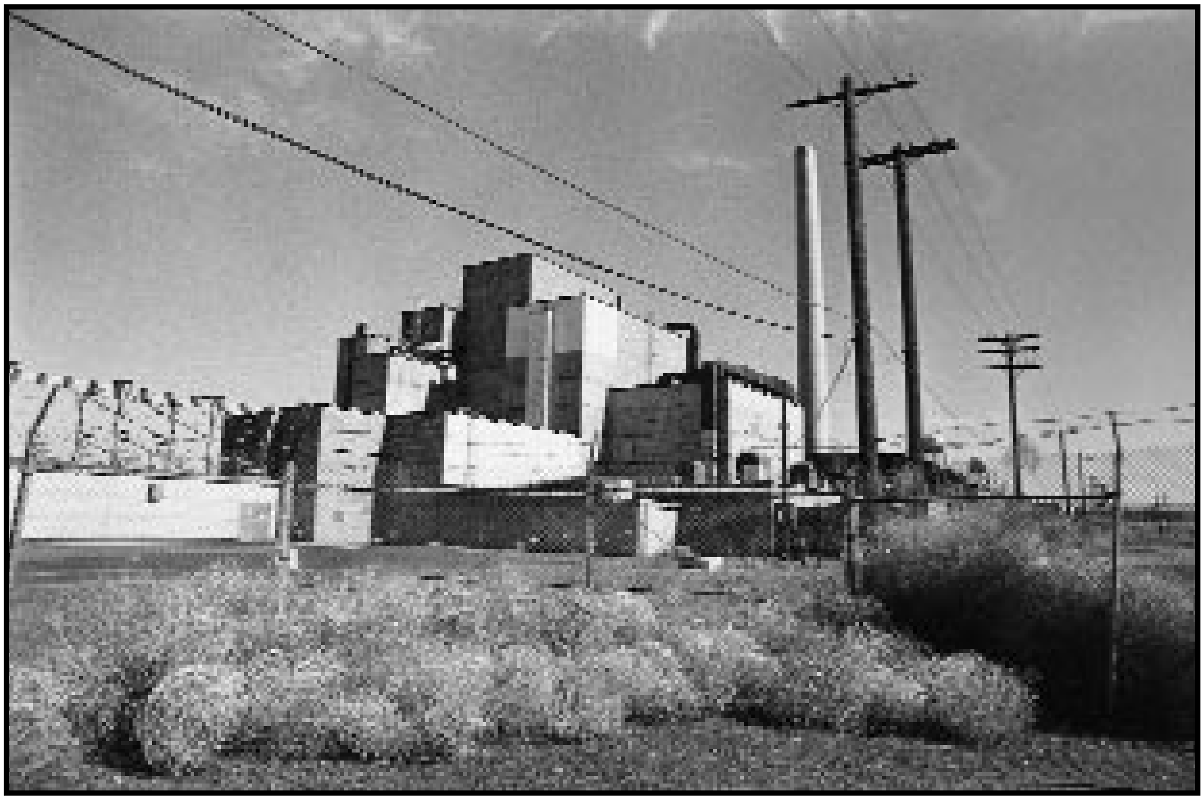
From Cleanup to Stewardship



a Companion Report to *Accelerating Cleanup: Paths to Closure*
and
Background Information
to Support the Scoping Process
Required for the 1998 PEIS Settlement Study

U.S. Department of Energy
Office of Environmental Management
October 1999

Long-term stewardship is expected to be needed at more than 100 DOE sites after DOE's Environmental Management program completes disposal, stabilization, and restoration operations to address waste and contamination resulting from nuclear research and nuclear weapons production conducted over the past 50 years. *From Cleanup to Stewardship* provides background information on the Department of Energy (DOE) long-term stewardship obligations and activities.

This document begins to examine the transition from cleanup to long-term stewardship, and it fulfills the Secretary's commitment to the President in the 1999 Performance Agreement to provide a companion report to the Department's *Accelerating Cleanup: Paths to Closure* report. It also provides background information to support the scoping process required for a study on long-term stewardship required by a 1998 Settlement Agreement.

From Cleanup to Stewardship was produced by the Department's Office of Strategic Planning and Analysis within the Office of Environmental Management, with assistance from hundreds of people throughout the Department, as well as from contractors, independent experts, and others.

To obtain copies of this report or for more information on the environmental management activities of the U.S. Department of Energy, contact:

The Environmental Management Information Center
1-800-736-3282 or
www.em.doe.gov/lts

Front cover:

Hanford "B" Reactor with Tumbleweeds
This reactor was the world's first large-scale plutonium production reactor. Built in less than one year, it produced plutonium from 1944 to 1968. It will be maintained as a National Historic Mechanical Engineering Landmark.
Hanford Site, Washington, July 1994.

From Cleanup
To Stewardship

Preparation for Entombment. Before the Hanford "C" reactor core is entombed within its shielding walls, related structures are first decontaminated and dismantled. Contaminated soils and materials from the area have been disposed of in the Environmental Restoration Disposal Facility (below). Once entombed, the reactor core will require monitoring and maintenance for up to 75 years until a decision is made on its final disposition. *C Reactor, Hanford Site, Washington, July 1998.*

The Environmental Restoration Disposal Facility. This engineered unit receives waste generated by the Hanford site cleanup. Its bottom is lined with multi-layer high-density polyethylene. When full, the facility will be covered with a RCRA-compliant multi–layer cap, a vegetative cover, and a five-meter intrusion barrier made of basalt, concrete, boulders, silty soil, and plastic. Between its opening in 1996 and 1999, the site has taken in more than 1.6 million tons of contaminated soils and material. It is expected to close in 2046. Access to waste disposal areas and buffer zones will be restricted for as long as necessary to protect human health and the environment. *Environmental Restoration Disposal Facility, Hanford Site, Washington, July 1998.*

DOE/EM-0466

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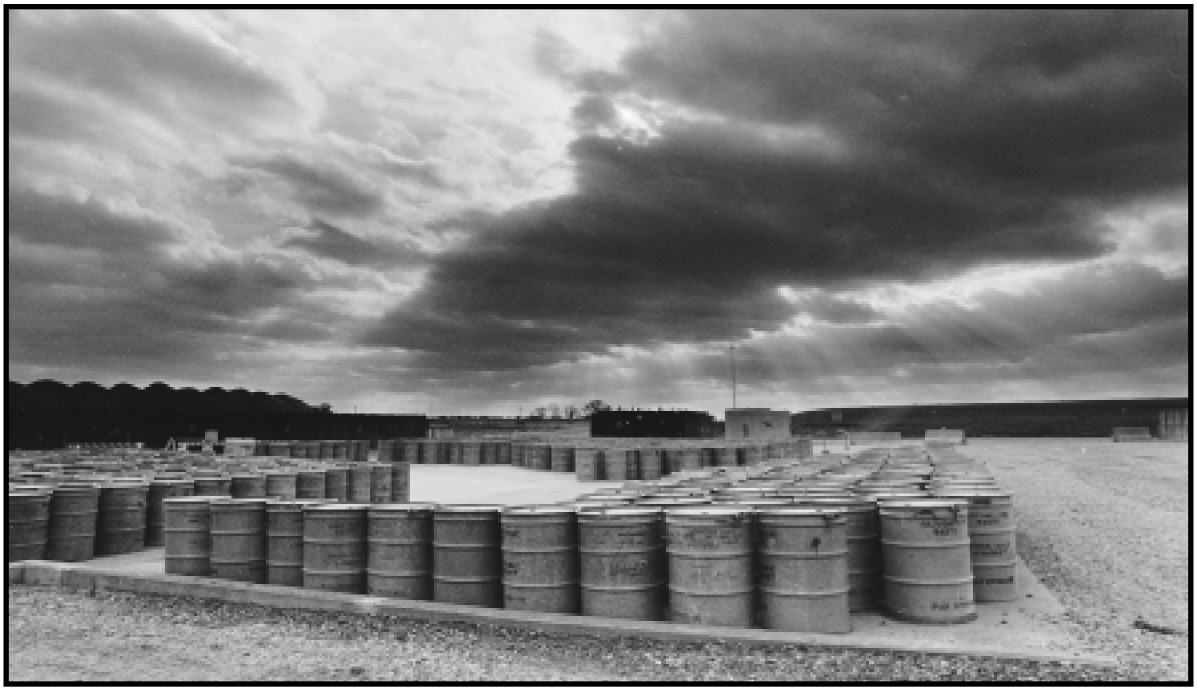

Transuranic Waste Storage Pads. Drums containing transuranic waste sit on a concrete pad in temporary storage. This waste is contaminated with uranium-233 and plutonium. In 1999, the Department began disposing of transuranic waste in the Waste Isolation Pilot Plant near Carlsbad, New Mexico. *Transuranic Waste Storage Pads, E Area Burial Grounds, Savannah River Site, South Carolina, January 1994.*

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Sedan Crater. This crater is the site of a 110-kiloton thermonuclear explosion at the Nevada Test Site in 1962. The crater is 600 feet deep and 1,200 feet wide. Because of the widely dispersed plutonium and other radionuclides that resulted from this explosion, this test area and others will require long-term institutional controls to prevent inadvertent exposure to residual contamination. *Area 10, Nevada Test Site, Nevada, October 1984.*

Low-Level Waste Burial. The Idaho National Engineering and Environmental Laboratory disposes of low-level waste in this pit at the Radioactive Waste Management Complex Subsurface Disposal Area. The laboratory has 4,700 cubic meters of low-level waste in inventory and is projected to generate an additional 115,000 cubic meters in the next 35 years. New waste will come from facility decommissioning and dismantlement, treating and characterizing other waste streams, and ongoing processes. *Radioactive Waste Management Complex, Idaho National Engineering and Environmental Laboratory, Idaho, March 1994.*

Preface

Beginning with the Manhattan Project during World War II, the Federal Government has carried out extensive nuclear weapons research and development, production, and testing activities. Since the Cold War began, significant institutional, scientific, and legal changes occurred: massive industrial facilities were constructed, operated, and in many cases, shut down; scientific research revealed much about how ionizing radiation may affect human health; major environmental laws have been enacted; and the missions of the Department of Energy (DOE) and its predecessors changed significantly as a consequence of national and world events.

Perhaps the biggest changes in the nation's nuclear weapons enterprise are now upon us. The Cold War ended nearly a decade ago, and the Department has undertaken a massive program to address the environmental consequences of nuclear weapons production, while using a smaller complex of facilities to maintain the nuclear weapons stockpile.

Despite these dramatic changes, one thing has remained constant — the Federal Government's obligation to protect human health and the environment. The Atomic Energy Act of 1954 provides for protecting health and minimizing danger to life and property. Since then, a number of environmental laws have imposed additional requirements on DOE's facilities, operations, and activities. The need to address environmental, safety, and health issues will remain as we enter a new millennium.

Eighty-third Congress of the United States of America

Begun and held at the City of Washington on Wednesday, the sixth day of January,
One thousand nine hundred and fifty-four

An Act

To amend the Atomic Energy Act of 1946, as amended, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the Atomic Energy Act of 1946, as amended, is amended to read as follows:

"ATOMIC ENERGY ACT OF 1954

"Sec.2.Findings.–The Congress of the United States hereby makes the following findings concerning the development, use, and control of atomic energy:...
"b. In permitting the property of the United States to be used by others, such use must be regulated in the national interests and in order to provide for the common defense and security and to protect the health and safety of the public...
"d. The processing and utilization of source, byproduct, and special nuclear material must be regulated in the national interest and in order to provide for the common defense and security and to protect the health and safety of the public...
"Sec.3.Purpose.–It is the purpose of this Act to effectuate the policies set forth above by providing for– ...
"d. a program to encourage widespread participation in the development and utilization of atomic energy for peaceful purposes to the maximum extent consistent with the common defense and security and with the health and safety of the public...

"Sec.161.General Provisions.– In the performance of its functions the Commission is authorized to– ...
"b. establish by rule, regulation, or order, such standards and instructions to govern the possession and use of special nuclear material, source material, and byproduct material as the Commission may deem necessary or desirable to promote the common defense and security or to protect health or to minimize danger to life or property;...
"i. prescribe such regulations or orders as it may deem necessary...
"(3) to govern any activity authorized pursuant to this Act, including standards and restrictions governing the design, location, and operation of facilities used in the conduct of such activity, in order to protect health and to minimize danger to life or property;...

Approved:
Dwight D Eisenhower.
30 August 1954
Washington, D.C., 1600 Penna. Avenue
9.44. a.m.

Excerpts from the Atomic Energy Act of 1954. This Act governs the management of radioactive materials by DOE. The Act was signed into law by President Dwight D. Eisenhower on August 30, 1954 (photo page A-1).

Introduction

During the last decade, the Department of Energy (DOE) has made significant progress in its environmental cleanup program (see Exhibit 1), resulting in substantially lower risks and lower annual costs for maintaining safe conditions. This experience in planning and completing cleanup has made one fact clear: complete restoration to levels acceptable for unrestricted use cannot be accomplished at many sites. Consequently, long-term stewardship will be needed at these sites to ensure that the selected remedies will remain protective for future generations. According to this background document, long-term stewardship includes all activities required to protect human health and the environment from hazards remaining at DOE sites after cleanup is complete.

DOE is required to conduct stewardship activities under existing requirements (see Appendix B), and many DOE organizations have been conducting stewardship activities over the years as part of their ongoing missions. Scientists and engineers have long understood that much of the waste and other materials managed by DOE (i.e., radionuclides and metals) cannot be broken down into non-hazardous materials. These materials must be managed by treatment, isolation, and monitoring.

Existing Requirements for Long-Term Stewardship

Existing laws, regulations, and DOE policies and directives provide broad requirements for DOE to conduct monitoring, reporting, record keeping, and long-term surveillance and maintenance for waste management facilities, soil and buried waste, engineered waste disposal units, facilities, surface water, and groundwater (see Appendix B).

Long-term stewardship activities are being conducted by a variety of DOE organizations. For many DOE sites and organizations, stewardship activities represent only a minor part of their principal mission, although long-term stewardship is the only mission at several sites.

Although statutory and regulatory requirements provide a general foundation for long-term stewardship, it is not certain whether existing requirements encompass all of the activities that may be involved in long-term stewardship, nor do they ensure the development of effective implementation strategies.

Exhibit 1: Cleanup Progress Since 1989

- **The Department has completed remedial work (i.e., "cleanup") at almost half of its sites.**
- **Significant progress has been made in constructing and operating waste treatment and disposal facilities.**
- **Hundreds of kilograms of dangerous nuclear materials have been stabilized.**
- **Approximately 450 facilities have been decommissioned through 1998.**
- **Dozens of new technologies, developed and implemented at DOE sites, have enabled the Department to reduce risks and "mortgage" costs and remedy previously intractable contamination.**

For example, the preferred remedy for many radionuclide contaminated soils will be to excavate the soil and place it in an engineered disposal cell (e.g., a landfill or an above-ground vault). While this results in a safer overall site end state, the radionuclides will remain at the site and pose a known hazard for years into the future while the natural decaying process takes place. The disposal cell, therefore, will need long-term monitoring, maintenance, and controls to ensure the remedy remains protective of human health and the environment in the future.

The realization that long-term stewardship ultimately will be a primary mission at most DOE sites grew out of analytical efforts to develop a clearer "path forward," and to improve the financial and managerial control of the Department's Environmental Management (EM) program. These analyses, published in the *Baseline Environmental Management Reports* (DOE 1995b, 1996c) and *Accelerating Cleanup: Paths to Closure* Report (DOE 1998a), have helped the Department estimate the long-term costs and schedule of the cleanup program well into the 21st Century.

Why Address Stewardship Now?

- **To provide for smooth transition from cleanup to long-term stewardship through technical, financial, and managerial planning**
- **Emphasize that the "cleanup" goal in many cases is to reduce and control, not eliminate, risk and cost**
- **Ensure that Congress, regulators, and other stakeholders have a clear understanding of what the cleanup mission will "produce" and clarify that there is an attainable end point**
- **Set realistic expectations and show interim successes and results**
- **Identify technology research and development needs**
- **Assure regulators and the public that DOE will not walk away from its enduring obligations.**

The results of these analyses have helped put a price on the environmental consequences of the Cold War, and they have revealed how to reduce that price through smarter ways of doing business, especially by accelerating cleanup. Four major findings of these analyses were:

- The initial projected cost was too high and the timetable too long for Congress to be expected to provide continuing support of the program.[1] Significant changes were therefore required to improve efficiency and expedite the cleanup.
- Substantial costs were projected for maintaining infrastructure and safe conditions during cleanup operations, rather than directly paying for cleanup. Therefore, accelerating cleanup will reduce costs.
- Many of the Department's cleanup plans assume that waste and residual contamination will be stabilized, but cannot be removed entirely. These plans have been and will continue to be approved by regulators and made in consultation with stakeholders.
- Many of the DOE sites that have not completed cleanup are just beginning to define the full scope and cost of long-term stewardship activities.

Upon publication of the second *Baseline* report in 1996, the Department established a goal of completing cleanup at as many sites as possible by the year 2006. To accomplish this goal, the Department increased its efforts to improve efficiency through greater integration among site cleanup programs, and related initiatives. The Department reorganized the budget structure for the EM program into more than 350 "projects" to focus attention on discrete sets of tasks with clear end points. The Department also established a new account structure with three general budget categories:

- "Site Closure" – sites for which EM has established a goal of completing cleanup by the end of FY 2006. After cleanup is completed at these sites, no further Departmental mission is envisioned, except for limited long-term surveillance and maintenance, and the sites will be available for some alternative use.
- "Site/Project Completion" – projects that will be completed by 2006 at EM sites where overall site cleanup will not be fully accomplished by 2006; and entire sites where cleanup will be completed by 2006 (except for long-term stewardship activities), and where there will be a continuing federal workforce at the site to carry out enduring missions.
- "Post 2006 Completion" – projects that are expected to require work beyond FY 2006.

This improved cleanup and closure effort was described initially in a draft report in February 1998, *Accelerating Cleanup: Paths to Closure,* and in a revised report issued in June 1998 (DOE 1998a). Among other things, this report described the projected end state for each site once cleanup has been completed.

1. The *Baseline Environmental Management Reports* estimated that cleanup costs would be approximately $230 billion, whereas the most recent estimate (*Paths to Closure*) has been $147 billion. The differences reflect efficiency improvements as well as smaller scope (i.e., newly generated waste is not included in the $147 billion estimate) [see DOE 1998a].

Submarine Hull Disposal Trench. When a nuclear-powered submarine is decommissioned, the spent nuclear fuel is removed from the submarine's reactors and the section of the submarine containing the reactor is disposed of in a trench. The radioactively-contaminated hull sections with the defueled reactors inside are transported by barge to the Hanford Site, where they are placed in a large trench for burial. The disposal trench will require long-term monitoring and maintenance to ensure that hazardous materials remain inside the hulls. *Trench 94, Hanford Site, Washington, July 1998.*

Submarine Hulls Up Close. Use of the thick steel submarine hull as a disposal container provides extra isolation between the environment and the low-level waste and hazardous lead that remain after the spent nuclear fuel has been removed. *Trench 94, Hanford Site, Washington, July 1998.*

Before. These four ponds received wastewater until 1985 from operations at the Y-12 Plant where uranium isotopes were separated using an electromagnetic process. *Oak Ridge Reservation, Tennessee. Photo circa 1985. Source: U.S. Department of Energy.*

After. From 1985 until 1990, liquids in the above four waste ponds were treated to remove contaminants, the ponds were then drained and capped with asphalt, and the capped area used as a parking lot. The asphalt cap will require long-term monitoring and maintenance to ensure its integrity and prevent migration of the residual contamination beneath it. *Oak Ridge Reservation, Tennessee. Photo circa 1990. Source: U.S. Department of Energy.*

Purpose of Report

This report has been prepared to fulfill two commitments made by the Department. First, *Paths to Closure* indicated that further discussion of end states and long-term stewardship would be presented in a companion report (see p. 6-3 in DOE 1998a). Secretary of Energy Bill Richardson formalized this commitment in his 1999 Performance Agreement with the President.

Second, the Department settled a lawsuit in December 1998 that requires DOE, among other things, to prepare a study on long-term stewardship (Joint Stipulation 1998). Although the study will not be conducted under the National Environmental Policy Act (NEPA), the study is required to follow certain of the procedures of the Council on Environmental Quality for conducting a scoping process under NEPA, as well as the Department's NEPA procedures regarding public comment. Specifically, the Settlement Agreement provides

> DOE [will] prepare a study on its long-term stewardship activities. By 'long-term stewardship,' DOE refers to the physical controls, institutions, information and other mechanisms needed to ensure protection of people and the environment at sites where DOE has completed or plans to complete 'cleanup' (e.g., landfill closures, remedial actions, removal actions, and facility stabilization). This concept of long-term stewardship includes, *inter alia*, land use controls, monitoring, maintenance, and information management.

See Appendix A for the complete language of the relevant section of the agreement.

For the purposes of this analysis, the definition of long-term stewardship also includes sites for which DOE will have long-term responsibility, even though DOE was not responsible for actual cleanup at these sites (e.g., certain uranium mill tailing sites). DOE will determine the breadth of the long-term stewardship study considering public scoping comments pursuant to the terms of the Settlement Agreement.[2] This report provides background information for that scoping process. It is intended to provide a basis for more informed discussions among various DOE offices, regulators, and affected communities on stewardship needs and the potential links between existing and future cleanup decisions, risks, costs, technologies,

How Does This Report Relate to the *Paths to Closure* Process and the Study Required by the Settlement Agreement?

The site-specific data used to develop *From Cleanup to Stewardship* are based on information submitted by the sites in support of the June 1998 *Paths to Closure* report. Significant public involvement is being conducted at both the site and national levels for this ongoing process. Therefore, issues regarding site-specific data are addressed through the *Paths to Closure* process. Information on that process can be obtained at *www.em.doe.gov/closure* or from the Environmental Management Information Center (1-800-736-3282). No additional data were collected for this report.

This background report provides a national summary of the nature and extent of DOE's current and anticipated long-term stewardship needs. It also examines some of the issues, challenges, and barriers associated with the transition from cleanup to long-term stewardship.

A follow-on long-term stewardship study, pursuant to the terms of the Settlement Agreement, will examine these issues, challenges, and barriers in greater detail and will begin to identify potential paths forward for the Department. However, the study process will not interfere with site-specific activities for developing cleanup and long-term stewardship strategies. Because long-term stewardship is a relatively new concept, there are few precedents upon which to rely. Therefore, the Department is actively seeking broad public input to the draft study process. Information on how to become involved in the draft study process can be obtained from *www.em.doe.gov/lts* or the Environmental Management Information Center at 1-800-736-3282.

2. According to the Settlement Agreement, DOE will follow the procedures set forth in the regulations of the President's Council on Environmental Quality (CEQ) for public scoping, 40 CFR 1507.7(a)(1)-(2), and the procedures set forth in DOE's NEPA regulations for public review of environmental impact statements, 10 CFR 1021.313, except that (a) DOE will not transmit the study, in draft form, to EPA, and DOE (not EPA) will publish a Notice of Availability in the Federal Register as set forth in 10 CFR 1021.313 (a), and (b) DOE will not include any Statement of Findings as set forth in 10 CFR 1021.313 (c).

future land use, and the level of effort required to conduct stewardship activities.

Organization of the Report

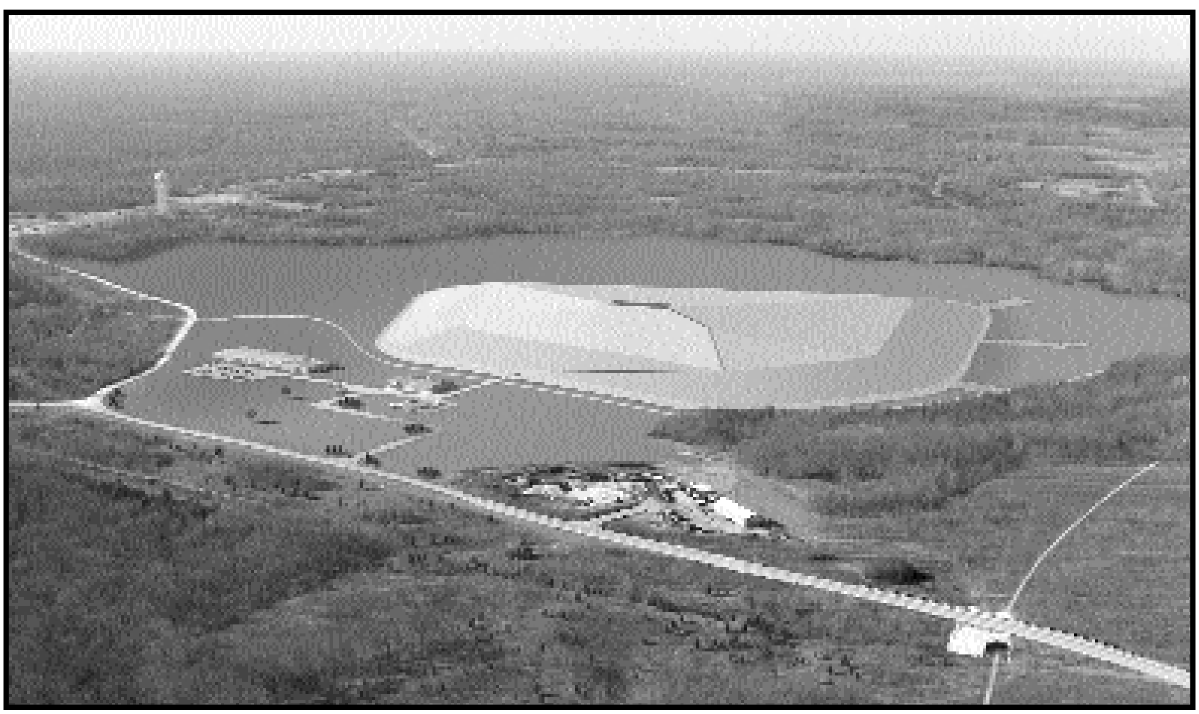
In three chapters this report will address the following:

- **The Nature of Long-Term Stewardship at DOE Sites (Chapter 1)**, which describes the scope and breadth of long-term stewardship activities and why they will be required.
- **Anticipated Long-Term Stewardship at DOE Sites (Chapter 2)**, which summarizes what is known so far about end states, the number and location of sites that will likely require stewardship, the type of stewardship required, and which sites are currently carrying out stewardship activities.
- **Planning for Long-Term Stewardship (Chapter 3)**, which outlines several issues the Department has initially identified that need to be addressed to ensure a successful transition from cleanup to long-term stewardship, and that may be appropriate to consider in the long-term stewardship study required by the Settlement Agreement.

The Weldon Spring Site Before, During and After Cleanup (Pages 6 and 7)

Before: The Weldon Spring Uranium Feed Materials Plant. This facility processed uranium ore concentrates and small amounts of thorium for use in nuclear weapons from 1958 to 1966. Between 1963 and 1969, the Atomic Energy Commission disposed of uranium residues and small amounts of thorium residues in the nearby Weldon Spring Quarry. Environmental remediation at this site began in 1985. *Weldon Spring Uranium Feed Materials Plant, near St. Louis, Missouri. Photo circa 1965. Source: U.S. Department of Energy - Weldon Spring Site Remedial Action Project.*

During: Weldon Spring Site Remedial Action Project. Remediation began at Weldon Spring in 1985 and involved dismantling the chemical plant buildings, excavating contaminated soils, and disposing of radioactive and chemically- contaminated soil and debris. *Weldon Spring Site Remedial Action Project, near St. Louis, Missouri, March 1996.*



Artist's Conception: Weldon Spring After Cleanup. This computer-generated image illustrates what the Weldon Spring disposal cell will look like after site remediation has been completed in 2002. Encompassing 42 acres, the cell will be 65 feet high and will contain approximately 1.4 million cubic yards of radioactively contaminated materials. After the cell has been completed, DOE will remain responsible for its long-term surveillance and maintenance. *Weldon Spring Site Remedial Action Project graphic. July 1999. Source: U.S. Department of Energy - Weldon Spring Site Remedial Action Project.*

Chapter 1:
The Nature of Long-Term Stewardship at DOE Sites

The Estes Gulch Disposal Cell. This engineered unit near Rifle, Colorado contains approximately 3.6 million cubic yards of vanadium and uranium mill tailings and contaminated materials from uranium mining and milling operations at two uranium processing sites (the Old and New Rifle Sites) and more than 100 vicinity properties. The 62-acre cell, completed in 1996, consists of a 1-2 foot thick erosion barrier layer of cobble and boulders, a 3-7 foot thick frost protection layer of silt, a 1-2 foot thick clay radon barrier over the tailings, and a high-density polyethylene plastic liner beneath the tailings. Under the provisions of the Uranium Mill Tailings Control Act, the disposal cell is designed to be effective in control of residual radioactive materials for up to 1,000 years, and for at least 200 years. *Estes Gulch Disposal Cell, Rifle, Colorado, April 1998.*

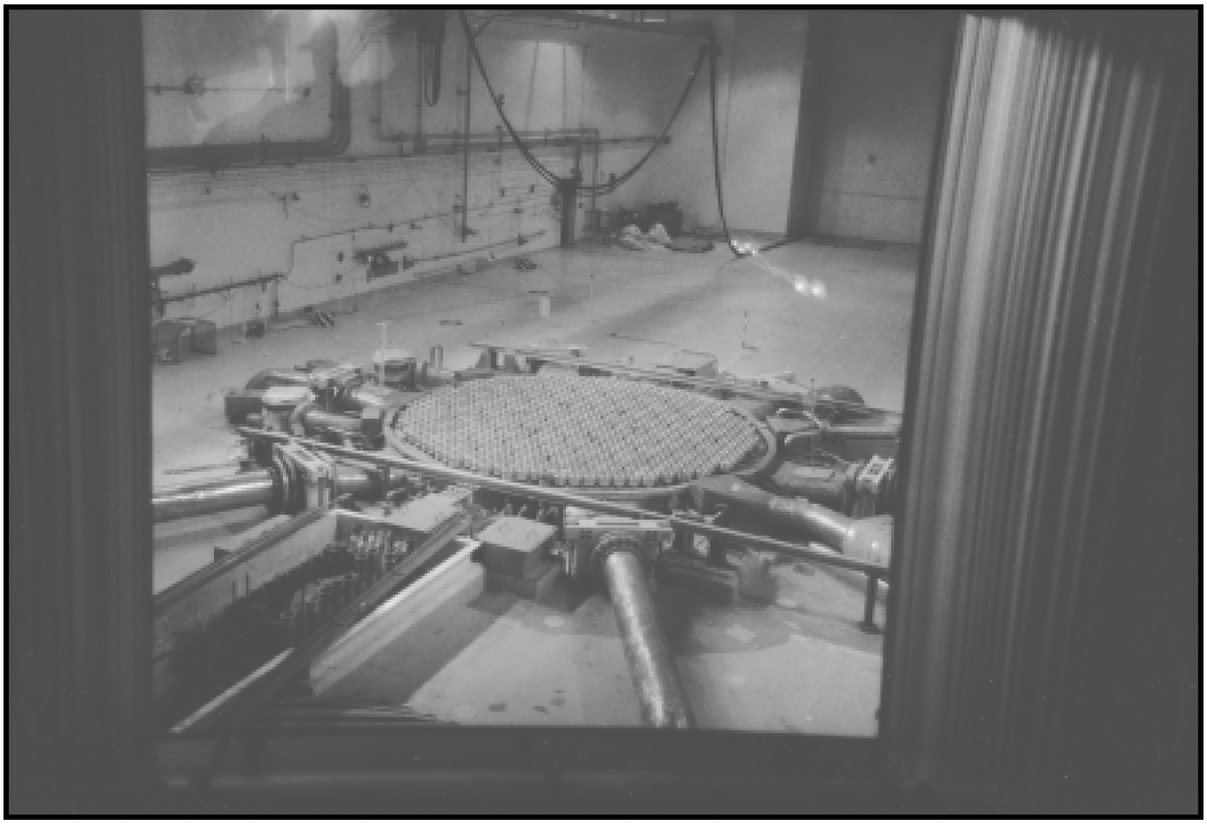
This chapter presents an overview of the hazards expected to remain at DOE sites after the assumed cleanup strategies have been implemented, and it discusses the activities required to protect humans and the environment from these hazards. It also views the regulatory context under which long-term stewardship has begun to be conducted. This report does not include materials or facilities that are part of two other programs that also use the word “stewardship:” the Nuclear Materials Stewardship Program, which provides for management and disposition of nuclear materials that are used or being stored at DOE sites; and the Stockpile Stewardship Program, which ensures the safety and reliability of the existing stockpile of nuclear weapons.

Key Definitions Used for this Analysis

Cleanup: The process of addressing contaminated land, facilities, and materials in accordance with applicable requirements. Cleanup does not imply that all hazards will be removed from the site. The term "remediation" is often used synonymously with cleanup.

End state: The physical state of a site after cleanup activities have been completed.

Long-term stewardship: All activities required to protect human health and the environment from hazards remaining after cleanup is complete.



K-Reactor Head. This nuclear reactor at the Savannah River Site was used during the Cold War to produce plutonium and tritium for nuclear weapons. Most of the radioactivity associated with the reactor was contained in the spent nuclear fuel, which has been removed for disposal. Nonetheless, some residual contamination will remain after the facility is deactivated, decommissioned and decontaminated, because there is no cost-effective technology for removing all of the contamination. Consequently, this facility will require some form of long-term stewardship after the current nuclear materials storage mission is completed between 2010 and 2016. *Savannah River Site, South Carolina, January 1994.*

Residual Hazards

A variety of hazards will remain at many DOE sites after these sites have been cleaned up to agreed upon levels. Exhibit 2 depicts the four categories of media where residual hazards will remain, including engineered units, soil and buried waste, facilities, and water. In some cases, cleanup reduces risks, but may not be able to reduce contaminant concentrations to levels deemed safe for unrestricted use of the site.

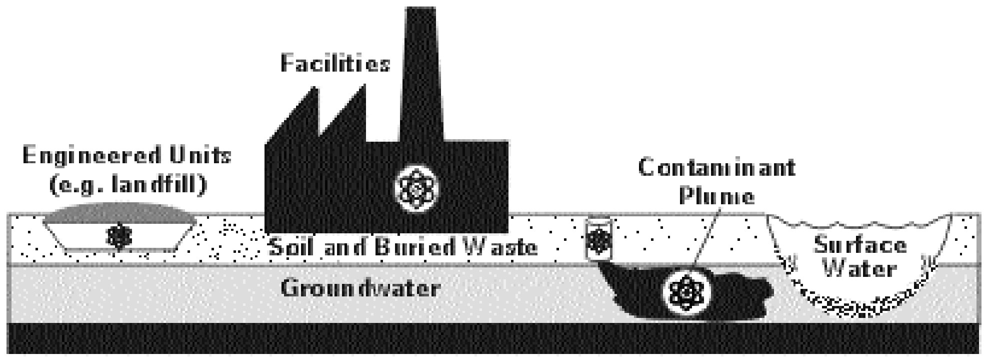
Cleanup goals are typically based on what is needed to allow the land or facility to be available for anticipated future uses. In many cases, however, hazards posed by these wastes and residual contaminants left in place may remain longer than the anticipated life of the engineered and institutional controls in place. If these controls fail, are not maintained, or are not as effective as anticipated, the remaining hazards could pose unacceptable risk.

Hazard and Risk

Hazards include materials or conditions that have the potential to cause adverse effects to health, safety, or the environment. Risk requires the presence of a hazard, but includes the probability that the potential harm will be realized.

Risk is expressed in terms of the likelihood that an adverse effect will occur as a result of the existence of a hazard. The existence of a hazard does not automatically imply the existence of a risk since risk requires a pathway (to a receptor) for an exposure to occur. Barriers and other controls can block or eliminate the pathway and consequently the risk from the residual hazard (see National Research Council 1988).

Exhibit 2: Examples of Residual Hazards at DOE Sites



Engineered Units

- Landfills and other land-based waste disposal units with engineered controls

Soil and Buried Waste

- Contaminants left in place in soils
- Old burial grounds

Facilities

- Entombed reactors, canyons, and other buildings with residual contamination

Water

- Residual contaminants in groundwater or surface water sediments

The need for stewardship at DOE sites results largely from the radioactive contaminants that will remain onsite and continue to pose some degree of risk indefinitely after cleanup is complete (see Exhibits 3 and 4). In addition to the long-lived radionuclides, other contaminants of concern that will remain onsite after cleanup is complete include organic and inorganic chemicals.

Organic contaminants include polychlorinated biphenyls (PCBs), chlorinated solvents, and polynuclear aromatics. Inorganic contaminants include mercury, arsenic, lead, cadmium, and asbestos. Unlike radiological constituents, chemical contaminants do not have well-defined rates of decay. Depending on site conditions, they may persist for a short time (as with some chlorinated organic solvents exposed to sunlight) or in perpetuity (as with inorganics, such as lead and asbestos).

Exhibit 3: Radiological Half Lives

Radioactive contaminants decay at a fixed rate, unaffected by factors such as temperature, solvents, or seasons of the year. The rate of decay is described by the half life – the amount of time required for one half of a given amount of a radionuclide to decay.

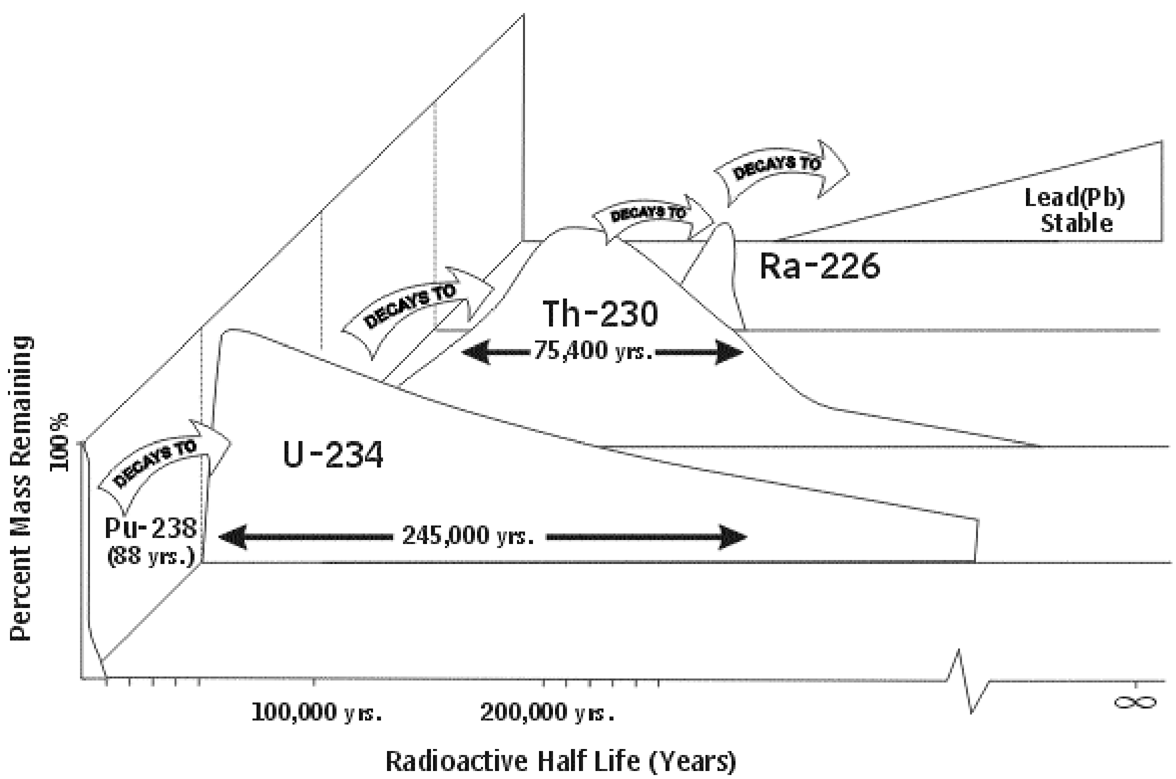
Radionuclide Half Lives

Curium-242	163 days
Cobalt-60	5 years
Tritium	12 years
Strontium-90	29 years
Cesium-137	30 years
Plutonium-238	88 years
Americium-241	432 years
Radium-226	1,600 years
Plutonium-239	24,100 years
Thorium-230	75,400 years
Technetium-99	211,100 years
Neptunium-237	2,144,000 years
Uranium-235	703,800,000 years
Uranium-238	4,468,000,000 years

The half life is inversely related to the rate of decay, and generally, to the intensity of radioactivity, so that a unit mass of a radionuclide having a half life of 100 years would undergo nuclear transformations at a rate 100 times lower than one with a half life of one year.

Source: National Nuclear Data Center

Exhibit 4: Some Radionuclides with Relatively Short Half Lives Decay into Radioactive Decay Products with Half Lives Measured in Geologic Time



Radiological constituents, or radionuclides, decay over time. As a radionuclide decays, it changes into a different radionuclide, or "decay product," by the spontaneous emission of an alpha particle, beta particle, or gamma rays, or by electron capture. Radionuclides decay at a fixed rate, unaffected by factors such as temperature or pressure. The fixed rate of decay is described by the "half life," which is the time required for half of the atoms of a given radionuclide to decay into a decay product. The decay product may have a shorter or longer half life than the radioactive isotope itself.

This Exhibit illustrates the radioactive decay chain of Plutonium-238. Plutonium-238, which has a radioactive half life of 88 years, decays to Uranium-234, which has a half life of 245,000 years. Uranium-234 decays to Thorium-230, which has a half life of 75,400 years. Thorium-230 decays to Radium-226, which has a half life of 1,600 years, and then to Radon-222 and shorter half life radionuclides (not shown in Exhibit) to Lead-206, a stable element. The Plutonium-238 decay chain illustrates that, although the Plutonium-238 itself would persist in the environment for approximately 880 years (10 half lives), the radioactive decay products would persist in the environment for hundreds of thousands of years before decaying into a stable, nonradioactive element (which itself is a hazardous substance).

Why Hazards Will Remain

Depending on the nature of the contaminant and the medium in which it is found, there are several limitations and challenges that preclude remediating many DOE sites to levels that would permit residential or other unrestricted land uses (see also pp. D-12 and D-13 of DOE 1996c).

Technical Limitations

At a number of DOE sites no complete remediation strategy currently exists, because of the type of contaminant and its location. For example, the high-level waste tanks at the Hanford and Savannah River sites pose particularly difficult technical challenges. Existing and projected technologies for removing liquid waste from these tanks will still

Canonsburg Disposal Cell. The 30-acre uranium mill tailings disposal cell in the center of the photograph is located in a residential area approximately 20 miles from Pittsburgh, Pennsylvania. Remedial actions were completed in 1985, and groundwater has been monitored since 1986. Annual groundwater monitoring will continue until 2004, and other long-term stewardship activities such as annual inspections and periodic vegetation control will be required indefinitely. Passive stewardship activities will include ensuring site access and groundwater use restrictions are maintained. *Canonsburg Disposal Cell, Canonsburg, Pennsylvania, March 1999.*

leave at least one percent of the waste in the bottom of the tanks. No technology currently exists to address these tank "heels." Furthermore, any action to remove the tanks may result in additional releases into the underlying soils.

Another difficult technical challenge includes sites where dense non-aqueous phase liquids (DNAPLs), such as trichloroethylene, trichloroethane, and tetrachloroethylene, were released into the subsurface during routine cleaning and maintenance operations (such contamination exists at the Lawrence Livermore National Laboratory in California and the Portsmouth Gaseous Diffusion Plant in Ohio).

Currently available groundwater treatment technologies are extremely inefficient at addressing DNAPL contamination. To date, the preferred remedy calls for stabilizing the groundwater plume (i.e., pumping groundwater in order to keep the plume from spreading) and monitoring until the DNAPLs naturally attenuate or break down into non-hazardous constituents. However, DNAPLs may take hundreds of years to break down or to attenuate.

Economic Limitations

Even when remediation technologies are available, the costs to employ them may be prohibitive. For example, large areas of the Nevada desert have been contaminated with radionuclides from nuclear weapons tests conducted during the Cold War. Although it is technically feasible to remediate identified hot spots of the surface contamination, the cost of remediating the hundreds of acres impacted by low levels of residual contamination across the entire site would be prohibitive.

Worker Health and Safety Challenges

In determining the remediation approach to sites, DOE and regulatory officials must balance the short-term risks to workers and potential longer-term risks to the general public. For example, DOE Savannah River Site officials, in conjunction with the Environmental Protection Agency (EPA) and South Carolina state officials, have signed Records of Decision agreeing that the best way to address some buried radioactive waste at the Savannah River Site is to contain it in place. DOE, EPA, and state officials agreed not to attempt to excavate an old disposal area near the center of the 310-square mile site, where more than 28,000 cubic meters of radioactive waste were buried from 1952 to 1974. Officials decided to evaluate alternative cleanup methods including stabilizing specific hot spots through grouting and covering the site with a surface barrier (i.e., “cap”). This decision to review alternatives to waste removal recognized that excavating the waste with existing technology would pose high risks to remediation workers. These risks were estimated to be much higher than the risks posed to off-site receptors if the waste was stabilized in-situ with long-term institutional controls.

To enhance cleanup and lower risks to workers, the Department has invested in science and technology research. For example, DOE has developed a robotic vehicle that can be lowered into a confined space where radiation levels may be unsafe for workers. This vehicle is used to perform investigations and help prepare waste and contaminated equipment for removal.

Collateral Ecological Damage Caused by Remediation

At some DOE sites a potential remedy may result in greater ecological damage than would occur by leaving the contaminated site undisturbed. This is often the case for contaminated surface waters and sediments. At the Oak Ridge Reservation, for example, sediment in the Clinch River has been contaminated with mercury and PCBs. These contaminants are bound to the sediment in the river bottom, becoming immobile; therefore, they represent relatively little risk to a small subpopulation (e.g., subsistence fishermen). One remediation strategy would involve dredging the sediment from the river bottom. Dredging, however, would cause the contaminants to be resuspended and transported downstream, spreading contamination and increasing the potential for exposure. Dredging and constructing temporary roads would also destroy surrounding vegetation and damage nearby wetlands. Therefore, the selected remedial alternative in this case is to leave the sediment in place, thus requiring long-term stewardship to ensure that the contaminants remain immobile and that access is restricted to prevent or limit human exposure.

Long-Term Stewardship Activities

Long-term stewardship involves a wide variety of activities, depending on the nature of the site conditions and/or the residual hazards. Overall requirements for stewardship over these sites and hazards are prescribed by statute, and additional requirements to implement these requirements are contained in regulations and DOE directives. In some cases, implementation plans and programs are defined to some degree in site-specific documents such as land use planning documents, environmental compliance documents and compliance agreements. In other cases, the plans and programs are not yet defined, but the general requirements for long-term stewardship are still applicable.

This background document focuses on identifying the sites and the basic site activities where long-term stewardship is expected to be required. These site-level stewardship activities include two general categories:

1. Active controls entail performing certain activities to control risk at a site on a relatively frequent or continuous basis, such as operating, maintaining and monitoring the engineered controls implemented at sites, including caps, other physical barriers, and groundwater pump-and-treat systems. This could include practical tasks such as repairing fences and erosion gullies, and collecting water samples (or using less expensive monitoring technologies yet to be developed).
2. Passive controls generally entail less intensive tasks required to convey information about site hazards and/or limiting access through physical or legal means. Passive controls could include ensuring the continued effectiveness of applicable controls, including physical systems (e.g., fences and other barriers), governmental controls (e.g., ordinances and building permits), and proprietary controls (e.g., deeds and easements).

Decisions about these activities are expected to be part of the local decision-making process during cleanup (and have typically been included explicitly in long-term surveillance and monitoring permits for uranium mill tailings sites with the Nuclear Regulatory Commission (NRC)). They are introduced here to provide background for involving regulators, Tribal, state and local governments, and other stakeholders as those local decisions are made.

In addition, there are a variety of other tasks, which may not occur at a local site level, that will likely be needed for an effective long-term stewardship program. These include:

- Supporting and evaluating new technologies as they develop that may be useful in reducing the long-term stewardship costs, improving performance, or performing a permanent remedy that obviates the need for long-term stewardship as well as improving our understanding of the health and environmental impacts of residual contaminants;
- Emergency response;
- Compliance oversight;
- Natural and cultural resource management;
- Information management;
- Budget preparation, and other administrative support; and
- Site redevelopment, and community liaison and planning.

These issues are not addressed in as much depth in this background document, and are expected to be among the broader programmatic issues addressed in the study being performed pursuant to the December 1998 Settlement Agreement.

Other terminology has been used to describe long-term stewardship activities. For example, EPA regulations (40 CFR 191) define the term "institutional controls" to encompass all three of the types of activities considered as "long-term stewardship" in this background document. According to these regulations, active institutional control means:

- Controlling or cleaning up releases from a site;
- Performing maintenance operations or remedial actions at a site;
- Monitoring parameters related to disposal system performance; or
- Controlling access to a disposal site by any means other than passive institutional controls.

Passive institutional control means:

- Permanent markers placed at a disposal site;
- Government ownership and regulations regarding land or resource use;
- Public records and archives; and
- Other methods of preserving knowledge about the location, design, and contents of a disposal system.

Exhibit 5 illustrates some stewardship activities that may be conducted at the sites and highlights some of the technical uncertainties that the Department currently is facing (additional information on stewardship activities can be found in ICF 1998).

Mound Plant. Located in Miamisburg, Ohio, the plant was used to produce actuators, ignitors, and detonators for nuclear weapons. DOE has begun transferring parts of the site to the Miamisburg Mound Community Improvement Corporation for reuse as a commercial/industrial complex and is expected to complete most of this transfer by 2005. The site is being cleaned up to meet industrial land use standards, and institutional controls in the form of deed restrictions will be placed on the transferred property to maintain land use restrictions. *Mound Plant, Miamisburg, Ohio, May 1984.*

Waste Pit Area at Fernald. This area was used for the disposal of process-related waste generated when site workers converted uranium ore into uranium metal and fabricated it into target elements for reactors that produced weapons-grade plutonium and tritium. When remediation is complete at this site, all facilities will be demolished but a 138-acre disposal facility for radioactive and hazardous waste will remain onsite similar to the Weldon Spring Site (see page 7). The Fernald site will require institutional controls and groundwater monitoring at the disposal facility in perpetuity. Remediated areas will be available for conservation or recreational purposes. *Fernald Environmental Management Project, Ohio, January 1994.*

Exhibit 5: Examples of Potential Site Stewardship Activities and Technical Uncertainties

Media Potentially Subject to Stewardship	Possible Stewardship Activities	Examples of Technical Uncertainties
Water All contaminated groundwater and surface water sediments that cannot or have not been remediated to levels appropriate for unrestricted use	• Verification and/or performance monitoring • Use restrictions, access controls (site comprehensive land use plan) • Five-year (or comparable) review requirements • Resource management to minimize potential for exposure	• What is the likelihood that residual contaminants will move toward or impact a current or potential potable water source? • Are dense non-aqueous phase liquids (DNAPLs) or long-lived radionuclides present in concentrations and/or locations different than those identified? • Will treatment, containment, and monitoring programs remain effective and protective? • Will ambient conditions change significantly enough to diminish the effectiveness of the selected remedy (i.e., monitored natural attenuation) or allow resuspension of stabilized contaminants in sediments?
Soils All surface and subsurface soils where residual contamination exists or where wastes remain under engineered, vegetative, or other caps	• Institutional controls to limit direct contact or food chain exposure • Maintaining engineered, asphalt, or clean soil caps • Permit controls, use restrictions, markers (site comprehensive land use plan) • Five-year (or comparable) remedy review requirements	• What is the likelihood of future contaminant migration if ambient conditions change? • How will changes in land use affect the barriers in place to prevent contaminant migration and potential exposure? • What is the likelihood of cap failure sooner than anticipated? • What is the effect of contaminant degradation on remedy components (e.g., cap, vegetation)?
Engineered Units All land-based waste disposal units with engineered controls	• Monitoring and inspections, per agreements, orders, or permits • Institutional controls, including restricted land use • Maintenance, including repairing caps • Five-year (or comparable) review requirements • Land and resource planning to minimize potential for exposure (site comprehensive land use plans)	• What is the effect of contaminant degradation on remedy components (e.g., liners, leachate collection systems, caps)? • At what point in time will the remedy require significant repair or reconstruction? • Is the monitoring system robust enough to capture remedy failure?
Facilities Buildings and other structures that are no longer in use, which are contaminated, or whose future plans call for maintaining the structure with contamination in place	• Monitoring, inspections, and safeguard and securities measures • Access restrictions • Five-year (or comparable) review requirements • Site reuse or redevelopment controls to minimize the potential for exposure (site comprehensive land use plan)	• Will current controls remain adequate to maintain protection of facilities? • How will fixed residual contamination remain adequately controlled given current facility uses?

Low-Level Waste Disposal Site. This engineered trench at the Savannah River Site contains approximately 30,000 stacked carbon-steel boxes of waste with each box measuring 4 by 4 by 6 feet. In 1996 the trench was backfilled with dirt to form a mound, which was seeded with grasses and sloped to reduce runoff. Long-term monitoring and maintenance will be needed to ensure the integrity of this waste containment system. *Engineered Low-Level Trench 4, Savannah River Site, South Carolina, January 1994.*

Regulatory Context

The Department conducts its stewardship activities in compliance with applicable laws, regulations, interagency agreements, and site-specific compliance agreements. Appendix B highlights some of the more significant statutes affecting DOE.

The Atomic Energy Act provides authority for the Department to protect the health and safety of the public from hazards associated with sources of radiation under its control. This responsibility encompasses properties with radioactive material, including radioactive waste disposal facilities.

DOE's waste disposal practices are subject to a variety of post-disposal care requirements. Applicable laws, regulations, and DOE Orders vary by waste type (e.g., transuranic waste, low-level waste; see Appendix B); however, DOE is generally required to implement controls at waste disposal sites in perpetuity. For example, mill tailing standards promulgated by EPA (40 CFR 192) prescribe institutional control requirements such as land ownership and DOE oversight and maintenance of mill tailings disposal facilities. These activities are conducted by DOE under a permanent license issued by the NRC under 10 CFR 40. As another example, NRC licensing criteria being developed for the proposed geologic repository would require that passive control measures be designed to serve their intended purpose for as long as practicable (64 FR 8640).

Regulations applicable to waste disposal facilities may include design standards that have specific time frames associated with them. For example, 40 CFR 192.02(a) requires that controls for mill tailing sites be effective for up to 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years. Design standards having specified time frames are developed to balance capital costs with expected maintenance costs. Controls with a design criteria of 10,000 years would be very expensive to construct, but inexpensive to maintain. Controls with a design criteria of 100 years would be inexpensive to construct, but would require more maintenance. In any case, uranium mill tailings sites contain wastes containing uranium-238 and thorium-230 with half-lives of 4.47 billion years and 75,400 years, respectively. It therefore is expected that controls established for mill tailing sites will require monitoring and maintenance activities to be conducted far beyond the time frame of the design standards.

Regulatory requirements for disposal systems for transuranic waste require that these systems be designed to provide a reasonable expectation that the cumulative releases of radionuclides to the environment for 10,000 years will not exceed exposure standards (40 CFR 191.13 and 191.15). The 10,000 year period upon which the performance assessment for the disposal system is based is less than the half lives of common transuranic elements (see Exhibit 4). Also, the regulations for transuranic disposal systems do not allow applicants to assume that active institutional controls will be effective more than 100 years (40 CFR 191.14a), even though the regulations also require that the applicant maintain active institutional controls for as long a period as practicable after disposal (40 CFR 191.14(a)).

Stewardship and Land Use

Future land use, cleanup strategies, and long-term stewardship needs are interdependent. Future use goals are an important factor in determining cleanup strategies and associated stewardship needs. However, the technological and other limitations discussed earlier will limit the range of attainable future use options. Furthermore, ongoing DOE missions (e.g., safeguarding nuclear materials, maintaining waste disposal cells, research and development activities, and performing trustee responsibility for cultural and ecological resources) may predetermine future use for affected areas of sites.

In the absence of a future non-EM site mission, some DOE property, if releasable, can be declared excess and transferred to other Federal or non-Federal entities. Such transfers require legal agreements and institutional controls to maintain ongoing long-term stewardship responsibilities.

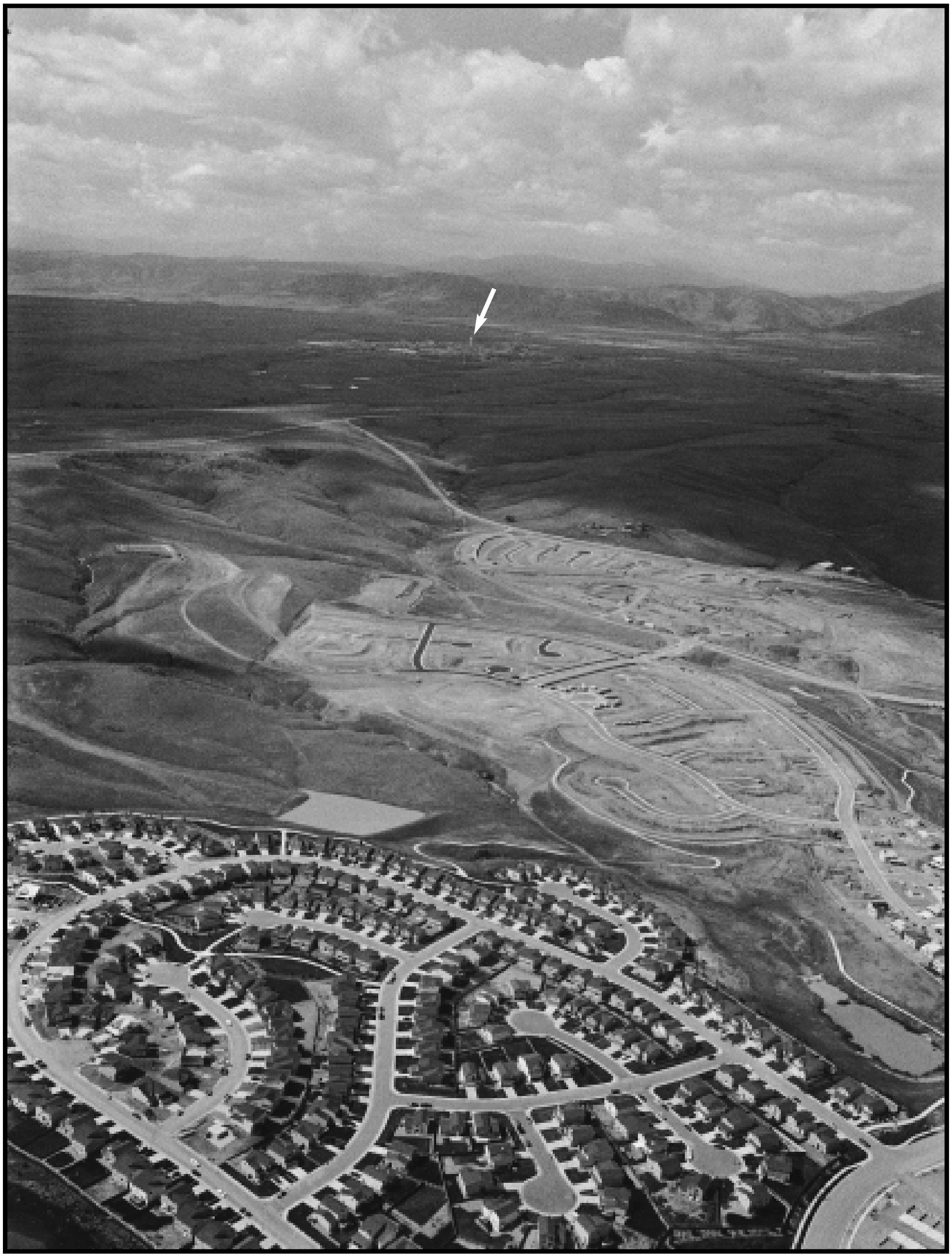
Exhibit 6 illustrates the importance of future use planning as urban areas expand and approach the boundaries of some of the Department's facilities.

A key element of many long-term stewardship programs will likely be the use of institutional controls—including governmental and proprietary controls—to ensure that land use restrictions are maintained. Local government controls include deed restrictions, zoning restrictions, permit programs, well-drilling restrictions, and other restrictions that are traditionally established by local governments. Proprietary controls include deed restrictions, easements, and restrictive covenants that are based on state property law. Successful implementation of these institutional controls will require coordination between Federal agencies as well as Tribal, state, and local governments.

Long-Term Stewardship Not Unique to DOE

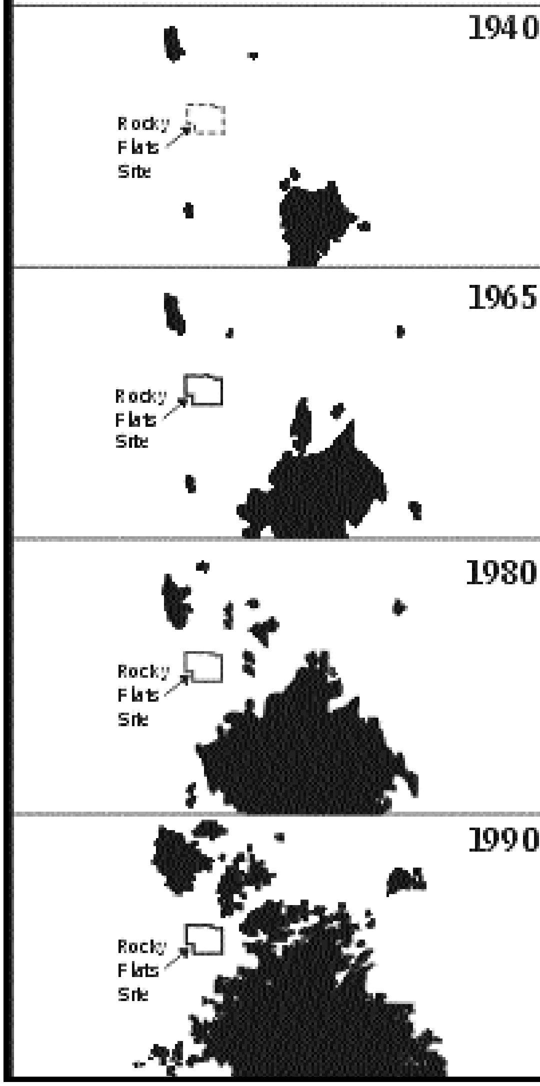
Although DOE sites are the subject of this report, stewardship responsibilities are not unique to the Department. At least three other Federal agencies are involved in cleanup programs at other sites that will result in residual hazards and require some type of stewardship after completion. The extent of long-lived radionuclide contamination distinguishes DOE from other Federal agencies, but the issues and challenges faced by other agencies are similar to those the Department must address.

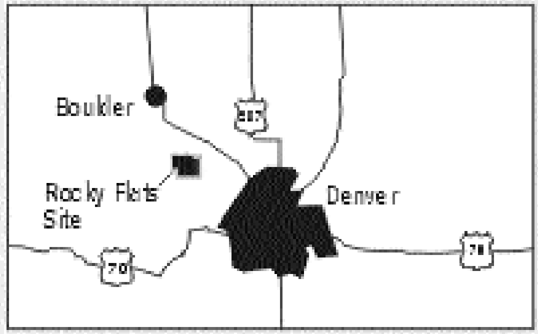
Representatives of EPA's Federal Facilities Restoration and Reuse Office have participated in long-term stewardship workshops sponsored by DOE and have recognized that long-term stewardship is critical to reducing the risk posed by remaining hazards. EPA is currently determining its stewardship responsibilities and is in the

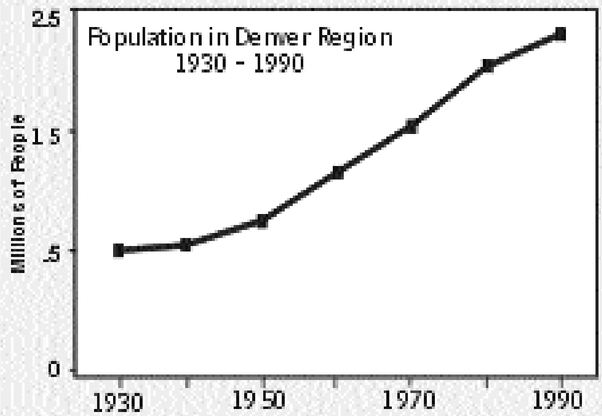


Residential Development Towards the Rocky Flats Environmental Technology Site. More than 2 million people live within a 50-mile radius of the Rocky Flats site, visible in the upper center of this photo. This population is expected to increase by 30 percent within the next 20 years. Residential areas now border the northeastern edge of the site's Buffer Zone. Current cleanup plans would result in an interim end state with caps over some soils and landfills, with the foundations and utilities of some facilities left in place, and with passive systems for treatment and containment of contaminated groundwater. Long-term stewardship requirements will include surveillance and maintenance of engineered caps, long-term monitoring of groundwater and surface water quality, and institutional controls to maintain land use restrictions. *Rocky Flats Environmental Technology Site, Colorado, September 1999.*

Exhibit 6: Demographic Changes Near the Rocky Flats Site







The Rocky Flats Site is located 17 miles northwest of Denver, Colorado. The site became operational in 1951. Four maps to the left illustrate the growth of suburban development from Denver to Boulder toward the once isolated Rocky Flats Site. The graph above charts the nearly five-fold population increase in the Denver area since 1930.

preliminary stages of reviewing options, including creating a stewardship program under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Resource Conservation and Recovery Act (RCRA) or amending the National Contingency Plan (NCP) to define post-closure responsibilities at Superfund sites.

In support of these initiatives, EPA has recently developed several guidance documents on the use and implementation of institutional controls. Both EPA Region IV and Region X have released policy documents on the use of institutional controls at Federal facilities, and EPA headquarters is developing a reference manual on institutional controls and their criteria at Federal facilities being transferred under CERCLA §120(h). EPA is also making progress in determining post-closure responsibilities at "brownfields" sites, which are abandoned, idled, or under-used industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contamination. However, the specific ways in which long-term institutional control issues are implemented vary considerably at state and local levels.

The Department of Defense (DoD) conducts cleanup activities at more than 10,000 sites - nearly

2,000 contaminated military installations and more than 9,000 formerly used defense properties – through its Defense Environmental Restoration Program. To some degree, remediation challenges posed by DoD sites are similar to those at DOE sites – they are often large tracts of land, frequently used for multiple purposes, and commonly contaminated with many constituents. Contamination at DoD facilities typically involves organic chemicals, such as solvents (e.g., trichloroethylene) or jet fuel; inorganic chemicals such as metals; and sometimes radioactive materials, though much less frequently and in much smaller quantities than at DOE sites. DoD sites also present similar stewardship challenges to those DOE is facing, including maintaining access controls; monitoring, pumping and treating groundwater; implementing monitored natural attenuation; and maintaining long-term caps. DoD faces unique, often difficult, challenges in determining the best way to remediate weapons ranges, many of which contain unexploded ordnance. Currently, DoD is working in several areas to address these and other long-term care issues. A multi-agency task force, led by the Air Force Base Conversion Agency, is preparing guidance for Defense installations on navigating the CERCLA and RCRA processes from the time the remedy is in place to the time of site closeout. The guidance, *The Road to Site Closure*, is expected to be final by spring of 2000. The draft document is available online at *http://www.afbca.hq.af.mil/closeout*.

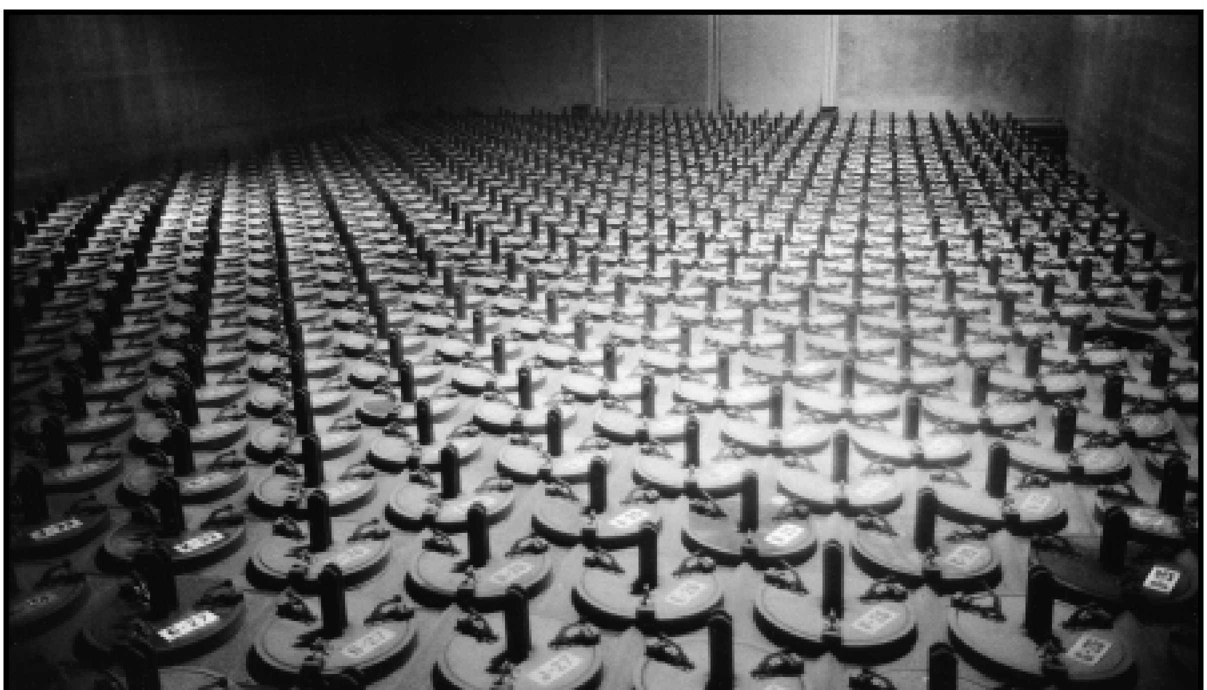
The Department of the Interior (DOI) is responsible for overseeing approximately 13,000 former mining sites, some of which have been abandoned by the original owners. Hazards remaining at former mining sites include byproducts such as tailings and leachates, blasting caps, wires, and open holes. Because many mining sites are so large, remediation is often infeasible and institutional controls will be heavily relied upon.

NRC regulates and licenses commercial, industrial, academic and medical uses of nuclear energy. NRC also regulates private sector and DOE uranium mill tailing sites cleanup projects and resulting disposal cells. NRC has developed regulations that address long-term stewardship at sites where unrestricted use is not attainable (10 CFR 20.1403(c)). These regulations require the facility to reduce residual radioactivity as low as reasonably achievable, provide for legally enforceable institutional controls, provide financial assurance for long-term control and maintenance of the site, submit a decommissioning plan, and demonstrate that annual doses will not exceed specified levels if the institutional controls are ineffective. Once the above requirements are met, NRC no longer regulates the site. Typically, oversight of the institutional controls and long-term stewardship is accepted by another Federal agency (including DOE) or a state or local government entity. For example, after NRC decommissioned mill buildings, consolidated mill tailings, and fenced off the disposal cell at the private Arco Bluewater facility in New Mexico, the site was transferred to DOE for long-term surveillance and monitoring.

The nation's commitment to long-term stewardship is not limited to radioactive materials, DOE sites, or Federal sites; it is intrinsic to the management of other types of waste and sources of contamination across the nation. For example, sanitary and hazardous landfills include long-lived hazardous constituents such as metals and organic compounds. Leachate from some of these landfills has contaminated groundwater resources. Furthermore, many industrial facilities and former waste management facilities (e.g., impoundments and storage facilities) contain long-lived hazardous constituents. At least part of the burden for long-term stewardship of these areas and facilities is likely to fall on state and local governments and/or the private sector.

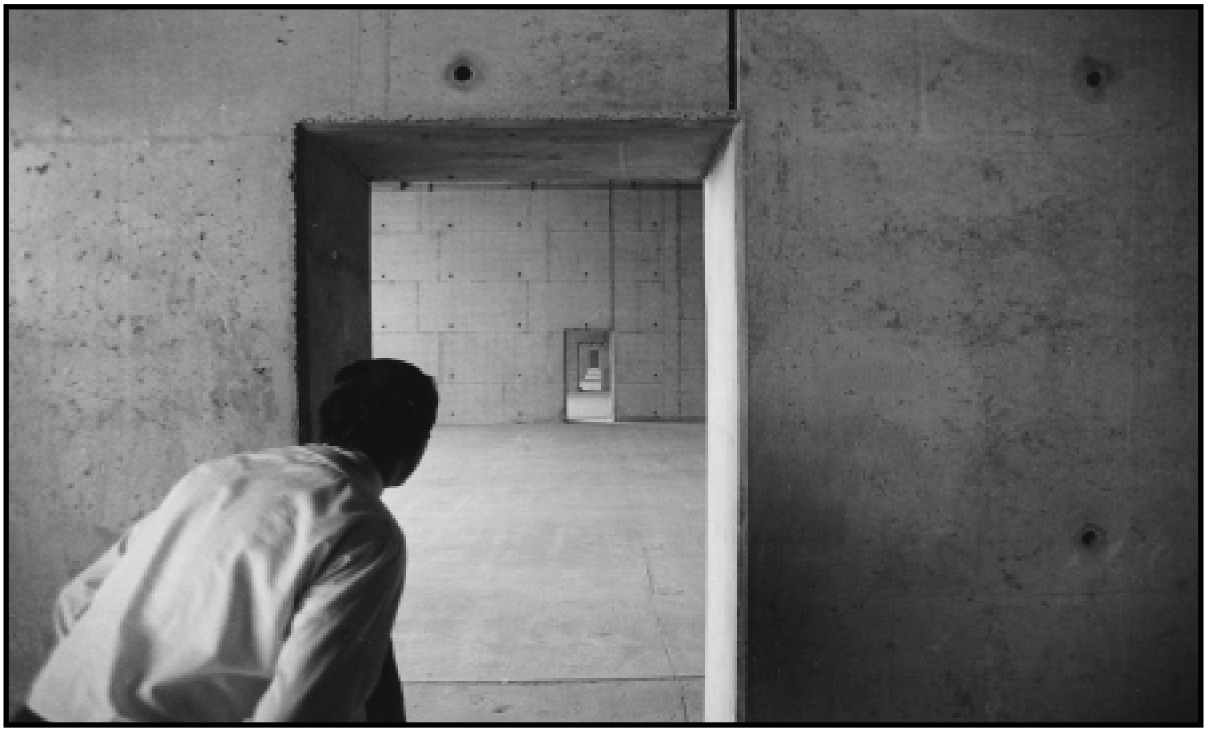
Given the diversity of issues and types of sites, the Department is seeking to coordinate its long-term stewardship activities with Federal, state and local officials, Tribes, and stakeholders.

Trinity Explosion Marker. Located in the Alamogordo Desert in southern New Mexico, this small obelisk marks ground zero at the Trinity Site, the exact location of the first atomic explosion that occurred on July 16, 1945. The site was designated a national historic landmark in 1975. Because the site is located within the White Sands Missile Range, a secured site maintained by DoD, visitors may access the site only two days a year. *Trinity Site, White Sands Missile Range, New Mexico, circa 1985.*



Irradiated Nuclear Fuel in Dry Storage. Spent nuclear fuel is a highly radioactive material that has not been reprocessed to remove the constituent elements. This waste must be stored in facilities that shield and cool the material. DOE plans to remove all spent nuclear fuel from the site by 2035 and dispose of it in the proposed geologic repository. *Building 603, Idaho Nuclear Technology and Engineering Center, formerly the Idaho Chemical Processing Plant, Idaho National Engineering and Environmental Laboratory, Idaho, March 1994.*

Chapter 2: Anticipated Long-Term Stewardship at DOE Sites



Low-Level Waste Vault. This vault at the Savannah River Site is used for storing low-level waste and contains 12 large cells, each 55 feet long, 150 feet wide, and 30 feet high. This vault replaces the previous waste management practice of burying low-level waste in shallow engineered trenches. Workers began storing waste in this vault in September 1994. Once it is full, it will be covered with clay, gravel, and a geotextile cap. These vaults will require environmental monitoring, institutional controls, and long-term surveillance and maintenance in perpetuity. *E Area Vault, Solid Waste Management Division, Savannah River Site, South Carolina, January 1994.*

This chapter summarizes the anticipated long-term stewardship needs at DOE sites, based on an analysis of existing information from field offices. It discusses the residual hazards at sites after cleanup projects are complete and examines the nature and extent of the stewardship activities likely to be needed.

Stewardship Expected at 109 Sites after Cleanup

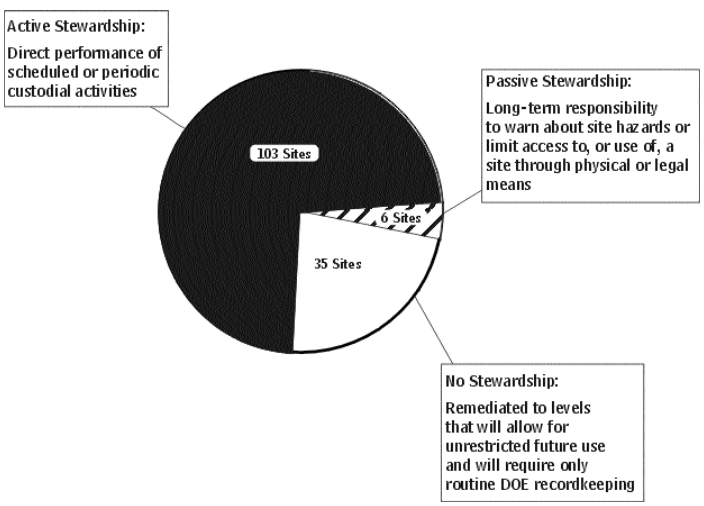
The Department first analyzed sites that might need stewardship by identifying sites where DOE has remediation, waste management, or nuclear materials and facility stabilization responsibilities. DOE then included in its analysis sites that have been (or will be) transferred to the Department for long-term care. This resulted in the Department's analyzing 144 sites in 31 states and one U.S. territory (see Appendix C). Of the 144 sites, 109 sites are expected to require some degree of long-term stewardship based on completed or planned cleanup strategies (see Exhibit 7). Most cleanup plans have already received some level of regulatory approval. The sites expected to require DOE stewardship range from small sites (approximately the size of a football field) with limited contamination, such as the General Atomics Site in California, to large and complex ones such as the Nevada Test Site (larger than the State of Rhode Island).

Exhibit 7: 109 Sites Are Expected to Require Long-Term Stewardship by DOE

35 Sites Not Expected to Require Stewardship by DOE

Alaska
Project Chariot (Cape Thompson)
California
Geothermal Test Facility
Oxnard Facility
Salton Sea Test Base
University of California
(Completed 98c -096543 site)
Connecticut
Seymour Specialty Wire
Florida
Peak Oil
Hawaii
Kauai Test Facility
Illinois
Granite City Steel
National Guard Armory
University of Chicago
Massachusetts
Chapman Valve
Ventron
Michigan
General Motors
New Jersey
Kellex/Pierpont
Middlesex Municipal Landfill
New Brunswick
New Mexico
Acid/Pueblo Canyons
Chupadera Mesa
Holloman Air Force Base
Pagano Salvage Yard
New York
Baker and Williams
Warehouses
Niagara Falls Storage Site
Vicinity Properties
Ohio
Alba Craft
Associated Aircraft
B&T Metals
Baker Brothers
Battelle Columbus Laboratory
King Avenue
Battelle Columbus Laboratory
West Jefferson
Herring-Hall Marvin Safe Co
Oregon
Albany Research Center
Pennsylvania
Aliquippa Forge
C.H. Schnoor
Shippingport
Tennessee
Elza Gate

Type of DOE Stewardship Activities Anticipated at 144 Sites in this Analysis



See Appendix C for details on methodology

Alaska
Amchitka Island
Arizona
Monument Valley[1]
Tuba City[1]
California
Energy Technology Engineering Center
General Atomics
General Electric Vallecitos Nuclear Center
Laboratory for Energy Related Health Research
Lawrence Berkeley Laboratory
Lawrence Livermore National Laboratory - Main Site and Site 300
Sandia National Laboratories
Stanford Linear Accelerator Center
Colorado
Burro Canyon Disposal Site
Cheney Cell
Cotter, Canon City[2]
Durango[1]
Estes Gulch
Grand Junction Office[1]
Gunnison Mill Site[1]
HECLA, Durita[2]
Maybell Mill Site[1]
Naturita Site[1]
New Rifle Site[1]
Old Rifle Site[1]
Project Rio Blanco Site
Project Rulison
Rocky Flats Environmental Technology Site
Slick Rock/Old North Continent[1]
Slick Rock/Union Carbide[1]
UMETCO, Maybell[2]
UMETCO, Uravan[2]
Florida
Pinellas Plant
Idaho
Argonne National Laboratory - West
Idaho National Engineering and Environmental Laboratory
Lowman[1]
Illinois
Argonne National Laboratory - East
Fermi National Accelerator Laboratory
Site A/Plot M, Palos Forest Preserve
Iowa
Ames Laboratory
Kentucky
Maxey Flats Disposal Site
Paducah Gaseous Diffusion Plant
Mississippi
Salmon Test Site
Missouri
Kansas City Plant
Weldon Spring Site Remedial Action Project
Nebraska
Hallam Nuclear Power Facility
Nevada
Central Nevada Test Site
Nevada Test Site
Project Shoal Test Site
New Jersey
Princeton Plasma Physics Laboratory
New Mexico
Ambrosia Lake[1]
Arco Bluewater[2]
Bayo Canyon[3]
Homestake, Grants[2]
Los Alamos National Laboratory
Lovelace Respiratory Research Institute
Project Gas Buggy
Project Gnome-Coach Test Area
Quivera, Ambrosia Lake[2]
Sandia National Laboratories
Shiprock[1]
SOHIO, L-Bar[2]
South Valley Superfund Site
UNC, Church Rock[2]
Waste Isolation Pilot Plant
New York
Brookhaven National Laboratory
Separations Process Research Unit
West Valley Demonstration Project
Ohio
Ashtabula
Fernald Environmental Management Project
Mound Plant
Piqua Nuclear Power Facility
Portsmouth Gaseous Diffusion Plant
Oregon
Lakeview[1]
Pennsylvania
Burrell[1]
Canonsburg [1]
Puerto Rico
Center for Energy and Environmental Research
South Carolina
Savannah River Site
South Dakota
Edgemont Vicinity Properties[2]
Tennessee
Oak Ridge Associated Universities
Oak Ridge Reservation
Texas
Chevron, Panna Maria[2]
Conoco, Conquista[2]
Exxon, Ray Point[2]
Falls City[1]
Pantex Plant
Utah
Atlas, Moab[2]
EFN, White Mesa[2]
Green River[1]
Mexican Hat[1]
Monticello Millsite & Vicinity Properties
Plateau, Shootaring[2]
Rio Algom, Lisbon Valley[2]
Salt Lake City[1]
Salt Lake City, Clive
Washington
Dawn, Ford[2]
Hanford Site
WNI, Sherwood[2]
West Virginia
Amax[4]
Wyoming
ANC, Gas Hills[2]
Exxon, Highlands[2]
Kennecott, Sweetwater[2]
Pathfinder, Lucky Mac[2]
Pathfinder, Shirley Basin[2]
Petrotomics, Shirley Basin[2]
Riverton[1]
Spook[1]
UMETCO, Gas Hills[2]
Union Pacific, Bear Creek[2]
WNI, Split Rock[2]

1. UMTRA Program Title I 2. UMTRA Program Title II 3. FUSRAP 4. NWPA

Stewardship Information

This report represents the Department's first attempt to quantify the likely scope of its stewardship activities. As such, data were not available to adequately address all issues relative to stewardship, such as natural, cultural, ecological, or human health risk.

DOE has used available information from field office personnel to catalogue known end states where cleanup has already been completed and projected end states where cleanup is ongoing. The primary source was data submitted in support of the 1998 *Accelerating Cleanup: Paths to Closure* report. DOE used the known and projected end state information to identify those sites where residual contamination in facilities and/or media (i.e., water, soil, and engineered units) would likely remain and to estimate the scope and duration of stewardship activities needed.

It is important to note that because of the lack of detailed data available for most sites, all information is summarized at the site level, instead of for each waste or contamination area within a site (e.g., Hanford, Fernald, and the Salmon Site are each considered one site, despite the differences in size and complexity) [see Appendix C].

Assumed end states and associated stewardship activities for each site are summarized in Appendix E. Appendix E is not included in the print version of this document due to its length. It is, however, available on the long-term stewardship web site *(www.em.doe.gov/lts)* and, by request, from the EM Information Center (1-800-736-3282).

Nature and Extent of Stewardship Activities

The nature and extent of anticipated long-term stewardship activities at the 109 sites will vary based on the amount and type of residual contamination, the anticipated future site uses, and other factors (e.g., proximity to a river and floodplain). To understand how stewardship activities can vary across sites, DOE analyzed the level of stewardship (e.g., active or passive) as well as the types of activities likely to be needed.

Appendix C presents more detailed information on the methodology used for this report.

Level of Stewardship – Active and Passive

Of the 109 sites currently expected to require stewardship, 103 are expected to require active stewardship (see Exhibit 7). Active stewardship ranges from detection monitoring on a continuous or periodically recurring basis, to enforcing access and use restrictions. Sites expected to require active stewardship vary in size and complexity.

DOE is expected to rely solely on passive stewardship at only 6 of the 109 long-term stewardship sites. Passive stewardship requires less oversight and care. Enduring obligations may include permanent markers or public records to convey information on previous uses or residual contamination. Sites where DOE expects to rely on passive controls include General Atomics and General Electric in California, where excavation and removal of contamination occurred to levels allowing for industrial use, and where NRC has released the site without radiological restrictions, but where DOE will need to maintain records of previous activities or residual contamination.

Long-term stewardship by DOE is not currently anticipated at 35 sites, most of which were remediated under the Formerly Utilized Sites Remedial Action Program (FUSRAP; see Exhibit 8). However, a record of the extent of cleanup will need to be maintained at a central DOE or Federal archiving facility.

The number of sites where DOE has stewardship responsibility may increase over time. Additional sites may be identified and added to DOE's responsibility under existing or new laws. The Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978 directs DOE to stabilize, dispose of, and control uranium mill tailings at inactive mill sites. Sites included under Title I of UMTRCA are those that operated prior to 1978, and where all uranium was produced for sale to the Federal Government. Title II of UMTRCA includes privately owned sites that were operating under

Exhibit 8: The Formerly Utilized Sites Remedial Action Program (FUSRAP)

From the 1940s through the 1960s, some of the work to support early nuclear weapons and energy programs was done by private companies at hundreds of locations throughout the United States. These companies performed numerous activities, including processing, storing, sampling, assaying, extruding, or machining radioactive materials. After completion of the work, the sites were decontaminated and released for other use under the cleanup guidelines in effect at the time. Because those standards were less stringent than current guidelines, radioactive materials remained at some sites. The waste at these sites consists primarily of low concentrations of uranium, radium, and thorium on building surfaces and in the soil. Over the years, contamination at some sites has spread to vicinity properties, primarily through the soil or air, as the result of releases from operating facilities when buildings were dismantled, or when materials were moved (DOE 1997b).

In the 1970s, the Atomic Energy Commission (a predecessor of the DOE) recognized that some sites did not meet current radiological release standards. In response, the FUSRAP program was established.

The early years of FUSRAP were spent researching the locations of these contract operations and conducting radiological surveys to determine whether the sites were contaminated above current standards. Cleanup work at the sites began in the late 1970s. Over 400 locations were assessed, and 46 sites in 14 states were designated for remediation through the FUSRAP program. Several of these sites are commercial operations that processed radioactive materials for profit and were subsequently designated for remediation by DOE at the request of Congress.

In October 1997, the Energy and Water Development Appropriations Act for fiscal year 1998 transferred responsibility for the administration and execution of the FUSRAP program from DOE to the U.S. Army Corps of Engineers. At the time of the transfer on October 13, 1997, DOE had completed the cleanup of 25 of the 46 FUSRAP sites.

The Department worked in conjunction with the Corps to ensure a smooth transition of the program. The Department and the Corps signed a Memorandum of Understanding (MOU) in March 1999 identifying the roles and responsibilities for cleanup and post-closure care of FUSRAP sites. The MOU establishes DOE's responsibility for any long-term stewardship required at the 25 FUSRAP sites where the Department completed cleanup activities prior to October 13, 1997. For the remaining 21 sites assigned to the Corps for remediation (see Appendix C for a list of these sites), the MOU assigns responsibility to DOE for any required long-term stewardship. These sites will be transferred to DOE for long-term stewardship two years after the Corps completes remedial actions. However, the cleanup decisions for these sites are not yet final and, therefore, the level of stewardship required for these sites, if any, is not yet known (MOU 1999).

a NRC license in 1978 when the Act was signed. Title II gave NRC the responsibility for transferring these sites to DOE, to another Federal agency, or to a state for long-term care after their licenses are terminated.

According to the Nuclear Waste Policy Act (NWPA), low-level radioactive waste disposal sites (with privately held licenses) can be transferred to DOE upon termination of the site's license (NWPA, Subtitle D, Section 151(b)). DOE is authorized to take title of these sites if NRC determines the transfer to be desirable, of no cost to the government, and necessary in order to protect human health and the environment. The NWPA also states that if low-level radioactive waste is the result of a licensed activity to recover zirconium, hafnium, and rare earth metals from source material, DOE shall assume title and custody of the site if requested by the site owner (NWPA, section 151(c)). For example, in 1994, the Secretary of Energy assumed title to the Amax site in West Virginia under this section.

Conversely, some sites may be removed from DOE's long-term stewardship responsibility, or sites may require stewardship for only a finite period. As contaminants decay, or if standards become less restrictive, the number of sites and the level of long-term stewardship required will decrease. In addition some sites may require long-term stewardship, but not by the Department. For example, at the request of the State of North Dakota, DOE revoked the UMTRCA designation of the Belfield and Bowman, North Dakota sites. As a result of the revocation, effective May 18, 1998, the sites will no longer require remediation under UMTRCA, and the State of North Dakota will be responsible for any long-term stewardship required at the sites.

Exhibit 9: Residual Contaminants and Anticipated Stewardship by Site and Media

State	Site Name	Soil					Water					Engineered Units						Facilities				
							VOCs	Metals	Rads	PCBs	Steward	Haz	MW	LLW	San/SW	TRU	Steward	VOCs	Metals	Rads	PCBs	Steward
Alaska	Amchitka Island	●		●		A			●		A						N					N
Arizona	Monument Valley			●		P			●		A						N					N
	Tuba City			●		P			●		A			●			A					N
California	Energy Technology Engineering Center	●			●	P	●		●		A	●					A		●	●		A
	General Atomics		●	●		P					N						N			●		N
	General Electric Vallecitos Nuclear Center					N					N						N			●		P
	Laboratory for Energy Related Health Research			●		A					N						N			●		P
	Lawrence Berkeley Laboratory	●	●			A	●		●		A						N			●	●	P
	Lawrence Livermore National Laboratory - Main Site	●		●		A	●		●		A			●			A			●		P
	Lawrence Livermore National Laboratory - Site 300	●			●	A	●		●		A		●				A					P
	Sandia National Laboratories/ California	●				P	●				A				●		A					N
	Stanford Linear Accelerator Center	●			●	A	●			●	A						N					N
Colorado	Burro Canyon Disposal Site					N					N			●			A					N
	Cheney Cell			●		P			●		A			●			A					N
	Cotter, Canon City					N			●		A			●			A					N
	Durango			●		P		●	●		A			●			A					N
	Estes Gulch			●		P			●		P			●			A					N
	Grand Junction Office			●		P			●		A						N			●		P
	Gunnison Mill Site			●		P			●		A			●			A					N
	HECLA, Durita					N			●		A			●			A					N
	Maybell Mill Site			●		P		●	●		P	●		●			A					N
	Naturita Site			●		P		●	●		A						N					N
	New Rifle Site			●		P		●	●		A						N					N
	Old Rifle Site			●		P		●	●		A						N					N
	Project Rio Blanco Site			●		A			●		A						N					N
	Project Rulison			●		A			●		A						N					N
	Rocky Flats Environmental Technology Site	●	●	●		A	●		●		A	●		●	●		A		●	●		P
	Slick Rock/ Old North Continent			●		P		●	●		A						N					N
	Slick Rock/ Union Carbide			●		P			●		A						N					N
	UMETCO, Maybell					N			●		A			●			A					N
	UMETCO, Uravan					N			●		A			●			A					N
Florida	Pinellas Plant					N	●				A						N					N
Idaho	Argonne National Laboratory - West		●	●		A		●	●		A						N			●		P
	Idaho National Engineering and Environmental Laboratory	●	●	●		A	●	●	●		A	●	●	●		●	A	●	●	●		A
	Lowman			●		P					A			●			A					N
Illinois	Argonne National Laboratory - East	●	●	●	●	A	●	●	●	●	A			●	●		A		●	●		P
	Fermi National Accelerator Laboratory				●	P					N						N					N
	Site A/Plot M, Palos Forest Preserve		●	●		A		●	●		A						N					N
Iowa	Ames Laboratory			●		A	●		●		A						N			●		P
Kentucky	Maxey Flats Disposal Site	●	●	●		A	●	●	●		A						N					N
	Paducah Gaseous Diffusion Plant	●		●	●	A	●		●	●	A	●		●	●	●	A	●	●	●	●	P
Mississippi	Salmon Test Site	●		●		P			●		A						N					N
Missouri	Kansas City Plant	●			●	A	●				A						N					N
	Weldon Spring Site Remedial Action Project			●		P	●		●		A		●				A					N
Nebraska	Hallam Nuclear Power Facility					N		●	●		A						N			●		A
Nevada	Central Nevada Test Site	●				P			●		A						N					N
	Nevada Test Site			●		A			●		A		●	●			A			●		A
	Project Shoal Test			●		P			●		A						N					N
New Jersey	Princeton Plasma Physics Laboratory	●				P	●				A						N					N
New Mexico	Ambrosia Lake			●		P			●		P			●			A					N
	Arco Bluewater					N			●	●	A	●		●			A					N
	Bayo Canyon			●		P					N						N					N
	Homestake, Grants					N			●		A			●			A					N
	Los Alamos National Laboratory	●	●	●		A			●		A		●				A	●	●	●		P
	Lovelace Respiratory Research Institute			●		P	●				A						N					N
	Project Gas Buggy			●		P			●		A						N					N
	Project Gnome-Coach Test Area			●		P			●		A						N					N

KEY:

A=Active Stewardship by DOE	N=No Stewardship by DOE	VOCs=Volatile Organic Compounds
MW=Mixed Waste	PCBs=Polychlorinated Biphenyls	P=Passive Stewardship by DOE
Rads=Radionuclides	LLW=Low Level Waste	Haz=Hazardous Waste
San/SW=Sanitary/Solid Waste	TRU=Transuranic	Steward=Anticipated Stewardship Requirements

Exhibit 9: (Continued)

State	Site Name	Soil					Water					Engineered Units						Facilities				
					PCBs	Steward	VOCs	Metals	Rads	PCBs	Steward	Haz	MW	LLW	San/SW	TRU	Steward	VOCs	Metals	Rads	PCBs	Steward
New Mexico (cont)	Quivera, Ambrosia Lake					N			●		A			●			A					N
	Sandia National Laboratories/New Mexico		●	●	●	P	●	●	●		A	●	●				A					N
	Shiprock			●		P		●	●		A			●			A					N
	SOHIO, L-Bar					N			●		A			●			A					N
	South Valley Superfund Site	●				P	●				A						N					N
	UNC, Church Rock					N			●		A			●			A					N
	Waste Isolation Pilot Plant			●		P			●		A					●	A					N
New York	Brookhaven National Laboratory	●		●		A	●	●	●		A	●		●	●		A			●		A
	Separations Process Research Unit			●		P					N						N			●		N
	West Valley Demonstration Project			●		P			●		P			●			P			●		P
Ohio	Ashtabula	●		●		P	●		●		A						N					P
	Fernald Environmental Management Project			●		P			●		A	●	●	●			A			●		N
	Mound Plant	●	●	●		P	●	●	●		A						N			●		A
	Piqua Nuclear Power Facility					N					N						N		●	●		A
	Portsmouth Gaseous Diffusion Plant	●	●	●	●	A	●	●	●		A	●		●	●		A		●	●	●	A
Oregon	Lakeview			●		P		●	●		A			●			A					N
Pennsylvania	Burrell					N			●		A			●			A					N
	Canonsburg			●		P			●		A			●			A					N
Puerto Rico	Center for Energy and Environmental Research					N					N						N			●		A
South Carolina	Savannah River Site	●	●	●	●	A	●	●	●		A	●		●	●		A	●	●	●	●	A
South Dakota	Edgemont Vicinity Properties					N					N			●			A					N
Tennessee	Oak Ridge Associated Universities					N	●				P						A					N
	Oak Ridge Reservation	●	●	●	●	A	●	●	●	●	A	●	●	●	●		A		●	●	●	A
Texas	Chevron, Panna Maria					N			●		A			●			A					N
	Conoco, Conquista					N			●		A			●			A					N
	Exxon, Ray Point					N			●		A			●			A					N
	Falls City			●		P		●	●		A			●			A					N
	Pantex Plant	●	●	●		P	●	●			A				●		A			●		P
Utah	Atlas, Moab					N			●		A			●			A					N
	EFN, White Mesa					N			●		A			●			A					N
	Green River			●		P		●	●		A			●			A					N
	Mexican Hat			●		P		●	●		A			●			A					N
	Monticello Millsite & Vicinity Properties		●	●		A		●	●		A			●			A					N
	Plateau, Shootaring					N			●		A			●			A					N
	Rio Algom, Lisbon Valley					N			●		A			●			A					N
	Salt Lake City			●		P		●	●		A						N					N
	Salt Lake City, Clive					N			●		A			●			A					N
Washington	Dawn, Ford					N			●		A			●			A					N
	Hanford Site	●	●	●		A	●		●		A		●	●		●	A		●	●		A
	WNI, Sherwood					N			●		A			●			A					N
West Virginia	Amax					N		●	●		A			●			A					N
Wyoming	ANC, Gas Hills					N			●		A			●			A					N
	Exxon, Highlands					N					A			●			A					N
	Kennecott, Sweetwater					N			●		A			●			A					N
	Pathfinder, Lucky Mac					N			●		A			●			A					N
	Pathfinder, Shirley Basin					N			●		A			●			A					N
	Petromics, Shirley Basin					N			●		A			●			A					N
	Riverton			●		P		●	●		A						N					N
	Spook					P		●	●		P			●			A					N
	UMETCO, Gas Hills					N			●		A			●			A					N
	Union Pacific, Bear Creek					N			●		A			●			A					N
	WNI, Split Rock					N			●		A			●			A					N
Total		28	17	60	11		28	29	99	5		12	9	81	9	4		4	11	28	5	

KEY:
A=Active Stewardship by DOE; N=No Stewardship by DOE; VOCs=Volatile Organic Compounds
MW=Mixed Waste; PCBs=Polychlorinated Biphenyls; P=Passive Stewardship by DOE
Rads=Radionuclides; LLW=Low Level Waste; Haz=Hazardous Waste
San/SW=Sanitary/Solid Waste; TRU=Transuranic; Steward=Anticipated Stewardship Requirements

Rulison Groundwater Monitoring Well. In September 10, 1969, a 43-kiloton nuclear explosive device was detonated at Rulison, Colorado 8,426 feet below ground surface. Today, subsurface rights to the approximately 40-acre parcel are controlled by the Federal Government to prevent excavation, drilling, or removal of materials below a depth of 6,000 feet. In addition, the U.S. Environmental Protection Agency regularly monitors an existing network of wells, springs, and the adjacent Battlement Creek for the movement of radionuclide contaminants in groundwater. *Project Rulison Site, Colorado, June 1999.*

Stewardship by Media Type: Water, Soil, Engineered Units, and Facilities

The nature and extent of stewardship will vary depending on which media are contaminated. To better understand the magnitude of the challenges, DOE identified for each site four categories of media that will likely remain contaminated: soil, water, engineered units, and facilities (see Exhibit 9 on preceding page).

Water includes groundwater, surface water and sediments. Groundwater at approximately 100 sites is expected to require long-term stewardship. The types of stewardship activities will range from future use restrictions to continuous pumping. In some cases (e.g., South Valley Superfund Site, New Mexico), the Department must supply alternate sources of drinking water to local residents. In other cases, such as many former uranium mill sites, background levels of contaminants are high and/or the natural quality of the aquifer is poor due to brine; however, mining and milling activities resulted in elevated levels of uranium in the groundwater. At those mill sites where groundwater cleanup is neither feasible nor warranted (e.g., Ambrosia Lake, New Mexico), monitored natural attenuation processes will be relied on to reduce contaminant levels. No active groundwater remediation will be performed. At some mill sites where groundwater is contaminated (e.g., Durango, Colorado), the Department is proposing monitored natural attenuation as the most appropriate remedy. In addition, contaminated surface waters (including sediments) also may require attention and long-term care.

N Reactor along the Columbia River. Originally, the river provided cooling water for the reactor. Spent nuclear fuel has been stored in the “wet storage” (water filled) basins in this complex of buildings supporting the reactor, which ceased operations in 1987. Because of corrosion of the cladding of the spent fuel rods, approximately 15 million gallons of water contaminated with strontium-90 has been released into the groundwater. DOE has installed a groundwater pump-and-treat system to control the movement of the contaminated groundwater. Institutional controls will remain in place at the site indefinitely to restrict groundwater use, and the semi-annual monitoring will continue for at least 30 years after closure of the last facilities. *N Reactor, Hanford Site, Washington, July 1994.*

Oak Ridge Waste Pond. This waste pond, in the south-central part of Oak Ridge National Laboratory’s main plant area, contains radiologically-contaminated sediments resulting from settling of low-level radioactive liquid wastes generated from experiments and material processing at the laboratory. The radionuclides contained in the sediment include americium, cesium, cobalt, plutonium, and strontium. *Oak Ridge National Laboratory, Tennessee, January 1994.*

Source of Soil Contamination. This exhaust stack was the source of emissions from the Fernald site's enriched uranium materials processing facility. The malfunctioning of systems like this resulted in releases of several hundred tons of uranium dust into the environment. Although remediation of contaminated soil can restore the Fernald site to an "end state" that serves a number of alternative land uses, residential and agricultural uses will not be considered. Institutional controls will be implemented to ensure that these restrictions are upheld. *Plant 9, Fernald Environmental Management Project, Ohio, December 1993.*

Soil includes release sites, burn pits, burial grounds, and areas contaminated from underground utilities, tanks, or surrounding buildings. Stewardship of contaminated soil is anticipated at 71 sites. At some sites, soil stewardship is driven by subsurface rather than surface contamination. At the "Nevada Offsites" (former nuclear test sites in Alaska, Colorado, Nevada, New Mexico, and Mississippi), extensive subsurface contamination exists from conducting underground nuclear tests. Because no cost-effective technology yet exists to remediate these types of subsurface contamination, they will continue to pose hazards over the long-term. Stewardship activities will be required to prevent people from intruding into these areas in the future.

Pit 9 Radioactive Waste Burial Ground. Engineers gather on the edge of Pit 9 to discuss remediation strategies for this burial ground where, from 1967 to 1969, approximately 150,000 cubic feet of transuranic and low-level waste were buried; but poor record-keeping of past disposal practices has made it difficult to calculate what lies beneath the surface here today. The lack of technologies to fully remediate this area will result in long-term stewardship responsibilities. *Radioactive Waste Management Complex, Idaho National Engineering and Environmental Laboratory, Idaho, March 1994.*

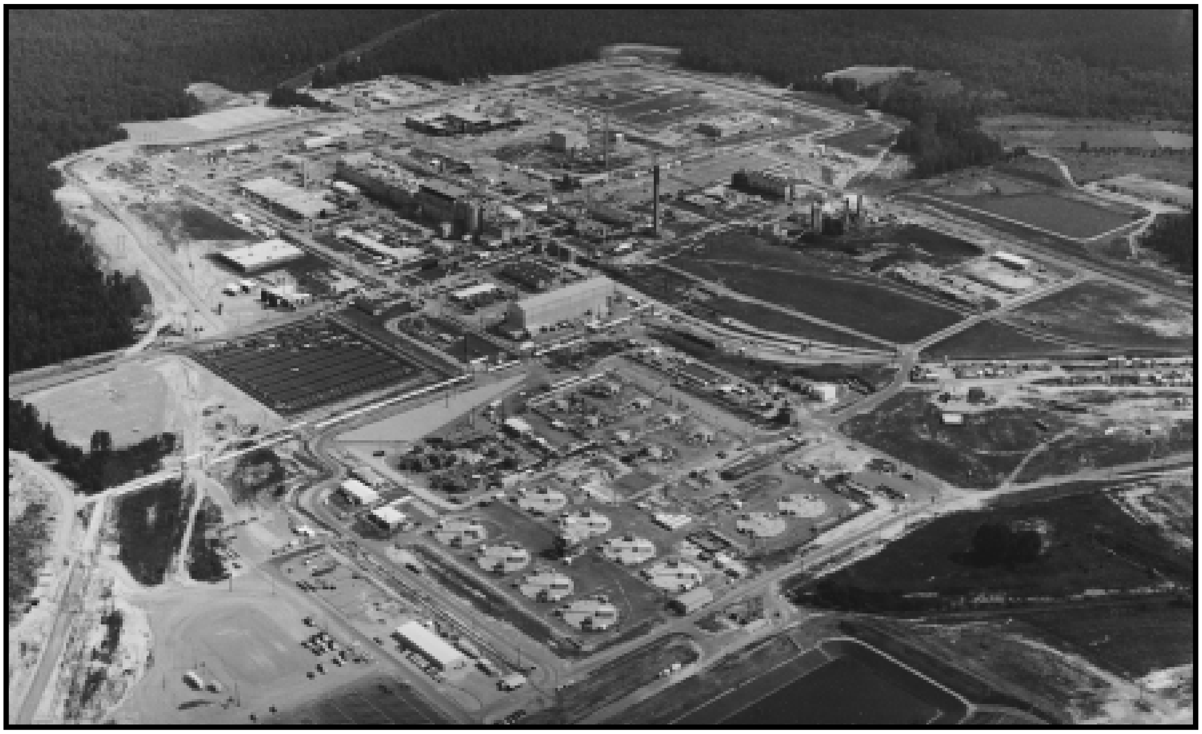
The Nevada Test Site. Atmospheric nuclear explosions here resulted in widely dispersed surface soil contamination. The warning sign is an example of passive stewardship; it reads "**Potential Radiation Hazard** Before any major excavation or earth-moving operation contact RAD-SAFE at C.P.2 tel 2571." *Nevada Test Site, near Mercury, Nevada, October 1984.*

Landfill with RCRA Cap. Ten acres of black, high-density polyethylene cover a mixed waste landfill at the Oak Ridge Reservation. The cap is designed to prevent gases from escaping, reduce erosion, and keep rainwater from leaching contaminants into groundwater. Installed in 1989, the cap is designed to last from 15 to 20 years. Maintenance and monitoring will be required at least until 2019. *Solid Waste Storage Area 6, Oak Ridge Reservation, Tennessee, January 1994.*

Engineered units include radioactive, hazardous, and sanitary landfills; vaults; and tank farms with man-made containment systems. Engineered units at 70 sites are expected to require some level of stewardship activity. These include units such as the Environmental Restoration Disposal Facility (ERDF) and the high-level waste tanks at the Hanford Site. Engineered units generally contain large volumes of waste and contamination and include areas where the most highly contaminated wastes have been consolidated for permanent disposal or long-term retrievable storage. Engineered units will require active stewardship activities such as leachate collection, cap maintenance, erosion control, and access restriction. Data on the size and number of all the engineered units that will remain on DOE sites were not readily available for this analysis. Some sites, however, provided the precise number and size of engineered units that will remain onsite, with most sites containing only one or two units at closure.

Tuba City Disposal Cell, Arizona. A total of 1,100,00 cubic meters of contaminated materials was stabilized onsite in a 50-acre disposal cell. The disposal cell has a radon barrier cover and rock surface layer to control erosion. Long-term surveillance and monitoring activities at the disposal cell include annual surface inspections and a 10-year revegetation program. The Tuba City Site consisted of 42 acres. Nine acres were covered by the uranium mill tailings pile, 18 acres were former evaporation ponds, and the remaining acres were contaminated by wind-blown materials. DOE will continue routine groundwater compliance monitoring after groundwater remediation is complete in 2010. *Tuba City Uranium Mill Tailings Repository, Tuba City, Arizona, June 1998.*

Low-Level Waste Disposal Vault. This vault for low-level waste is located at the Savannah River Site. It is a reinforced concrete structure 25 feet tall, 600 feet long, and 200 feet wide. It houses 12 concrete cells that will be filled with solid grout ("saltstone") made by mixing a low-level waste solution with cement, fly ash, and slag. Radionuclides in the grout will include technetium-99, strontium-90, and cesium-137. Once all 12 cells are filled, the vault will be covered with earth and capped with clay. Active maintenance and monitoring will be required, along with passive institutional controls to prevent intrusion. *Z-Area Vault, Savannah River Site, South Carolina, January 1994.*

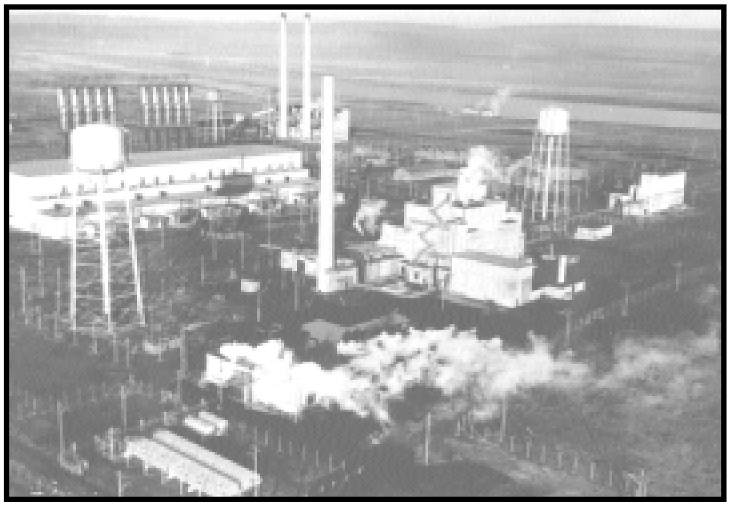


F-Area at the Savannah River Site. A number of facilities in this ½ square mile area will remain contaminated indefinitely because of a lack of cost-effective technologies available to remove the intense levels of radioactivity. The reprocessing "canyon" near the center of the photo is still operating, but, even after deactivation and decommissioning, it is unlikely to ever be decontaminated sufficiently to allow for unrestricted use. The underground storage tanks in the lower part of the photo will contain residual waste after most of the high-level waste has been removed for vitrification. Grout (similar to concrete) has been poured in the "emptied" tanks to immobilize the residual waste and prevent the buried tank shells from collapsing. *F Area, Savannah River Site, South Carolina, August 1983.*

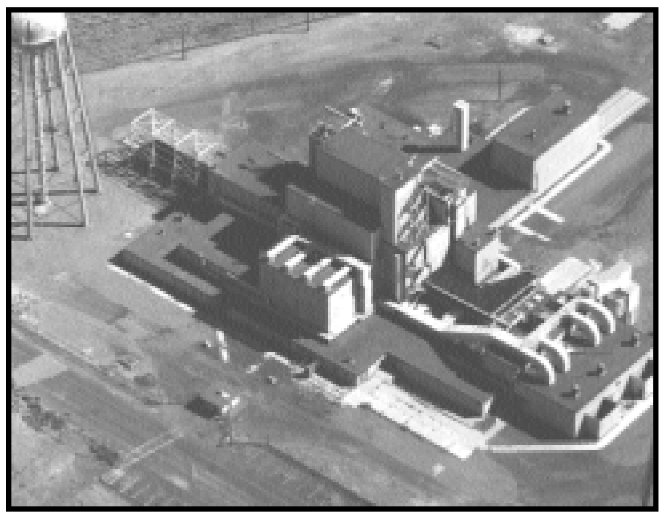
Facilities include entombed reactors, canyons and other buildings with residual contamination, as well as remaining infrastructure. Contaminated facilities will remain at as many as 32 sites. Many of the currently contaminated buildings across the complex will be fully demolished and will only require stewardship for an interim phase prior to decontamination and demolition.

Most contaminated facilities can be addressed by decontamination or demolition and disposal. Consequently, contaminated facilities typically pose less of a technical challenge for cleanup and stewardship than underground storage and disposal situations, such as high-level waste tanks. Nonetheless, certain contaminated facilities pose significant stewardship challenges, such as the nuclear production reactors and chemical separations facilities (reprocessing "canyons"). These facilities are very large, with extensive radionuclide contamination that is both intense and long-lived, and that could pose risks to workers conducting remediation activities. There are no specific plans as yet for the final disposition of the canyons. One option being considered is to demolish the buildings, bury them in place, and place an engineered cap on the area. Whatever the final disposition, these facilities will be in a long-term surveillance and maintenance mode until final decisions are made, and probably for very long periods of time thereafter. For example, the reactors at the Hanford Site will be placed in an interim safe storage mode for 75 years to allow the radioactive contamination to decay to safer levels, and the Department will then consider options for their final disposition. The photos in Exhibit 10 illustrate the changes in a reactor when it undergoes transition from production to interim safe storage. During the interim safe storage phase, DOE will be conducting technology demonstration projects to test at least 20 new technologies and approaches that may provide safer, less expensive, and more efficient ways to decommission aging nuclear facilities.

Exhibit 10: Interim Safe Storage of C Reactor at Hanford Site



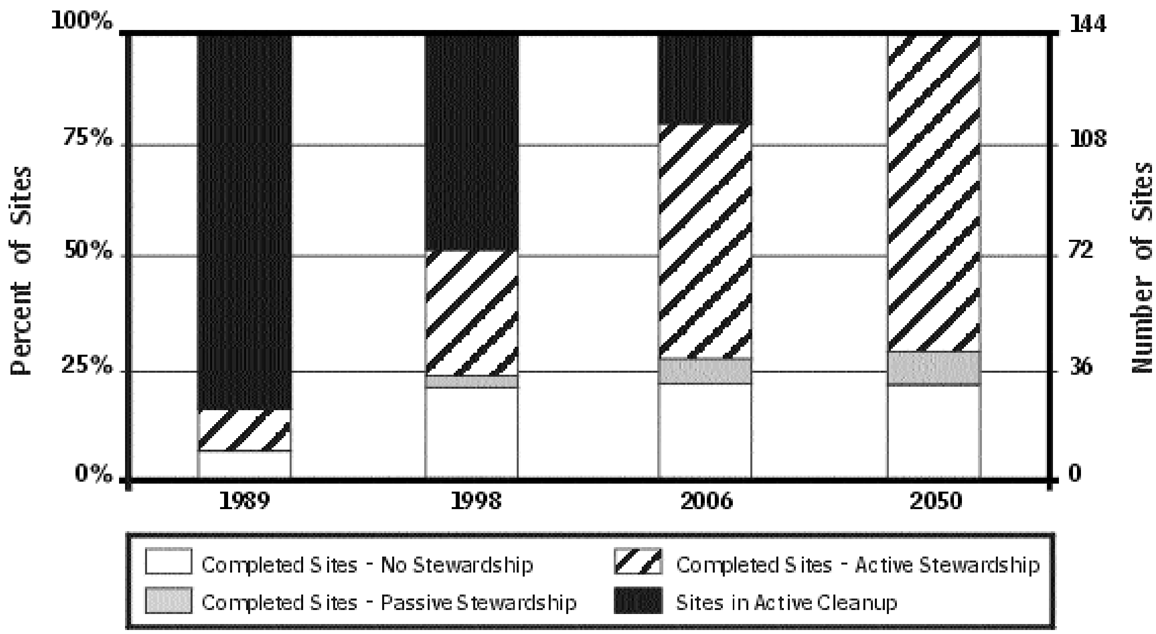
Hanford B/C Reactor Complex During Operation. Construction of the 100-B/C plutonium production reactor complex at Hanford began in August 1943 as part of the Manhattan Project. B Reactor (shown here), was the first of Hanford's nine production reactors to begin operating in September 1944, under the direction of Enrico Fermi. Work on C Reactor began in June 1951; it operated from November 1952 to April 1969. *Photo circa 1953. Source: U.S. Department of Energy-Richland Operations.*



C Reactor During Surveillance & Maintenance Phase. The reactor facility was abandoned in-place from 1969 until 1996, with only minimal surveys and structural maintenance work performed. Access was controlled, but the buildings gradually deteriorated and posed serious industrial safety and environmental risks. Assessments determined that aggressive cleanup action would be far less costly than structural repairs. *June 1996. Source: U.S. Department of Energy-Richland Operations.*

C Reactor in Interim Safe Storage. Decontamination and demolition of C Reactor secondary structures from 1996 to 1998 reduced the facility's "footprint" by 81%. All hazardous materials and nonessential equipment were removed. The reactor's core remains within its existing shielding walls, with the walls serving as a base for a new corrosion-resistant steel roof. This Safe Storage Enclosure, completed in September 1998, is designed to safely contain the reactor for up to 75 years while the radioactive contamination decays. *September 1998. Source: U.S. Department of Energy-Richland Operations*

Exhibit 11: Stewardship Activities Increase as Cleanup is Completed



Timing of Long-Term Stewardship Activities

DOE has already completed cleanup and is conducting long-term stewardship at 41 of the 109 sites expected to require stewardship. Long-term stewardship is also underway at portions of many other sites where cleanup activities and other missions (e.g., nuclear weapons maintenance) continue. Exhibit 11 illustrates that stewardship activities will increase as cleanup is completed.

- In 1989, 126 sites were undergoing active cleanup. Of the 18 completed sites, active stewardship was ongoing at nine sites, passive stewardship was occurring at one site, and no stewardship was required at eight sites.
- In 1998, fewer than half of the 144 sites were still undergoing active cleanup. Of the 74 completed sites, active stewardship was required at 39 sites, passive stewardship at two sites, and no stewardship at 33 sites.
- By 2006, only 21 of the sites (15 percent) are expected to be undergoing active cleanup. Of the 123 sites where cleanup is expected to be complete, active stewardship is anticipated at 84 sites, passive stewardship at four sites, and no stewardship at 35 sites.
- Active cleanup is expected to be completed at all sites by 2050. By then, active stewardship currently is anticipated at 103 sites, passive stewardship at six sites, and no stewardship at 35 sites.

The 21 sites expected to require active cleanup beyond 2006 generally are larger sites or sites with contamination requiring more complex remediation measures. All 21 sites will likely require extensive stewardship. Some stewardship activities already are taking place at portions of these sites where specific remediation goals have been met. For example, while cleanup at the Hanford Site as a whole is not expected to be complete until 2046, cleanup of portions of the site is already complete, and stewardship is underway. As other portions of these sites meet cleanup goals, stewardship will begin there as well.

Field of Wells at Savannah River Site A-M Area. The Integrated Demonstration site contains 150 monitoring wells, some quite shallow and some as deep as 200 feet. The wells keep track of the contamination left after the major cleanup project at the M Area, which included removing large amounts of waste, capping the old disposal area, and pumping and treating contaminated groundwater. The site also includes the world's first horizontal injection well used for environmental remediation. *M Area Settling Basin, Savannah River Site, South Carolina, January 1994.*

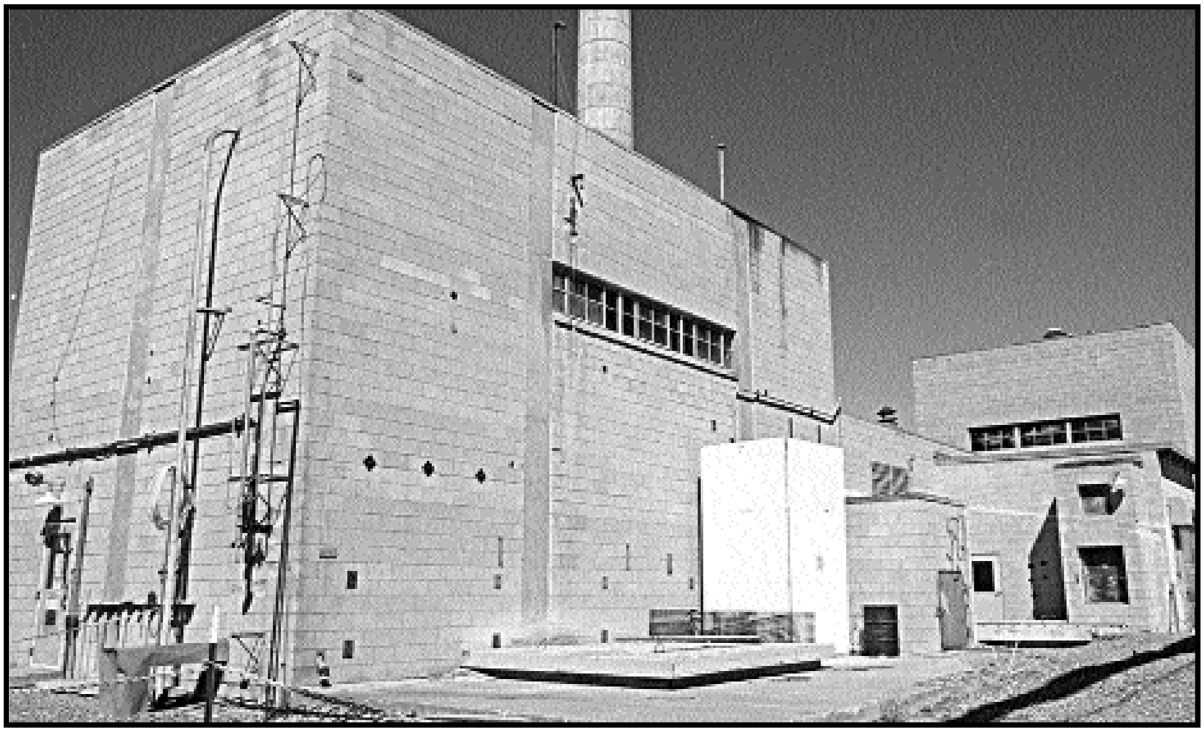
The duration of stewardship depends on the persistence of site hazards as well as the technologies available for remediation. The data submitted on the duration of stewardship activities were insufficient to determine a definitive end date for stewardship; however, several sites expected stewardship to be needed for 100 years or in perpetuity.

Land Use

As noted in Chapter 1 of this report (page 19), future land use, cleanup strategies, and long-term stewardship are interdependent. Therefore, information regarding future land use for DOE facilities is critical for developing effective cleanup strategies and long-term stewardship plans.

The *Paths to Closure* data that were used as the basis for this report provide very little information regarding future land use assumptions at DOE sites. Therefore, previous land use planning analyses (DOE 1996b, 1998b) were used to develop the future use assumptions provided in Appendix E.

Because these previous land use planning reports addressed a limited number of sites, DOE is seeking to improve its understanding of current and anticipated future land use to aid in site cleanup and stewardship planning. Moreover, DOE is working with its field office personnel to develop common definitions for land use categories (e.g. industrial vs. recreational), which will allow for inter-site planning and comparisons. Finally, site personnel are continuing to work with local governments and



Before: Waste Calcining Facility. This facility solidified high-level radioactive waste generated by the reprocessing of spent nuclear fuel. The photo, taken in 1990, shows the early stages of facility deactivation. *Idaho National Engineering and Environmental Laboratory, Idaho, 1990. Source: U.S. Department of Energy - Idaho Operations.*

After: Waste Calcining Facility. After the calcining plant's superstructure and contaminated equipment had been demolished, the remaining rubble pile was filled with grout to stabilize any residual contamination. *Idaho National Engineering and Environmental Laboratory, Idaho, May 1999. Source: U.S. Department of Energy - Idaho Operations.*

other stakeholders to develop plans for anticipated future land use that are consistent with required planning assumptions.

There are a number of reasons why decisions have not been made regarding post-cleanup alternative future use of many sites. First, many sites have, or are seeking, a non-EM mission (e.g., nuclear weapons materials management or scientific research), so active DOE control of the site is expected to continue indefinitely. Second, many fundamental cleanup decisions have not been made (e.g., cleanup strategy, amount of residual contamination, and disposition of excess property); until decisions have been made on these issues, definitive future use cannot be determined.

In some cases, before determining the future use of a site, DOE may prepare an environmental impact statement or environmental assessment pursuant to NEPA to analyze the potential environmental impacts of alternative uses. A number of DOE sites (e.g., Hanford, Nevada Test Site, and Los Alamos National Laboratory) have already been the subject of an environmental impact statement covering land use. Land use or resource management plans have also been developed for other sites (DOE 1998b).

Current Organizational Responsibilities

Current responsibility for long-term stewardship resides with a variety of DOE offices. For most sites, when cleanup is ongoing, but where cleanup of certain portions has been completed (e.g., Hanford and Savannah River Sites), long-term stewardship is part of the overall infrastructure maintenance responsibilities of the DOE operations office managing the site. For a number of sites where cleanup has been completed, personnel assigned to the Grand Junction Office (GJO) in Colorado perform a variety of long-term stewardship functions. The mission of DOE's GJO is to assume long-term custody of certain sites where cleanup is complete and to provide a common basis for their operation, security, surveillance, monitoring, maintenance, annual reporting, and emergency response. There are currently five types of sites assigned to the GJO program for long-term surveillance and maintenance:

(1) UMTRCA Title I sites, which are inactive uranium milling sites where NRC licenses terminated prior to November 1978;
(2) UMTRCA Title II sites, which are uranium milling sites licensed as of 1978;
(3) NWPA Section 151 sites that were privately owned and that contain radioactive wastes but not low-level mill tailings;
(4) Decontamination and decommissioning sites, including three entombed nuclear reactors (Hallam reactor, Nebraska; Piqua reactor, Ohio; and the Site A/Plot M burial site of Enrico Fermi's original "Chicago Pile" reactor, Illinois) and associated waste materials; and
(5) Other sites, including the former Pinellas Plant in Florida, transferred to GJO in 1997.

Long-term stewardship responsibilities for additional sites will likely be transferred to this program. For example, long-term stewardship responsibility for the Weldon Spring Site is expected to be transferred to GJO in 2002.

The Department's Nevada Operations Office is responsible for long-term stewardship at former nuclear explosion test sites in Alaska, Colorado, Nevada, New Mexico, and Mississippi (referred to as "Nevada Offsites").

Other offices perform stewardship functions following waste management activities. For example, Savannah River Site personnel are managing two underground storage tanks that had been filled with high-level waste and subsequently "closed" by removing and vitrifying most of the waste and filling the tank with grout. Also, DOE's West Valley (New York) personnel are developing long-term stewardship plans for the site following completion of waste management and other cleanup tasks.

Costs of Post-Cleanup Stewardship Activities Unknown

There are a number of long-term stewardship activities for which funding will likely be required. First, there are tasks required as part of direct site maintenance, including site monitoring, maintenance of the remedy, and regular (e.g., annual or five-year) review of the long-term stewardship plan to determine if changes are appropriate. Second, site security and overhead costs may include maintaining fences, gates, signs, roads, and utilities (e.g., electric, water and sewer) for security facilities in some cases. Third, a relatively small cost is required for record keeping, including archiving records, indexing, reproduction, title and deed recording, and distribution of records.

Compared to other activities (e.g., waste management, environmental restoration, fissile materials stabilization, and security) the Department currently spends relatively little money on long-term stewardship. As part of its cleanup program, the Department is seeking to lower the post-cleanup risks as much as possible and, as a result, the required costs for long-term stewardship site maintenance. There is little specific information available, however, on the Department's long-term stewardship funding requirements.

The primary reason for this lack of comprehensive and specific information is that the Department is conducting much of its current long-term stewardship responsibilities as part of the larger site infrastructure support and maintenance activities associated with operations.[4] Because these costs are combined with other site maintenance costs, such as site security, emergency response, and road repair, there is relatively little explicit information on long-term stewardship. Moreover, long-term stewardship costs are dwarfed by other site support costs incurred during active environmental management (i.e., environmental restoration, waste management, and nuclear materials and facilities stabilization) or other missions (e.g., Defense Programs or Nuclear Energy). The costs for long-term stewardship are more apparent when these other costs are eliminated through completions of the environmental management missions or cessation of the other missions, thereby eliminating the need for large site infrastructure support funding. Also, site personnel cannot project long-term stewardship costs until specific end states are determined for the active environmental management tasks.

Nonetheless, the Department has recently developed a significant amount of general long-term stewardship cost information, including cost elements (i.e., What is being funded?) and responsibility for costs (i.e., Who is funding it?), as well as some useful anecdotal cost information from specific projects.

The most explicit funding for long-term stewardship is provided through GJO. The FY 1999 budget for the Grand Junction long-term surveillance and monitoring program is $1.6 million, with life cycle costs for individual sites ranging from $4,000 to $2.5 million. These costs generally include collecting groundwater samples, repairing fences, conducting minor erosion control, restricting access, and conducting periodic surface inspections. These costs do not include potentially required major site repair if a breach in site containment were to occur. The costs also do not include active pumping and treatment of contaminated groundwater as part of a long-term remediation or containment system. In the near future, however, GJO will likely be responsible for such "pump and treat" systems at three former uranium mill tailings sites.

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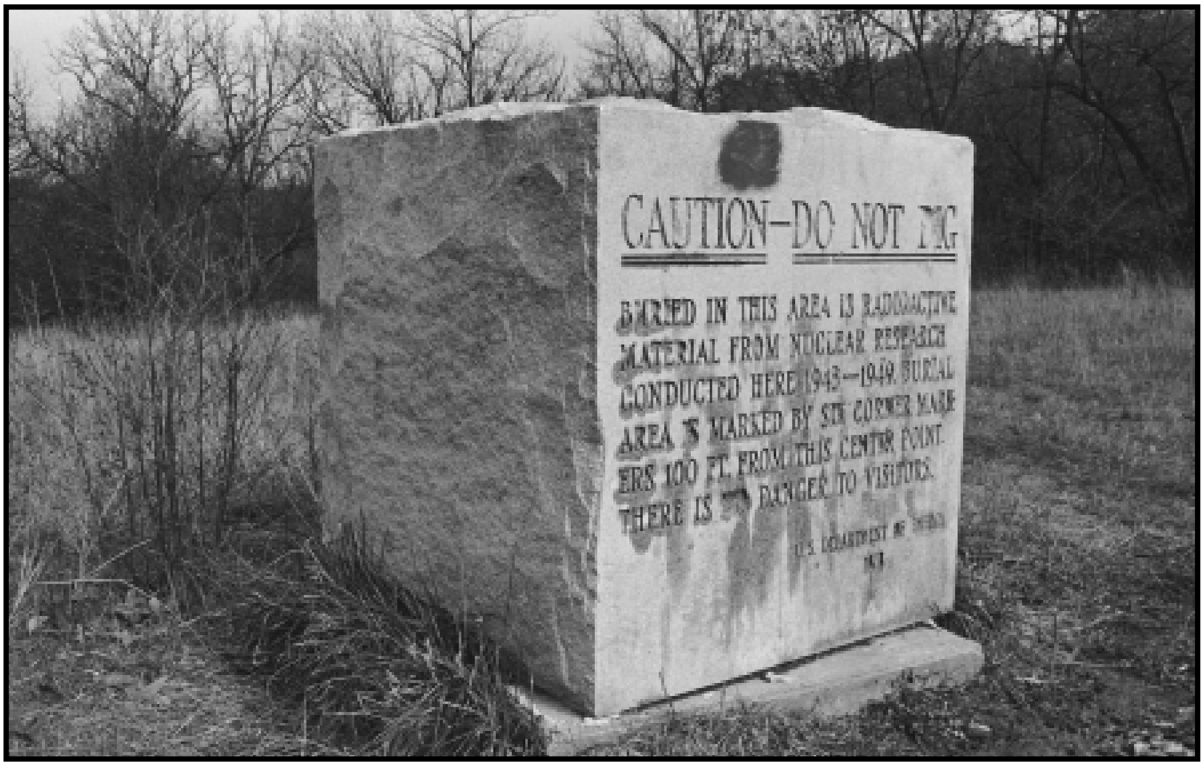
4. In a broader sense, long-term stewardship is an extension of the current funding for site infrastructure to maintain safe conditions (e.g., roof repair, repaving parking lots, radiation control). Clearly, one of the goals of cleanup, in addition to reducing risks, is to reduce the cost of maintaining safe site conditions, thereby reducing long-term stewardship costs.

The Department's Nevada Operations Office has managed long-term stewardship (mostly collecting groundwater and surface water samples near the underground test locations) at the "Nevada Offsites" for about 25-35 years. These activities are assumed to continue indefinitely. Annual costs currently range from $30,000 to $50,000 per site. The monitoring at these sites is performed by EPA but paid for by DOE. Experience with these sites suggests that such monitoring can be conducted at a modest cost, although its direct applicability to other DOE sites has not yet been determined.

Chapter 3: Planning for Long-Term Stewardship



Granite Marker Plot M, in the Palos Forest Preserve Cook County Forest Preserve District. This granite block marks the location of buried radioactive materials that include wastes relocated from Enrico Fermi's uranium-graphite pile at the University of Chicago. The Fermi pile was built for the Manhattan Project in 1942 and achieved the world's first man-made self-sustaining nuclear chain reaction. The caption on the marker reads: "CAUTION - DO NOT DIG Buried in this area is radioactive material from nuclear research conducted here 1943-1949. The burial area is marked by six corner markers 100 ft. from this center point. There is no danger to visitors. U.S. Department of Energy 1978." *Plot M, Palos Forest Preserve, Cook County Forest Preserve District, 20 miles Southeast of Chicago, Illinois, November 1995.*

The Department has made significant progress in its cleanup program. Workers have completed environmental restoration of hundreds of contaminated release sites across the nation. Millions of cubic meters of waste have been disposed, much of it in independently regulated commercial facilities. The Department has opened and begun disposition of radioactive transuranic (i.e., plutonium-contaminated) waste at the nation's first deep geological repository – the Waste Isolation Pilot Plant in New Mexico (Exhibit 12). The enduring success of all these activities will depend on effective long-term stewardship.

Running a long-term stewardship program over the extended periods of time discussed in Chapter 1 is an unprecedented task with many uncertainties. No existing institution has yet acquired experience in protecting public health and the environment from hazards for such a long period of time.

Although statutory and regulatory requirements provide guidelines for a blueprint for long-term stewardship, it is not clear that existing requirements anticipate the measures that may be needed in the future for long-term stewardship. Nor do they ensure the development of effective implementation strategies. The challenges ahead may be

Special Casks for Shipping Transuranic Waste. These demonstration models are similar to those being used to ship transuranic waste to the Waste Isolation Pilot Plant in New Mexico. Each of these Transuranic Package Transporter (TRUPACT-II) casks can hold fourteen 55-gallon drums. A window in the center model cask shows mock waste drums cut open to reveal typical constituents of transuranic waste. *Waste Isolation Pilot Plant, New Mexico, February 1994.*

Underground Transuranic Waste Disposal Room. This room, excavated in 1986, is the first of 56 chambers to be excavated at the Waste Isolation Pilot Plant. It is 300 feet long, 33 feet wide, and 13 feet tall and can hold six thousand 55-gallon drums of transuranic waste. It lies 2,150 feet below the surface of the earth in an ancient stable salt formation. *Room 1 of Panel 1, Waste Isolation Pilot Plant, New Mexico, February 1994.*

Exhibit 12: The Waste Isolation Pilot Plant (WIPP)

After years of research, construction and regulatory reviews, DOE began disposing of waste at WIPP in March 1999. WIPP is the world's first engineered geologic repository for radioactive waste disposal. It will dispose of much of the transuranic waste from the research and production of nuclear weapons that has been stored at numerous locations throughout the United States.

WIPP is located in southeastern New Mexico in an ancient stable salt formation 2,150 feet underground. Its disposal location was selected in part because the salt formation is stable and has "plastic" properties; in time, the salt will surround and contain the waste. The site was evaluated by EPA and the National Academy of Sciences and was determined to be suitable for permanent disposal of waste based on its ability to isolate the waste safely for at least 10,000 years.

WIPP was certified by EPA based on extensive technical documentation about the site provided as part of the regulatory process. Current estimates are that it will take at least 35 years for WIPP to be filled to its capacity. It will be shut down over a 10-12 year period, then will be carefully monitored for another two or three generations. In about 2099, the site will be closed permanently and marked to warn future generations to keep out. In response to regulatory requirements for passive institutional controls, DOE submitted designs for markers that identify the WIPP site and convey information about the disposal system's design and contents. The conceptual design includes the following elements:

A massive berm 10 meters (33 feet) tall and 30 meters (98 feet) wide at its base will surround the surface of the repository. To decrease collection of precipitation in the enclosed area of the berm, drainage paths will be built at approximately 100 meter (328 foot) intervals. Large permanent magnets buried at intervals in the berm will give the structure a distinctive magnetic signature. These magnets will measure approximately 1 meter (3.2 feet) long and 0.5 meters (1.6 feet) square in cross-section and will produce a signal detectable with current airborne detection equipment.

A series of 16 granite monuments, each standing 6.7 meters (22 feet) above ground and buried 6.7 meters (22 feet) into the soil, will be placed along the inside perimeter of the berm. A warning of the dangers of the materials entombed below will be inscribed in seven languages: English, French, Spanish, Chinese, Russian, and Arabic (the six official United Nations languages), and Navajo.

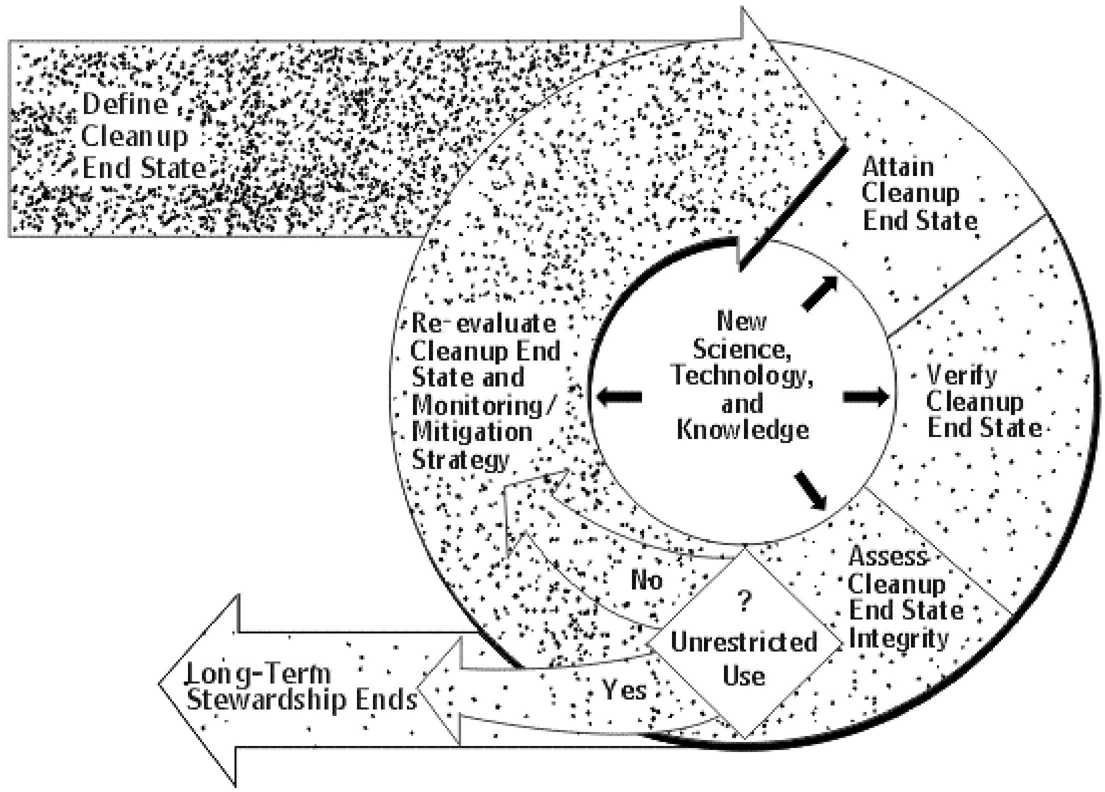
Several thousand small markers, constructed of three different materials (granite, aluminum oxide, and fired clay) will be buried at random intervals within the repository footprint and in the berm. Each of the markers will have a warning message in one of the seven languages used on the monuments.

Three granite-walled information centers with four exterior walls, seven parallel interior information walls, and no roof will be inscribed with more detailed warnings in tables, figures, diagrams, and maps. One will be built above ground without a roof to permit observation of the messages in natural light. The others will be buried. One information room will be buried within the center of the southern section of the berm. The final information room will be buried 160 meters (525 feet) north of the berm on a line between the above ground information center and the disposal area. The location of the buried information rooms will be documented in records located off-site in archives and record centers and in the above-ground information center.

technical, economic, institutional, cultural, environmental, or of a type not yet anticipated. The uncertainties associated with long-term stewardship of DOE sites include the nature of the hazards, the effectiveness of monitoring and maintenance of barriers and institutional controls, and the cost of these activities. Other unknowns include the availability of adequate technologies, the future development of better remedial and surveillance technologies, long-term funding and other resources, and long-term management of data. These uncertainties and unknowns make it difficult to shape definitive plans for the many years that stewardship will be needed. Exhibit 13 illustrates how science and technology will affect cleanup end state and long-term stewardship strategies over time.

The long-term stewardship challenges facing DOE also include the disposition of “materials in inventory.” The Department is responsible for managing a variety of materials resulting from the operation of large production facilities and numerous laboratories that acquired and produced enormous amounts of chemicals, metals, radioactive substances, and other materials. As described in the report of the

Exhibit 13: Changing Knowledge and Technology: The Dynamic Nature of Long-Term Stewardship



The relationship between cleanup, end states, and long-term stewardship requirements outlined in this report represents a static projection, or snapshot in time, based on existing knowledge and technologies. However, technologies will improve over time, creating opportunity for improved efficiencies in both the cleanup and stewardship phases. Efforts to accelerate cleanup will more rapidly reduce risks posed by hazards at DOE's sites and also will reduce ongoing maintenance costs significantly. This, in turn, should make more resources available for investments in new science and technologies.

Changing knowledge and technology will affect cleanup goals and strategies. New scientific understanding or regulatory changes may affect end state requirements such as residual contamination levels. New technologies may provide more economical approaches to achieve the same end state or may allow currently infeasible end states to be achieved. A key focus of efforts to attain different end states will be the ability to reduce long-term stewardship requirements.

Changing knowledge and technology will affect long-term stewardship activities. New scientific understanding and new technologies may lead to more economical and effective strategies for verifying that a desired end state actually is achieved, for monitoring the long-term integrity of the end state, and for developing and implementing contingency plans to anticipate and mitigate failures. Changes in information technology will affect strategies for generating, preserving, and providing access to critical long-term stewardship data.

Changing knowledge and technology will require periodic re-evaluation of existing end states. If history is our guide, we can expect profound changes in human economics, culture, science, and technology over time. For example, patterns of land and other resource use at and near long-term stewardship sites will change, and knowledge and technology will evolve in a variety of fields. At some point in the future, existing engineered controls will begin to fail unless additional actions are taken. At the same time, new technology can translate to more robust engineered controls requiring less intensive long-term stewardship activities. A critical part of long-term stewardship will be a systematic re-evaluation and modification of existing end states over time to ensure that developments in science, technology, and other knowledge are incorporated into long-term stewardship strategies.

Maintenance of Uranium Hexafluoride Cylinders. A worker at the Oak Ridge Reservation uses ultrasound to evaluate the effects of corrosion on a steel cylinder containing depleted uranium hexafluoride — the material left over from the uranium enrichment process. DOE owns over 46,000 cylinders of this material weighing 10 to 14 tons each. By mass, depleted uranium makes up over 70 percent of the Department's Materials in Inventory. After decades of storing this material, the Department is now undertaking a conversion project to stabilize the uranium hexafluoride for final disposition. *K-1066-K Cylinder yard, K-25 Site, Oak Ridge, Tennessee January 1994.*

Materials in Inventory Initiative (DOE 1996a), there are as yet no feasible disposition options for many of these materials, including both nuclear materials (e.g., uranium hexaflouride, U-233, spent nuclear fuel) and non-nuclear materials (e.g., reactive sodium, contaminated metals). Managing these materials often involves stabilization and long-term storage until final disposition options become available. Much like the entombed reactors placed in interim storage until final disposition is possible, these materials will require years of long-term management and control at DOE sites.

Despite these uncertainties, the Department is carrying out its stewardship obligations and planning for future stewardship efforts. As the Department accelerates cleanup, the need for post-cleanup stewardship is also accelerated. Because stewardship is already underway at some sites and will soon be at others, DOE needs to ensure that there is a smooth transition from cleanup to stewardship. To succeed, this planning must be done in consultation with Federal agencies, Tribal Nations, state and local governments, and other stakeholders.

Personnel at DOE headquarters and many field sites are now examining future stewardship activities. In addition, states and Tribal Nations, through the State and Tribal Government Working Group (STGWG) and local community groups and coalitions (such as the Energy Communities Alliance and the Rocky Flats Coalition of Local Governments), are working with the Department to raise long-term stewardship issues and determine the best ways to address them. Other organizations, such as the National Academy of Sciences, the

Exhibit 14: Long-Term Stewardship Recommendations

Long-term stewardship is recognized as an issue not only within DOE, but also outside the Department. Several organizations, including several stakeholder and advisory organizations, are actively working on issues related to long-term stewardship at DOE sites. These organizations have developed reports, established subcommittees on long-term stewardship, and in several cases, provided specific written recommendations to the Department for long-term stewardship both at the site-specific level, as well as the national level. For example, the Environmental Management Advisory Board (EMAB) and the State and Tribal Government Working Group (STGWG) address stewardship at a national level. Two other organizations, the Oak Ridge Reservation End Use Working Group (EUWG) and the Rocky Flats Stewardship Dialogue Planning Group, address stewardship issues more focused at the site-specific level. The EMAB, STGWG, and EUWG submitted specific recommendations to DOE that address the following three themes:

- **Establishing long-term stewardship plans at the site level;**
- **Developing or clarifying a DOE-wide long-term stewardship program or organization; and**
- **Enhancing long-term stewardship implementation.**

In addition, each organization provided specific details on how DOE should pursue these recommendations. Imbedded in the supporting information provided were additional recommendations for the Department to pursue. Although these ideas were implied in each of the organizations recommendations, they may have only been specifically addressed by one or two of the reports. Other recommendations addressed by one or more of the organizations included:

- **Identifying the appropriate data for collection, maintenance, and dissemination of stewardship information.**
- **Ensuring local government and stakeholder involvement in developing transition and long-term stewardship implementation plans.**
- **Fully explaining and quantifying the required long-term cost and funding commitment required for long-term institutional controls.**
- **Making stewardship requirements an integral part of all CERCLA decision documents.**

Although the Rocky Flats Stewardship Dialogue Planning Group did not include specific recommendations to the Department, this organization is addressing stewardship needs at the Rocky Flats Environmental Technology Site, and is beginning to frame the critical issues and concerns associated with stewardship at the site. For more detail on the specific recommendations provided by these organizations, please refer to the documents listed in the Reference section in the back of this report. Copies of these documents are available on the DOE Long-term Stewardship Information Center website at *www.em.doe.gov/lts*.

Environmental Law Institute, and Resources for the Future are also considering stewardship issues, as are some of the national laboratories. Some of these efforts are highlighted in Exhibit 14.

The Department has begun planning for long-term stewardship through the process of developing the *Paths to Closure* document and this companion document, *From Cleanup to Stewardship*, as well as through the accumulated experience of carrying out long-term stewardship in the field. This planning is still in its early stages; the Department recognizes that more research and analysis are needed to ensure reliable and cost-effective stewardship at a programmatic level. The follow-on long-term stewardship study, pursuant to the terms of the 1998 Settlement Agreement, is the next step in this planning process (see Appendix A for information on the Settlement Agreement).

The long-term stewardship study will describe the scope of DOE's long-term stewardship responsibilities, the status of current and ongoing stewardship obligations, activities, and initiatives, and the plans for future activities; it will analyze the national issues DOE needs to address in planning for and conducting long-term stewardship activities; and it will promote information exchange on long-term stewardship among DOE, Tribal Nations, state and local governments, and local citizens. The study will <u>not</u> be a National Environmental Policy Act document or "decision document;" it will not identify or address site-specific issues except as examples in the context of national issues; nor will it address issues specific to nuclear stockpile stewardship, other activities related to national security, or the Central Internet Database required by the Settlement Agreement.

Development of the long-term stewardship study will begin with a public scoping process. Scoping includes opportunities for interested parties to learn about the goals of the study, comment on what issues or topics the study should consider, and discuss key elements of the study with DOE staff. As there is no predetermined scope for the study, broad public input is essential. Based on the results of the scoping process, DOE will prepare a draft study that is anticipated to be released for public comment in Spring 2000. The public comment process will allow comprehensive public comment on the draft study. After the public comment period, DOE will prepare a final study.

What Might Future Generations Question?

In 1995, the Department published a document in which it asked, "What Might Future Generations Question?" (DOE 1995a):

A question that haunts many who are involved in the Department's environmental management program is: "What are we doing today that will prompt another generation to say, 'how could those people – scientists, policymakers, and environmental specialists – not have seen the consequences of their actions?'" . . . No one can yet know what these future questions will be, much less the correct answers. Nonetheless, part of the inheritance of the people working on this new enterprise is desired to look to the future and anticipate those questions.

If the intellectual giants of the Manhattan Project could not foresee all of the implications of their actions, it is particularly daunting for those involved in this new undertaking to consider what they might be missing in taking on the equally challenging task of cleaning up after the Cold War.

Perhaps a question for current and future generations might be "How do we ensure effective long-term stewardship of sites with residual waste and contamination?" The question has technical, financial, cultural, and institutional elements. We cannot today provide complete answers to it. But, as we conclude cleanup operations and dispose of waste, we will need to work together on individual, community, state, and national levels to address this question.

For additional information on DOE's long-term stewardship initiatives, including the full text of this report and the appendices, please log on to *www.em.doe.gov/lts*. This web address also includes reports prepared about DOE stewardship activities by entities outside of the Department. For written copies of these or other long-term stewardship materials, please call 1-800-7-EMDATA (1-800-736-3282).

References

Environmental Management Advisory Board, Long-Term Stewardship Committee. 1998. *Long-Term Stewardship Committee Recommendations to the Full Environmental Management Advisory Board,* October 8, 1998.

ICF Kaiser Consulting Group (ICF). 1998. *Managing Data for Long-term Stewardship.* Report prepared for EM Office of Strategic Planning and Analysis, March 1998.

Joint Stipulation. 1998. Natural Resources Defense Council, et. al. v. Richardson, et. al., Civ. No. 97-963 (SS).

Livingstone, Steve, Bashaw, Janet, and Powell, Elizabeth, *Moving from Cleanup to Stewardship,* Waste Management '98, Sesson 62, Tuscon, Arizona, March 1-5 1998

Livingstone, Steve and Hegner, Robert, *Managing Data for Long-Term Stewardship,* Waste Management '98, Session 62, Tuscon, Arizona, March 1-5 1998.

Memorandum of Understanding (MOU). 1999. *Memorandum of Understanding between the U.S. Department of Energy and the U.S. Army Corps of Engineers Regarding Program Administration and Execution of the Formerly Utilized Sites Remediation Action Program (FUSRAP)*, March 17, 1999.

National Conference of State Legislatures. 1999. *Closure for the Seventh Generation: A Report from the Stewardship Committee of the State and Tribal Government Working Group*, February 1999.

National Research Council. 1988. *Improving Risk Communication.* National Academy Press, Washington, DC.

Oak Ridge Reservation End Use Working Group. 1998. *Stakeholder Report on Stewardship*, July 1998.

Performance Agreement (Revised Final Performance Plan). 1999. *Performance Agreement Between the President of the United States and the Secretary of Energy. Fiscal Year 1999*.

Rocky Flats Stewardship Dialogue Planning Group. 1999. *Beyond Closure: Stewardship at Rocky Flats,* April 1999.

Rudzinski, Suzanne, Sykes, Merle and Dahling, Peter. *The Impact of Excess Facility Disposition on Near-Term Budgets and Long-Term Infrastructure Planning in the U.S. Department of Energy.* Waste Management '98, Session 16, Tuscon, Arizona, March 1-5 1998.

U.S. Department of Energy (DOE). 1995a. *Closing the Circle on the Splitting of the Atom: The Environmental Legacy of Nuclear Weapons Production in the United States and What the Department of Energy is Doing About It*, January 1995 (reprinted January 1996).

U.S. Department of Energy (DOE). 1995b. *Estimating the Cold War Mortgage: The 1995 Baseline Environmental Management Report (*Volumes 1, 2, & 3), DOE/EM-0232, March 1995.

U.S. Department of Energy (DOE). 1996a. *Taking Stock: A Look at the Opportunities and Challenges Posed by Inventories from the Cold War,* DOE/EM-0275, January 1996.

U.S. Department of Energy (DOE). 1996b. *Charting the Course: The Future Use Report*, DOE/EM-0283, April 1996.

U.S. Department of Energy (DOE). 1996c. *The 1996 Baseline Environmental Management Report* (Volumes 1, 2, & 3), DOE/EM-0290, June 1996.

U.S. Department of Energy (DOE). 1997a. *Linking Legacies: Connecting the Cold War Nuclear Weapons Processes to their Environmental Consequences*, DOE/EM-0319, January 1997.

U.S. Department of Energy (DOE). 1997b. *Decontaminating Commercial Facilities for Reuse on DOE's FUSRAP Program*. DOE Oak Ridge Operations Office, September 1997.

U.S. Department of Energy (DOE). 1997c. *Cross-Cut Guidance on Environmental Requirements for DOE Real Property Transfers.* Office of Environmental Policy and Assistance RCRA/CERCLA Division, DOE/EH-413/9712. October 1997.

U.S. Department of Energy (DOE). 1998a. *Accelerating Cleanup: Paths to Closure*, DOE/EM-0362, June 1998.

U.S. Department of Energy (DOE). 1998b. *Planning for the Future: An Overview of Future Use Plans at Department of Energy,* October 1998.

Werner, James D., *Secrecy and Its Effect on Environmental Problems in the Military: An Engineers Perspective*, New York University Environmental Law Journal, Vol. 2 No. 2, 1993.

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Below Ground Waste Disposal Silos. These concrete domes form the caps for underground silos at the Oak Ridge Reservation, each measuring 8 feet in diameter. These disposal silos are 15-20 feet deep and were placed in the ground at least two feet above the highest known groundwater levels. These silos were used from 1986 to 1993 for the disposal of laboratory equipment, construction debris, and other dry waste contaminated principally with cesium-137, strontium-90, and cobalt-60. Although no final cleanup decisions have been made, long-term groundwater monitoring is currently being conducted and may be required for decades. *Melton Valley Area, Solid Waste Storage Area 6, Oak Ridge Reservation, Tennessee, January 1994.*

Appendices

A) The December 1998 PEIS Lawsuit Settlement Agreement

B) Regulatory Requirements

C) Methodology

D) Glossary of Terms

E) Site Profiles - Not in Document, available at *www.em.doe.gov/lts*

Appendix A:
The December 1998 PEIS Lawsuit Settlement

Satellite Dish at Rocky Flats Environmental Technology Site. The phrase, "Make it Safe, Clean it Up, Close it Down" was developed through a public process to summarize the new mission for the site after the nuclear weapons component production ended. In March 1995, DOE sponsored a "Rocky Flats Summit" in Arvada, Colorado involving 150 people, including state and federal regulators, local and headquarters DOE officials, state officials, oversight group members and community activists. At this meeting the fundamental goals and priorities for the site were established, which were subsequently used to negotiate the Rocky Flats Compliance Agreement. *Rocky Flats Environmental Technology Site, Colorado, September 1999.*

On December 14, 1998, DOE settled a lawsuit with the Natural Resources Defense Council (NRDC), and 38 other environmental organizations.[1] The terms of the Settlement Agreement include three major items:

- A central Internet database with information on waste, facilities, and contaminated media, as well as information on waste transfers;
- A study on long-term stewardship; and
- A $6.25 million fund for technical and scientific reviews.

DOE is preparing to conduct a national study on long-term stewardship in compliance with the settlement agreement. The breadth of this study will be determined through a public scoping process. The overall objective of the scoping process is to help DOE determine the facts, analysis, questions, issues, resources, and other matters that should be included in the national study, within the general parameters established by the Settlement Agreement. The specific terms of the Settlement Agreement

1. Natural Resources Defense Council, et. al. v. Richardson, et. al., Civ. No. 97-963 (SS).

regarding the long-term stewardship national study are as follows:

> DOE will prepare a study on its long-term stewardship activities. By "long-term stewardship," DOE refers to the physical controls, institutions, information and other mechanisms needed to ensure protection of people and the environment at sites where DOE has completed or plans to complete "cleanup" (e.g., landfill closures, remedial actions, removal actions, and facility stabilization). This concept of long-term stewardship includes, inter alia, land use controls, monitoring, maintenance, and information management. While DOE's study on long-term stewardship will not be a NEPA document or its functional equivalent, DOE will, nevertheless, follow the procedures set forth in the regulations of the President's Council on Environmental Quality (CEQ) for public scoping, 40 C.F.R § 1501.7(a)(1)-(2), and the procedures set forth in DOE's NEPA regulations for public review, of environmental impact statements (EIS's), 10 C.F.R. § 1021.313, except that (a) DOE will not transmit the study, in draft form, to EPA, and DOE (not EPA) will publish a Notice of Availability in the Federal Register, as set forth in 10 C.F.R. § 1021.313(a); and (b) DOE will not include any Statement of Findings as set forth in 10 C.F.R. § 1021.313(c). In the study, DOE will discuss, as appropriate, alternative approaches to long-term stewardship and the environmental consequences associated with those alternative approaches.

Appendix B:
Regulatory Requirements Governing Long-Term Stewardship

Storage of Uranium Metal Billets. A worker at the Fernald Environmental Management Project examines storage requirements for depleted uranium metal billets, which once were an essential precursor element in the production of weapons-grade plutonium for nuclear warheads. Today, billets like these are one of DOE's many types of chemicals, metals, radioactive substances, and other materials collectively known as "materials in inventory." Materials in Inventory are not considered by DOE to be waste, but are materials for which no use is expected for one year and that have not been used for at least one year. *Fernald Environmental Management Project, Ohio, December 1993.*

Exhibit B-1: DOE Orders and Policies Providing a Framework for Long-Term Stewardship

DOE Order 200.1 Information Management Program.	Provides a framework for managing information, information resources, and information technology investment.
DOE Order 430.1 Life Cycle Asset Management and DOE Order 4320.1B Site Development Planning.	Identify what analyses must be conducted in order for a site manager to determine whether a particular portion of DOE real property is considered to be excess and available for transfer to another entity.
DOE Order 435.1 Radioactive Waste Management.	Requires DOE radioactive waste management activities to be systematically planned, documented, executed, and evaluated in a manner that protects worker and public safety, as well as the environment.
DOE Order 1230.2 DOE American Indian Tribal Government Policy.	Requires DOE sites to consult with potentially affected Tribes concerning impacts of proposed DOE actions (including real property transfers), and to avoid unnecessary interference with traditional religious practices.
DOE Order 5400.5 Radiation Protection of the Public and the Environment.	Establishes acceptable levels for the release of property on which any radioactive substances or residual radioactive material was present.
Secretary of Energy's Land and Facility Use Policy, issued December 21, 1994, and DOE Policy 430.1, also titled "Land and Facility Use Planning Policy," issued July 9, 1996.	State that DOE sites must consider how best to use DOE land and facilities to support critical missions and to stimulate the economy while preserving natural resources, diverse ecosystems, and cultural resources.

Exhibit B-2: Regulatory Requirements by Waste Type

Waste Type	Typical Radioactive and Chemical Characteristics	Disposal Plans and Long-Term Requirements
High-Level Waste (HLW) The highly radioactive waste material resulting from the reprocessing of spent nuclear fuel, including liquid waste that contains fission products in sufficient concentrations; and other highly radioactive material that is determined, consistent with existing law, to require permanent isolation.	Contains short- and long-lived fission products, usually in high concentrations, as well as hazardous chemicals and heavy metals.	DOE currently plans to vitrify HLW and dispose of it in a geologic repository. DOE also plans to dispose of SNF in a repository. Disposal of HLW and SNF in a potential repository at Yucca Mountain in Nevada would be licensed by NRC in accordance with licensing criteria that have been proposed (64 FR 8640) and radiation protection standards to be issued by EPA (40 CFR 197), under the authority of the Nuclear Waste Policy Act and the Energy Policy Act of 1992.
Spent Nuclear Fuel (SNF) Fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing.	Usually contains high concentrations of short- and long-lived isotopes, including fission products, activation products, and transuranic isotopes.	
Transuranic Waste (TRU) Radioactive waste containing more than 100 nanocuries (3700 becquerels) of alpha-emitting transuranic isotopes per gram of waste, with half-lives greater than 20 years, except for: (1) high-level radioactive waste; (2) waste that the Secretary of Energy has determined, with the concurrence of the Administrator of the Environmental Protection Agency, does not need the degree of isolation required by the 40 CFR 191 disposal regulations; or (3) waste that the Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with 10 CFR 61.	Contains neptunium, plutonium, curium, americium, and other elements with an atomic number greater than 92.	DOE plans to dispose of defense TRU wastes in the Waste Isolation Pilot Plant (WIPP). EPA issued its final permit for certification of WIPP in May 1998. The New Mexico Environmental Department, delegated the authority by EPA, is currently reviewing the draft RCRA "Part B" permit it issued in August 1998. WIPP began receiving waste in March 1999. For WIPP, EPA must certify that there is a reasonable expectation that the waste will remain isolated for 10,000 years. Although permanent DOE control is required by law and regulation, for purposes of analysis, EPA prohibits reliance on active institutional controls for longer than 100 years. For purposes of analysis, passive institutional controls cannot be relied upon to delay possible human intrusion into the site longer than several hundred years following disposal (40 CFR 191 and 194).
Low-Level Waste (LLW) Radioactive waste that is not high-level radioactive waste, spent nuclear fuel, transuranic waste, byproduct material (as defined in section 11e.(2) of the *Atomic Energy Act of 1954*, as amended), or naturally occurring radioactive material.	Contains a wide variety of radionuclides. Some wastes in this category may have more short-lived radioactivity per unit volume than average high-level waste, although most wastes contains small amounts of radioactivity among large volumes of other material (e.g., trash, soil, debris, water).	Low-level waste is disposed of in landfills, shafts, concrete vaults, or other near-surface containment units. DOE guidance interpreting DOE Order 435.1 states that for purposes of performance assessment, lapses in active institutional controls should be considered following a 100-year period. Performance assessments look forward for a minimum of 1,000 years.

Exhibit B-2: Continued		
Waste Type	**Typical Radioactive and Chemical Characteristics**	**Disposal Plans and Long-Term Requirements**
Mixed Waste Waste that contains both source, special nuclear, or byproduct material subject to the *Atomic Energy Act of 1954*, as amended, and a hazardous component subject to the *Resource Conservation and Recovery Act.*	Can include all of the radioactive waste characteristics described for high level, TRU, or low-level wastes, as well as heavy metals or hazardous organic constituents.	A variety of treatment and disposal technologies and requirements are being used to treat and manage mixed wastes. Statutory or regulatory requirements pertaining to the hazardous (i.e., RCRA) constituents of the material apply as well as those for the radioactive constituents.
Uranium Mill Tailings Tailings or waste produced by the extraction or concentration of uranium or thorium from ore processed primarily for its source material content. **11e.(2) Materials** The tailings or waste produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material (i.e., uranium or thorium) content.	Contain several long-lived constituents, including uranium-238 and radium-226, in extremely large volumes of soil.	Mill tailings are generally disposed in landfills in accordance with design requirements prescribed in 40 CFR 192. Control and stabilization features must be designed to provide, to the extent reasonably achievable, an effective life of 1,000 years with a minimum life of at least 200 years. 11e.(2) materials are generally disposed in landfills in accordance with design requirements prescribed in 40 CFR 192. Control and stabilization features must be designed to provide, to the extent reasonably achievable, an effective life of 1,000 years with a minimum life of at least 200 years.
Hazardous Waste Wastes defined by either listing, exhibiting a hazardous characteristic under Subtitle C of the *Resource Conservation and Recovery Act*, or declared hazardous by the generator.	Can contain a wide variety of organic, heavy metal, and other constituents.	Subject to a wide variety of treatment and disposal processes, some of which may destroy certain contaminants (e.g., bioremediation), or render them less hazardous, followed by disposal in landfills. Encapsulation is often required for metals, which reduces their hazards as long as encapsulation is effective. RCRA requires post-closure care (maintenance and monitoring) for at least 30 years after a waste unit has been cleaned to closure standards. The EPA Regional Administrator can either shorten or extend the 30 year post-closure care period in order to protect human health and the environment.
Hazardous Substances Substances not regulated as hazardous waste under RCRA, but considered hazardous under CERCLA, TSCA, etc.	Includes contaminants such as PCBs, asbestos, and petroleum products.	Subject to a wide variety of treatment and disposal processes, some of which may destroy certain contaminants (e.g., bioremediation), or render them less hazardous, followed by disposal in landfills. CERCLA requires 5-year reviews of residually contaminated areas and waste disposal units. In addition all cleanup levels are subject to Applicable and Relevant and Appropriate Requirements (ARARs).

Appendix C: Methodology

Remaining Foundation of Building 889 at the Rocky Flats Environmental Technology Site. The first radioactively contaminated building at the site to be demolished, this multi-purpose facility was a former uranium and beryllium waste repackaging plant that supported rolling and milling operations. Current plans call for virtually all of the facilities at Rocky Flats to be demolished and rubble to be disposed of appropriately. Foundations and utilities will remain in place unless removal is necessary to remediate underlying soil. Subsurface utilities between facilities will be capped and left in place. Future use options for this portion of the site include open space or light industrial uses. *Rocky Flats Environmental Technology Site, Colorado, September 1999.*

DOE reviewed and analyzed the Department's existing data on anticipated cleanup levels to determine the type and amount of residual contamination likely to remain when cleanup activities are completed (i.e., when the site reaches its end state). DOE then determined the appropriate unit of measure for analyzing stewardship and identifying the scope of the Department's stewardship obligations.

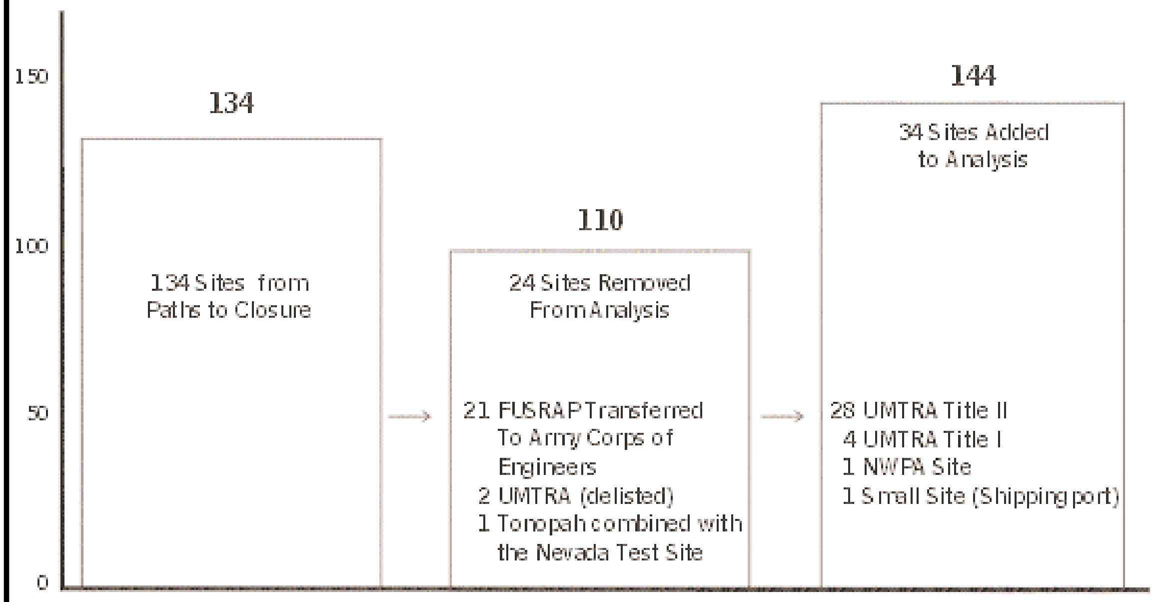
DOE identified those sites where residually contaminated facilities, water, soil, and/or engineered units are expected to remain. This allowed the Department to estimate the long-term stewardship activities that will be required to protect human health and the environment. Information for each site includes:

- The location of sites expected to require stewardship by DOE;
- The expected nature and extent of DOE stewardship;
- The projected costs of stewardship activities;
- The timing and duration of stewardship activities;
- The projected post-cleanup site ownership and land use; and
- The organizations expected to be responsible for stewardship.

Unit of Measure

DOE first had to determine the appropriate unit of measure for analyzing stewardship obligations. Although the number of acres that will require stewardship seemed to be the most consistent unit of measure, data were not readily available at that level of detail for most sites; most DOE data are currently recorded and

Exhibit C-1: Origin of Number of Sites in This Analysis



reported at the site level. Therefore, the Department chose to measure stewardship on a site level.[1] For the purpose of this analysis, the Department defined a "site" as a contiguous geographically distinct area (as opposed to a release site or sub-area of a site). For example, the Idaho National Engineering and Environmental Laboratory, Fernald, and the Tuba City UMTRA Cell are each considered one site although they differ significantly in size as well as type and extent of contamination.

In identifying those sites that are expected to require stewardship, the Department started with the list of sites identified in the *Accelerating Cleanup: Paths to Closure* report, hereinafter referred to as *Paths to Closure* (see Exhibit C-1). The *Paths to Closure* report included 134 geographic sites that EM has historically included in its scope (including the Waste Isolation Pilot Plant). In addition to the 134, DOE included additional sites where long-term stewardship responsibilities have been transferred to the Department through existing laws. The additional sites include 28 sites transferred under the authority of UMTRCA of 1978, one site transferred under the NWPA, and one additional small site.

The universe of sites identified in this report also differs from *Paths to Closure* because this analysis did not include the 21 FUSRAP sites transferred to the Army Corps of Engineers in 1998 (Exhibit C-2). Also excluded from the list of sites included in this report are the Belfield and Bowman sites, which were delisted from UMTRCA in May of 1998. Lastly, the Tonopah Test Range was combined with the Nevada Test Site because the long-term planning for the sites is based on the two areas being managed as one site. This resulted in a net difference of 10 sites, and an overall list of 144 sites where the

1. The data used in this report were drawn from existing DOE Headquarters sources used for high-level planning efforts. Specific sites and field offices may have more detailed information, however, obtaining more detailed information from sites was outside the scope of this document, due to time and budget constraints.

Exhibit C-2: 21 FUSRAP Sites Transferred to Army Corps of Engineers in 1998

Connecticut
- Combustion Engineering

Illinois
- Madison

Maryland
- W.R. Grace & Company

Massachusetts
- Shpack Landfill

Missouri
- Latty Avenue Properties
- St. Louis Airport Site
- St. Louis Airport Site Vicinity Properties
- St. Louis Downtown Site

New Jersey
- DuPont & Company
- Maywood Chemical Works
- Middlesex Sampling Plant
- Wayne Interim Storage Site

New York
- Ashland Oil #1
- Ashland Oil #2
- Bliss and Laughlin Steel
- Colonie Site
- Linde Air Products
- Niagara Falls Storage Site
- Seaway Industrial Park

Ohio
- Luckey
- Painesville

Department potentially has long-term stewardship obligations. A complete list of the sites included in this analysis is provided in Chapter 2.

Sites included under Title I of UMTRCA are those that operated prior to 1978 and where all or most of the uranium was used for a Federal Agency. Title II of UMTRCA includes sites that were operating under an NRC license in 1978 when the Act was promulgated. Section 202 of UMTRCA gave NRC the authorization to transfer title and custody of these sites (other than land owned by Federal, state, or Tribal governments) to either the Federal government (DOE) or a state government. This transfer of custody would occur prior to termination of the license, and NRC would then issue a separate license for long-term care and maintenance of the site. Because the responsibility for providing long-term stewardship at 28 sites is likely to be transferred to DOE, these sites are included in the scope of DOE's long-term obligations.

According to the NWPA, Subtitle D, Section 151(b), low-level radioactive waste disposal sites with privately held licenses can be transferred to DOE upon the termination of the site's license, provided that NRC requirements for site closure, decontamination, and decommissioning have been met, title and custody of the site will be transferred to DOE at no cost to the Federal government, and DOE ownership and management of the site is necessary or desirable in order to protect public health and safety and the environment. Section 151(c) states that if low-level radioactive waste is the result of a licensed activity to recover zirconium, hafnium and rare earth metals from source material, DOE can accept title and custody of the site if requested by the site owner. Currently, responsibility for one NWPA Section 151(c) site has been transferred to the Department and is included in this analysis.

Data Sources

DOE analyzed the data submitted by the sites in support of *Paths to Closure* to determine a site's expected cleanup levels and resulting end state. Determining the overall site end state from the data submitted for *Paths to Closure* involved interpreting and compiling data from numerous project-level data elements known as project baseline summaries (PBSs). To ensure that the data were aggregated correctly, site and operations office contacts were asked to review the information compiled, verify the accuracy of

The number of sites where DOE has stewardship responsibility may increase over time. Additional sites may be identified and added to DOE's responsibility under existing or new laws.

the data, fill in data gaps, and update the data based on any changes in site cleanup plans that may have occurred since the original data were submitted. For sites that did not submit data for *Paths to Closure*, site cleanup and end state descriptions were obtained from the *Accelerating Cleanup: Focus on 2006 Discussion Draft* or the *1996 Baseline Environmental Management Report*. To the extent possible, site and operations contacts were also contacted to verify data for sites where the majority of the data were obtained from older source documents. For all sites included in this analysis, the assumptions used as the foundation for this analysis are likely to change as site-specific factors change or are better understood (see Exhibit C-3 for a discussion of how stewardship activities are likely to change over time).

Date Cleanup Complete

The Department identified the anticipated date for completing cleanup activities or putting ongoing remediation systems in place. These dates were determined based on the projected date for completing cleanup identified in *Paths to Closure*, or on the actual date that remediation was completed if the site is already closed. The date for completing cleanup represented the start date when long-term stewardship is the sole remaining mission for the site. Any activities aimed at containing, managing, or providing long-term maintenance for contamination or remedies that are in place after this date are included as part of the site's long-term stewardship responsibility.

Exhibit C-3: Levels of Stewardship Activities Are Likely to Change Over Time

Stewardship activities identified in this analysis indicate the activities expected when cleanup is completed; however, the stewardship process is dynamic and the specific activities at a site will change over time in response to both site-specific and external factors. These factors include regulatory changes, technology developments, demographic shifts, and changes in the contamination due to attenuation or ongoing remediation. For example, changes in scientific understanding of the effects of residual contamination may result in changes to our regulatory standards resulting in more or less stringent stewardship activities. Similarly, technology developments may enable additional contamination to be removed, which could decrease the need for long-term stewardship.

Site End State

Although general information on the extent of residual contamination was available in *Paths to Closure*, that report did not focus on the anticipated long-term stewardship requirements after cleanup was completed. DOE had to look more in-depth at the types of residual contamination likely to remain on the site once all cleanup was completed in order to determine the long-term stewardship requirements for each site. To develop a more informed understanding of the residual contamination and resulting stewardship activities, DOE divided the overall site end state information by the type of media that was contaminated:

- Water (groundwater and surface waters);
- Soil (including buried waste);
- Engineered units (e.g., landfills); and
- Facilities.

The method used to differentiate among media types (e.g., soil vs. engineered units) is solely for purposes of this analysis and does not reflect regulatory or policy determinations.

The first step in identifying media that will have residual contamination was to determine if any contamination of those media had ever occurred. If no evidence existed of any prior contamination, that medium was assumed to require no stewardship. If contamination had occurred and the planned cleanup strategy will not return the medium to a degree of residual contamination suitable for unrestricted use, then that medium was assumed to require some degree of long-term stewardship. Remediation to levels acceptable for unrestricted use is not considered to require stewardship because this level of use is based on calculations that project that unacceptable human health risks will not occur even under the most extensive exposure scenarios (e.g. residential use).

Water

Ongoing groundwater remediation will continue at many sites after the official site "closure" date. This situation exists because of the long time frames required to capture and remediate contaminated groundwater. Therefore, unlike other media, the end date for groundwater remediation was often set at the time that the remedy was put in place, and the ongoing natural attenuation or pump and treat activities are included as part of the water stewardship activities. The Department assumed that stewardship would be required for any groundwater or surface water areas where remediation will not return the water to below drinking water standards or, in some cases, to background levels. Drinking water standards are not the norm for all sites since in many areas the natural background levels of contaminants are above drinking water standards. This is particularly true for some uranium mill tailings sites where the natural background levels of uranium in the groundwater are above drinking water standards and/or the groundwater is not naturally potable due to other concerns (e.g. elevated salinity or turbidity levels).

Soil

The Department assumed stewardship will be required for all discrete areas of soil that will have residual contamination above levels that will allow for unrestricted use. Soil areas are defined to include soils, sediments, burial grounds, burn pits, and other historical disposal areas that do not have engineered containment structures. For many residually contaminated soil areas, the remedial approach includes placing a cap over the residual contamination to prevent precipitation from infiltrating the contamination and transporting the contamination to groundwater. Capped soil areas are primarily areas where contaminated soils are partially excavated but some residually contaminated soils will remain in place; however, they also include some burial grounds where waste was disposed. These areas are not classified as "engineered units" for this analysis, because they do not have liners, engineered side walls, or leachate collection systems. The caps over residually contaminated soil areas (typically composed of clay, asphalt, cement, or multi-layer synthetic material) will need to be actively maintained to ensure that cracks or breaks in the cap, implied into the contaminant, do not occur or are repaired when necessary.

Engineered Units

For this analysis, the Department defined engineered units as permanent, land-based disposal units such as landfills, vaults, and tank farms that have engineered containment structures such as liners and leachate collection systems. Engineered units also include units designed for long-term retrievable storage of nuclear materials or high-level waste. In evaluating the stewardship needed for engineered units, DOE identified those units currently accepting waste, as well as historical units that no longer receive waste but that will remain onsite following the completion of remediation activities. All engineered units that are likely to remain onsite are assumed to require some type of long-term stewardship, partially as a result of the post-closure care activities required in the various regulations that apply to DOE's waste disposal activities, but also due to the general nature of the units. Engineered units are areas where wastes and residual contamination are consolidated for permanent disposal or long-term retrievable storage. Therefore, these units will require stewardship activities.

Exhibit C-4: Potential Stewardship Activities by Media

Water
- Conducting ongoing pump and treat;
- Providing alternate sources for drinking water;
- Restricting either ground or surface water use;
- Posting signs;
- Conducting groundwater or surface water monitoring at various frequencies; and
- Maintaining records of contamination, departmental activities, and use restrictions.

Soil
- Maintaining and repairing soil caps;
- Establishing zoning and land use restrictions;
- Establishing easements and deed restrictions;
- Erecting and maintaining fences and other physical barriers;
- Posting warning signs;
- Conducting soil monitoring at various frequencies; and
- Maintaining records of contamination, departmental activities, and use restrictions.

Engineered Units
- Maintaining and repairing engineered unit caps, liners, and leachate collection systems;
- Erecting and maintaining fences and physical barriers;
- Posting warning signs;
- Establishing easements and deed restrictions, monitoring and inspections; and
- Maintaining records of contamination, departmental activities, and use restrictions.

Facilities
- Monitoring residual contamination;
- Maintaining access restrictions;
- Enforcing limitations on reuse;
- Posting signs;
- Conducting structural maintenance and repairs; and
- Maintaining records of contamination, departmental activities, and use restrictions.

Facilities

Many of the Department's contaminated facilities will be fully demolished, including all below-grade structures and foundations. The Department defined facilities requiring stewardship as any contaminated buildings no longer in use where the future plans include maintaining the structure with contamination in place (regardless of the assumed future use). Additionally, the Department included in this analysis any entombed facilities and facilities that will be demolished to grade with the below-grade structure capped in place. These facilities range in size and character from slightly contaminated laboratories and support structures to reactors and canyons. No feasible remediation or decommissioning technology currently exists for the reactors and canyons without seriously endangering the health of workers.

Stewardship Activities

The Department identified the anticipated stewardship activities necessary to protect human health and the environment. The anticipated stewardship activities are a function of the anticipated future land uses, existing regulations, as well as the type and amount of contamination that will remain in place. In some cases the site data indicated the specific stewardship activities that are planned for a site. For the most part, the sites that are able to identify specific, planned, stewardship activities are either currently undergoing stewardship, or are nearing site closure. Sites with a more distant closure date are less likely to be able to identify the specific stewardship activities that might be required to protect human health and the environment. When the specific stewardship activities are not identified, DOE estimated the stewardship activities that will be required. Exhibit C-4 presents the stewardship activities identified for each of the contaminated media. In addition to these activities identified by the Department, most engineered units will require repairs over time. These repairs will be needed because the wastes consolidated in the engineered units tend to remain hazardous longer than the design life of the units that contain them. Because the Department did not have sufficient data to evaluate the deterioration rate of engineered units, DOE did not attempt to estimate the frequency of repairs for this analysis.

Stewardship Categories

For analysis purposes, this background document divides long-term stewardship activities into two categories, active and passive. Active stewardship entails performing certain activities to control risk at a site, including pumping groundwater; performing maintenance work such as repairing fences, caps, and erosion gullies; and collecting water samples for monitoring purposes. Passive stewardship generally refers to the long-term function of conveying information about site hazards and/or limiting access to a site through physical or legal means. Other terminology has been used to describe long-term stewardship activities. For example, EPA regulations for WIPP (40 CFR 191) define the term "institutional controls" to encompass all three of the types of activities considered "long-term stewardship" in this background document. The definitions of the stewardship categories used by the Department for this analysis are presented in Exhibit C-5.

After categorizing each residually contaminated medium, DOE then combined the results to categorize the overall type of stewardship expected for each site, with the overall ranking defaulting to the most rigorous case. For example, if three of the four residually contaminated media at a site will require only passive stewardship, but the fourth is expected to require active stewardship, the overall type of stewardship at the site is categorized as active. Another example would be at sites where one or more media are not expected to require stewardship, but the remaining media will have residual contamination requiring passive controls. In this case, the overall site stewardship level is identified as passive.

Exhibit C-5: Category Definitions

Active stewardship is the direct performance of continuous or periodic custodial activities such as controlling access to a site; controlling or cleaning up releases from a site; performing maintenance operations; or monitoring performance parameters.

Passive stewardship is the long-term responsibility to convey information warning about the hazards at a site or limiting access to, or use of, a site through physical or legal mechanisms.

No stewardship required is where cleanup has been completed to levels that will allow for an unrestricted or residential future use.

Data Limitations

Although the data used for this analysis are the best currently available to DOE Headquarters, the following limitations apply:

- Stewardship activities are linked to site cleanup and future use decisions. As these decisions are finalized, the Department's stewardship activities will be modified accordingly.
- Data on the completion of cleanup and transition to stewardship imply that stewardship does not begin until all remediation is complete. At many sites, cleanup and stewardship activities will occur simultaneously. Because data available for this analysis existed only at the geographic site level, this analysis does not account for or represent the areas of sites where stewardship will be occurring before all site remediation is complete.
- Site stewardship activities are extrapolated from data submitted for other purposes. The Department is in the process of developing a framework for sites to more explicitly report these data at the level of detail and quality necessary for adequately estimating the long-term stewardship requirements.
- Data were only available at the geographic site level, which results in each site being represented as an equal unit. The variance in the size and complexity of individual DOE sites would be better captured by the ability to link stewardship requirements to a consistent unit of measure such as site acres.

Appendix D: Glossary of Terms

Active Stewardship: The direct performance of continuous or periodic custodial activities such as controlling access to a site by means other than passive institutional controls; controlling or cleaning up releases from a site; performing maintenance operations on remediated areas at a site; or monitoring performance parameters at a disposal or release site.

Activity: The rate at which radioactive material emits radiation, stated in terms of the number of nuclear disintegrations occurring in a unit of time; the common unit of radioactivity is the curie (Ci).

Agricultural land use: Unfenced areas where subsistence or commercial agriculture predominates without any restrictions on surface or groundwater use.

Atomic Energy Act: The Federal law that regulates the production and uses of atomic power. The act was passed in 1946 and amended substantially in 1954 and several times since then.

Atomic Energy Commission: Created by the United States Congress in 1946 as the civilian agency responsible for producing nuclear weapons. It also researched and regulated atomic energy. In 1975, its weapons production and research activities were transferred to the Energy Research and Development Administration, and its regulatory responsibility was given to the new Nuclear Regulatory Commission.

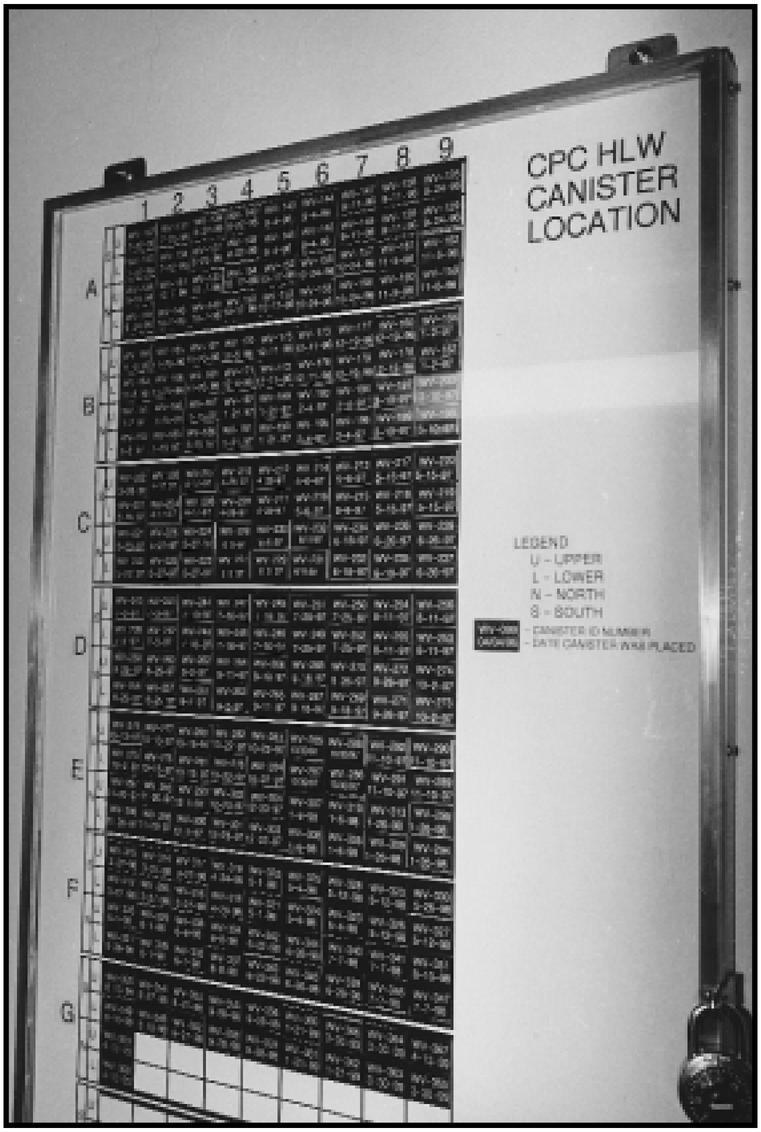


Chart of Vitrified Waste Canisters. At the West Valley Demonstration Project, high-level radioactive waste is being combined with borosilicate glass-forming chemicals and melted in a high-temperature melter in a process called vitrification. Heating the melter to approximately 2000°F produces a molten waste/glass blend that is poured into stainless steel canisters and placed in an interim storage facility to await disposal in the proposed geologic repository. The interim storage facility currently holds approximately 240 canisters and eventually may hold as many as 300. As each canister is placed in the storage facility, the date and location are noted on this chart. *West Valley Demonstration Project, New York, June 1999.*

Base Case: The estimate of total program cost (e.g., in the 1995 and 1996 *Baseline Environmental*

Management Reports) that reflects the most likely activities and schedule under current projections.

Baseline Environmental Management Report (Baseline Report): Congressionally mandated report prepared by the Secretary of Energy to estimate the cost and schedule of cleaning up the nation's nuclear weapons complex.

Brownfields: Abandoned, idled, or under-used industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contamination.

Burial Grounds: Areas designated for near-surface disposal of containers of low-level radioactive waste and obsolete or worn-out radioactively contaminated equipment.

Cleanup: The process of addressing contaminated land, facilities, and materials in accordance with applicable requirements. Cleanup does not imply that all hazards will be removed from the site. The term "remediation" is often used synonymously with cleanup. See also "environmental restoration."

Cold War Mortgage: The cost and effort associated with addressing the environmental legacy of 50 years of nuclear weapons production.

Completion of Cleanup: A condition in which cleanup of a site is considered complete when deactivation or decommissioning of all facilities currently in the Environmental Management program has been completed, excluding any long-term surveillance and monitoring; all releases to the environment have been cleaned up in accordance with agreed-upon cleanup standards; groundwater contamination has been contained, or long-term treatment or monitoring is in place; nuclear material and spent fuel have been stabilized and/or placed in safe long-term storage; and "legacy" waste (i.e., waste produced by past nuclear weapons production activities, with the exception of high-level waste) has been disposed of in an approved manner.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA): A Federal law (also known as Superfund), enacted in 1980 and reauthorized in 1986, that provides the legal authority for emergency response and cleanup of hazardous substances released into the environment and for the cleanup of inactive waste sites.

Comprehensive Land Use Planning: A required site planning and management system which involves stakeholders to develop and maintain current and future land use plans and any type of development, use, or disposal planning for the site.

Controlled Access land use: The Department maintains restricted access areas for secure storage or disposal of nuclear materials or waste. Barriers and security fences prevent access by unauthorized persons. Wildlife and plants are controlled or removed.

Curie (Ci): A unit of radioactivity equal to 37 billion disintegrations per second (i.e., 37 billion becquerels); also a quantity of any radionuclide or mixture of radionuclides having 1 curie of radioactivity.

Decommissioning: Retirement of a nuclear facility, including decontamination and/or dismantlement.

Decontamination: Removal of radioactive or hazardous contamination by a chemical or mechanical process.

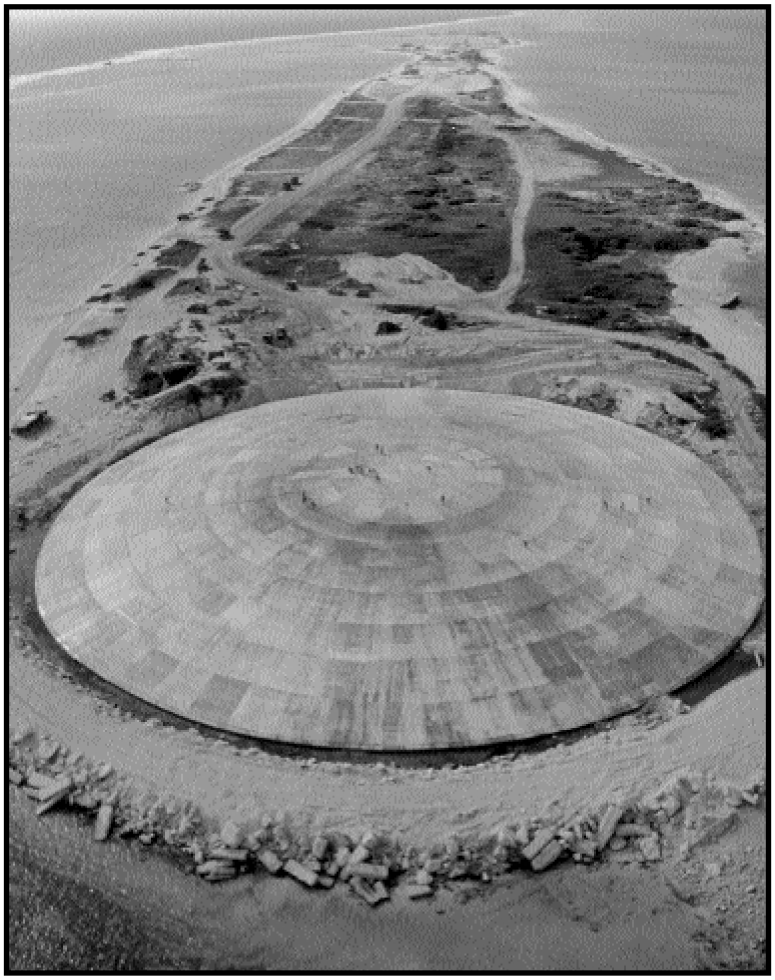
DNAPL: An acronym for denser-than-water nonaqueous-phase liquid–an organic liquid, composed of one or more contaminants, that does not mix with water and is denser than water. The most common DNAPL contaminants in ground water are chlorinated solvents.

End State: The physical state of a site after agreed upon remediation activities have been completed.

Engineered Units: Includes radioactive, hazardous, and sanitary landfills; vaults; tank farms; and other units with man-made containment systems.

Environmental Impact Statement (EIS): The detailed written statement that is required by section 102(2)(C) of NEPA for a proposed major Federal action significantly affecting the quality of the human environment. A DOE EIS is prepared in accordance with applicable requirements of the Council on Environmental Quality NEPA regulations in 40 CFR 1500-1508, and the DOE NEPA regulation in 10 CFR 1021.

The statement includes, among other information, discussions of the environmental impacts of the proposed action and all reasonable alternatives, adverse environmental effects that can not be avoided should the proposal be implemented, the relationship between short-term uses of the human environment and enhancement of long-term productivity, and any irreversible and irretrievable commitments of resources.



The Cactus Dome at Runit Island. Beneath this concrete dome on Runit Island (part of Enewetak Atoll), built between 1977 and 1980 at a cost of about $239 million, lie 111,000 cubic yards (84,927 cubic meters) of radioactive soil and debris from Bikini and Rongelap atolls. The dome covers the 30-foot (9 meter) deep, 350-foot (107 meter) wide crater created by the May 5, 1958 Cactus test. Note the people atop the dome. *Enewetak Atoll, Marshall Islands. Photo circa 1990. Source: Defense Special Weapons Agency.*

Environmental Management (EM) Program: An Office of DOE that was created in 1989 to oversee the Department's waste management and environmental cleanup efforts. Originally called the Office of Environmental Restoration and Waste Management, it was renamed in 1993.

Environmental Restoration: Often described broadly as "cleanup," this function encompasses a wide range of activities, such as stabilizing contaminated soil; treating ground water; decommissioning process buildings, nuclear reactors, chemical separations plants, and many other facilities; and exhuming sludge and buried drums of waste.

Feasibility Study: An analysis of the practicality of a proposal such as a description and analysis of the potential cleanup alternatives for a site. The Feasibility Study emphasizes data analysis and usually recommends selecting a cost-effective alternative. It is usually performed with and uses data from a Remedial Investigation; together, they are commonly referred to as a "RI/FS" or Remedial Investigation/Feasibility Study.

Fissile Material: Although sometimes used as a synonym for fissionable material, this term has acquired a more restricted meaning; namely, any material fissionable by low-energy (i.e., thermal or slow) neutrons. Fissile materials include Uranium-235, Uranium-233, Plutonium-239, and Plutonium-241.

Formerly Utilized Sites Remedial Action Program (FUSRAP): A Federal program initiated in 1974 to identify and remediate sites around the country that were contaminated during the 1940s and 1950s as a result of researching, developing, processing, and producing uranium and thorium, and storing processing residues.

Future Land Use: The ultimate uses to be permitted for currently contaminated lands, waters, and structures at each DOE installation. land use decisions will strongly influence the cost of environmental management.

Geologic Repository: A mined facility for disposal of radioactive waste that uses waste packages and the natural geology as barriers to provide waste isolation.

Half Life: The time in which one half of the atoms of a particular radionuclide disintegrate into another nuclear form. Half lives for specific radionuclides vary from millionths of a second to billions of years.

Hazard: A source of danger (i.e., material, energy source, or operation) with the potential to cause illness, injury, or death to personnel or damage to an operation or to the environment (without regard for the likelihood or credibility of accident scenarios or consequence mitigation).

Hazardous Substances: Substances not regulated as hazardous waste under RCRA, but considered hazardous under CERCLA, TSCA, etc.

Hazardous Waste: A category of waste regulated under RCRA. To be considered hazardous, a waste must be a solid waste under RCRA and must exhibit at least one of four characteristics described in 40 CFR 261.20 through 40 CFR 261.24 (i.e., ignitability, corrosivity, reactivity, or toxicity) or be specifically listed by the Environmental Protection Agency in 40 CFR 261.31 through 40 CFR 261.33. Source, special nuclear, or by-product materials as defined by the Atomic Energy Act are not hazardous waste because they are not solid waste under RCRA.

Hazards: Materials or conditions that have the potential to cause adverse effects to health, safety, or the environment.

High-Level Waste (HLW): High-level waste is the highly radioactive waste material resulting 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 other highly radioactive material that is determined, consistent with existing law, to require permanent isolation.

In Situ: In place.

Industrial Land Use: Active industrial facility where groundwater may be restricted.

Institutional Controls: Non-engineering measures—usually, but not always, legal controls—intended to affect human activities in such a way as to prevent or reduce exposure to hazardous substances. Institutional controls include, but are not necessarily limited to: land and resource (e.g., water) use and deed restrictions; well-drilling prohibitions, building permits and well use advisories and deed notices; other legally enforceable measures. However, they are distinct from physical engineering measures such as treatment and containment systems.

Isotopes: Any of two or more variations of an element in which the nuclei have the same number of protons (i.e., the same atomic number) but different numbers of neutrons so that their atomic masses differ. Isotopes of a single element possess almost identical chemical properties, but often different physical properties (e.g., carbon-12 and 13 are stable, carbon-14 is radioactive).

Landlord: Activities that involve the physical operation and maintenance of DOE installations. Specific tasks vary but generally include providing utilities, maintenance, and general infrastructure for the entire installation.

Legacy Waste: Any waste within a complex that was generated by past weapons production or research activities and is in storage awaiting treatment or disposal.

Life-Cycle Cost Estimate: All the anticipated costs, associated with a project or program alternative throughout its life. This includes costs from pre-operations through operations or to the end of the alternative.

Long-Term Stewardship: All activities required to protect human health and the environment from hazards remaining after cleanup is complete.

Low-Level Waste (LLW): Low-level radioactive waste is radioactive waste that is not high-level radioactive waste, spent nuclear fuel, transuranic waste, byproduct material (as defined in section 11e.(2) of the *Atomic Energy Act of 1954*, as amended), or naturally occurring radioactive material.

Manhattan Project: The U.S. Government project that produced the first nuclear weapons during World War II. Started in 1942, the Manhattan Project formally ended in 1946. The Hanford Site, Oak Ridge Reservation, and Los Alamos National Laboratory were created for this effort. The project was named for the Manhattan Engineer District of the U.S. Army Corps of Engineers.

Mixed Waste: Waste that contains both source, special nuclear, or byproduct material subject to the *Atomic Energy Act of 1954,* as amended, and a hazardous component subject to the *Resource Conservation and Recovery Act.*

National Environmental Policy Act of 1969 (NEPA): NEPA is the basic national charter for protection of the environment. It establishes policy, sets goals (in Section 101), and provides means (in Section 102) for carrying out the policy. Section 102(2) contains "action-forcing" provisions to ensure that Federal agencies follow the letter and spirit of the Act. For major Federal actions significantly affecting the quality of the human environment, Section 102(2)(C) of NEPA requires Federal agencies to prepare a detailed statement that includes the environmental impacts of the proposed action and other specified information.

National Priorities List (NPL): The Environmental Protection Agency's list of the most serious uncontrolled or abandoned hazardous waste sites identified for possible long-term remedial action under CERCLA. The list is based primarily on the score a site receives from the EPA Hazard Ranking System described in 40 CFR 300, Appendix A. EPA must update the NPL at least once a year.

Nevada Offsites: Underground nuclear tests conducted at eight locations in five different states (Alaska, Colorado, Mississippi, Nevada, and New Mexico) from 1957 to 1973 as part of the Plowshare program to develop peaceful (industrial and scientific) applications for nuclear explosives and the Vela Uniform program to improve the capability of detecting, monitoring, and identifying underground nuclear detonations.

Nuclear Waste Policy Act (NWPA): The Federal law that provides for the development of geologic repositories for disposal of high-level waste and spent nuclear fuel and other issues (see page 29).

Nuclear Weapons Complex: The chain of foundries, uranium enrichment plants, reactors, chemical separation plants, factories, laboratories, assembly plants, and test sites that produced nuclear weapons. Sixteen major U.S. facilities in 12 states formed the nuclear weapons complex.

Open Space Land Use: Posted areas are reserved generally as buffer or wildlife management zones. Native Americans or other authorized parties may be allowed permits for occasional surface area use. Access to or use of certain areas may be prevented by passive barriers (e.g., where soil is capped). Limited hunting or livestock grazing may be allowed.

Passive Stewardship: Includes ongoing custodial controls such as land or resource use restrictions; permanent markers, signs, or restrictions at a site; or public records, deed restrictions, and archived information.

Plutonium (Pu): A heavy, radioactive, metallic element with the atomic number 94. It is produced artificially by neutron bombardment of uranium. Plutonium has 15 isotopes with atomic masses ranging from 232 to 246 and half lives from 20 minutes to 76 million years. Its most important isotope is fissile plutonium-239.

Radioactive: Of, caused by, or exhibiting radioactivity.

Radioactivity: The spontaneous transformation of unstable atomic nuclei, usually accompanied by the emission of ionizing radiation.

Radioisotope or Radionuclide: An unstable isotope that undergoes spontaneous transformation, emitting radiation.

Record of Decision (ROD): A public document that explains the cleanup alternatives to be used at National Priorities List sites where, under CERCLA, trust funds pay for the cleanup. In addition, a ROD under NEPA is a concise public document that records a Federal agency's decision(s) concerning a proposed action for which the agency has prepared an environmental impact statement (EIS). The ROD is prepared in accordance with the requirements of the Council on Environmental Quality NEPA regulations (40 CFR 1505.2). A ROD identifies the alternatives environmentally preferable alternative(s), factors balanced by the agency in making the decision, whether all practicable means to avoid or minimize environmental harm have been adopted, and if not, why they were not.

Recreational Land Use: Unfenced areas where daytime use for recreational activities (e.g., hiking, biking, sports), hunting, and some overnight camping is allowed. Fishing may be limited to catch-and-release.

Residential Land Use: Unfenced areas where permanent residential use predominates. There is no restriction on surface water use, but groundwater use may be restricted.

Resource Conservation and Recovery Act (RCRA): A Federal law enacted in 1976 to address the treatment, storage, and disposal of hazardous waste.

Risk: Risk requires the presence of a hazard, but adds to the hazard the probability that the potential harm or undesirable consequences will be realized. Risk is expressed (qualitatively or quantitatively) in terms of the likelihood that an adverse effect will occur as a result of the existence of a hazard. The existence of a hazard does not automatically imply the existence of a risk since risk requires a pathway (to a receptor) for an exposure to occur. Barriers and other controls can block or eliminate

Signing the Atomic Energy Act of 1954. President Eisenhower, at his desk, August 30, 1954, after signing the Atomic Energy Act (see excerpts on page viii). Seated: President Eisenhower, Rep. Sterling Cole (R-NY), Atomic Energy Commission (AEC) Chairman Lewis Strauss. Back: Military Liaison Commission Chairman Herbert B. Loper, Sen. Edwin C. Johnson (D-CO), Rep. Carl Hinshaw (R-CA), Rep. James E. Van Zandt (R-PA), Rep. Melvin Price (D-IL), Rep. Carl T. Durham (D-NC) and AEC Commissioner Thomas Murray. *Washington DC, August 30, 1954. Source: National Archives*

the pathway and related risk from the residual hazard.

Spent Nuclear Fuel (SNF): Fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing.

Stewardship (or long-term stewardship): Encompasses all activities required to maintain an adequate level of protection to human health and the environment posed by nuclear and/or chemical materials, waste, and residual contamination remaining after cleanup is complete.

Stockpile Stewardship: A DOE program to ensure core competencies in activities associated with the research, design, development, and testing of nuclear weapons; it also refers to the assessment and certification of their safety and reliability.

Superfund: A term commonly used to refer to CERCLA.

Toxic Substances Control Act (TSCA): A Federal law enacted in 1976 to protect human health and the environment from unreasonable risk caused by manufacturing, distribution, use, disposal of, or exposure to, substances containing toxic chemicals.

Transuranic Elements: All elements beyond uranium on the periodic table; that is, all elements with an atomic number greater than 92. All transuranic elements are man made. They include neptunium, plutonium, americium, and curium.

Transuranic Waste (TRU): Transuranic waste is radioactive waste containing more than 100 nanocuries (3700 becquerels) of alpha- emitting transuranic isotopes per gram of waste, with half-lives greater than 20 years, except for: (1) high-level radioactive waste; (2) waste that the Secretary of Energy has determined, with the concurrence of the Administrator of the Environmental Protection Agency, does not need the degree of isolation required by the 40 CFR 191 disposal regulations; or (3) waste that the Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with 10 CFR 61.

Unrestricted Land Use: Unfenced areas where there is no restriction on the types of activities that may occur, including permanent residential use.

Uranium (U): A radioactive, metallic element with the atomic number 92; the heaviest naturally occurring element. Uranium has 14 known isotopes, of which uranium-238 is the most abundant in nature. Uranium-235 is commonly used as a fuel for nuclear fission.

Uranium Mill Tailings: Tailings or waste produced by the extraction or concentration of uranium or thorium from ore processed primarily for its source material content.

Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978: The act that directed DOE to provide for stabilization and control of the uranium mill tailings from inactive uranium milling sites in a safe and environmentally sound manner to minimize radiation health hazards to the public. It authorized the Department to undertake remedial actions at 24 designated inactive uranium processing sites and at an estimated 5,048 vicinity properties (see pages 28 and 29).

Uranium Mill Tailings Remedial Action (UMTRA): A DOE program to plan, implement, and complete environmental restoration (e.g. cleanup of contaminated surface water and groundwater) at inactive uranium-processing sites and their vicinity sites, as directed and authorized by the Uranium Mill Tailings Radiation Control Act of 1978.

Vitrification: A process by which waste is transformed from a liquid or sludge into an immobile solid that traps radionuclides and prevents waste from contaminating soil, ground water, and surface water. DOE has selected vitrification processes to solidify and stabilize certain forms of radioactive and hazardous waste. This process does not reduce radioactivity. The will use borosilicate glass to immobilize its high-level radioactive waste.

Waste Isolation Pilot Plant (WIPP): A DOE facility designed and authorized to permanently dispose of transuranic radioactive waste in a mined underground facility in deep geologic salt beds. It is located in southeastern New Mexico, 26 miles (42 km) east of the city of Carlsbad.

Waste Management: Activities that include treating, storing, and disposing of high-level radioactive waste, transuranic waste, low-level radioactive waste, low-level mixed waste, hazardous chemical waste, and sanitary waste.

Appendix E: Site Profiles

The site profiles in Appendix E provide a description of the anticipated stewardship activities at each geographic site included in the analysis for this report. These profiles are based on the data submitted for the 1998 *Paths to Closure* report and include a site overview that describes the site location, landlord, anticipated future use, and any identified site-wide stewardship issues. Site cleanup plans, anticipated residual contamination, and resulting stewardship activities are then described in more detail for each of the media (i.e., water, soil, engineered units, and facilities) described in this report.

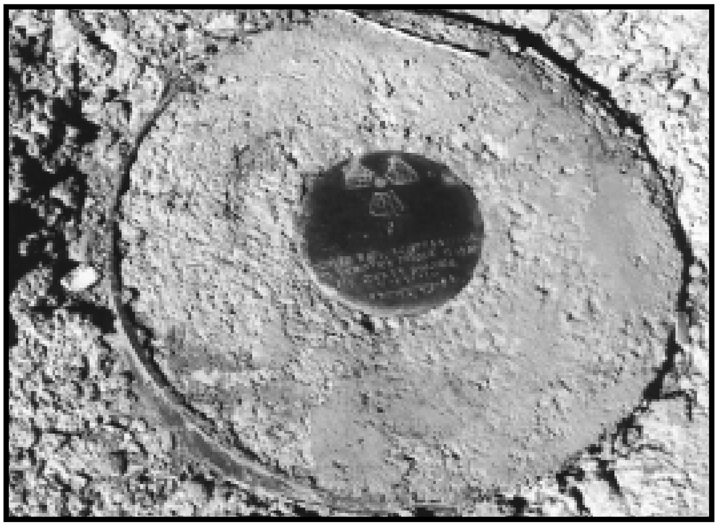
Appendix E is not included in the printed version of this document; however, an electronic version of Appendix E is available at *www.em.doe.gov/lts*. If you do not have access to the internet, copies of the site profiles included in Appendix E can be obtained by contacting the Center for Environmental Management Information at 1-800-7-EMDATA.

Stainless Steel Canister for Vitrified Waste at West Valley Demonstration Project. This 10-foot by 2-foot stainless steel canister is identical to those being used to store vitrified high level radioactive waste prior to disposal in the proposed geologic repository. The waste, primarily cesium-137 and strontium-90, was generated from reprocessing commercial spent nuclear fuel to recover uranium and plutonium and was stored in a 740,000-gallon tank. Vitrification of the liquid high-level waste (containing most of the cesium-137) was completed in June 1998. DOE is now removing and vitrifying the "tank heel," the remaining sludge layer at the bottom of the tank, which contains most of the strontium-90 and transuranic elements. *West Valley Demonstration Project, New York, June 1999.*

Markers at Sites with Residual Contamination

Fermi Marker located 20 miles outside of Chicago, Illinois, identifying the site of buried radioactive wastes that inclulde materials from Enrico Fermi's uranium-graphite pile at the University of Chicago. The text of the inscription is on page 47. *Plot M, Palos Forest Preserve, Illinois, November 1995.*

Bayo Canyon Site Marker identifying a site near Los Alamos, New Mexico, where cleanup was completed in 1982 and strontium-90 was left in subsurface soil. The inscription reads: "Buried Radioactive Materials. No Excavation Prior to 2142 A.D. See County Records. N 21 48 21 W." *Bayo Canyon Site, New Mexico, 1986. Source: DOE EM Visuals Resource Center.*



Rulison Marker identifying the site of the 1969 Rulison underground nuclear explosion. The inscription reads "Project Rulison Nuclear Explosive Emplacement Well (R-E). Site of the second nuclear gas stimulation experiment in the United States. One 43 kiloton nuclear explosive was detonated in this well, 8,426 feet below the surface on September 10, 1969. No excavation, drilling, and/or removal of subsurface materials below a depth of 6,000 feet is permitted within Lot II, NE 1/4 SW 1/4, of Section 25, Township 7, South, Range 95 West, 6th Principal Meridian, Garfield County, Colorado without U.S. Government permission. U.S. Energy Research and Development Administration, September 1976." *Rulison, Garfield County, Colorado, June 1998.*

Buried Waste Pipe Sign indicating location of buried waste pipe. *N Reactor Area, Hanford Site, Washington, July 1998.*

Estes Gulch Disposal Cell Marker identifying the site of buried uranium mill tailings at Estes Gulch, near Rifle, Colorado. In addition to a scale map of the site, the inscription reads: “Rifle, Colorado. Date of Closure April 26, 1996. Dry tons of tailings 4,967,451. Radioactivity 2,738 Curies RA-226.” *Estes Gulch Disposal Cell, Rifle, Colorado, June 1998.*

Canonsburg Disposal Cell Marker identifying the site of buried Manhattan Project uranium mill tailings in the town of Canonsburg, Pennsylvania, 20 miles outside Pittsburgh. In addition to a scale map of the site, the inscription reads: “Canonsburg PA. Date of Closure December 1985. Dry tons of tailings 266,000. Radioactivity 100 curies RA-226.” *Canonsburg, Pennsylvania, March 1999.*

All of the photographs in this report were taken by Robert Del Tredici, except for those on pages 3, 6, 7 (bottom), 39, 42, D-3, D-7 and E-2 (bottom).

Photographs on pages vi (top) and 16 (top) are from *At Work in the Fields of the Bomb* by Robert Del Tredici and are copyrighted by Robert Del Tredici. These photographs are used here by special arrangement with the photographer, as are the Del Tredici photos on page 23 (top), 35 (bottom), 38, 47 and E-2 (top).

Back Cover Photos:
Preparation for Entombment, see caption on page vi.
Maintenance of Uranium Hexafluoride Cylinders, see caption on page 51.
Granite Marker, Plot M, see caption on page 47.

"How do we ensure effective long-term stewardship of sites with residual waste and contamination?"

This question has technical, financial, cultural, and institutional elements. We cannot today provide complete answers to it. But, as we complete cleanup operations and dispose of waste, we will need to work together on individual, state, and national levels to address this question.

Chapter 3, *Planning for Long-Term Stewardship*

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

This report examines the transition from the cleanup to the long-term stewardship of contaminated facilities and radioactive materials resulting from nuclear research and nuclear weapons production over the past 50 years.