United States Government Accountability Office

Report to Congressional Committees

May 2023

HANFORD CLEANUP

DOE Should Validate Its Analysis of High-Level Waste Treatment Alternatives

Accessible Version

GAO-23-106093

GAO Highlights

Highlights of GAO-23-106093, a report to congressional committees

May 2023

HANFORD CLEANUP

DOE Should Validate Its Analysis of High-Level Waste Treatment Alternatives

Why GAO Did This Study

DOE oversees the treatment and disposal of about 54 million gallons of radioactive and hazardous waste at the Hanford Site in Washington State. Before treating the tank waste, DOE plans to separate it into two streams: (1) a high-activity portion, which DOE estimates will contain about 5 percent of the volume but more than 70 percent of the radioactivity; and (2) a low-activity portion, which will contain about 95 percent of the volume. Hanford's high-activity tank waste is mixed with hazardous components and, under current law, must be vitrified—a process in which the waste is immobilized in glass—prior to land disposal. DOE has been exploring alternative methods to treat the HLW portion of the waste.

Senate Report 117-39 includes a provision for GAO to assess DOE's approach to analyzing options for treating the HLW at Hanford. This report examines (1) DOE's current HLW treatment plans, (2) the results of DOE's analysis of alternatives for treating the HLW, and (3) the next steps that DOE plans to take in selecting a HLW treatment alternative. GAO reviewed DOE reports and data on the waste at Hanford, as well as DOE's current plans for treating it, and interviewed DOE officials.

What GAO Recommends

DOE should obtain an independent review to validate the process of the analysis of high-level waste treatment alternatives at Hanford. DOE concurred with GAO's recommendation.

View GAO-23-106093. For more information, contact Nathan Anderson at 202-512-3841 or andersonn@gao.gov.

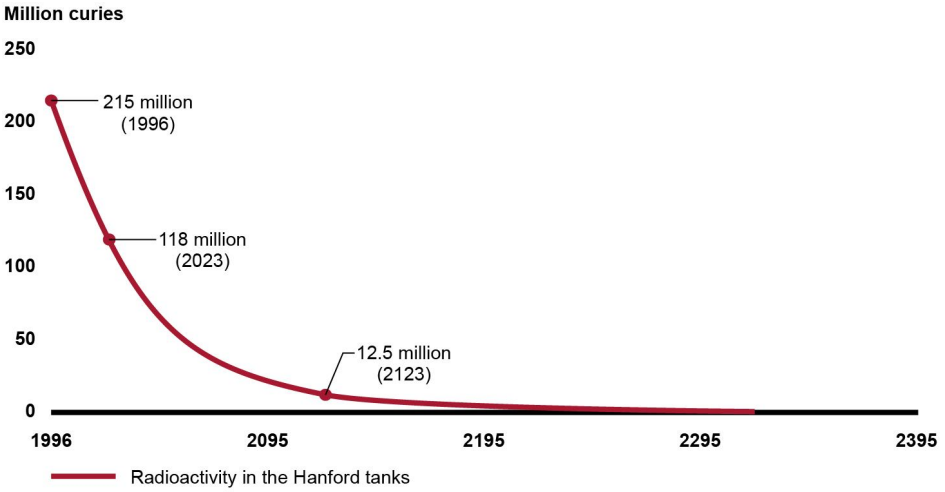
What GAO Found

The Department of Energy (DOE) plans to separate out and vitrify the most radioactive portion of the waste held in 177 underground tanks at its Hanford Site in the State of Washington. This high-activity waste—which DOE calls high-level waste, or HLW—represents about 72 percent of the estimated radioactivity in the tanks, though much of radioactivity will decay over the next 100 years (see fig. below). DOE's current plan for treating this HLW relies on a vitrification facility that will be part of Hanford's Waste Treatment and Immobilization Plant. This plant is partially complete and faces ongoing technical challenges.

In 2023, DOE released an analysis of alternatives that considered 24 options for treating Hanford's HLW. The analysis found that the life-cycle cost estimates for treating the HLW ranged from $135 billion to $5 trillion. The analysis also found that the current plan, as well as several other alternatives, would require a significant increase in annual funding (up to $8 billion a year) over the next 10 years. According to the analysis, none of the alternatives could complete HLW treatment by 2047—the treatment deadline set in legal agreements with environmental regulators—with the earliest estimated completion date for any alternative being 2061.

DOE plans to select an alternative for HLW treatment in the near future—though no timeline has been set—and has restarted some efforts to complete construction of the HLW treatment facility. According to DOE guidance and GAO best practices, before selecting an alternative, an independent entity should review and validate the analysis of alternatives process. However, DOE has not committed to obtaining an independent review to validate the portions of the analysis of alternatives process related to HLW treatment. Given the enormous cost and schedule implications of the decision, it is essential for DOE to take steps now to provide assurance that all viable alternatives for optimizing the tank waste treatment mission are considered.

Approximate Radioactivity in the Hanford Tank Waste over Time



Source: GAO analysis of Department of Energy data. | GAO-23-106093

Accessible Data for Approximate Radioactivity in the Hanford Tank Waste over Time

Year	Radioactivity in the Hanford Tanks (million curies)
1996	215
2023	118
2123	12.5
2322	.56
3022	.11

Contents

Abbreviations

AOA	analysis of alternatives
DOE	Department of Energy
DST	double-shell tank
Ecology	Washington State Department of Ecology
EPA	Environmental Protection Agency
HLW	high-level waste
LAW	low-activity waste
RCRA	Resource Conservation and Recovery Act of 1976
TPA	Tri-Party Agreement (Hanford Federal Facility Agreement and Consent Order of 1989)
WTP	Waste Treatment and Immobilization Plant

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May 24, 2023

Congressional Committees

The Hanford Site in Washington State is home to one of the largest and most expensive environmental cleanup efforts in the world. After decades of research and production of weapons-grade nuclear materials at the 586-square-mile site ceased in the late 1980s, the Department of Energy (DOE) began cleanup efforts. These efforts include addressing approximately 54 million gallons of hazardous and radioactive waste stored in 177 large underground waste storage tanks.[1] As part of the cleanup mission, DOE must retrieve and treat the waste before disposal, according to legal requirements and agreements made with federal and state environmental regulators.

To accomplish this task, DOE has spent more than 20 years constructing a set of facilities—known as the Waste Treatment and Immobilization Plant, or WTP—so that the waste can be taken out of the tanks and vitrified, a process in which the waste is immobilized in glass. However, the design and construction of the WTP has faced many technical challenges over the years. We have made numerous recommendations to DOE related to considering less complex cleanup approaches, which may have the benefit of shortening the cleanup mission and being less expensive.[2] Following our reporting, and as a result of these challenges,

[1]According to DOE officials, the waste has been retrieved from 18 of these tanks. According to DOE officials, DOE plans to "landfill close" these tanks, which involves in part leaving the tanks in place and filling them with grout. The State of Washington and the Environmental Protection Agency, however, have not yet agreed to this plan.

[2]See, for example, GAO, *Nuclear Waste: Hanford Tank Waste Program Needs Cost, Schedule, and Management Changes*, GAO/RCED-93-99 (Washington, D.C.: Mar. 8, 1993); *Nuclear Waste: Department of Energy's Hanford Tank Waste Project Schedule, Cost, and Management Issues*, GAO/RCED-99-13 (Washington, D.C.: Oct. 8, 1998); *Nuclear Waste: Challenges to Achieving Potential Savings in DOE's High-Level Waste Cleanup Program*, GAO-03-593 (Washington, D.C.: June 17, 2003); *Nuclear Waste: Absence of Key Management Reforms on Hanford's Cleanup Project Adds to Challenges of Achieving Cost and Schedule Goals*, GAO-04-611 (Washington, D.C.: June 9, 2004); *Hanford Waste Treatment Plant: Contractor and DOE Management Problems Have Led to Higher Costs, Construction Delays, and Safety Concerns*, GAO-06-602T (Washington, D.C.: Apr. 6, 2006); and *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).

DOE stopped or slowed work on parts of the WTP in 2012. In 2016, after years of delays in waste treatment stemming from these challenges, DOE created the Direct-Feed Low-Activity Waste program to treat a portion of the least radioactive tank waste.[3] The facilities needed to begin treating this waste are largely complete, and DOE plans to begin treating waste in 2025. However, as of February 2023, DOE reported that the WTP overall is only partially complete.

Since halting construction of some of the WTP facilities, DOE officials have considered alternative approaches for treating the waste, some of which have the potential to save tens of billions of dollars.[4] In particular, as we reported in July 2022, DOE is now exploring alternative treatment approaches for the more highly radioactive portion of the tank waste.[5] Similar to other recent shifts in the cleanup approach, the treatment alternatives that DOE is now considering will affect decades of future cleanup activities and could save tens of billions of dollars. For projects over a certain cost threshold, DOE is required by an agency order to conduct an analysis of alternatives (AOA) that is consistent with best practices that we have previously identified.[6]

According to DOE officials, as a matter of policy, DOE manages all Hanford tank waste as if it is “high-level radioactive waste” unless, and until, the waste is formally classified as another waste type. “High-level radioactive waste” is defined by federal law and subject to specific legal

[3]The Direct-Feed Low-Activity Waste program involves the construction or modification of several waste treatment facilities, systems, and infrastructure to immobilize a portion of the least radioactive waste.

[4]In 2022, DOE estimated that completing cleanup of the entire site would cost between $300 billion and $640 billion and take decades. Over the last 5 fiscal years, the site has received annual appropriations of about $2.4 billion to $2.6 billion. All costs and cost estimates in this report are presented in 2020 dollars, unless otherwise noted. See Department of Energy, *2022 Hanford Lifecycle Scope, Schedule and Cost Report* (Richland, WA: January 2022).

[5]GAO, *Nuclear Waste Cleanup: Hanford Site Cleanup Costs Continue to Rise, but Opportunities Exist to Save Tens of Billions of Dollars*, GAO-22-105809 (Washington, D.C.: July 29, 2022).

[6]Department of Energy, Progra*m and Project Management for the Acquisition of Capital Assets*, DOE Order 413.3B (Change 6) (Washington, D.C.: Jan. 12, 2021).

requirements.[7] Under Environmental Protection Agency (EPA) regulations also adopted by the State of Washington, radioactive high-level wastes must be vitrified prior to land disposal.[8] Before treating the tank waste, DOE plans to separate it into two streams: (1) the high-activity portion, which DOE estimates will contain about 5 percent of the volume but more than 70 percent of the radioactivity; and (2) the low-activity portion, which will contain about 95 percent of the volume.[9] At Hanford, DOE often uses the term "high-level waste," or HLW, to refer only to the high-activity portion of the tank waste; and "low-activity waste," or LAW, to refer to the rest of the tank waste.[10] For the purposes of this report, when we refer to "HLW," we are referring only to the approximately 5 percent of the waste

[7]The Nuclear Waste Policy Act of 1982, as amended, defines "high-level radioactive waste" as "(A) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations; and (B) other highly radioactive material that the [Nuclear Regulatory] Commission, consistent with existing law, determines by rule requires permanent isolation." 42 U.S.C. § 10101(12). This definition is also cross-referenced in the Atomic Energy Act of 1954, as amended. See 42 U.S.C. § 2014(dd).

[8]The referenced regulations apply specifically to radioactive high-level wastes generated during the reprocessing of fuel rods that exhibit specified hazardous waste characteristics. See 40 C.F.R. § 268.40. Treatment of these wastes must meet the "HLVIT" treatment standard, which requires vitrification of high-level mixed radioactive wastes in units in compliance with all applicable radioactive protection requirements under control of the Nuclear Regulatory Commission. 40 C.F.R. §§ 268.40, 268.42(a); Wash. Admin. Code 173-303-140(2)(a).

[9]We have reported in the past that the high-activity portion of the waste will comprise 10 percent of the volume and 90 percent of the radioactivity (see GAO, *Nuclear Waste Disposal: Actions Needed to Enable DOE Decision That Could Save Tens of Billions of Dollars*, GAO-22-104365 (Washington, D.C.: Dec. 9, 2021). This estimate was based on DOE's prior plan for pretreating the tank waste. Under DOE's current approach, much of the lower-activity waste is pretreated, using an approach designed to filter out solids, including cesium, from liquid tank waste. As we discuss later in this report, cesium contains a large percentage of the radioactivity in the tanks' waste. As a result, under this new approach, DOE estimates that less of the radioactivity will remain in the tanks after the lower-activity waste is removed. DOE has not yet determined how it will address the cesium and other radionuclides removed from the low-activity waste.

[10]LAW is DOE's term for the primarily liquid portion of the tank waste, including dissolved saltcake, that contains low levels of long-lived radionuclides. DOE's current plan is to vitrify about 60 percent of the LAW through the Direct-Feed Low-Activity Waste program and to treat the remaining LAW (which is referred to as "supplemental LAW") in a second (not yet built) vitrification facility. DOE is also evaluating alternatives to vitrification, such as immobilizing the waste in a concrete-like grout.

that DOE considers to have high radioactivity, not to all tank waste that DOE currently manages as if it is legally "high-level radioactive waste."

Senate Report 117-39 includes a provision for us to assess DOE's approach to analyzing options for treating the HLW at Hanford. This report examines (1) DOE's current HLW treatment plans, (2) the results of DOE's AOA[11] for treating the HLW, and (3) the next steps that DOE plans to take in selecting a HLW treatment alternative.

To conduct our work, we reviewed DOE documents on waste treatment options and databases on the composition of Hanford's tank waste, and we interviewed DOE officials to summarize the source and composition of the HLW at the Hanford Site. To describe and summarize the results of DOE's AOA, we reviewed the AOA for information on Hanford's HLW mission and interviewed DOE and Washington State Department of Ecology (Ecology) officials who contributed to the AOA. We summarized the cost and schedule estimates for DOE's current plan and the alternative approaches being considered. To analyze DOE's next steps, we reviewed DOE documents and interviewed DOE officials to summarize DOE's plans and timeline for making a decision about how to retrieve and prepare the HLW for treatment. We compared this plan with past Hanford cleanup plans, as well as with DOE project management guidance and our risk-informed decision-making framework.[12] In addition, we reviewed DOE documents to identify factors that may affect DOE's selection of an alternative for a HLW treatment approach. We also reviewed the status of our past recommendations and interviewed DOE and Ecology officials regarding factors that may affect DOE's decision about a path forward. A more detailed description of our scope and methodology is included in appendix I.

We conducted this performance audit from August 2022 to May 2023 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

[11]Department of Energy, *Final Report: Waste Treatment and Immobilization Plant High-Level Waste Treatment Analysis of Alternatives* (Richland, WA: Jan. 12, 2023).

[12]GAO, *Environmental Liabilities: DOE Would Benefit from Incorporating Risk-Informed Decision-Making into Its Cleanup Policy*, GAO-19-339 (Washington, D.C.: Sept. 18, 2019).

the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

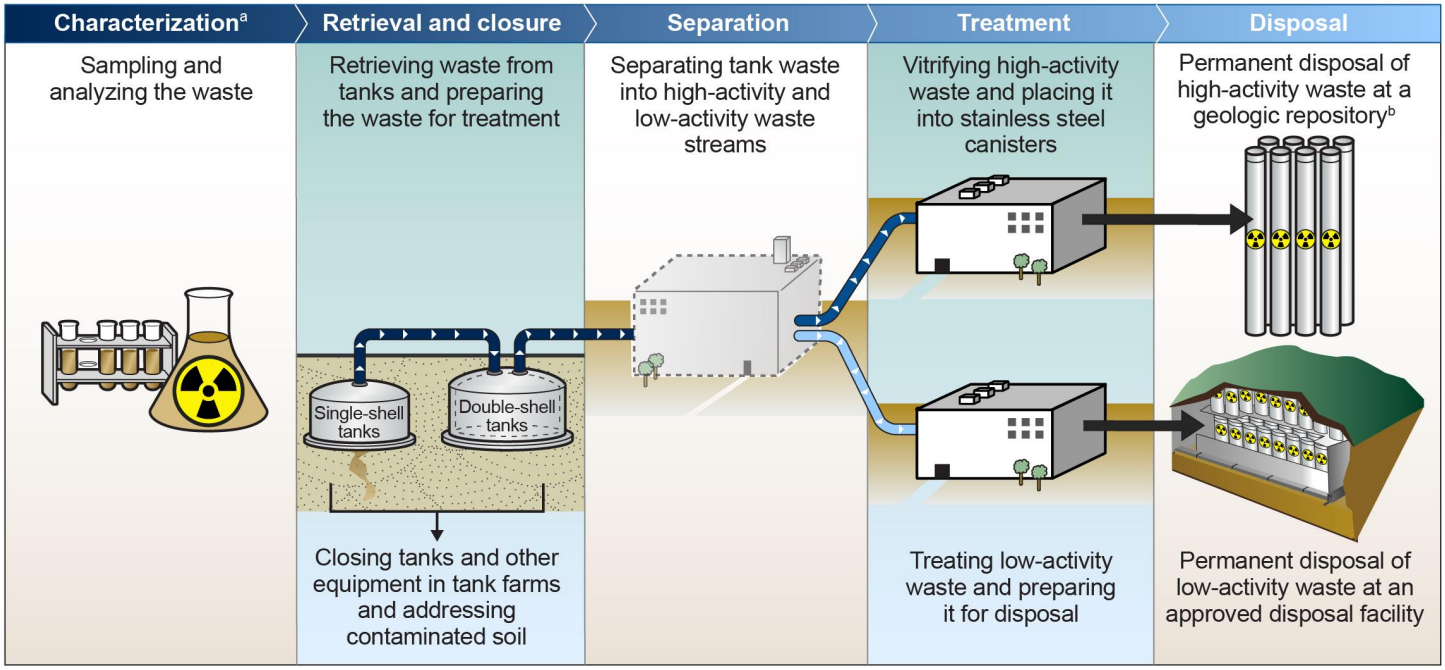
The tank waste treatment and disposal effort at Hanford generally consists of five phases (see fig. 1):

1. **Characterization.** Characterization of the waste through sampling and analysis to determine the specific physical, radiological, and chemical components of the contents of each tank. DOE may also characterize the composition and properties of the waste at other points in the process.
2. **Retrieval and closure.** Retrieving waste from the underground tanks, transferring it to staging tanks, and ultimately closing the existing underground tanks.[13]
3. **Separation.** Separating the waste into HLW and LAW streams as part of a process called pretreatment.
4. **Treatment.** Treating the HLW and LAW to immobilize the constituents.
5. **Disposal.** Disposing of the waste.

This report focuses on the HLW treatment phase of the waste cleanup mission.

[13]One-hundred forty-nine of these tanks have a single carbon steel liner containment system; these are known as single-shell tanks. The remaining 28 tanks have a double carbon steel liner containment system; these are known as double-shell tanks.

Figure 1: Phases of Tank Waste Treatment and Disposal at the Hanford Site



Source: GAO analysis of Department of Energy documents. | GAO-23-106093

[a]The Department of Energy may also characterize the composition and properties of the waste at other points in the process.

[b]A geologic repository for permanent disposal has not yet been designated.

Prior GAO Work on Technical Challenges Facing the WTP

The WTP has faced hundreds of technical challenges since the early 2000s, when the Hanford tank waste treatment and disposal effort first began. We have reported on these challenges in the past and have made numerous related recommendations to DOE. For example, in 2003, we found that the WTP contractor and outside experts had concerns about the pretreatment technology for separating the waste—including problems associated with mixing the waste during separation and evaporating water from the waste.[14] We recommended that DOE consider further testing before moving forward with construction of the Pretreatment Facility. In response to our recommendation, in early 2007, DOE decided to build a pilot-scale facility for the WTP to fully test

[14]GAO-03-593.

pretreatment technologies before completing the full-scale design of the facility.

Similarly, in 2006, we found that the WTP continued to face numerous technical challenges and that many of the technical challenges had not been addressed, even though DOE was moving forward with construction on the Pretreatment Facility.[15] We recommended that DOE resolve the technical challenges before moving forward. DOE agreed and took steps to ensure that the design of each WTP component was at least 90 percent complete before construction or installation.

In December 2012, we found that the WTP continued to face significant technical challenges—ranging from facility ventilation concerns to preventing explosions during waste treatment—when construction was halfway complete.[16] We recommended that DOE pause construction of the Pretreatment Facility until the issues had been fully resolved. Because of these ongoing challenges, in December 2012, DOE's WTP Engineering Division issued a memorandum that recommended that all activities affecting design, construction, and installation of structures, systems, and components be stopped. According to the memorandum, stopping work would help DOE avoid future nuclear safety and quality compromises and substantial rework. Instead of stopping all work at the WTP, DOE stopped work only on those facilities that faced the most significant technical challenges, namely, the Pretreatment and HLW Facilities. As of February 2023, DOE has not resumed construction on the Pretreatment Facility but, as we discuss in this report, DOE is preparing to restart design and construction of the HLW Facility.

In 2015, we reported that because of these challenges, DOE was analyzing pretreatment alternatives but had not properly defined the mission need for the analysis or developed a reliable life-cycle cost estimate for the alternatives being analyzed.[17] We recommended that DOE revise its analysis to consider a variety of alternatives without limiting potential solutions. We also recommended that DOE further limit construction activities on the Pretreatment Facility until aggressive risk

[15]GAO-06-602T.

[16]GAO, *Hanford Waste Treatment Plant: DOE Needs to Take Action to Resolve Technical and Management Challenges*, GAO-13-38 (Washington, D.C.: Dec. 19, 2012).

[17]GAO, *Hanford Waste Treatment: DOE Needs to Evaluate Alternatives to Recently Proposed Projects and Address Technical and Management Challenges*, GAO-15-354 (Washington, D.C.: May 7, 2015).

mitigation strategies are developed and employed to address the technical challenges. DOE and Ecology opted to change the pretreatment approach and, in 2018, DOE began design work on an alternative pretreatment approach.

Regulatory Framework Governing Hanford's Tank Waste

As we have previously reported, the treatment and disposal of Hanford's tank waste is governed by a number of federal and state laws and regulations, DOE Orders, and cleanup agreements.[18] The list below includes those of particular relevance to DOE's current AOA and forthcoming decision on HLW treatment:

- **Resource Conservation and Recovery Act of 1976, as amended (RCRA).** Hanford tank waste contains both radioactive and hazardous components. RCRA governs the treatment, storage, and disposal of the hazardous component of this mixed waste. EPA has authorized the State of Washington to administer its own hazardous waste regulatory program in lieu of the federal RCRA program. Under RCRA requirements also adopted by Ecology, radioactive high-level wastes generated during the reprocessing of fuel rods that exhibit specified hazardous waste characteristics (including those present in Hanford tank waste) must meet the treatment standard of vitrification prior to disposal.[19]
- **Hanford Federal Facility Agreement and Consent Order of 1989 (Tri-Party Agreement, or TPA).** This agreement among DOE, EPA, and Ecology lays out a series of legally enforceable milestones for completing major waste treatment and cleanup activities at Hanford. The purposes of the TPA include ensuring that Hanford cleanup activities comply with the applicable requirements of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended (often referred to as the Superfund); RCRA; and the Washington Hazardous Waste Management Act. Among other things, the TPA requires DOE to complete pretreatment processing and vitrification of Hanford HLW and LAW tank wastes by 2047.

[18]GAO, *Hanford Cleanup: DOE's Efforts to Close Tank Farms Would Benefit from Cleaner Legal Authorities and Communication*, GAO-21-73 (Washington, D.C.: Jan. 7, 2021); and GAO-22-104365.

[19]40 C.F.R. §§ 268.40; 268.42(a); Wash. Admin. Code § 173-303-140(2)(a).

- **Consent Decree of 2010, as amended.** This decree was established as a result of litigation brought against DOE by Ecology for missing certain TPA milestones. It requires DOE to, among other things, substantially complete construction of the HLW Facility by 2030 and complete hot commissioning of the facility by 2033.[20]
- **DOE Order 413.3B.** This order establishes program and project management direction for the acquisition of capital assets with the purpose of delivering projects within budget, on time, and capable of meeting mission performance.[21] In particular, for projects with a total project cost greater than $50 million, Order 413.3B requires DOE to conduct an AOA that is consistent with our published best practices.[22]

DOE's Current Plan to Treat the HLW Is No Longer Feasible Due to Technical Challenges and Rising Costs

Two radioactive constituents in the tanks at Hanford contain the majority of radioactivity and decay relatively quickly. DOE officials intend to separate out the most radioactive waste in the tanks prior to treatment. DOE's current plan is to vitrify the HLW in a vitrification facility—one of many facilities being constructed as part of the WTP—that is partially complete. Under the current approach, completion of another key part of the WTP (the Pretreatment Facility) is no longer technically feasible. DOE and others have also concluded that construction of both the Pretreatment and HLW Facilities, as currently planned, cannot be completed under current cost and schedule constraints.

[20]The Consent Decree states that "HLW Facility Hot Commissioning Complete" means the point at which the HLW Facility has demonstrated its ability to produce immobilized HLW glass of acceptable quality.

[21]Department of Energy, *Program and Project Management for the Acquisition of Capital Assets*, DOE Order 413.3B (Change 6) (Washington, D.C.: Jan. 12, 2021).

[22]GAO, *Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Program Costs,* GAO-20-195G (Washington, D.C.: Mar. 12, 2020).

Strontium and Cesium in the Tanks at Hanford Contain the Majority of Radioactivity and Decay Relatively Quickly

As of January 2023, Hanford's tank waste contains about 118 million curies of radioactivity (see sidebar).[23] DOE officials estimate that the HLW, when separated prior to vitrification, will represent about 72 percent of the radioactivity in the tanks. Another 25 percent of the radioactivity will be separated from the LAW during the direct-feed low-activity waste pretreatment process.[24] The remaining 3 percent of radioactivity is contained in the tank waste that DOE plans to manage as LAW.

According to DOE data, at least 53 different radioactive constituents account for the radioactivity in the Hanford tanks. The vast majority (about 97 percent) of the radioactivity of the tank waste comes from the two-step radioactive decay of two constituents, strontium-90 and cesium-137, which have half-lives of about 29 years and 30 years, respectively.[25] Much of the radioactive material in the tank waste will decay relatively quickly over time (see fig. 2). Specifically, since 1996, about 45 percent of the radioactivity in the tanks has decayed without any treatment, and over 90 percent of the current radioactive material will decay in the next 100 years. At that time, the radioactivity will still come mainly from strontium-90, cesium-137, and their short-lived decay products (see fig.3). Some of the remaining radioactive constituents, which currently account for about 2 percent of the tank waste's total radioactivity, have much longer half-lives. For example, the half-life of technetium-99 is 211,000 years, and that of iodine-129 is 15.7 million years.[26]

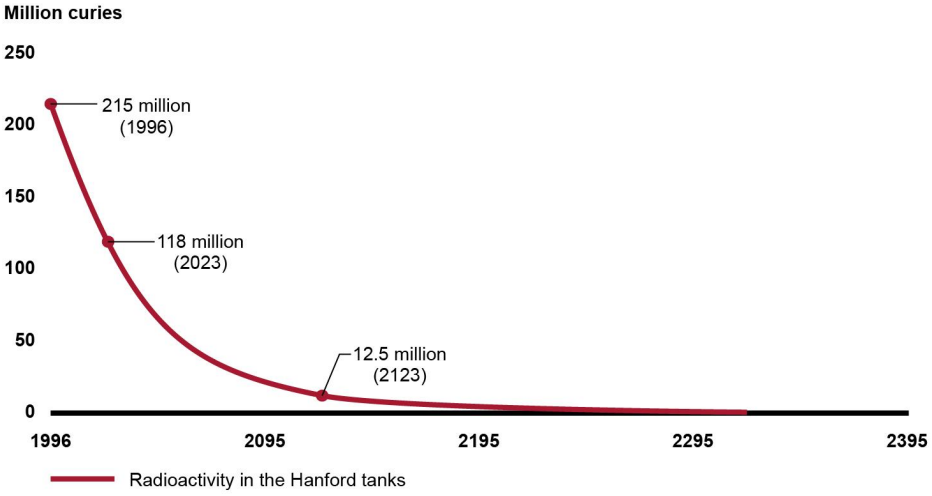
[23]DOE manages an additional 74 million curies of radioactivity at Hanford that are found primarily in concentrated capsules of cesium and strontium. DOE has not yet determined a treatment and disposal path for these wastes.

[24]DOE's current plan is to store this waste on concrete pads on-site until a final disposal path is determined.

[25]The atoms of a radioactive constituent decay over time, emitting their radiation. The time required for half of that radioactive constituent to decay is its half-life. Some of these constituents decay to a stable (or nonradioactive) form in a relatively short time, while others remain radioactive for millions of years or decay into another radioactive constituent (called a decay product). For example, the decay product of strontium-90 is yttrium-90—that is also radioactive, has its own half-life of less than 3 days, and subsequently decays to zirconium-90, which is stable.

[26]These radionuclides pose challenges for waste management because of their high mobility in groundwater, as compared with most other radionuclides.

Figure 2: Approximate Radioactivity in the Hanford Tank Waste over Time



Source: GAO analysis of Department of Energy data. | GAO-23-106093

Accessible Data for Figure 2: Approximate Radioactivity in the Hanford Tank Waste over Time

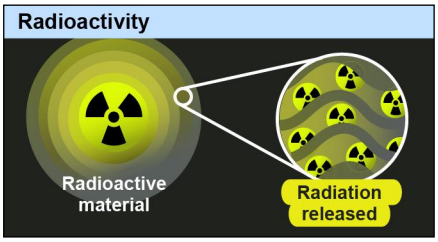
Year	Radioactivity in the Hanford Tanks (million curies)
1996	215
2023	118
2123	12.5
2322	.56
3022	.11

Note: Curies are a measure of the intensity of the amount of radiation released when an element emits energy as a result of radioactive decay. The data used to create this chart come from the Department of Energy's best basis inventory dataset. The 1996 figure was reported by the Pacific Northwest National Laboratory, *Hanford Tank Cleanup: A Guide to Understanding the Technical Issues*, PNL-10773 (Richland, WA: 1995).

Radiation Terms and Uses

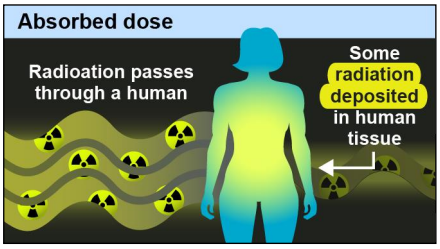
Radioactivity is the energy released by a radioactive material. Different types of radiation also have the potential to damage human tissue. Interrelated units measure radioactivity and estimate its health effects. There are three key interrelated units that measure radioactivity and estimate its health effects: curies, rads, and rems.

Curies – Radioactivity is measured in curies (Ci) and picocuries (pCi). One pCi = 0.000000000001 Ci. The natural radium-226 level of surface water is approximately 0.5 pCi/L, and the maximum contaminant level for combined radium-226 and -228 in drinking water is 5 pCi/L.



Source: Environmental Protection Agency. | GAO-23-106093

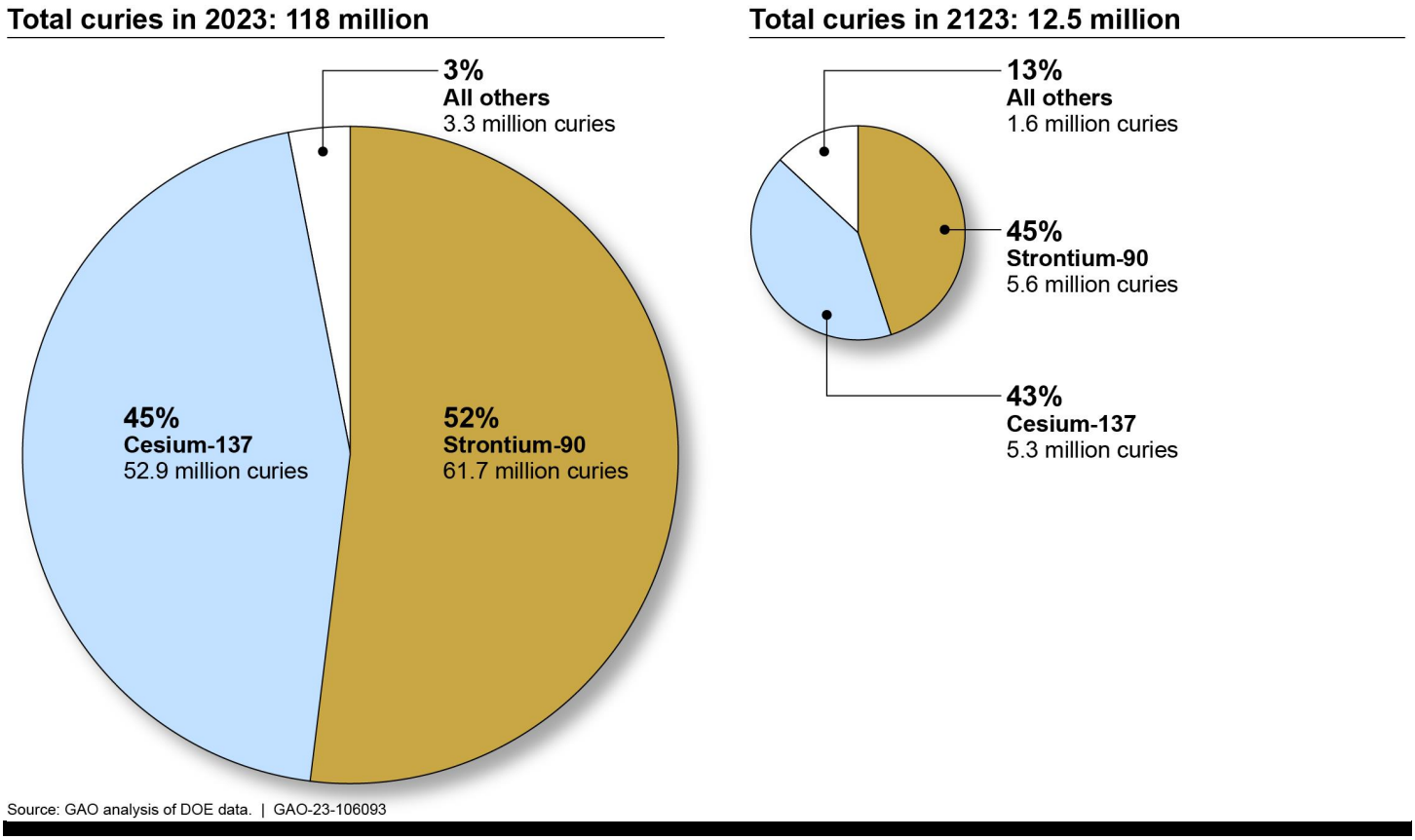
Rads - Absorbed dose describes the amount of energy deposited per unit mass in an object or person. This is often used for measuring the dose, which is measured in rad units, from medical equipment. For example, the dose to the thyroid from a chest CT scan is about 1 rad, while the dose to the eye lens from a brain CT scan is about 6 rad.



Source: Environmental Protection Agency. | GAO-23-106093

Rems **-** Effective dose takes the absorbed dose and adjusts it for radiation type and relative organ sensitivity. The result is an indicator for the potential for long-term health effects, measured in rems, from an exposure. For example, Environmental Protection Agency guidance recommends evacuation or shelter in place be implemented as a protective action during an incident, if a projected whole body dose is 1-5 rem over 4 days.

Figure 3: Approximate Decay over the Next 100 Years of Key Radionuclides in the Hanford Tank Waste



Source: GAO analysis of DOE data. | GAO-23-106093

Accessible Data for Figure 3: Approximate Decay over the Next 100 Years of Key Radionuclides in the Hanford Tank Waste

	Million curies in 2023	Million curies in 2123
Strontium-90	61.7 (52%)	5.6 (45%)
Cesium-137	52.9 (45%)	5.3 (43%)
All others	3.3 (3%)	1.6 (13%)
Total	118	12.5

Note: Curies are a measure of the intensity of the amount of radiation released when an element emits energy as a result of radioactive decay. The data used to create this chart comes from the Department of Energy's (DOE) best basis inventory dataset. Totals may not add up due to rounding.

DOE's Current Plan Is to Vitrify the High-Level Waste after Completion of Two Key, Partially Built Facilities

DOE's current plan for addressing the HLW is to pretreat (in the Pretreatment Facility), vitrify (in the HLW Facility), and then dispose of the waste (see fig. 4):

- **Separation.** Before treating the waste, DOE plans to separate out the HLW and treat it separately from the LAW. However, in 2012, technical challenges, as discussed below, led DOE to halt construction on the Pretreatment Facility. In 2012 and 2015, we recommended that DOE not resume construction of the Pretreatment Facility until all technical challenges had been resolved.[27]
- **Treatment.** Once the HLW has been separated out, DOE's current plan is to mix it with a glass-forming material, melt the mixture into glass, and pour the vitrified waste into stainless-steel canisters to cool and harden. Work began on the WTP in 2002 and continued until 2012, when construction, engineering, and procurement work on the facility was put on hold, as a result of technical challenges raised by the Defense Nuclear Facilities Safety Board and others.[28] Construction was estimated to be 43 percent complete at that time.[29]
- **Disposal.** DOE plans to store the vitrified HLW on-site until a geologic repository is available.[30] Depending on the technologies selected to accomplish the work and the amount of waste that can be added to each batch of molten glass, DOE estimated in its most recent system plan that approximately 7,000 to 9,000 stainless steel canisters of HLW glass will require disposal.

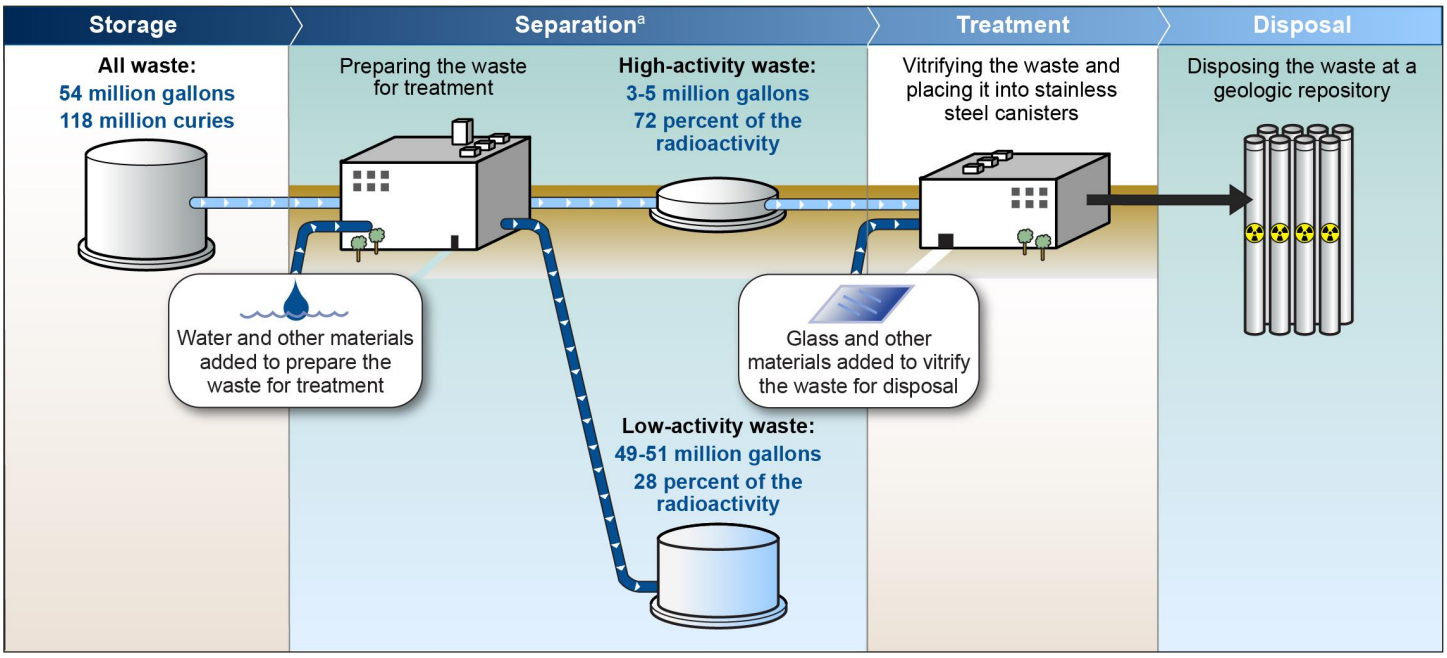
[27]GAO-13-38; and GAO-15-354.

[28]The Defense Nuclear Facilities Safety Board is an agency that provides independent analysis, advice, and recommendations to the Secretary of Energy regarding the adequate protection of public health and safety at DOE's defense nuclear facilities.

[29]The percent complete is measured in terms of the budgeted cost of the work performed thus far compared with the total estimated cost to complete construction of the facility.

[30]In 2010, DOE began taking steps to terminate its proposal for a deep geologic repository for high-level radioactive waste at Yucca Mountain, Nevada, and is now considering other final disposal options.

Figure 4: Department of Energy's Current Plan for Treating the Tank Waste at the Hanford Site



Source: GAO analysis of Department of Energy documents. | GAO-23-106093

Note: Waste volumes are approximates and may vary depending on the treatment options selected.

[a]Separation of the high-activity and low-activity portions of the waste is planned using different technologies, including tank-side facilities and a Pretreatment Facility.

Completion of the WTP as Currently Planned Is No Longer Feasible

DOE and others have concluded that construction of both the Pretreatment and HLW Facilities cannot be completed as currently planned because of two key barriers. First, under the current approach, completion of a key part of the Pretreatment Facility as currently designed is no longer technically feasible. According to DOE officials, this is because advances in glass engineering have resulted in the Pretreatment Facility (as currently designed and partially constructed) being insufficient to feed waste to the treatment facilities at an acceptable rate. In short, completing the Pretreatment Facility as designed will slow down the waste treatment mission. In addition, unresolved technical challenges remain—including facility ventilation concerns and preventing explosions during waste treatment. As we reported in May 2020, these challenges,

which have hampered progress on the WTP for over a decade, still require additional design and engineering work by DOE.[31]

Second, DOE and others have concluded that completing tank waste treatment and disposal as currently planned—including the construction of the Pretreatment and HLW Facilities—will likely exceed past annual project funding and total project cost estimates. For example:

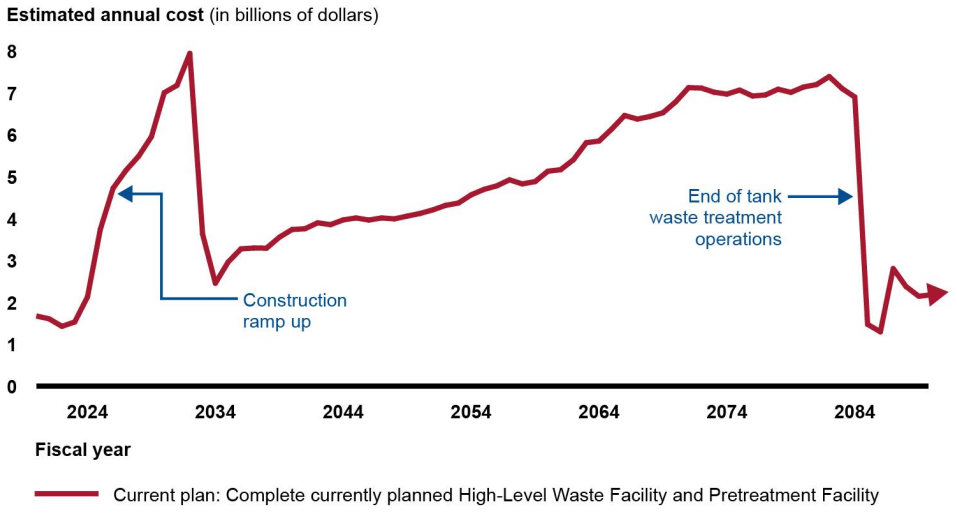
- In the AOA, DOE's contractor estimates that annual spending on tank waste treatment and disposal at Hanford would exceed $8 billion in fiscal year 2032 under the current plan. In comparison, from fiscal year 2018 through fiscal year 2022, Hanford received about $1.6 billion in appropriations per year for this work.
- DOE estimated in 2022 that completing construction of the Pretreatment Facility would cost approximately $9 billion, and completing the HLW Facility would cost approximately $10 billion.[32]
- The U.S. Army Corps of Engineers estimated in 2018 that completing the WTP as planned would cost between $21 billion and $30 billion, in addition to the nearly $12 billion that DOE had spent at that time, for a total cost of $33 billion to $42 billion.

These estimates form the basis for DOE's current annual spending estimates for completing the waste treatment mission (see fig. 5). The main drivers for the increased costs in the next 10 years are construction of the Pretreatment Facility and a second vitrification facility to treat supplemental LAW (about $7 billion), and operation of the treatment facilities and transfer of waste from existing tanks to staging tanks for treatment (about $17 billion). DOE estimates that, under the current plan, waste treatment will conclude in 2084.

[31]GAO, *Hanford Waste Treatment Plant: DOE Is Pursuing Pretreatment Alternatives, but Its Strategy Is Unclear While Costs Continue to Rise*, GAO-20-363 (Washington, D.C.: May 12, 2020). DOE is currently proceeding with treating a portion of the LAW by using a tank-side pretreatment technology, called tank-side cesium removal; however, DOE has not determined whether this technology would be sufficient to pretreat all 54 million gallons of Hanford's tank waste.

[32]Department of Energy, 2022 *Hanford Lifecycle Scope, Schedule and Cost Report*, DOE/RL-2021-47 (Richland, WA: Jan. 27, 2022).

Figure 5: Projected Funding Needed under the Current Plan for Hanford Tank Waste Cleanup, 2024-2084



Source: GAO analysis of Department of Energy data. | GAO-23-106093

Accessible Data for Figure 5: Projected Funding Needed under the Current Plan for Hanford Tank Waste Cleanup, 2024-2084

Fiscal year	Estimated annual cost (in billions of dollars)
2020	1.675
2021	1.607
2022	1.428
2023	1.531
2024	2.131
2025	3.740
2026	4.722
2027	5.146
2028	5.488
2029	5.953
2030	7.002
2031	7.179
2032	7.940
2033	3.628
2034	2.457
2035	2.963
2036	3.276
2037	3.297

Fiscal year	Estimated annual cost (in billions of dollars)
2038	3.294
2039	3.553
2040	3.738
2041	3.756
2042	3.898
2043	3.854
2044	3.968
2045	4.014
2046	3.964
2047	4.014
2048	3.992
2049	4.058
2050	4.121
2051	4.206
2052	4.314
2053	4.369
2054	4.565
2055	4.695
2056	4.780
2057	4.924
2058	4.826
2059	4.882
2060	5.129
2061	5.166
2062	5.404
2063	5.810
2064	5.849
2065	6.139
2066	6.459
2067	6.373
2068	6.436
2069	6.525
2070	6.787
2071	7.123
2072	7.114
2073	7.014

Fiscal year	Estimated annual cost (in billions of dollars)
2074	6.970
2075	7.066
2076	6.924
2077	6.948
2078	7.086
2079	7.011
2080	7.139
2081	7.196
2082	7.388
2083	7.103
2084	6.899
2085	1.475
2086	1.297
2087	2.807
2088	2.378
2089	2.145
2090	2.181

Note: According to DOE's methodology, these estimates come with uncertainty ranges of -50 percent/+100 percent for project/capital costs and -30 percent/+50 percent for operations costs.

Cost and Schedule Estimates for Alternatives for Treating HLW Vary, and None Are Projected to Meet the Regulatory Deadline

DOE's AOA found that the life-cycle cost estimates for treatment and disposal of the tank waste ranged from $135 billion to $5 trillion.[33] The AOA also found that the current plan, as well as several alternatives, would require a significant increase in annual funding (as high as $8 billion a year) in the next 10 years. The AOA found that none of the alternatives could complete HLW treatment by 2047 (as required by the TPA), with the soonest not estimated to be complete until 2061.

DOE Analyzed Multiple Alternatives for Completing the Tank Waste Treatment and Disposal Mission

From 2020 to 2023, DOE's selected contractor analyzed 24 different alternatives for treating the HLW and completing tank waste treatment and disposal (see table 1). In January 2023, DOE made the results of the AOA available to the public. The team originally analyzed 17 alternatives (assuming that all LAW would be vitrified) and then analyzed an 18th alternative (assuming that some of the LAW would be grouted, which is a process that immobilizes the waste in a concrete-like mixture) at the request of DOE. Five alternatives (6, 7, 10, 11, and 13) were screened out early in the process because they involved technologies that were either not sufficiently mature or, in the case of alternative 6, involved treatment methods other than vitrification, which is the treatment standard for radioactive high-level wastes under applicable regulations.[34] Five additional alternatives (3, 4, 8, 9, and 12) were screened out by DOE due to "information discovered during the alternative definition and evaluation

[33]DOE commissioned an AOA in 2019 to examine various options for treating the HLW at the Hanford Site. This request instructed the contractor to "conduct an AOA to provide the analytical basis for the allocation of funding to meet DOE policy and requirements… to inform both the fiscal year 2021-fiscal year 2025 budget process and the options for the treatment of HLW." Later, the AOA expanded to include not only treatment of the HLW but also many aspects of the entire WTP mission of treating and disposing of all of the waste in the tanks. Department of Energy, *Final Report: Waste Treatment and Immobilization Plant High-Level Waste Treatment Analysis of Alternatives* (Richland, WA: Jan. 12, 2023).

[34]As discussed above, this treatment standard applies specifically to radioactive high-level wastes generated during the reprocessing of fuel rods that exhibit specified hazardous waste characteristics, including those present in Hanford tank waste.

process." Some of the reasons that these alternatives were dropped included (1) no distinguishable difference from other alternatives, (2) unnecessarily high risks, and (3) high costs that were deemed unreasonable.

The eight remaining alternatives were analyzed in detail by the AOA team. Metrics of analysis included cost, schedule, and risk (technical, operational, and programmatic). Ecology recommended that six additional alternatives (2-Grout, 14-Grout, 18-Vitrification, 18-Prime, 19, and 19A) be examined, and the AOA ultimately analyzed 14 alternatives in detail.

Table 1: Alternatives Analyzed in the Department of Energy's (DOE) 2023 Waste Treatment and Immobilization Plant (WTP) High-Level Waste (HLW) Treatment Analysis of Alternatives for the Hanford Site

Description of alternatives (All alternatives assume completion of the existing HLW Facility by 2033 and treatment of supplemental low-activity waste (LAW) by vitrification, unless otherwise noted.)[a]	**Life-cycle cost estimate** (Dollars in billions[b])	**Estimated year complete** (HLW treatment to begin in 2033)
1. Current baseline: Complete currently planned HLW and Pretreatment Facilities.	$341	2084
2: HLW pretreatment and effluent management in new HLW Feed Preparation and Effluent Management Facility[c]	215	2061
2-Grout: Same as alternative 2, but assumes that supplemental LAW is grouted.	135	2061
3: HLW pretreatment in existing tanks and in a new HLW Feed Preparation Facility; effluents are concentrated in a new HLW Effluent Management Facility.	no data	no data
4: Same as alternative 3; some pretreatment activities are done at a higher temperature.	no data	no data
5: HLW pretreatment in repurposed Pretreatment Facility and a new HLW Feed Preparation Facility	217	2064
6: Treat HLW with steam reforming or grout (including technology development).[d]	no data	no data
7: HLW pretreatment in existing tanks (including technology development)	no data	no data
8: HLW in one portion of Hanford, referred to as the "West Area," pretreated in a new HLW Feed Preparation Facility; West Area effluents are concentrated in a new HLW Effluent Management Facility; supplemental LAW is vitrified.	no data	no data
9: Complete currently planned Pretreatment Facility; LAW Pretreatment in repurposed Pretreatment Facility and HLW pretreatment in a new HLW Feed Preparation Facility; effluents are treated in two new facilities: Plant Wash and Disposal system and Feed Evaporation Process system; pretreated HLW feed is vitrified in HLW Facility; Pretreatment Facility removes solids and cesium and concentrates, and stages LAW feed; effluents from LAW Facility are collected in a new Treated Low-Activity Waste Evaporation Process system; supplemental LAW is vitrified.	no data	no data
10: HLW shipped to the Savannah River Site for treatment; supplemental LAW is vitrified.	no data	no data
11: HLW pretreatment in retrofitted Fuels Material Examination Facility	no data	no data
12: HLW Facility would be abandoned; repurposed Pretreatment Facility would pretreat and vitrify HLW.	no data	no data
13: HLW pretreated and treated, using bulk vitrification technology (including technology development).[e]	no data	no data

Description of alternatives (All alternatives assume completion of the existing HLW Facility by 2033 and treatment of supplemental low-activity waste (LAW) by vitrification, unless otherwise noted.)[a]	Life-cycle cost estimate (Dollars in billions[b])	Estimated year complete (HLW treatment to begin in 2033)
14: Same as alternative 2, with added capability to filter additional solids from the liquid waste during pretreatment.	212	2064
14-Grout: Same as alternative 14; supplemental LAW is grouted.	144	2064
15: HLW pretreatment in existing tanks; effluents are concentrated in a new HLW Effluent Management Facility.	214	2064
16: Same as alternative 15; HLW is concentrated in the HLW Effluent Management Facility prior to treatment.	214	2062
17: Complete HLW Facility only; construct a new WTP after the design life of current one ends.	5,099	>2168
18: Complete HLW Facility, and construct HLW Feed Preparation and Effluent Management for pretreatment capabilities in 2050; supplemental LAW is grouted.	199	2075
18-Vitrification: Same as alternative 18; supplemental LAW is vitrified.	269	2075
18-Prime: Similar to alternative 18, with HLW Effluent Management Facility available in 2032.	243	2075
19: Same as alternative 18-Prime; startup dates for Waste Retrieval Facilities are changed from 2050 to 2031, 2032, and 2033; and two new double-shell tanks are added in 2037 and six more added in 2043.[f]	234	2074
19A: Same as alternative 19; only two new double-shell tanks are added in 2037.	229	2076

Legend: ─ = No data.

Source: GAO analysis of DOE data. | GAO-23-106093

Notes: Alternatives in gray cells were dropped from further analysis for various reasons, such as regulatory noncompliance or similarity to other alternatives.

According to DOE's methodology, these estimates come with uncertainty ranges of -50 percent/+100 percent for project/capital costs and -30 percent/+50 percent for operations costs. As a result, alternatives that appear to have different cost estimates might not actually have different costs, if the confidence intervals for their estimates overlap. In addition, DOE concluded that its assumptions, such as a total operating efficiency of the plant of 40 percent, were conservative, resulting in schedule estimates that are "not considered overly optimistic."

DOE plans to separate Hanford's tank waste into two streams for treatment: (1) the high-activity portion, which DOE refers to as "high-level waste," or HLW, and estimates will contain 5 percent of the volume but more than 70 percent of the radioactivity; and (2) the low-activity portion, which DOE refers to as "low activity waste," or LAW, and comprises the remainder of the tank waste. We use "HLW" and "LAW" terminology here in keeping with DOE's typical usage.

[a]The WTP is currently designed to treat only one-third to one-half of the LAW at Hanford. DOE will need to identify and select another approach for treating the remaining LAW. The portion of the LAW remaining in the tanks for which DOE has yet to select a treatment approach is commonly referred to as "supplemental LAW."

[b]Dollar values presented in table 1 are not adjusted for inflation and, therefore, reflect different average prices at different times.

[c]Effluent is the liquid waste generated during the treatment process.

[d]Steam reforming is a process that dries liquid waste into a solid granular material.

[e]The bulk vitrification process would convert LAW into solid glass by drying the waste, mixing it with Hanford soils, and applying an electric current within a large steel container.

[f]Double-shell tanks are tanks with a second carbon-steel lining, or shell, within the outer concrete housing to provide secondary containment of the waste.

We have identified 22 best practices for an AOA process by (1) compiling and reviewing commonly mentioned AOA policies and guidance used by different government and private-sector entities and (2) incorporating experts' comments on a draft set of practices to develop a final set of practices.[35] DOE Order 413.3B requires that an analysis of alternatives be completed for projects with a total project cost greater than $50 million and that the completed analysis be consistent with our published best practices. According to the AOA, DOE's contractor aimed to follow our best practices while conducting its analysis.

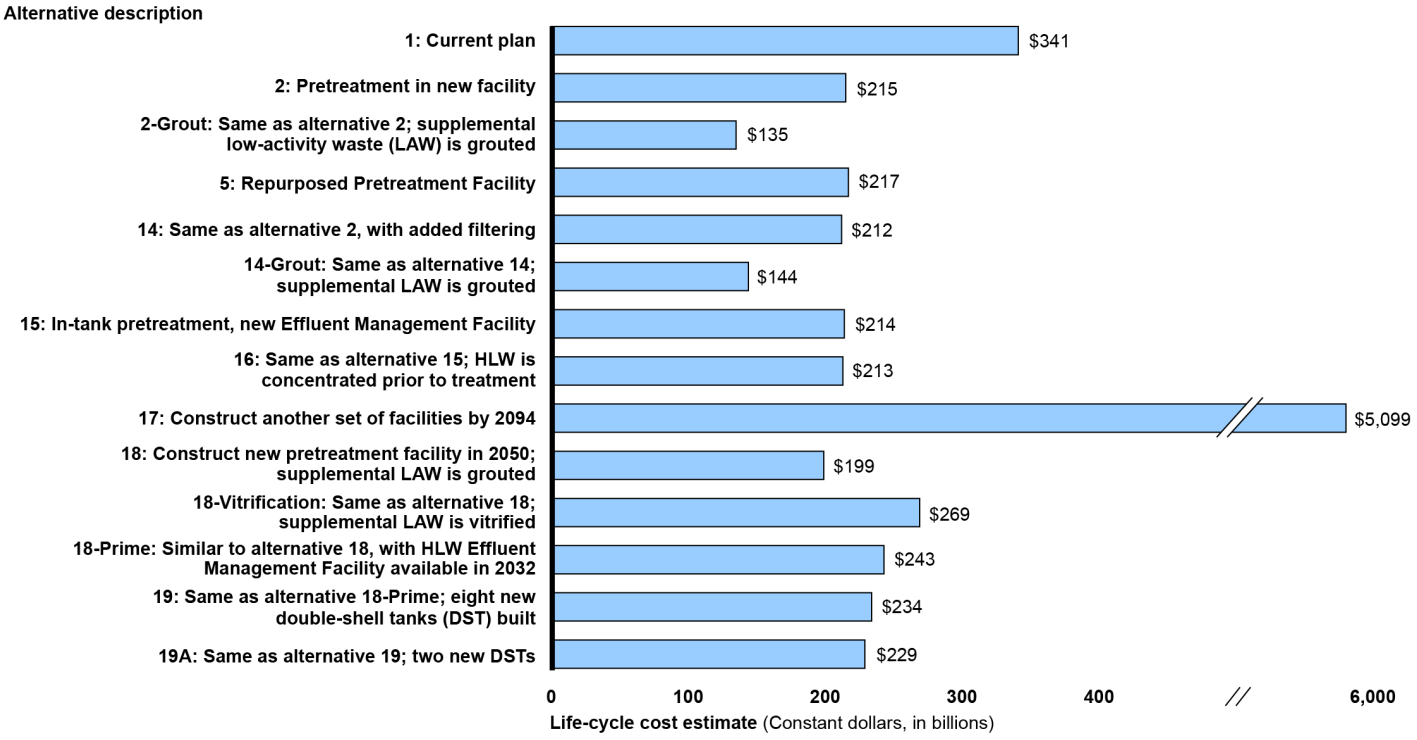
Life-Cycle Cost Estimates for the Alternatives Ranged from $135 Billion to over $5 Trillion, and Annual Costs Could Be up to $8 Billion

The AOA found that the life-cycle cost estimates for treating the HLW ranged widely, from $135 billion (alternative 2-Grout) to over $5 trillion (alternative 17), with most alternatives estimated to cost about $200 billion to $300 billion (see fig. 6). The three alternatives that assume that a portion of the LAW will be treated with grout rather than vitrification (alternatives 2-Grout, 14-Grout, and 18) have the lowest cost estimates—all less than $200 billion. Notably, an April 2022 report by Savannah River National Laboratory similarly found that grout alternatives are cheaper than vitrification. That report found that DOE could save approximately $95 billion (escalated) over the next 50-60 years by grouting a portion of the LAW rather than vitrifying it.[36] Alternative 17 is by far the most expensive (over $5 trillion) based on (1) the length of the mission, which is not expected to be finished until 2168; and (2) the expectation that an entirely new WTP facility will be built to continue the mission. The next most expensive alternative is the current baseline approach ($341 billion).

[35]See GAO-20-195G. We did not assess the extent to which DOE and its contractor followed these best practices while undertaking the AOA.

[36]This analysis uses a 2.4 percent escalation factor to allow for comparisons against past estimates that were also reported in escalated dollars. Savannah River National Laboratory, *Follow-on Report of Analysis of Approaches to Supplemental Treatment of Low-Activity Waste at the Hanford Nuclear Reservation* (Aiken, SC: 2022). According to DOE's cost estimating guide, escalation is the provision in a cost estimate for increases in the cost of equipment, material, and labor affected by continuing price changes over time. Department of Energy, *Cost Estimating Guide*, DOE G 413.3-21A (Washington, D.C.: Jun. 6, 2018).

Figure 6: Hanford High-Level Waste (HLW) Treatment Analysis of Alternatives: Estimated Life-Cycle Cost of Select Alternatives



Source: GAO analysis of Department of Energy data. | GAO-23-106093

Accessible Data for Figure 6: Hanford High-Level Waste (HLW) Treatment Analysis of Alternatives: Estimated Life-Cycle Cost of Select Alternatives

Alternative descriptive	Life-Cycle Cost Estimate (Constant dollars, in billions)
1: Current plan	$341
2: Pretreatment in new facility	$215
2-Grout: Same as alternative 2; supplemental low-activity waste (LAW) is grouted	$135
5: Repurposed Pretreatment Facility	$217
14: Same as alternative 2, with added filtering	$212
14-Grout: Same as alternative 14; supplemental LAW is grouted	$144
15: In-tank pretreatment, new Effluent Management Facility	$214
16: Same as alternative 15; HLW is concentrated prior to treatment	$213
17: Construct another set of facilities by 2094	$5,099
18: Construct new pretreatment facility in 2050; supplemental LAW is grouted	$199
18-Vitrification: Same as alternative 18; supplemental LAW is vitrified	$269

Alternative descriptive	Life-Cycle Cost Estimate (Constant dollars, in billions)
18-Prime: Similar to alternative 18, with HLW Effluent Management Facility available in 2032	$243
19: Same as alternative 18-Prime; eight new double-shell tanks (DST) built	$234
19A: Same as alternative 19; two new DSTs	$229

Notes: According to DOE's methodology, these estimates come with uncertainty ranges of -50 percent/+100 percent for project/capital costs and -30 percent/+50 percent for operations costs. As a result, alternatives that appear to have different cost estimates might not actually have different costs, if the confidence intervals for their estimates overlap.

DOE plans to separate Hanford's tank waste into two streams for treatment: (1) the high-activity portion, which DOE refers to as "high-level waste," or HLW, and estimates will contain 5 percent of the volume but more than 70 percent of the radioactivity; and (2) the low-activity portion, which DOE refers to as "low activity waste," or LAW, and comprises the remainder of the tank waste. We use "HLW" and "LAW" terminology here, in keeping with DOE's typical usage. DOE plans to vitrify a portion of Hanford's LAW, but it has not made a decision on how to treat and dispose of the roughly 40 percent referred to as supplemental LAW.

For a more complete description of the alternatives, see table 1.

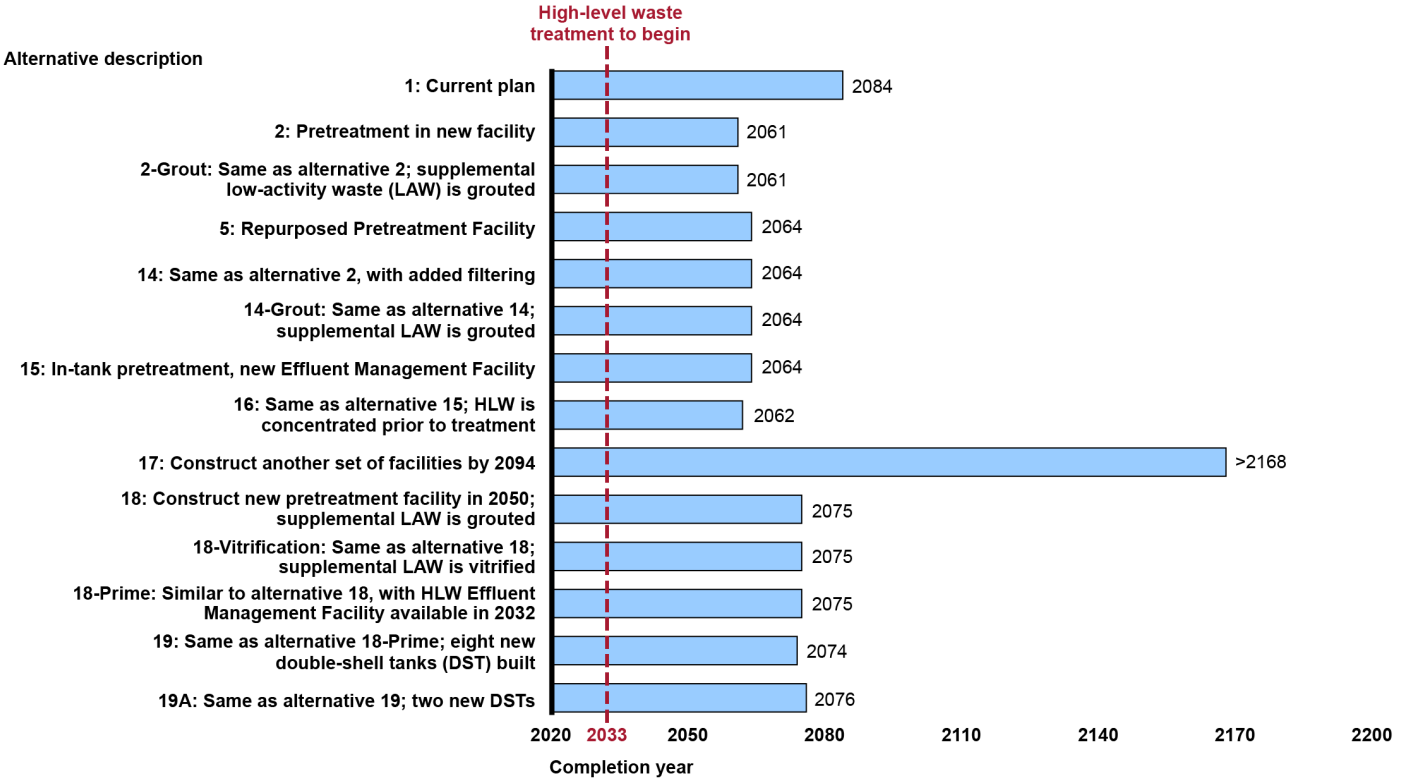
The AOA also found that, as with the current plan, several of the alternatives would require a significant increase in annual funding for the tank waste cleanup mission (up to $8 billion a year) in the next 10 years. This is in contrast to the typical annual funding for this scope of work of about $1.6 billion per year over the last 5 years. According to the AOA, this increase in funding is to design and construct the various new facilities needed to complete the tank waste treatment. The AOA also found that none of the alternatives would be achievable if annual funding were constrained to less than $2.5 billion per year. According to the report, "Under the constrained funding scenario, the full scope of the various capital facilities needed to support the HLW treatment mission cannot be constructed and operated due to insufficient funding being available."

Estimated Completion Dates among the Alternatives Analyzed Ranged from 2061 to 2168

Regarding completion dates, based on the schedule estimates in the AOA, none of the alternatives are projected to be completed by 2047 (as required by the TPA). The alternative with the soonest estimated completion of treatment (alternative 2) would not be complete until 2061; the latest (alternative 17), not until after 2168 (see fig. 7). In addition, each of the alternatives assumes that the HLW treatment would begin by 2033, as required by the amended Consent Decree. However, we and

others have reported that meeting that start date is unlikely.[37] As a result, the estimated completion dates in the AOA are likely optimistic.

Figure 7: Hanford High-Level Waste (HLW) Treatment Analysis of Alternatives: Estimated Years to Complete Treatment under Select Alternatives



Source: GAO analysis of Department of Energy data. | GAO-23-106093

Accessible Data for Figure 7: Hanford High-Level Waste (HLW) Treatment Analysis of Alternatives: Estimated Years to Complete Treatment under Select Alternatives

Alternative descriptive	Completion year
1: Current plan	2084
2: Pretreatment in new facility	2061
2-Grout: Same as alternative 2; supplemental low-activity waste (LAW) is grouted	2061
5: Repurposed Pretreatment Facility	2064
14: Same as alternative 2, with added filtering	2064
14-Grout: Same as alternative 14; supplemental LAW is grouted	2064

[37]U.S. Army Corps of Engineers, *Parametric Evaluations of the Waste Treatment and Immobilization Plant* (Washington, D.C.: July 10, 2018); and GAO-20-363.

Alternative descriptive	Completion year
15: In-tank pretreatment, new Effluent Management Facility	2064
16: Same as alternative 15; HLW is concentrated prior to treatment	2062
17: Construct another set of facilities by 2094	> 2168
18: Construct new pretreatment facility in 2050; supplemental LAW is grouted	2075
18-Vitrification: Same as alternative 18; supplemental LAW is vitrified	2075
18-Prime: Similar to alternative 18, with HLW Effluent Management Facility available in 2032	2075
19: Same as alternative 18-Prime; eight new double-shell tanks (DST) built	2074
19A: Same as alternative 19; two new DSTs	2076

Notes: DOE plans to separate Hanford's tank waste into two streams for treatment: (1) the high-activity portion, which DOE refers to as "high-level waste," or HLW, and estimates will contain 5 percent of the volume but more than 70 percent of the radioactivity;, and (2) the low-activity portion, which DOE refers to as "low activity waste," or LAW, and comprises the remainder of the tank waste. We use "HLW" and "LAW" terminology here, in keeping with DOE's typical usage. DOE plans to vitrify a portion of Hanford's LAW, but it has not made a decision on how to treat and dispose of the roughly 40 percent referred to as supplemental LAW.

For a more complete description of the alternatives, see table 1.

DOE Is Restarting Construction on the HLW Facility and Has Not Committed to Validating Its Analysis of Alternatives Process for HLW Treatment

DOE plans to select an alternative—though no timeline has been set—and has restarted some efforts to complete construction of the HLW Facility. According to DOE officials, the AOA report is not a decision document, but it will be used to inform DOE's required project management decision-making process, as well as ongoing negotiations among DOE, EPA, and Ecology regarding a path forward for Hanford tank waste treatment and disposal. However, DOE officials have not committed to having the AOA independently reviewed to validate the AOA process, and particularly with respect to the HLW treatment alternatives, as required by best practices. Apart from the AOA process, DOE's decision about HLW treatment may be affected by other factors, such as ongoing cleanup negotiations with EPA and Ecology and aging site infrastructure at Hanford.

DOE Plans to Select an Alternative and Has Restarted Some Efforts to Complete Construction of the HLW Facility

DOE plans to select a preferred alternative, though no timeline has been set. According to DOE officials, the AOA estimates do not provide the detail necessary for DOE decision makers to select a preferred alternative. The AOA states that the final report is not a decision document and that DOE will need additional information to make a selection. For example, DOE guidance notes that, following an AOA, the decision maker may need to consider other sources of information—such as an engineering study—to select a preferred alternative.[38] DOE officials said that they expect the next steps in the process to be selecting the "best" alternatives for additional analysis, using that information to select a preferred alternative, and restarting the WTP project. However, they do not have a timeline for when these next steps will begin and end.

Other efforts that DOE plans to take include developing a baseline cost and schedule estimate for completing design of the HLW Facility, holding future workshops with Ecology and other stakeholders, developing more detailed cost and schedule estimates for HLW treatment, and hiring new staff to initiate a contract modification for this work. According to DOE officials, the HLW Facility will be built under a "design and then build" strategy, consistent with DOE's project management order and past GAO recommendations. This is a shift from DOE's original 2000 WTP design-build contract that allowed design and construction to occur concurrently.[39]

[38]We have found that developing sound business cases, which include plans for a stable design, mature technologies, reliable cost estimates, and a realistic schedule before committing resources, can lead to a successful request for proposals and contract acquisition process (see GAO-20-195G).

[39]Prior to proceeding with construction of certain capital assets, DOE is required by DOE Order 413.3B to achieve at least 90 percent design completion. DOE Order 413.3B allows for a specific circumstance, known as design-build: a single contract awarded for both design and construction to occur concurrently. Design-build is typically used with projects that have well-defined requirements with limited complexity and risks. We have reported on and made numerous recommendations related to the need for DOE to wait until the WTP design is sufficiently complete before proceeding with construction. See GAO/RCED-93-99; GAO/RCED-99-13; GAO-03-593; GAO-04-611; GAO-06-602T; GAO-07-336; GAO-13-38; and GAO-15-354.

In the meantime, DOE has begun ramping up design and construction work on the partially completed HLW Facility. DOE requested a $316 million increase in funding for fiscal year 2023 and an additional increase of over $200 million for fiscal year 2024 to restart design and prepare for construction of the stalled HLW Facility. DOE's fiscal year 2023 budget request stated that this funding would be used for "engineering design activities" (such as completing the design of off-gas and ventilation systems and updating the facility's safety analysis) and "procurement activities" (such as paying vendors for maintenance and purchasing waste feed equipment) related to the HLW Facility. According to January 2023 monthly project updates, beginning in early 2022, with this additional funding, the DOE contractor increased staff to advance design, procure equipment, and restart construction.[40]

DOE Has Not Committed to Obtaining an Independent Review to Validate the AOA

DOE guidance and GAO best practices call for an independent review of an AOA to validate the process before selecting a preferred alternative. DOE manages most Hanford cleanup projects in accordance with DOE Order 413.3B, which requires DOE to conduct an AOA for projects above a certain cost threshold and requires that the completed AOA be consistent with published GAO best practices.[41] Our best practices outline common AOA policies and guidance used by different government and private-sector entities and incorporate expert commentary. According to both DOE guidance and our best practices, before selecting a preferred alternative, agencies should obtain an independent review to validate the AOA process.[42] In addition, according to our risk-informed decision-making framework, conducting independent reviews can help ensure the credibility and quality of analyses.[43]

[40]The $392 million appropriated in fiscal year 2023 for HLW Facility construction was an increase of nearly $250 million from the previous year. DOE is requesting $600 million, or over $200 million more in funding, for HLW Facility construction in fiscal year 2024.

[41]Most recently published in GAO-20-195G.

[42]Department of Energy, *Analysis of Alternatives Guide*, DOE G 413.3-22 (Washington, D.C.: Jun. 6, 2018).

[43]GAO-19-339.

Certain aspects of the AOA, such as alternative treatment methods for LAW, have been widely studied and reviewed by independent organizations, including the Savannah River National Laboratory and the National Academies of Sciences, Engineering, and Medicine.[44] However, the HLW treatment alternatives analyzed in the AOA have not been similarly studied or independently reviewed.

DOE officials told us that DOE has not committed to obtaining an independent review to validate the portions of the AOA process that analyze the feasibility and effectiveness of HLW treatment alternatives. As stated earlier, DOE received $392 million for fiscal year 2023 to resume construction of the HLW Facility, which has been stalled for more than 10 years because of design and technical challenges. Officials stated that they may seek out opportunities to optimize HLW treatment in the future by assessing options that may allow DOE to minimize the fraction of tank waste deemed to be HLW, thereby potentially reducing the schedule and costs of the tank waste treatment mission.[45] Officials also noted that representatives from Ecology were involved in developing and reviewing the AOA, which helped to ensure that multiple viewpoints were included.

Nevertheless, an independent review can provide assurance to decision makers that the mission need is appropriate and that the alternatives analyzed are comprehensive. By obtaining an independent review of those portions of the AOA process that analyzed the feasibility and effectiveness of the HLW treatment alternatives, in particular, DOE and other decision makers may have greater assurance that all viable alternatives for optimizing the tank waste treatment mission are considered.

[44]Savannah River National Laboratory, *Follow-on Report of Analysis of Approaches to Supplemental Treatment of Low-Activity Waste at the Hanford Nuclear Reservation* (Aiken, SC: 2022); and National Academies of Sciences, Engineering, and Medicine, *Review of the Continued Analysis of Supplemental Treatment Approaches of Low-Activity Waste at the Hanford Nuclear Reservation: Review #2 (2022)* (Washington, D.C.: 2022).

[45]One academic source defines optimization as an analysis used to achieve the best approach relative to a set of prioritized criteria and constraints. Further, EPA has applied the concept of optimization to its Superfund program, describing optimization as a systematic review by a team of independent technical experts at any phase of a cleanup process to identify opportunities to improve a remedy's protectiveness, effectiveness, and cost efficiency, and to facilitate progress toward completion of site work.

Selection of an Alternative for Hanford HLW Treatment May Be Affected by Other Factors, Including Ongoing Cleanup Negotiations

DOE's selection of an alternative for Hanford HLW treatment may be affected by other factors, such as ongoing cleanup negotiations among DOE, EPA, and Ecology; DOE's lengthy decision-making process; limited double-shell tank (DST) space; and aging site infrastructure.[46]

- **Ongoing cleanup negotiations among DOE, EPA, and Ecology.** Since June 2020, DOE, the State of Washington, and EPA (Region 10) have been engaged in confidential, mediated negotiations regarding a holistic and realistic path forward for managing Hanford's tank waste. DOE officials have told us that they do not plan to make a decision about a preferred alternative until these negotiations are complete and, therefore, further steps to finalize HLW treatment plans cannot be made. At the time the final AOA report was issued in January 2023, the holistic negotiations were not finished, and it is unknown how the outcome of these negotiations may impact DOE's decision on HLW treatment.
- **DOE decision-making process.** DOE faces a lengthy decision-making process before an alternative can be implemented. First, DOE Order 413.3B establishes milestones (called critical decisions) over the life of a project that each end with a major approval milestone.[47] The order specifies requirements that must be met, including developing and managing project cost and schedule estimates to move a project past each critical decision milestone. DOE officials said that the WTP is currently at the fourth critical decision milestone. However, AOAs are typically conducted prior to the second critical decision milestone (Critical Decision 1), and selection of a new preferred alternative for treating the HLW would then be followed by the approval of a definitive scope, schedule, and cost baseline at the third critical decision milestone (Critical Decision 2). According to DOE officials, this process could take 1 to 3 years to complete. Next, DOE will need to secure permits from the State of Washington to modify

[46]DSTs are tanks with a second carbon-steel lining, or shell, within the outer concrete housing to provide secondary containment of the waste.

[47]An AOA may also be conducted again when a performance baseline deviation occurs or if new technologies or solutions become available. Department of Energy, *Program and Project Management for the Acquisition of Capital Assets, DOE Order 413.3B* (Change 6) (Washington, D.C.: Jan. 12, 2021).

existing facilities and build the new facilities before moving forward with a new HLW treatment approach. According to DOE officials, this permitting process could take 18 months. Ecology officials, on the other hand, said that this process could take up to 3 to 5 years to complete.

- **Limited DST space.** According to a DOE Office of Inspector General 2020 report, the condition of some DSTs has deteriorated over time and, in the current system plan, the overall mission treatment and retrieval strategy, as well as mission requirements, could change as a result of any leaking DSTs.[48] In particular, the DSTs were constructed from 1968 through 1986, each with a design life ranging from 20 to 50 years. Hanford's DSTs are needed for waste retrieval operations and staging prior to waste treatment. However, as we found in January 2021, Hanford may have insufficient DST space available for current and future waste transfers, in particular if the WTP is further delayed. We reported in 2021 that, according to DOE documents, there is a 95 percent chance it will run out of DST space, which could delay overall waste treatment operations.[49]
- **Aging site infrastructure.** In addition, due to the age of site utilities and infrastructure, (e.g., air, water, electrical, power, fire protection) and the long Hanford tank waste retrieval and closure mission duration, the availability of necessary services for HLW treatment is uncertain. According to DOE officials, upgrades for HLW treatment infrastructure will be needed throughout the mission, and unanticipated repairs of Hanford Site infrastructure could add cost and time to HLW treatment.

Conclusions

After over 20 years and billions of dollars spent, the WTP is only partially complete and faces numerous technical challenges, cost overruns, and schedule delays. Even after DOE has reset the cost and schedule baseline numerous times, we and others have repeatedly reported that the project is unlikely to be completed as designed and scheduled. In recent years, DOE has taken a number of steps to examine alternative

[48]Department of Energy, Office of Inspector General, *Tank Waste Management at the Hanford Site*, DOE-OIG-20-57 (Washington, D.C.: September 2020); Department of Energy, *River Protection Project System Plan*, ORP-11242 rev. 9 (Richland, WA: November 2020).

[49]GAO-21-73.

approaches for treating the least radioactive portions of Hanford's tank waste that could save billions of dollars, reduce certain risks, and speed up the completion of the treatment effort. As DOE now shifts its attention to analyzing alternatives for treating the remaining, more highly radioactive tank waste, the decisions made in the coming years will affect decades of future cleanup activity and could save tens of billions of dollars. However, DOE officials told us that DOE has not committed to obtaining an independent review to validate its recent AOA, as required by agency guidance, specifically those alternatives involving the HLW Facility. By obtaining an independent review of the portions of the AOA process that considered HLW treatment, decision makers will have greater assurance that an appropriately diverse range of alternatives were analyzed. Given the enormous cost and schedule implications of the decision, it is essential for DOE to take steps now to provide assurance that all viable alternatives for optimizing the tank waste treatment mission are considered.

Recommendation for Executive Action

The Secretary of Energy should ensure that the Assistant Secretary for Environmental Management obtains an independent review to validate the process of the analysis of high-level waste treatment alternatives at Hanford. (Recommendation 1)

Agency Comments and Our Evaluation

We provided a draft of this report to DOE for review and comment. In its comments, reproduced in appendix II, DOE concurred with our recommendation and stated that it believes its actions thus far, along with those that it will be required to take under DOE's project management order, satisfy the recommendation. However, we believe further action is needed, per best practices for developing an analysis of alternatives (AOA), to provide greater assurance that all viable alternatives for optimizing the tank waste treatment mission are considered. In its letter to GAO, DOE stated that, "independent entities have validated the quality of the alternatives analysis, such as the National Academies of Science and the Federally Funded Research and Development Center's Program Management Office." As we note in this report, alternative treatment methods for LAW have been widely studied and reviewed by independent organizations—including the Savannah River National Laboratory and the National Academies of Sciences, Engineering, and Medicine. However,

the HLW treatment alternatives in DOE's AOA have not been similarly studied or independently reviewed. In addition, an official from the National Academies confirmed to us they have not conducted an independent review of the AOA.

DOE also provided technical comments, which we incorporated as appropriate.

We are sending copies of this report to the appropriate congressional committees, the Secretary of Energy, and other interested parties. In addition, the report is available at no charge on the GAO website at http://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-3841 or andersonn@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made significant contributions to this report are listed in appendix III.

Nathan J. Anderson
Director, Natural Resources and Environment

List of Committees

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The Honorable Roger Wicker
Ranking Member
Committee on Armed Services
United States Senate

The Honorable Dianne Feinstein
Chair
The Honorable John Kennedy
Ranking Member
Subcommittee on Energy and Water Development
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The Honorable Mike Rogers
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The Honorable Adam Smith
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House of Representatives

The Honorable Chuck Fleischmann
Chair
The Honorable Marcy Kaptur
Ranking Member
Subcommittee on Energy and Water Development, and Related Agencies
Committee on Appropriations
House of Representatives

Appendix I: Objectives, Scope, and Methodology

Our report examines (1) the Department of Energy's (DOE) current high-level waste (HLW) treatment plans at Hanford, (2) the results of DOE's analysis of alternatives (AOA) for treating the HLW, and (3) next steps that DOE plans to take in selecting a HLW treatment alternative.[1]

To determine DOE's current HLW treatment plans at Hanford, we reviewed DOE documents, including the current *River Protection Project System Plan* (System Plan 9) and the *Final Report: Waste Treatment and Immobilization Plant High-Level Waste Treatment Analysis of Alternatives.*[2] We compiled information on the composition of Hanford's HLW by analyzing data from DOE's Best-Basis Inventory.[3] To assess the reliability of these data, we compared DOE's cost estimates for treating and disposing of the Hanford tank waste with other datasets and requested information provided by DOE from a proprietary database used for System Plan 9 and an upcoming update to the plan to be issued by the end of 2023. We also interviewed DOE officials to obtain information on its current plans for HLW treatment, as well as any cost, schedule, and technical challenges that may affect DOE's current plans.

To assess the results of DOE's AOA, we analyzed key AOA documents developed by a DOE contractor, including DOE's April 2021 draft AOA (and addendum) and DOE's final AOA issued in January 2023 (and two

[1]Before treating the Hanford tank waste, DOE plans to separate it into two streams: (1) the high-activity portion, which DOE estimates will contain about 5 percent of the volume but more than 70 percent of the radioactivity; and (2) the low-activity portion, which will contain about 95 percent of the volume. At Hanford, DOE often uses the term "high-level waste," or HLW, to refer only to the high-activity portion of the tank waste and "low-activity waste," or LAW, to refer to the rest of the tank waste. For the purposes of this report, when we refer to "HLW," we are referring only to the approximately 5 percent of the waste that DOE considers to have high radioactivity.

[2]Department of Energy, *River Protection Project System Plan*, ORP-11242 rev. 9 (Richland, WA: November 2020); and *Final Report: Waste Treatment and Immobilization Plant High-Level Waste Treatment Analysis of Alternatives* (Richland, WA: Jan. 12, 2023).

[3]The Best-Basis Inventory contains inventory estimates for chemical and radionuclide components in the 177 Hanford Site underground storage tanks. Inventories are presented on both a tank-by-tank and global (total) basis.

addendums). We also reviewed accompanying documentation related to the cost and schedule estimates of the alternatives analyzed by DOE. We reviewed the AOA and addendums to summarize and describe all 24 alternatives analyzed by DOE. In addition, we interviewed DOE officials about their methodology for developing the original alternatives and how alternatives were added and eliminated in the AOA process.

To assess the reliability of the AOA's future cost and schedule projections for the purposes of the report, we compared the AOA's estimates with other available cost and schedule estimates, including (1) the U.S. Army Corps of Engineers' 2018 report on the status of the Waste Treatment and Immobilization Plant (WTP);[4] (2) DOE's Hanford System Plan 9;[5] (3) the National Academies of Sciences, Engineering, and Medicines' projections in their 2020 study on supplemental treatment approaches of low-activity waste at Hanford;[6] (4) the 2019 Savannah River National Laboratory's *Report of Analysis of Approaches to Supplemental Treatment of Low-Activity Waste at the Hanford Nuclear Reservation,* a federally funded research and development center's projections of approaches to supplemental treatment of low-activity waste at Hanford;[7] and (5) our December 2021 projections.[8] DOE described its cost estimates in the AOA as "rough order of magnitude cost estimates for the design and construction of new facilities, as well as the life-cycle cost for each alternative." According to DOE's methodology, these estimates come with uncertainty ranges of -50 percent/+100 percent for project/capital costs and -30 percent/+50 percent for operations costs. In addition, DOE stated that its schedule estimates contain "a great deal of uncertainty as to overall duration that is dependent on a wide set of factors." DOE concluded that its assumptions, such as a total operating efficiency of the HLW Facility of 40 percent, were conservative, resulting

[4]U.S. Army Corps of Engineers, *Parametric Evaluations of the Waste Treatment and Immobilization Plant* (Washington, D.C.: July 10, 2018).

[5]ORP-11242 rev. 9.

[6]National Academies of Sciences, Engineering, and Medicine, *Final Review of the Study on Supplemental Treatment Approaches of Low-Activity Waste at the Hanford Nuclear Reservation: Review #4* (Washington, D.C.: The National Academies Press, 2020).

[7]Savannah River National Laboratory, *Report of Analysis of Approaches to Supplemental Treatment of Low-Activity Waste at the Hanford Nuclear Reservation, SRNL-RP-2018-00687* (Aiken, SC: Oct. 18, 2019).

[8]GAO, *Nuclear Waste Disposal: Actions Needed to Enable DOE Decision That Could Save Tens of Billions of Dollars*, GAO-22-104365 (Washington, D.C.: Dec. 9, 2021).

in schedule estimates that are "not considered overly optimistic." We determined that these data were sufficiently reliable for our purposes when reported in conjunction with the aforementioned uncertainties.

To identify the next steps in DOE's process to select a preferred alternative for HLW treatment, we interviewed DOE officials regarding the results from the final AOA issued publicly in January 2023 and its planned next steps, including when it plans to select a preferred alternative for HLW treatment. We compared these next steps with our AOA best practices.[9] We also asked DOE officials for a description of the AOA public feedback process, time frame, and methodology, and any planned use of the feedback that it receives. We also reviewed recent DOE reports and documentation—such as DOE's fiscal years 2023 and 2024 budget requests[10] and DOE's strategic vision report for 2022-2032[11]—related to DOE efforts to restart construction of the HLW Facility.

To examine factors that could affect DOE's ongoing efforts to select a preferred alternative for HLW treatment, we interviewed officials from the Defense Nuclear Facilities Safety Board—an agency that provides independent analysis, advice, and recommendations to the Secretary of Energy regarding health and safety at DOE defense nuclear facilities—regarding remaining technical challenges facing WTP's Pretreatment and HLW Facilities. We interviewed Washington State Department of Ecology officials about their participation in the AOA process and any remaining regulatory requirements needed to proceed with HLW treatment. We also reviewed DOE Order 413.3B and its critical decision-making process.[12]

We conducted this performance audit from August 2022 to May 2023 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

[9]GAO, *Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Program Costs,* GAO-20-195G (Washington, D.C.: Mar. 12, 2020).

[10]Department of Energy, *Department of Energy FY 2023 Congressional Budget Justification, Environmental Management* (Washington, D.C.: May 2022); and *Department of Energy FY 2024 Congressional Budget Justification, Environmental Management* (Washington, D.C.: March 2023).

[11]Department of Energy, *EM Strategic Vision: 2022–2032* (Washington, D.C.: Mar. 8, 2022).

[12]Department of Energy, *Program and Project Management for the Acquisition of Capital Assets*, DOE Order 413.3B (Change 6) (Washington, D.C.: Jan. 12, 2021).

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: Comments from the Department of Energy

Department of Energy
Washington, DC 20585
May 11, 2023

Mr. Nathan Anderson
Director
Natural Resources
and Environment
U.S. Government Accountability Office
Washington, DC 20548

Dear Mr. Anderson:

This letter provides the Department of Energy's (DOE) Office of Environmental Management (EM) response to the U.S. Government Accountability Office (GAO) draft report, GAO-22-106093, *HANFORD CLEANUP: DOE Should Validate Its Analysis of High-Level Waste Treatment Alternatives.*

EM is approaching a crossroads of its cleanup mission after over 30 years of cleanup efforts to address decades of nuclear weapons development and research. The plan for the remaining cleanup work, particularly tank waste cleanup, extends decades into the future and requires EM to seek innovative approaches to complete the remaining sites more expeditiously than currently planned while continuing to protect the health of workers, communities, and the environment. The cleanup of tank waste is the most technically challenging aspect of EM's cleanup mission and represents about 48 percent of the remaining estimated cleanup cost for the EM program.

The tank waste cleanup mission at the Hanford site, where first-of-a-kind tank waste processing facilities have taken decades to construct, represents the largest volume of liquid tank waste in the EM complex. While significant progress has been made at Hanford, EM is evaluating various approaches to treat Hanford high-level waste (HLW) while maintaining EM's number one priority of protecting human health and the environment. An analysis of alternatives (AoA), developed by a third-party independent contractor, was released in 2023 that considered 24 options for treating Hanford's HLW. The State of Washington Department of Ecology also participated in the development of the AoA and produced its own alternatives, which were evaluated. To date, independent entities have validated the quality of the alternatives analysis, such as the National Academies of Science and the Federally Funded Research and Development Center's Program Management Office.

EM plans to use the completed AoA to select an HLW alternative. This alternative will undergo independent reviews prior to establishing a project cost and schedule baseline as set forth by DOE Order 413.3A, *Program and Project Management for the Acquisition of Capital Assets.*

DOE concurs with GAO's recommendation, which encompasses actions that have already occurred or are a required part of the DOE capital asset process.

If you have any questions, please contact me or Mr. Dae Y. Chung, Associate Principal Deputy Assistant Secretary for Corporate Services, at (202) 586-9636.

Sincerely,

William I. White
Senior Advisor for Environmental Management

Enclosures

Accessible Text for Appendix II: Comments from the Department of Energy

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Natural Resources and Environment
U.S. Government Accountability Office
Washington, DC 20548

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Sincerely,

William I. White
Senior Advisor for Environmental Management

Enclosures

Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

Nathan J. Anderson, Director, Natural Resources and Environment, (202) 512-3841 or andersonn@gao.gov

Staff Acknowledgments

In addition to the contact named above, Amanda K. Kolling (Assistant Director), Jeffrey T. Larson (Analyst in Charge), Claudia Hadjigeorgiou, Megan Harries, Dennis Mayo, and Mark Young-McMurchie made key contributions to this report. Also contributing to this report were Mark Braza, Corinna Nicolaou, and Dan Royer.

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