking the generation, storage, treatment, and disposal phases of the TRUW management system. The size and complexity of the transportation facilities and operations are commensurate with the volume of waste to be shipped or received.

A certified transport container, TRUPACT-II, a type B reusable container is available for use in rail and truck shipments of contact-handled TRUW. (The initial version of this container was flawed and

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failed the certification tests). It has a capacity of fourteen 55-gallon drums or two standard waste boxes. Three TRUPACT-II's fit on custom semi-trailers pulled by conventional tractors. Transportation of remote-handled TRUW is based on the use of the proposed shielded NuPAC 72B cask that is designed for shipping a single canister approximately 2 feet in diameter and 10 feet long. It must be certified as meeting the requirements for Type B packaging.

It is expected that transport of all shipments to WIPP will be made by a dedicated carrier under contract to WIPP. The transport trucks are to be equipped with mobile telephones, a satellite tracking system, emergency response, accident recovery procedures, and rigging hardware.

WIPP has facilities that are capable of receiving the TRUPACT-II and 72B cask, checking for surface contamination, unloading the TRUPACT-II's and the 72B casks, preparing the containers for reuse, and transferring the waste to the waste-handling building for emplacement in WIPP.⁶⁵

The DOE sites with significant inventories of stored TRUW have available or under construction facilities for sorting, characterizing, and repackaging retrieved waste to meet transportation and disposal requirements.

the 'information' and 'communication' fields. The 'information' field is defined as:

...the study of the processes of information production, distribution, access, use and evaluation, and the study of the social, cultural, economic and political contexts in which these processes take place. (p. 10)

The 'communication' field is defined as:

...the study of the processes of communication production, distribution, access, use and evaluation, and the study of the social, cultural, economic and political contexts in which these processes take place. (p. 10)

The 'information science' field is defined as:

...the study of the processes of information production, distribution, access, use and evaluation, and the study of the social, cultural, economic and political contexts in which these processes take place. (p. 10)

The 'information studies' field is defined as:

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Special Case Waste

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6.0 Special-Case Waste

There is a significant volume of radioactive waste currently stored throughout the DOE complex for which a management strategy beyond indefinite storage does not exist. These materials are normally referred to as Special-Case Waste (SCW). They have been generated over the history of the atomic energy program from a variety of programs and reflect a wide spectrum of radiological characteristics.

It was only in the late 1980's that these materials were generally considered as a separate category of waste. Unlike the traditional classes of waste, such as HLW and LLW, the SCW consists of several sub-categories with, in most cases, quite different characteristics, having only one common characteristic to justify their membership in the same waste grouping—none of them have a long-term strategy for their management.

A survey was conducted in 1989-1990 that produced an estimate of approximately 1.075 million cubic meters of SCW in storage across the DOE complex.⁶⁶ This inventory was reported in the breakdown shown in the following table:

Estimated SCW Inventory Data Summary (1990)⁶⁶

<u>Waste Category*</u>	<u>Volume (x 10³ m³)</u>	<u>Curies (x 10³)</u>
Non-Certifiable Defense TRUW	35.5	580.
Non-Defense TRUW	0.846	117.
SPAR**	34.2	122,000.
Fuel and Fuel Debris	8.30	21,600.
Uncharacterized	871.	201,000.
Excess Nuclear Materials	125.	796.
	<hr/> 1074.846	<hr/> 346,093.

* Two additional categories were included in the survey but were reflected in the data summary only as number of items. The additional categories were: "Sealed Sources" and "DOE-Title, held by others."

** Specific performance assessment required (SPAR) waste.

The categories of SCW cited above are described more fully in Table 6-1. The waste manager at one DOE site has added the SCW category, "site-specific disposal problem LLW" (SSDP LLW), which includes waste that technically complies with established LLW classification criteria but cannot satisfy the specific disposal performance requirements and waste acceptance criteria of its host site. Such occurrences have been more frequent since the DOE sites have completed performance assessments (PA) for their LLW disposal facilities in recent years and have accordingly revised

TABLE 6.1
SPECIAL-CASE WASTE SUBCATEGORIES

SCW Subcategory	Description	Example Waste Streams
Non-Certifiable Defense TRUW	TRU wastes (>100nCi/g) generated by Defense programs that are not certifiable for disposal at the WIPP or for transport in the TRUPACT-II shipping container.	Includes wastes resulting from D&D of hot cells, solidified and non-solidified sludge, large metallic structures containing or contaminated with TRU elements, and large pieces of alpha and fission-product contaminated equipment that require remote handling.
Non-Defense TRUW	TRU wastes (>100 nCi/g) generated by non-Defense programs and , therefore, are not eligible for disposal in WIPP.	Includes wastes generated from selected D&D activities and wastes transferred to DOE from licensed generators.
SPAR LLW	These wastes in the DOE system contain radionuclides in concentrations that exceed the limits established for Class C LLW in Tables 1 and 2 10CFR61.55 (excludes those wastes that contain transuranics >100 nCi/g.)	Includes reactor core components, equipment contaminated with alpha and mixed fission products, ion exchange resins, sludge, filter media, and sealed sources.
SSDP LLW	All radioactive wastes that have radionuclide concentrations below the 10CFR61 .55 Table 1 and 2 limits, but cannot meet its host site's disposal performance requirements and waste acceptance criteria (WAC).	Includes low-level hot-cell wastes from destructive examination of fuels; sludge containing mixed fission products; ion exchange resins containing transuranics; gauges and dials containing Ra-226; and uranium solids with associated decay products.
Fuel & Fuel Debris	DOE-titled fuel and fuel debris used for research and development purposes or results from nuclear incidents.	These wastes contain items such as material from the core of the TMI-2 reactor, fuel from various DOE test reactors, and fuel and debris from various DOE research and development projects.
Uncharacterized	This category includes any containers of waste with unknown or marginally characterized contents. Expected in most cases to contain nuclear materials at or near the limits of SPAR or TRU wastes. Further characterization of these wastes will determine their classification.	These wastes have been generated by research, production, or decontamination activities.

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their waste acceptance criteria (WAC). These "orphaned" materials should in the long term either be accepted for disposal at another site or new disposal capacity with enhanced containment should be provided onsite.

The "excess nuclear materials" category has, since the 1989 survey, been broken out and subjected to separate studies to improve their management and ultimate disposition. These materials are currently referred to as "materials in inventory." Deletion of this material from the SCW category leaves an estimated volume of 950 thousand cubic meters plus several thousand sealed sources and DOE - owned radioactive materials held by licensees under loan or lease arrangements. It is expected that a significant portion of the SCW will be reassigned to the LLW, MLLW, or TRUW management systems once the large inventory of uncharacterized waste has been appropriately characterized and classified.

An awareness of these "orphaned" wastes stored around the DOE complex has heightened in recent years. As facilities have been targeted for D&D projects, it is not unusual to find they are serving as a storage facility for SCW. The December 1995 report by the Secretary's Advisory Committee on External Regulation of Department of Energy Nuclear Safety included a section on SCW's,⁶⁷ noting that the current inventory of these wastes is approximately 955,200m³.

The draft PEIS for managing the Department's radioactive waste issued in August 1995 does not consider management alternatives for this category of waste. It simply notes that the Department is currently developing strategies for both GTCC LLW and SCW that include disposal.

Mixed Low-Level Waste

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7.0 Mixed Low-Level Waste

Mixed waste contains both radioactive and nonradioactive hazardous components as defined by the Atomic Energy Act and Resource Conservation and Recovery Act (RCRA), respectively. RCRA was enacted in 1976, but it was only after extensive debate and a series of developments over several years involving DOE, EPA, the courts, and Congress that the nonradioactive hazardous components of DOE's mixed waste were subjected, pursuant to a DOE rulemaking in 1987, to EPA and State regulations. These developments included:

- In 1983 DOE was charged in Federal district court of being in violation of RCRA after the Department revealed it had released to the environment from the Y-12 Plant in Oak Ridge 2 million pounds of mercury between 1950 and 1977. DOE maintained that application of RCRA to Y-12 was inconsistent with several provisions of the Atomic Energy Act. The Act precluded State regulation of DOE activities; it placed authority with DOE for setting standards for waste disposal; and it restricted dissemination of classified information pertaining to nuclear weapons and materials. In parallel with the court deliberations, DOE and EPA negotiated a compromise agreement concerning the application of RCRA requirements to DOE's hazardous waste. In a memorandum of understanding (MOU), the two agencies agreed that DOE's facilities would not be subject to RCRA but would be required to comply with certain RCRA - based standards, with only EPA having the right to inspect the DOE plants.
- The Federal attorneys requested dismissal of the litigation concerning the Y-12 Plant case, stressing that DOE could not ignore the national security implications posed by State regulatory control. In spite of these arguments and the existence of the DOE-EPA MOU, the court on July 13, 1984, found DOE in violation of RCRA and ordered the Department to seek a RCRA permit for the storage, treatment, and disposal of hazardous waste at the Y-12 facility.⁶⁸ While the court ruling was applicable only to the Y-12 Plant, all parties recognized it would undoubtedly establish a precedent for all DOE facilities. Full compliance could be very expensive.
- DOE decided not to appeal the court ruling. Since the ruling was made in a case involving a nonradioactive waste stream, DOE attempted to constrain this precedent to apply only to its nonradioactive hazardous waste and exclude all mixed waste. This position was reflected in a Savannah River environmental impact statement issued in May 1984.
- In August 1984, DOE and EPA agreed on a program to implement RCRA for hazardous wastes at DOE weapons facilities, recognizing that RCRA would not apply when there was a risk of compromising national security.⁶⁹
- In the meantime, Congress was upset about EPA's general lack of enforcement of RCRA and decided to enact major revisions to RCRA in the Hazardous and Solid Waste Amendments

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(HSWA) of 1984. The revisions closed loopholes and eliminated EPA's decisionmaking discretion. If EPA failed to meet specific deadlines in issuing regulations, stringent requirements provided in HSWA would automatically go into effect. This legislation provided the land disposal restrictions (LDR). Under HSWA, land disposal of untreated hazardous wastes would no longer be acceptable. HSWA directed EPA to develop and issue regulations specifying methods of treatment for each restricted waste. Such treatment must either diminish waste toxicity or the likelihood that the waste would migrate from the land disposal facility.

- DOE continued efforts to evade the application of RCRA/HSWA to its mixed waste. In late 1985, DOE adopted regulations that modified the definition of byproduct material in the Atomic Energy Act from application to "radioactive material" to a "waste substance containing radioactivity." Since the AEA exempts byproduct material from consideration by RCRA, it would follow that the modified definition would effectively exempt mixed waste from RCRA requirements. There was extensive opposition to the "byproduct rule" including NRC, many Governors, the Congress, and EPA. The latter initiated consideration of criminal action against DOE under RCRA. Under these pressures, DOE began a policy review of the byproduct ruling in early 1986.
- In late 1986, DOE undertook discussions with EPA with respect to the withdrawal of the byproduct ruling if EPA would grant a blanket exemption from existing RCRA regulations for all HLW and TRUW, noting that the exemption should supersede State laws. EPA did not agree with the proposed compromise, leading to the DOE capitulation reflected in a rule change published on May 1, 1987, that subjected all DOE mixed waste to EPA and State regulation under RCRA.

This development posed significant implications for the management of DOE's LLW. First, it was necessary to define the problem. Individual waste streams across the entire complex had to be examined to determine whether they contained RCRA - controlled hazardous constituents. The results of this effort, as reported in 1994, reflected a listing of MLLW at 1788 locations, with a total inventory of 173,890 m³ and a projected 5 - year generation of 150,149m³. Approximately 95 percent of the total volume of MLLW, both current and projected, is located at 8 major DOE sites and includes 103 waste streams.⁷⁰

The Federal Facility Compliance Act (FFCA, Public Law 102-386) was enacted in October 1992. This legislation waived sovereign immunity from environmental regulations for Federal facilities and, therefore, subjected DOE to fines and penalties for violations of RCRA and State hazardous waste regulations. The FFCA introduced a strong incentive for DOE to comply with EPA regulations concerning: a) constraints for storage of untreated mixed wastes; and b) treatment of mixed wastes as prerequisite to land disposal.

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Since DOE was technically unable to comply with the storage prohibition for untreated mixed waste, the FFCA delayed the waiver of sovereign immunity for untreated wastes for three years. The waiver was intended to give EPA time to issue new mixed waste standards and DOE time to develop a plan for complying with these standards. More specifically, the Act required DOE to develop site-specific treatment plans (STP) for compliance with the regulations at each of the Department's sites where mixed wastes were to be generated or stored for a period of five years. The plans were to be approved by EPA or the host States by October 1995.

Once agreement had been reached on the STP's and their associated schedules for implementation, DOE would be subject to fines for noncompliance. Agreement was reached by October 1995 on the STP's with all host States except Idaho and New Mexico, both of which have since been approved.

Work is currently proceeding on the implementation of the site-specific plans and the national MLLW management configuration. This configuration is expected to include both Federal and commercial capabilities.

Lessons Learned

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8.0 Lessons Learned

One of the benefits of reviewing the history of the waste management program is the opportunity it affords for avoiding past mistakes and building on past successes. Examples include the following:

- 1) Waste that must be stored for an unknown period of time should be thoroughly characterized with the results appropriately documented before storage. If the mode of disposal and acceptance criteria are known, any necessary pre-disposal treatment before storage would be highly desirable.
- 2) Progress in minimizing the volumes of waste generated and in reducing the volumes that have to be disposed has been realized principally when financial incentives are involved.
- 3) Operations involved in managing waste from generation to disposal should be managed as an integrated system. Efforts to optimize the system will be well served by viewing the disposal phase as the primary "driver" that often has significant risk and cost implications for the requirements of all other elements of the system. Use of life-cycle costs should also be utilized as a tool for system optimization.
- 4) Limited resources normally preclude prompt attention to all problems posing a potential threat to human health and safety and/or the environment. It is therefore desirable to prioritize and rank the problems in terms of their respective ES&H risks.
- 5) In view of the long time involved in managing the waste from generation to disposal with the attendant changes in regulations and policy decisionmakers at the Federal and host State levels, it is difficult to maintain long-term stability and continuity in the overall strategic plan and implementing policies and is, therefore, prudent to employ robust (and perhaps more costly) components for all phases of the STD system. Experience has indicated this approach is more cost-effective in the long run. The problem could be significantly minimized if the senior managers stayed with the program for a sufficient length of time to develop and implement their program plans and to provide continuity in defending the requests for the necessary resources to conduct the program.
- 6) In addition to the radiological characteristics of waste to be disposed, it is important to have information about the nonradioactive constituents of the waste to provide appropriate treatment and packaging to inhibit migration of the radionuclide in the postclosure phase of disposal operations.
- 7) Developing the technical wherewithal for the safe and effective management of radioactive waste is usually not sufficient for the deployment of the STD facilities. It is also necessary to obtain political and general public acceptance for such courses of action. Preferred

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strategies and implementing actions should be proposed, explained, and defended by waste program management at all levels, with the support of senior departmental management.

- 8) There is a critical interdependence among the following considerations for safe and effective disposal of radioactive waste: the design of a waste disposal system; the long-term performance assessment of the system; the waste acceptance criteria for the disposal system; and the characteristics of the waste to be disposed (i.e., the source-term inventory). External factors can influence these considerations (e.g., changes in environmental regulations and constraints imposed by the host States on the transfer of DOE wastes between sites that could impact the characteristics of wastes to be disposed onsite). When uncertainties exist about these external factors, conservative assumptions should apply for defining the waste acceptance criteria and the facility design requirements.
- 9) The early development of a strategy and implementation plan for a waste management and disposal system that has a high level of stability over the life cycle of the system is generally cost-effective and entails lower risk to workers and the environment.

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ACRONYMS/ABBREVIATIONS

AEC	U.S. Atomic Energy Commission
AECM	U.S. Atomic Energy Commission Manual Chapter
ANL	Argonne National Laboratory
ANPRM	Advanced Notice of Proposed Rule Making
BNL	Brookhaven National Laboratory
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act.
CFR	Code of Federal Regulations
D&D	Decontamination and Decommission
DNFSB	Defense Nuclear Facilities Safety Board
DOE	U.S. Department of Energy
EIS	Environmental Impact Statement
EM	Environmental Management
EPA	U.S. Environmental Protection Agency
ERDA	U.S. Energy Research and Development Administration
ES&H	Environmental Safety and Health
FFCA	Federal Facility Compliance Act
GAO	U.S. Government Accounting Office
GTCC	Greater-Than Class C
HANF	Hanford Site
HLW	High-Level Waste
HSWA	Hazardous and Solid Waste Amendments
INEL	Idaho National Engineering Laboratory
IRG	Inter-Agency Review Group
ITSA	Interim TRUW Storage Area
LANL	Los Alamos National Laboratory
LLW	Low-Level Waste
MOU	Memorandum of Understanding
NEPA	National Environmental Policy Act
NRC	U.S. Nuclear Regulatory Commission; also, National Research Council
NTS	Nevada Test Site
NWPA	Nuclear Waste Policy Act
OCRWM	Office of Civilian Radioactive Waste Management
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
OR	DOE's Oak Ridge Operations
PA	Performance Assessment
RCRA	Resource Conservation and Recovery Act
RFP	Rocky Flats Plant
SARA	Superfund Amendment and Reauthorization Act
SCW	Special-Case Waste
SNF	Spent Nuclear Fuel

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SRS	Savannah River Site
STD	Storage, Treatment, Disposal
TRUW	Transuranic Waste
WAC	Waste Acceptance Criteria
WIPP	Waste Isolation Pilot Plant
WVDP	West Valley Demonstration Project