HANFORD LONG-TERM HIGH-LEVEL
WASTE MANAGEMENT PROGRAM PLAN

PHASE I

TECHNOLOGY DEVELOPMENT

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HANFORD LONG-TERM HIGH-LEVEL WASTE MANAGEMENT PROGRAM PLAN

PHASE I

TECHNOLOGY DEVELOPMENT

I. INTRODUCTION

Radioactive waste has been generated at Hanford since 1944, when the first facilities were operated to produce plutonium for the Manhattan Project. To provide safe containment for this waste, there has been an evolving waste management program. The bulk of the radionuclides have accumulated in the waste from chemically processing spent nuclear fuel to recover the useful plutonium and uranium. Those wastes, referred to as high-level wastes, have been stored as liquids in 156 underground tanks, ranging in size from 50,000 to 1,000,000 gallons located on the 200 Areas plateau. Because these tanks are deteriorating and some have leaked, high-level liquid radioactive wastes are currently being processed to convert them to less mobile forms which can be safely stored for at least decades. This current waste solidification program will:

- Remove, solidify, and store in double-wall metal capsules most of the ^{137}Cs and ^{90}Sr (the major heat generators),
- Concentrate the liquid wastes via evaporation to produce salt crystals which are then stored as a salt cake in existing tanks,

- Continue to store the insoluble chemical fraction (sludge), which precipitated from the original liquid waste, in the existing tanks, and
- Store the nonevaporable residual liquid in double-shell tanks (a tank within a tank).

At this time (May 1976), the high-level wastes consist of approximately:

- 22,000,000 gallons of liquids,
- 29,000,000 gallons of solids, and
- 240 capsules of ^{90}Sr and ^{137}Cs .

Upon completion of the current solidification program in the early 1980's, the high-level wastes will consist of approximately:

- 2,000,000 gallons of liquids generated by ongoing activities,
- 6,000,000 to 12,000,000 gallons of terminal liquors,
- 38,000,000 to 42,000,000 gallons of solids, and
- 3,500 capsules of ^{90}Sr and ^{137}Cs .

In addition to the waste solidification activities of the current program, an intensive waste surveillance program is required to detect any waste leakage from the many tanks and pipelines.

When the bulk of the liquids has been converted to less mobile solids and the residual liquids are placed in double-shell tanks (which are under construction or will

be built in the next few years), the waste will be satisfactorily stored for an interim period, as described in a recent environmental statement for the current waste solidification program.⁽¹⁾

The radionuclides in the wastes will remain hazardous for hundreds to thousands of years. Consequently, long-term storage or control of these wastes must be provided. The long-term safe management of these high-level wastes is the subject of this document.

In the following sections, this document describes the high-level radioactive wastes addressed by this plan, discusses the development and organization of the plan, and describes the first phase of the plan called "Technology Development." Separate plans will be prepared for the long-term management of radioactive wastes which exist in other forms such as contaminated soils and sediments, failed equipment, and obsolete processing buildings. These separate plans will include the management or decommissioning of the empty waste tanks, the contaminated sediments beneath some of the tanks resulting from leaks, and any new facilities which will be required if the wastes are retrieved, processed, and put elsewhere.

II. DESCRIPTION OF RADIOACTIVE WASTES

The high-level radioactive wastes which will exist upon completion of the current waste solidification program in the early 1980's, and are considered in this plan, are described below and summarized in Table I.

TABLE I
SUMMARY OF HANFORD HIGH-LEVEL RADIOACTIVE WASTE
(Post 1980)

	Volume (Cubic Feet)	Radionuclides	
		Fission Products (Megacuries)	Plutonium (Kilograms)
Sludge	1,000,000	50	350
Salt cake	4,000,000	25	75
Terminal liquor	1,600,000	20	1
¹³⁷ Cs & ⁹⁰ Sr capsules	100	265	-
Totals (Rounded)	6,600,000	360	425

- Sludges: The sludges consist of approximately 1,000,000 cubic feet of insoluble oxides and hydroxides in layers from a few inches deep up to 15 feet deep at the bottoms of most underground tanks. They will contain about 50 megacuries of radioactive fission products and 350 kilograms of plutonium.
- Salt Cake: The salt cake consists of approximately 4,000,000 to 4,500,000 cubic feet of mainly sodium nitrate crystals in layers up to 25 feet thick in approximately 45 underground tanks. In addition to the salt cake crystals, the voids around the crystals will contain some interstitial liquor, held by capillary attraction, which cannot be removed from the salt cake by a salt well pump. The salt cake will contain an estimated 25 megacuries of radioactive fission products and 75 kilograms of plutonium.
- Terminal Liquor: Terminal liquor consists of approximately 800,000 to 1,600,000 cubic feet of caustic residual liquid which cannot be converted to an acceptable solid product by simple evaporation processes. The terminal liquor, which will be stored in double-shell underground tanks, will contain approximately 20 megacuries of radioactive fission products and one kilogram of plutonium.

- ^{137}Cs and ^{90}Sr Capsules: These wastes consist of approximately 3,500 double-wall capsules (100 cubic feet of waste total) containing strontium fluoride or cesium chloride stored in water basins. The capsules are approximately 2 inches in diameter by 20 inches long, fabricated of stainless steel or Hastelloy tubing with welded end closures. Each capsule contains up to either 150,000 curies of strontium or 60,000 curies of cesium, for a total of 265 megacuries.

III. DEVELOPMENT OF THE LONG-TERM HIGH-LEVEL WASTE MANAGEMENT PLAN

The demonstration of acceptable methods for the long-term safe storage of radioactive waste is receiving increased national and international attention. An extensive evaluation of alternative disposal methods for high-level wastes from commercial nuclear facilities, made by Battelle-Pacific Northwest Laboratories, included such diverse concepts as disposal in geologic formations deep in the earth, seabed burial, placement in polar ice caps, deep space disposal, and transmutation.⁽²⁾

The conclusion was that viable alternatives available in the next few decades would be limited to geologic or surface storage. A recent study on alternatives for managing wastes from commercial nuclear facilities supports this conclusion.⁽³⁾

While Hanford high-level wastes are significantly different from commercial high-level wastes, most of the same storage considerations are applicable. Some of the major differences are that Hanford wastes have a greater percentage of inerts, have a larger relative volume, and have much less decay heat per unit volume. This large volume of waste already exists in underground tanks, whereas commercial wastes are yet to be generated. These differences must be considered when evaluating the alternatives for long-term management of these wastes.

Two philosophies can be considered for long-term safe care of the waste: (1) controlled management of the waste in a form and location where isolation from man is provided by surveillance and maintenance, or (2) storage in a form and location where isolation from man is provided by natural barriers rather than by actions of man. The alternatives being considered for Hanford high-level wastes are:

- A. Upon completion of the current Waste Solidification Program, continue to store high-level wastes in the existing tanks and capsules as is, or with improvements to the storage facilities to permit storage for an extended period of time. Assure waste isolation from man through a continuing maintenance, surveillance, and evaluation program. If this storage mode can be continued safely, radioactive decay will reduce the radioactivity so that, in time, retrieval of the waste should be simplified. Also, it would permit more time for the technology of waste processing and storage to be demonstrated.

- B. Retrieve the waste, process and store it in a deep geologic storage site. This alternative would isolate the waste from man and remove the need for continuous management.
- C. Retrieve the waste, process and store it in new surface storage facilities. The technology for engineered surface storage facilities is readily available. The waste might be stored indefinitely in such facilities, or on an interim basis with eventual transfer to a final site when it becomes available.

These alternatives are shown schematically in Figure 1.

Before an alternative can be selected and put into operation, technology must be developed, the alternatives must be assessed, and an environmental report must be prepared and evaluated. To accomplish this, the Long-Term High-Level Waste Management Program has been divided into two phases:

- Phase I — Technology Development
- Phase II — Operational

During Phase I, which will extend until the mid-1980's, research and development programs will be conducted to develop, demonstrate, and evaluate technologies for the long-term control of the wastes and to evaluate alternative methods of long-term waste management. Technology Development will include hardware development and testing

FIGURE 1
LONG-TERM HIGH-LEVEL
WASTE MANAGEMENT ALTERNATIVES

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at a level which will provide a high degree of confidence that the process steps could be carried out successfully and that the Operational costs can be reasonably estimated. The waste management alternatives evaluation will lead to the preparation of an environmental statement on the development and demonstration program alternatives. The recent Environmental Statement on Waste Management Operations at Hanford briefly discussed the research and development activities under way for long-term management of high-level wastes and states that "ultimate disposal of Hanford waste will be considered in another impact statement prior to decisions on various ultimate disposal options."⁽¹⁾ Another environmental statement will be prepared before the Phase II plans can be completed.

Phase II involves the authorization, design, construction, and operation of facilities necessary to implement and carry out the long-term management alternative selected. It is estimated that if an Operational program requiring waste retrieval is authorized by the mid-1980's, it would take 15 - 20 years to carry it out. Figure 2 illustrates the timing of these phases as well as their relationship to the current solidification program.

The Operational program may establish different action plans for the different high-level waste forms. For example, the plans for terminal liquor and capsules could be significantly different in technology and timing from the plan for salt cake and sludge in underground tanks. Because the terminal liquor will be in liquid

**CURRENT WASTE
SOLIDIFICATION PROGRAM**

**LONG-TERM HIGH-LEVEL
WASTE MANAGEMENT PROGRAM
PLAN**

**PHASE I, TECHNOLOGY
DEVELOPMENT**

PHASE II, OPERATIONAL

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FIGURE 2

LONG-TERM HIGH-LEVEL WASTE MANAGEMENT PROGRAM
SCHEDULE

form, one plan which will receive serious consideration will be to move ahead with immobilization of these wastes in large-scale demonstration facilities. Immobilization of salt cake and sludge could follow.

The following section discusses the Technology Development phase of the program. Information on the status of work in this phase is provided in reference 4.

IV. DESCRIPTION OF PHASE I — TECHNOLOGY DEVELOPMENT

Three long-term waste management alternatives are being developed concurrently. To accomplish this, Phase I has been divided into nine tasks, six in Technology Development, two in Engineering Analysis, and one in Program Management and Evaluation. These tasks are described in the following paragraphs.

Technology Development

1. Engineered Improvements

This effort is designed to identify, develop, and test methods for improving the safety of the existing waste storage system so that in-tank waste storage can be continued or extended. Options being evaluated include *in situ* immobilization of the waste, fixation of the soil surrounding the tanks, and addition of barriers around and above the tanks.

2. Waste Retrieval

The objective of the waste retrieval task is to develop and demonstrate equipment and methods for production-scale removal of the waste material from the underground tanks and transportation to a processing plant. Retrieval technologies under investigation include hydraulic, pneumatic, and mechanical methods. It is expected that the final waste retrieval system will be a combination of these methods. The program involves testing of components and a full-scale waste retrieval system on nonradioactive materials, followed by demonstration on an actual high-level radioactive waste tank. Conceptual designs will also be prepared on systems to transport the waste from the tanks to the processing facility.

3. Waste Processing

The objective of this task is to develop processes for converting the waste removed from the tanks to less mobile (safer) forms and/or reduce the volume of the high-level waste to be stored. Improved waste forms are being developed which are more desirable than salt cake, sludge, and terminal liquor for long-term storage. Desirable product characteristics include thermal stability, low dispersibility, and low solubility. Because of the apparent high cost of storage containers and storage space, economic incentive may exist for reducing the volume of high-level waste which requires high-integrity storage. The volume of radioactive waste can be reduced by removing the radionuclides from the bulk of the inert chemical waste.

The waste form and volume reduction processes currently under development are:

- Glass immobilization, which would incorporate the radioactive waste into a silicate glass. The technology development will be mostly transfer and adaptation of industrial glass-making experience for processing a highly radioactive material.
- Clay immobilization, which would incorporate the waste into a crystalline sodium-aluminum-silicate matrix (nepheline). The technology requirements for this process would involve a denitration operation and, quite likely, a pressing and sintering operation.
- Radionuclide removal, which would separate the waste into a small volume of radioactive waste (i.e., that requiring long-term isolation) and a large volume of chemical waste with the potential for lower-cost storage or disposal. The radionuclide removal technology used would include ion exchange, with some possible use of precipitation.

Several versions of these processes are being developed by process chemists and engineers. Laboratory and batch tests, large-scale engineering tests, and continuous process demonstrations with actual radioactive waste materials are being utilized. In addition to these major processes,

several others (such as cement immobilization, glass frit immobilization, and sodium removal via solvent extraction) will be tested on a limited basis to assess their applicability. As part of the process development program, a significant waste sampling and characterization effort is required to assure flowsheet operability and versatility as the waste composition in the tanks varies.

4. Deep Geologic Storage

Storage in geologic formations is the most promising method being considered for the long-term storage of radioactive waste. The Energy Research and Development Administration, through its prime contractor Union Carbide's Office of Waste Isolation, has a program in progress to qualify geologic storage sites for radioactive wastes. The objective of this program is to find technically and environmentally acceptable locations for the terminal storage of waste in geologic formations. Information from prior studies on the geology of the Hanford site suggests that thick basalt flows may be an acceptable geologic formation for a terminal storage site.

In cooperation with the basalt investigation program being directed by the Office of Waste Isolation, this task will investigate the Hanford basalt as a waste storage site for radioactive waste, and if findings are positive, will proceed with site testing and development. The work in this task will include determination of the compatibility of waste form and host rock, heat transfer studies, conceptual design, and possible development of a demonstration storage site.

5. Surface Storage

Engineered surface storage facilities could be constructed which would provide safe storage for tens to hundreds of years. Such facilities would consist of structures, located at ground surface or below grade, which would have more than one containment barrier and would require monitoring and surveillance. The waste would be packaged for easy retrieval and could be maintained in this condition for many years. The options of continued storage in this facility, or future removal to another storage site, could be maintained. Conceptual designs for storing radioactive wastes by this mode will be developed under this task.

6. Waste Transportation

Transportation of the waste from the processing plant to the storage site will be required. If the storage site is not at Hanford, the transportation effort for Hanford high-level waste will be very significant. Under this task, transport modes for both onsite and offsite shipment will be evaluated for design, safety, cost, and regulatory requirements.

Engineering Analysis

1. Existing Storage Systems Analysis

The storage systems of underground tanks and water basins containing waste capsules, as they will exist upon completion of the current waste solidification program, will be analyzed for their capability to continue the safe storage

of radioactive waste. During the analysis, primary consideration must be given to the mechanisms for release and transport of the radionuclides to man. The incentive for selecting other waste management options would be to reduce the risk to man. Studies will be conducted on tank failure analysis, tank structural integrity, waste - concrete chemical reactions, radionuclide migration through soils, and surveillance systems.

2. Alternative Storage System Analysis

The information being generated by the technology development tasks must be assembled into conceptual waste management strategies and analyzed for effectiveness. Safety, technology, cost, and reliability of a variety of strategies will be compared, and the ones which should be developed further will be identified. The information will also be analyzed and compiled so that the technical bases for decisions are understood and documented.

Program Management and Evaluation

In support of the technology development and engineering evaluation tasks, a continuing overview of the total program must be maintained so that the program is properly guided, scheduled, budgeted, and managed. To accomplish this, activities will include:

- Preparation and updating of program planning documents. In addition to this broad plan, more detailed program plans will be prepared on various segments of the program such as waste retrieval, waste processing, waste storage, etc.

- Requesting program funding through submittal of budget documents.
- Program guidance through regularly scheduled program reviews with ARHCO and ERDA management.
- Independent program review via a waste management consulting group of recognized experts in the fields of chemical processes, hydrology-geology, health physics, environmental impact, and design and construction engineering. These consultants will not be affiliated with either ERDA or Hanford.
- Information exchange with personnel at other ERDA sites who are working on similar programs. This exchange will occur at both the technical and management levels.
- The review of and compliance with certain ERDA and national regulations and criteria. The ERDA Manual provides specific guidance on waste management.⁽⁵⁾ In addition, other national criteria on waste management are evolving from the emerging nuclear industry. These will be reviewed and adapted as appropriate.
- Assessment studies and/or integration with the total long-term Hanford waste management program, which considers wastes other than high-level.

This effort is needed to assure consistency in plans and recognition of the relative hazards of the various kinds of waste which exist at Hanford.

- Assisting ERDA in the preparation of an environmental impact statement(s) on the long-term management of Hanford high-level waste. This statement will be prepared late enough in the development program to contain meaningful information, but early enough to permit the information contained to be factored into the decision-making process.

Phase I of the Long-Term High-Level Waste Management Program is charted in Figure 3. While work on some of the tasks has been in progress for two or three years, the chart only illustrates current and future work.

GUIDE TO FIGURE 3
LONG-TERM HIGH-LEVEL WASTE MANAGEMENT PROGRAM PLAN
PHASE I: TECHNOLOGY DEVELOPMENT

Purpose: Figure 3 charts the major steps or efforts required to complete the Technology Development Phase of the Long-Term High-Level Waste Management Program. All of the technology development tasks are illustrated on the chart. Only key engineering analyses and management evaluation and decision point are shown.

Organization: For charting convenience, the program tasks are grouped into six categories, shown on the left of the chart. They are:

- Tasks relating to the safe time Hanford waste can be stored in the existing underground tanks.
- Tasks relating to the retrieval of Hanford waste from the tanks.
- Tasks associated with the immobilization of Hanford wastes after retrieval from the tanks.
- Tasks required to develop storage facilities for immobilized Hanford waste.
- Tasks directed toward the establishment of a deep geologic storage facility in Hanford basalt.
- Tasks directed toward preparation of key program assessment documents.

Legend: Because of the complexity of the program, only major steps and key decisions are illustrated. Each of the steps are contained within boxes which are scaled with respect to time. The boxes show the estimated timing of each step, and the time required to complete the step. Formal charting symbols have been avoided in preparing Figure 3; however, several comments regarding the format are appropriate.

- An oval is used to highlight all key decisions.
- Flows of critical information between tasks and decision points are emphasized by dotted lines. Decisions made prior to these data being available would be high-risk decisions.
- Engineering analyses which provide significant program guidance are shown in boxes with arrow-shaped ends at their right.
- All construction, operations, and task-oriented engineering, such as the design of equipment facilities, are shown within squares and rectangles without arrow-shaped ends.
- The small hexagon located on the budget timing line for several decisions illustrates the lead time required in securing funding in order to provide contiguous progress as shown on the chart.
- The small circle with darkened alternate quadrants shows the probable timing of environmental statements or key ERDA/public program-assessment documents.

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FIGURE 3
LONG-TERM WASTE MANAGEMENT PROGRAM PLAN
PHASE I: TECHNOLOGY DEVELOPMENT

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