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Report to the Subcommittee on Energy and Water Development, Committee on Appropriations, House of Representatives

September 2009

NUCLEAR WASTE

Uncertainties and Questions about Costs and Risks Persist with DOE's Tank Waste Cleanup Strategy at Hanford

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GAO-09-913

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Highlights

Highlights of GAO-09-913, a report to the Subcommittee on Energy and Water Development, Committee on Appropriations, House of Representatives

Why GAO Did This Study

At its Hanford Site in Washington State, the Department of Energy (DOE) is responsible for one of the world's biggest cleanup projects: the treatment and disposal of about 56 million gallons of radioactive and hazardous waste, stored in 177 underground tanks. Two decades and several halted efforts later, none of this waste has yet been treated, cleanup costs have grown steadily, and prospective cleanup time frames have lengthened.

GAO was asked to assess (1) DOE's current tank waste cleanup strategy and key technical, legal, and other uncertainties; (2) the extent to which DOE has analyzed whether this strategy is commensurate with risks from the wastes; and (3) opportunities to reduce tank waste cleanup costs. GAO reviewed pertinent documents, visited the site, and interviewed officials and independent experts.

What GAO Recommends

GAO is recommending that, for Hanford, DOE (1) improve its life-cycle cost and schedule estimates, (2) adopt a risk assessment framework that considers available guidance, (3) consider seeking congressional clarification about reclassifying its high-level tank waste, and (4) work with regulators on tank closure options. DOE agreed with three of these; it disagreed with seeking further clarification about reclassifying high-level waste. GAO believes this recommendation remains valid, given the importance of waste reclassification to DOE's strategy.

View GAO-09-913 or key components.
For more information, contact Gene Aloise at (202) 512-3841 or aloisee@gao.gov.

What GAO Found

DOE's tank waste cleanup strategy consists of five key phases—waste characterization, retrieval, pretreatment, treatment, and permanent disposal—but critical uncertainties call into question whether the strategy can succeed as planned. Technical uncertainties include whether DOE can retrieve waste from tanks at the rate needed to support continuous operation of the waste treatment complex now under construction and whether key treatment technologies will work. Legal uncertainties include whether DOE can treat and dispose of some tank waste as other than high-level (highly radioactive) waste and how much residual waste can be left in the tanks when they are eventually closed. Such uncertainties could lead to significant cost increases and further delays in completing Hanford's tank waste cleanup activities.

DOE has not systematically evaluated whether its tank waste cleanup strategy is commensurate with risks posed by the wastes. DOE lacks credible or complete estimates of how much the strategy will cost or how long it will take. The total project cost of constructing the waste treatment plant alone grew from $4.3 billion in 2000 to $12.3 billion in 2006. In addition, DOE did not include, or has been unable to quantify, a number of significant costs in its current estimate of the overall cost of its cleanup strategy. For example, DOE has not included some actual expenditures to date or storage costs for high-level waste canisters. Further, DOE's schedule targets have slipped, with end of treatment extending from 2028 to 2047, which increases overall operations costs. Overall the total estimated cost could significantly exceed DOE's current estimate of $77 billion, with estimates ranging from about $86 billion to over $100 billion, depending upon the date cleanup is completed. DOE has also fallen short in terms of risk-informed decision making. While DOE has analyzed risks in environmental impact statements required for its tank waste treatment activities at Hanford, it has not followed a systematic risk assessment framework, like one outlined in a 1983 report, updated in 2008, by the National Academy of Sciences. As a result, DOE cannot be assured that its present strategy is proportional to the reduction in risk that cleanup is to achieve.

Some opportunities may still exist to reduce the costs of DOE's tank waste cleanup strategy, but the likelihood of success is unknown. For example, DOE is trying to increase the concentration of high-level waste in each disposal canister, thereby reducing the number of canisters and possibly shortening treatment time frames. DOE could also work with regulators to demonstrate, on a tank-farm basis, the feasibility of leaving varying amounts of residual waste in tanks at closing without threatening human or ecological health. In removing waste from tanks, DOE has found that the last portion can be disproportionately difficult and costly to remove. Specifically, the cost of removing the last 15 percent of waste can equal or exceed the cost of removing the first 85 percent.

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Abbreviations

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DOE	Department of Energy
EPA	Environmental Protection Agency
RCRA	Resource Conservation and Recovery Act

United States Government Accountability Office
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September 30, 2009

The Honorable Peter J. Visclosky
Chairman
The Honorable Rodney P. Frelinghuysen
Ranking Member
Subcommittee on Energy and Water Development
Committee on Appropriations
House of Representatives

The Department of Energy (DOE) is responsible for one of the world's largest environmental cleanup programs: the treatment and disposal of nuclear waste created as a by-product of producing nuclear weapons. Decades of nuclear weapons production have left a legacy of radioactive and hazardous wastes to be cleaned up at DOE sites across the country. One of DOE's most contaminated locations is its Hanford Site, which lies along the Columbia River in southeastern Washington State. The site occupies 586 square miles upriver from the Tri-Cities area of Richland, Pasco, and Kennewick, with a combined regional population of over 200,000. DOE and its predecessor agencies[1] produced nuclear materials at the Hanford Site from 1944 through 1988, generating millions of gallons of radioactive and hazardous waste during those years. Some of this waste was deposited directly into the soil; some was encased in drums or other containers and buried; and some was stored in 177 large, underground tanks. In total, these tanks, clustered together in 18 locations called tank farms, contain about 56 million gallons of waste—enough to cover an entire football field to a depth of over 150 feet, or the height of a 15-story building.

Since plutonium production ended at Hanford in the late 1980s, DOE has spent more than $12 billion[2] to manage the tank waste and explore ways to treat and dispose of it. After beginning and discontinuing several different tank waste cleanup strategies, DOE has now embarked on a strategy that involves building a complex of treatment facilities, collectively called the

[1]DOE has managed the Hanford Site since 1977. Before then, the site was managed by the U.S. Army Corps of Engineers (1943-47), the Atomic Energy Commission (1947-75), and the Energy Research and Development Administration (1975-77).

[2]Unless otherwise specified, all cost numbers come from DOE and are reported in current dollars.

Hanford Waste Treatment and Immobilization Plant. Currently under construction and estimated to cost $12.3 billion to design, build, and commission, this waste treatment plant consists of a laboratory for analyzing the waste's composition; a pretreatment plant to separate the waste into two streams (a highly radioactive fraction called high-level waste and a lower-radioactivity fraction called low-activity waste); two waste treatment facilities, one for high-level waste and one for low-activity waste; and more than 20 support facilities. DOE estimates that it will cost tens of billions of dollars and take until 2047 to complete tank waste cleanup and permanently close the underground storage tanks. To date, however, no tank waste at Hanford has been treated for final disposal, and none of the tanks has been permanently closed.

DOE's cleanup, treatment, and disposal of radioactive and hazardous wastes are governed by a number of federal and state laws and implemented under the leadership of DOE's Assistant Secretary for Environmental Management. Key laws include the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended, and the Resource Conservation and Recovery Act of 1976 (RCRA), as amended.[3] In addition, most of the cleanup activities at Hanford, including emptying the underground tanks, are carried out under the Hanford Federal Facility Agreement and Consent Order among DOE, the Washington State Department of Ecology, and the federal Environmental Protection Agency (EPA).[4] Commonly called the Tri-Party Agreement, this accord was signed in May 1989 and has been amended a number of times since then. The agreement lays out a series of legally enforceable milestones for completing major activities in Hanford's waste treatment and cleanup process. A variety of local and regional stakeholders, including county and local government agencies, citizen and advisory groups, and Native American tribes, also have long-standing interests in Hanford cleanup issues. Like nearly all of DOE's missions, the majority of the work at the Hanford Site is performed by private firms under contract to DOE. Cleanup activities employ thousands of people in

[3]42 U.S.C. 9601 et seq. (CERCLA); 42 U.S.C. 6901 et seq. (RCRA).

[4]Since 2007, DOE has been renegotiating Tri-Party Agreement milestones that it has missed or believes it will miss, such as the starting date of waste treatment operations. In 2008, the state of Washington filed suit against DOE, claiming DOE violated the Tri-Party Agreement by missing enforceable milestones, including tank retrieval and treatment milestones. On August 10, 2009, DOE and the state announced they had reached a tentative settlement, including agreement on new cleanup milestones. A 2047 completion date was agreed to by DOE and its regulators in the tentative settlement.

the private and public sectors, thus contributing significantly to the economy of the Tri-Cities area.

As requested, this report discusses (1) Hanford's current tank waste cleanup strategy and key associated technical, legal, and other uncertainties; (2) the extent to which DOE has determined whether its cleanup strategy at Hanford is commensurate with risks posed by the wastes; and (3) opportunities for DOE to reduce the costs of cleaning up Hanford's tank waste while still protecting human health and the environment.

To address these objectives, we gathered and reviewed information on the Hanford waste cleanup strategy, including technical reports and internal and external reviews. We reviewed legal and regulatory requirements governing cleanup of hazardous and radioactive wastes, including requirements for determining whether some tank wastes can be classified as other than high-level waste. We also reviewed the Tri-Party Agreement to gain an understanding of its requirements and time frames. Several key documents were released by DOE just before, or were scheduled to be released shortly after, the date of this report. These included a tentative legal settlement with the state of Washington, an amended Tri-Party Agreement, a draft environmental impact statement for tank closure, and a new cost and schedule baseline for the Hanford tank waste cleanup effort. We reviewed an August 10, 2009, version of the tentative legal settlement and were provided access to a version of the draft environmental impact statement, but the remaining documents were not available at the time of our review. These documents are discussed in our report and factored into its conclusions and recommendations as available and appropriate. As agreed with DOE, we included only publicly available information about the draft environmental impact statement in our report. In addition, we interviewed officials at the Hanford Site's Office of River Protection and at DOE headquarters, including in the Office of Engineering and Construction Management and the Office of Environmental Management. We interviewed contractor officials at the Hanford Site responsible for building the waste treatment plant. We also visited the Hanford Site, including the waste treatment plant construction site. We interviewed officials with regulatory and other agencies, specifically, the Washington State Department of Ecology, EPA, the Nuclear Regulatory Commission, and the Defense Nuclear Facilities Safety Board. To assist in understanding concerns with various aspects of Hanford's tank waste cleanup strategy, we interviewed staff at the National Academy of Sciences. In addition, we identified and interviewed 18 independent experts for their input on various aspects of DOE's Hanford tank waste cleanup strategy. We provided an interim briefing in May 2009 to the subcommittee on the status of our work. Appendix I describes our scope and methodology in more detail. We conducted this performance audit from July 2008 to September 2009, in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

Established in 1943, the Hanford Site produced plutonium for the world's first nuclear device. At the time, little attention was given to the resulting by-products—massive amounts of radioactive and chemically hazardous waste. From 1944 through 1988, about 525 million gallons of radioactive tank waste was generated by Hanford's plutonium-processing plants. The federal government initially managed this waste by intentionally discharging it into the ground; reducing its volume through various waste concentration methods, such as evaporating off the liquids; and building underground tanks to store the waste until it could be treated and permanently disposed of.

From the 1940s through the mid-1960s, 149 underground "single-shell" storage tanks were built at Hanford. Originally expected to last 10 to 20 years until a permanent disposal solution could be found, each of these tanks consisted of an outer concrete wall lined with one layer of carbon steel. Grouped into 12 tank farms and buried some 6 to 11 feet beneath the surface, most of these single-shell tanks measure roughly 75 feet in diameter, range from 30 to 49 feet high, and have a capacity ranging from 530,000 to 1 million gallons of waste.[5] Together, the single-shell tanks contain almost 30 million gallons of waste; about 27 million gallons are in solid or semisolid form, and about 3 million gallons are liquid. By the mid-1990s, 67 of the single-shell tanks had leaked or were presumed to have leaked about 1 million gallons of waste into the surrounding soil. To address concerns with the design of the single-shell tanks, a new tank design with two carbon-steel shells was adopted in the late 1960s. From 1968 through 1986, 28 of these double-shell tanks, with storage capacities ranging from 1 million to 1.2 million gallons, were built and sited in 6 more

[5]Sixteen of Hanford's 149 single-shell tanks are much smaller, with a storage capacity of 55,000 gallons.

tank farms at Hanford. Together, these double-shell tanks contain about 26 million gallons of waste.[6] To help minimize further leaking, DOE had, by 2005, transferred most of the liquid in the single-shell tanks to the double-shell tanks, a process called interim stabilization. DOE is currently retrieving the remaining waste from single-shell tanks and moving it to the double-shell tanks in preparation for treatment.[7]

The contents of these tanks have settled and today exist in four main forms or layers:

- *Vapor:* Gases produced from chemical reactions and radioactive decay occupy tank space above the waste.
- *Liquid:* Fluids may float above a layer of settled solids or under a floating layer of crust; fluids may also seep into pore spaces or cavities of settled solids, crust, or sludge.
- *Saltcake:* Water-soluble compounds, such as sodium salts, can crystallize or solidify out of wastes to form a moist saltlike hardened or crusty material.
- *Sludge:* Denser, water-insoluble or solid components generally settle to the bottom of a tank to form a thick layer having the consistency of peanut butter.

About 46 different radioactive elements—by-products of chemically separating plutonium from uranium for use in nuclear weapons—represent the majority of the radioactivity currently residing in the tanks. Some of these elements lose most of their radioactivity in a relatively short time, while others remain radioactive for millions of years. The rate of radioactive decay is measured in half-lives, that is, the time required for half the unstable atoms in a radioactive substance to disintegrate, or decay, and release their radiation. The half-lives of major radioactive tank constituents differ widely. The vast majority (98 percent) of the tank

[6]The total volume of waste in all of Hanford's underground tanks fluctuates over time as DOE carries out its tank waste cleanup process.

[7]Hanford's underground storage tanks were not designed with specific waste retrieval features. Waste must be retrieved through openings, called risers, in the top of the tanks. Technicians must therefore insert specially designed pumps into the tanks to pump the waste up about 45 to 60 feet to ground level. Removing waste from the tanks that have already leaked without releasing still more material into the soil also poses a challenge, which DOE is trying to address with new retrieval technologies.

waste's radioactivity comes from two elements, strontium-90 and cesium-137, which have half-lives of about 29 and 30 years, respectively. The remaining radioactive elements, which account for about 2 percent of the waste's total radioactivity, have much longer half-lives. For example, the half-life of technetium-99 is 213,000 years, and that of iodine-129 is 15.7 million years. As we reported in 2003 on the basis of radioactivity levels measured as of August 2002, within 100 years, more than 90 percent of the radioactivity in the tanks will have dissipated, and within 300 years, 99.8 percent will disappear.[8] After the waste is separated, the high-level waste stream will contain over 95 percent of the radioactivity but total less than 10 percent of the volume to be treated. In comparison, the low-activity waste stream will contain less than 5 percent of the radioactivity but constitute over 90 percent of the volume.

The tanks also contain large volumes of hazardous chemical waste, including various metal hydroxides, oxides, and carbonates. Like radioactive by-products of plutonium production, some of these chemicals—including acids, caustic sodas, solvents, and toxic heavy metals such as chromium—came from chemically reprocessing spent nuclear fuel to extract weapons-grade plutonium. Altogether, DOE added about 240,000 tons of chemicals to the tanks from the 1940s to the mid-1980s. A majority of the chemicals (caustics, such as sodium hydroxide) were added to neutralize acids in the waste. Other chemicals, such as solvents, ferrocyanide, and several organic compounds, were added during various waste extraction operations to help recover selected radioactive elements (uranium, cesium, and strontium) for reuse. These hazardous chemicals are dangerous to human health, and they can remain dangerous for thousands of years.

Over the past 20 years, DOE has tried developing various approaches for treating and disposing of these wastes, at varying costs and with little success (see fig. 1). In 1989, DOE's original strategy called for treating waste only from the double-shell tanks. Part of this effort involved renovating a World War II-era facility, called B Plant,[9] in which it planned to start waste treatment. DOE spent about $23 million on this project but

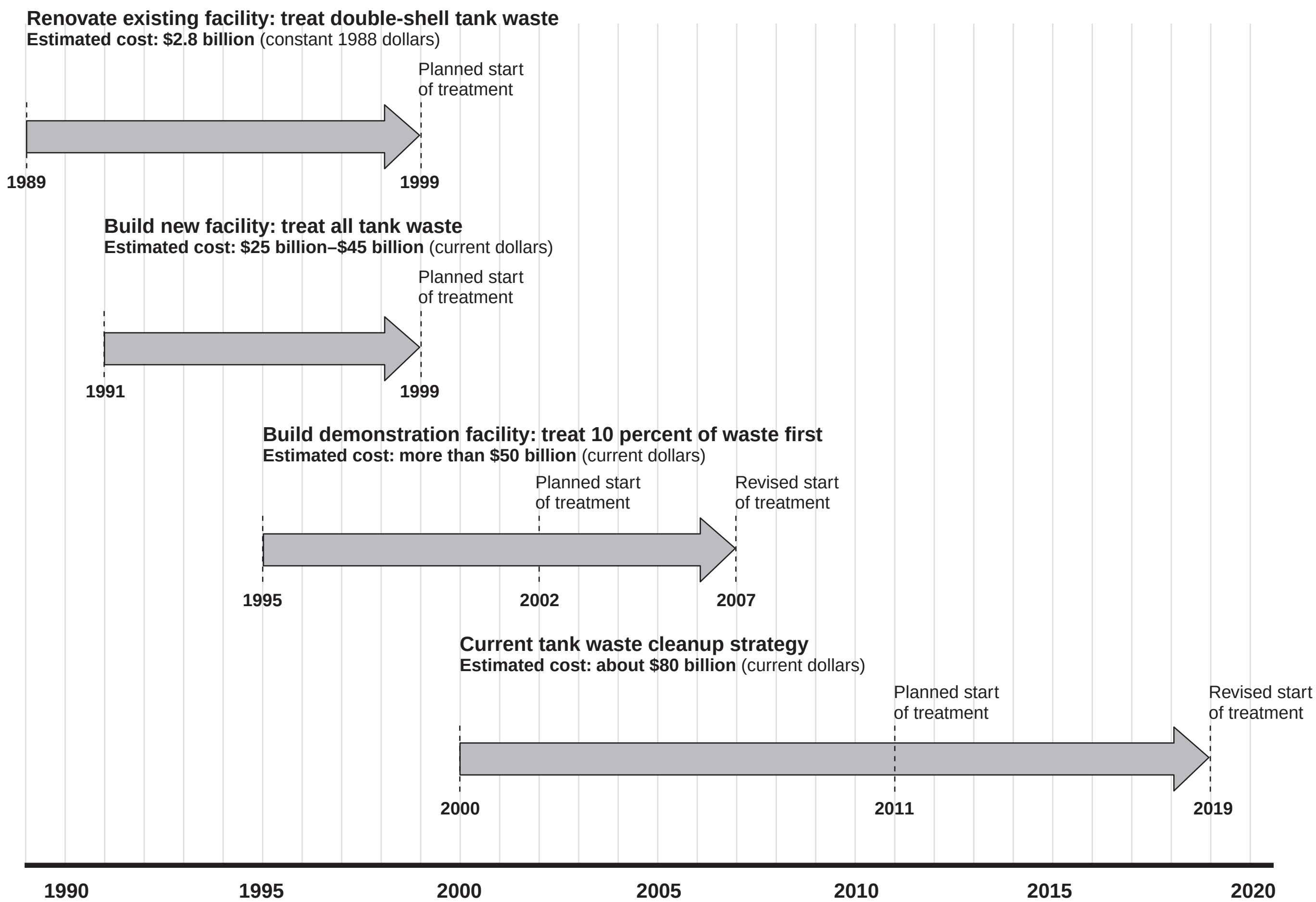
[8]GAO, *Nuclear Waste: Challenges to Achieving Potential Savings in DOE's High-Level Waste Cleanup Program*, GAO-03-593 (Washington, D.C.: June 17, 2003).

[9]B Plant was originally used to recover plutonium for nuclear weapons. In the early 1960s, it was refurbished and used to remove certain high-level radioactive materials from the tank wastes.

discontinued it because of technical and environmental issues and stakeholder concerns that not all the waste would be treated. In 1991, DOE decided to treat waste from all 177 tanks. Under this strategy, DOE would have completed the treatment facility before other aspects of the waste treatment program were fully developed, and the planned treatment facility would have had insufficient capacity to treat all the waste in a time frame acceptable to regulators. DOE spent about $418 million on this approach. Beginning in 1995, DOE attempted to "privatize" tank waste cleanup, shift risk to its contractor,[10] build a demonstration facility to treat 10 percent of the waste and 25 percent of the radioactivity by 2018, and end cleanup in 2028. But because of dramatically escalating costs and concerns about contractor performance, DOE terminated the contract after spending about $300 million, mostly on plant design. According to available information, since 1997 DOE has spent an average of more than $300 million each year on tank management and risk reduction activities, such as retrievals and facility upgrades.

[10]Under its privatization approach, DOE planned to set a fixed price and pay the contractor for canisters and containers of immobilized tank waste that complied with contract specifications. If costs grew as a result of contractor performance problems, the contractor, not DOE, was to bear these cost increases. Any cost growth occurring as a result of changes directed by DOE was to result in an adjustment to the contract price and was to be borne by DOE.

Figure 1: Changes in Hanford's Tank Waste Cleanup Strategy, 1989 to Present



Source: GAO analysis of DOE data.

Note: When estimating costs for its cleanup strategies, DOE has not always included adequate contingency funding for unforeseen circumstances. The $80 billion estimate for DOE's current strategy includes such contingency funding of about $19 billion.

Critical Uncertainties Persist in DOE's Hanford Tank Waste Cleanup Strategy

Critical uncertainties, such as technical and legal issues, call into question whether DOE's strategy to treat and dispose of millions of gallons of radioactive and hazardous tank wastes at its Hanford Site can succeed as planned.

DOE's Waste Treatment Strategy Consists of Five Key Phases

DOE's current strategy generally consists of removing, or retrieving, waste from the underground tanks; separating the wastes into high-level and low-activity waste streams through a process called pretreatment; treating the waste on site; and ultimately disposing of the low-activity waste on site and sending the high-level waste to a geologic repository for permanent disposal (see fig. 2). Specifically, the five key phases are:

- *Characterization:* Sampling and analysis to determine the specific physical, radiological, and chemical components of the wastes in each tank. Waste is sampled and analyzed starting before it is retrieved from the tanks and continuing until it is ready for final treatment.

- *Retrieval:* Removing waste from the tanks by pumping or other means and transferring it to the treatment facilities. DOE uses a variety of technologies, including high-pressure sprays to break up hardened waste on the tank bottom and vacuum systems to suck the waste out of the tanks. Because a large amount of liquid may be introduced during retrieval to break up hardened waste, waste removed from a tank is transferred to a facility to evaporate some of the liquid and reduce its volume before being sent to the waste treatment plant.[11]

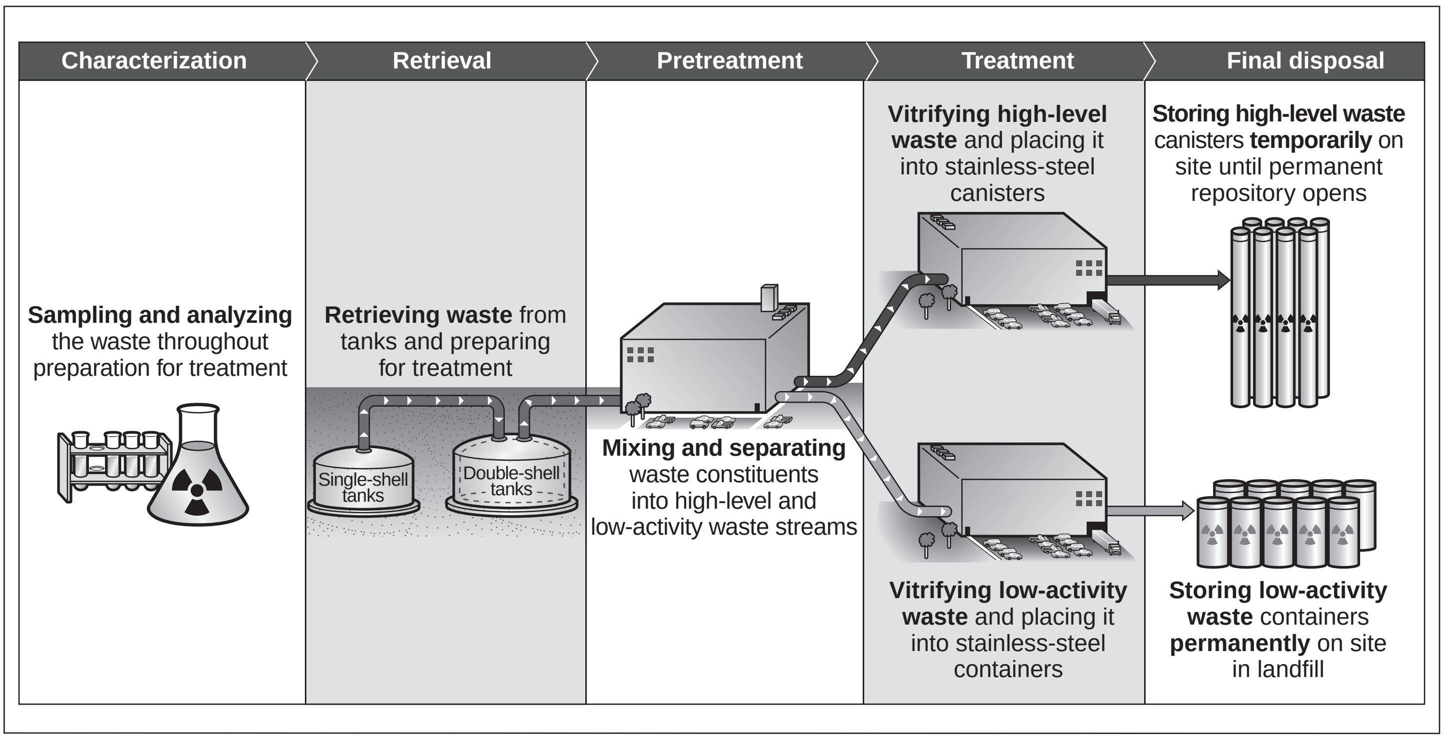
- *Pretreatment:* Mixing and separating waste constituents into high-level and low-activity waste streams by filtering, dissolving, and extracting radioactive from nonradioactive constituents such as aluminum, chromium, and salts. DOE uses a variety of technologies to extract specific radioactive and hazardous materials during this pretreatment phase.

- *Treatment:* Immobilizing the radioactive and hazardous constituents in glass through a process called vitrification. The entire high-level waste stream, and about half the low-activity waste, is to be immobilized in the waste treatment plant by mixing it with a glass-forming material, melting the mixture into glass in two vitrification facilities—one for high-level waste and a second for low-activity waste—and pouring the vitrified waste into stainless-steel canisters (high-level waste) or containers (low-activity waste) to cool and harden.

[11]DOE estimates that additional liquid introduced into the tanks may amount to three or four times the volume of waste in the tanks, or 176 million gallons for single-shell tanks. DOE does not have an estimate of the additional liquid that will be added to the double-shell tanks during retrieval.

- *Final disposal:* Storing high-level waste canisters temporarily on site until a permanent geologic repository opens and then permanently disposing of it in a designated geologic repository and disposing of the low-activity waste on site in a designated disposal landfill. Tanks will be closed permanently after as much waste as technically possible has been removed.

Figure 2: Key Phases in DOE's Tank Waste Cleanup Strategy



Sources: GAO and DOE.

Technical Uncertainties at Each Phase Could Threaten Cleanup Success

DOE faces critical technical uncertainties, including whether the pace of retrieving waste from the tanks will be sufficient to keep the waste treatment plant operating as planned and whether key treatment technologies will work. Unless DOE successfully resolves these uncertainties, it could face problems, such as facility shutdowns, facility modifications and retrofitting, or significant cost increases and delays in completing Hanford's tank waste cleanup activities.

It Is Unclear Whether Systems Designed to Characterize the Waste Will Operate at the Rate Planned

DOE plans to rely on new systems to collect and analyze waste samples, but the performance of these new systems has not yet been fully demonstrated, although DOE continues to test them. It is unclear, for example, whether these systems will be able to complete the more than 10,000 samples needed each year to ensure that the waste's composition is understood and meets the criteria for treatment and disposal. A sampling and analysis rate of 10,000 samples per year for the new analytical laboratory is several times the rate that samples have been taken and analyzed in existing Hanford laboratories. Given that waste sampling and analysis are to occur throughout preparation of the waste for treatment, a backlog in this system could substantially slow the overall waste treatment process. DOE officials told us that they recognize this uncertainty and that they are working to reduce the number of samples that will need to be analyzed.

DOE May Have Difficulty Retrieving Waste from the Tanks at Planned Rates

DOE's strategy assumes that transferring waste from the single-shell tanks into the double-shell tanks (for mixing and blending before treatment) will progress faster than experience to date suggests. It is unclear, however, whether DOE can increase its retrieval rate to adequately supply waste to the waste treatment plant on a continuous, long-term basis when the plant begins operating in 2019, as currently planned. Since 2003, DOE has emptied 7 tanks—about 1 tank per year.[12] According to an August 2009 tentative legal settlement, DOE has agreed to retrieve 10 tanks over the next 5 years—or an increase to 2 tanks per year. Even if DOE is successful in retrieving this number of tanks, it is uncertain whether sufficient space is available in the double-shell tanks to hold this waste. Further, according to DOE officials, to provide adequate waste feed to the pretreatment facility, waste retrieval will need to increase to an average of 5 to 7 tanks per year when operation of the waste treatment plant begins. Even if DOE is successful in retrieving waste at this rate from the single-shell tanks, the waste must again be retrieved from the double-shell tanks to feed into the pretreatment facility. Retrieving the waste in an uninterrupted manner over several decades requires enough trained personnel; equipment and infrastructure such as pumps, transfer lines, monitoring equipment, and scaffolding around the tanks; and a place to transfer and store waste removed from the tanks. A 2008 DOE report noted that tank waste retrieval rates could become the limiting process in maintaining the

[12]DOE is limited in the amount of waste it can retrieve from single-shell tanks, in part because of limited storage capacity in the double-shell tanks. Although the double-shell tanks have an estimated capacity of slightly over 32 million gallons, as of June 2009 (the latest data available), they already contained nearly 26 million gallons of waste.

overall treatment schedule.[13] Nevertheless, DOE officials told us they believe they will gain enough experience in retrieving waste over the next 10 years that increasing the retrieval rates will not be a problem.

Failure of Pretreatment Technologies Could Shut Down the Entire Waste Treatment Operation

In 2006, an external team of experts reported that several problems and uncertainties with technologies designed to remove particular radioactive and hazardous constituents from the waste streams could make the pretreatment facility difficult to operate and maintain. Specifically, the experts noted the potential for plugging of piping that transports the waste through the facility; inadequate filtering to remove certain constituents, such as aluminum and chromium; and insufficient mixing of the waste before and during pretreatment. To address these problems, DOE built a test facility called the pretreatment engineering platform to test and demonstrate selected pretreatment technologies using simulated tank wastes.[14] On the basis of preliminary results, DOE has adjusted the pretreatment technologies and believes that several potential problems have been mitigated. Although final test results have not been disclosed, DOE officials report that the first testing phase appears to be successful. Still, DOE has tested the systems in the pretreatment engineering platform using only simulated waste, and according to some independent experts we spoke with, using simulated waste to test a new system may not uncover all potential problems. Thus, until the pretreatment facility is operating with real waste, it will remain unclear how well the pretreatment technologies will perform. DOE's 2008 report noted that any single-point failure in pretreatment capabilities could halt operation of the entire waste treatment plant.

Uncertainties over Waste Treatment Plant Capacity Complicate Treatment Time Frames

In addition to other rate-limiting uncertainties, questions persist over how to treat all the low-activity waste—about 90 percent of the total volume of waste that must be treated. At present, the low-activity waste vitrification facility is to process only about half the anticipated amount of low-activity waste by midcentury, when DOE hopes to complete treatment of high-level waste. Without supplemental capacity, DOE has estimated that tank waste cleanup could last as long as the 2090s. Over the years, DOE has taken steps to evaluate various supplemental options for treating low-

[13]Department of Energy, *External Technical Review of System Planning for Low-Activity Waste Treatment at Hanford* (Washington, D.C., November 2008).

[14]The pretreatment engineering platform also partially addresses a recommendation we made in 2003 to pilot-test pretreatment technologies before full-scale operation. See GAO-03-593.

activity waste, and the department has an environmental impact statement under way that includes further evaluation of supplemental treatment options (see app. II). Nevertheless, the department has indicated that it is planning on a second vitrification facility specifically for low-activity waste. The amount of low-activity waste that will ultimately need treatment depends in large part on the amount of sodium in this waste stream. Sodium hydroxide, which was added to the tanks to control corrosion, is also added during pretreatment to help dissolve and remove aluminum from the waste. Adding sodium helps reduce the volume of the high-level waste stream but increases the volume of the low-activity waste stream. DOE is still studying how much sodium is likely to be needed, and if this amount is large, treatment time frames could be lengthened by several years. Building another vitrification facility—which, like the existing high-level and low-activity vitrification facilities, would depend on the same series of characterization, retrieval, and pretreatment processes—could worsen such potential bottlenecks. That is, because DOE has no alternative to the pretreatment facility, if this facility fails, the entire treatment operation, including all three vitrification facilities, could come to a halt.

The Permanent Storage Location for High-Level Waste Has Become Uncertain

While DOE's plan to permanently dispose of Hanford's vitrified low-activity tank waste in an on-site landfill has been approved by state regulators, final disposition of the vitrified high-level wastes has become less certain. DOE had planned to store this waste temporarily at Hanford until it could be shipped to Yucca Mountain, Nevada, the designated repository for the nation's spent fuel and high-level waste.[15] DOE has been developing a license application for constructing the repository and in June 2008 submitted this application to the Nuclear Regulatory Commission for review. In March 2009, however, the Secretary of Energy announced that Yucca Mountain would no longer be the final repository for the nation's nuclear waste and in its fiscal year 2010 budget justification, DOE proposed to eliminate all project funding, except $197 million, primarily for licensing activities. If no other high-level waste repository is established, DOE sites, including Hanford,[16] could end up

[15]Congress approved the Yucca Mountain site in 2002. Pub. L. No. 107-200, 116 Stat. 735 (2002).

[16]DOE's budget justification noted that the administration intends to convene a panel of experts to evaluate alternative approaches for meeting the federal responsibility to manage and ultimately dispose of spent nuclear fuel and high-level radioactive waste from both commercial and defense activities. The panel is to provide recommendations that will form the basis for working with Congress to revise the statutory framework for managing and disposing of spent nuclear fuel and high-level radioactive waste.

storing their high-level waste canisters on site indefinitely. Hanford's existing temporary storage facility can accommodate only 880 high-level waste canisters; at DOE's currently expected production rates of more than 500 canisters of vitrified high-level waste per year, Hanford will run out of storage space less than 2 years after treatment operations begin, or as early as 2021. Consequently, Hanford officials told us they are exploring ways to provide additional temporary high-level waste storage space on site. DOE plans to look at a range of options, one of which could entail building additional modular storage facilities that could initially store about 2,000 to 4,000 high-level waste canisters, with future expansion for an additional 12,000 to 14,000 canisters if necessary. Until a final decision is made about permanent disposal of high-level waste, neither the extent of additional storage capacity needed on site nor associated costs will be known.

Legal and Regulatory Uncertainties May Limit DOE's Ability to Carry Out Certain Aspects of Its Tank Waste Cleanup Strategy as Planned

DOE's tank waste cleanup strategy faces two key legal and regulatory challenges. First, DOE's plans assume that the department will obtain regulatory approval to reclassify some tank waste as transuranic waste, thereby reducing the overall amount of high-level waste to be treated.[17] Second, because the tank waste is managed as high-level waste and the technology to remove all of it from the tanks either does not exist or is extremely costly to use, DOE could face potential legal hurdles in leaving any radioactive waste in the bottom of the tanks at closing since the tanks are not considered permanent storage facilities for high-level waste.

Regulatory Approval Uncertain for DOE to Treat Some Waste as Transuranic Waste

DOE believes that waste in 11 single-shell tanks, nearly 1.5 million gallons (of about 56 million gallons of waste at Hanford), can be treated and disposed of as transuranic, rather than high-level, waste.[18] According to a DOE official, the waste in these tanks comes largely from chemical additives and other processes, not directly from the reprocessing of spent nuclear fuel that generates high-level waste. In addition, DOE believes that the tanks' contents are not radioactive enough to warrant the heavy

[17]The term *transuranic* generally applies to wastes containing radionuclides (radioactive elements) with atomic numbers higher than 92 (uranium's atomic number) and half-lives longer than 20 years in concentrations exceeding 100 nanocuries (a measure of radioactivity) per gram.

[18]DOE's transuranic wastes are destined for transfer to and final disposal at the Waste Isolation Pilot Plant, a geologic repository in Carlsbad, New Mexico.

shielding needed to protect workers when they handle high-level waste. DOE's present tank waste treatment strategy assumes that the department will be able to reclassify and treat this waste as transuranic waste, at a cost of $233 million. Before DOE can go ahead with this plan, however, it will have to gain a series of regulatory approvals from EPA, the Washington State Department of Ecology, and the state of New Mexico, each of which has previously expressed reservations. In 2007, EPA raised doubts as to whether the waste qualified as transuranic waste and asked DOE for further substantiating documentation. Ecology must approve DOE's plans to retrieve and treat the transuranic tank waste and package it for final disposal, but Ecology officials told us they are reluctant to approve any treatment plans until DOE receives assurance that New Mexico will accept the waste in its geologic repository. And New Mexico, which has been reluctant to accept any waste once regarded as high-level waste, may decide not to allow disposal of Hanford's tank waste at its repository. If regulators do not approve DOE's plans for this waste, the schedule—and associated costs—of operating Hanford's waste treatment plant could increase by 1 year and about $1 billion.

DOE Could Face Legal Challenges over Leaving Residual Waste in the Tanks at Closure

Under the Tri-Party Agreement, DOE must retrieve as much waste as technically possible from Hanford's single-shell tanks. Any waste left in the tanks, along with the tanks themselves, could be considered high-level waste, which would not be permitted to stay in the ground but would have to be disposed of in a geologic repository. DOE has a process (spelled out in its order 435.1 and associated guidance manual) for determining whether high-level waste can be reclassified as another waste type, and it plans to use this process to allow residual waste to remain in Hanford's tanks when they are permanently closed. DOE's authority to apply this order to certain high-level waste, however, was challenged in a 2002 lawsuit, which eventually failed on procedural grounds.[19] Meanwhile, in 2004 DOE sought legislation clarifying its authority to reclassify high-level waste, but although Congress enacted legislation allowing waste reclassification at two other sites, the relevant provision of the law specifically excluded Hanford.[20] This conclusion could leave DOE open to further legal challenges if the department followed its reclassification process to close Hanford's tanks. And if DOE lost such a challenge, it could be forced to exhume Hanford's tanks, and any residual waste, and

[19]Natural Resources Defense Council v. Abraham, 271 F.Supp.2d 1260 (D.Idaho 2003), vacated as unripe 388 F.3d 701 (9th Cir. 2004).

[20]Pub. L. No. 108-375, Div. C, Title XXXI, § 3116, 118 Stat. 2162 (2004).

dispose of it all in a geologic repository (called clean closure). In 2004, DOE estimated that this scenario could add delays and more than $19 billion to Hanford's cleanup costs.

DOE Has Not Systematically Evaluated Whether Its Tank Waste Cleanup Strategy, Including Costs, Is Commensurate with Risks from the Waste

As the National Academy of Sciences and others have pointed out, a number of factors warrant consideration when undertaking a project of the magnitude of DOE's cleanup mission. Among these are costs, risks to human and ecological health, and cultural and societal impacts. Yet DOE lacks much of the information it would need to weigh these factors fully.

DOE Lacks Credible Life-Cycle Cost Estimates for Cleaning Up Hanford's Tank Waste

DOE's estimates of how much it will cost to clean up Hanford's tank waste are not credible or complete. DOE has estimated the cost of a number of components that would go into a life-cycle cost estimate, including the cost to design and construct the waste treatment plant, the cost to manage and treat the tank waste, and contingency funds to cover unanticipated costs involved with this effort.[21] But these estimates are not credible or complete, and each new estimate has increased over previous estimates.[22]

Specifically, in 2007 we reported that from 2000 to 2006, the estimated costs to construct the waste treatment plant almost tripled, increasing from $4.3 billion to about $12.3 billion (see fig. 3),[23] because of contractor and management performance problems, changes in contract scope, and

[21]Unless otherwise specified, all cost numbers come from DOE and are reported in current dollars.

[22]Our report on best practices for estimating project costs highlights the need for credible cost estimates as a critical function in managing agency projects. See GAO, *GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs*, GAO-09-3SP (Washington, D.C.: March 2009).

[23]The original $4.3 billion was to construct and operate a demonstration waste treatment plant with initial capacity to vitrify 10 percent by mass of the waste and 25 percent of the radioactivity by 2018. The $12.3 billion is to construct a plant with increased capacity to vitrify all the high-level waste and about half the low-activity waste.

technical issues.[24] Likewise, DOE's estimates of costs for managing and treating the tank waste have increased significantly, raising doubts about the estimates' reliability. In 2006, for example, DOE estimated that cleanup activities would be finished by 2032, at an estimated cost of about $23 billion.[25] Two years later, the completion date was pushed out by 13 years, to 2045, with a corresponding rise in costs of about $23 billion, to $46 billion overall,[26] and indications are that these costs could increase still further. DOE also normally develops an estimate for contingency costs when carrying out large projects like Hanford's tank waste cleanup—in this case, an estimate of the costs to cover unknown or unforeseen events during the design and construction of facilities and during tank waste management and treatment activities. While DOE has included a contingency-cost estimate of about $1 billion in the waste treatment plant's total project cost, DOE project officials estimate that an additional contingency of $700 million may be needed. DOE has also estimated that a contingency amount of about $18 billion may be needed for tank waste management and treatment.[27] The magnitude of such contingency funding is still another indication of the overall uncertainty surrounding DOE's cost estimates for its tank waste cleanup strategy. In all, the estimated cost of these three key components—waste treatment plant construction and initial operations, tank farm maintenance and treatment operations, and contingency costs—totals nearly $77 billion.

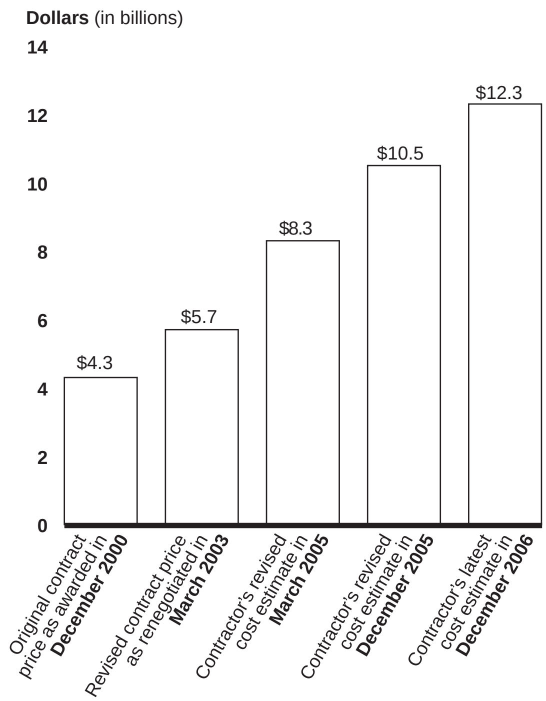
[24]GAO, *Department of Energy: Major Construction Projects Need a Consistent Approach for Assessing Technology Readiness to Help Avoid Cost Increases and Delays*, GAO-07-336 (Washington, D.C.: Mar. 27, 2007).

[25]This figure reflects estimated costs from fiscal year 2007 to 2032. If DOE had included available actual costs from fiscal year 1997 through fiscal year 2006, this estimate would come to about $26 billion.

[26]These dollar amounts reflect actual costs from 1997 through 2007 and future costs from 2008 through 2045. Complete cost information before 1997 was not available from DOE.

[27]Both the $700 million and $18 billion figures are "unfunded contingency" estimates, which represent additional funds that may be needed for potential future problems.

Figure 3: Cost Estimates for Constructing Hanford's Waste Treatment Plant



Source: GAO analysis of DOE data.

Notes: Neither the $8.3 billion figure nor the $10.5 billion figure was approved by DOE. The $12.3 billion figure represents the current total project cost. The $10.5 billion figure does not include a contractor performance fee, which is a fee that a contractor can earn above a project's costs and that offers an added incentive to complete a project on time and on budget.

DOE did not include, or was unable to quantify, a number of significant costs when estimating the overall cost of its cleanup strategy. DOE's own guidance states that life-cycle cost estimates should include actual expenditures and estimated costs from the time an activity begins until it is completed. For the cleanup strategy, however, DOE's estimates excluded

- *Actual expenditures before 1997.* DOE incurred more than $3 billion from 1989 through 1996 to manage Hanford's tank waste and explore ways to treat and permanently dispose of it, bringing life-cycle costs to about $80 billion.
- *Costs associated with any increase in waste volume.* Uncertainties over the amount of sodium to be added during pretreatment could increase the volume of low-activity waste needing treatment and ultimately increase

waste treatment costs by approximately $3 billion, according to a January 2009 DOE study.[28]

- *Costs to build a second low-activity waste vitrification facility.* DOE has yet to size or design this facility, but given costs for a supplemental technology that DOE already included in its estimate for managing and treating the tank waste, additional estimated costs for a second low-activity waste facility could increase total life-cycle costs by nearly $1 billion, according to DOE project officials.

- *Upgrading additional facilities.* DOE is considering the need for as many as four interim holding facilities for temporarily storing waste retrieved from underground tanks before pretreatment. DOE will also need to upgrade Hanford's facility for processing secondary waste generated from the waste treatment operations. The costs of upgrading or building these facilities are not fully known but, according to DOE project officials, could be on the order of several hundred million dollars.

- *Adding temporary storage capacity for high-level waste canisters.* DOE recently estimated that its present plans to expand existing space for storing high-level waste canisters would cost about $200 million. According to DOE project officials, uncertainties over the fate of Yucca Mountain could demand still more storage space on site—perhaps nearly 14 times as much as what DOE has planned—at a cost of hundreds of millions of additional dollars to build, maintain, and secure.

- *Transporting high-level waste canisters to, and permanently disposing of them in, a geologic repository.* DOE expects to ship these canisters to a geologic repository eventually, but the transportation and long-term disposal costs are not included in a life-cycle cost estimate for Hanford. Although DOE project officials could not precisely estimate how much these activities would cost, they stated that the costs could amount to billions of dollars.

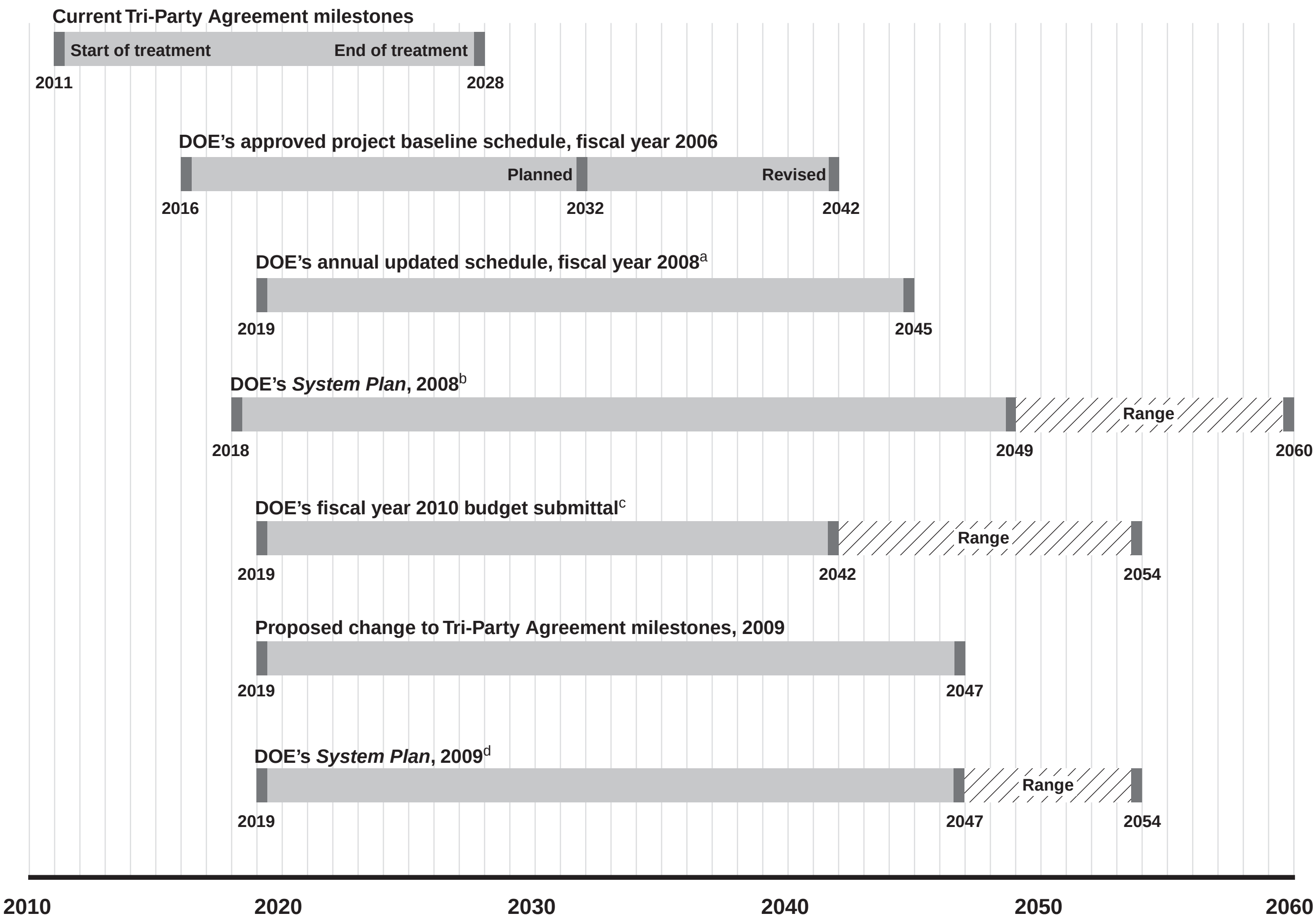
Developing a credible, complete cost estimate including the foregoing components is especially important now that, under the terms of the August 2009 tentative legal settlement with Washington State, DOE is required to have a comprehensive life-cycle cost estimate and to update it annually. Since DOE has not included these cost components in its

[28]Department of Energy, *Technical Studies Plan for Assessing Alternative Sodium Management Strategies for the River Protection Project*, DOE/ORP-2009-01 (Richland, Wash., January 2009).

estimates to date, it is unclear whether the department will do so in future life-cycle cost estimates.

Uncertainty surrounding DOE's overall tank waste cleanup schedule adds further doubt to the reliability of life-cycle cost estimates. Cleanup costs stem directly from cleanup duration, and any lengthening of cleanup time leads to cost increases of comparable magnitude. According to present Tri-Party Agreement milestones, DOE is required to complete treatment by 2028. In recent years, however, DOE's estimate of when it expects to complete tank waste treatment has shifted repeatedly. In its negotiations of new cleanup milestones with its regulators, it has agreed that tank waste treatment may not be completed until 2047. In addition, DOE's proposed fiscal year 2010 budget shows a range of treatment completion dates from 2042 to 2054. Other documents consider treatment time frames extending even further (see fig. 4).

Figure 4: Shifting Estimates of the Duration of Hanford Tank Waste Treatment



Source: GAO analysis of DOE data.

[a]Department of Energy, Office of River Protection, *Fiscal Year (FY) 2008 Project Baseline Summary Sheets: GEN-02 Reports* (Richland, Wash., September 2008). This document, submitted annually to Congress, represents DOE's best estimate of project costs and schedules.

[b]CH2M Hill Hanford Group, *River Protection Project System Plan,* ORP-11242, rev. 3A, prepared for DOE (Richland, Wash., July 2008). This planning document explains how DOE believes it can carry out its tank waste cleanup strategy.

[c]Department of Energy, *FY 2010 Congressional Budget Request: Environmental Management, Defense Nuclear Waste Disposal, Nuclear Waste Disposal,* DOE/CF-039, vol. 5 (Washington, D.C., May 2009).

[d]Washington River Protection Solutions and AEM Consulting, *River Protection Project System Plan,* ORP-11242, rev. 4, prepared for DOE (Richland, Wash., September 2009).

In the absence of a clear and reliable schedule, DOE cannot develop a reliable cost estimate for its tank waste cleanup strategy. Moreover, the former project manager for waste treatment plant construction suggested that a reliable completion schedule may not be known until 2022—some years after treatment operations are to begin. Given that estimated average annual expenditures amount to about $1.2 billion,[29] if treatment activities actually last until 2054, as some DOE planning documents suggest, tank waste management and treatment could increase about $8.4 billion dollars more than anticipated (see table 1).

Table 1: Estimated Costs Associated with DOE's Tank Waste Cleanup Strategy

Cost components	Costs included in DOE's estimate	Costs not included in DOE's estimate[a]
Waste treatment plant total project cost	$12.3 billion	
Tank waste management and waste treatment operations, fiscal years 1997 to 2045[b]	46.0 billion	
Contingency		
Waste treatment plant Tank waste management and waste treatment operations	0.7 billion 18.0 billion	
Total of DOE's current estimate for cleanup	**$77.0 billion**	
Actual costs, fiscal years 1989 to 1996		$ 3.0 billion
Increases in waste volume		3.0 billion
Second low-activity vitrification facility		1.0 billion
Cleanup schedule extension from 2045 to 2047[c]		2.4 billion
Total potential costs if treatment extends to 2047		**$86.4 billion**
Cleanup schedule extension to 2054[d]		8.4 billion
Total potential costs if treatment extends to 2054		**$94.8 billion**
Additional facilities		Hundreds of millions of dollars
Temporary storage capacity for high-level waste canisters		Hundreds of millions of dollars
Transporting and disposing for high-level waste canisters		Billions of dollars
Potential cost of DOE's cleanup strategy		**$86 billion to more than $100 billion**

Source: GAO analysis of DOE data.

[29]This $1.2 billion estimate includes costs of both tank farm and waste treatment plant activities beginning in 2019.

[a]Unless otherwise indicated, these estimates, provided by DOE, represent only rough orders of magnitude.

[b]DOE's most recent estimate, dated September 2008, reflects a cleanup completion date of 2045.

[c]DOE's most recent estimate, dated September 2008, reflects a cleanup completion date of 2045. In an August 2009 proposed legal settlement, however, DOE agreed to complete cleanup by 2047. The cost estimate is based on data provided by DOE.

[d]DOE's latest internal planning document shows a range of cleanup completion dates from 2047 to 2054. The cost estimate is based on data provided by DOE.

Overall the total estimated cost could significantly exceed DOE's current estimate of $77 billion, with estimates ranging from about $86 billion to over $100 billion, depending upon the date cleanup is completed.

DOE Has Not Applied Risk-Informed Decision Making in Its Tank Waste Cleanup Strategy

Although the importance of risk assessment for decision making had been recognized for more than 2 decades before cleanup of DOE's weapons complex began, to date DOE has analyzed risks to human and ecological health mainly in the context of complying with environmental analysis requirements under the National Environmental Policy Act of 1969.[30] Under this act, agencies evaluate the likely environmental effects of projects they are proposing by using an environmental assessment or, if the projects are likely to significantly affect the environment, a more detailed environmental impact statement. Under regulations implementing the act, an environmental impact statement must assess the environmental effects of the proposed agency action and all reasonable alternatives. A 1983 National Academy of Sciences report, on the other hand, explicitly assessed the feasibility of, and offered guidelines for, federal agencies' use of risk assessment—separate from regulatory functions—in their decision making.[31] Since DOE's cleanup efforts started, some three dozen studies by academics, the National Academy, and DOE itself have examined aspects of risk assessment in relation to DOE's cleanup work. Many of these studies have identified shortcomings in the department's efforts to address risk in its decision making and urged it both to adopt a more disciplined process for analyzing risks and to use the results of such risk analyses when making key decisions.

[30]42 U.S.C. § 4332(2)(C).

[31]National Research Council, *Risk Assessment in the Federal Government: Managing the Process* (Washington, D.C.: National Academy Press, 1983).

DOE's principal risk assessment to date with regard to tank waste is found in its 1996 environmental impact statement. This statement discussed the potential environmental effects related to several strategies for managing and treating Hanford's tank wastes.[32] Most of these alternatives involved vitrification technologies, to the near exclusion of other potential alternative treatment pathways. This environmental impact statement was not required to be—and was not—a systematic risk assessment of all options to treat Hanford's tank wastes. As we previously reported, for example, it did not purport to analyze the condition or long-term viability of Hanford's aging tanks or the risks of leaving waste in the tanks for several decades during cleanup operations.[33] The environmental impact statement did examine 10 tank waste treatment strategies—including "no action" and a "preferred alternative"—and the potential effects of these strategies on different groups of people, such as site workers, recreational river shoreline users, farmers, and Native American users, under different long-term land-use scenarios. The "no action" alternative was predicted to result in 600 "latent cancer fatalities" among future farmers on the site over 10,000 years. DOE's preferred alternative—on which DOE's present strategy is based—was predicted to reduce to 10 the number of farmers' deaths over 10,000 years. This alternative would also result in disturbing the widest area of the region's native shrub-steppe ecosystem of all the alternatives presented. In comparison with no action, however, this alternative would add thousands of regional jobs during treatment plant construction. Significant costs were associated with all 10 treatment alternatives; in 1996 dollars, no action was estimated to cost $13 billion to $16 billion, while the preferred alternative was projected at the time to reach $30 billion to $38 billion.

Internal as well as external reports since that time have noted problems with DOE's risk assessment and decision making. One of the major findings of DOE's 2002 "top-to-bottom" review of its Environmental Management program, for example, states that "[Environmental Management's] complex-wide cleanup strategy is not based on a comprehensive, coherent, technically supported risk prioritization. . . . This approach has resulted in costly waste management and disposition

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[32]Department of Energy and Washington State Department of Ecology, *Final Environmental Impact Statement for the Tank Waste Remediation System, Hanford Site, Richland, Washington*, DOE/EIS-0189 (Richland, Wash., August 1996).

[33]GAO, *Nuclear Waste: DOE Lacks Critical Information Needed to Assess Its Tank Management Strategy at Hanford*, GAO-08-793 (Washington, D.C.: June 30, 2008).

strategies that are not proportional to risks posed to human health and the environment."[34] More recently, a 2005 National Academy of Sciences report observed that "DOE risk assessments and decision processes . . . do not exhibit all of the characteristics of an effective and credible risk-informed decision-making process."[35]

DOE is planning to issue another environmental impact statement,[36] expected in October 2009, but it is unclear to what extent its consideration of risks will follow available risk assessment guidelines. According to the National Academy's 2005 report, a risk assessment framework would weigh a number of factors—including costs, worker and public safety, effect on ecosystems, technical feasibility, cultural impact, and other trade-offs. A 2008 report by the academy goes further, outlining a three-phase framework for risk-based decision making that "maximizes the utility of risk assessment" in evaluating options to reduce hazards.[37] DOE's forthcoming environmental impact statement will evaluate a number of alternative strategies for carrying out tank waste cleanup and other cleanup-related activities—in particular, options for supplementing the capacity for treating low-activity waste and options for closing the tanks.[38] Regarding tank waste cleanup, for example, the document will discuss the short- and long-term effects of several options for treating both high-level and low-activity tank waste, coupled with various tank closure alternatives. These options include retrieving an amount of waste (90 percent) that is less than the goal set by the Tri-Party Agreement (99 percent) and retrieving nearly all the waste (99.9 percent), an amount that would have to be achieved if the tanks are to be removed from the ground. In addition, the environmental impact statement will consider long-term cumulative effects from past practices (including waste already

[34]Department of Energy, *A Review of the Environmental Management Program* (Washington, D.C., Feb. 4, 2002).

[35]National Research Council, *Risk and Decisions about Disposition of Transuranic and High-Level Radioactive Wastes* (Washington, D.C.: National Academies Press, 2005), and list of references therein.

[36]Department of Energy, *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*, forthcoming.

[37]National Research Council, *Science and Decisions: Advancing Risk Assessment* (Washington, D.C.: National Academies Press, 2008).

[38]This document considers tank waste cleanup and closure in combination with two other major cleanup-related activities: decommissioning of the Fast Flux Test Facility (a nuclear research reactor that operated at Hanford from 1982 to 1992) and waste management and disposal on the Hanford Site.

discharged into the soil), present activities, and future actions. The document's release has been delayed more than 2 years, and it is not yet clear when it will be issued.[39]

Given that environmental impact statements are DOE's primary risk assessment vehicle, the current effort provides an opportunity to use available risk assessment guidelines to consider scenarios the department has not considered to date—in particular, the possibility of removing varied quantities of waste from the tanks. The National Academy's 2005 report stated, for example, that removing every gram of high-level waste is technologically unfeasible without also removing the tanks themselves and that the effort is likely to be out of proportion with the concomitant risk reduction. Indeed, more than half the experts we spoke with said that the 99 percent figure has no scientific basis, and several recommended that DOE conduct a comprehensive risk assessment of residual tank waste.

Some Opportunities May Exist to Reduce Costs of DOE's Hanford Tank Waste Cleanup Strategy

Given the current status of DOE's cleanup strategy and associated costs, three primary options appear available for reducing life-cycle costs of tank waste cleanup. The likelihood of their success—and potential effects on cleanup costs—has not yet been determined.

[39] DOE had originally intended to issue a public draft of the environmental impact statement in spring 2007. After delays, DOE officials told us in May 2009 that the document would be issued by the end of June 2009. As of July 2009, DOE had again delayed the statement's release until revisions could be made analyzing the effects of the uncertainty regarding the ultimate repository site for DOE's high-level waste. DOE officials said they plan to issue the statement for public review before the end of October 2009.

Increasing the Amount of High-Level Waste Captured in Each Canister Could Reduce the Number of Canisters and Treatment Duration, Thereby Reducing Costs

DOE officials at Hanford are researching methods for increasing the amount of high-level waste ultimately immobilized in each canister in an attempt to reduce the total number of canisters produced and, perhaps, treatment duration. The total concentration of high-level waste per canister depends on, among other factors, the specific mix of radioactive and other constituents going into the canister. Certain chemical mixes lend themselves less well to vitrification than others. Chemicals such as aluminum can be added to glass only up to specific limits without altering glass quality. If aluminum concentration exceeds these limits, the resulting glass product may not be able to keep the radioactive constituents from leaching out over time. DOE is therefore studying techniques for fine-tuning the mix of constituents so as to maximize the concentration and retention of high-level waste in each canister. DOE estimates that its waste canisters may, on average, contain about 28-31 percent high-level waste.[40] At this concentration, DOE would generate more than 500 high-level waste canisters per year, or a total of 9,000 to 15,000 high-level waste canisters. DOE is hoping to increase high-level waste concentrations in each canister, but it is too early to tell what levels can be consistently achieved during full-scale treatment. If successful, according to some DOE officials, such increases in waste concentrations could reduce the number of high-level waste canisters, potentially shaving years—and associated costs—off treatment operations. While it is unclear what savings could be achieved, DOE believes the savings could be substantial.

Performing Additional Testing on Pretreatment Technologies Could Help Minimize Problems during Waste Treatment Operations

In 2008, DOE built a test facility, the pretreatment engineering platform, to help resolve uncertainties in selected pretreatment technologies, particularly the engineering designs for ultrafiltration, or filtering the waste to remove solids; efficiently dissolving components such as aluminum and chromium to facilitate separating high-level from low-activity waste streams; and ensuring that piping throughout the facility will not clog with waste sludge moving through the system. A number of the experts we spoke with had concerns about the reliability of these and other pretreatment technologies.[41] In May 2009, DOE officials stated that the department has completed most of the testing on these technologies (with a report to be released later this year), and project officials stated

[40]The remaining canister contents consist of glass-forming material.

[41]Some of the experts we interviewed also had concerns about the reliability of the ion exchange system that extracts the waste from the highly radioactive element cesium-137. The ion exchange process was not tested as part of the pretreatment engineering platform.

that they had improved the facility's design as a result of the testing. It appears, however, that the pretreatment platform provides DOE with an opportunity to use the platform to test additional pretreatment technologies and also to refine or enhance the efficiency and effectiveness of future pretreatment operations. Given the delays—and costs—that could arise if the pretreatment facility becomes a significant bottleneck for waste treatment plant operations overall, some of the experts we spoke with commented that using the pretreatment engineering platform for testing before full operations begin could help reduce uncertainties. As we reported in 2003, if pretreatment processes at Hanford do not work as planned, facilities would likely have to be retrofitted, resulting in potential cost increases and schedule delays much greater than those associated with process testing in a pilot facility.[42] DOE has recognized this opportunity and is considering options for further testing and for obtaining needed funding.

Allowing More Residual Waste to Remain in Selected Tanks at Closing Could Help Reduce Costs without Adding Risks to Human or Ecological Health

With regard to amounts of residual waste permitted in the tanks at closure, DOE's present strategy is driven in large measure by milestones agreed to in the Tri-Party Agreement. This agreement calls for retrieving as much waste as technically possible, with tank waste residues not to exceed specified volumes.[43] Federal regulations under RCRA define a waste container as "empty" if, among other criteria, it contains no more than 1 inch of waste residues, which is the equivalent of the volume limits stipulated in the Tri-Party Agreement.[44] According to one DOE official, the volume limits in the agreement were set to ensure that at least 99 percent of the waste would be removed from the single-shell tanks. Several of the experts we interviewed, however, suggested that DOE could leave more waste in selected tanks at closing and still protect human health and the environment.

[42] GAO-03-593.

[43] Under the Tri-Party Agreement, DOE is required to retrieve as much tank waste as technically possible, with tank waste residues not to exceed 360 cubic feet in the so-called "100" series of tanks, 30 cubic feet in the "200" series tanks, or the limit of waste retrieval technology capability, whichever is less. (*Tri-Party Agreement Action Plan*, appendix D, milestone M-045-00.) These quantities represent 99 percent waste retrieval for each single-shell tank. If DOE believes that waste retrieval to these levels is not possible for individual tanks, DOE may request an exception.

[44] 40 C.F.R. 261.7(b)(1)(ii). A container is also considered empty if no more than 0.3 percent by weight of the total capacity of the container remains in the container or inner liner, if the container is greater than 119 gallons in size. 40 C.F.R. 261.7(b)(1)(iii)(B).

As DOE has emptied the single-shell tanks, it has found that estimates for retrieving the waste have significantly understated actual costs. For example, in 2003, DOE estimated that retrieving waste from all the single-shell tanks would cost approximately $1.1 billion, or an average of about $7.6 million per tank. Actual costs of removing waste from the first seven tanks, however, have amounted to $236 million, or about $34 million per tank.[45] Because four of the emptied tanks were Hanford's smallest, actual costs for the more-numerous larger tanks could be much higher.

In retrieving waste from Hanford's single-shell tanks, DOE has also found that retrieving the last portion of waste from a tank can be disproportionately costly. In at least five out of the seven tanks emptied to date, DOE has found it technically challenging to retrieve 99 percent of the waste and meet the Tri-Party Agreement goal. For some of these tanks, DOE has estimated that the cost of retrieving the last 15 percent of the waste can equal or exceed the cost of removing the first 85 percent (the cost per gallon can be as much as three times higher). For example, as we previously reported, DOE found that in retrieving the waste from one large tank (C-106), the cost of removing each additional cubic foot, or about 8 gallons, of waste ranged from $35,000 to $84,000—in other words, from 7 to 16 times the average cost per cubic foot to retrieve the first nearly 99 percent of the waste.[46] Moreover, in its analysis, DOE concluded that the risk to workers from removing this waste, combined with the high cost, outweighed a relatively minimal reduction in risk to the public and future users of the site. Similarly, a DOE official told us that for another tank (C-103), the cost to date of retrieving about 85 percent of its residual waste was about $4 million and for retrieving an additional 12 percent of the residual waste, $2 million.[47]

Currently, DOE has not analyzed how to close the tanks in a manner that would balance risk with cost. The Washington State Department of Ecology and DOE developed a plan for a tank closure demonstration project to be carried out in collaboration with DOE, its contractors, EPA, and the state itself. The project's purpose was to bring the agencies

[45]Retrieval costs per tank for each of the seven tanks retrieved thus far have varied significantly, ranging from $143 million for a large tank (530,000 to 1 million gallons) to less than $10 million per tank for four of the smallest tanks (55,000 gallons).

[46]GAO-08-793.

[47]These costs do not include costs to design and construct tank waste retrieval structures and equipment.

together to, among other objectives, gather engineering and cost data on technologies that might be used to close single-shell tank systems; identify and begin to gather information needed for specific regulatory decisions associated with tank closure; and develop a common understanding of the relevant regulatory processes in order to facilitate permitting. In the August 2009 tentative legal settlement, DOE agreed to complete certain activities in this tank closure demonstration project by 2011. These activities include determining the process DOE will follow to reclassify residual tank waste, studying technical aspects of exhuming tanks, and evaluating alternatives for removing residual waste from a selected tank. Such a demonstration project could be expanded to include analyzing varying amounts of waste that could be left in a group of tanks at closing, with the goal of reducing costs while adequately protecting human and ecological health. This demonstration could allow DOE and the state to determine how to close the tanks in a cost-effective manner, as well as to streamline the tank closure process by determining closure goals and methodologies on a group of tanks, instead of one tank at a time.

Conclusions

In 1989, when DOE began its cleanup mission at the Hanford Site, the total estimated cost was $2.8 billion, with treatment to begin in 1999. Despite the passage of two decades, investment of $12 billion, attempts at several ultimately discontinued strategies, and numerous recommendations from us and others, no waste has yet been treated for final disposal. DOE has, however, learned lessons along the way. It has improved its strategy, developed and refined its retrieval and treatment technologies, and made progress constructing the treatment facilities. DOE has also learned that cleaning up the legacy of radioactive and hazardous waste is more complex, more time-consuming, and significantly more expensive than envisioned. Yet DOE still faces many critical unknowns, including whether the treatment plant will actually work as planned, whether DOE can reclassify waste as planned without explicit statutory authority, and where treated high-level waste will be permanently disposed of. And although it is clear that the total costs—now estimated at $77 billion—will be much higher than originally anticipated, ranging from $86 billion to more than $100 billion, it is unclear at this point what the final costs will be. Moreover, as we have previously reported, certain risks—such as radioactivity—are declining with time, even as costs continue to climb and cleanup completion dates recede into the future. Given that the intersection is constantly shifting between actual cleanup costs and changing risks posed by the wastes, it is imperative that Congress have access to reliable life-cycle cost and risk information as it decides how to best allocate limited financial resources among many competing needs.

And given escalating expenditures, it is also imperative that DOE diligently seek ways to reduce the costs of this massive undertaking without unduly compromising ecological, worker, or public health. Otherwise, the effort, worker exposure, and expense associated with retrieval, immobilization, and final disposal of tank waste in a geologic repository might be out of proportion with the risk reduction achieved.

Recommendations for Executive Action

In light of growing costs and lengthening schedules as DOE proceeds with its strategy to treat and permanently dispose of Hanford's tank waste, we recommend that the Secretary of Energy direct the Assistant Secretary for Environmental Management to take the following four actions:

- Develop credible and complete life-cycle cost and schedule estimates, which include actual costs expended to date and projected future expenditures for all key elements; obtain independent expert evaluation of these estimates; and report these estimated costs to Congress.
- Adopt a risk assessment framework for Hanford cleanup that considers available guidance, such as that provided by the National Academy of Sciences.
- Consider seeking clarification from Congress about the department's authority at Hanford to determine whether some waste now managed by DOE as high-level waste can be treated and disposed of as a waste type other than high-level waste.
- Work with state and federal regulators to develop a risk-based approach for closing waste storage tanks in an efficient and effective manner—such as through a tank closure demonstration project—and to analyze varying amounts of waste that could be safely left in the tanks or a group of tanks at closing, with the goal of reducing costs while adequately protecting human and ecological health.

Agency Comments and Our Evaluation

We provided a draft of this report to the Department of Energy for its review and comment. On behalf of the department, DOE's Assistant Secretary for Environmental Management wrote that DOE generally agreed with three of the four recommendations we made. DOE did not agree with our recommendation to consider seeking clarification from Congress about the department's authority at Hanford to determine whether some waste now managed as high-level waste can be treated and disposed of as other than high-level waste. In addition, DOE expressed concerns about how we characterized the Office of Environmental Management's progress at cleaning up Hanford tank waste with respect to three primary issues: addressing technical and other challenges, developing credible and complete life-cycle cost and schedule estimates, and assessing risks. On September 18, 2009, we met with the Assistant Secretary for Environmental Management to discuss selected DOE comments on our draft report, as well as the Assistant Secretary's concerns that readers may be confused about the scope of our report and assume that we also reviewed and based our conclusions on an assessment of legal and technical documents that are scheduled to be released shortly after our report is issued. We added a clarification in the scope and methodology section of this report to note that our conclusions and recommendations are based only on information available to us during our review. DOE's written comments on our draft report are reproduced in appendix III. DOE also provided general and specific technical comments, which we discuss below or incorporated in the body of the report as appropriate.

The first major issue for DOE regards progress in addressing technical and other challenges. DOE stated that we did not adequately describe the department's substantial experience in and processes in place for addressing technical and other challenges of treating and disposing of Hanford's tank waste. In its letter, DOE cited a number of examples of cleanup activities across the DOE complex of sites that it said are applicable to the challenges at Hanford and inform its technical and project management approach. Without doubt, DOE has gained knowledge about treating tank waste and closing tanks through its work at the Savannah River Site, South Carolina; the Idaho National Laboratory; and other locations. At none of these sites, however, does the waste approach the amount and complexity of Hanford tank waste. About 56 million gallons of tank waste must be treated at Hanford, more than at any other DOE site. In addition, this tank waste is uniquely complex because of the specific radioactive and chemical elements that have been mixed in it over the years, so that work done at other sites, though helpful, may not always be directly relevant to treating Hanford's tank waste. The examples of success DOE cited in its written comments are informative but, relative to the final output expected at the Hanford Site, of much smaller scope. For example, DOE cited West Valley, New York, where about 275 high-level waste canisters were produced. Some estimates for Hanford, in contrast, put the number of high-level waste canisters alone between 9,000 and 15,000. Moreover, the scope of our study, as requested by Congress, was to look at Hanford's tank waste cleanup project, not cleanup across the rest of the DOE complex.

DOE also commented that we did not cite all the initiatives it has under way to help address technical uncertainties specifically at the Hanford Site. We did discuss several initiatives, including the pretreatment engineering platform and external review teams, which have been very useful in identifying and helping address technical challenges that DOE faces at Hanford. Even with these and other efforts mentioned by DOE in its letter, however, DOE's own assessments of the waste treatment plant point out that a number of uncertainties still exist and that solving these may be critical to operating the plant as planned. Also, some experts we spoke with said that it is to be expected that some technical issues may remain unresolved until the plant is operating and actual waste is being treated. As discussed in our report, many of the technical uncertainties at Hanford surround whether treatment operations will be able to achieve the throughput assumed in DOE's planning documents. The former project manager at the Hanford Site told us that it may take a few years of plant operation before DOE will be able to accurately determine how many years it will take to treat all of the site's tank waste. Finally, technical concerns discussed in this report have been documented in DOE's own assessments and studies, as well as echoed by the experts we spoke with.

Further, DOE stated that our report should provide better context for our analysis of the challenges at Hanford and, as evidence, cited a 2001 report we issued on the Rocky Flats closure project.[48] In that report, we stated that DOE could have difficulty meeting the target closure date because of significant challenges that DOE and its Rocky Flats contractor faced. Nevertheless, despite these challenges, DOE and its contractor did meet their target closure date of 2006. Our conclusions in that report were based on the contractor's own assessment that it had only about a 15 percent probability of completing the project by 2006. In our view, by highlighting the challenges DOE and its contractor faced, our report helped focus attention needed to successfully complete the project in a timely manner.

The second issue DOE raised in its written comments relates to whether DOE is developing credible and complete life-cycle cost and schedule estimates. In agreeing with our recommendation on this topic, DOE stated that it has a process for developing credible and complete life-cycle cost estimates for Hanford. We maintain, however, that past cost estimates for

[48]GAO, *Nuclear Cleanup: Progress Made at Rocky Flats, but Closure by 2006 Is Unlikely, and Costs May Increase*, GAO-01-284 (Washington, D.C.: Feb. 28, 2001).

Hanford tank waste cleanup were neither credible nor complete. As discussed in this report, costs for constructing the waste treatment plant and managing the tank waste, for example, have grown significantly over the life of the project. Although DOE stated that we used a point estimate of our own construct, we in fact discussed with DOE officials at the Office of River Protection the cost estimates making up the $77 billion figure in table 1. These officials provided updated figures to reflect a 2045 completion date, rather than a 2042 date for the figures quoted by DOE in its written comments. DOE's current estimate for cleanup could range from $58.3 billion if no contingency is included to $77.0 billion if the full $18.7 billion contingency is included, in contrast to the range of $56 billion to $74 billion that DOE provided in its letter.

Further, many potentially significant costs were not included in any estimates DOE provided us. If these are added in, the total cost for this undertaking could range from $86 billion to more than $100 billion. We recognize that DOE has been taking steps to try to improve its cost-estimating process, including using GAO's cost-estimating guide,[49] when developing cost and schedule estimates. DOE is also developing a new cost and schedule baseline for the Hanford tank waste cleanup effort, but since this baseline has not yet been validated or approved by DOE, it was not available for our review. Further, as noted in its comments, under the August 2009 tentative legal settlement for Hanford (which is still subject to public review and comment), DOE has agreed to prepare a life-cycle analysis of all Hanford cleanup costs to meet the legally mandated cleanup timelines. We look forward to development of this analysis because we believe that until DOE develops a complete life-cycle cost analysis at Hanford—one that takes into account all potentially significant costs stemming from the effort to clean up tank wastes, including those for interim and permanent storage of waste canisters—information presented to Congress could understate the true costs of this challenging cleanup effort.

DOE's third issue relates to consideration of risk. DOE agreed with our related recommendation to adopt a risk assessment framework that considers available guidance, such as that provided by the National Academy of Sciences, but added that it believes it already has a risk assessment framework for Hanford and that our report does not recognize existing DOE risk *management* efforts (our emphasis). We acknowledge

[49] GAO-09-3SP.

that DOE has taken steps to assess risks, such as in its forthcoming draft environmental impact statement, which is expected to be released for public comment in October 2009. DOE also has a process for managing risks, and its letter says the Tri-Party Agreement contains provisions for mitigation of programmatic risk. Risk assessment, however, is not the same as risk management. Specifically, in the view of the National Academy of Sciences, the assessment of risks and related scientific findings and policy judgments should be distinguished from risk management alternatives. In essence, the science of risk analysis and assessment to inform policy are related to but distinct from actions taken to manage identified risks. In its technical comments on our report, DOE addressed risk management activities at some length. For example, it stated that we failed to mention DOE guidance on risk management, the *River Protection Project Federal Risk Management Plan*, and other key documents that include risk mitigation actions. DOE described these documents, for example noting that the river protection plan lays out the critical technical, programmatic, and operational risks facing Hanford's cleanup projects. But in our view, DOE's description focuses on mitigation steps for addressing risks to meeting the project's cost and schedule estimates. Therefore, although we considered these documents, we did not include them in our analysis because they focused on project risks rather than addressing risks to human and ecological health.

Moreover, we are not the first to suggest that DOE's risk assessment framework falls short. As stated in our report, some three dozen studies by academics, the National Academy of Sciences—including studies done at the behest of DOE—and DOE itself have examined aspects of risk assessment in relation to DOE's cleanup efforts and found shortcomings. As early as 1983, a National Academy of Sciences report offered guidelines for federal agencies' use of risk assessment, distinct from regulatory functions, in their decision making. Yet we found, and DOE's comments also stated, that the draft environmental impact statement on tank waste treatment and closure, required under the National Environmental Policy Act, is a primary risk assessment vehicle. In light of DOE's comments on this topic, confusion seems to persist about the differences between risk assessment and risk management.

With regard to the issue of the risks of leaving more waste in tanks, DOE stated that it is important to recognize that the department has limited discretion when it comes to decisions on how to proceed with cleanup. It noted that the Tri-Party Agreement generally requires removal of 99 percent of waste from the tanks using available technologies. We recognize that DOE must operate within the legal constraints placed on it.

That said, the Tri-Party Agreement does allow DOE to seek an exemption from the 99 percent target on a tank-by-tank basis, and DOE is currently using this exemption process for one tank it has been emptying. Our point is that, given the enormous task DOE faces and the enormous associated costs, if and when situations arise where the efforts and costs to meet the 99 percent waste removal standard are significantly out of proportion with the actual risk reduction achieved, DOE and its regulators should perhaps reconsider the reasonable and appropriate path forward. We, like DOE, believe the tank closure demonstration project DOE plans to carry out in collaboration with Washington State and EPA will be useful in informing this discussion.

DOE disagreed with our recommendation suggesting that the department consider seeking clarification from Congress about its authority to reclassify high-level waste, stating that it does not believe it needs clarification about the department's authority at this time. DOE stated that its attention for the next 10 years will be on removing waste from tanks, finishing construction of the waste treatment plant, and starting waste treatment operations. The department was silent, however, on the merits of the recommendation itself. We recognize that DOE requested this clarification once before and that in 2004 legislation (section 3116 of Public Law No. 108-375), Congress provided this authority to DOE sites in Idaho and South Carolina while specifically excluding DOE sites in Washington State. Given the importance of waste classification to the overall Hanford cleanup strategy, however, we believe that it may be prudent to consider revisiting the topic with Congress. By indefinitely postponing potential resolution of this question, DOE may be leaving itself vulnerable to future litigation on a topic that could pose more severe problems later. By pursuing the question now, DOE could have time on its side and can work with regulators and stakeholders to tailor its strategy appropriately.

Finally, in its technical comments, DOE stated that many comparisons made in the report do not have consistent or equitable bases. DOE commented that while the costs and schedules for its Hanford tank waste cleanup strategy have varied over time, the associated scope has greatly changed, and earlier cost estimates did not include over $2 billion in funded contingency. In describing the previous and current treatment strategies, our report does note that the scope, as well as associated costs, has changed over time. This information is given as background for readers, not an exhaustive discussion of previous strategies that did not reach fruition. DOE also commented that we compared information, such as treatment completion dates, from documents having different purposes, such as a baseline schedule and a strategic planning document. We recognize that the documents were developed for varied reasons. Nevertheless, we believe that the wide range of completion dates from these different documents, in particular, contributes to a better understanding of the potential uncertainties surrounding an effort of this magnitude and complexity.

We are sending copies of this report to other interested congressional committees and to the Secretary of Energy. The report also is available at no charge on the GAO Web site at http://www.gao.gov.

If you or your staff have any questions regarding this report, please contact me at (202) 512-3841 or aloisee@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. Key contributors are listed in appendix IV.

Gene Aloise

Gene Aloise
Director, Natural Resources and Environment

Appendix I: Scope and Methodology

To determine the Department of Energy's (DOE) current Hanford Site cleanup strategy and the key technical, legal, and other uncertainties it faces, we gathered and reviewed numerous reports and studies addressing DOE's overall plan to retrieve, treat, and dispose of Hanford's tank waste. We reviewed historical documents to understand how DOE's tank waste cleanup strategy has evolved. We reviewed reports by DOE and its contractors, which discussed technical problems with the waste treatment plant and other phases of DOE's strategy. We also reviewed documents analyzing DOE's need for supplemental capacity, and the department's analysis of potential options, for treating low-activity waste. To identify legal, regulatory, and other uncertainties, we reviewed applicable laws, regulations, policy, and guidance documents, as well as information on past and pending lawsuits. In addition, we interviewed DOE Hanford Site officials in the Office of River Protection and visited the Hanford Site. We also interviewed officials at DOE headquarters in the Office of Engineering and Construction Management and in the Office of Environmental Management's Office of Project Recovery and Office of Engineering and Technology. We interviewed contractor officials at the Hanford Site responsible for building the waste treatment plant. We interviewed officials with regulatory and other agencies—specifically, the Washington State Department of Ecology, the Environmental Protection Agency (EPA), the Nuclear Regulatory Commission, and the Defense Nuclear Facilities Safety Board—as well as the National Academy of Sciences.

To determine the extent to which DOE has assessed whether Hanford's tank waste cleanup strategy, including costs, is commensurate with the risks from its tank wastes, we examined budget and financial documents, environmental impact studies, and other relevant DOE documents. Budget information we reviewed included DOE's proposed budget for 2010, DOE's estimated costs for tank waste cleanup, and project cost and schedule baselines. We spoke with DOE officials and took other steps to ensure that all cost data were sufficiently useful for purposes of this report. We reported all cost data as provided by DOE—rather than normalize them for comparison by using constant dollars, for example—because not all cost information was available annually. We also reviewed GAO's recent cost-estimating guide for further information on life-cycle costs and risks in developing credible cost estimates.[1] Further, we reviewed milestones DOE agreed to under the Tri-Party Agreement, as well as alternative schedules, such as DOE's suggested milestone changes proposed during

[1] GAO-09-3SP.

negotiations with the state of Washington and EPA, and other documents showing schedule plans. We reviewed DOE's guidance on risk assessments, as well as National Academy of Sciences reports and published articles by risk assessment professionals. We also reviewed DOE's past environmental impact statement and information on DOE's most recent environmental impact statement, as well as performance assessments; both assessment types discuss risks.

To evaluate options that DOE could follow to reduce costs of its tank waste cleanup strategy, we reviewed DOE documents discussing various options. To gain additional insights, we interviewed 18 experts, all of whom are independent of DOE and its contractors and have extensive knowledge of DOE's tank waste cleanup strategy. We identified these experts in consultation with various sources, including the National Academy of Sciences and Defense Nuclear Facilities Safety Board; prior independent reviews of DOE's Hanford tank waste cleanup strategy; and our technical consultant, George W. Hinman, Professor Emeritus of Applied Energy Studies at Washington State University, who has extensive nuclear energy experience in industry, government, and academia. We developed a structured interview guide, containing open-ended questions about various aspects of Hanford's waste cleanup strategy. These questions addressed uncertainties with DOE's current waste treatment strategy, treatment technologies for low-activity waste, and developing risk assessment information for DOE's tank waste cleanup strategy. We pretested our interview guide to ensure the questions were clear and relevant. Using the guide, we interviewed each expert either by telephone or in person. Because the questions were open-ended, and experts were knowledgeable about varied but not all aspects of the issues covered, we did not attempt to quantify their responses for reporting purposes.

Several key documents were just released or were scheduled to be released by DOE shortly after our report was to be issued. These included a tentative legal settlement with the state of Washington, an amended Tri-Party Agreement, a draft environmental impact statement for tank closure, and a new cost and schedule baseline for the Hanford tank waste cleanup effort. We reviewed an August 10, 2009, version of the tentative legal settlement and were provided access to a version of the draft environmental impact statement, but the remaining documents were not available at the time of our review. These documents are discussed in our report and factored into its conclusions and recommendations as available and appropriate. As agreed with DOE, we included only publicly available information about the draft environmental impact statement in our report.

We conducted this performance audit from July 2008 to September 2009, in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: Overview of DOE's Efforts to Select an Approach to Supplement Its Low-Activity Tank Waste Treatment Capacity

As DOE's strategy for cleaning up tank waste at the Hanford Site has evolved over the past 20 years, the department has evaluated a number of technologies to supplement its capacity to treat the low-activity fraction of the waste.[1] As of July 2009, however, DOE officials told us they had postponed further testing of one potential supplemental technology at Hanford and were proceeding with planning for another low-activity waste vitrification facility to provide more treatment capacity.

Over the years, DOE's approach to treating low-activity waste at Hanford has moved away from grout, a method used at other DOE sites, to vitrification. DOE's original plan in 1989 called for mixing low-activity waste with materials to form the hardened, cementlike substance called grout, which would be permanently disposed of on site in more than 200 large, underground vaults with elaborate environmental controls. This disposal method is similar to those widely used in the commercial nuclear industry and by DOE at sites besides Hanford, such as Savannah River and West Valley, for immobilizing and disposing of low-activity and hazardous wastes. In the early 1990s, however, state regulators and other stakeholders raised concerns about using grout at Hanford. These concerns included doubts about grout's ability to prevent long-lived radionuclides, such as technetium-99, from migrating into groundwater over a long period; reliance on engineered barriers to further limit water infiltration into the vaults; the irretrievability of grout from the vaults once disposed of; and the large land area (over 200 acres) that would be needed for the underground vaults. Given these concerns, DOE suspended efforts to develop a grout-based disposal form while it studied the feasibility of other options, including various vitrification alternatives.

In 1994, DOE officially decided against grout and chose to pursue vitrifying Hanford's low-activity tank waste. DOE studies concluded that a vitrified disposal form offered superior performance over grout. These studies showed that glass was capable of retaining long-lived radionuclides over a much longer period, required a much smaller permanent disposal facility, and had life-cycle costs generally comparable to those for grout. In 1994, the Tri-Party Agreement was amended to

[1]Under Tri-Party Agreement milestone M-62-08, DOE was to submit by June 30, 2006, a report comparing the performance of potential supplemental technologies with that of a second low-activity waste vitrification facility. In an August 2009 proposed legal settlement with its regulators, DOE agreed to submit a report on potential supplemental treatment technologies by 2014 only if the department proposed to pursue a technology other than a second vitrification plant for low-activity waste.

include immobilization of low-activity waste by vitrification.[2] DOE's 1996 tank waste remediation system environmental impact statement—which evaluated treatment options and short- and long-term effects for Hanford's tank waste cleanup—largely considered vitrification as the technological option for treating low-activity waste. DOE ultimately decided on a phased approach to treating the waste, that is, building demonstration-sized facilities to test treatment technologies on a small portion of the waste—eventually determined to be 10 percent of the waste volume—with construction of a full-scale facility after testing was complete.[3] After the contract was awarded in 2000 to build the waste treatment plant, however, DOE opted to have its contractor build a full-scale treatment plant, which included a low-activity vitrification facility that was not large enough to treat all of Hanford's low-activity tank waste by the time high-level waste treatment was completed.

In 2002, DOE shifted its treatment strategy to an accelerated approach to meet regulatory and other commitments calling for completing treatment of Hanford's tank waste by 2028. DOE recognized, however, that the low-activity vitrification facility planned for Hanford would not be able to treat more than 50 percent of the low-activity waste by this deadline. DOE, along with the Washington State Department of Ecology; EPA; and experts from national laboratories, industry, and academia, then met to evaluate a number of technologies that could be used to supplement Hanford's treatment capacity to meet the accelerated schedule.[4]

Together, the agencies identified three technologies—bulk vitrification, fluidized bed steam reforming, and cast stone—along with a second low-activity vitrification facility, as the most viable options for supplementing DOE's treatment capability. Bulk vitrification is a vitrification process similar to the technology planned for the first low-activity waste vitrification facility—whereby waste is mixed with other materials, heated in a melter to form a glass substance, then poured into stainless-steel

[2]Tri-Party Agreement, appendix D, milestones M-61 and M-62.

[3]"Record of Decision for the Tank Waste Remediation System, Hanford Site, Richland, Washington," 62 *Fed. Reg.* 8693 (February 1997).

[4]In all, DOE compared about 10 available technical options for treating Hanford's low-activity waste. Criteria used to rank them were (a) waste treatment acceleration, (b) technology maturity, (c) implementation flexibility, (d) ease of regulatory compliance, (e) human health and safety risk reduction, (f) operational safety (worker protection), (g) compatibility with the Tri-Party Agreement (milestone schedules), and (h) waste retrieval acceleration.

containers for disposal—except that in bulk vitrification, the melter also serves as the final disposal container. Steam reforming is a thermal process that uses steam and chemical additives mixed with the waste to form a granular, mineral-like waste form. Cast stone is a nonthermal, cement-based approach that mixes the waste with Portland cement to create a monolithic disposal form. While the Washington State Department of Ecology participated in selecting technologies for further testing, the state has maintained that any supplemental treatment technology must be shown to be "as good as glass," which means that it must meet or exceed all the same performance standards and disposal criteria to protect human and ecological health that apply to the approved glass form. Further evaluations concluded that steam reforming and bulk vitrification showed the most promise for performing comparably to glass in immobilizing Hanford's low-activity tank waste.

Then, in 2003, DOE decided to proceed with development of bulk vitrification at the Hanford Site because it believed the technology would be less costly, able to be more rapidly demonstrated and deployed, and more acceptable to state regulators than the other options. After spending more than $100 million on the bulk vitrification demonstration project, however, DOE officials have suspended construction activities and elected not to pursue additional funding for the project in fiscal year 2009. Throughout testing, bulk vitrification had proved to be more costly and technically difficult to develop than initially envisioned. Because DOE opted to proceed only with testing and developing bulk vitrification for Hanford wastes, other technologies—such as steam reforming or cast stone—have not been extensively tested using actual Hanford waste. With the suspension of bulk vitrification, DOE officials told us they currently have no other supplemental technology development under way or planned for treating a majority of Hanford's low-activity waste.

Since suspending bulk vitrification, DOE officials have said that the department is planning for a second low-activity vitrification facility to provide the additional capacity needed to complete treatment of Hanford's low-activity waste within a realistic time frame.[5] While DOE maintains the

[5]While the Tri-Party Agreement still includes a milestone for completing treatment by 2028, both DOE and Washington State acknowledge that DOE will not be able to achieve this goal, and the August 2009 tentative legal settlement sets a revised cleanup date of 2047. Even with this extended treatment schedule, DOE believes that the low-activity waste vitrification facility currently under construction will lack the capacity to treat all the low-activity waste within this time frame.

decision is not final, a second vitrification facility will be the path forward for planning purposes. For example, in 2008, DOE released an external review of its systems planning for low-activity waste treatment at Hanford, which concluded that a second low-activity waste vitrification facility was the most viable option from a cost perspective for supplementing DOE's low-activity waste treatment capability.[6] In addition, the report suggested that further demonstration of bulk vitrification should be given a low priority while the department focuses its attention on resolving other uncertainties with its strategy, such as the total amount of waste to be processed.

On the basis of its 2008 report, DOE project officials told us in March 2009 that they are moving forward in their planning as if a second vitrification facility were the selected technology and that the new project baseline, due out by the end of the year, will include a second low-activity vitrification plant as the supplemental treatment approach. Despite these planning decisions, DOE maintains that a final determination on its supplemental treatment approach will be made in accordance with its project management orders and after issuance of the environmental impact statement. In a December 2008 letter to Congress, DOE indicated that a final decision on its supplemental treatment approach will not likely be made until 2015 at the earliest.

[6]Although the report acknowledged cast stone and steam reforming as other potentially viable options, and noted that these options were being evaluated within the environmental impact statement process, it did not assess these options, focusing only on alternatives to increase Hanford's vitrification capacity.

Appendix III: Comments from the Department of Energy

Department of Energy
Washington, DC 20585

September 18, 2009

Mr. Gene Aloise
Director of Natural Resources and Environment
U.S. Government Accountability Office
441 G Street, NW
Washington, DC 20548

Dear Mr. Aloise:

Thank you for the opportunity to review the draft report "Nuclear Waste: Uncertainties and Questions about Costs and Risks Persist with DOE's Tank Waste Cleanup Strategy at Hanford." Although we generally agree with three of the four recommendations, we would like to provide clarifications regarding key technical and legal uncertainties facing the Tank Waste project at Hanford. In addition, we are concerned with how the U.S. Government Accountability Office (GAO) has characterized the Office of Environmental Management's (EM) progress at Hanford. Specifically, we believe the report's findings should provide a better supported, balanced and more accurate portrayal of EM's Tank Waste Strategy at Hanford, in part by including descriptions of ongoing initiatives and actions, a number of which EM launched in recognition of the need for improvement. We are providing our concerns on the draft report below and through technical comments, which include factual corrections to certain information in GAO's draft report. We are looking forward to reporting in the future on the progress being made as we continue to focus on removing waste from tanks, finishing construction of the Waste Treatment Plant (WTP), and initiating waste treatment operations.

We believe that we have gained substantial experience over the past decade in the cleanup of tank waste within the EM complex with the vitrification of waste at Savannah River Site's (SRS) Defense Waste Processing Facility, with the cleanup in New York State's West Valley Demonstration Project and Oak Ridge, and from waste processing and tank closures completed at Idaho National Laboratory (INL). This experience is applicable to our challenges at Hanford and informs our technical and project management approach. In 2009, one of our key initiatives is an Integrated Project Team specifically to evaluate current and emerging tank waste strategies for Hanford and SRS, to take advantage of best practices and lessons learned, and to provide recommendations on which strategies to pursue to reduce technical risks and uncertainties. This is one example of information we believe is critically important to the concerns raised and the characterization of this program by the GAO, but absent from the draft report.

We agree that some technical uncertainties remain; however, we believe that we have developed a systematic approach to evaluate alternative strategies and transformational solutions that will continue to improve and optimize the tank waste operations and help us realize life-cycle cost reductions. We believe that the processes we have put in place

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to reduce technical uncertainties will result in the resolution of the issues in a timely manner. We have gained a great deal of experience in tank waste characterization, retrieval, treatment, and immobilization from the cleanup efforts at other sites and believe that this experience will also help to reduce uncertainties at Hanford. Tank closure and waste processing successes have been realized at Department of Energy (DOE) facilities at West Valley, SRS, Oak Ridge, and INL. At West Valley, for instance, 628 tons of glass in 275 canisters were produced, immobilizing 8,640 cubic feet of high-level waste. Since 1996, SRS has vitrified over 2.6 million gallons of sludge waste, and since 2008 has vitrified about 2.9 million gallons of high-level waste producing over 2,700 canisters of high-level waste that are in two onsite storage facilities. At Oak Ridge 8 tanks with a capacity of 90,000 gallons were cleaned and grouted, and at INL 11 high-level waste tanks with a capacity of 2.2 million gallons were grouted and closed. The River Protection Project (RPP) takes advantage of that experience in many ways; e.g., through lessons learned, technical exchanges, contracting and through interaction of contractor and Federal staff that have been involved in operations at these sites. Highlights of these exchanges included updated approaches to high-level waste tank integrity, new approaches to tank chemistry, and aluminum and chromium mitigation.

The report should be revised to reflect that the Secretary of Energy is planning on convening a Blue Ribbon Panel to evaluate the options for high-level waste disposal, and the Panel will provide DOE recommendations to resolve this issue. In the meantime, EM has already built two interim storage facilities at SRS and one at Hanford (Canister Storage Building). Therefore, we are confident that we are fully able to build interim storage facilities at Hanford if necessary and will be able to calculate life-cycle costs for this operation at Hanford, if it is needed. We believe it is premature to anticipate these costs until after the Blue Ribbon Panel completes its work.

DOE agrees that it is important to assess the impacts on human health and the environment for the range of possible cleanup strategies with regard to the Hanford tanks. To that end, the Department is nearing completion of a draft Environmental Impact Statement (EIS) which rigorously evaluates 11 alternatives for accomplishing cleanup of the tanks ranging from no action to complete removal of the tanks. The Office of River Protection provided the GAO access to review the draft EIS.

While DOE has assessed the costs and risks of its actions at Hanford, it is important to recognize that the Department has limited discretion when it comes to decisions on how to proceed with cleanup. Pursuant to Federal law, DOE must comply with state requirements for control of hazardous waste (such as the chemical constituents of the tanks at Hanford) "in the same manner and to the same extent as any person is subject to such requirements" (42. U.S.C. section 6961). The pertinent Washington State regulatory framework requires the use of best available technology. Hanford's Tri-Party Agreement thus requires removal of 99 percent of waste from the tanks using available technologies.

Likewise, the regulatory framework established by Congress in Section 3116 of Public Law 108-375 (if it were applicable to Hanford) would require a technology-based approach where highly radioactive radionuclides are removed from the tanks to the maximum extent practical.

DOE agrees that it is important to develop credible and complete life-cycle cost and schedule estimates, and we have done this. We believe that our estimates represent our most current and best understanding of the actions necessary to meet regulatory commitments and to complete tank waste cleanup at Hanford. The Tank Farms Project (TFP) life-cycle cost estimate range is between $44 and $62 Billion (B). The Office of Engineering and Construction Management (OECM) verified the reasonableness of that range. An External Independent Review of the TFP was performed as required in DOE Order 413.3A prior to validation of the near-term baseline. The WTP total estimated contract price is $11.07B, including incentives and award fee; $12.26B when DOE contingency and other DOE project costs are included. This cost was reviewed by the U.S. Army Corps of Engineers, validated by OECM, and approved by the Deputy Secretary of Energy in late 2006. The RPP, which includes TFP and WTP, total cost range is $56B to $74B as provided during the factual accuracy review with your staff. GAO, instead, chose to use a point estimate of their own construct.

EM utilizes strategic planning in developing its overall approach to high-level waste treatment at Hanford, and other sites where such waste was created, to reduce life-cycle costs. This effort includes ongoing evaluations to identify opportunities for cost and schedule improvement and risk reduction, and the use of External Technical Reviews and Technology Readiness Assessments to focus attention on resolving technical uncertainties and ensuring that technology risks are properly managed. EM focuses its Technology Development and Demonstration (TDD) efforts to identify and develop promising technologies for use in further reducing baseline costs and schedule durations, and has requested more than a three-fold increase in TDD funding in fiscal year (FY) 2010.

The draft GAO report should provide a better context for its analysis of the challenges at Hanford. The GAO's conclusion in 2001 (GAO-01-284, Nuclear Cleanup: Progress Made at Rocky Flats, but Closure by 2006 Is Unlikely, and Costs May Increase) stated that "Kaiser-Hill and DOE are unlikely to meet the December 2006 target closure date" for Rocky Flats, and yet this closure date was indeed met by DOE and the Rocky Flats cleanup contractor Kaiser-Hill. The Rocky Flats cleanup was completed nearly 50 years earlier and for $20.5B less than original estimates. As recommended by the GAO in 2006 (GAO-06-352, Nuclear Cleanup of Rocky Flats: DOE Can Use Lessons Learned to Improve Oversight of Other Sites' Cleanup Activities), EM used the lessons learned from Rocky Flats for other cleanup efforts across the complex to accomplish extremely successful cleanups. We won the Project Management Institute award for our prowess in project management in 2006 and 2007 for the Rocky Flats and Fernald cleanup projects, respectively.

The draft GAO report does not recognize existing DOE risk management efforts. The report states that DOE has not applied risk-informed decision making to its tank waste cleanup strategy. While there is a limited discussion of the Tri-Party Agreement and draft EIS, there are gaps in addressing the overall RPP risk management. Uncertainties noted in the report are in the RPP risk management plan and risk mitigation actions, and contingencies are included in the life-cycle baseline, yet GAO fails to mention this.

In addition, the Tri-Party Agreement does include provisions for mitigation of programmatic risk; Appendix H is in place to provide a means to set, evaluate, and revise criteria for determining the allowable residual waste following waste retrieval operations on the Hanford single shell tanks (SST). The process allows reassessment of the retrieval goals based upon the tank farm retrieval experience. A Performance Assessment for each SST waste management area will be performed. This process includes a risk-based analysis. Finally, the draft EIS provides a cumulative risk analysis of the overall process.

As new technological improvements are developed, we are committed to continuously assess the strategies and operations of the WTP to ensure that it is protective of human and ecological health and that it is operated cost effectively and efficiently.

Although we agree with the finding that "Some Opportunities May Exist to Reduce Costs of DOE's Hanford Tank Waste Cleanup Strategy," it may be premature to state that "Allowing More Residual Waste to Remain in Selected Tanks at Closing Could Help Reduce Costs without Adding Risks to Human and Ecological Health." We need to complete the analysis for the tank closure demonstration project in collaboration with Washington State and the U.S. Environmental Protection Agency and to work with the regulators to determine what will be acceptable.

With the August 11, 2009, announcement by Secretary of Energy Chu, Washington State Governor Gregoire, Oregon State Governor Kulongoski, U.S. Senators Murray and Cantwell, and Acting Assistant Attorney General Cruden, we have a proposed legal settlement for Hanford (still subject to a public comment period). Under the agreement, DOE will prepare a life-cycle analysis of all Hanford cleanup costs to meet the legally mandated timelines for cleanup. We are also committed to an "End Date Review Process" that will ensure that the Hanford tank waste cleanup remains as aggressive as possible. In addition, DOE is committed to publishing an upcoming draft EIS that fully examines the costs and consequences of a wide range of cleanup options.

The draft GAO report does not acknowledge the work that DOE has been doing on the RPP. It does not reflect the successful tank waste treatments that DOE has completed nationwide, which have advanced the RPP tank waste cleanup efforts. Furthermore, the report does not adequately acknowledge the environmental risk reduction activities that DOE has performed. Removal of the pumpable liquids from SSTs to achieve Interim Stabilization was conducted from late 1970 until 2005. In addition, DOE has removed 140 million curies from Hanford's tanks in the form of cesium and strontium capsules.

We generally agree with GAO's recommendation one, two and four. We believe that we have a process for developing credible and complete life-cycle cost and will continue to update the costs on an annual basis. We already have a risk assessment framework for Hanford and will be publishing the draft EIS in FY 2010. We continue to work closely

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with the States of Washington and Oregon, the Tribal nations, the Environmental Protection Agency, the Defense Nuclear Facility Safety Board, the Hanford Advisory Board, and other stakeholders to complete Hanford's cleanup.

DOE does not agree with GAO's third recommendation. At this time, we do not believe that we need to seek clarification from Congress about the Department's authority at Hanford to determine whether some waste now managed by DOE as high-level waste can be treated and disposed of as a waste type other than high-level waste. Our focus for the next ten years is to remove waste from tanks, finish construction of the WTP, and initiate waste treatment operations.

Again, thank you for your assistance as we seek to strengthen our tank waste cleanup strategy at Hanford. We welcome direct dialogue with you on these issues prior to finalizing your report. We would also appreciate you including the enclosed comments in the final report. If you have any questions with regard to these comments, please contact me at (202) 586-7709 or Mr. Mark Gilbertson at (202) 586-0755.

Sincerely,

Inés Triay

Inés R. Triay
Assistant Secretary for
Environmental Management

Enclosure

cc:
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Appendix IV: GAO Contact and Staff Acknowledgments

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Staff Acknowledgments

In addition to the individual named above, Janet E. Frisch, Assistant Director; Ellen W. Chu; Doreen Eng; George W. Hinman; Richard P. Johnson; Karen Keegan; Nancy Kintner-Meyer; Mike Meleady; Mehrzad Nadji; Joshua Ormond; Thomas C. Perry; Timothy M. Persons; Jena Sinkfield; and John Smale made key contributions to this report.

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