HANFORD CLEANUP

Alternatives for Treating and Disposing of High-Level Waste Could Save Billions of Dollars and Reduce Certain Risks

Report to Congressional Committees

September 2024
GAO-24-106989
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GAO Highlights

Highlights of GAO-24-106989, a report to congressional committees
September 2024

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Alternatives for Treating and Disposing of High-Level Waste Could Save Billions of Dollars and Reduce Certain Risks

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. DOE has historically planned to manage a portion of this waste—Hanford's HLW—as a waste type (high-level radioactive waste) that requires treatment by vitrification and disposal in a deep geological repository. DOE currently plans to pretreat the HLW and vitrify it in facilities that have been under construction since 2000 and are estimated to cost about $20 billion to complete. DOE intends to store the vitrified waste on-site at Hanford until the establishment of a deep geologic repository.

Senate Report 118-58 includes a provision for GAO to assess DOE's plans for minimizing the portion of waste at Hanford that will be treated as high-level radioactive waste. This report examines (1) the status of DOE's current approach to addressing Hanford's HLW; (2) alternative approaches that could minimize the fraction of waste that would require treatment as high-level radioactive waste and the extent to which these approaches would affect DOE's current cost and schedule estimates; and (3) steps, if any, DOE could take to pursue alternative approaches.

GAO reviewed DOE reports; interviewed DOE, EPA, and Washington State officials; and worked with the National Academies to convene meetings of 17 experts to discuss options for addressing Hanford's HLW.

What GAO Found

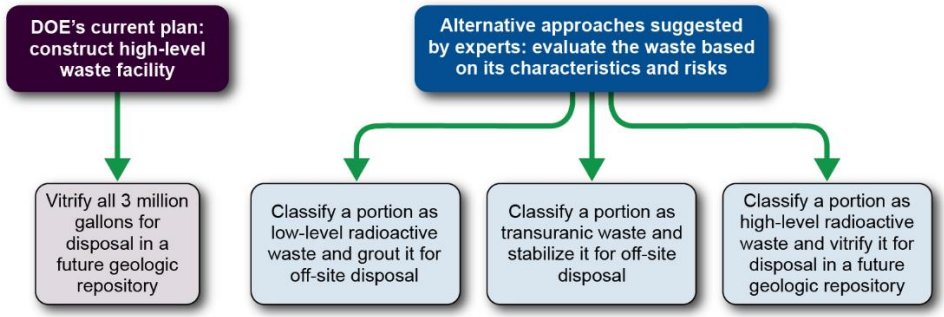
The Department of Energy's (DOE) planned approach to treating about 3 million gallons of Hanford's waste with the highest radioactivity—Hanford's high-level waste (HLW)—is to ramp up construction of the HLW Facility, where the HLW would be vitrified (immobilized in glass). Construction of this facility was paused in 2012 due to technical challenges. In 2022, DOE resumed construction and has since spent over $200 million on the facility. However, DOE has not fully addressed the challenges that led to the pause. DOE also has not considered all viable alternatives for addressing the HLW. While DOE analyzed alternatives for HLW treatment in 2023, it only evaluated alternatives that included vitrifying the waste in the HLW Facility. This limited evaluation was inconsistent with DOE requirements for developing such analyses.

In addition, an April 2024 agreement among DOE, the U.S. Environmental Protection Agency (EPA), and the Washington State Department of Ecology proposed sweeping changes to DOE's approach for cleaning up the Hanford Site. The agreement proposes that DOE reconfigure HLW Facility for a direct-feed approach under which DOE would send HLW directly to the HLW Facility and vitrify it. This approach would not rely on the Pretreatment Facility—stalled since 2012 due to technical challenges—originally intended to prepare the waste for treatment. However, the agreement does not specify how DOE would prepare the HLW for treatment in the absence of the Pretreatment Facility or how it would reconfigure the HLW Facility for the direct-feed approach.

Alternative approaches for addressing Hanford's HLW were discussed by a group of experts during meetings convened by GAO and the National Academies of Sciences, Engineering, and Medicine (National Academies) in

early 2024. According to experts, portions of Hanford's HLW could be classified as low-level radioactive waste (LLW) or transuranic (TRU) waste because of the physical characteristics and level of risk posed by the waste. Experts emphasized that waste classified as LLW or TRU waste has existing disposal options and would not require vitrification. In contrast, there is currently no repository for the disposal of high-level radioactive waste. Classifying some portions of the HLW as LLW or TRU waste could allow DOE to treat those portions using methods that are less expensive than vitrification and to dispose of them in existing facilities.

Approaches for Treating Approximately 3 Million Gallons of Highly Radioactive Waste at the Hanford Site



Source: GAO analysis of Department of Energy (DOE) plans and experts' recommendations. | GAO-24-106989

What GAO Recommends

GAO is recommending that Congress clarify DOE's authority to manage portions of Hanford's tank waste as a waste type other than high-level radioactive waste. GAO is also making three recommendations to DOE, including that it pause work on the HLW Facility until it takes several actions, including considering other alternatives for addressing Hanford's HLW.

DOE agreed with two of GAO's recommendations and disagreed with GAO's third recommendation that it pause work on the HLW Facility. DOE stated that pausing activity on the HLW Facility would be in conflict with existing cleanup milestones and proposed changes to those milestones in the April 2024 agreement.

GAO disagrees because the current deadline for DOE to complete the HLW Facility is more than 9 years from the date of this report. Further, the April 2024 proposed agreement indicates that the parties intend to modify this deadline as additional information is developed. GAO's recommended pause in activity on the HLW Facility does not specify a length of time, and GAO emphasizes that such a pause should be undertaken in coordination and negotiation with DOE's regulators. GAO believes sufficient time exists for DOE to complete this coordination and factor in the recommended pause while remaining faithful to its regulatory commitments.

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If DOE could manage portions of the HLW as LLW or TRU waste, it could use simpler treatment technologies, such as drying and packaging the waste or immobilizing it in concrete, according to experts. None of the alternative approaches that experts identified would require the Pretreatment Facility, which DOE estimated would cost an additional $9 billion to complete. Some of the HLW should still be managed as high-level radioactive waste and vitrified accordingly, experts said. However, they suggested that the HLW Facility as currently designed may not be needed and the vitrification capability could be right-sized for a smaller volume of waste. Experts said this could result in potential cost savings from processing less waste and avoiding construction of certain infrastructure, such as cross-site waste transfer lines. The experts also said that using approaches targeted at specific characteristics of the waste would allow DOE to begin waste treatment sooner, resulting in cost savings, reduced schedule, and decreased risks to human health and the environment.

However, DOE faces legal and regulatory uncertainties in implementing alternative approaches, according to experts. For example, experts stressed that DOE needs greater clarity about its legal authority to classify some of the HLW as a waste type other than high-level radioactive waste. DOE has existing processes for doing so, but each process has limitations that prevent DOE from applying it to Hanford's waste or that could leave the agency vulnerable to legal challenges. Congressional action to clarify DOE's authority to classify certain tank waste at Hanford as LLW or TRU waste could help DOE save billions of dollars and complete its waste treatment sooner.

Some of the alternative approaches that experts identified may be compatible with the April 2024 proposed agreement, which anticipates DOE will reconfigure the HLW Facility and does not specify a particular volume of waste that must be treated through the facility. These include alternatives that involve reducing the volume of waste to be treated as high-level radioactive waste and right-sizing the HLW Facility. As DOE prepares to reconfigure the HLW Facility, it has an opportunity to obtain an independent analysis to support an optimal HLW treatment path. By pausing engineering design and construction activities on the HLW Facility until it obtains this analysis, DOE will have greater assurance it has considered all viable alternatives for treating Hanford's HLW and chosen the optimal approach before devoting more taxpayer resources to the facility.

Construction of the High-Level Waste Vitrification Facility at Hanford

2012 2024

Source: Department of Energy. | GAO-24-106989

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Figures

Abbreviations

AOA	Analysis of Alternatives
DNFSB	Defense Nuclear Facilities Safety Board
DOE	Department of Energy
EPA	U.S. Environmental Protection Agency
HLW	high-level waste at Hanford
LAW	low-activity waste at Hanford
LLW	low-level radioactive waste
NRC	Nuclear Regulatory Commission
RCRA	Resource Conservation and Recovery Act of 1976, as amended
TPA	Hanford Federal Facility Agreement and Consent Order, or Tri-Party Agreement
TRU	transuranic
TSCR	Tank Side Cesium Removal
WIPP	Waste Isolation Pilot Plant
WTP	Waste Treatment and Immobilization Plant

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U.S. GOVERNMENT ACCOUNTABILITY OFFICE
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September 26, 2024

Congressional Committees

In April 2024, the Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the Washington State Department of Ecology (Ecology) announced a holistic agreement that proposes a set of sweeping changes to the approach for cleaning up tank waste at the Hanford Site in Washington State.[1] The site, which the federal government used for decades for research and production of weapons-grade nuclear materials, is now home to one of the largest and most expensive environmental cleanup efforts in the world. DOE is tasked with cleaning up approximately 54 million gallons of radioactive and hazardous waste stored in 177 aging underground tanks at the site.[2] Over the last 2 decades, DOE has faced numerous technical challenges related to the design and construction of the facilities intended to accomplish this mission. Between 2020 and 2024, DOE officials participated in confidential mediated negotiations with officials from Ecology and EPA—which regulate aspects of the cleanup at Hanford—over cleanup methods and milestones for the treatment and disposal of Hanford tank waste. Among other things, the holistic agreement announced following those negotiations proposes a reconfiguration of DOE's approach to addressing the most highly radioactive portions of Hanford's tank waste, which is referred to in this report as high-level waste, or HLW.

Before treating Hanford's tank waste, DOE plans to separate it into two streams: (1) the highly radioactive HLW stream and (2) the less radioactive low-activity waste, or LAW, stream. According to the holistic agreement, DOE plans to pursue a "direct-feed" approach for moving the HLW from the underground tanks to a yet-to-be completed facility that will mix the waste with molten glass and pour it into stainless steel canisters (a process called vitrification) to await permanent disposal. This new approach differs significantly from DOE's prior plan that relied on a complex Pretreatment Facility to prepare and feed the waste to the HLW Facility for vitrification.[3] The proposed agreement calls for the HLW Facility to be "reconfigured" to support the direct-feed approach and states that the parties intend to continue negotiations regarding the future configuration, construction, and schedule for the HLW Facility.

According to DOE officials and DOE's 2023 River Protection Project System Plan—which describes the baseline plan for completion of the tank waste cleanup mission—the agency estimates that about 3 million gallons (approximately 5 percent) of the total waste currently in the tanks is HLW that DOE assumes for

[1]As explained in greater detail below, the holistic agreement comprises three parts—a new settlement agreement and proposed changes to two existing agreements that govern cleanup activities at Hanford. Those proposed changes are subject to public comment, possible revisions, and (for one of the agreements) court approval. At the time of publication of this report, that public comment and approval process was not complete, so references to the holistic agreement herein refer to the version that includes proposed changes announced on April 29, 2024, and thus do not necessarily reflect the final form of the agreement. Nonetheless, we believe the April 29, 2024 version of the holistic agreement is—as of the time of our publication—the best indication of DOE's path forward at Hanford.

[2]According to DOE's Tank Waste Monthly summary, which provides the status of the 177 tanks, waste from 21 tanks has been retrieved as of May 2024, and retrieval of waste from one other tank, AX-101, is in progress. DOE plans to "landfill close" these tanks, which in part involves leaving the tanks in place and filling them with grout. Ecology and EPA have not yet agreed to this plan.

[3]DOE stopped construction on both the Pretreatment Facility and HLW Facility in 2012 as a result of technical challenges.

planning purposes will ultimately be classified and managed as high-level radioactive waste.[4] In 2022, DOE estimated that designing and constructing the facilities to treat this waste will cost about $20 billion.[5] These facilities for the HLW mission are part of a larger construction project known as the Waste Treatment and Immobilization Plant or WTP, which has been under construction since 2000 and consists of multiple facilities.

Senate Report 118-58 includes a provision for us to assess DOE's plans for minimizing the fraction of waste at Hanford that will be treated as high-level radioactive waste. This report examines (1) the status of DOE's current approach to addressing the HLW, including any barriers to its approach; (2) alternative approaches that could minimize the fraction of waste that would need to be treated as high-level radioactive waste and the extent to which these approaches would affect DOE's current cost and schedule estimates; and (3) steps DOE could take to pursue alternative approaches.

To address these objectives, we reviewed DOE documents on waste treatment options and data on the composition of Hanford's tank waste, and we interviewed DOE and EPA officials to better understand DOE's plans for treating the HLW. We also interviewed officials from Ecology in August 2023. Thereafter, Ecology officials declined our requests for interviews regarding this report. When we refer to DOE's current plan for treating the waste, we are referring to the baseline case presented in DOE's 2023 River Protection Project System Plan.[6] The holistic agreement among DOE, EPA, and Ecology announced in April 2024 is expected to result in changes to the baseline plan, which we acknowledge to the extent possible throughout the report. We also reviewed DOE's past efforts to analyze options for treating the HLW, including its January 2023 HLW Analysis of Alternatives (AOA) and its Research and Development Roadmap for Hanford Tank Waste Mission Acceleration.[7] We examined whether its past efforts to analyze alternatives were consistent with DOE project management Order 413.3B and have previously reviewed whether DOE's 2023 AOA was consistent with our best practices for conducting an AOA and making risk-informed decisions.[8]

To identify alternative approaches to DOE's current plan for addressing the HLW and potential steps DOE could take to pursue them, we worked with the National Academies of Sciences, Engineering, and Medicine (National Academies) to identify experts on nuclear waste cleanup from a variety of disciplines. With the

[4]Department of Energy, *River Protection Project System Plan*, ORP-11242 Rev. 10 (Richland, WA: Dec. 2023). As discussed further below, "high-level radioactive waste" is defined by federal law and subject to specific treatment requirements. DOE is currently, as a matter of policy, managing all of Hanford's tank waste, including the LAW and HLW, as if it is "high-level radioactive waste" unless the waste has been formally classified as another waste type. According to DOE officials, DOE generally does not formally classify its waste until it is retrieved from the tanks and pretreated, to inform treatment and disposition decisions. However, DOE has already determined that certain Hanford tank waste—including approximately 23.5 million gallons of separated, pretreated, and vitrified LAW—will, in the future, be classified and managed as low-level, rather than high-level, radioactive waste. The 3 million gallons above represents the portion that DOE assumes will continue to be managed as high-level radioactive waste in the future.

[5]The $20 billion estimate represents DOE's escalated lifecycle cost estimate. See Department of Energy, *2022 Hanford Lifecycle Scope, Schedule and Cost Report*, DOE/RL-2021-47 (Richland, WA: Jan. 2022).

[6]ORP-11242 Rev. 10.

[7]Department of Energy, *Final Report: Waste Treatment and Immobilization Plant, High-Level Waste Treatment Analysis of Alternatives* (Washington, D.C.: January 2023); and Network of National Laboratories for Environmental Management and Stewardship, *R&D Roadmap for Hanford Tank Waste Mission Acceleration*, NNLEMS-2022-00005 (Oct. 19, 2022).

[8]Department of Energy, *Program and Project Management for the Acquisition of Capital Assets*, DOE Order 413.3B (Change 7) (LtdChg) (Washington, D.C.: June 21, 2023); 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); and 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).

assistance of the National Academies, we convened two experts' meetings virtually and in-person over 4 days in January and February 2024 to discuss alternative approaches to addressing Hanford's HLW. To summarize alternative approaches identified by the experts that could minimize the amount of waste to be treated as high-level radioactive waste and reduce cost and schedule estimates, we analyzed statements from the transcripts of these meetings to identify common themes. We also reviewed DOE data and documentation to corroborate key themes raised by experts and spoke with DOE officials. During the meetings, we also asked experts to discuss potential solutions related to the alternative approaches and subsequently summarized these statements into key themes. A more detailed description of our scope and methodology is included in appendix I.

We conducted this performance audit from July 2023 through September 2024 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.

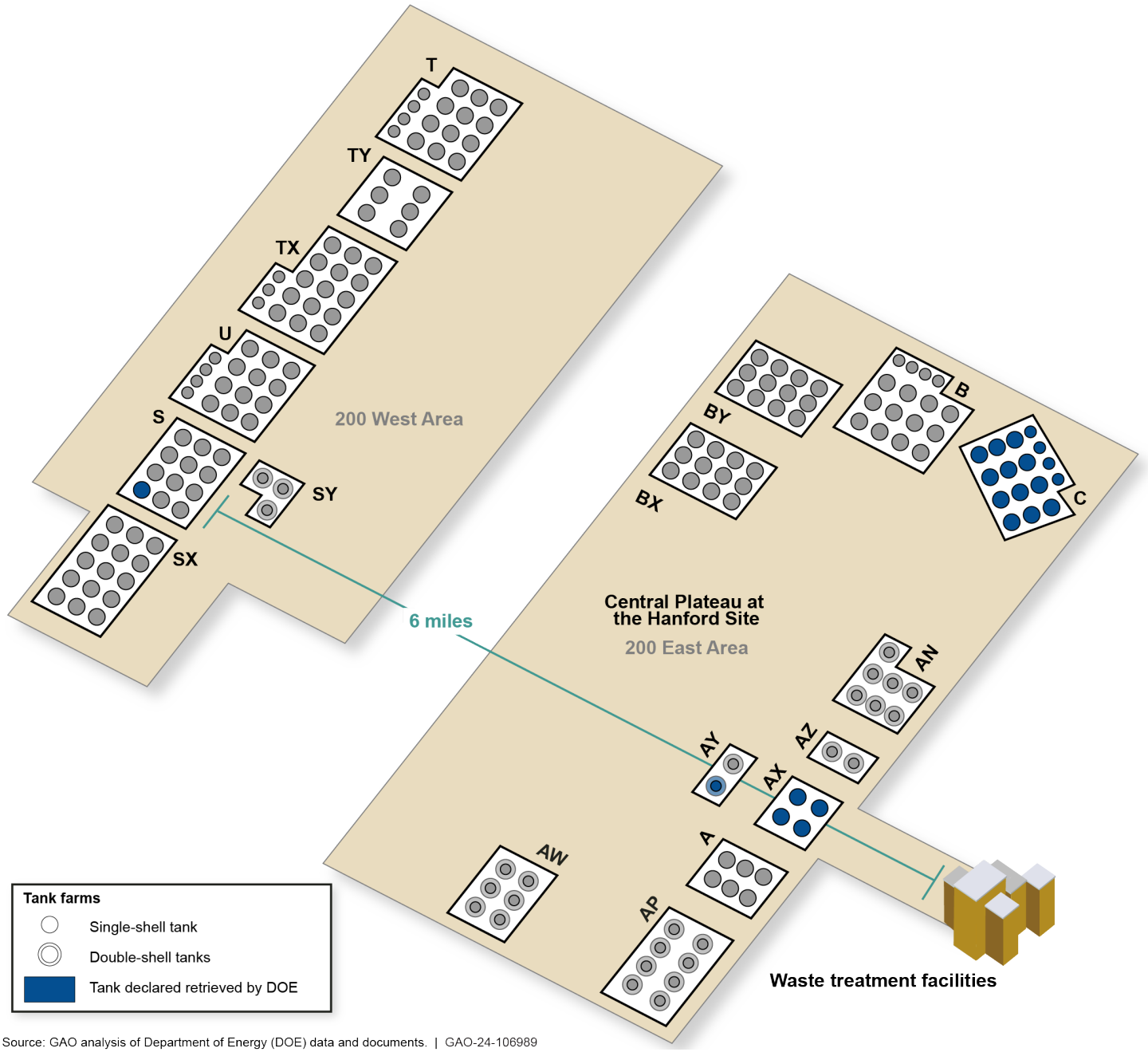
Background

High-Level Waste at the Hanford Site

The nuclear waste at the 586-square-mile Hanford Site is a result of decades of research and production of weapons-grade nuclear materials that began during the Manhattan Project and ceased in the 1980s. Within the site, Hanford's 177 underground waste tanks are clustered in 18 groupings, referred to as "tank farms," with each containing between two and 18 tanks.[9] The tank farms are divided between the "200 West" and "200 East" areas of the Hanford Site, which are about 6 miles apart. The 200 East area consists of seven tank farms (35 tanks) located in the southeast region, which is closest to the WTP, and four tank farms (56 tanks) located in the northeast region of the area. The 200 West area consists of four tank farms (46 tanks) located in the southwest and three tank farms (40 tanks) located in the northwest regions of the area. Figure 1 shows the number and location of the tanks and tank farms at Hanford.

[9]Of the 177 tanks, 149 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: Number and Location of the Tanks and Tank Farms at Hanford



Source: GAO analysis of Department of Energy (DOE) data and documents. | GAO-24-106989

Note: Of the 177 tanks, 149 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.

The waste stored in the tanks generally sits in layers and comes in three forms, depending on its physical and chemical properties.

- **Sludge.** The denser, water-insoluble components of the waste generally settle to the bottom of the tank to form a thick layer known as sludge, which has the consistency of peanut butter. Although the sludge makes up the smallest portion of waste in the tanks, it constitutes over half of the radioactivity.[10]
- **Saltcake.** Water-soluble components, such as sodium salts, sit above the sludge. These components crystalize or solidify out of the waste solution to form a moist sand-like material called saltcake.
- **Supernate.** Liquids composed of water and dissolved salts may sit above or between the denser layers; these liquids are called supernate.

According to DOE officials, as a matter of agency policy, DOE currently manages all Hanford tank waste as if it is "high-level radioactive waste" unless the waste has been formally classified as another waste type, such as low-level radioactive waste. "High-level radioactive waste" is defined by federal law and subject to specific legal requirements.[11] For example, under EPA regulations also adopted by the State of Washington, radioactive high-level wastes must be vitrified prior to land disposal.[12] DOE presently handles Hanford tank waste as if it meets the statutory definition of "high-level radioactive waste;" however, at Hanford, the term "high-level waste" is often used to refer only to the high-activity portion of the tank waste; and "low-activity waste" is used to refer to the rest of the tank waste (see textbox).[13]

Hanford Waste Terminology

Radioactive defense waste at Hanford is often referred to using specific terminology. However, that terminology does not always match or clearly track definitions of different categories of radioactive waste established by federal laws. Below, we include some of the relevant statutory definitions and explain key Department of Energy (DOE) terminology.

Legal Definitions

- Low-level radioactive waste is defined by the Low-Level Radioactive Waste Policy Amendments Act of 1985 as "radioactive material that (A) is not high-level radioactive waste, spent nuclear fuel, or byproduct material as defined in [42 U.S.C. § 2014(e)(2)]; and (B) the Nuclear Regulatory Commission, consistent with existing law and in accordance with paragraph (A), classifies as low-level radioactive waste." The term does not include byproduct material as defined in 42 U.S.C. § 2014(e)(3) and (4).[a]
- Transuranic waste is defined in the Waste Isolation Pilot Plant Land Withdrawal Act as "waste containing more than 100 nanocuries of alpha-emitting transuranic isotopes per gram of waste, with half-lives greater than 20 years, except for – (A) high-level radioactive waste; (B) waste that the Secretary [of Energy] has determined, with the concurrence of the Administrator [of the Environmental Protection Agency], does not need the degree of isolation required by the disposal regulations; or (C) waste that the Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with [10 C.F.R. Part 61]."[b]

[10]Much of the radioactive material in the tank waste will decay relatively quickly over time. 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.

[11]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, 42 U.S.C. § 2014(ee).

[12]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. 40 C.F.R §§ 268.40, 268.42(a); Wash. Admin. Code 173-303-140(2)(a).

[13]DOE's current plan is to vitrify some of the LAW through the Direct-Feed Low-Activity Waste program, which is discussed further below. DOE is continuing to evaluate and test alternative treatment pathways for some of the remaining LAW, including building a second vitrification facility or grouting the waste.

- High-level radioactive waste is defined in the Nuclear Waste Policy Act of 1982 as "(A) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in the 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."[c]

DOE Waste Terminology at Hanford

As a matter of policy, DOE currently manages all Hanford tank waste as if it is high-level radioactive waste until the waste is formally classified. However, for modeling, planning, and other purposes, the waste at Hanford has been generally separated into the following categories.

- Low-activity waste (LAW) is the term used at Hanford for the primarily liquid portion of the tank waste, including dissolved saltcake, that contains low levels of long-lived radionuclides. According to DOE officials, LAW represents the tank waste that has been pretreated with a treatment path to be ultimately managed as low-level radioactive waste.
- High-activity or high-level waste (HLW) is the term used at Hanford for the approximately 5 percent of the tank waste that DOE considers to have high radioactivity, including waste captured in the columns of the Tank Side Cesium Removal system.

Source: GAO analysis of laws and DOE documents and interviews with DOE officials. | GAO-24-106989.

[a]Pub. L. No. 99-240, § 102, 99 Stat 1842 (1986) (codified as amended at 42 U.S.C. § 2021b(9)). Low-level radioactive waste is also defined in the Nuclear Waste Policy Act of 1982 as radioactive material that "(A) is not high-level radioactive waste, spent nuclear fuel, transuranic waste, or by-product material as defined in [42 U.S.C. § 2014(e)(2)]; and (B) the [Nuclear Regulatory] Commission, consistent with existing law, classifies as low-level radioactive waste." Pub. L. No. 97-425, § 2(16), 96 Stat 2201 (1983) (codified at 42 U.S.C. § 10101(16)).

[b]Pub. L. No. 102–579, § 2(20), 106 Stat. 4777 (1992). Transuranic waste is also defined in the Atomic Energy Act of 1954, as amended, as "material contaminated with elements that have an atomic number greater than 92, including neptunium, plutonium, americium, and curium, and that are in concentrations greater than 10 nanocuries per gram, or in such other concentrations as the Nuclear Regulatory Commission may prescribe to protect the public health and safety." 42 U.S.C. § 2014(jj).

[c]Pub. L. No. 97-425, § 2(12), 96 Stat. 2201 (1983) (codified at 42 U.S.C. § 10101(12)). This definition is also cross-referenced in the Atomic Energy Act of 1954, as amended, 42 U.S.C. § 2014(ee), and the Waste Isolation Pilot Plant Land Withdrawal Act, Pub. L. No. 102–579, § 2(10), 106 Stat. 4777 (1992).

For the purposes of this report, when we refer to "HLW," we are referring to specific Hanford waste that DOE does not plan to treat as LAW, which includes the approximately 3 million gallons of tank waste that DOE considers to have high radioactivity (mostly concentrated in the sludge).

Specifically, our definition of HLW for this report includes the following HLW at Hanford:

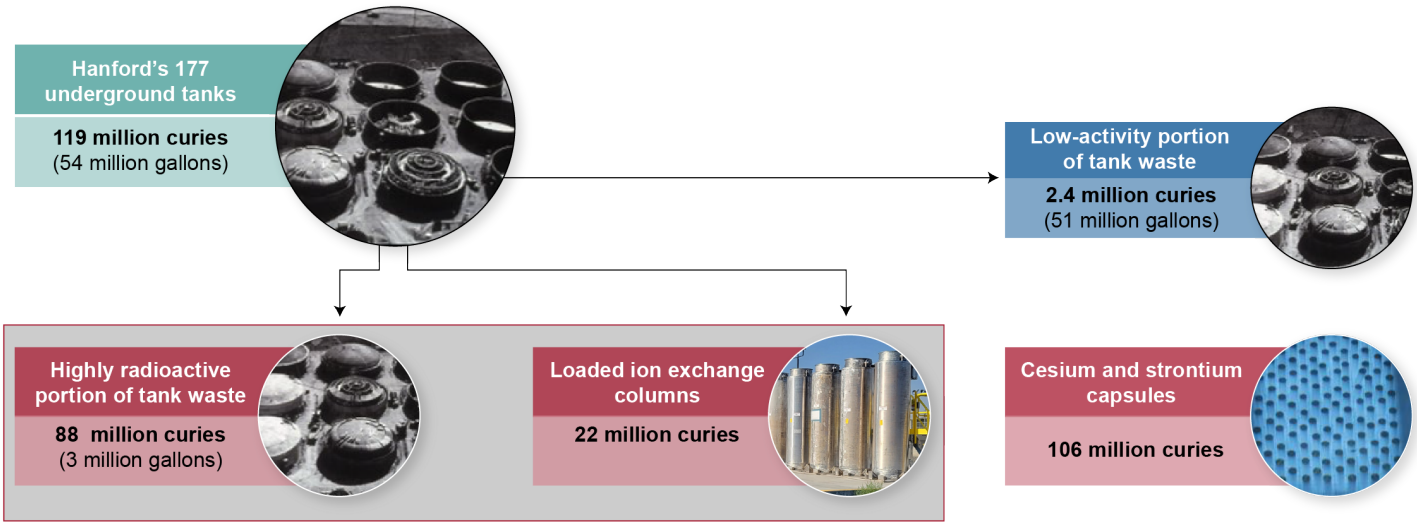
- **High-level tank waste.** About 3 million gallons or approximately 5 percent of the total volume of tank waste containing approximately 88 million curies or more than 70 percent of the total radioactivity.
- **Loaded ion exchange columns.** As we reported in 2023, DOE has been pursuing an approach for the LAW that directly feeds the waste to the LAW Facility—another WTP facility—for vitrification after it is pretreated.[14] To accomplish this direct-feed low-activity waste pretreatment, DOE designed the Tank-Side Cesium Removal (TSCR) system to filter out highly radioactive solids, including cesium-137 and strontium-90, from liquid tank waste. These solids, which DOE estimates will account for about 22 million curies of radioactivity, are being stored in loaded ion exchange columns. DOE plans to generate an estimated 451 ion exchange columns containing separated waste. DOE currently stores the columns at the TSCR storage pad, but the baseline plan assumes that DOE will eventually vitrify these columns in the HLW Facility. However, according to DOE officials, DOE has not yet conducted an AOA for the eventual treatment and disposal of the waste resulting from the TSCR system.

In addition to these wastes, cesium and strontium capsules stored at Hanford also contain highly radioactive waste that originated in Hanford's tanks. During the 1970s and 1980s, DOE removed some cesium and strontium from waste tanks at Hanford to reduce the temperature of the waste inside the tanks. Some cesium

[14]GAO, *Hanford Cleanup: DOE Should Consider Including Expedited Nuclear Waste Treatment Alternatives in Upcoming Analysis*, GAO-23-106151 (Washington, D.C.: July 26, 2023).

and strontium were separated from other radioactive tank waste, converted to cesium chloride and strontium fluoride, then encapsulated for long-term storage. There are 1,335 cesium and 601 strontium capsules stored under water in a pool at the Waste Encapsulation Storage Facility.[15] As of 2024, these concentrated capsules of cesium and strontium contain about 106 million curies of radioactivity. We do not include the capsules in our definition of Hanford HLW for the purposes of this report because DOE has not determined a final treatment and disposition path for these capsules, and therefore it is unclear if they will ultimately be treated as HLW or another waste type. Nonetheless, we include insights below on options for addressing these capsules offered by experts who participated in our experts' meetings. Figure 2 depicts the highly radioactive waste at Hanford, including the waste referred to in this report as HLW.

Figure 2: The Highly Radioactive Waste at the Hanford Site



Source: Department of Energy (DOE) documents and officials; DOE (photos). | GAO-24-106989

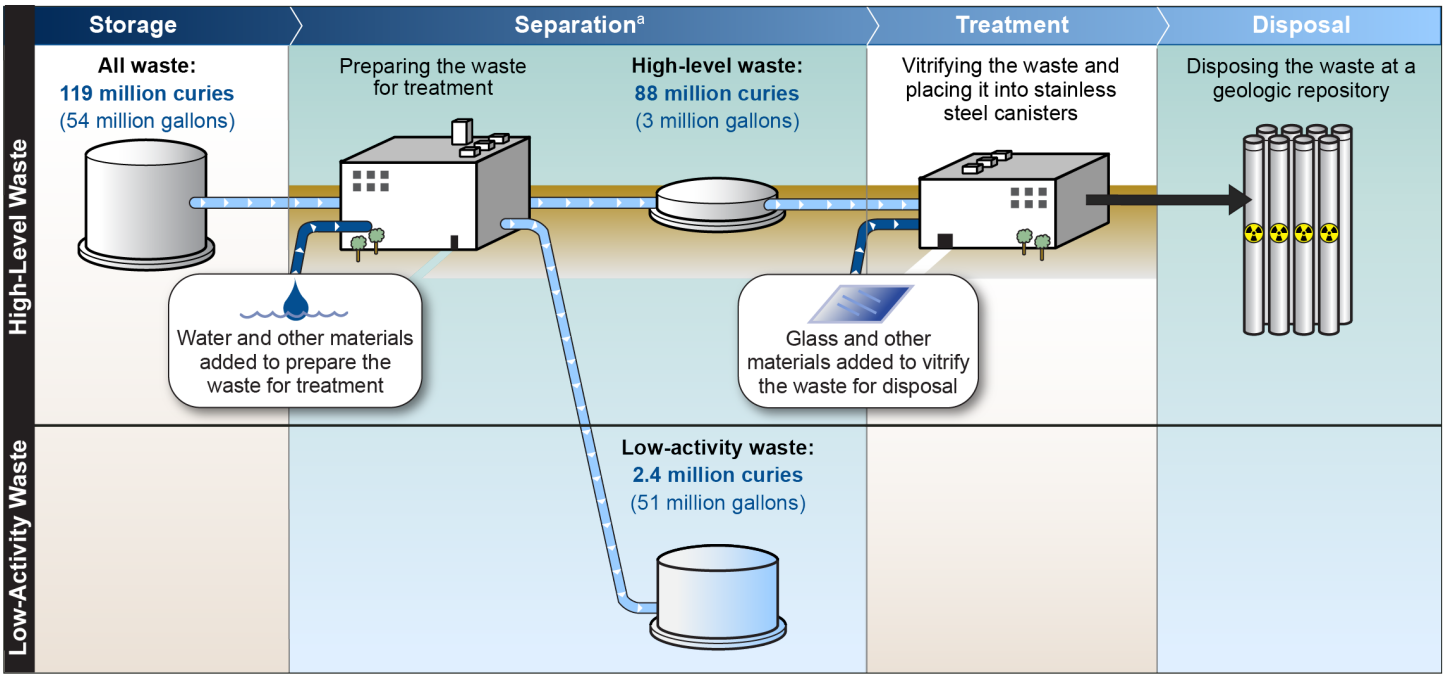
Note: According to DOE officials, as a matter of policy, DOE manages all Hanford tank waste as if it is "high-level radioactive waste" as defined by federal law unless, and until, the waste is formally classified as another waste type. The radioactivity and volume amounts reported here come from DOE's River Protection Project System Plan (2023) and other DOE documents. DOE estimates that approximately 6.5 million curies will remain in the tanks after retrieval. Figures differ slightly from the amounts reported in appendix II (which draws on DOE's Best Basis Inventory data). The curie estimates included in this figure are estimates and may change depending on different waste retrieval scenarios.

DOE's High-Level Tank Waste Cleanup Approach

As of July 2024, DOE's baseline plan for treating high-level tank waste under the WTP project consists of constructing a large processing system of major facilities that are planned to vitrify—or immobilize the waste into glass logs for long-term storage—the HLW stream (see fig. 3).

[15]The Waste Encapsulation and Storage Facility has long surpassed its useful life. The degradation of the facility has increased the risk that a beyond design basis natural event (for example, an earthquake) could cause the walls to fail, resulting in loss of the water that shields the capsules. Due to this concern and the realization that the capsules would likely need to stay in the facility for a period longer than the facility's design life, DOE concluded that interim dry storage of the capsules in a new facility would significantly reduce the potential risk of onsite radiological exposures and airborne releases from a failure of the facility. In 2018, DOE announced a decision to move the capsules from wet storage at the Waste Encapsulation and Storage Facility to a new dry storage facility. DOE has constructed a new dry storage facility and plans to start transferring the capsules to this facility in 2025.

Figure 3: The Department of Energy's Current Baseline Plan for Treating High-Level Waste from the Tanks at the Hanford Site



Source: GAO analysis of Department of Energy documents; GAO (icons). | GAO-24-106989

Note: For the purposes of this report, we define high-level waste as specific Hanford waste that DOE does not plan to treat as low-activity waste, which includes approximately 3 million gallons of tank waste that DOE considers to have high radioactivity. According to DOE officials, as a matter of policy, DOE currently manages all Hanford tank waste as if it is "high-level radioactive waste" as defined by federal law unless, and until, the waste is formally classified as another waste type.

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

Two key facilities—the Pretreatment Facility and the High-Level Waste Facility—are planned to address the highly radioactive portion of the tank waste:

- **Pretreatment Facility:** This facility was originally intended to receive waste from the tanks and separate it into HLW and LAW. Under the current WTP design, all waste would have first passed through this facility before it could be treated. DOE paused construction of this facility in 2012, due to technical issues, and construction had not resumed as of July 2024.[16] Construction of this facility as originally designed is about 40 percent complete. To continue making progress on treating some of the LAW portion of the tank waste in the absence of a completed Pretreatment Facility, DOE elected to deploy a set of alternative technologies and facilities known as Direct-Feed Low-Activity Waste. This approach uses TSCR to pretreat the waste by removing much of the highly radioactive constituents in the waste before feeding the pretreated waste directly to the LAW Facility for vitrification.[17] As part of the holistic agreement, DOE and Ecology have proposed a similar "direct-feed" approach for the HLW portion of the waste, which would bypass the Pretreatment Facility. The holistic agreement proposes keeping the cleanup milestones

[16]GAO-20-363.

[17]DOE's current plan is to vitrify about 60 percent of the LAW through the Direct-Feed Low-Activity Waste program. DOE has not decided on a treatment method for the remaining LAW (which is referred to as "supplemental LAW") but has evaluated building another vitrification facility or grouting the waste.

associated with the Pretreatment Facility. The agreement notes that DOE and Ecology anticipate further modifying these milestones as information is developed and decisions are made regarding new milestones, including those related to pursuing a direct-feed approach for feeding HLW to the HLW Facility. The agreement also proposes a deadline by which DOE will select additional pretreatment capabilities after the HLW Facility is operational. According to DOE officials, in keeping with the holistic agreement, DOE has no plans to restart construction of the Pretreatment Facility. Instead, DOE plans to keep the facility in standby until at least 2029, when, under the proposed agreement, DOE would be required to select additional pretreatment capabilities.

- **HLW Facility:** This facility is designed to receive the HLW and immobilize it through vitrification. DOE estimates it will produce 10,300 cannisters of immobilized HLW through this facility, with storage on-site until a deep geologic repository is established for disposal. DOE also slowed construction of this facility in 2012 when it was about 40 percent complete due to technical issues. DOE restarted design and construction of the HLW Facility in 2022.
- **Other infrastructure and facilities:** In addition to the key waste processing facilities discussed above, transfer systems will be required to move waste retrieved from tanks located miles across the site to the WTP for processing. Some cross-site piping has already been built, but its condition will need evaluation prior to operating, while other planned cross-site piping is not yet built. The WTP also has a variety of auxiliary facilities, such as an analytical laboratory to ensure that the glass produced by the WTP meets all regulatory requirements and standards.

Legal and Regulatory Framework Governing Hanford's Tank Waste

Hanford's tank waste is "mixed waste" that contains both radioactive and hazardous components.[18] The treatment and disposal of this waste is governed by many federal and state laws and regulations, DOE Orders, and cleanup agreements. The list below includes those of particular relevance to DOE's plans for addressing Hanford's HLW:

- **Atomic Energy Act of 1954, as amended.** The Atomic Energy Act authorizes DOE to regulate the radioactive component of mixed waste.
- **Resource Conservation and Recovery Act of 1976, as amended (RCRA).** RCRA governs the treatment, storage, and disposal of the hazardous component of this mixed waste. EPA has authorized the State of Washington, through the state's Department of Ecology, 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 some of Hanford's tank waste—must meet the treatment standard of vitrification prior to disposal.[19]
- **Nuclear Waste Policy Act of 1982, as amended.** The Nuclear Waste Policy Act establishes procedures for the evaluation, selection, and approval of deep geologic repositories for the disposal of spent nuclear fuel and high-level radioactive waste. It also provides the definition of high-level radioactive waste.

[18]The term "mixed waste" means waste that contains both (1) hazardous waste subject to the Resource Conservation and Recovery Act of 1976, as amended (RCRA) or authorized state programs that operate in lieu of the RCRA; and (2) radioactive source, special nuclear, or byproduct material subject to the Atomic Energy Act of 1954.

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

- **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 purpose of the TPA includes 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 CERCLA or Superfund); RCRA; and the Washington Hazardous Waste Management Act. The TPA requires DOE to complete pretreatment processing and vitrification of Hanford HLW and LAW tank wastes by 2047.[20]
- **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 substantially complete construction of the HLW Facility by 2030 and complete hot commissioning of the facility by 2033.[21]
- **April 2024 Holistic Agreement.** Following years of negotiations, DOE, EPA, and Ecology announced this agreement in April 2024. The agreement includes three parts: (1) proposed amendments to the Consent Decree; (2) proposed changes to the TPA; and (3) a settlement agreement among DOE, EPA, and Ecology that addresses other aspects of the approach at Hanford. The proposed changes to the Consent Decree and the TPA are subject to public comment, possible revision, and—with respect to the Consent Decree—court approval before the changes become final and effective. The proposed amendments to the Consent Decree include new milestones for reconfiguring the WTP for the direct-feed of waste to the HLW Facility and for selecting additional capabilities for pretreating some of the waste after the startup of direct-feed HLW.
- **DOE Order 435.1 and Manual 435.1-1.** This order and manual set forth procedures for the management of DOE's radioactive wastes in a manner that is protective of worker and public health and safety, as well as the environment.[22] Under the manual, DOE has two processes for determining that waste resulting from the reprocessing of spent nuclear fuel can be managed as something other than high-level radioactive waste.
- **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.[23] For capital asset projects with a total project cost greater than $50 million, Order 413.3B requires DOE to establish a statement of mission need before selecting a preferred path forward and designing and constructing new facilities. This mission need statement is a description of the mission as defined by a desired end-point, not a contract statement of work.[24] In addition, for projects with a total

[20]In the holistic agreement, the parties have acknowledged that this milestone must be revised and proposed that a new date be established within eighteen months of the startup of the HLW Facility.

[21]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. In the holistic agreement, DOE and Ecology have proposed keeping these milestones for the time being while noting that they anticipate further modifying the Consent Decree in the future as information is developed and decisions are made pursuant to newly proposed milestones.

[22]Department of Energy, *Radioactive Waste Management*, Order 435.1, Chg 2(AdminChg) (Washington, D.C.: Jan. 11, 2021); and Department of Energy, *Radioactive Waste Management Manual*, Manual 435.1-1, Chg 3(LtdChg) (Washington, D.C.: Jan. 11, 2021).

[23]DOE Order 413.3B (Change 7).

[24]Department of Energy, *Mission Need Statement Guide*, DOE Guide 413.3-17 (Change 1) (Washington, D.C.: Oct. 22, 2015).

project cost greater than $50 million, the order requires DOE to conduct an AOA that is consistent with our published best practices.[25]

Uncertainties and Unresolved Issues with the HLW Facility Persist While Spending Has Resumed

Since 2022, DOE has spent over $200 million on design and construction of the HLW Facility. However, technical challenges with the HLW Facility that led DOE to pause its construction beginning in 2012 remain unresolved. DOE's steps to address these challenges and develop a strategy for managing the HLW have neither fully complied with DOE orders and guides, nor addressed all recommendations we and others have made to DOE related to resuming the project.

DOE Is Moving Forward with HLW Treatment in the HLW Facility Despite Uncertainties

In 2022, DOE began ramping up design and construction activities on the HLW Facility despite uncertainties about various issues, as well as unaddressed deficiencies in its analysis of potential treatment alternatives. Since 2022, Congress has appropriated more than $1 billion for the HLW Facility, of which DOE has spent over $200 million. DOE has used this funding to restore installed equipment, evaluate the facility's structure, and prepare systems for construction. In its fiscal year 2025 budget request, DOE requested $608 billion for "long-term construction planning" and "low-risk construction" on the HLW Facility. According to DOE officials, these activities include pouring concrete and constructing waste-receiving vessels.

However, significant uncertainties remain with the design and mission of the HLW Facility. These uncertainties include unaddressed technical issues, the physical characteristics and amount of the waste that will ultimately be processed, and the extent to which the waste will be pretreated prior to processing.

Technical Issues

DOE has not fully addressed all technical issues that led to the 2012 pause in construction of the HLW Facility. These issues, which we reported on in December 2012, included concerns that the buildup of flammable gas in excess of safety limits could cause significant safety and operational problems.[26] Another concern included ensuring that the waste is properly mixed in the Pretreatment Facility to prevent the buildup of flammable hydrogen and fissile material that could inadvertently result in a nuclear accident. In May 2015, we recommended DOE consider limiting construction activities on the Pretreatment and HLW Facilities until it addressed these technical challenges.[27]

Although DOE has made progress in resolving long-standing technical issues that contributed to the pause in construction, several issues remain unresolved, according to an April 2022 review by the Defense Nuclear

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

[26]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).

[27]GAO-15-354.

Facilities Safety Board (DNFSB).[28] For example, the DNFSB found that DOE's strategy to prevent the buildup of flammable gas needed further refinement and that DOE's plans to ensure that the waste is properly mixed in the HLW Facility, including during the loss of mechanical mixing, needed further analysis. DOE officials said that they believe the issues have been resolved but not yet fully incorporated into the facility's design.

The reconfiguration of the facility proposed by the holistic agreement also contributes to uncertainties about DOE's resolution of these technical issues. DNFSB officials told us in April 2024 that they were aware DOE would likely make changes to the HLW Facility's design as a result of the proposed plan to bypass the Pretreatment Facility and pursue a direct-feed approach instead. The officials said these changes likely would result in modifications not only to the facility, but also to the assumptions about the amount and type of waste that the facility will treat. Until DOE reconfigures the facility to incorporate these changes, DNFSB officials said they cannot fully assess whether DOE has resolved these technical issues. Similarly, a recent DOE review of the status of the HLW Facility's design found that because of the changes related to this new direct-feed approach, there is a risk of rework if the contractor does not first review how these changes may impact the overall project.[29]

Characteristics and Amount of Waste

Uncertainties remain about the physical characteristics and amount of the waste that will eventually be treated in the HLW Facility. First, the holistic agreement proposes a reconfiguration of the WTP for the direct feed of waste to the HLW Facility, which means the waste would not be processed through the Pretreatment Facility. However, because the facilities and technologies that would be deployed to achieve a direct-feed approach remain undecided, DOE has not selected an alternative pretreatment approach necessary to separate and remove certain constituents from the waste before it can be vitrified. Therefore, the characteristics and amount of waste is not yet known. Second, DOE is still in the process of establishing the waste acceptance criteria for the HLW Facility.[30] As a result, the physical characteristics of the waste that will need to be achieved (by pretreatment or other means) before DOE can process the waste in the HLW Facility are uncertain.

Pretreatment of Waste

DOE is currently deploying pretreatment activities for the LAW portion of waste that will affect the radioactivity of the remaining HLW. Specifically, DOE is scaling up its TSCR technology to remove millions of curies of highly radioactive cesium and strontium from the tank waste before sending it to the LAW Facility for treatment. This highly radioactive material is being stored in steel columns on site.[31] Because of the removal of cesium and strontium from the tank waste for treatment in the LAW Facility, the radioactivity of the remaining waste in the tank—the portion that DOE intends to process in the HLW Facility—will likely be much lower than the current design assumes, according to experts we interviewed. According to some of the experts who

[28]Defense Nuclear Facilities Safety Board (DNFSB), "Staff Report" (Washington, D.C., July 19, 2022). Established in 1988, DNFSB provides independent analysis, advice, and recommendations to the Secretary of Energy—in the Secretary's role as operator and regulator of DOE's defense nuclear facilities—to ensure adequate protection of public health and safety at these facilities.

[29]Department of Energy, *Baseline Design Review Report for the High-Level Waste Facility* (Richland, WA: April 2024).

[30]Waste acceptance criteria are the technical and administrative requirements that a waste must meet to be accepted at a storage, treatment, or disposal facility.

[31]DOE currently plans to eventually vitrify this cesium and strontium in the HLW Facility.

participated in our meetings convened by the National Academies, these pretreatment activities will "significantly lower" the radioactivity of the HLW in the tanks before it is fed into the HLW Facility.

DOE Did Not Comply with Its Project Management Requirements or Best Practices When Considering Changes to the HLW Mission

DOE's efforts to respond to challenges facing the HLW Facility and to analyze approaches for addressing Hanford's HLW have not always complied with DOE requirements or best practices. Specifically, DOE's efforts have not fully complied with the requirements of DOE Order 413.3B, which governs program and project management for the acquisition of capital assets. This order requires DOE to take a number of steps for all capital asset projects estimated to cost more than $50 million.[32] DOE has not fully followed some of these requirements when planning how to address Hanford's HLW. For example:

- **Define the mission need.** For capital asset projects estimated to cost more than $50 million, DOE Order 413.3B includes a requirement for DOE to establish a mission need. It specifies that the mission need should be independent of a specific solution and should not be defined by a particular facility, equipment, technological solution, or physical end item. According to the guidance that accompanies DOE Order 413.3B, DOE is not to allow the mission need to be defined in solution-specific terms, as it creates a potential bias that could exclude viable alternatives and invalidate the analysis.[33]

  In 2015, we reported that because of ongoing problems hampering progress with the WTP, DOE was pursuing alternatives (e.g., feeding waste from the tanks directly to the vitrification facilities) but had not properly defined the mission need or developed a reliable life-cycle cost estimate for the alternatives being analyzed.[34] In 2020, as DOE began an analysis of HLW alternatives, we again found that DOE had not developed a statement of mission need, which is critical to determine on what basis decision-makers will consider and assess alternatives. We recommended that DOE ensure that its AOA include an appropriately defined mission need.[35]

  DOE added a mission need statement to a later version of its AOA. However, this statement and the AOA made assumptions about the need for the already-planned HLW Facility and the technology (vitrification) that would be used to treat the waste.[36] As a result, the AOA used screening criteria to eliminate certain alternatives from consideration, including a criterion that tank waste classified as high-level radioactive waste be immobilized by vitrification. According to the AOA, this criterion was based on the EPA

[32]DOE Order 413.3B (Change 7). In addition to the requirements in this order, in July 2024, we noted that by not providing additional proactive oversight for projects recognized to be particularly complex or high-risk—such as the WTP—DOE may be missing opportunities to prevent cost and scheduling issues. We recommended that DOE develop a process to determine if capital asset projects that meet certain criteria—such as those that are particularly high risk or complex—need additional proactive federal oversight from the beginning of the project's lifecycle. DOE concurred with this recommendation. See GAO, *Nuclear Waste Cleanup: More Effective Oversight Is Needed to Help Ensure Better Project Outcomes*, GAO-24-106716 (Washington, D.C.: July 31, 2024).

[33]DOE Guide 413.3-17 (Change 1).

[34]GAO-15-354.

[35]GAO-20-363.

[36]Specifically, the mission need statement for DOE's HLW AOA was "… to immobilize pretreated waste in borosilicate glass, cast the glass into stainless steel canisters, and store the canisters at Hanford until they are shipped to a Federal geologic repository." Department of Energy, *Final Report: Waste Treatment and Immobilization Plant High-Level Waste Treatment Analysis of Alternatives* (Richland, WA: Jan. 12, 2023).

regulations that specify that mixed radioactive high-level wastes generated during the reprocessing of fuel rods must be vitrified.[37] As a result, DOE did not evaluate potential approaches other than vitrification for treating the HLW. DOE initially included 17 alternatives in its AOA but eliminated 10 of them for various reasons; one because it would not have vitrified the waste.

- **Obtain an independent review of the alternatives analysis.** DOE Order 413.3B requires DOE to conduct an AOA for projects estimated to cost more than $50 million and requires the completed AOA be consistent with published GAO best practices. Best practices for an AOA call for an independent review of an AOA to validate the process before selecting a preferred alternative.[38] In May 2023, we found DOE had 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.[39] We recommended that DOE obtain an independent review to validate the process it used for its HLW AOA. As of July 2024, DOE had not implemented this recommendation.

Because it narrowly defined the mission need statement for HLW treatment and did not obtain an independent review of the HLW AOA, DOE does not have assurance that it analyzed an appropriately diverse range of potentially viable alternatives as part of its HLW AOA process.

Similarly, we have reported in the past that applying a risk-informed decision-making framework to its decision processes could help DOE implement consistent decision-making processes and ensure that resource allocation is risk informed to the extent practicable.[40] This decision-making framework includes a step to identify constraints for decision-making, some of which may be fixed and some which may be flexible. Legal constraints, such as the requirement that certain waste types be vitrified, may be flexible if DOE could mitigate the constraint by, for example, determining that the vitrification requirement does not apply to Hanford's HLW that could be classified as a waste type other than high-level radioactive waste. However, DOE's AOA excluded any options that did not involve vitrification of all HLW, which could have included options that could reduce costs, schedule, and risks.

DOE officials said that as a result of the recently proposed changes to the HLW mission, DOE is resetting the project management approval process for the HLW Facility. Projects at DOE such as the HLW Facility go through a series of five critical decisions, which require approval at each decision point that represents a commitment for additional resources to proceed to the next critical decision.[41] The HLW Facility project will restart at the first critical decision, which includes approval of the mission need, according to DOE officials. As we discuss further below, the restarting of this process represents an opportunity for DOE to define a mission

[37]40 C.F.R §§ 268.40, 268.42(a).

[38]GAO-20-195G.

[39]GAO, *Hanford Cleanup: DOE Should Validate Its Analysis of High-Level Waste Treatment Alternatives*, GAO-23-106093 (Washington, D.C.: May 24, 2023).

[40]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).

[41]DOE Order 413.3B establishes five critical decision processes over the life of a capital asset project, each of which is marked by a major approval milestone—or CD point—at the end of the process. These CD points include the following: CD-0: approve mission need; CD-1: approve alternative selection and cost range; CD-2: approve project performance baseline (e.g., scope, cost, and schedule estimates); CD-3: approve start of construction or execution; CD-4: approve start of operations or project completion.

need in keeping with DOE Order 413.3B and to conduct additional analyses of alternatives aimed at optimizing the HLW mission before proceeding with the design and construction of the HLW Facility.

Alternative Approaches Targeted at the Level of Risk Posed by the Waste Could Allow DOE to Expedite HLW Cleanup and Save Billions of Dollars

According to experts that attended GAO's meetings convened by the National Academies, portions of Hanford's HLW could potentially be classified as a waste type other than high-level radioactive waste based on the physical characteristics of the waste. If portions of the waste were classified as other waste types, DOE could deploy several alternative treatment approaches that use simpler and, in many cases, existing technologies targeted at the physical characteristics of the waste. Pursuing such approaches could negate the need to continue construction of the Pretreatment Facility and the HLW Facility as currently designed and save billions of dollars, according to experts. Experts also stated that DOE could reduce costs, accelerate the cleanup schedule, and reduce risks to workers and the environment if it took a more risk-informed approach to classifying and treating the waste it currently plans to process through the HLW Facility. Experts further noted that research and development on various approaches and technologies may be necessary.

Portions of the HLW Could Potentially Be Classified as Something Other than High-Level Radioactive Waste Based on the Waste's Physical Characteristics

Most experts who participated in our meetings agreed that portions of Hanford's HLW could be classified and treated as low-level radioactive waste (LLW) or transuranic (TRU) waste based on the waste's physical characteristics. Classifying portions of the HLW as LLW or TRU waste could potentially allow DOE to use existing and less expensive treatment and disposal options.

As previously discussed, DOE currently manages all Hanford tank waste as if it is "high-level radioactive waste" as defined by federal statutes. Under EPA regulations also adopted by the

The Department of Energy (DOE) Faces Challenges in Siting a Defense High-Level Radioactive Waste Repository

DOE had long planned to dispose of defense and commercial high-level radioactive waste in a single repository at Yucca Mountain, Nevada, funded largely from commercial power fees. In 2010, DOE terminated this plan and then considered developing a separate defense repository for high-level radioactive waste, which would likely be funded by taxpayer dollars.

In 2017, we reported that DOE faced significant public opposition and distrust in trying to site a high-level radioactive waste disposal facility. We also reported that certain prerequisites for an effective consent-based siting process—including updated health and safety regulations specifying the length of time that the federal government must show it can safely store nuclear waste—had not been addressed. This time period is a key piece of information for the public and potential host communities to have when commenting on DOE's siting process.

We recommended that DOE reassess its decision to conduct site selection activities until key prerequisites have been met. DOE disagreed with this recommendation, and as of June 2024, had not taken any action to implement it.

Sources: GAO, *Nuclear Waste: Benefits and Costs Should Be Better Understood Before DOE Commits to a Separate Repository for Defense Waste* GAO-17-174 (Jan. 31, 2017); GAO (photo). | GAO-24-106989

State of Washington, radioactive mixed high-level wastes must be vitrified prior to land disposal. DOE has also indicated that any waste ultimately classified as high-level radioactive waste will be disposed of in a deep geological repository. There currently is no deep geological repository for the disposal of high-level radioactive waste in the United States (see sidebar).

By comparison, DOE and several commercial entities operate disposal facilities for mixed LLW. As we have previously reported, there is no general RCRA treatment standard for mixed LLW.[42] There is also an existing facility for the disposal of TRU waste generated by defense activities: the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico. At WIPP, waste is disposed of in underground "panels," made up of rooms mined out of an ancient salt formation more than 2,000 feet below the earth's surface. Therefore, as a general matter, DOE has a wider array of options for treating and disposing of waste classified as LLW and TRU waste than it does high-level radioactive waste.

The definition of high-level radioactive waste in federal law considers both the origin of the waste (i.e., material resulting from the reprocessing of spent nuclear fuel) as well as its physical characteristics (i.e., highly radioactive material). As we have previously reported, DOE has a number of tools at its disposal for classifying

[42]RCRA regulations specify treatment standards for a few hazardous wastes that are radioactive, but there is no general standard for low-level mixed waste. Other mixed waste must generally be physically, chemically, or thermally treated to substantially diminish its toxicity or reduce the mobility of the hazardous constituents according to waste-specific regulatory levels. 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).

and managing reprocessing waste as a waste type other than high-level radioactive waste.[43] We discuss those processes and their limitations in greater detail below and in appendix III.

We asked experts about the extent to which Hanford's HLW could potentially be classified as LLW or TRU waste, rather than high-level radioactive waste, based solely on the waste's physical characteristics rather than its origin. Of the 15 experts who responded, nine said that it is somewhat, or very likely that some of Hanford's HLW could be classified as LLW. Thirteen experts responded that it is somewhat or very likely that some of Hanford's HLW could be classified as TRU waste.[44] Eleven also responded that about half or less of the waste would need to be vitrified based on its physical characteristics. One expert thought it was not very likely that DOE could classify portions of Hanford's HLW as LLW or TRU waste, in part because the current definition of high-level radioactive waste is mainly based on the origin or processing of the waste. Some experts also thought that vitrifying the HLW waste could be beneficial if it avoids difficult steps associated with separating HLW and LLW, or if it generates more flexible storage and disposal options for the immobilized waste.

Experts' assessment of the portions of the HLW that could potentially be managed and treated as LLW or TRU waste depended in part on the location of the waste, because the radioactivity of the waste varies among the tank farm areas. For example:

- **Northeast and northwest tank farms.** Experts stated that much of the waste in Hanford's northeast and northwest tank farms has lower radioactivity than waste in the southwest and southeast tank farms. One expert stated that the waste in the northeast and northwest tank farms resulted from a chemical separations process, which created fairly homogenous sludges with less radioactivity than the waste in the southeast and southwest tank farms.[45] As a result, several experts concluded that the HLW in these tank farms could likely be managed as LLW or TRU waste. Similarly, DOE officials told us that the northeast and northwest tank farms contain less than 10 percent of the radioactivity in all of the tank waste. DOE currently plans to transfer HLW in these tanks several miles to be processed in the HLW Facility using cross-site transfer lines that do not yet exist. In addition to cross-site transfer lines, experts stated that the northeast and northwest tank farms would need other significant infrastructure investments, such as electrical systems and waste retrieval infrastructure before DOE could begin transferring waste to the HLW Facility. We reported in 2021 that DOE spent $1.5 billion to build such infrastructure for two tank farms located in the southeast area, which is closest to the HLW Facility, according to DOE officials we spoke to at that time.[46]
- **Southeast tank farms.** Experts stated that the waste containing the highest radioactivity is in the southeast tank farms, though the TSCR process will reduce some of the radioactivity. For example, one

[43]GAO-22-104365.

[44]These results reflect the responses of the 15 experts that participated in the January 2024 virtual portion of our meetings. Responses of the two additional experts that participated in the February 2024 in-person portion of our meetings were not collected. See appendix I for further details on our methodology.

[45]The Hanford Site historically used different chemical processing methods and facilities to produce plutonium. The B and T Plants generated plutonium in the 1940's from the bismuth phosphate separations process. From 1952 through 1967, the Reduction Oxidation Plant (REDOX) was used for the chemical separation of plutonium and uranium from irradiated fuel rods. In the second half of the century, Hanford operated the Plutonium Uranium Extraction Plant (PUREX) to recover plutonium, uranium, and neptunium from irradiated fuel rods received from Hanford Site reactors.

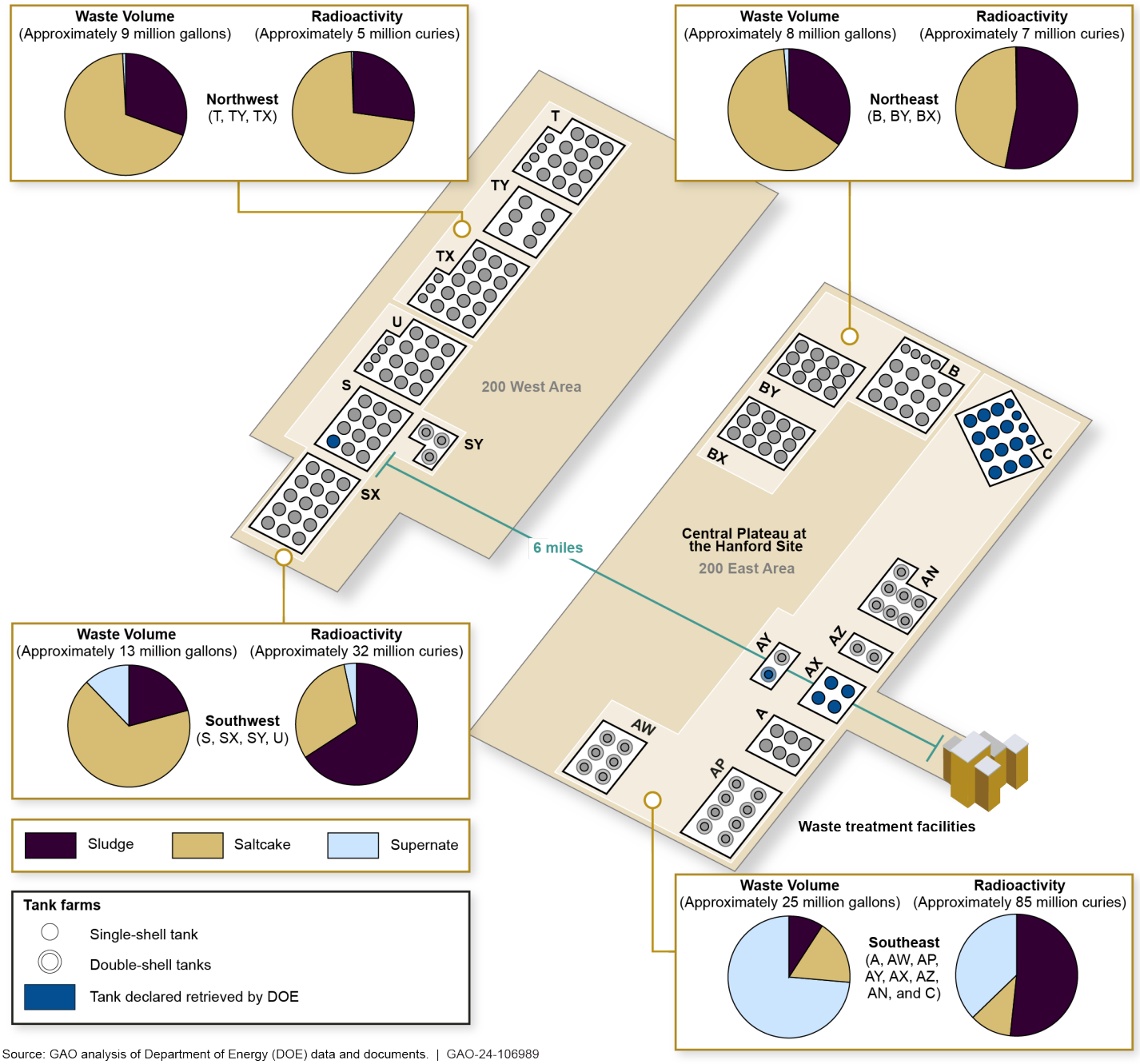
[46]GAO, *Hanford Cleanup: DOE's Efforts to Close Tank Farms Would Benefit from Clearer Legal Authorities and Communication*, GAO-21-73 (Washington, D.C.: January 7, 2021).

expert said that the concentration of cesium-137, which is driving the amount of shielding needed in the HLW Facility designs, will be significantly reduced. This expert also noted there would still be significant radioactivity from the strontium-90 in the sludge portion of the waste—the primary portion of the waste that DOE plans to treat in the HLW Facility.

- **Southwest tank farms.** Experts said that some of the HLW in the southwest tank farms has higher levels of radioactivity, but some may be able to be classified as LLW or TRU waste based on the waste's physical characteristics.

Figure 4 shows the total volume and radioactivity of waste in each of the tank farm areas, according to our analysis of DOE data as of May 2024.

Figure 4: Total Volume and Radioactivity of Waste in Hanford Tanks by Tank Farm Area, as of May 2024



Source: GAO analysis of Department of Energy (DOE) data and documents. | GAO-24-106989

Accessible Data for Figure 4: Total Volume and Radioactivity of Waste in Hanford Tanks by Tank Farm Area, as of May 2024

Vol Pie Charts

Area	Volume (thousands of gallons): Sludge	Volume (thousands of gallons): Saltcake	Volume (thousands of gallons): Supernate
SE tank farms (approx. 25 million gallons)	2333.2	4284.1	18436.6
NE tanks farms (approx. 8 million gallons)	2687	4950	99
SW tank farms (approx. 13 million gallons)	2674.9	8548	1540.4
NW tank farms (approx. 9 million gallons)	2778	6204	67

Area	Radioactivity (curies): Sludge	Radioactivity (curies): Saltcake	Radioactivity (curies): Supernate
SE tank farms (approx. 85 million curies)	44086552.64	9504902.279	31699608.06
NE tanks farms (approx. 7 million curies)	3862792.857	3379918.992	14870.16321
SW tank farms (approx. 32 million curies)	20942618.15	9748603.828	1006184.238
NW tank farms (approx. 5 million curies)	1409854.064	3716043.044	23916.23731

- SE quadrant: A, AW, AP, AY, AX, AZ, AN, and C)
- SW quadrant: S, SX, SY, U
- NW quadrant: T, TY, TX
- NE quadrant: B, BY, BX

Source: GAO analysis of Department of Energy (DOE) data and documents. I GAO-24-106989

Note: The focus of this report is the approximately 3 million gallons of tank waste at Hanford that the Department of Energy (DOE) considers having high radioactivity (mostly concentrated in the sludge portion of the waste). DOE refers to this portion of the waste as high-level waste (HLW). DOE plans to treat the remaining tank waste as low-activity waste (LAW), which is the term used at Hanford for the primarily liquid portion of the tank waste, including dissolved saltcake, that contains low levels of long-lived radionuclides. The waste volume and radioactivity data reported here reflects the total waste in Hanford's 177 tanks, including both HLW and LAW.

Alternative Approaches Targeted at the Risks of the Waste Could Optimize the Volume of Waste Requiring Vitrification and Disposal as High-Level Radioactive Waste

According to experts who participated in our meetings, there are several alternative approaches to addressing the approximately 3 million gallons of waste that DOE plans to manage as HLW. Using these approaches could optimize the volume of waste that DOE would need to manage as high-level radioactive waste, therefore minimizing the volume of waste that must be vitrified and disposed of in a deep geologic repository.

Experts generally agreed that taking a risk-informed approach to addressing the HLW could allow DOE to begin treating the waste sooner and in less expensive ways.[47] Such a risk-informed approach would pursue treatment approaches targeted at the physical characteristics of the waste rather than its origin. In particular, experts identified several approaches for treating the waste if DOE could classify portions of the HLW into LLW, TRU waste, and high-level radioactive waste streams based on its physical characteristics.

In contrast to experts' identified alternatives, DOE's current plan is to continue managing the HLW from across the tank farms as mixed high-level radioactive waste and to vitrify that waste in the HLW Facility. The holistic agreement proposes that DOE implement additional pretreatment capabilities, such as sludge washing, after startup of direct-feed to the HLW Facility.[48] The extent of pretreatment will be determined after the HLW Facility is operational, currently planned for 2033.[49]

Below we discuss the alternative approaches experts identified that might be taken if portions of the HLW can be broken down into LLW, TRU waste, and high-level radioactive waste streams. Some of these approaches have been explored by DOE in the past or are currently the subject of DOE research and development efforts.

Low-Level Radioactive Waste

Experts identified several existing technologies that DOE could pursue if it can classify portions of the HLW as LLW based on its physical characteristics. These primarily consisted of dry or wet retrieval technologies with different options for grouting the waste. In particular, experts said that this potential LLW could be grouted (1) in a single facility located near the tank farms, (2) in smaller grouting facilities built in each tank farm to reduce the need to transfer the waste long distances, or (3) in a tank-side grouting system.

Some experts said that DOE could use sludge washing—which can remove some constituents from the waste—to further reduce the radioactivity of the waste before grouting. One expert thought this type of pretreatment would not be necessary. Specifically, this expert said that many of the tanks in the northeast and northwest tank farms, and some tanks in the southwest tank farms, do not require any removal of cesium-137 or strontium-90 to be considered LLW. Rather, the waste could be retrieved using low-water methods and go directly to a grouting facility.

In 2022, DOE commissioned a Research and Development Roadmap for Hanford Tank Waste Mission Acceleration that, among other things, stated it is technically possible to remove HLW sludge from the tanks, dry it, and dispose of it as LLW or TRU waste.[50] The roadmap identified dry retrieval and characterization

[47]We asked experts to identify approaches to addressing Hanford's HLW that could be less expensive than DOE's baseline plan, while remaining protective of human health and the environment. We described DOE's baseline plan consistent with Scenario 1 of the agency's *River Protection Project System Plan Revision 9,* which was the most recent published baseline plan at the time we planned the content of the meetings. We did not ask experts to identify alternatives to the proposed plans outlined in the April 2024 holistic agreement given that the agreement was published after we held our meetings. See appendix I for further details about our methodology.

[48]Sludge washing or "enhanced sludge washing" is a process by which as much of the soluble materials as practical are removed from the waste.

[49]As noted above, DOE and Ecology have proposed keeping this milestone for the time being while noting that they anticipate modifying the milestone in the future.

[50]The roadmap assumed that processes outlined in DOE Manual 435.1-1 could be applied to classify and dispose of some of the tank wastes as something other than high-level radioactive waste. See NNLEMS-2022-00005.

technology as a high-priority research and development project. This project would develop dry retrieval equipment and techniques to remove waste from the tanks and transport it to the treatment or disposal facilities using commercially available instrumentation or technologies that are in the developmental stage. The roadmap estimated that this technology could save more than $25 billion and 7 to 10 years for the tank waste mission.

Experts emphasized that regardless of what facility or system DOE uses to grout the waste, the agency has already had success grouting similar waste at its Savannah River Site. For example, one expert noted that at the Savannah River Site, DOE is already grouting waste that contains higher levels of radioactivity than Hanford waste once it is processed through TSCR.[51]

DOE is exploring using grout approaches for some of the Hanford waste. In May 2024, EPA granted DOE a treatment variance under RCRA that authorized DOE to grout 2,000 gallons of LAW for off-site disposal as a part of DOE's Test Bed Initiative.[52] Additionally, in the April 2024 holistic agreement, the parties have proposed new cleanup milestones under which DOE would complete retrieval of 22 tanks in the southwest tank farms by 2040 for which the low-activity portion of the waste would be grouted and disposed of offsite.

The waste in several tanks may already fall below certain radionuclide concentration limits for LLW without any further separation or treatment steps, according to our comparison of DOE tank waste data on applicable radionuclides to the Nuclear Regulatory Commission's (NRC) Class A, B, and C waste classifications.[53] NRC regulations specify how LLW should be classified according to its radiological hazard for disposal in licensed commercial facilities.[54] We found that as of May 2024, waste from 21 tanks could fall below the concentration limits for Class A, B, or C LLW, as defined by the NRC.[55] These 21 tanks contain approximately 11 million gallons of waste—about half a million gallons of which is sludge. Nonetheless, under DOE's baseline plan,

[51]We reported in 2017 that experts from a different meeting we convened with the assistance of the National Academies stated that grout could effectively treat the low-activity portion of tank waste at Hanford and that DOE has successfully treated millions of gallons of LAW with grout at its Savannah River Site for a substantially lower cost than Hanford's estimated costs for vitrifying LAW. See GAO, *Nuclear Waste: Opportunities Exist to Reduce Risks and Costs by Evaluating Different Waste Treatment Approaches at Hanford*, GAO-17-306 (Washington, D.C.: May 3, 2017).

[52]Department of Energy Hanford Mixed Radioactive Waste Land Disposal Restrictions Variance, 89 Fed. Reg. 35008 (May 1, 2024).

[53]NRC regulation 10 C.F.R. § 61.55 specifies certain radionuclide concentration limits for Class A, B, and C low-level radioactive waste for near surface disposal. DOE does not use the NRC classification system for low-level radioactive waste disposed of at DOE facilities, but it instead relies on site-specific performance assessments and waste acceptance criteria. Nonetheless, DOE also disposes of defense LLW at commercial mixed waste facilities, and those facilities are subject to NRC's classification system. DOE can also use its Waste Incidental to Reprocessing Evaluation process, where appropriate, to classify reprocessing waste as non-high-level radioactive waste. This process also references the NRC's classification system established in 10 C.F.R. § 61.55. Because of the potential relevance of the NRC's classification system to DOE's management of Hanford's tank waste, we determined it was appropriate to rely on that system to complete our analysis of Hanford's tank waste. Appendix II contains more details about our methodology.

[54]10 C.F.R. § 61.55.

[55]Under 10 C.F.R. § 61.55, if radioactive waste contains both long- and short-lived radionuclides, as Hanford's tank waste does, classification is determined by two sets of radionuclides and their associated radioactivity limits established in the regulation. We identified the short-lived and long-lived radionuclides listed in the regulation that are present in the 177 Hanford tanks according to DOE's Best Basis Inventory data. We then applied the steps outlined in the regulation for waste containing a mixture of long-lived and short-lived radionuclides to determine whether the concentrations of these long-lived and short-lived radionuclides present in each tank could potentially meet Class A, B, or C criteria.

some of the waste in these tanks is expected to be vitrified in the HLW Facility. Appendix II contains further details on our tank waste analysis, including the waste volume and radioactivity levels of each tank.

If DOE classifies portions of the HLW as LLW based on its physical characteristics, experts said the waste could potentially be disposed of at two commercial LLW disposal sites—Waste Control Specialists in Texas and EnergySolutions in Utah. One expert noted that Waste Control Specialists accepts a wider array of LLW, including Class A, B, and C, while EnergySolutions in Utah only accepts Class A waste, which could limit the amount of Hanford LLW that could be disposed of there.

Transuranic (TRU) Waste

Experts identified several existing or in-development technologies that DOE could pursue if it classified portions of the HLW as TRU waste based on its physical characteristics. According to experts, such treatment methods could start with using low-water or dry retrieval methods to remove the waste from the tanks. All of the tanks located in the northeast and northwest tank farms are single-shell tanks, which have had leaks and are well past their design life. Experts said that wet retrieval of waste in these tanks—where liquids are added to remove the sludge—could lead to further leaks, underscoring the importance of dry or low-water retrieval techniques. Dry-retrieval techniques—using robotics to mine or scrape out the waste from the tanks—would avoid adding water and potentially causing additional leaks, according to experts. However, one expert noted that dry retrieval technologies have not yet been proven successful and said the radioactivity levels in the tanks could damage the robotics.[56]

Once the waste is retrieved, experts said DOE could use existing methods to stabilize potential TRU waste to prepare it for disposal at WIPP in New Mexico, assuming it meets the waste acceptance criteria.[57] According to experts, waste disposed of at WIPP needs to be dry but does not need to be in a specific waste form, so either drying or grouting methods could be acceptable. For example, one expert said that the sludge, which would contain some amount of liquid, could be heated through an auger to remove some of the liquid, then mixed with a drying material to remove any remaining liquid before packaging it for disposal.

If DOE used grouting methods, experts said the potential TRU waste could be grouted in a single facility located near the tank farms or in smaller grouting facilities built in each tank farm. Other experts suggested using a modular, tank-side grouting system. Both a tank-side grouting system or grouting facilities in each tank farm would avoid costs associated with building transfer lines to move the waste from the tank farms to the HLW Facility. However, some experts noted that drying methods may be more efficient since grouting the waste would require adding a concrete-like material, increasing the overall volume of waste.

DOE has already identified several tanks that may contain TRU waste. In its 2023 River Protection Project System Plan, DOE evaluated 11 tanks located in the northwest and northeast tank farms that could potentially be classified as TRU waste based on the origin of the waste. Specifically, according to DOE, because the waste in these tanks did not originate from the reprocessing of spent nuclear fuel, it could not properly be

[56]Robots have been used at DOE sites to access areas restricted to workers due to contamination levels. For example, a robotic "snake" arm that can cut through metal and concrete materials in highly radioactive areas has been tested at the Portsmouth and Idaho sites. See GAO, *Nuclear Waste Cleanup: DOE Needs to Better Coordinate and Prioritize Its Research and Development Efforts*, GAO-22-104490 (Washington, D.C.: Oct. 28, 2021).

[57]WIPP is the nation's only repository for disposal of defense origin TRU waste.

classified as high-level radioactive waste. DOE has not taken formal steps to classify this waste as TRU waste. However, DOE has stated that it prefers to retrieve, treat, package, characterize, and certify these wastes that are properly and legally classified as transuranic mixed waste for disposal at a yet-to-be-determined offsite TRU waste disposal facility. According to the system plan, DOE has completed the design of a potential TRU waste packaging system, but the project was placed on standby in 2005. DOE officials said that restarting the project will depend on need and the availability of funding.

High-Level Radioactive Waste

Most experts agreed that some of the HLW is highly radioactive based on its physical characteristics and should be treated and disposed of as high-level radioactive waste. However, experts emphasized that the volume of waste needing to be vitrified as high-level radioactive waste is much smaller than the amount DOE currently plans to vitrify in the HLW Facility. As such, experts identified alternative approaches targeted at vitrifying a smaller volume of waste—particularly the waste located in the southeast tank farms.

One approach experts identified is to feed the sludges from the southeast tank farms directly to the HLW Facility, which would require adding liquid to the tanks to retrieve the sludge into a staging vault before vitrification in the HLW Facility. This approach is technically similar to the approach DOE stated it would pursue for HLW in the April 2024 holistic agreement—reconfiguring the WTP for the direct-feed of waste to the HLW Facility. However, the experts' approach would use a direct-feed approach for only the HLW in the southeast tank farms, assuming the remaining HLW could be addressed using other methods for LLW and TRU waste discussed above.

Experts also identified modular vitrification technologies as a potential alternative to the HLW Facility. Specifically, experts said DOE could deploy smaller, at-tank or near-tank vitrification capabilities only in the areas where the waste needs to be vitrified based on its physical characteristics and risk. Experts proposed that DOE design a modular vitrification system similar to the scale of the TSCR system, contained in a metal box on a pad near the tanks where it is being used. They emphasized that a modular approach would eliminate the need for waste transfer lines, and possibly waste receiving facilities, such as the staging vault needed for the direct-feed approach.

Experts noted that modular vitrification approaches are not yet well-tested, but that similar approaches have been developed in the past. For example, in 1997, DOE developed the Transportable Vitrification System at its Oak Ridge Site in Tennessee to demonstrate this technology on a mixed low-level waste sludge stream. One expert estimated that a similarly sized system at Hanford could process the HLW sludge in about 10 years.

Additionally, two companies have developed different in-container vitrification technologies. In-container vitrification technologies have been demonstrated or deployed in the United States, Japan, and the United Kingdom for waste similar to what the United States considers mixed LLW and TRU waste. In the United States, in-container vitrification systems for radioactive waste treatment have been installed at Perma-Fix in Washington State and Waste Control Specialists in Texas. However, none of these technologies have been demonstrated or deployed on Hanford's HLW, according to experts.

For each of these approaches, experts said the vitrified waste would be disposed of in a deep geologic repository, which does not yet exist. They also said that until a deep geologic repository is identified and built, DOE would have to store vitrified HLW on-site indefinitely. One expert emphasized that this means the more waste that DOE vitrifies, the more immobilized glass they will have to store and monitor until such a repository

is established. Classifying and treating portions of the waste as LLW or TRU waste could allow DOE to divert some of that waste to existing disposal sites outside Washington State.

Cesium and Strontium

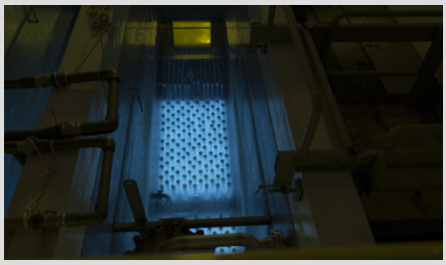
Experts said that DOE could use an alternative approach to address the 451 loaded ion exchange columns containing cesium and strontium that it plans to vitrify in the HLW Facility. Specifically, DOE could store and monitor the columns until the radioactivity decays to a point where they could be disposed of as LLW.[58]

As we found in May 2023, the vast majority of the radioactivity in the tank waste comes from the decay of strontium-90 and cesium-137, which have half-lives of about 29 years and 30 years, respectively.[59] 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 over the next century. Experts estimated that it would take around 300 years for the columns to decay to the extent that the waste would be considered LLW.

Hanford Site: Examples of a Store-and-Decay Approach to Treatment of Radioactive Waste

From 1967 to 1983, the Department of Energy (DOE) removed some cesium and strontium from Hanford's single-shell tanks to reduce the temperature of the waste inside the tanks. The cesium and strontium were placed in 1,936 stainless steel containers, called capsules, at Hanford's Waste Encapsulation Storage Facility for safe storage and monitoring. The facility stores the capsules in 13 feet deep pools filled with water. The water shields workers from radiation and keeps the containers cool. As a result of the radioactive decay of the cesium and strontium, the water in the pools glows blue (see photo).

(*continued on next page*)



Source: DOE documents and photos. | GAO-24-106989

DOE is pursuing a similar store-and-decay approach for other radioactive waste at the Hanford Site (see sidebar). For example, DOE is preparing to move approximately 2,000 capsules containing cesium and strontium being stored in the Waste Encapsulation and Storage Facility to dry interim storage, though DOE has not yet determined a final treatment or disposition path for the capsules. In its 2018 amended Record of Decision for managing the capsules, DOE stated that constructing and operating a dry storage facility for the capsules would include maintaining and monitoring the facility for up to 145 years, by which time the

[58]According to one expert, these columns, containing primarily cesium-137 and strontium-90 decay to background levels of radioactivity in about 10 half-lives, which is approximately 300 years. Some of the cesium-137 and strontium-90 in the Hanford tank waste has already decayed almost three half-lives.

[59]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.

radioactivity will have been reduced to about 1.6 million curies.[60] The agency noted that the capsules had already decayed from about 68 million curies to 46 million curies as of June 2017.

Hanford Site: Examples of a Store-and-Decay Approach to Treatment of Radioactive Waste

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Due to the delays in waste treatment at the Hanford Site, the Waste Encapsulation Storage Facility is beyond its design life, increasing the risk that an event, such as an earthquake, could cause the shielding of the capsules to fail. In 2018, DOE decided to move the capsules to a new facility for interim dry storage, where they will continue to decay, and be maintained and monitored for up to 145 years. DOE has not decided on a final treatment or disposal path for the capsules.

Similarly, DOE has taken a store-and-decay approach for former plutonium production reactors around the site. Specifically, the agency has "cocooned" or constructed protective enclosures around seven of nine reactors on the site (see photo). The enclosures provide safe interim storage while the radioactivity of the deactivated reactor core decays over several decades, until DOE can complete disposition of the reactor in the future.

Source: DOE documents and photos. | GAO-24-106989

Experts stated that an additional approach could be to dispose of the capsules in a deep borehole.[61] A 2014 DOE report that assessed disposal options for high-level radioactive waste found that some smaller waste forms, including Hanford's cesium and strontium capsules, could be disposed of in deep boreholes using currently available drilling technology.[62] Deep borehole disposal had a high potential for robust isolation of the waste and could offer a pathway for the waste to be disposed of sooner than might be possible with a deep geologic repository, according to the report. DOE has considered both a comingled repository that would store both commercial and defense high-level radioactive waste and spent nuclear fuel, as well as a defense-only repository. Defense high-level radioactive waste is less radioactive than commercial spent nuclear fuel, the latter of which would make up about 97 percent of the radioactivity in a comingled repository.[63] As discussed above, there is currently no deep geologic repository for high-level radioactive waste in the United States. A deep borehole approach could allow DOE to dispose of a portion of Hanford's HLW before it has established a deep geologic repository and avoid the potential complications of disposing of the capsules in a comingled repository.[64]

[60]Department of Energy, *Amended Record of Decision for the Management of Cesium and Strontium Capsules at the Hanford Site, Richland, Washington*, 6450-01-P (May 14, 2018).

[61]According to the International Atomic Energy Agency, the concept of disposal in a deep borehole considers disposal in a stable geologic formation at depths ranging from several hundred meters—comparable to those of a mined deep geologic repository—to depths of several kilometers into the base rock.

[62]Department of Energy, *Assessment of Disposal Options for DOE-Managed High-Level Radioactive Waste and Spent Nuclear Fuel* (Oct. 2014). In 2016, DOE commissioned a team to drill a test borehole in North Dakota but stopped the project after local opposition.

[63]GAO-17-174.

[64]DOE's 2014 assessment of disposal options found that disposing of DOE-managed high-level radioactive waste and spent nuclear fuel separate from commercial waste and spent nuclear fuel, could lead to benefits in repository cost or performance based on the different radioactive and chemical characteristics of the waste streams.

Some experts also stated that there could be other ways to address the strontium capsules being stored in the Waste Encapsulation and Storage Facility that would not require vitrification. For example, commercial companies may be interested in obtaining the strontium capsules for reuse in a variety of medical and defense applications. One expert noted that there has been significant interest in reusing the strontium, but it could be challenging to retrieve the capsules after they are placed in dry storage.[65]

Implementing Risk-Informed Approaches to Addressing the HLW Could Save Billions of Dollars, Accelerate Retrievals, and Lower Risks

Experts who participated in our meetings emphasized that by pursuing the alternative approaches they identified, DOE could minimize the amount of HLW requiring vitrification and deep geologic disposal. This would allow the agency to concurrently treat portions of the waste using alternative methods while building scaled-down vitrification capability. Experts stated that this strategy could reduce capital and operating costs by billions of dollars, shorten the tank waste cleanup mission, and reduce risks to workers and the environment.

Potential Cost Savings

According to experts, concurrently deploying smaller-scale approaches targeted at the physical characteristics of the waste, such as those discussed above, could lead to billions in savings. Experts did not quantify the precise costs of pursing alternative approaches. However, they highlighted several ways DOE could generate cost savings by shifting away from treating all of the HLW in a single set of large facilities with significant infrastructure and capital requirements and, instead, using simpler treatment technologies based on the physical characteristics of the waste. For example:

- **Avoid construction of the Pretreatment Facility.** Experts emphasized that none of the alternative approaches they identified would require completion of the WTP Pretreatment Facility, which DOE estimated would cost about $9 billion.[66]
- **Avoid construction of transfer lines and the HLW Facility as currently designed.** Given that the alternative approaches would reduce the volume of waste requiring vitrification, experts said DOE may not need the HLW Facility as currently designed, which the agency estimated would cost about $10 billion to complete. As noted below, experts suggested that a scaled-down vitrification capability could cost less and still meet the mission need. Experts also said that developing a modular vitrification system for a reduced volume of HLW could eliminate the need for the HLW Facility altogether. Depending on the waste location, reducing the volume of HLW requiring vitrification or eliminating the HLW Facility could eliminate the need for cross-site transfer lines, which do not yet exist, to connect waste from the northeast and northwest tank

[65]DOE has recycled excess materials in the past. For example, a DOE contractor sells hydrofluoric acid from depleted uranium hexafluoride conversion facilities to a private company. The contractor then applies the proceeds of those sales to contract costs. We found in 2022 that appropriations laws for fiscal years 2011 through 2022 allowed DOE to keep and use the proceeds of the hydrofluoric acid sales. See GAO, *Nuclear Waste Cleanup: DOE's Efforts to Mange Depleted Uranium Would Benefit from Clearer Legal Authorities*, GAO-22-105471 (Washington, D.C.: July 27, 2022).

[66]While the Pretreatment Facility is included in DOE's 2023 River Protection Project System Plan for treating the HLW, the April 2024 holistic agreement proposes effectively putting the Pretreatment Facility on hold until DOE and its regulators revisit and revise the facility milestones and implement additional pretreatment capabilities after the HLW Facility is operational. Further, DOE officials we interviewed said that they assume these future pretreatment capabilities will focus on sludge-washing methods to reduce the overall volume of waste that will be directly fed to the HLW Facility.

farms to the HLW Facility. We reported in 2021 that DOE officials said the infrastructure needed to retrieve and transfer waste from tanks in the southeast area, which is closest to the HLW Facility, cost the agency $1.5 billion to build.[67] While there is an existing transfer line connecting the southwest tank farms to the southeast tank farms, the 2023 HLW AOA estimated it would cost $50 million to $60 million to refurbish and replace components of this line.

- **Reduce the need for upfront capital.** Experts stated that smaller or modular systems such as a tank-side grouting or scaled-down vitrification capability would likely require less up-front capital than a large complex facility like the WTP, reducing the need for large appropriations in a single year. DOE's baseline plan for addressing the HLW would require up to $3.3 billion in annual appropriations to treat all tank waste by 2066.[68]
- **Reduce the cost of a HLW Facility reconfigured for a reduced volume of waste.** Some experts acknowledged that it may be more efficient for DOE to complete the HLW Facility instead of pursuing a new approach, such as modular vitrification, given that the facility is already partially complete. Nevertheless, they said that reducing the volume of waste requiring vitrification could result in reduced capital and operating costs because DOE could design the facility to treat a smaller volume of waste. Avoiding vitrification has been shown to have significant potential cost benefits in the context of Hanford's LAW. Specifically, we estimated in 2023 that vitrifying 1 gallon of LAW at Hanford is estimated to be about seven times the cost of grouting 1 gallon of similar waste at DOE's Savannah River Site.[69]

Likewise, DOE's 2022 Research and Development Roadmap identified similar approaches that, according to the report, would reduce the overall cost of the tank waste mission. For example, the roadmap states that prioritizing research into dry waste characterization, monitoring, and retrieval technologies—consistent with the LLW and TRU waste approaches that experts identified—could save over $25 billion. Further, the roadmap states that prioritizing research for in-tank or at-tank pretreatment of HLW could also save over $25 billion over the life of the mission.

Potential Schedule Benefits

According to experts, concurrently deploying smaller-scale approaches targeted at the physical characteristics and risks of the waste could accelerate the tank waste cleanup. Specifically, experts said that if DOE could classify and treat portions of the HLW as LLW or TRU waste, the agency could begin waste retrieval sooner and in parallel with vitrification. For example:

- **Avoid tank space limitations.** Experts stated that if DOE could use existing LLW and TRU waste treatment methods for portions of the HLW, the agency would not have to wait for space to become available in the southeast tank farms before it begins treating waste in other tank farms. One expert noted that under DOE's current plan, it cannot start processing waste in the southwest tank farms until waste currently held in the southeast double-shell tanks is vitrified in the HLW Facility.

[67]GAO-21-73.

[68]According to DOE's River Protection Project System Plan 10, the baseline plan contains both an unconstrained and constrained funding scenario. The unconstrained funding scenario assumes annual appropriations of up to $3.3 billion to complete all tank waste treatment by 2066, while the constrained scenario assumes a cap of $2.7 billion in annual appropriations to complete all tank waste treatment by 2070.

[69]GAO, *Hanford Cleanup: Alternative Approaches Could Save Tens of Billions of Dollars,* GAO-23-106880 (Washington, D.C.: Sept. 28, 2023).

- **Smaller approach advantages.** Experts emphasized that smaller, modular approaches may be faster to implement than large, one-size-fits-all facilities like the Pretreatment Facility. Smaller, modular approaches benefit from being able to apply lessons learned from one system to subsequent systems, potentially saving time in design, start-up, and operation of the subsequent systems, according to experts. Similarly, a 2023 Federally Funded Research and Development Center noted that using concurrent technologies in the context of low-activity waste treatment could provide flexibility that could reduce potential delays.[70]

DOE's Research and Development Roadmap also estimated significant schedule benefits for pursuing risk-informed approaches. For example, according to the roadmap, implementing dry-retrieval technologies—like those that experts identified for treating waste that could be classified as LLW or TRU waste—could reduce the tank waste cleanup mission by 7 to 10 years. Further, DOE could reduce the mission by more than 10 years if it implements in-tank or at-tank pretreatment of HLW, according to the roadmap.

Potential Risk Reduction

According to experts, concurrently deploying smaller-scale approaches targeted at the physical characteristics of the waste could reduce risks to workers, human health, and the environment. For example:

- **Avoid further tank leaks.** Experts stated that approaches that begin retrieving the waste from these tanks sooner reduce risks associated with additional leaks and uncertain structural integrity of the tanks. In 2023, we reported that most of the Hanford tanks were beyond their design life, and according to DOE, may have already collectively leaked over 1 million gallons of waste into the ground.[71] In June 2024, DOE reported that 57 tanks were known or assumed to be leaking, over half of which are located in the northeast and northwest tank farms.[72] One expert noted that pursuing approaches that can be implemented in the near term, rather than waiting on the HLW Facility to be built and process the wastes in the southeast tank farms, is significantly better from a risk-reduction standpoint given the state of the single-shell tanks.
- **Reduce radioactivity through additional pretreatment.** Experts emphasized that the current WTP design may be overly conservative and does not consider pretreatment steps that could reduce risks. According to experts, TSCR reduces risks to workers by removing radioactivity from Hanford's LAW to the point that remaining waste that will be processed in the HLW Facility will be less radioactive than waste currently processed using grout at DOE's Savannah River Site. Some experts also suggested that DOE could conduct sludge washing of the HLW in the northeast, northwest, and southwest tank farms and then process the water used to wash the sludges through a TSCR-like system to remove cesium from the sludge, further reducing risk.
- **Increase redundancy through modular approaches.** Experts stated that as opposed to pursuing a single, large facility like the Pretreatment Facility or HLW Facility as currently configured, deploying multiple, smaller-scale technologies targeted at the risks of the waste may require fewer workers to operate. It also has the benefit of redundancy if one facility or technology is unable to operate for a period of time. For example, multiple experts said that modular approaches targeted at specific tank farms would require smaller crews of specialized workers than what would be needed to operate a large facility like the WTP, in addition to retrieval, waste-feed delivery, and processing workers. Other experts noted that

[70]Savanah River National Laboratory, *Follow-on Report of Analysis of Approaches to Supplemental Treatment of Low-Activity Waste at the Hanford Nuclear Reservation*, SRNL-STI-2023-00007 (Aiken, SC: January 2023).

[71]GAO-23-106151.

[72]As recently as August 2024, DOE's tank farm contractor concluded that another tank in the northwest tank farms is likely leaking.

smaller-scale technologies, such as a modular vitrification system deployed in multiple tank farms, would allow DOE to continue processing some of the waste even if there were issues with individual systems, and to apply lessons learned from one system to the next. Under DOE's current plan, if there are issues with the HLW Facility, all HLW processing could come to a halt.

Further Research and Development of Approaches Experts and DOE Identified Is Needed

Experts who participated in our meetings stated that some of the alternatives they identified, such as modular technologies or dry waste retrieval technologies, have not yet been well-tested, suggesting that further research specific to Hanford waste is needed.

As discussed above, DOE's 2022 Technology Roadmap for Hanford Tank Waste Acceleration identified several technology opportunities similar to the approaches identified by experts in our meetings.[73] The roadmap generally found that DOE could achieve significant time and cost savings by transitioning from currently planned large-scale capital projects, to options that use at-tank or modular options and non-vitrified waste forms that require less expensive treatment facilities and processes. For example, the roadmap states that investments of up to $50 million in dry waste retrieval technologies could yield over $25 billion in savings. Also, investments of up to $300 million in a TSCR-like system to perform at-tank pretreatment of the HLW sludge could yield over $25 billion in savings.

According to DOE's Technology Development Framework, the focus of the Technology Development Program is to target technology development critical to DOE needs, where solutions will reduce risks, schedule, or costs of cleanup and have a significant effect on site closures. While the framework identifies tank waste treatment as a focus area for technology development, we found in October 2021 that DOE does not have a comprehensive approach to prioritizing research and development within its focus areas.[74] We also found this could hinder the agency's ability to address long-term needs such as the Hanford tank waste cleanup mission. Further, according to the National Academies, an effective and credible risk-informed decision-making process should use current scientific knowledge and practice to produce technically credible results.[75] We recommended in 2021 that DOE develop a comprehensive approach to prioritizing research and development investments across its sites that follows a risk-informed decision-making framework. As of February 2024, DOE had not taken steps to do so.

Both DOE and experts who participated in our meetings have identified potential approaches to addressing Hanford's HLW that could accelerate the mission and save billions of dollars. By targeting research and development investments toward these known opportunities to reduce risks, schedule, and costs associated with Hanford's HLW, DOE could have greater assurance that it has identified optimal solutions to achieve its mission of cleaning up Hanford's tank waste in an efficient, cost-effective, and protective manner.

[73]The roadmap identified 35 recommended research and development areas that are expected to have the greatest benefit in cost and schedule reduction.

[74]GAO-22-104490.

[75]National Research Council of the National Academies, Committee on Risk-Based Approaches for Disposition of Transuranic and High-Level Radioactive Waste, National Research Council of the National Academies, *Risk and Decisions About Disposition of Transuranic and High-Level Radioactive Waste* (Washington, D.C.: National Academies Press, 2005).

DOE Faces Uncertainty in Implementing Alternative Approaches But Additional Analysis Could Help Identify an Optimal HLW Treatment Pathway

Legal and regulatory uncertainties are one of the main barriers DOE faces in implementing alternative approaches to managing Hanford's HLW, according to the experts who participated in our meetings convened by the National Academies. The experts also said that DOE should further analyze risk-informed approaches that could reduce costs, time, and risks before determining a path forward for HLW treatment.

DOE Faces Uncertainties That Need to Be Addressed for It to Pursue Alternative Approaches

Experts described several uncertainties that would need to be addressed to allow DOE to implement alternative approaches targeted at the physical characteristics of the waste. In some cases, experts suggested ways Congress could take steps to help address these uncertainties. In addition, we have identified uncertainties regarding whether and how DOE can pursue alternative approaches and meet commitments proposed in the holistic agreement.[76]

DOE's Authority to Classify the Waste

Experts stated that for DOE to pursue alternative approaches targeted at the physical characteristics of the waste, the agency needs greater clarity around its authority to classify some of the waste as a waste type other than high-level radioactive waste. Specifically, before DOE can consider alternate options to vitrification for treating Hanford's HLW, it has to show that this waste may be classified and managed as a type other than high-level radioactive waste for two primary reasons:

- Under EPA's RCRA regulations also adopted by Ecology, radioactive high-level mixed waste generated during the reprocessing of fuel rods must be vitrified prior to disposal.
- The waste acceptance criteria at the potential disposal facilities identified by experts (as described above) do not permit disposal of high-level radioactive waste.

DOE generally has three processes it can use to determine that certain waste from reprocessing is not high-level radioactive waste: (1) the Waste Incidental to Reprocessing Evaluation as outlined in DOE Manual 435.1-1, (2) Section 3116 of the Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005, and (3) DOE's HLW interpretation, as later incorporated in DOE Manual 435.1-1. Once a determination is made, such waste can then be managed as either LLW or TRU waste. See appendix III for further information about these tools.

However, as we have previously reported, each process has certain limitations that may prevent DOE from applying them to the treatment and disposal of Hanford's tank waste.[77] For example, DOE may be vulnerable

[76]Given that the holistic agreement was announced in April 2024, after our January and February 2024 meetings with experts, contents of the holistic agreement were not included in the scope of our discussions with experts.

[77]GAO-22-104365.

to legal challenges if it uses the Waste Incidental to Reprocessing Evaluation process set out in Manual 435.1-1 for evaluating Hanford's HLW. In addition, Section 3116 is limited to waste in Idaho and South Carolina and does not apply to Hanford or to the disposal of waste out of state. Further, the National Defense Authorization Acts of fiscal years 2020 and 2021 prohibited DOE from applying its HLW interpretation at the Hanford Site in fiscal years 2020 and 2021.[78] Finally, in the April 2024 holistic agreement, DOE stated that it intends to forebear from applying its HLW interpretation to Hanford waste for the purposes of disposal of treated waste or closure of tank systems within Washington State.

On several occasions—including in May 2017, January 2021, and December 2021—we have suggested that Congress consider clarifying DOE's authority to manage Hanford's tank waste as a waste type other than high-level radioactive waste.[79] We found that without such clarity, DOE may be vulnerable to legal challenges if it attempted to manage portions of the waste as a waste type other than high-level radioactive waste. Likewise, DOE remains vulnerable to legal challenges if it were to attempt to manage the HLW that it currently plans to vitrify in the HLW Facility as LLW or TRU waste.

The experts who participated in our meetings emphasized that congressional action to clarify DOE's authority to classify HLW as something other than high-level radioactive waste would help clear a pathway for DOE to pursue alternative approaches for the HLW. Such action could include legislation that gives DOE specific authority to classify Hanford's HLW as LLW or TRU waste under specified conditions, and to dispose of any such waste outside Washington State. This type of legislation could help DOE save billions of dollars, complete its waste treatment mission sooner, and reduce certain risks to human health and the environment.

Resource Conservation and Recovery Act Treatment Standards

Experts also stated that DOE could encounter challenges pursing alternative approaches because of lack of clarity surrounding how RCRA applies to waste that has been formerly managed as high-level radioactive waste, as we have previously reported.[80] According to DOE officials, DOE determined in the late 1980s that Hanford's tank waste possessed several hazardous waste characteristics. Under RCRA's land disposal requirements also adopted by Ecology, when hazardous waste constituents with these waste characteristics are mixed with radioactive high-level wastes generated during the reprocessing of fuel rods, the waste is required to be immobilized to meet the treatment standard of vitrification before disposal. By comparison, RCRA regulations do not require LLW with these hazardous characteristics—called mixed low-level waste—to be vitrified. Instead, mixed low-level waste is required to be treated in a way that reduces the mobility of the hazardous constituents and that meets the requirements of the disposal facility.[81]

However, in cases where waste that has previously been managed as high-level radioactive waste is classified as LLW or TRU waste, there is disagreement as to whether the associated RCRA treatment standards also

[78]The National Defense Authorization Act for Fiscal Year 2020, Pub. L. No. 116-92, § 3121, 133 Stat. 1198, 1953 (2019); The William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021, Pub. L. No. 116-283, § 3124, 134 Stat. 3388.

[79]GAO-17-306, GAO-21-73, and GAO-22-104365.

[80]GAO-22-104365.

[81]Other mixed waste must generally be physically, chemically, or thermally treated to substantially diminish its toxicity or to reduce the mobility of the hazardous constituents according to waste-specific regulatory levels. This waste may then be disposed of in a near-surface landfill, which must meet requirements established under RCRA, including that it have a double liner and a leachate collection system, which collects any liquids that leach from the disposal unit.

change or if the original treatment requirements (e.g., vitrification) must still be met. RCRA regulations are silent on whether vitrification is required for mixed low-level radioactive waste that was previously managed as mixed high-level radioactive waste. We have previously reported that DOE and Ecology disagree as to the circumstances under which waste that is classified as mixed LLW or TRU waste—but that was once managed as mixed high-level radioactive waste—need not meet the vitrification treatment standard prior to disposal.[82] According to the experts in our meetings, this disagreement regarding RCRA treatment standards is limiting DOE's ability to treat the waste using alternative approaches even though the resulting immobilized waste could be disposed of in other states.

In December 2021, we suggested that Congress consider specifying that RCRA's vitrification standard does not apply to a portion of the LAW that DOE intends to grout under the second phase of a demonstration project called the Test Bed Initiative. After we raised this issue and made our recommendation, in May 2024, EPA granted DOE a treatment variance under RCRA authorizing DOE to grout 2,000 gallons of LAW for off-site disposal. However, questions remain about how RCRA's land disposal regulations will apply to other portions of Hanford's tank waste that DOE has historically managed as high-level radioactive waste, but does not intend to vitrify.

Gaining Support from States That Could Accept the Waste for Disposal

Experts also emphasized that to pursue alternative approaches for treating HLW, DOE would need to engage with stakeholders in potential waste-receiving states and states affected by transportation. Specifically, experts stated that regulators and the public in states with disposal sites, such as Texas and Utah, could take action to try to prevent DOE from disposing of Hanford HLW that is classified as LLW at those sites. Specifically, one expert said that even though Waste Control Specialists in Texas is permitted to receive LLW, the state has a ban on high-level radioactive waste disposal. As such, if DOE faces legal challenges over its ability to classify HLW as LLW, its ability to dispose of waste in Texas would be jeopardized.[83] Other experts said that states with disposal sites could take actions, such as changing their permit requirements for disposal facilities to foreclose acceptance of Hanford tank waste, like New Mexico has done with WIPP, as discussed below. Lastly, experts raised the topic of transportation, noting that DOE may need buy-in from states along the transportation route to disposal sites.

According to experts, to allow the agency to pursue alternative approaches, it is important for DOE to improve its engagement with stakeholders in states with potential disposal sites and those that would be affected by transportation. Specifically, experts emphasized the need for DOE to improve trust with stakeholders by involving them in its decision-making processes, increasing transparency, and being proactive and specific in its communications about the alternative approaches. We reported in September 2024 that DOE does not have a national framework for engaging with stakeholders and governments about its cleanup projects, and that it

[82]As we previously reported, DOE officials believe that waste determined by the agency to be low-level radioactive waste based on the radioactivity of the waste—regardless of how it was previously managed—should be subject to the same RCRA requirements as mixed low-level waste, which does not require vitrification. Ecology officials, on the other hand, believe that RCRA regulations require mixed low-activity waste that has been reclassified from mixed high-level radioactive waste to be vitrified because the applicable treatment standards remain attached to the waste until the treatment standards, or alternative standards established through a treatability variance, have been met. For more information on this disagreement, see GAO-22-104365.

[83]DOE has shipped 3 gallons of grouted Hanford waste as Class A waste for disposal at Waste Control Specialists as part of a pilot program in 2017, indicating that this is a viable disposal site for Hanford waste that is classified as LLW.

instead delegates engagement activities to its individual cleanup sites.[84] We recommended that DOE develop a national framework for engagement that incorporates leading practices for engaging with stakeholders. One expert noted that national organizations, such as the Western Governors' Association and the National Governors Association could also aid DOE in coordinating with states on waste transportation and disposal.[85]

Waste Isolation Pilot Plant Permit Conditions

Experts who participated in our meetings also stated that regulatory changes would need to occur at WIPP for DOE to pursue alternative approaches that would classify portions of the waste as TRU waste. WIPP is the nation's only repository for defense-origin TRU waste (see sidebar). However, WIPP's permit with the State of New Mexico prohibits disposal at WIPP of waste that has ever been managed as high-level radioactive waste as well as waste from certain specified tanks at Hanford, even if the waste meets the waste acceptance criteria based on its characteristics, unless the waste is specifically approved through a permit modification.[86]

[84]GAO, *Nuclear Waste Cleanup: Adopting Leading Practices Could Strengthen DOE's Engagement with Stakeholders and Governments*, GAO-24-106014 (Washington, D.C.: Sept. 9 2024).

[85]The Western Governors' Association represents governors of the westernmost 19 states and three territories and works across a wide spectrum of policy issues to advance western priorities, according to its website. The National Governors Association includes representation from all 50 states and five territories.

[86]This restriction on Hanford tank waste going to WIPP applies to the 11 tanks that DOE has identified as potentially containing contact-handled TRU waste based on its origin.

Waste Isolation Pilot Plant: Disposal of Transuranic Waste

The Waste Isolation Pilot Plant (WIPP) is a waste repository located near Carlsbad, New Mexico, where the Department of Energy (DOE) disposes of defense-related transuranic waste.

The term “transuranic” refers to elements with an atomic number greater than that of uranium. Transuranic waste generally includes radioactive wastes containing more than 100 nanocuries of alpha-emitting transuranic isotopes per gram of waste, with half-lives greater than 20 years.

WIPP also accepts transuranic mixed waste, which is transuranic waste that also contains hazardous constituents regulated under the Resource Conservation and Recovery Act of 1976, as amended, and the New Mexico Hazardous Waste Act.

In February 2014, two accidents occurred at WIPP, one of which involved the release of radiological material that contaminated portions of the facility. As a result, DOE was forced to halt waste disposal operations while it worked to recover from the accidents. In January 2017, DOE resumed waste disposal operations at WIPP. However, DOE has been limited to disposing of no more than 10 shipments of transuranic waste per week at WIPP because of airflow issues resulting from the 2014 accidents.

We reported in November 2020 that DOE estimates WIPP’s existing physical space will be full around 2025, and DOE faces a statutory limitation on how much waste can be disposed of at WIPP. We recommended that DOE improve its schedule for adding physical space at WIPP. DOE implemented this recommendation in September 2021.

Sources: GAO, Nuclear Waste: Opportunities Exist to Reduce Risks and Costs by Evaluating Different Waste Treatment Approaches at Hanford, GAO-17-306 (May 3, 2017), and Nuclear Waste Disposal: Better Planning Needed to Avoid Potential Disruptions at Waste Isolation Pilot Plant, GAO-21-48 (Nov. 19, 2020); DOE (photo). | GAO-24-106989

One expert said that this prohibition would need to be reversed or modified before DOE could dispose of any Hanford tank waste at WIPP.

Adherence to the April 2024 Holistic Agreement

As noted above, the holistic agreement proposes that DOE will treat the HLW by reconfiguring the WTP for direct-feed of waste to the HLW Facility. While this proposed change remains subject to public comment, compliance with other laws, and court approval, it represents a strong indication of DOE's likely commitment to a path forward with its regulatory agencies.

This path forward may be compatible with some of the alternative approaches suggested by our experts. For example, the holistic agreement retains construction of the HLW Facility, but anticipates that the facility will be reconfigured and does not specify a particular volume of waste that must be treated through the facility. Thus, alternatives that the experts suggested that would involve reducing the volume of waste to be treated as high-level radioactive waste and right-sizing the HLW Facility could remain compatible with the holistic agreement as proposed.

By comparison, alternative approaches that would involve forgoing the HLW Facility entirely, such as developing a modular vitrification capability for HLW, may be more difficult to square with the future vision reflected in the agreement. However, DOE has bypassed a planned facility in the past in favor of modular approaches to meet its deadlines. For example, we previously reported that to meet its deadline to begin treating LAW by 2023, DOE suspended work on the Pretreatment Facility, which was intended to separate LAW before feeding it to the LAW Facility, and instead is accomplishing pretreatment through the smaller direct-feed LAW approach and TSCR system.[87] Experts cited TSCR as a successful model for DOE to use in considering a modular vitrification capability for HLW, as discussed above.

Under the proposed changes to the Consent Decree of 2010, as amended, DOE and Ecology would complete negotiations for revisiting and revising milestones and adding new milestones for the construction and commissioning of a reconfigured HLW Facility by 2029. While uncertainty remains regarding how DOE can pursue alternative approaches that are consistent with its commitments, this time frame reflects an opportunity for DOE, in coordination with its regulators, to complete additional analysis to support an optimal HLW treatment path.

Additional Analysis Could Assist DOE in Determining an Optimal HLW Treatment Path Before Continuing with HLW Facility Design and Construction

Experts stated that DOE should conduct additional analysis on alternative approaches before the agency moves forward with HLW treatment. Specifically, experts suggested that DOE should evaluate the extent to which Hanford's HLW should be treated as high-level radioactive waste based on its risk to human health and the environment and further assess optimal disposition pathways to identify a subset of potential approaches that would remain protective and be more cost-effective than the current baseline HLW approach.

As discussed above, DOE cannot be sure that its 2023 HLW AOA included an appropriately diverse range of alternatives for the HLW because the AOA had a narrowly defined mission need statement, presupposed the use of the HLW Facility, and was not subject to an independent review. DOE officials said the agency is restarting the critical decision process outlined in DOE Order 413.3B for the HLW Facility given the proposed changes to the HLW mission in the April 2024 holistic agreement. Restarting this process presents an

[87]GAO-20-363.

opportunity for DOE to address the issues we have identified with the 2023 HLW AOA and to conduct the additional analysis suggests by experts.

Under DOE Order 413.3B, an AOA should be conducted as part of the critical decision process for capital asset projects estimated to cost greater than $50 million, which would include the HLW Facility. DOE officials said the agency has not decided the extent to which it will conduct a new AOA for HLW treatment. Notably, the order states that an AOA may be conducted at various points in the critical decision process if new technologies or solutions become available. Experts who participated in our meetings identified new solutions that DOE did not consider in its previous AOA for addressing the HLW that could reduce risk, cost, and schedule. These solutions rest in part on the premise that some of Hanford's HLW could be managed as LLW or TRU waste based on the waste's characteristics, and therefore would not require vitrification. But DOE's 2023 HLW AOA did not evaluate potential approaches other than vitrification for treating the HLW—approaches that would rely on DOE's classification of portions of Hanford's HLW as LLW or TRU waste, rather than high-level radioactive waste. By obtaining an independent analysis of alternatives that considers opportunities to manage, treat, and dispose of Hanford's HLW as a waste type other than high-level radioactive waste, DOE would be in a better position to understand whether it is pursuing the optimal approach for HLW treatment at Hanford.

A similar analysis helped clear a new treatment pathway for DOE in the past. Specifically, in 2017, DOE contracted with a Federally Funded Research and Development Center to conduct a study related to alternative treatment options for Hanford's LAW. At the time, DOE's baseline plan was to vitrify all of Hanford's LAW, but the study recommended that DOE expeditiously implement multiple pathways for grouting of portions of the LAW for disposal off-site.[88] Since the release of the study in January 2023, DOE, EPA, and Ecology have announced the holistic agreement, which includes the proposed grouting of LAW from 22 tanks for offsite disposal.

DOE has resumed design and construction of the HLW Facility in recent years despite uncertainties and technical issues and despite the fact that DOE's efforts to analyze alternatives for treating Hanford's HLW have not followed the agency's own project management requirement. This has left DOE and its stakeholders without assurance that DOE has considered an appropriately diverse range of alternatives for optimizing HLW treatment and disposal. In light of DOE's recent announcement that it plans to reconfigure the HLW Facility as part of the holistic agreement, DOE has an opportunity to take a more risk-informed approach to determining what that reconfiguration should entail before devoting additional resources to HLW Facility, which the agency estimates will cost $10 billion to complete as currently planned. Pausing engineering design, reconfiguration, and construction activities on the HLW Facility until DOE has incorporated the results of an independent analysis of approaches that could optimize the amount of HLW that needs to be treated in the HLW Facility would give DOE greater assurance that it is directing its resources towards the most cost-effective approach. It could also accelerate the mission and reduce risks to human health and the environment by removing HLW expeditiously and reducing the risk of leaking tanks.

[88]SRNL-STI-2023-0007.

Conclusions

The April 2024 holistic agreement among DOE, EPA, and Ecology represents significant progress in right-sizing the Hanford cleanup mission. The proposed path forward could speed up site cleanup, remove waste from Washington State sooner, and save taxpayer money. The agreement proposes a reconfiguration of the HLW Facility and mission. However, according to experts who participated in our meetings convened by the National Academies, there are additional opportunities for DOE to optimize the HLW mission by pursuing alternative approaches that could be consistent with the proposed agreement, accelerate the tank waste cleanup mission, and save billions of dollars. These alternative approaches include classifying and treating portions of the HLW based on the waste's physical characteristics and reconsidering the design and need for the HLW Facility.

However, DOE faces hurdles to implementing potential alternatives, including regulatory hurdles that may leave DOE vulnerable to legal challenges if it attempts to manage some of Hanford's HLW as LLW or TRU waste. Legislation that gives DOE specific authority to classify Hanford's HLW as LLW or TRU waste—if the waste meets certain requirements—and to dispose of any such waste outside Washington State, could help DOE implement potential alternatives. Specifically, it could help DOE make risk-informed decisions for managing the HLW that would save money, complete waste treatment sooner, and reduce certain risks to human health and the environment.

Further, DOE has identified potential technologies, such as dry retrieval and in-tank or at-tank pretreatment of HLW, in its 2022 Research and Development Roadmap that have the potential to save billions of dollars and cut several years off the tank waste mission. These technologies would support the alternative approaches identified by experts that involve treating portions of the waste based on its physical characteristics and reconsidering the design and need for the HLW Facility. However, DOE has not acted on our 2021 recommendation that it develop a comprehensive approach to prioritizing research and development investments across its sites that follows a risk-informed decision-making framework. By targeting research and development investments at DOE and Hanford toward approaches that could reduce risks, schedule, and costs, DOE would have greater assurances that it has identified optimal solutions to achieve its mission of cleaning up Hanford's HLW.

While experts and DOE have identified alternative approaches for addressing Hanford's HLW, DOE has moved forward with design and construction of the HLW Facility in recent years despite significant uncertainties and unresolved technical issues. As we note above, DOE's approach for the HLW mission has not fully followed project management requirements that could have ensured the agency considered a robust range of alternatives for managing this waste before proceeding with construction. Despite the recent proposal to reconfigure the HLW Facility, it remains unclear whether DOE plans to conduct a new AOA for the HLW mission. By having an independent analysis performed on opportunities to optimize the mission by evaluating the portion of Hanford's HLW that should be managed, treated, and disposed of as high-level radioactive waste based on the risks posed by the waste, DOE and congressional decision-makers will have better assurance that DOE has assessed the best pathways for addressing the HLW.

Until this analysis is complete and DOE better understands the possible future configuration of and need for the HLW Facility, DOE risks using funds on design, reconfiguration, and construction activities that are suboptimal and may ultimately not be needed. DOE has not (1) fully explored opportunities to optimize the HLW treatment mission, (2) addressed recommendations we have made about defining a mission need

statement for the HLW treatment mission and commissioning an independent analysis of its HLW AOA, and (3) addressed certain technical issues identified by DNFSB. In our meetings convened by the National Academies, experts questioned whether the HLW Facility as currently designed would be needed if DOE took a more risk-informed approach to addressing Hanford's HLW. By pausing work on the HLW Facility until DOE takes these steps, the agency will have a defensible basis on whether the facility is needed. In addition, DOE will have greater assurance that all viable alternatives for treating Hanford's HLW have been considered and taxpayer funds are going toward the optimal approach for the HLW treatment mission.

Matter for Congressional Consideration

Congress should consider clarifying—in a manner that does not impair the regulatory authorities of EPA and the State of Washington—DOE's authority at Hanford to determine, in consultation with the Nuclear Regulatory Commission, whether portions of the tank waste can be managed as a waste type other than high-level radioactive waste. (Matter for Consideration 1)

Recommendations for Executive Action

We are making a total of three recommendations to DOE. Specifically:

The Secretary of Energy should ensure that the Senior Advisor for Environmental Management targets research and development projects for addressing Hanford's HLW toward known approaches that have the potential to reduce risks, schedule, and costs, such as the approaches identified by experts in this report and those in the 2022 Research and Development Roadmap for Hanford Tank Waste Mission Acceleration. (Recommendation 1)

The Secretary of Energy should ensure that the Senior Advisor for Environmental Management has an independent analysis performed, such as by a Federally Funded Research and Development Center, on opportunities to optimize, in a manner that is protective of human health and the environment, the portion of Hanford's high-level waste that should be managed, treated, and disposed of as high-level radioactive waste based on the physical characteristics of the waste. (Recommendation 2)

The Secretary of Energy should ensure the Senior Advisor for Environmental Management pauses engineering design, reconfiguration, and construction activities on the HLW Facility at Hanford until DOE (1) defines a mission need for the HLW project that is independent of a particular facility, technological solution, or physical end-item; (2) considers the results of an independent analysis of opportunities to optimize the portion of Hanford's HLW that should be managed, treated, and disposed as high-level radioactive waste; and (3) addresses technical issues with the HLW Facility identified by DNFSB. (Recommendation 3)

Agency Comments and Our Evaluation

We provided a draft of this report to DOE and EPA for review and comment. We also provided a copy of the draft report to Ecology in August 2024.

In its comments, reproduced in appendix IV, DOE concurred with our first and second recommendations. In response to our first recommendation that DOE target its HLW research and development efforts, DOE said that in March 2024, the department initiated technology development efforts for management and treatment of HLW. In response to our second recommendation that DOE have an independent analysis performed on opportunities to optimize HLW treatment, DOE stated that its Office of Project Management will perform an independent HLW project peer review in September 2024 and that the review will include a technical review of HLW treatment and process optimization. DOE also stated that it plans to have an independent HLW treatment optimization analysis performed, such as by a Federally Funded Research and Development Center, of alternatives to manage, treat, and dispose of Hanford's HLW within the context of legally and regulatorily permissible options.

DOE disagreed with our third recommendation that DOE pause engineering design, reconfiguration, and construction activities on the HLW Facility at Hanford until it considers the results of an independent analysis, among other things. We emphasize that this recommendation is driven by the 17 experts who participated in our National Academies' panel who highlighted opportunities to optimize HLW treatment—and noted that such opportunities differ from DOE's current plans—and in turn could help DOE remove waste from Washington State sooner than planned and save taxpayer money.

DOE stated that pausing HLW Facility design and construction activities is not an option for the reasons below. However, we believe these concerns do not preclude our recommendation.

- DOE stated that a pause in the engineering design, reconfiguration, and construction activities on Hanford's HLW Facility is inconsistent with the Consent Decree's requirements—both as they exist now and as the parties have proposed to amend them through the holistic agreement. Specifically, DOE claimed that any pause in activity on the HLW Facility could affect its ability to complete hot commissioning by 2033, as currently required by the Consent Decree. We disagree. Notably, under the existing Consent Decree, the deadlines associated with the HLW Facility do not begin until 2030—more than 5 years from the time of this report. Further, the holistic agreement indicates that the parties intend to modify the deadlines associated with the HLW Facility as additional information is developed and decisions are made regarding the proposed reconfiguration of the facility, among other things. Our recommended pause in activity on the HLW Facility does not specify a length of time, and the current deadline for DOE to complete hot commissioning of the facility is more than 9 years from the date of this report. Therefore, sufficient time exists for DOE to factor in the recommended pause without necessarily leading DOE to violate the Consent Decree.

  Moreover, we do not suggest that DOE should pause activity on the HLW Facility without coordinating with its regulators.[89] The holistic agreement proposes new milestones under which (1) DOE will provide to Ecology a "critical path" schedule for achieving a direct-feed configuration of the HLW Facility by December 2028 and (2) DOE and Ecology will complete negotiations to revisit and, if necessary and appropriate, revise the HLW Facility milestones by June 2029. The holistic agreement further notes that the DOE plans to charter several AOAs as a part of the proposed changes to the cleanup approach and notes that DOE and Ecology have agreed "that it can be beneficial for Ecology to have early and meaningful insight, and in some cases input, into these processes." We believe the negotiations contemplated by the holistic agreement (such as those related to revised milestones for the HLW Facility) and DOE's stated plans to conduct further AOAs with input from Ecology present an

[89]See, for example, our September 2024 report on stakeholder engagement. GAO-24-106014.

opportunity for DOE to work with its regulators to pause activity on the HLW Facility while it undertakes the analyses we recommend in concert with other AOAs already anticipated by the parties.

- DOE stated that other regulatory requirements also inhibit DOE's ability to pause its planned path forward on HLW treatment. Specifically, DOE noted that the hazardous component of Hanford's tank waste is subject to regulation under the RCRA permit administered by Ecology and that RCRA requires HLW to be vitrified. Thus, DOE concludes, a vitrification facility will be required for Hanford's HLW "regardless of any potential future waste characterization decisions." This claim, however, does not comport with DOE's prior statements, or the path forward outlined in the holistic agreement. In 2021, DOE officials told us that DOE has the authority under the Atomic Energy Act of 1954, as amended, to manage the radioactive component of tank waste, including the authority to determine if the waste is no longer considered to be high-level radioactive waste based on its characteristics. At that time, DOE officials informed us that they believe that waste determined to be LLW based on its radioactivity should be subject to the same RCRA requirements as mixed LLW, which does not require vitrification.[90] Thus, DOE's claim that Hanford's HLW has to be vitrified—even if DOE characterizes portions of the HLW as TRU waste or LLW in the future—is not supported by its prior statements on this subject.

  The holistic agreement likewise does not support DOE's assertion. Therein, the parties have proposed that DOE will treat the LAW from 22 tanks at Hanford with grout. Like Hanford's HLW, the LAW in these 22 tanks is currently being managed by DOE as high-level radioactive waste, and DOE will need to go through specific steps to manage this waste as LLW.[91] Thus, DOE and its regulators have already considered a path forward under which DOE will use grout to treat waste that DOE once managed as high-level radioactive waste. Similarly, according to experts, if portions of the waste that DOE intended to vitrify as HLW were classified as other waste types, DOE could deploy alternative treatment approaches that use simpler and, in many cases, existing technologies targeted at the physical characteristics of the waste. This in turn could speed up site cleanup, remove waste from Washington State sooner, and save taxpayer money.

  Furthermore, we emphasize that our report does not state that DOE will not require any vitrification capability to address Hanford's waste. To the contrary, our experts noted that some portion of Hanford's HLW should still be managed as high-level radioactive waste and vitrified accordingly. Thus, our experts acknowledged that DOE will need a facility or other capability to vitrify waste at Hanford. Our recommendation is aimed at ensuring that DOE has evaluated not whether the department requires *any* vitrification facility, but rather whether it specifically needs the HLW Facility as it is currently designed. None of the existing agreements governing Hanford cleanup specify a particular volume of waste that must be treated through the HLW Facility, and if DOE does not pause construction of the facility before analyzing alternatives and resolving technical issues, it could be wasting taxpayer money on a facility that is not appropriately scaled to the volume of waste that requires vitrification.

- DOE suggested that pausing activity on the HLW Facility would not align with Congress's decision to fund design and construction activities for the facility for the last 2 years. However, recent

[90]GAO-22-104365.

[91]See appendix III for further information about the processes DOE can use to classify waste from the reprocessing of spent nuclear fuel as something other than high-level radioactive waste.

appropriations for the HLW Facility have been no-year money that will remain available for construction in the future. DOE has carried over large sums of Hanford project funding in years past, and could do so again while it assesses the best configuration for the HLW Facility. Despite prior appropriations, DOE slowed construction of the HLW Facility for 12 years—from 2012 through 2024—due to technical challenges with the facility. We believe an additional pause to ensure that DOE is taking the optimal path forward for HLW treatment is the best approach to guarantee that the department is wisely spending the funding it has been appropriated.

- DOE stated that it believes a pause in the HLW Facility would likely result in increased project costs upon resumption of HLW Facility activities. The uncertainties we noted in our report related to the HLW Facility design and construction—along with the potential alternative approaches that experts identified for treating the HLW that could save money over the long term—we believe constitute a legitimate programmatic reason for delaying obligating funds to the design and construction of the HLW Facility. In addition, in the absence of analysis supporting this comment, we continue to question the prudence of spending billions of taxpayer dollars to design and build a facility that DOE has not determined to be the optimal HLW treatment approach.

- DOE stated that it will continue to consider opportunities to optimize the fraction of Hanford's tank inventory that should be managed as high-level radioactive waste and noted that its 2023 HLW Facility AOA and its associated addendum considered multiple options for management, treatment, and disposal of Hanford HLW. However, in May 2023, we found that DOE had not committed to obtaining an independent review to validate the portions of that analysis related to HLW treatment.[92] According to DOE guidance and GAO best practices, before selecting an alternative, an independent entity should review and validate the analysis of alternatives process. We recommended that DOE obtain such an independent review before selecting an alternative. DOE concurred with our recommendation, but as of July 2024, has not obtained such an independent review and validation of its analysis. Given the enormous cost and schedule implications of the HLW treatment decision, it is essential for DOE to take steps before it continues construction of the HLW Facility—a project that is expected to cost $10 billion to complete and billions more to operate—to provide assurance that all viable alternatives for optimizing the tank waste treatment mission are considered.

- DOE stated that pausing construction of the HLW Facility is not necessary to address the DNFSB technical issues because DOE continues to actively work with the DNFSB throughout the HLW facility design and construction. However, DNFSB officials told us in April 2024 that shifting to a direct-feed approach to HLW treatment would likely result in modifications not only to the facility, but also to the assumptions about the amount and type of waste that the facility will treat. Until DOE reconfigures the facility to incorporate these changes, DNFSB officials said they cannot fully assess whether DOE has resolved these technical issues. Similarly, an April 2024 DOE review of the status of the HLW Facility's design found that because of the changes related to this new direct-feed approach, there is a risk of rework if the contractor does not first review how these changes may impact the overall project.[93] We believe that proceeding with construction of a facility that was paused for over a decade without ensuring that its technical challenges have been fully resolved is an irresponsible use of taxpayer dollars.

[92]GAO-23-106093.

[93]Department of Energy, *Baseline Design Review Report for the High-Level Waste Facility* (Richland, WA: April 2024).

As DOE prepares to reconfigure the HLW Facility, it has an opportunity to obtain an independent analysis to support an optimal HLW treatment path and ensure that all technical issues have been fully resolved. By pausing engineering design and construction activities on the HLW Facility until DOE obtains such an analysis and fully resolves technical issues, DOE will have greater assurance it has considered all viable alternatives for treating Hanford's tank waste and chosen an optimal approach before devoting more taxpayer resources to the facility.

We also received technical comments from DOE, which we incorporated as appropriate.

In its comments, reproduced in appendix V, EPA stated that it disagreed with our Matter for Congressional Consideration, as well as two of our recommendations to DOE. Regarding the Matter for Congressional Consideration—which suggests that Congress clarify DOE's authority to manage portions of Hanford's tank waste as a waste type other than high-level radioactive waste—EPA made the points below, which we address in turn.

- EPA stated that it would be "extremely difficult" to craft the suggested clarification in a manner that does not impair the regulatory authority of the EPA or the State of Washington. We believe EPA's concern is misplaced. Our Matter is directed specifically at clarifying DOE's authority to manage the radioactive portion of Hanford's tank waste pursuant to the Atomic Energy Act of 1954, as amended, and the Nuclear Waste Policy Act of 1982, as amended. Our Matter does not, by comparison, ask Congress to adjust, impair, or in any way opine on EPA or Ecology's authority to regulate the hazardous portion of Hanford's waste pursuant to RCRA. Congress has already acted—in Section 3116 of the Ronald W. Reagan National Defense Authorization Act for 2005—to clarify DOE's authority to determine that certain radioactive waste from the reprocessing of spent nuclear fuel is not high-level radioactive waste, but this provision applies only to waste in Idaho and South Carolina. This law has been successfully applied at the Savannah River Site in South Carolina for nearly two decades. We fail to see how Congress acting to provide similar clarity in support of DOE's management of *radioactive* waste at Hanford would necessarily impair EPA or Ecology's regulatory authorities related to the *hazardous* portions of the waste.

- EPA stated that the holistic agreement addresses retrieval and disposal of tank waste without needing to rely upon such a clarification. However, the holistic agreement does not address DOE's legal authority to classify Hanford's waste as a waste type other than high-level radioactive waste. As EPA noted in its agency comments, on several occasions—including in May 2017, January 2021, and December 2021—we have suggested that Congress consider clarifying DOE's authority to manage Hanford's tank waste as a waste type other than high-level radioactive waste.[94] We found that without such clarity, DOE may be vulnerable to legal challenges if it attempts to manage portions of the waste as a waste type other than high-level radioactive waste. In the holistic agreement, DOE has agreed to forebear from applying the HLW Interpretation at Hanford for certain purposes and, as previously stated, Section 3116 does not apply in Washington State. That leaves DOE just one tool—the Waste Incidental to Reprocessing Evaluation process—that it can generally use to determine that reprocessing waste at Hanford is not high-level radioactive waste. DOE will need to rely on this tool to achieve the path forward proposed in the holistic agreement. For example, because mixed radioactive high-level wastes generated during the reprocessing of fuel rods must be vitrified under RCRA, in order to grout waste from 22 of Hanford's tanks, DOE will first need to determine that the waste in those

[94]See GAO-17-306, GAO-21-73, and GAO-22-104365.

tanks can be managed as something other than high-level radioactive waste, presumably using its Waste Incidental to Reprocessing Evaluation. But, as we note above, we have found that this process—which is laid out in DOE Manual 435.1-1—is vulnerable to legal challenges. Aspects of the holistic agreement rely on DOE's ability to classify portions of Hanford's waste a something other than high-level radioactive waste, but the agreement itself does nothing to address the legal uncertainty surrounding DOE's authority to do so.

- EPA stated that the EPA's recent issuance of a variance from Land Disposal Restrictions under RCRA for the Hanford Test Bed Initiative is a demonstration of how existing legal authorities can be used effectively to manage waste using a technology other than vitrification. We note, however, that RCRA governs the *hazardous* waste component of Hanford's tank waste, while our Matter for Congressional Consideration addresses the *radioactive* components of Hanford's tank waste. Even with EPA's variance allowing the Test Bed Initiative to proceed under RCRA, DOE remains vulnerable to legal uncertainty related its management of the radioactive portions of the waste pursuant to the Atomic Energy Act of 1954, as amended, and the Nuclear Waste Policy Act of 1982, as amended.

We continue to believe that legislation that gives DOE specific authority to classify portions of Hanford's tank waste as LLW or TRU waste under specified conditions, and to dispose of any such waste outside Washington State, could help DOE complete its waste treatment mission sooner, save billions of dollars, and reduce certain risks to human health and the environment.

In its comments, EPA noted that it also disagrees with our second and third recommendations. Both recommendations are directed to DOE and therefore do not require concurrence from EPA, but we will respond to EPA's concerns nonetheless.

First, EPA stated that it disagrees with our second recommendation that DOE have an independent analysis conducted on opportunities to optimize HLW treatment. Regarding this recommendation, EPA made the following points:

- EPA stated that implementing this recommendation is unnecessary because the three parties to the holistic agreement considered DOE's independent analyses. However, as we state in our report, DOE has no assurance that its 2023 HLW AOA included an appropriately diverse range of alternatives for the HLW because the AOA had a narrowly defined mission need statement that presupposed the use of the HLW Facility. In addition, that AOA was not subject to an independent review. Moreover, DOE officials said the agency is restarting the critical decision process outlined in DOE Order 413.3B for the HLW Facility given the proposed changes to the HLW mission in the holistic agreement. DOE Order 413.3B requires DOE to conduct an AOA for capital asset projects estimated to cost more than $50 million, which would include the HLW Facility.

- EPA stated that "this report seems to point to the DOE interpretation of HLW in 2019 as justification for further analysis and optimization." This is not an accurate statement. We do not include any mention of the HLW Interpretation in our presentation of information regarding the experts' recommendation that DOE should conduct additional analysis on alternative approaches before the agency moves forward with HLW treatment. Nor did our experts suggest that optimizing HLW treatment at Hanford would necessarily rely on DOE's HLW Interpretation. Therefore, EPA's concern is misplaced.

- EPA stated that attempts to optimize waste treatment would "trigger the need to change the regulatory authority of both the EPA and the State of Washington." Our report acknowledges that there is

disagreement between DOE and Ecology regarding Ecology's regulatory authority over certain Hanford waste under RCRA. Specifically, the parties disagree on how RCRA's treatment standards apply to waste that DOE classifies as mixed LLW or TRU waste but that DOE once managed as mixed high-level radioactive waste. We note that this area of uncertainty presents a barrier that would need to be addressed to implement alternative approaches discussed by experts. But that does not mean that the analysis we recommend is, as EPA stated, "unlikely to add value." By conducting an independent analysis of opportunities to optimize HLW treatment, all parties, as well as Congress and American taxpayers, will have greater assurance that DOE has assessed the best pathways for addressing the HLW. We believe information gained through such assessment is particularly important where DOE, EPA, and Ecology have already found existing regulatory mechanisms—such as EPA's variance for the Test Bed Initiative—to address areas of legal disagreement that could inhibit opportunities to optimize HLW treatment.

We continue to believe that in light of DOE's recent announcement that it plans to reconfigure the HLW Facility as part of the holistic agreement, DOE has an opportunity to take a more risk-informed approach to determining what that reconfiguration should entail.

Second, EPA stated that it disagrees with our third recommendation that DOE should pause engineering design, reconfiguration, and construction activities on the HLW Facility until it takes several steps, including addressing technical issues raised by the DNFSB. Regarding this recommendation, EPA made the following points:

- EPA stated that this recommendation will conflict with achieving the objectives and milestones of the holistic agreement and thereby slow the treatment and disposal of tank waste. For the reasons stated above in our response to DOE's comments, we do not agree.

- EPA stated that several milestones related to retrieval of tank waste, including from known and assumed leaking tanks, hinge on the completion of HLW hot commissioning. We agree that urgent action is needed to address leaking tanks. However, according to experts, DOE could *accelerate* the overall cleanup schedule and reduce risks to the environment if DOE took a more risk-informed approach to classifying and treating the HLW. For example, one expert said that pursuing approaches that can be implemented in the near term, rather than waiting on the HLW Facility as currently designed to be built and process waste, is significantly better from a risk-reduction standpoint given the state of the single-shell tanks. Experts also said that there are benefits to deploying multiple, smaller-scale technologies targeted at the risks of the waste, rather than pursing a single, large facility like the HLW Facility as currently configured. For example, under DOE's current plan, if there are issues with the HLW Facility, all HLW processing could come to a halt. Completing construction of a facility that may not be appropriately sized and designed for the amount of HLW that needs to be vitrified may not be the most optimal way to accelerate treatment and disposal of the HLW.

- EPA stated that the recommended pause on the HLW Facility "upends the holistic negotiations" and ignores the product of "these difficult, but fruitful, negotiations and will lead to inefficient additional resource investment and delay." As we state above, many of the alternatives proposed by our experts could be compatible with the holistic agreement and would not "upend" the negotiations. Moreover, continuing to spend taxpayer dollars on a facility that may not be needed in its current design may lead to inefficient resource investments. We applaud the progress made by holistic agreement, but we believe there is more work to be done to ensure that the reconfiguration of the HLW Facility proposed by the agreement is done in the most optimal way possible.

We continue to believe that by pausing engineering design, reconfiguration, and construction activities on the HLW Facility until DOE has taken certain steps, DOE would have greater assurance that it is directing its resources towards the most cost-effective approach that could also accelerate the mission and reduce risks to human health and the environment.

We also received technical comments from EPA, 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 VI.

Nathan J. Anderson
Director, Natural Resources and Environment

List of Committees

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

The Honorable Patty Murray
Chair
The Honorable John Kennedy
Ranking Member
Subcommittee on Energy and Water Development
Committee on Appropriations
United States Senate

The Honorable Mike Rogers
Chairman
The Honorable Adam Smith
Ranking Member
Committee on Armed Services
House of Representatives

The Honorable Chuck Fleischmann
Chairman
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

The objectives of our review were to examine (1) the status of the Department of Energy's (DOE) current approach to addressing Hanford's high-level waste (HLW), including any barriers to its approach; (2) alternative approaches that could minimize the fraction of waste that would need to be treated as high-level radioactive waste and the extent to which these approaches would affect DOE's current cost and schedule estimates; and (3) steps, if any, DOE could take to pursue alternative approaches.

According to DOE officials, as a matter of policy, DOE manages all Hanford tank waste as if it is "high-level radioactive waste" as defined by federal law unless, and until, the waste is formally classified as another waste type.[1] By comparison, 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. To determine the scope of Hanford's waste that would be included in our objectives, we reviewed past GAO work on DOE's plans for treating Hanford waste, DOE reports on Hanford waste, and visited the Hanford Site in August 2023. Based on these sources, we consider HLW for the purposes of our objectives to be the tank waste the DOE does not plan to treat as low-activity waste (LAW). This includes:

- the high-radioactivity portion of waste in the tanks at Hanford (excluding the waste DOE is treating as low-activity waste); and
- waste captured in ion exchange columns at Hanford as part of the Tank Side Cesium Removal (TSCR) system.

To inform and provide context for all three objectives, we reviewed reports on DOE's plans and associated costs for treating Hanford's HLW, such as the River Protection Project System Plan Revisions 9 and 10.[2] We also reviewed reports on alternative approaches DOE has analyzed for treating the waste, such as the agency's 2023 report on the Waste Treatment and Immobilization Plant High-Level Waste Treatment Analysis of Alternatives.[3] We interviewed officials from DOE, the Environmental Protection Agency (EPA), the Defense Nuclear Facilities Safety Board (DNFSB), and professionals and former DOE officials with experience in nuclear waste management to better understand the history of DOE's HLW management at Hanford and alternative approaches it has considered for treatment. We identified potential professionals and former DOE officials to interview through our Hanford Site visit and by reviewing who had participated in our past work on Hanford tank waste cleanup, including prior experts' meetings. Through these interviews and document reviews, we developed a conceptual model that summarized key decision points that DOE faces in addressing the HLW at Hanford (see fig. 5). This conceptual model informed the structure and questions that we developed for our January and February 2024 experts' meetings, as described below. We also interviewed

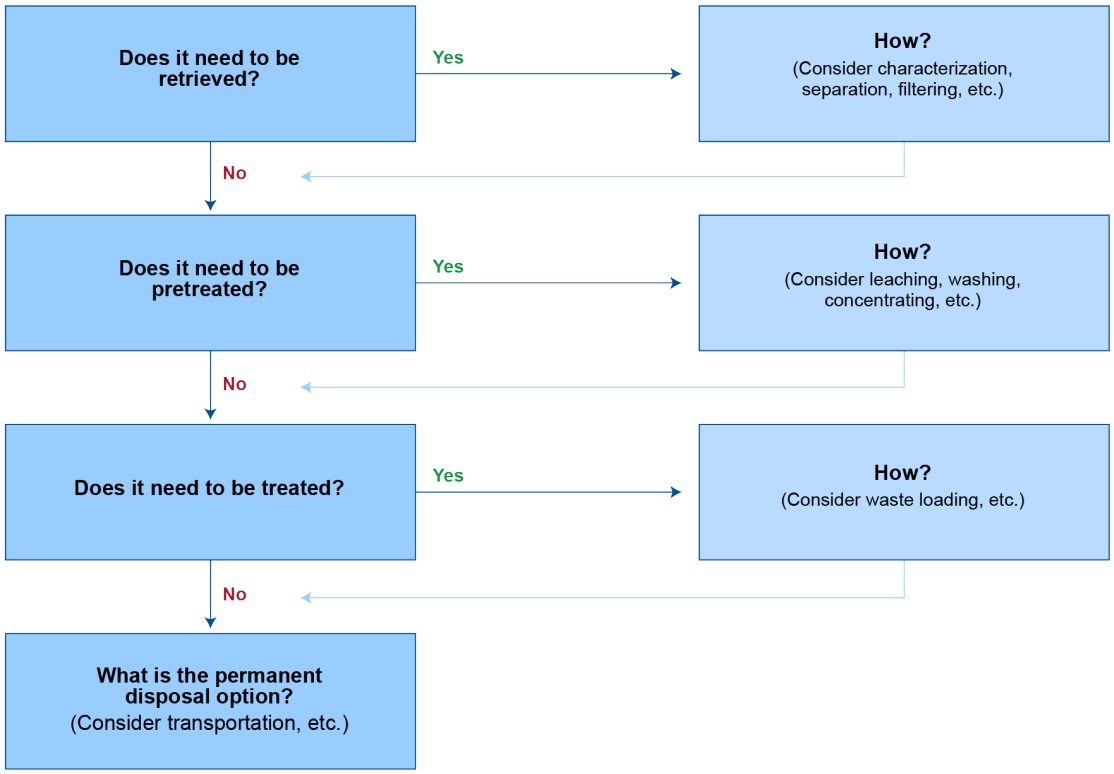
[1]High-level radioactive waste is defined in the Nuclear Waste Policy Act of 1982 as "(A) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in the reprocessing and any solid material derived from such liquid waste that contains 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, 42 U.S.C. § 2014(ee), and the Waste Isolation Pilot Plant Land Withdrawal Act, Pub. L. No. 102–579, § 2(10), 106 Stat. 4777 (1992).

[2]United States Department of Energy, *River Protection Project System Plan,* ORP-11242 Rev. 9 (Richland, WA: October 2020) and United States Department of Energy, *River Protection Project System Plan,* ORP-11242 Rev. 10 (Richland, WA: December 2023)

[3]Department of Energy, *Waste Treatment and Immobilization Plant High-Level Waste Treatment Analysis of Alternatives* (Washington, D.C.: Jan. 12, 2023).

officials from the Washington State Department of Ecology (Ecology) in August 2023. Thereafter, Ecology officials declined our requests for interviews regarding this report. In addition, we provided a copy of the draft report to Ecology in August 2024, when we also sent the draft to DOE and EPA for comment.

Figure 5: Conceptual Model of Key Decision Points for Addressing Hanford High-Level Waste



Source: GAO analysis of interviews and Department of Energy documents. | GAO-24-106989

Selection of Experts

To address all three of our objectives, we collaborated with the National Academies of Sciences, Engineering, and Medicine (National Academies) to convene 4 days of virtual and in-person meetings with a total of 17 experts on alternative approaches to address Hanford's HLW. The 2-day virtual component of the meetings were held by Zoom on January 9 and 10, 2024, with 15 of the experts attending.[4] The 2-day in-person component of the meetings was held in Washington, D.C. on February 27 and 28, 2024, with 17 experts attending.[5]

[4]Two experts who were invited to both meetings could not attend the virtual sessions but were able to attend the in-person sessions.

[5]One international expert participated virtually for both the January virtual sessions and the February in-person sessions.

We used three methods to identify experts to invite to participate in the meetings. First, we reviewed a list of experts familiar with Hanford's nuclear waste that was identified in prior GAO work.[6] We identified 21 potential experts through this method.

Second, we conducted a general search of academic literature and past GAO work and interviewed former DOE officials and others knowledgeable about Hanford waste to better understand the complexities of addressing Hanford HLW. During these interviews, we asked for suggestions of additional potential experts. We identified 19 potential experts through this method.

Lastly, we requested that the National Academies identify a list of experts with specializations in the areas of Hanford HLW treatment and policy, legal, and related factors relevant to Hanford HLW treatment. The National Academies identified 55 potential experts through this method, some of whom we had also identified through the other methods described above. In total across the four methods, we identified 67 unique potential experts.

Pulling from the potential experts identified by all three methods, we collaborated with the National Academies to select a list of experts representing different areas of expertise on nuclear waste cleanup and a broad mix of backgrounds, such as from state and federal government agencies, academia, and industry. In our final selection of experts, we sought to balance experts that would represent a variety of expertise on scientific topics, including nuclear waste characterization, treatment, and disposal, as well as legal, policy, and economics topics. Our final list of experts who agreed to participate contained 17 experts.

We asked the experts to disclose any potential conflicts of interest, such as any current financial or other interest that might conflict with their service. We determined the 17 experts were free of conflicts of interest and judged the group as a whole to have no inappropriate biases. The views of these experts cannot be generalized to everyone with expertise on HLW or Hanford; they represent only the views of the experts who participated in our meetings hosted by the National Academies. The experts who participated in our meetings are listed in table 1.

Table 1: Experts Participating in GAO's January 2024 (Virtual) and February 2024 (In-Person) Experts' Meetings

Expert	Affiliation
John Applegate	Indiana University
Thomas Brouns	Pacific Northwest National Laboratory
James Conca	UFA Ventures, Inc.
Rodney Ewing	Stanford University
Gerald Frankel	The Ohio State University
Christine Gelles	Longenecker and Associates
Michael Greenberg	Rutgers University
Jane Hedges	Independent Strategic Management Solutions
Michael Kavanaugh	Independent Consultant
David Kosson	Vanderbilt University
Robert Ledoux	Advanced Research Projects Agency—Energy

[6]GAO, *Nuclear Waste: Opportunities Exist to Reduce Risks and Costs by Evaluating Different Waste Treatment Approaches at Hanford*, GAO-17-306 (Washington, D.C.: May 3, 2017).

Expert	Affiliation
Ken Picha	TechSource, Inc.
William Ramsey	Savannah River National Laboratory
Monica Regalbuto	Idaho National Laboratory
James Rispoli	North Carolina State University
Rebecca Robbins	International Atomic Energy Agency
Jane Stewart	Consortium for Risk Evaluation with Stakeholder Participation

Source: GAO. | GAO-24-106989

Meetings Content

In the virtual component of the meetings, we asked the experts to discuss issues related to the definition of HLW at Hanford, including its characteristics and potential classifications, possible alternative approaches for addressing the waste, and prioritizing these approaches for further discussion. Specifically, these topics were covered in four virtual sessions over 2 days: (1) potential waste types, (2) brainstorming alternative approaches for waste that could be characterized as something other than high-level radioactive waste, (3) brainstorming alternative approaches for waste characterized as high-level radioactive waste, and (4) prioritizing potential approaches.

For the first virtual session of four held over 2 days, we asked experts to discuss the extent to which the HLW that DOE currently plans to treat as high-level radioactive waste should be treated as such according to its physical characteristics and risk. We based this discussion on background information provided to the experts about statutory and regulatory definitions of different classifications of waste, DOE tools used to classify and manage waste, international approaches for classifying waste, and DOE data on the chemical and radiological components of the waste.

For the second and third virtual sessions, we asked experts to brainstorm approaches for addressing the waste that have the potential to result in cost savings and remain protective of human health and the environment when compared to DOE's baseline plan.[7] As previously mentioned, we developed a conceptual model shown in figure 5 above representing the various decision points DOE faces in addressing Hanford's HLW, based on our review of DOE documents and interviews with officials and knowledgeable professionals. We used this conceptual model to structure the discussion in three virtual breakout groups, each containing a subset of the experts. Specifically, we asked experts in each breakout room to identify alternative approaches that included each decision point of the conceptual model. To foster innovative idea generation, experts were instructed to remove some assumptions that have guided DOE's past efforts for developing HLW alternatives. These assumptions included all tank waste considered HLW must be immobilized by vitrification, and alternatives must use proven and established technologies.

For the fourth virtual session, we asked experts to discuss and complete a series of polls—administered via Zoom—to prioritize each of the alternative approaches brainstormed in sessions two and three. Specifically, experts anonymously rated each alternative approach on the likelihood that it would be less expensive than DOE's baseline plan and their confidence that the approach would be protective of human health and the environment. Each expert also selected a subset of approaches that had the greatest and least potential to

[7]We described DOE's baseline plan consistent with Scenario 1 of the agency's *River Protection Project System Plan Revision 9*.

result in cost savings, and be protective of human health and the environment. Between the virtual and in-person components of the meetings, we sent a questionnaire to the experts. The questionnaire asked them to review the alternative approaches that were most frequently selected as having the least potential and respond with any that they believe had enough potential to be discussed during the in-person component of the meetings and why. The questionnaire also asked experts to review the remaining approaches developed during the virtual component and provide a rationale for which approaches, if any, were similar enough to be combined. Based on experts' responses to the questionnaire, we reduced the number of individual approaches that would be discussed during the in-person component of the meetings from 24 to 14.

For the in-person component of the meetings, we asked the experts to discuss issues related to the potential cost, risk, and schedule outcomes associated with the 14 alternative approaches identified during the virtual component. We also asked them to discuss barriers that DOE may face in implementing the approaches, and potential solutions that DOE or Congress could pursue to overcome the barriers. Specifically, these topics were covered in four sessions over 2 days: (1) the locations of different waste types at Hanford, (2) brainstorming components needed to implement each alternative approach and potential cost and schedule outcomes, (3) brainstorming changes that would be needed to implement alternative approaches, and (4) future actions related to Hanford high-level waste.

For the first in-person session, we asked experts to discuss where different potential waste types are located in Hanford's tank farms and which of the 14 alternative approaches would be appropriate for each waste type and location. In the second in-person session, we split the experts into breakout rooms by waste type to discuss the components that would be needed to implement a subset of the 14 alternative approaches that applied to that particular waste type. The specific components we asked experts to discuss included new facilities or technologies required, the possible repurposing of existing facilities or technologies, and the continued need for existing facilities or technologies. We also asked experts to discuss why they believed the approach would be protective of human health and the environment. Experts also discussed, and to the extent possible, estimated potential cost and schedule outcomes that may be associated with each approach. These included potential cost savings, cost increases, schedule impacts, and general barriers, constraints, or risks related to each approach.[8]

For the third in-person session, we asked experts to discuss barriers and potential solutions related to the alternative approaches. Specifically, we asked experts what changes or actions would be needed to address the various barriers, constraints, and risks related to alternative approaches that they identified during session two. We grouped these barriers, constraints, and risks into three general categories for ease of discussion: (1) administrative (including legal and regulatory), (2) technical, and (3) other. We also asked experts what specific steps DOE or Congress could take to enable the changes and potential benefits of implementing the changes. The fourth in-person session was a final discussion where we asked experts to discuss the future of Hanford HLW management and potential recommendations for saving taxpayer money.

Content Analysis

All sessions of the January and February meetings were recorded and transcribed to ensure that we accurately captured the experts' statements. After the meetings, we analyzed the transcripts to characterize the experts' responses and to identify major themes. Specifically, we used NVivo—a software program for qualitative

[8]We asked experts to brainstorm rough order of magnitude estimates of potential cost savings, not precise cost or savings estimates.

analysis—to assist with coding the comments using categories that we identified based on (1) our researchable questions, (2) the structure that we established for the meetings sessions, and (3) key topics summarized at various points during the meetings.

Two analysts reviewed all statements made by experts during the January virtual and February in-person meetings and coded them into 37 topic areas, as applicable. Example topic areas included cost benefits, risk barriers, and technology solutions. After relevant expert statements has been coded into topic areas by the two analysts, one analyst reviewed all coding and flagged any statements that appeared to be coded to conflicting topic areas (e.g., the same statement coded to cost benefits and cost barriers). The two analysts discussed any conflicting categorizations and reconciled them as appropriate.

For each topic area, we exported each experts' statements on that topic into a single document. We further analyzed the statements made by each expert related to that topic area, and summarized experts' statements into common themes about that topic. We did not include all statements made by experts in analyzing common themes about a topic. In determining what statements were relevant to a particular topic and should be included as a common theme stated among experts, we considered whether the statement (1) was raised by multiple experts, (2) was within the core of the commenting experts' base of knowledge (e.g., a legal expert was not commenting on the specifics of a technological approach), (3) provided illuminating detail or illustrative examples, and (4) was well articulated. We considered statements that met some or all of these characteristics to be strong evidence and used language such as "experts discussed," "experts said," or "according to experts" to characterize such themes. If a statement was raised by only one expert with particular expertise in that area, and we considered the statement to be strong evidence, we characterized those statements using language such as "according to one expert" or "one expert said."

Because every expert did not speak on every topic and did not have the same level of expertise on every topic, we do not specify the number of experts who agreed or disagreed with various themes raised. In addition, for reporting purposes, we cannot include a complete list of themes and comments made by the experts because of the technical complexities of this subject and the various ways that each theme could be articulated. We believe we were able to identify the common themes that emerged from the meetings, noted any key differences of opinion on a topic, and selected specific comments to include in our report to serve as illustrative examples of these themes. To the extent possible, we corroborated experts' statements with documents and data.

We also administered polls via Zoom to the experts to ensure that we could collect anonymous responses from each expert on several questions. Because the poll questions were administered to all experts and included the option to respond, "no basis to judge" to account for experts who may not have expertise in a particular area, for reporting purposes, we specify the number of experts who agreed on a particular response, such as "10 of 15 experts."

Hanford Tank Waste Analysis

We also conducted an analysis of Hanford tank waste data to corroborate experts' views on the extent to which DOE may be able to identify and potentially treat portions of the Hanford tank waste as a waste type other than high-level radioactive waste based on its physical characteristics. We downloaded data as of May 2024 from DOE's Best Basis Inventory (BBI), which is DOE's publicly available database containing inventory estimates for chemical and radionuclide components in Hanford's tanks. We reviewed documents on how the data are

compiled and updated. According to DOE officials, the BBI contains the best information available regarding the contents of the tanks and based on the same data that DOE uses estimate the contents of the tanks. We determined the data to be sufficiently reliable for corroborating experts' views on the extent to which the tank waste could potentially be classified as low-level radioactive waste (LLW) based on its physical characteristics.

Specifically, we analyzed the extent to which waste in each of the 177 Hanford tanks may fall below radionuclide concentration limits for LLW established in Nuclear Regulatory Commission (NRC) regulation 10 C.F.R. § 61.55. On a tank-by-tank basis, we analyzed the downloaded BBI data to determine whether the concentration of certain radionuclides in each tank fell below concentration limits for Class A, B, or C LLW defined in 10 C.F.R. § 61.55. We also calculated total radioactivity of all radionuclides in the tank waste using BBI data, and reviewed waste volumes as reported in DOE's Tank Waste Monthly Summary for additional context. Appendix II contains further detail on our tank waste analysis methodology.

We conducted this performance audit from July 2023 through September 2024 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: GAO Analysis of Select Characteristics of Hanford's Tank Waste

Background on Hanford Tank Waste

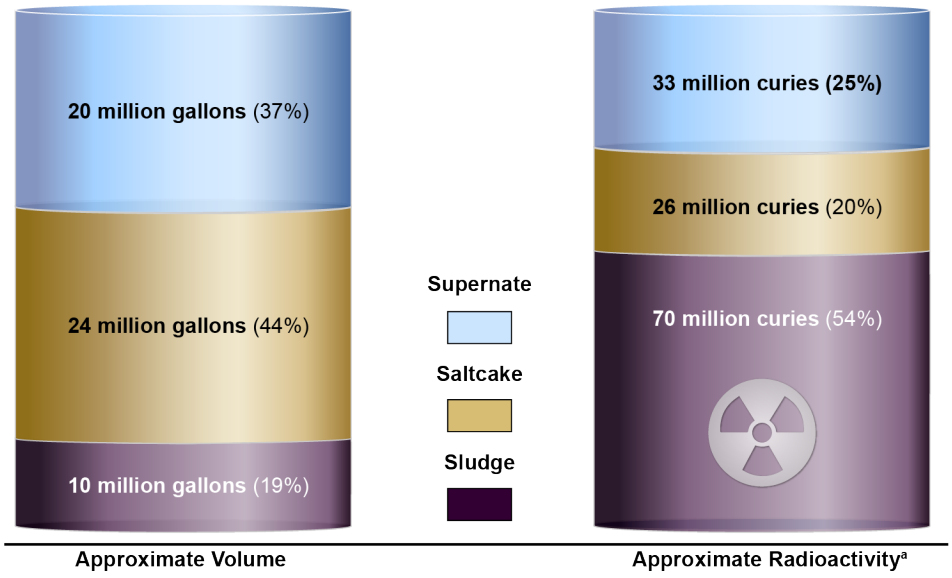
The Hanford Site has 177 tanks with legacy waste left over from the production of plutonium for nuclear weapons dating back to the Manhattan Project in 1943 through the Cold War. Plutonium was produced at Hanford by irradiating fuel rods containing uranium in a nuclear reactor to create a fission reaction. The rods were then put through chemical processes to remove cladding and other materials and extract the plutonium. As a result of the fuel processing and plutonium removal, a mixture of radioactive and chemical waste was produced. At Hanford, this waste was put into 177 underground storage tanks—ranging from 55,000 gallons to 1 million gallons—until treatment and final disposal paths could be determined. In total, waste in the 177 tanks contain about 129 million curies of radioactivity.[1]

Over the years, the tank waste has settled into three main layers (see fig. 6):

- **Sludge.** The bottom layer, consisting of denser, water-insoluble components. These components form a thick substance with the consistency of peanut butter.
- **Saltcake.** The middle layer—consisting of water-soluble components, such as sodium salts—sits above the sludge. These components crystalize or solidify out of the waste solution to form a moist sand-like material.
- **Supernate.** The top layer, consisting of water and dissolved salts. It generally sits above denser layers.

[1]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. In its System Plan 10, the Department of Energy (DOE) uses 119 million curies as the total radioactivity in the 177 tanks. We use 119 million curies in the body of our report; however, for the purposes of this appendix, we use 129 million curies, which reflects the total radioactivity for the 177 tanks from the Best Basis Inventory (BBI), as of the end of May 2024. In our analysis below, where we specifically look at 155 tanks that do not include 22 tanks considered retrieved or retrieval in process, the total radioactivity is 126 million curies.

Figure 6: Volume and Radioactivity of Hanford Tank Waste, by Waste Layer, as of May 2024



Source: GAO analysis of Department of Energy data. | GAO-24-106989

Accessible Data for Figure 6: Volume and Radioactivity of Hanford Tank Waste, by Waste Layer, as of May 2024

	Volume (Approximately millions of gallons)	Volume percent	Radioactivity (Approximately million curies)	Radioactivity percent
Supernate	20	(37 percent)	33	(25 percent)
Saltcake	24	(44 percent)	26	(20 percent)
Sludge	10	(20 percent)	70	(54 percent)

Source: GAO analysis of Department of Energy data. I GAO-24-106989

[a]Percentages do not add up to 100 due to rounding.

The tank waste consists of both radioactive and chemically hazardous materials. The key radioactive constituents are cesium-137 and strontium-90, which have relatively short half-lives of 30 years and 29 years, respectively. Other key radioactive constituents are technetium-99 and iodine-129. Both technetium-99 and iodine-129 have half-lives of over 100,000 years (213,000 years and 15.7 million years, respectively). As of May 2024, cesium-137 and strontium-90 constituted the vast majority of the radioactivity from these four key constituents according to our analysis of Department of Energy (DOE) data (see table 2).

Table 2: Radioactivity of Selected Constituents in Hanford Tank Waste, as of May 2024

Key Radioactive Constituent	Radioactivity (curies): Supernate	Radioactivity: Saltcake	Radioactivity: Sludge	Total radioactivity from selected constituents[a]
Iodine-129	13	12	5	30
Cesium-137	16,396,174	10,309,082	3,151,891	29,857,147
Strontium-90	334,641	2,524,185	31,142,278	34,001,104
Technetium-99	10,915	12,460	1,761	25,136

Source: GAO analysis of the Department of Energy's (DOE) estimated inventory of selected radionuclides from its Best Basis Inventory data. | GAO-24-106989

[a]These four constituents of concern total approximately 65 million curies—or about half—of the total 129 million curies in the tanks. The remaining approximately 65 million curies are made up largely of three other radionuclides, including yttrium-90 (34 million curries), barium-137 (28 million curies) and samarium-151 (3 million curies).

Much of the radioactive material in the tank waste will decay relatively quickly over time. Specifically, we reported in 2023 that since 1996, about 45 percent of the radioactivity in the tanks has decayed and over 90 percent will decay over the next 100 years.[2] At that time, the remaining radioactivity will come mainly from strontium-90, cesium-137, and their short-lived decay products.[3]

Methodology

Although DOE has traditionally managed all of its tank waste as if it is high-level radioactive waste as defined by federal law, the decay of certain radionuclides and preliminary processing treatments (e.g., Tank-Side Cesium Removal) means that some waste in the tanks may now fall below the radionuclide concentration limits established by the Nuclear Regulatory Commission (NRC) for low-level radioactive waste (LLW) disposal in licensed commercial facilities.[4] To determine which of Hanford's tanks could potentially fall below these concentration limits, we analyzed DOE data on the radionuclides in each tank from DOE's Best Basis Inventory (BBI), which is DOE's publicly available database of inventory estimates for chemical and radionuclide components in Hanford's tanks. We looked at this data by tank farm, as well as by waste volume using data from DOE's tank waste monthly summary for tanks at Hanford. Our analysis included 155 of the total 177 tanks. We did not include in this analysis the 22 tanks in C Farm, AX Farm, AY Farm, and S Farm for which retrieval of the waste is in process or has been completed, as of May 2024, according to DOE's tank waste monthly summary.[5]

Specifically, to determine the extent to which the waste in Hanford tanks could potentially meet the physical characteristics of LLW as defined by the NRC, we downloaded data as of May 2024 from the BBI. According to DOE, the BBI contains the best information available regarding the contents of the tanks and is the basis for DOE's own estimates about the tanks' contents. We determined this data to be sufficiently reliable for the purposes of corroborating experts' views on the extent to which the tank waste could potentially fall below these NRC-established concentration limits for LLW based on its physical characteristics.

To analyze which tanks may contain waste that falls below the NRC radionuclide concentration limits for LLW, we downloaded data on the radioactivity of all radionuclides in the Hanford tanks. We then determined which radionuclides were relevant to the classifications of LLW (Classes A, B, and C) established by the NRC in 10 C.F.R. § 61.55. These classifications are noted below. Our results are not meant to serve as evidence that

[2]GAO, *Hanford Cleanup: DOE Should Validate Its Analysis of High-Level Waste Treatment Alternatives*, GAO-23-106093 (Washington, D.C.: May 24, 2023).

[3]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.

[4]10 C.F.R. § 61.55.

[5]As of May 2024, DOE's tank waste summary shows that waste in 20 tanks has been fully retrieved and retrieval is considered complete. Waste in tank AY-102 is considered complete to the limit of retrieval technologies, and retrieval of waste in tank AX-101 is in progress.

tanks meeting these characteristics are LLW, but that the waste potentially meets the technical criteria of these waste classifications.

Radioactive Waste Definitions

"High-level radioactive waste" is defined by the Nuclear Waste Policy Act of 1982, as amended, as follows:

> "(A) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in the 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."[6]

This definition contains both a source component ("resulting from the reprocessing of spent nuclear fuel") and a characteristic component ("highly radioactive"). We asked experts who participated in our meetings convened by the National Academies of Sciences, Engineering, and Medicine whether some of the waste that DOE plans to manage as high-level radioactive waste could potentially be classified as another waste type based solely on its physical characteristics, rather than its source. Most experts generally agreed that portions of this waste could likely be classified as LLW or transuranic (TRU) waste based on its physical characteristics, rather than its origin.

Low-level radioactive waste is defined by the Low-Level Radioactive Waste Policy Amendments Act of 1985 as

> "[R]adioactive material that
>
> (A) is not high-level radioactive waste, spent nuclear fuel, or by-product material as defined in [42 U.S.C 2014(e)(2)]; and
>
> (B) the Nuclear Regulatory Commission, consistent with existing law and in accordance with paragraph (A), classifies as low-level radioactive waste."[7]

By regulation, the NRC has established classifications of waste for near surface disposal.[8] To determine which radionuclides were relevant to the classification of LLW, we reviewed the NRC's regulation on determining the classification of radioactive waste for near surface disposal. The regulation establishes three classes of waste that are generally appropriate for near surface disposal: Class A, B, and C. Under the regulation, determination of the classification involves consideration of both long-lived and short-lived radionuclides. If radioactive waste

[6]Pub. L. No. 97-425, § 2(12), 96 Stat. 2201, 2203 (1983) (codified at 42 U.S.C. § 10101(12)). This definition is also cross-referenced in the Atomic Energy Act of 1954, as amended, 42 U.S.C. § 2014(ee), and the Waste Isolation Pilot Plant Land Withdrawal Act, Pub. L. No. 102–579, § 2(10), 106 Stat. 4777 (1992).

[7]Pub. L. No. 99-240, § 102, 99 Stat 1842 (1986) (codified as amended at 42 U.S.C. § 2021b(9)). Under 42 U.S.C. § 2021b(9), low-level radioactive waste does not include byproduct material as defined in 42 U.S.C. § 2014(e)(3) and (4). Low-level radioactive waste is also defined in the Nuclear Waste Policy Act of 1982 as radioactive material that "(A) is not high-level radioactive waste, spent nuclear fuel, transuranic waste, or by-product material as defined in [42 U.S.C. § 2014(e)(2)]; and (B) the [Nuclear Regulatory] Commission, consistent with existing law, classifies as low-level radioactive waste." Pub. L. No. 97-425, § 2(16), 96 Stat 2201 (1983) (codified at 42 U.S.C. § 10101(16)).

[8]10 C.F.R. § 61.55.

contains both long- and short-lived radionuclides, as Hanford's tank waste does, classification is determined by two sets of radionuclides and their associated radioactivity limits established in the regulation. We identified the short-lived and long-lived radionuclides listed in the regulation that are present in the 177 Hanford tanks according to BBI data. We then applied the steps outlined in the regulation for waste containing a mixture of long-lived and short-lived radionuclides to determine whether the concentrations of these long-lived and short-lived radionuclides present in each tank could potentially meet Class A, B, or C criteria.

DOE does not use the NRC's classification system for low-level radioactive waste disposed of at DOE facilities, but instead relies on site-specific performance assessments and waste acceptance criteria. Nonetheless, DOE also disposes of defense LLW at commercial facilities, and those facilities are subject to the NRC's classification system for near surface disposal. DOE can also use its Waste Incidental to Reprocessing Evaluation process, where appropriate, to determine when reprocessing waste is not high-level radioactive waste. This process also references the NRC's classification system established in 10 C.F.R. § 61.55.[9] Because of the potential relevance of the NRC's classification system to DOE's management of Hanford's tank waste, we determined it was appropriate to rely on that system for our analysis of Hanford's tank waste.

TRU waste is defined in the Waste Isolation Pilot Plant Land Withdrawal Act as:

> "Waste containing more than 100 nanocuries of alpha-emitting transuranic isotopes per gram of waste, with half-lives greater than 20 years, except for
>
> (A) high-level radioactive waste;
>
> (B) waste that the Secretary of Energy has determined, with the concurrence of the Administrator of the Environmental Protection Agency, does not need the degree of isolation required by the disposal regulations; or
>
> (C) waste that the Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with part 61 of title 10, Code of Federal Regulations."[10]

As discussed above, the definition of high-level radioactive waste states that the waste must be "highly radioactive," but does not specify to what degree of radioactivity would be considered sufficient to qualify as "highly radioactive." Further, while the definition of TRU waste establishes a lower limit ("waste containing more than 100 nanocuries of alpha-emitting transuranic isotopes per gram of waste, with half-lives greater than 20 years"), there is no upper limit established to differentiate potential TRU waste from potential high-level

[9]Specifically, one of the criteria for DOE to manage spent nuclear fuel reprocessing waste as low-level radioactive waste pursuant to the Waste Incidental to Reprocessing Evaluation process is that the waste will be incorporated in a solid physical form at a concentration that does not exceed the applicable concentration limits for Class C low-level waste as set out in 10 C.F.R. § 61.55, or will meet alternative requirements for waste classification and characterization as DOE may authorize.

[10]Pub L. No. 102-579, § 2(20), 106 Stat. 4777, 4779 (1992). Transuranic waste is also defined in the Atomic Energy Act of 1954, as amended, as "material contaminated with elements that have an atomic number greater than 92, including neptunium, plutonium, americium, and curium, and that are in concentrations greater than 10 nanocuries per gram, or in such other concentrations as the Nuclear Regulatory Commission may prescribe to protect the public health and safety." 42 U.S.C. § 2014(jj). Because experts discussed the possibility that some Hanford waste might be disposed of in the future at the Waste Isolation Pilot Plant, we rely in this report on the definition of transuranic waste in the Waste Isolation Pilot Plant Land Withdrawal Act for our analysis.

radioactive waste. Therefore, our analysis did not analyze the extent to which Hanford tank waste could potentially meet the definitions of TRU waste or high-level radioactive waste based on its radioactivity.

Results

Our analysis found that 21 tanks of the 155 tanks that have not been declared retrieved or are not currently in the retrieval process could qualify as Class A, B, or C LLW, as laid out in 10 C.R.F. § 61.55. The waste in these 21 tanks potentially falls below the radionuclide concentration limits for Class A, B, or C LLW in its current state—for example, without any additional pretreatment or treatment—and represents about 11 million gallons of Hanford's total 54 million gallons of tank waste.[11]

Determining the location of tanks that contain waste that potentially qualifies as LLW is important because tank farms located further away from the Waste Treatment Plant (WTP)—namely the southwest, northwest, and northeast tank farms—require expensive cross-site piping and shielding to transport the waste miles across the site to the WTP to be processed under DOE's current plan. Our analysis found that each of the four tank farm areas at the Hanford Site may contain volumes of waste that could potentially qualify as LLW, based on the radionuclide concentration limits in 10 C.F.R. § 61.55. By tank farm area, our analysis found:

- Southeast tank farms (A Farms). Waste in 10 out of 30 tanks may fall below the radionuclide concentration limits for Class A, B, or C LLW;
- Northeast tank farms (B Farms). Waste in four out of 40 tanks may fall below the radionuclide concentration limits for Class A, B, or C LLW;
- Northwest tank farms (T Farms). Waste in three of 40 tanks may fall below the radionuclide concentration limits for Class A, B, or C LLW;
- Southwest tank farms (S and U Farms). Waste in four of 45 tanks may fall below the radionuclide concentration limits for Class A, B, or C LLW.

In terms of overall radioactivity present in the tank waste, our analysis showed that a majority—about 65 percent—of the radioactivity in the 155 Hanford tanks could be found in the southeast area tank farms. These tank farms are located closest to the WTP. Much of the waste in the southeast tank farms—about 74 percent—is supernate, or liquid. By contrast, total radioactivity in the northeast (B Farms) and northwest (T Farms) tank farms was about 10 percent of the overall radioactivity in the Hanford tanks. As previously mentioned, in its River Protection Project System Plan, Revision 10, DOE has identified waste in at least 11 tanks in the B and T Farms as potential contact-handled transuranic waste.[12]

[11]The 54 million gallons of waste represents the current volume in the Hanford tanks. As waste is retrieved from the tanks, the volume changes with the introduction of liquid and preparation for treatment. The volume of waste to be treated is much greater than the volume of waste currently in the tanks because liquid is added during retrieval, staging and pretreatment processes.

[12]Contact-handled TRU waste has a radioactive surface dose rate not greater than 200 millirem per hour. Such waste typically emits relatively little gamma radiation, and waste containers can be handled directly by workers. Remote-handled TRU waste has a radioactive surface dose rate of 200 millirem or more per hour. Remote-handled TRU waste emits relatively high levels of gamma radiation, which represents the primary radiological health hazard for workers handling such waste; the waste containers should not be handled directly by workers, and they require heavy container shielding or remote-handling equipment. For the purposes of this report, when we refer to TRU waste, we are referring to the total of contact-handled and remote-handled waste, unless otherwise specified.

Our analysis also showed that, of the total radioactivity in the 155 Hanford tanks, approximately 55 percent resides in the sludge layer of the tanks. Of that amount, about 61 percent of the sludge radioactivity is found in the southeast quadrant, which is closest to the WTP. We found that the southeast quadrant—containing most of the double-shell tanks and most of the supernate material—contains about 46 percent of the total tank waste volume and about 65 percent of the total radioactivity.

For a tank-by-tank breakdown of tank waste volumes and radioactivity, by tank farm area, see table 3 below.

Table 3: Hanford Site Tank-By-Tank Waste Volumes by Layer and Total Radioactivity[a]

Southeast tank farms

Tank number	Sludge volume (thousands of gallons)	Saltcake volume (thousands of gallons)	Supernate volume (thousands of gallons)	Total radioactivity (curies)
A Tank Farm (6 single-shell tanks): 241-A-101	3	387	6	663,965
A Tank Farm (6 single-shell tanks): 241-A-102	1	38	2	183,634
A Tank Farm (6 single-shell tanks): 241-A-103	2	376	14	723,595
A Tank Farm (6 single-shell tanks): 241-A-104	28	0	0	2,595,883
A Tank Farm (6 single-shell tanks): 241-A-105	20	0	0	2,938,291
A Tank Farm (6 single-shell tanks): 241-A-106	50	29	0	3,942,460
AN Tank Farm (7 double-shell tanks): 241-AN-101	635	30	423	2,403,916
AN Tank Farm (7 double-shell tanks): 241-AN-102	0	167	855	2,264,104
AN Tank Farm (7 double-shell tanks): 241-AN-103[b]	0	510	452	2,545,417
AN Tank Farm (7 double-shell tanks): 241-AN-104[b]	0	491	559	2,941,264
AN Tank Farm (7 double-shell tanks): 241-AN-105[b]	0	536	582	2,165,265
AN Tank Farm (7 double-shell tanks): 241-AN-106	488	17	577	6,827,903
AN Tank Farm (7 double-shell tanks): 241-AN-107	0	240	805	2,262,390
AP Tank Farm (8 double-shell tanks): 241-AP-101[b]	0	33	1030	2,152,350
AP Tank Farm (8 double-shell tanks): 241-AP-102	165	0	959	6,521,960
AP Tank Farm (8 double-shell tanks): 241-AP-103[b]	0	48	619	2,440,238

Tank number	Sludge volume (thousands of gallons)	Saltcake volume (thousands of gallons)	Supernate volume (thousands of gallons)	Total radioactivity (curies)
AP Tank Farm (8 double-shell tanks): 241-AP-104[b]	0	88	1128	375,345
AP Tank Farm (8 double-shell tanks): 241-AP-105[b]	0	102	1104	2,066,988
AP Tank Farm (8 double-shell tanks): 241-AP-106[b]	0	0	259	4,143
AP Tank Farm (8 double-shell tanks): 241-AP-107[b]	0	61	834	403,901
AP Tank Farm (8 double-shell tanks): 241-AP-108[b]	0	111	1026	1,267,597
AW Tank Farm (6 double-shell tanks): 241-AW-101	0	405	731	2,419,389
AW Tank Farm (6 double-shell tanks): 241-AW-102	0	53	866	1,002,824
AW Tank Farm (6 double-shell tanks): 241-AW-103	280	40	739	554,214
AW Tank Farm (6 double-shell tanks): 241-AW-104	81	157	774	1,448,193
AW Tank Farm (6 double-shell tanks): 241-AW-105	248	0	670	581,579
AW Tank Farm (6 double-shell tanks): 241-AW-106	0	266	867	2,191,403
AX Tank Farm (4 single-shell tanks): 241-AX-101[d]	<1	22	6	319,201
AX Tank Farm (4 single-shell tanks): 241-AX-102[d]	3	0	0	99,373
AX Tank Farm (4 single-shell tanks): 241-AX-103[d]	6	0	0	142,936
AX Tank Farm (4 single-shell tanks): 241-AX-104[d]	5	0	0	1,637,417
AY Tank Farm (2 double-shell tanks): 241-AY-101	95	0	908	4,878,974
AY Tank Farm (2 double-shell tanks): 241-AY-102[d]	8	0	2	386,835
AZ Tank Farm (2 double-shell tanks): 241-AZ-101	53	0	934	14,717,522
AZ Tank Farm (2 double-shell tanks): 241-AZ-102	100	77	705	6,823,036
Southeast tank farms totals	**2271**	**4284**	**18436**	**84,893,505**
Northeast tank farms				

Tank number	Sludge volume (thousands of gallons)	Saltcake volume (thousands of gallons)	Supernate volume (thousands of gallons)	Total radioactivity (curies)
B Tank Farm (16 single-shell tanks): 241-B-101	30	75	0	339,892
B Tank Farm (16 single-shell tanks): 241-B-102[b]	0	30	1	1,228
B Tank Farm (16 single-shell tanks): 241-B-103	1	36	2	1,541
B Tank Farm (16 single-shell tanks): 241-B-104	309	54	5	29,103
B Tank Farm (16 single-shell tanks): 241-B-105	28	260	0	7,845
B Tank Farm (16 single-shell tanks): 241-B-106	109	0	4	63,140
B Tank Farm (16 single-shell tanks): 241-B-107	84	72	1	20,740
B Tank Farm (16 single-shell tanks): 241-B-108[b]	25	59	1	11,950
B Tank Farm (16 single-shell tanks): 241-B-109	50	80	0	2,744
B Tank Farm (16 single-shell tanks): 241-B-110	237	0	7	174,714
B Tank Farm (16 single-shell tanks): 241-B-111	215	0	5	559,247
B Tank Farm (16 single-shell tanks): 241-B-112[b]	14	17	4	12,063
B Tank Farm (16 single-shell tanks): 241-B-201[c]	28	0	2	486
B Tank Farm (16 single-shell tanks): 241-B-202[c]	27	0	2	625
B Tank Farm (16 single-shell tanks): 241-B-203[c]	49	0	1	157
B Tank Farm (16 single-shell tanks): 241-B-204[c]	48	0	2	73
BX Tank Farm (12 single-shell tanks): 241-BX-101	43	0	11	154,090
BX Tank Farm (12 single-shell tanks): 241-BX-102	89	0	0	151,608
BX Tank Farm (12 single-shell tanks): 241-BX-103	62	0	13	41,992
BX Tank Farm (12 single-shell tanks): 241-BX-104	93	0	4	230,688
BX Tank Farm (12 single-shell tanks): 241-BX-105	42	22	4	81,007

Tank number	Sludge volume (thousands of gallons)	Saltcake volume (thousands of gallons)	Supernate volume (thousands of gallons)	Total radioactivity (curies)
BX Tank Farm (12 single-shell tanks): 241-BX-106	10	21	6	60,939
BX Tank Farm (12 single-shell tanks): 241-BX-107	337	0	6	58,309
BX Tank Farm (12 single-shell tanks): 241-BX-108	25	0	0	26,304
BX Tank Farm (12 single-shell tanks): 241-BX-109[b]	185	0	4	189,842
BX Tank Farm (12 single-shell tanks): 241-BX-110	65	140	9	114,903
BX Tank Farm (12 single-shell tanks): 241-BX-111	30	91	3	72,107
BX Tank Farm (12 single-shell tanks): 241-BX-112	156	0	1	53,745
BY Tank Farm (12 single-shell tanks): 241-BY-101	37	329	0	571,278
BY Tank Farm (12 single-shell tanks): 241-BY-102	0	315	0	204,906
BY Tank Farm (12 single-shell tanks): 241-BY-103	9	398	1	308,352
BY Tank Farm (12 single-shell tanks): 241-BY-104	43	358	0	816,654
BY Tank Farm (12 single-shell tanks): 241-BY-105	48	429	0	456,483
BY Tank Farm (12 single-shell tanks): 241-BY-106	30	399	0	617,280
BY Tank Farm (12 single-shell tanks): 241-BY-107	16	270	0	414,249
BY Tank Farm (12 single-shell tanks): 241-BY-108	44	219	0	315,256
BY Tank Farm (12 single-shell tanks): 241-BY-109	23	273	0	191,446

Tank number	Sludge volume (thousands of gallons)	Saltcake volume (thousands of gallons)	Supernate volume (thousands of gallons)	Total radioactivity (curies)
BY Tank Farm (12 single-shell tanks): 241-BY-110	44	304	0	522,087
BY Tank Farm (12 single-shell tanks): 241-BY-111	0	398	0	222,803
BY Tank Farm (12 single-shell tanks): 241-BY-112	2	301	0	155,705
Northeast tank farm totals	**2687**	**4950**	**99**	**7,257,582**

Tank number	Sludge volume (thousands of gallons)	Saltcake volume (thousands of gallons)	Supernate volume (thousands of gallons)	Total radioactivity (curies)
C Tank Farm (16 single-shell tanks not included in analysis): 241-C-101[d]	6	0	0	21,217
C Tank Farm (16 single-shell tanks not included in analysis): 241-C-102[d]	16	0	0	2,755
C Tank Farm (16 single-shell tanks not included in analysis): 241-C-103[d]	2	0	<1	14,088
C Tank Farm (16 single-shell tanks not included in analysis): 241-C-104[d]	2	0	0	13,720
C Tank Farm (16 single-shell tanks not included in analysis): 241-C-105[d]	2	0	0	13,505
C Tank Farm (16 single-shell tanks not included in analysis): 241-C-106[d]	2	0	0	84,337
C Tank Farm (16 single-shell tanks not included in analysis): 241-C-107[d]	10	0	0	31,609
C Tank Farm (16 single-shell tanks not included in analysis): 241-C-108[d]	3	0	0	2,552
C Tank Farm (16 single-shell tanks not included in analysis): 241-C-109[d]	2	0	0	4,531
C Tank Farm (16 single-shell tanks not included in analysis): 241-C-110[d]	2	0	0	5,889
C Tank Farm (16 single-shell tanks not included in analysis): 241-C-111[d]	5	0	0	77,686
C Tank Farm (16 single-shell tanks not included in analysis): 241-C-112[d]	10	0	0	123,758

Tank number	Sludge volume (thousands of gallons)	Saltcake volume (thousands of gallons)	Supernate volume (thousands of gallons)	Total radioactivity (curies)
C Tank Farm (16 single-shell tanks not included in analysis): 241-C-201[d]	<1	0	<1	475
C Tank Farm (16 single-shell tanks not included in analysis): 241-C-202[d]	<1	0	<1	824
C Tank Farm (16 single-shell tanks not included in analysis): 241-C-203[d]	<1	0	<1	390
C Tank Farm (16 single-shell tanks not included in analysis): 241-C-204[d]	<1	0	<1	223

Southwest tank farms

Tank number	Sludge volume (thousands of gallons)	Saltcake volume (thousands of gallons)	Supernate volume (thousands of gallons)	Total radioactivity (curies)
S Tank Farm (12 single-shell tanks): 241-S-101	235	116	0	871,429
S Tank Farm (12 single-shell tanks): 241-S-102	22	68	6	250,337
S Tank Farm (12 single-shell tanks): 241-S-103	9	221	1	332,879
S Tank Farm (12 single-shell tanks): 241-S-104	132	148	1	596,595
S Tank Farm (12 single-shell tanks): 241-S-105	2	506	0	160,116
S Tank Farm (12 single-shell tanks): 241-S-106[b]	0	451	0	337,983
S Tank Farm (12 single-shell tanks): 241-S-107	327	26	2	614,789
S Tank Farm (12 single-shell tanks): 241-S-108	5	537	0	602,014
S Tank Farm (12 single-shell tanks): 241-S-109	13	520	0	228,168
S Tank Farm (12 single-shell tanks): 241-S-110	91	296	0	536,526
S Tank Farm (12 single-shell tanks): 241-S-111	72	325	0	899,142
S Tank Farm (12 single-shell tanks): 241-S-112[d]	3	0	0	123
SX Tank Farm (15 single-shell tanks): 241-SX-101	141	275	0	845,764
SX Tank Farm (15 single-shell tanks): 241-SX-102	55	287	0	658,458
SX Tank Farm (15 single-shell tanks): 241-SX-103	80	519	0	1,265,931
SX Tank Farm (15 single-shell tanks): 241-SX-104	68	354	0	782,796

Tank number	Sludge volume (thousands of gallons)	Saltcake volume (thousands of gallons)	Supernate volume (thousands of gallons)	Total radioactivity (curies)
SX Tank Farm (15 single-shell tanks): 241-SX-105	65	311	0	1,233,459
SX Tank Farm (15 single-shell tanks): 241-SX-106	0	267	1	354,314
SX Tank Farm (15 single-shell tanks): 241-SX-107	130	0	0	1,038,718
SX Tank Farm (15 single-shell tanks): 241-SX-108	72	0	0	1,698,963
SX Tank Farm (15 single-shell tanks): 241-SX-109	66	206	0	1,540,213
SX Tank Farm (15 single-shell tanks): 241-SX-110	49	10	0	2,240,167
SX Tank Farm (15 single-shell tanks): 241-SX-111	97	20	0	2,855,404
SX Tank Farm (15 single-shell tanks): 241-SX-112	71	0	0	2,108,083
SX Tank Farm (15 single-shell tanks): 241-SX-113	19	0	0	20,782
SX Tank Farm (15 single-shell tanks): 241-SX-114	127	29	0	2,834,145
SX Tank Farm (15 single-shell tanks): 241-SX-115	4	0	0	472,457
SY Tank Farm (3 double-shell tanks): 241-SY-101	0	226	881	563,142
SY Tank Farm (3 double-shell tanks): 241-SY-102	220	0	297	472,752
SY Tank Farm (3 double-shell tanks): 241-SY-103	0	410	323	1,598,022
U Tank Farm (16 single-shell tanks): 241-U-101	21	0	9	93,744
U Tank Farm (16 single-shell tanks): 241-U-102	43	296	4	726,292
U Tank Farm (16 single-shell tanks): 241-U-103	13	396	3	458,801
U Tank Farm (16 single-shell tanks): 241-U-104	45	39	0	64,275
U Tank Farm (16 single-shell tanks): 241-U-105	32	311	2	438,568
U Tank Farm (16 single-shell tanks): 241-U-106	0	163	2	266,342
U Tank Farm (16 single-shell tanks): 241-U-107	16	259	0	206,088
U Tank Farm (16 single-shell tanks): 241-U-108	29	399	0	453,733
U Tank Farm (16 single-shell tanks): 241-U-109	32	357	1	325,796

Tank number	Sludge volume (thousands of gallons)	Saltcake volume (thousands of gallons)	Supernate volume (thousands of gallons)	Total radioactivity (curies)
U Tank Farm (16 single-shell tanks): 241-U-110	186	0	0	236,858
U Tank Farm (16 single-shell tanks): 241-U-111	26	200	0	328,934
U Tank Farm (16 single-shell tanks): 241-U-112	44	0	4	83,536
U Tank Farm (16 single-shell tanks): 241-U-201[b]	4	0	1	297
U Tank Farm (16 single-shell tanks): 241-U-202[b]	5	0	<1	167
U Tank Farm (16 single-shell tanks): 241-U-203[b]	2	0	1	152
U Tank Farm (16 single-shell tanks): 241-U-204	2	0	1	155
Southwest tank farms totals	**2675**	**8548**	**1540**	**31,697,406**

Northwest tank farms

Tank number	Sludge volume (thousands of gallons)	Saltcake volume (thousands of gallons)	Supernate volume (thousands of gallons)	Total radioactivity (curies)
T Tank Farm (16 single-shell tanks): 241-T-101	37	49	7	48,699
T Tank Farm (16 single-shell tanks): 241-T-102	19	0	11	31,892
T Tank Farm (16 single-shell tanks): 241-T-103	23	0	3	1,818
T Tank Farm (16 single-shell tanks): 241-T-104[c]	310	0	0	5,395
T Tank Farm (16 single-shell tanks): 241-T-105	89	0	1	50,356
T Tank Farm (16 single-shell tanks): 241-T-106	21	0	0	2,268
T Tank Farm (16 single-shell tanks): 241-T-107	160	0	7	165,770
T Tank Farm (16 single-shell tanks): 241-T-108	8	8	0	1,436
T Tank Farm (16 single-shell tanks): 241-T-109[b]	0	98	1	1,750
T Tank Farm (16 single-shell tanks): 241-T-110[c]	351	0	2	348
T Tank Farm (16 single-shell tanks): 241-T-111[c]	397	0	0	14,320
T Tank Farm (16 single-shell tanks): 241-T-112	55	0	7	525
T Tank Farm (16 single-shell tanks): 241-T-201[c]	29	0	3	144

Tank number	Sludge volume (thousands of gallons)	Saltcake volume (thousands of gallons)	Supernate volume (thousands of gallons)	Total radioactivity (curies)
T Tank Farm (16 single-shell tanks): 241-T-202[c]	20	0	0	23
T Tank Farm (16 single-shell tanks): 241-T-203[c]	36	0	0	98
T Tank Farm (16 single-shell tanks): 241-T-204[c]	36	0	0	80
TX Tank Farm (18 single-shell tanks): 241-TX-101	73	9	5	359,032
TX Tank Farm (18 single-shell tanks): 241-TX-102	2	231	0	180,961
TX Tank Farm (18 single-shell tanks): 241-TX-103	0	126	2	125,885
TX Tank Farm (18 single-shell tanks): 241-TX-104	33	30	3	151,297
TX Tank Farm (18 single-shell tanks): 241-TX-105	11	589	0	365,459
TX Tank Farm (18 single-shell tanks): 241-TX-106	5	386	0	340,178
TX Tank Farm (18 single-shell tanks): 241-TX-107	0	27	0	32,115
TX Tank Farm (18 single-shell tanks): 241-TX-108	6	110	1	110,545
TX Tank Farm (18 single-shell tanks): 241-TX-109	375	0	0	63,574
TX Tank Farm (18 single-shell tanks): 241-TX-110	37	424	0	307,412
TX Tank Farm (18 single-shell tanks): 241-TX-111	43	317	0	219,574
TX Tank Farm (18 single-shell tanks): 241-TX-112	0	627	0	441,715
TX Tank Farm (18 single-shell tanks): 241-TX-113	88	546	0	90,521
TX Tank Farm (18 single-shell tanks): 241-TX-114	4	510	0	283,833
TX Tank Farm (18 single-shell tanks): 241-TX-115	9	625	0	461,675
TX Tank Farm (18 single-shell tanks): 241-TX-116	66	497	0	120,777
TX Tank Farm (18 single-shell tanks): 241-TX-117	29	597	0	271,422
TX Tank Farm (18 single-shell tanks): 241-TX-118	0	250	0	423,086
TY Tank Farm (6 single-shell tanks): 241-TY-101	59	47	0	6,989
TY Tank Farm (6 single-shell tanks): 241-TY-102[b]	0	61	10	20,350

Tank number	Sludge volume (thousands of gallons)	Saltcake volume (thousands of gallons)	Supernate volume (thousands of gallons)	Total radioactivity (curies)
TY Tank Farm (6 single-shell tanks): 241-TY-103	108	40	0	132,775
TY Tank Farm (6 single-shell tanks): 241-TY-104	39	0	4	45,404
TY Tank Farm (6 single-shell tanks): 241-TY-105[b]	187	0	0	252,298
TY Tank Farm (6 single-shell tanks): 241-TY-106	13	0	0	18,014
Northwest tank farms totals	**2778**	**6204**	**67**	**5,149,813**

Source: GAO analysis of Department of Energy (DOE) Best-Basis Inventory data and Hanford tank monthly summary reports, as of May 2024 | GAO-24-106989.

Note: Tank waste volumes are rounded to the nearest whole number. Totals may be different due to rounding.

[a]Some additional radioactivity may be removed through DOE's Tank-Side Cesium Removal (TSCR) system.

[b]Tank identified in our analysis as containing waste that could potentially fall below radionuclide concentration limits for Class A, B, or C low-level radioactive waste, as defined in 10 C.F.R. § 61.55.

[c]Tank identified by DOE as likely containing transuranic (TRU) waste according to DOE's River Protection Project System Plan, Revision 10.

[d]Tank declared by DOE to have waste retrieval completed or to be in process of waste retrieval.

Appendix III: DOE's Classification of High-Level Radioactive Waste from Defense Activities

According to Department of Energy (DOE) officials, as a matter of policy, DOE manages all of Hanford's tank waste as if it is high-level radioactive waste as defined by federal law unless, and until, the waste is formally classified as another waste type.

High-level radioactive waste is defined by the Nuclear Waste Policy Act of 1982, as amended, as follows:

> (A) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in the 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.[1]

The management of high-level radioactive waste is subject to specific legal requirements. Generally, DOE has three processes it can use to determine that certain waste from reprocessing is not high-level radioactive waste. Once a determination is made, such waste can then be managed as either transuranic waste—which is waste contaminated with elements that have an atomic number greater than uranium—or low-level radioactive waste.[2] See table 4 below for a description of each of the three tools available to DOE and their limitations.

[1]Pub. L. No. 97-425, § 2(12), 96 Stat. 2201, 2203 (1983) (codified at 42 U.S.C. § 10101(12)). This definition is also cross-referenced in the Atomic Energy Act of 1954, as amended, 42 U.S.C. § 2014(ee), and the Waste Isolation Pilot Plant Land Withdrawal Act, Pub. L. No. 102–579, § 2(10), 106 Stat. 4777 (1992).

[2]For more information about high-level radioactive waste classification, see Department of Energy, *Classifying Radioactive Tank Waste* (Washington, D.C.: Aug. 2020), and 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. 09, 2021).

Table 4: Department of Energy (DOE) Processes to Classify Waste from the Reprocessing of Spent Nuclear Fuel as Something Other Than High-Level Radioactive Waste and Their Limitations

Process	Description	Limitations
Waste Incidental to Reprocessing Evaluation process under DOE Order 435.1 and Manual 435.1-1	Under DOE Manual 435.1-1, DOE may determine that waste is incidental to reprocessing and manage the waste as low-level radioactive waste if it (1) has been processed such that key radionuclides have been removed to the maximum extent technically and economically practicable, (2) will meet safety requirements comparable to the performance objectives established in Nuclear Regulatory Commission (NRC) regulations for the low-level waste disposal facilities, and (3) will be in a solid form that does not exceed NRC concentration limits for Class C low-level radioactive waste or will meet alternative requirements for waste classification and characterization as DOE may authorize. Also under Manual 435.1-1, DOE may determine that waste is incidental to reprocessing and manage the waste as transuranic waste if it (1) has been processed to remove key radionuclides to the maximum extent that is technically and economically practical, (2) will be incorporated in a solid physical form and meet alternative requirements for waste classification and characteristics, as DOE may authorize, and (3) is managed pursuant to DOE's authority under the Atomic Energy Act of 1954, as amended, in accordance with the Manual, as appropriate.	The validity of this process and Manual 435.1-1 and the associated order were challenged in a 2002 lawsuit. If applied at Hanford, DOE could be vulnerable to further legal challenges.[a] However, the process is applicable to all DOE-managed waste resulting from the reprocessing of spent nuclear fuel.
Section 3116 of the Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005[b]	Section 3116 of the National Defense Authorization Act for Fiscal Year 2005 authorized the Secretary of Energy, in consultation with NRC, to determine that certain waste from reprocessing is not high-level radioactive waste if it (1) does not require disposal in a deep geologic repository, (2) has had highly radioactive radionuclides removed to the maximum extent practical, and (3)(a) does not exceed radioactive concentration limits for low-level radioactive waste, and will be disposed of in accordance with NRC performance objectives for low-level radioactive waste disposal and pursuant to a state-approved closure plan or permit, or (b) exceeds Class C concentration limits but will be disposed of in accordance with NRC performance objectives for low-level radioactive waste disposal, and pursuant to a state-approved closure plan or permit and pursuant to plans developed by DOE in consultation with NRC.	Section 3116 only applies to waste in South Carolina and Idaho; it does not apply to the Hanford Site. Section 3116 also does not apply to waste being transported out of state from South Carolina or Idaho.
High-level waste interpretation[c]	In June 2019, DOE issued its interpretation of the statutory term "high-level radioactive waste." DOE subsequently incorporated this definition into Manual 435.1-1 in January 2021. Under the interpretation, DOE will manage tank waste as something other than high-level radioactive waste if it (1) does not exceed concentration limits for Class C low-level radioactive waste as set out in 10 C.F.R. § 61.55 and meets the performance objectives of a disposal facility, or (2) does not require disposal in a deep geologic repository and meets the performance objectives of a disposal facility as demonstrated through a performance assessment conducted in accordance with applicable requirements.	The National Defense Authorization Acts for fiscal years 2020 and 2021 prohibited DOE from spending funds from those years at the Hanford Site to apply this interpretation in fiscal years 2020 and 2021. In addition, in the April 2024 holistic agreement, DOE expressed its intent to forbear from applying this interpretation to wastes at or from the Hanford Site for the purposes of disposal of treated waste or tank system closure within the State of Washington.[d]

Source: GAO-22-104365. | GAO-24-106989

[a]A federal district court held that the relevant provisions of the Order and Manual were inconsistent with the Nuclear Waste Policy Act, Nat. Res. Def. Council v. Abraham, 271 F. Supp. 2d 1260 (D. Idaho 2003). However, a federal appeals court reversed that decision on procedural grounds in October 2004 and ordered dismissal of the suit without ruling on the underlying claim. Nat. Res. Def. Council v. Abraham, 388 F.3d 701 (9th Cir. 2004). Since then, DOE has, on five occasions, successfully used the Waste Incidental to Reprocessing Evaluation under Manual 435.1-1 to determine that certain reprocessing wastes—including certain Hanford tank wastes—could be managed as low-level radioactive waste.

[b]Pub. L. No. 108-375, § 3116, 118 Stat. 1811, 2162–64 (2004).

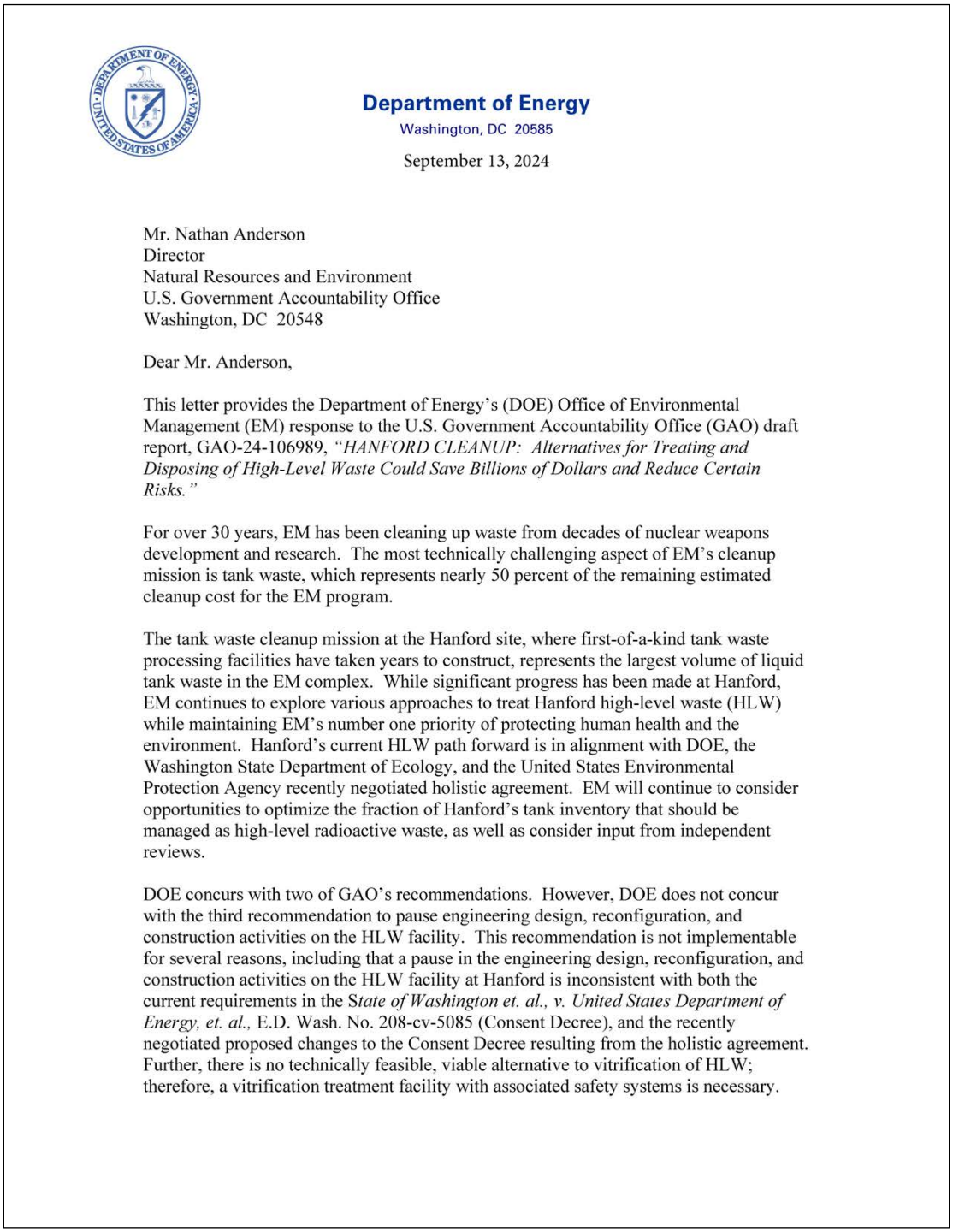
[c]For additional details, see DOE, Supplemental Notice Concerning U.S. Department of Energy Interpretation of High- Level Radioactive Waste, 84 Fed. Reg. 26835 (June 10, 2019); DOE, High-Level Radioactive Waste Interpretation Limited Change to DOE Manual 435.1–1, Radioactive Waste Management Manual and Administrative Change to DOE Order 435.1, Radioactive Waste Management, 86 Fed. Reg. 5173 (Jan. 19, 2021), DOE, Assessment of Department of Energy's Interpretation of the Definition of High-Level Radioactive Waste, 86 Fed. Reg. 72220 (Dec. 21, 2021).

[d]The April 29, 2024 holistic agreement comprises three parts—a new settlement agreement and proposed changes to two existing agreements that govern cleanup activities at Hanford. Those proposed changes are subject to public comment, possible revisions, and (for one of the agreements) court approval. At the time of publication of this report, that public comment and approval process was not complete, so references to the holistic agreement herein refer to the version that includes proposed changes announced on April 29, 2024, and thus do not necessarily reflect the final form of the agreement. Nonetheless, we believe the April 29, 2024 version of the holistic agreement is—as of the time of our publication—the best indication of DOE's path forward at Hanford.

DOE has used each of these three processes for managing waste across its cleanup sites. For example:

1. **The Waste Incidental to Reprocessing Evaluation**. Examples of this being used include the Hanford Waste Management Area-C Tank Farm (ongoing), Hanford vitrified low-activity waste (ongoing), Hanford Test Bed Initiative (2016 and 2023), West Valley Demonstration Project Concentrator Feed Makeup Tank and Melter Hold Tank (2013), and the West Valley Demonstration Project Melter (2012).
2. **Section 3116 of the Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005.** Examples of this being used include Savannah River Site H Tank Farm (2014), Savannah River Site F Tank Farm (2012), Savannah River Site Saltstone Disposal Facility (2006), and the Idaho Nuclear Technical and Engineering Center Tank Farm Facility (2006).
3. **DOE's HLW interpretation.** Examples of this being used are the Savannah River Site Defense Waste Processing Facility Recycle Wastewater (2020) and the Savannah River Site Contaminated Process Equipment (2023 and ongoing).

Appendix IV: Comments from the Department of Energy



Department of Energy
Washington, DC 20585

September 13, 2024

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-24-106989, *"HANFORD CLEANUP: Alternatives for Treating and Disposing of High-Level Waste Could Save Billions of Dollars and Reduce Certain Risks."*

For over 30 years, EM has been cleaning up waste from decades of nuclear weapons development and research. The most technically challenging aspect of EM's cleanup mission is tank waste, which represents nearly 50 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 years to construct, represents the largest volume of liquid tank waste in the EM complex. While significant progress has been made at Hanford, EM continues to explore various approaches to treat Hanford high-level waste (HLW) while maintaining EM's number one priority of protecting human health and the environment. Hanford's current HLW path forward is in alignment with DOE, the Washington State Department of Ecology, and the United States Environmental Protection Agency recently negotiated holistic agreement. EM will continue to consider opportunities to optimize the fraction of Hanford's tank inventory that should be managed as high-level radioactive waste, as well as consider input from independent reviews.

DOE concurs with two of GAO's recommendations. However, DOE does not concur with the third recommendation to pause engineering design, reconfiguration, and construction activities on the HLW facility. This recommendation is not implementable for several reasons, including that a pause in the engineering design, reconfiguration, and construction activities on the HLW facility at Hanford is inconsistent with both the current requirements in the S*tate of Washington et. al., v. United States Department of Energy, et. al.,* E.D. Wash. No. 208-cv-5085 (Consent Decree), and the recently negotiated proposed changes to the Consent Decree resulting from the holistic agreement. Further, there is no technically feasible, viable alternative to vitrification of HLW; therefore, a vitrification treatment facility with associated safety systems is necessary.

General and technical comments on the draft report have been provided separately to GAO.

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,

Candice Trummell Robertson
Senior Advisor for Environmental Management

Enclosure

2

Enclosure

Management Response to GAO Draft Report
GAO-24-106989
"HANFORD CLEANUP: Alternatives for Treating and Disposing of High-Level Waste Could Save Billions of Dollars and Reduce Certain Risks"

Recommendation 1: The Secretary of Energy should ensure that the Senior Advisor for Environmental Management targets research and development projects for addressing Hanford's high-level waste (HLW) towards known approaches that have the potential to reduce risks, schedule, and costs, such as the approaches identified by experts in this report and those in the 2022 Research and Development Roadmap for Hanford Tank Waste Mission Acceleration.

Management Response: Concur

The Department of Energy (DOE) has initiated technology development efforts for management and treatment of HLW that may reduce risks, schedule, and costs. In March 2024, DOE awarded $27.3 million for research and development projects related to the 2022 Research and Development Roadmap for Hanford Tank Waste Mission Acceleration. The awards were made to several different external entities, including private companies, colleges and universities, other executive departments and independent agencies, and international partners. Technological solutions resulting from the research and development efforts are tracked and progress evaluated. The technological solutions will be assessed for adoption.

Estimated Completion Date: September 30, 2025

Recommendation 2: The Secretary of Energy should ensure that the Senior Advisor for Environmental Management has an independent analysis performed, such as by a Federally Funded Research and Development Center (FFRDC), on opportunities to optimize, in a manner that is protective of human health and the environment, the portion of Hanford's high-level waste that should be managed, treated, and disposed of as high-level radioactive waste based on the physical characteristics of the waste.

Management Response: Concur

DOE EM's Office of Project Management will perform an independent HLW project peer review in September 2024. The peer review will include a technical review of HLW treatment and process optimization. EM will continue to assess HLW treatment optimization strategies as part of system planning. Additionally, DOE plans to have an independent HLW treatment optimization analysis performed, such as by an FFRDC, of alternatives to manage, treat, and dispose of Hanford's HLW within the context of legally and regulatorily permissible options.

Estimated Completion Date: December 31, 2027

Recommendation 3: The Secretary of Energy should ensure the Senior Advisor for

1

Enclosure

Environmental Management pauses engineering design, reconfiguration, and construction activities on the HLW Facility at Hanford until DOE (1) defines a mission need for the HLW project that is independent of a particular facility, technological solution, or physical end-item; (2) considers the results of an independent analysis for the HLW project that considers opportunities to optimize the fraction of Hanford's tank inventory that should be managed as high-level radioactive waste; and (3) addresses technical issues with the HLW Facility identified by the Defense Nuclear Facilities Board (DNFSB).

Management Response: Non-concur

DOE is unable to implement certain actions to address this recommendation. A pause in the engineering design, reconfiguration, and construction activities on the HLW facility at Hanford is inconsistent with both the current requirements in the S*tate of Washington et. al., v. United States Department of Energy, et. al.,* E.D. Wash. No. 208-cv-5085 (Consent Decree), and the recently negotiated proposed changes to the Consent Decree. In addition, the recommended pause does not align with congressional support of the current path forward for HLW treatment. In addition, DOE believes a pause would likely result in increased project costs upon resumption of HLW facility activities. There is no technically feasible, viable alternative to vitrification of HLW; a vitrification treatment facility with associated safety systems is necessary.

The Consent Decree currently requires DOE to complete hot commissioning of the HLW Facility by December 31, 2033. Any pause would likely affect DOE's ability to meet certain Consent Decree requirements including the hot commissioning milestone date.

Regarding necessary and appropriate changes to the Consent Decree, DOE, the Washington State Department of Ecology, and the United States Environmental Protection Agency Region 10, spent four years in mediated negotiations discussing a realistic and achievable path forward for Hanford's tank waste mission. The resulting negotiated agreement includes an achievable path forward for treating high-level waste starting with a "direct-feed" approach, building on our experiences from the Direct-Feed Low-Activity Waste Program.

Other regulatory requirements also inhibit DOE's ability to pause its planned path forward on HLW treatment. The hazardous component of Hanford's tank waste is subject to regulation under the Resource Conservation and Recovery Act (RCRA) permit administered by the Washington State Department of Ecology. Tank waste that is HLW under RCRA is required to be vitrified prior to land disposal, thus a vitrification facility for HLW will be required regardless of any potential future waste characterization decisions. DOE alone cannot change the regulatory approach of treating the waste through vitrification for this fraction of the tank waste.

In addition, Congress has continued to support DOE's current plans and path forward for the HLW facility including funding design and construction activities for the last two years.

Lastly, a pause would likely introduce negative workforce impacts, necessitating layoffs of highly skilled, technical employees that may not be available to support a ramp up after a pause. This would likely result in a significant increase in the cost of the HLW facility

activities and could further delay completion of the project.

DOE has and will continue to consider opportunities to optimize the fraction of Hanford's tank inventory that should be managed as HLW. In 2023, the independent HLW Facility Analysis of Alternatives and its associated addendum considered multiple options for management, treatment, and disposal of Hanford HLW. Alternatives were evaluated against well-defined criteria with consideration towards technical feasibility, safety and environmental risks, as well as cost and schedule. The HLW project has and will continue to conduct optimization of facility and system design and operating life cycle costs during the design, construction, and operation of the HLW project. Additionally, DOE routinely assesses waste treatment technologies and strategies as part of system and facility design. Recent examples of these efforts are the Enhanced Waste Glass development program and the Glass Forming Reagent System re-design reviews.

Pausing the HLW facility is not necessary to address the DNSFB technical issues. DOE continues to actively work with the DNSFB throughout the HLW facility design and construction. The DNFSB was fully engaged with the development of the HLW Facility Safety Design Strategy.

Estimated Completion Date: N/A

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

September 13, 2024

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

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Candice Trummell Robertson
Senior Advisor for Environmental Management

Management Response to GAO Draft Report
GAO-24-106989
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DOE EM's Office of Project Management will perform an independent HLW project peer review in September 2024. The peer review will include a technical review of HLW treatment and process optimization. EM will continue to assess HLW treatment optimization strategies as part of system planning. Additionally, DOE plans to have an independent HLW treatment optimization analysis performed, such as by an FFRDC, of alternatives to manage, treat, and dispose of Hanford's HLW within the context of legally and regulatorily permissible options.

Estimated Completion Date: December 31, 2027

Recommendation 3: The Secretary of Energy should ensure the Senior Advisor for Environmental Management pauses engineering design, reconfiguration, and construction activities on the HLW Facility at Hanford until DOE (1) defines a mission need for the HLW project that is independent of a particular facility, technological solution, or physical end-item; (2) considers the results of an independent analysis for the HLW project that considers opportunities to optimize the fraction of Hanford's tank inventory that should be managed as high-level radioactive waste; and (3) addresses technical issues with the HLW Facility identified by the Defense Nuclear Facilities Board (DNFSB).

Management Response: Non-concur

DOE is unable to implement certain actions to address this recommendation. A pause in the engineering design, reconfiguration, and construction activities on the HLW facility at Hanford is inconsistent with both the current requirements in the State of Washington et. al., v. United States Department of Energy, et. al., E.D. Wash. No. 208-cv-5085 (Consent Decree), and the recently negotiated proposed changes to the Consent Decree. In addition, the recommended pause does not align with congressional support of the current path forward for HLW treatment. In addition, DOE believes a pause would likely result in increased project costs upon resumption of HLW facility activities. There is no technically feasible, viable alternative to vitrification of HLW; a vitrification treatment facility with associated safety systems is necessary.

The Consent Decree currently requires DOE to complete hot commissioning of the HLW Facility by December 31, 2033. Any pause would likely affect DOE's ability to meet certain Consent Decree requirements including the hot commissioning milestone date.

Regarding necessary and appropriate changes to the Consent Decree, DOE, the Washington State Department of Ecology, and the United States Environmental Protection Agency Region 10, spent four years in mediated negotiations discussing a realistic and achievable path forward for Hanford's tank waste mission. The resulting negotiated agreement includes an achievable path forward for treating high-level waste starting with a "direct-feed" approach, building on our experiences from the Direct-Feed Low-Activity Waste Program.

Other regulatory requirements also inhibit DOE's ability to pause its planned path forward on HLW treatment. The hazardous component of Hanford's tank waste is subject to regulation under the Resource Conservation and Recovery Act (RCRA) permit administered by the Washington State Department of Ecology. Tank waste that is HLW under RCRA is required to be vitrified prior to land disposal, thus a vitrification facility for HLW will be required regardless of any potential future waste characterization decisions. DOE alone cannot change the regulatory approach of treating the waste through vitrification for this fraction of the tank waste.

In addition, Congress has continued to support DOE's current plans and path forward for the HLW facility including funding design and construction activities for the last two years.

Lastly, a pause would likely introduce negative workforce impacts, necessitating layoffs of highly skilled, technical employees that may not be available to support a ramp up after a pause. This would likely result in a significant increase in the cost of the HLW facility activities and could further delay completion of the project.

DOE has and will continue to consider opportunities to optimize the fraction of Hanford's tank inventory that should be managed as HLW. In 2023, the independent HLW Facility Analysis of Alternatives and its associated addendum considered multiple options for management, treatment, and disposal of Hanford HLW. Alternatives were evaluated against well-defined criteria with consideration towards technical feasibility, safety and

environmental risks, as well as cost and schedule. The HLW project has and will continue to conduct optimization of facility and system design and operating life cycle costs during the design, construction, and operation of the HLW project. Additionally, DOE routinely assesses waste treatment technologies and strategies as part of system and facility design. Recent examples of these efforts are the Enhanced Waste Glass development program and the Glass Forming Reagent System re-design reviews.

Pausing the HLW facility is not necessary to address the DNSFB technical issues. DOE continues to actively work with the DNSFB throughout the HLW facility design and construction. The DNFSB was fully engaged with the development of the HLW Facility Safety Design Strategy.

Estimated Completion Date: N/A

Appendix V: Comments from the Environmental Protection Agency

REGION 10 ADMINISTRATOR
SEATTLE, WA 98101

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

Dear Mr. Anderson:

Thank you for the opportunity to review and comment on the U.S. Government Accountability Office's draft report titled, "HANFORD CLEANUP: Alternatives for Treating and Disposing of High-Level Waste Could Save Billions of Dollars and Reduce Certain Risks, GAO-24-106989".

The purpose of this letter is to provide the U. S. Environmental Protection Agency's response to the draft report. The EPA disagrees with the matter for congressional consideration offered by the GAO, as well as two of the three recommendations the report makes to the Department of Energy.

The report examined (1) the status of the Department of Energy's current approach to addressing Hanford's high-level waste, including what GAO identified as barriers to its approach; (2) alternative approaches that could minimize the fraction of waste that would need to be treated as high-level waste and the extent to which these approaches would affect DOE's current cost and schedule estimates; and (3) steps, if any, DOE could take to pursue alternative approaches. The report included the GAO's Matter for Congressional Consideration and three recommendations made to the Department of Energy.

Matter for Congressional Consideration:

Congress should consider clarifying – in a manner that does not impair the regulatory authorities of the EPA and the State of Washington – DOE's authority at Hanford to determine, in consultation with the Nuclear Regulatory Commission, whether portions of the tank waste can be managed as a waste type other than high-level radioactive waste.

Response: The EPA disagrees. GAO has made the same recommendation on this matter twice before in GAO reports issued in 2023 and 2021.[1], and both the EPA and the State of Washington have conveyed concerns about this issue in previous comments to GAO. In particular, the EPA continues to believe it would be extremely difficult to craft the suggested clarification in a manner that does not impair the regulatory authority of the EPA or the State of Washington. In addition, important recent developments provide further demonstration that no congressional action in this regard is needed at this time to accomplish the Hanford mission. First, the holistic agreement addresses retrieval and disposal of tank waste without needing to rely upon such a clarification. Second, the EPA's recent

issuance of a variance from Land Disposal Restrictions under RCRA for the Hanford Test Bed Initiative is a demonstration of how existing legal authorities can be used effectively to manage waste using a technology other than vitrification, even without resolving the differences in interpretation regarding whether a particular waste is high-level. The holistic agreement has milestones addressing supplemental treatment selection and alternative selection for facilities to prepare waste for off-site disposal, which expressly evaluates technologies other than vitrification.

GAO Recommendation 2:

The Secretary of Energy should ensure that the Senior Advisor for Environmental Management has an independent analysis performed, such as by a Federally Funded Research and Development Center, on opportunities to optimize, in a manner that is protective of human health and the environment, the portion of Hanford's high-level waste that should be managed, treated and disposed of as high-level radioactive waste based on the physical characteristics of the waste.

Response: The EPA disagrees. Consistent with the EPA's response to the matter for congressional consideration, the EPA believes implementing this recommendation is unnecessary. The holistic agreement reflects the parties' consideration of the independent analyses conducted to date, including the numerous reports on the subject authored by this GAO team. The holistic agreement includes an agreement to a direct feed configuration for treatment of HLW tank waste. DOE is currently demonstrating that a direct feed configuration can be effective through the DFLAW facility. Furthermore, this report seems to point to the DOE interpretation of HLW in 2019 as justification for further analysis and optimization. However, the holistic agreement documents DOE's agreement to forbear their HLW interpretation. Implementing GAO's recommendation would undo some of the agreements the Tri-Parties reached and lead to delays in achieving the objectives and milestones of the holistic agreement. Moreover, any attempt to "optimize" in this manner is likely to trigger the need to change the regulatory authority of both the EPA and the State of Washington. In short, further analyses or reports are unlikely to add value at this time.

GAO Recommendation 3:

The Secretary of Energy should ensure the Senior Advisor for Environmental Management pauses engineering design, reconfiguration, and construction activities on the HLW Facility at Hanford until DOE (1) defines a mission need for the HLW project that is independent of a particular facility, technological solution or physical end-item; (2) considers the results of an independent analysis for the HLW project that considers opportunities to optimize the fraction of Hanford's tank inventory that should be managed as high-level radioactive waste; and (3) addresses technical issues with the HLW Facility identified by DNFSB.

Response: The EPA disagrees and believes this is the most problematic recommendation in the report. Implementing recommendation 3 would directly conflict with achieving the objectives and milestones of the holistic agreement and thereby slow the treatment and disposal of tank waste. The intense time and effort invested to create the holistic agreement would be for nought, and the recommendation could create an incentive for interested entities to seek judicial action to enforce yet-to-be-amended milestones in the current agreement.

2

After four years of intensive holistic negotiations involving dozens of experienced civil servants with substantial history and understanding of the Site, the parties entered into an historic settlement that moves the Hanford mission forward. The parties negotiated multiple milestones as part of the holistic agreement to prepare waste for the HLW facility and store the waste after vitrification. Several milestones related to retrieval of tank waste, including from known and assumed leaking tanks, three of which are leaking right now, hinge on the completion of HLW hot commissioning. Recommending a pause to DFHLW upends those negotiations and ignores the product of these difficult, but fruitful, negotiations and will lead to inefficient additional resource investment and delay.

Conclusion

The EPA appreciates the opportunity to review the draft report. For the reasons described above, the EPA disagrees with the matter for congressional consideration, as well as Recommendations 2 and 3. In sum, the matter offered for congressional consideration does not warrant congressional attention and the condition GAO has added—that Congress not impair the regulatory authority of the EPA or the State of Washington—makes this complex matter even more difficult to address. Recommendation 2 creates a significant risk of delay in implementing the holistic agreement's important objectives and milestones. Recommendation 3 is an even more direct threat to the holistic agreement and risks replacing the agreement's carefully considered plan for completing a substantial portion of the tank-waste cleanup mission with the expense of additional new analyses and the time-intensive uncertainty of potential protracted litigation.

Thank you again for the opportunity to comment. If you have any questions or need further information, please contact Tim Hamlin, Director, Land, Chemicals and Redevelopment Division, at (206) 553-1563 or Hamlin.Tim@epa.gov.

Sincerely,

DANIEL OPALSKI

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Acting For Casey Sixkiller
Regional Administrator

ENCLOSURE
EPA Technical Comment

cc: EPA GAO Liaison Team

[1] GAO, "*Snapshot: Hanford Cleanup: Alternative Approaches Could Save Tens of Billions of Dollars*", GAO-23-106880 (Washington, D.C.: September 28, 2023.

GAO, "*Actions Needed to Enable DOE Decision That Could Save Tens of Billions of Dollars*", GAO-22-104365 (Washington, D.C.: December 9, 2021.

Accessible Text for Appendix V: Comments from the Environmental Protection Agency

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DANIEL OPALSKI

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Acting For
Casey Sixkiller
Regional Administrator

ENCLOSURE
EPA Technical Comment

cc: EPA GAO Liaison Team

Appendix VI: 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), Taylor Bailey, Claudia Hadjigeorgiou, and Nancy Kintner-Meyer made key contributions to this report. Also contributing to this report were Mark Braza, Tara Congdon, Charlotte E. Hinkle, Eli Lewine, Katrina Pekar-Carpenter, Amber Sinclair, and Sara Sullivan.

Related GAO Products

Nuclear Waste Cleanup: Adopting Leading Practices Could Strengthen DOE's Engagement with Stakeholders and Governments, GAO-24-106014. Washington, D.C.: Sept. 9 2024.

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