United States Government Accountability Office

Report to Congressional Committees

May 2020

HANFORD WASTE TREATMENT PLANT

DOE Is Pursuing Pretreatment Alternatives, but Its Strategy Is Unclear While Costs Continue to Rise

GAO-20-363

GAO Highlights

Highlights of GAO-20-363, a report to congressional committees

May 2020

HANFORD WASTE TREATMENT PLANT

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Why GAO Did This Study

The Hanford Site in Washington State contains large quantities of nuclear waste. EM has been building the Waste Treatment and Immobilization Plant—which consists of multiple facilities, including a key pretreatment facility—to treat a large portion of the nuclear waste at Hanford. Under way since 2000 and costing over $11 billion to date—$3.8 billion of that spent on the pretreatment facility—the plant has faced technical challenges, cost overruns, and schedule delays. In late 2012, work on the pretreatment facility stopped until technical challenges could be resolved. In 2018, the U.S. Army Corps of Engineers reported that at current annual funding levels, completing the pretreatment facility on time would not be possible.

Senate Report 116-48 accompanying the National Defense Authorization Act for fiscal year 2020 included a provision for GAO to review this project. This report examines (1) the cost of pretreatment efforts from fiscal year 2013 through fiscal year 2018, (2) the status of the technical challenges facing the pretreatment facility, and (3) the steps EM is taking to start treating waste by 2023 as required, among other things. GAO toured the facility, analyzed EM documents and expenditure data, and interviewed EM officials.

What GAO Recommends

GAO is making two recommendations, including that DOE ensure that its analysis of alternatives for pretreatment of high-level waste include a mission need statement and a life-cycle cost estimate for the baseline alternative. DOE concurred in principle with both recommendations.

View GAO-20-363. For more information, contact David C. Trimble at (202) 512-3841 or trimbled@gao.gov

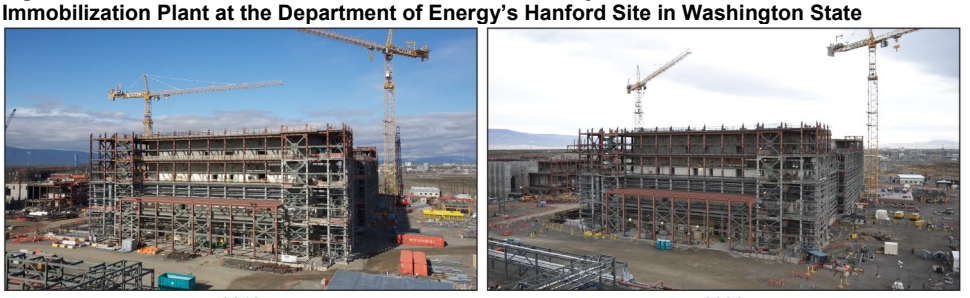
What GAO Found

The Department of Energy's (DOE) Office of Environmental Management (EM) spent $752 million in fiscal years 2013 through 2018 on the pretreatment facility at the Hanford Site in Washington State. This facility was to separate nuclear waste into two streams for treatment in other site facilities. However, EM stopped design and construction of the facility in 2012 due to technical challenges. According to expenditure data, over half of the $752 million EM spent was for overhead, oversight, procurements, and facility maintenance. The rest was spent resolving the technical challenges. DOE's fiscal year 2020 budget request states that EM plans to continue "limited activities"—such as maintaining the existing facility and storing uninstalled equipment—while construction remains on hold.

After working to address pretreatment facility technical challenges since 2012, EM and its contractor consider these challenges—ranging from facility ventilation concerns to preventing explosions during waste treatment—to be conceptually resolved. However, EM has not yet designed, engineered, or tested solutions to the challenges. In addition, the Defense Nuclear Facilities Safety Board—an independent agency that provides analysis, advice, and recommendations regarding safety at DOE's defense nuclear facilities—does not consider the challenges resolved pending additional information and, in some cases, additional design and engineering work by EM.

To begin treating waste by 2023 as required, EM has been pursuing alternatives to the pretreatment facility. Since 2013, EM has spent over $400 million pursuing alternatives for low-activity waste pretreatment capabilities originally planned for the pretreatment facility. However, as GAO reported in May 2015, EM did not properly define a mission need statement or a life-cycle cost estimate prior to selecting its preferred alternative for treating low-activity waste, consistent with analysis of alternatives best practices and DOE policy, and GAO recommended EM revise its analysis. In April 2019, EM began an analysis of alternatives for treating high-level waste, which EM expects to be completed in September 2020. However, as of February 2020, EM had not yet defined a mission need for this new analysis of alternatives and did not have a life-cycle cost estimate for its baseline alternative. Without these, decision makers will not have the information they need to make the best decisions for pretreating high-level waste, and EM cannot assure decision makers that alternative approaches meet mission needs.

Figure: Status of Construction on the Pretreatment Facility, Part of the Waste Treatment and Immobilization Plant at the Department of Energy's Hanford Site in Washington State



2013 2020

Source: Department of Energy. | GAO-20-363

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Abbreviations

AOA	analysis of alternatives
BNI	Bechtel National, Inc.
DFLAW	Direct-Feed Low-Activity Waste
DNFSB	Defense Nuclear Facilities Safety Board
DOE	Department of Energy
Ecology	Washington State Department of Ecology
EM	Office of Environmental Management
EVM	Earned Value Management
HLW	high-level waste
LAW	low-activity waste
LCCE	life-cycle cost estimate
ORP	Office of River Protection
TCCR	Tank Closure Cesium Removal
TPA	Tri-Party Agreement
TSCR	Tank Side Cesium Removal
WTP	Waste Treatment and Immobilization Plant

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May 12, 2020

Congressional Committees

The Hanford Site in Washington State is one of the largest environmental cleanup projects in the world. After decades of producing nuclear materials for weapons during World War II and the Cold War, operators of the 586-square-mile campus ceased plutonium production in the late 1980s and began cleaning up the hazardous and radioactive waste that was left behind. Fifty-four million gallons of this waste is stored in 160 large underground waste storage tanks and must be treated—or immobilized—before disposal, according to legal requirements and agreements made with federal and state environmental regulators.[1] The U.S. Department of Energy (DOE) is responsible for the treatment and disposal of radioactive and hazardous waste created as a byproduct of producing nuclear weapons and energy research, and DOE's Office of Environmental Management (EM) manages most of DOE's cleanup activities for legacy defense waste and energy research, including activities at Hanford. In January 2019, DOE estimated that completing the cleanup of the Hanford Site would cost between $323 billion and $677 billion and would last for decades.[2]

In 2000, EM awarded a contract to Bechtel National, Inc. (BNI) to design, construct, and commission a Waste Treatment and Immobilization Plant (WTP) at Hanford to treat large quantities of the site's waste. The WTP, under construction for nearly 20 years and costing over $11 billion to date, has faced numerous technical challenges, cost overruns, and schedule delays. As designed, the WTP is to consist of several facilities, including a pretreatment facility that separates waste into streams with high levels and lower levels of radioactivity. (See fig. 1.) In late 2012, EM stopped work on the pretreatment facility and slowed work on other parts of the WTP until the technical challenges could be resolved. While working to resolve technical challenges within the pretreatment and other WTP facilities, EM began exploring options to bypass the pretreatment facility if necessary because EM is required by an amended consent

[1]There are 177 underground waste storage tanks on site that historically have held the waste. According to DOE officials, the waste has been retrieved from 17 of these tanks.

[2]Department of Energy, *2019 Hanford Lifecycle Scope, Schedule and Cost Report* (Richland, WA: January 2019).

decree with the State of Washington to begin treating tank waste by 2023.[3] In 2018, the U.S. Army Corps of Engineers and BNI reported that at current annual funding levels (nearly $700 million per year), completing the construction of the pretreatment facility by 2031, as required by the amended consent decree, likely would not be possible.[4] Furthermore, EM estimated in its *2019 Hanford Lifecycle Scope, Schedule and Cost Report* that completing the WTP would cost between $19 billion and $30 billion, in addition to the more than $11 billion already spent.[5]

Figure 1: The Partially Constructed Pretreatment Facility at the Hanford Waste Treatment and Immobilization Plant

2013 2020

Source: Department of Energy. | GAO-20-363

Noting these ongoing challenges at the Hanford Site, Senate Report 116-48 accompanying the National Defense Authorization Act for Fiscal Year 2020 included a provision for us to evaluate the status of the WTP. This

[3]Specifically, the consent decree requires DOE to begin "hot commissioning" of the Low Activity Waste Facility, one of the components of the waste treatment plant, by December 31, 2023. The consent decree defines "hot commissioning" to mean "the point at which the LAW facility has demonstrated its ability to produce immobilized LAW glass of acceptable quality." Washington v. Moniz, Case 2:08-cv-05085-RMP, Consent Decree at 16 (E.D. Wash, March 11, 2016).

[4]U.S. Army Corps of Engineers, *Parametric Evaluations of the Waste Treatment and Immobilization Plant* (Washington, D.C.: July 10, 2018). The report states that, through an interagency agreement, ORP requested support from the U.S. Army Corps of Engineers to provide an analysis of options to meet the milestones related to the completion of construction on pretreatment and high-level waste facilities.

[5]Department of Energy, *2019 Hanford Lifecycle Scope, Schedule and Cost Report* (Richland, WA: January 2019).

report examines (1) the cost of pretreatment efforts from fiscal year 2013 through fiscal year 2018 and the status of the pretreatment facility, (2) the status of the technical challenges facing the pretreatment facility, and (3) the steps EM is taking to begin treating waste by 2023 as required and the extent to which EM has engaged with regulators.

To determine the cost and status of the pretreatment facility, we reviewed BNI's Earned Value Management (EVM) status reports and fiscal year totals for EM's oversight costs and BNI's award and contract modification fees for the pretreatment facility for fiscal years 2013 through 2018. These reports and data were provided to us by officials in EM's Office of River Protection (ORP), which oversees WTP construction at Hanford. To determine the cost of alternative pretreatment efforts, we reviewed EVM status reports for the Direct-Feed Low-Activity Waste project, the Low-Activity Waste Pretreatment System, and the Tank Side Cesium Removal project for fiscal years 2014 through 2018. To gain context on the planned capabilities of these projects, we reviewed project presentations for pretreatment alternatives and interviewed ORP and BNI officials to learn more about the progress made in developing each project. To assess the reliability of all cost data for both the pretreatment facility and alternative pretreatment efforts, we reviewed documentation and officials' responses related to data gathering processes, data storage systems, and data limitations for each of the relevant sources. Based on this, we found all of the data sources to be sufficiently reliable for our reporting objectives. Finally, to determine the extent to which EM has established a cost estimate to complete the pretreatment facility that is consistent with the policy set out in DOE Order 413.3B, we interviewed officials about EM's cost estimate to complete the facility.

To examine the status of technical challenges facing the pretreatment facility and to gather information pertaining to obstacles and risks to project completion, we reviewed EM documents, such as ORP's 2018 briefing to the Washington State Department of Ecology (Ecology) regarding the status of challenges; BNI documents, such as a 2018 briefing about the status of the pretreatment facility; and other documents, including the U.S. Army Corps of Engineers' 2018 report on the status of the WTP. We also interviewed EM officials, regulators at Ecology and the U.S. Environmental Protection Agency, and contractor officials who are working to resolve these challenges, to better understand the status of the technical challenges, as well as any concerns they might have. In addition, we interviewed officials from the Defense Nuclear Facilities Safety Board (DNFSB)—an independent agency that provides analysis, advice, and recommendations to the Secretary of Energy regarding the

adequate protection of public health and safety at DOE's defense nuclear facilities—regarding their assessment of the technical challenges and what additional steps, if any, DOE needs to take to resolve the challenges.

To examine the steps EM is taking to begin treating waste by 2023, as required, we visited the WTP construction site at Hanford in May 2019 to observe the status of the construction of the pretreatment facility and pretreatment alternatives. We also reviewed project documentation and plans. We interviewed the following: DOE officials from headquarters, to discuss the status of and future plans for the WTP; DOE officials from ORP at Hanford, to gather information about the project; ORP contractors, regarding their ongoing and planned efforts related to pretreatment of the tank waste; and regulator officials from Ecology, to better understand their concerns and priorities. We reviewed historical documentation, such as technical reports summarizing testing and studies conducted by EM and its contractors beginning in 2006. We interviewed DOE officials and reviewed EM's available documentation associated with its ongoing analysis of alternatives (AOA) to determine the status of DOE's draft AOA. We also reviewed DOE project management guidance and our best practices for developing AOAs.[6] Specifically, we selected two key best practices in an AOA process—define mission need and develop a life-cycle cost estimate for the baseline (or status quo) alternative—because, as discussed later in this report, these steps are requisite for completing the remaining steps of an AOA and are essential to ensuring that the basis for the AOA is credible and based on accurate information. We also compared EM's decision-making process, in particular its stakeholder engagement, to a framework for risk-informed decision-making we developed in our prior work. A more detailed description of our scope and methodology is included in appendix I.

We conducted this performance audit from February 2019 to May 2020 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

[6]Department of Energy, *Program and Project Management for the Acquisition of Capital Assets*, DOE Order 413.3B (Washington, D.C.: Nov. 29, 2010). Department of Energy, *Analysis of Alternatives Guide*, DOE G 413.3-22 (Washington, D.C.: June 6, 2018). GAO, *Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Program Costs*, GAO-20-195G (Washington, D.C.: March 2020).

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

Background

EM's Strategy for Addressing Tank Waste at the Hanford Site

From 1944 through 1988, the production of plutonium at Hanford generated about 525 million gallons of radioactive and hazardous waste. Some of the waste was dumped directly into the soil, some was encased in drums or other containers and buried, and about 54 million gallons were stored on-site in 177 underground tanks. Some of the waste stored in the underground tanks is "high-level waste" (HLW) mixed with hazardous chemicals that is to be vitrified—a process in which the waste is immobilized in glass—prior to disposal. "Low-activity waste" (LAW) is EM's term for the portion of the tank waste with low levels of radioactivity.[7] EM estimates that LAW comprises more than 90 percent of the volume in the tanks but contains less than 10 percent of the radioactivity.

EM currently plans to treat much of Hanford's tank waste in the WTP. The WTP is the most technically complex and largest construction project within EM. As figure 2 shows, the WTP consists of facilities that are designed to separate waste into low-activity and high-level waste streams. Once completed, the WTP is to treat the HLW and a portion of the LAW in separate facilities using vitrification.[8] The WTP consists of the following facilities:

- **Pretreatment Facility.** This facility is to receive the waste from the tanks and separate it into HLW and LAW. Under the original WTP design, all waste must first pass through this facility before it can be treated. Tank waste to be sent to the pretreatment facility for processing must meet specific physical and chemical characteristics, known as waste acceptance criteria, and the waste must be certified as having met these criteria before transfer from the tanks to the pretreatment facility. For example, WTP waste acceptance criteria may stipulate that waste meet certain requirements for chemical composition, particle size, and density in order to be handled by the

[7]EM uses the term "low-activity waste" to mean the waste that, when solidified, may be disposed of as low-level radioactive waste in a near-surface facility.

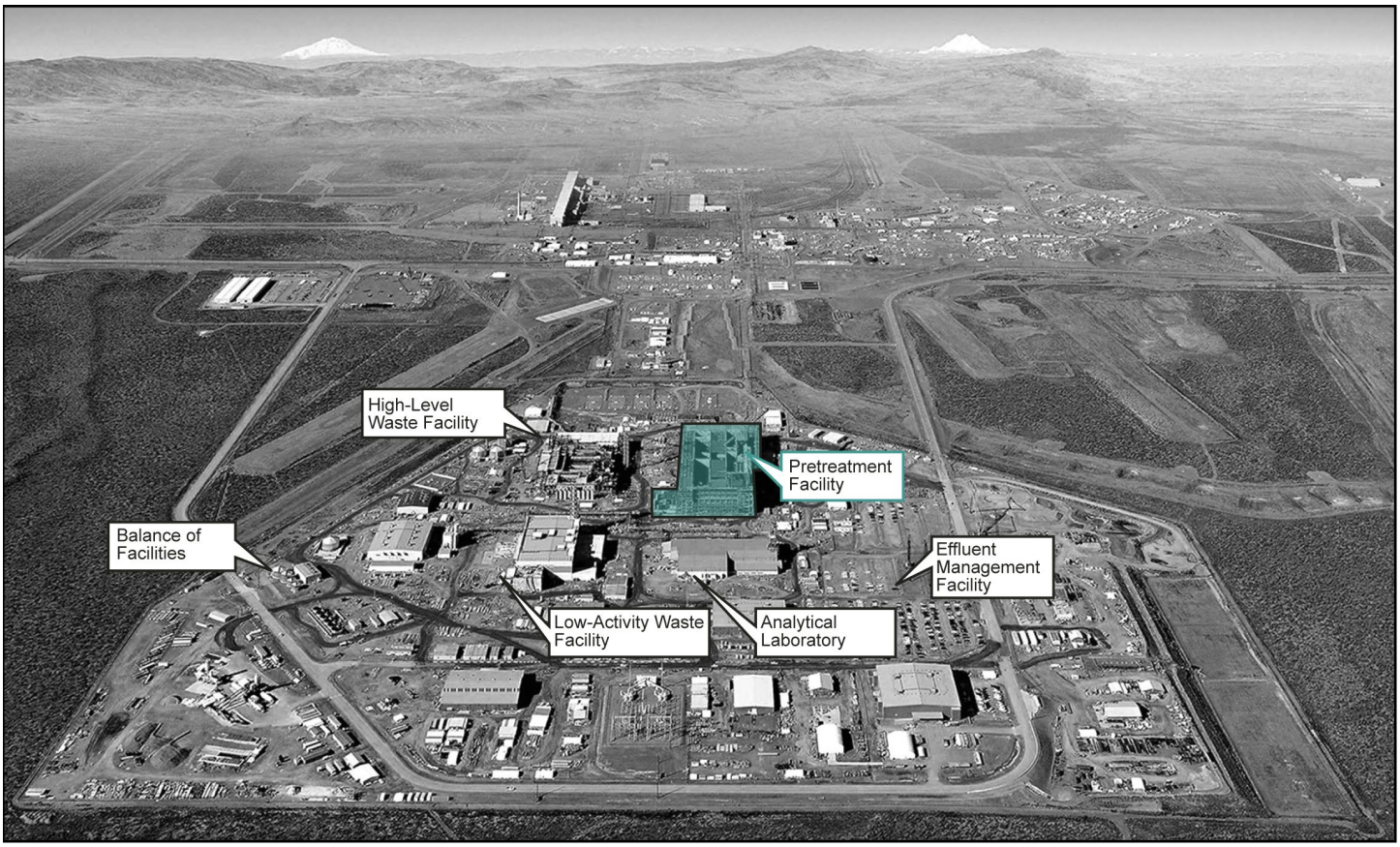
[8]The WTP is currently designed to treat all of Hanford's HLW but only a third to half of the LAW. EM has yet to identify and select another approach for treating the remaining LAW.

pretreatment facility. Construction of this facility as originally designed is about 40 percent complete.

- **LAW Vitrification Facility.** This facility is designed to receive the LAW and immobilize it by vitrification. The canisters of vitrified waste will be permanently disposed of at another facility on the Hanford Site. Construction of this facility is nearing completion, and EM plans to complete commissioning of the facility no later than December 31, 2023. As currently designed, this facility would only have capacity to treat a third to half of the LAW currently in the waste tanks. EM is analyzing alternatives for treating the remaining LAW, known as supplemental LAW.
- **HLW Vitrification Facility.** This facility is designed to receive the HLW and immobilize it by vitrification. The canisters of vitrified waste will be stored on-site until a final repository is established.[9] Construction of this facility is about 40 percent complete.
- **Effluent Management Facility.** The Effluent Management Facility is being built to evaporate much of the liquid waste produced during LAW processing and vitrification at the LAW Facility. Design work on this facility is nearly complete and construction is under way. EM plans to complete construction of this facility in December 2021.
- **Analytical Laboratory.** This facility will be used to analyze the waste at various stages of treatment, such as testing samples of the vitrified waste to ensure that it meets certain criteria and regulatory requirements for disposal. Construction of this facility is complete and EM has begun startup and commissioning activities.
- **Balance of Facilities.** These facilities consist of the 22 support facilities that make up the plant infrastructure, such as cooling water systems and silos that hold glass-forming materials. Construction of these facilities is nearing completion, and EM has begun startup and commissioning activities.

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

Figure 2: Waste Treatment and Immobilization Plant and Other Facilities Planned for Hanford Tank Waste Treatment



Source: Department of Energy. | GAO-20-363

Prior GAO Work on Technical Challenges Facing the WTP

The WTP has faced hundreds of technical challenges since the early years of the project. These challenges ranged from effectively mixing the waste prior to treatment to addressing potential erosion in the facility piping. We have reported on these challenges in the past and have made numerous related recommendations to EM. For example, in 2003 we found that BNI and outside experts had concerns about the technology for separating the waste—including problems associated with mixing the waste during separations and evaporating water from the waste—and they proposed more testing to resolve those challenges.[10] We recommended that EM consider further testing to resolve those

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

challenges before moving forward with construction of the pretreatment facility. In early 2007, EM decided to build a pilot-scale facility for the WTP to fully test pretreatment technologies before completing the full-scale design of the facility.

Similarly, in 2006 we found that the WTP continued to face numerous technical challenges and that many of the technical challenges still had not been addressed even though EM was moving forward with construction on the pretreatment facility.[11] We recommended that EM resolve the technical challenges before moving forward. EM agreed and took steps to ensure that the design of each WTP component was at least 90 percent complete before construction or installation.

In December 2012, we found that the WTP continued to face significant technical challenges, even though construction was 55 percent complete, and we recommended that EM not resume construction of the pretreatment facility until the issues had been fully resolved.[12] Because of these ongoing challenges, in December 2012, EM's WTP Engineering Division issued a memorandum that recommended that all activities affecting design, construction, and installation of structures, systems, and components be stopped. According to the memorandum, stopping work would help ORP avoid future nuclear safety and quality compromises and substantial rework. Instead of stopping all work at the WTP, ORP management stopped work only on those facilities that faced the most significant technical challenges, namely, the pretreatment and HLW facilities. As we discuss in this report, EM has not yet resumed construction on the pretreatment and HLW facilities.

In 2015, we reported that because of ongoing problems hampering the progress of the pretreatment facility at Hanford, EM was pursuing other pretreatment alternatives (such as feeding the waste from the tanks directly to the vitrification facilities) but had not properly defined the mission need for the analysis or developed a reliable life-cycle cost estimate for the alternatives being analyzed.[13] We recommended that EM

[11]GAO, *Hanford Waste Treatment Plant: Contractor and DOE Management Problems Have Led to Higher Costs, Construction Delays, and Safety Concerns*, GAO-06-602T (Washington, D.C.: Apr. 6, 2006).

[12]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).

[13]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).

revise its analysis to consider a variety of alternatives without limiting potential solutions and that EM further limit construction activities on the pretreatment facility until aggressive risk mitigation strategies are developed and employed to address the technical challenges. EM opted to change the alternative pretreatment approach it had been pursuing and in 2018 began design work on a different alternative pretreatment approach.

In April 2018, we reported that seven of nine ORP quality assurance experts expected rework would be needed for existing facilities, including the pretreatment facility.[14] In that report we noted that according to three experts with knowledge about maintenance programs, BNI had not established a fully effective WTP quality assurance program, particularly for the pretreatment facility and HLW facility, and as a result, structures, systems, and components at these facilities have deteriorated and been damaged. We recommended that EM (1) determine the full extent to which problems exist in all WTP structures, systems, and components, (2) stop work in areas where quality assurance problems are recurring until ORP's Quality Assurance Division can verify that the problems are corrected and will not recur, and (3) revise ORP's organizational structure so that the quality assurance function is independent of ORP upper management. As of March 2020, EM had implemented one of our three recommendations (revising ORP's organizational structure), but had not yet fully implemented the other recommendations.

Regulatory Framework Governing the Hanford Cleanup

Cleanup of the Hanford Site is governed by two main documents. The 1989 Hanford Federal Facility Agreement and Consent Order—or Tri-Party Agreement (TPA)—is an agreement among DOE, Ecology, and the Environmental Protection Agency. The TPA lays out a series of legally enforceable milestones for completing major activities in Hanford's waste treatment and cleanup process.[15] The 2010 Consent Decree, as

[14]GAO, *Hanford Waste Treatment Plant: DOE Needs to Take Further Actions to Address Weaknesses in Its Quality Assurance Program,* GAO-18-241 (Washington, D.C.: Apr. 24, 2018).

[15]Hanford Federal Facility Agreement and Consent Order, EPA Docket No. 1089-03-04-120, Ecology Docket No. 89-54, as amended through August 1, 2016. The agreement is available at http://www.hanford.gov/page.cfm/TriParty/TheAgreement. The purpose of the TPA is to ensure that Hanford's cleanup activities comply with the Comprehensive Environmental Response, Compensation, and Liability Act; Resource Conservation and Recovery Act; and Washington's Hazardous Waste Management Act. DOE entered into the TPA pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act; Executive Order 12580; and the Atomic Energy Act of 1954.

amended, resolves certain disputes between Ecology and DOE and addresses a subset of cleanup activities, including completing the construction and achieving initial operations of the WTP and retrieving waste from specified single-shell tanks.[16] Among other things, the consent decree requires DOE to do the following:

- Begin treating LAW by 2023;
- Substantially complete the construction of the pretreatment facility by 2031; and
- Start WTP operations by 2036.

The TPA requires DOE to complete the treatment and vitrification of all HLW and LAW in the Hanford tanks by 2047.

In addition to oversight by Ecology and the Environmental Protection Agency, DNFSB is responsible for, among other things, reviewing the design of new defense nuclear facilities at DOE's sites, including the WTP. DNFSB, established in 1988, 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. DNFSB is not authorized to issue regulations binding on DOE apart from establishing reporting requirements. Instead, DNFSB uses both informal interactions and formal communications with DOE to help ensure that its concerns are addressed.

DOE Order 413.3B establishes program and project management requirements for the acquisition of capital assets with the purpose of delivering projects within budget, on time, and capable of meeting mission performance.[17] EM is required to manage its cleanup projects in accordance with this order. In particular, Order 413.3B requires EM to conduct an AOA that is consistent with the 22 AOA best practices we identified.[18] DOE also has an AOA guide, which describes suggested approaches for DOE and its contractors to be consistent with the 22 best

[16]Washington v. Chu, Civ. No. 08-05085 (E.D. Wash), entered October 25, 2010, amended sub. nom. Washington v. Moniz, in March and April 2016, and sub. nom. Washington v. Perry in October 2018.

[17]Department of Energy, *Program and Project Management for the Acquisition of Capital Assets*, DOE Order 413.3B (Washington, D.C.: Nov. 29, 2010), as amended.

[18]GAO-20-195G

practices for an AOA process.[19] The 22 best practices compile common AOA policies and guidance used by different government and private-sector entities and incorporate experts' comments. These best practices include the following:

- Define mission need,
- Develop AOA time frame,
- Establish AOA team,
- Define selection criteria,
- Weight selection criteria,
- Include baseline (or status quo) alternative, and
- Develop a life-cycle cost estimate for each viable alternative.

EM Spent About $752 Million on the Pretreatment Facility in Fiscal Years 2013 through 2018, but Construction of the Pretreatment Facility Remains on Hold

From early fiscal year 2013 until the end of fiscal year 2018, EM spent about $752 million to maintain the pretreatment facility and resolve technical challenges. Over half of the $752 million went toward overhead, oversight, and other costs to maintain the partially constructed facility. The remaining costs went toward resolving technical challenges.[20] Design and construction of the pretreatment facility is on hold, and DOE's budget request for fiscal year 2020 states that EM plans to continue "limited activities" on the pretreatment facility to keep the facility in a preservation and maintenance mode. However, officials told us that EM does not have a cost estimate for completing the pretreatment facility, and EM has no plans to develop such an estimate in the near future.

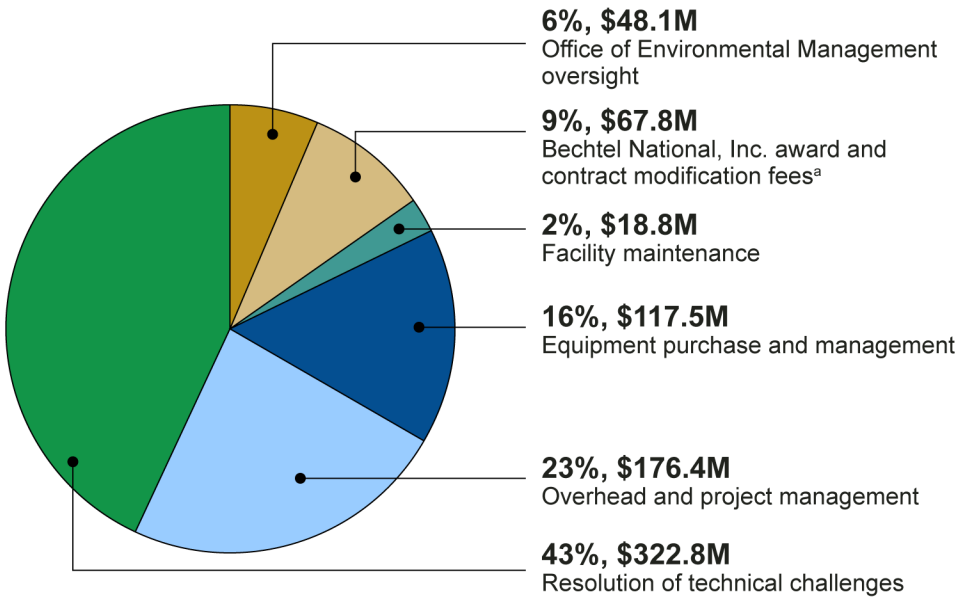
[19]Department of Energy, *Analysis of Alternatives Guide*, DOE G 413.3-22 (Washington, D.C.: June 6, 2018).

[20]Activities to resolve technical challenges include identifying research tasks needed to resolve the technical challenges and performing testing, as well as the cost of subcontracts to assist BNI in resolving the technical challenges. Activities to maintain the partially constructed facility include monitoring the project's cost and schedule, purchasing items and maintaining items in storage, and cleaning the facility.

Over Half of the $752 Million Spent on the Pretreatment Facility in Fiscal Years 2013 through 2018 Went Toward Overhead, Oversight, and Other Costs to Maintain the Partially Completed Facility

From early fiscal year 2013—when work involving design and construction of the pretreatment facility was suspended—until the end of fiscal year 2018, EM spent about $752 million on the pretreatment facility. Among other things, EM used this funding for resolution of the technical challenges that led to the suspension of the facility's construction, overhead and project management, equipment purchase and management, facility maintenance, BNI award and contract modification fees, and EM oversight. (See fig. 3.)

Figure 3: Pretreatment Facility Costs by Cost Type, Fiscal Years 2013 through 2018



Source: GAO analysis of Department of Energy data. | GAO-20-363

Note: In addition to these costs, Bechtel National, Inc. (BNI) also had costs in accounts for startup and construction subcontracts, which together totaled about $1.1 million, or 0.15 percent of the total $752 million, for fiscal years 2013 through 2018. See appendix II for category definitions. Percentages do not add to 100 due to rounding.

[a]The majority of BNI fees was paid for work done on both the pretreatment and high-level waste facilities. EM officials estimate that about half of those fees were specifically for work done on the pretreatment facility. However, since this estimate was not an official number, we chose to use the full amount for this analysis.

Less than half of the $752 million spent on the pretreatment facility in fiscal years 2013 through 2018 went toward resolving technical challenges associated with the facility. According to EVM system reports,

EM spent approximately $323 million—or 43 percent of the $752 million in total costs—on costs incurred by BNI to resolve the technical challenges.[21] This includes activities such as identifying research tasks needed to resolve the technical challenges and performing testing, as well as the cost of subcontracts to assist BNI in resolving the technical challenges.

EM also spent about $430 million—over half of the $752 million—on costs to maintain the condition of the pretreatment facility and its related procurements. This includes BNI's costs for:

- **Overhead and Project Management.** BNI spent about $176.4 million—or 23 percent of the total $752 million—on overhead and project management combined.[22] According to ORP officials, what we refer to as overhead includes traditional overhead costs as well as the cost of common activities for multiple facilities at the Hanford Site and the management system they use for those facilities. According to BNI documentation, project management includes, for example, the costs of administrative support and records management, as well as monitoring and reporting on the project's cost and schedule performance.
- **Equipment Purchase and Management**. About $117.5 million—or 16 percent of the total $752 million—went toward BNI's purchase and management of equipment. Specifically, after EM suspended construction on the pretreatment facility, BNI continued to purchase certain equipment such as piping materials. In addition, BNI had to store certain procured items in a storage yard where, according to ORP officials, these items have been monitored and maintained and are expected to still be in good condition when construction resumes. BNI also either suspended—put on hold until future need—or terminated other contracts it had entered into with vendors to procure components for the facility. Through fiscal year 2018, BNI terminated 16 procurements for reasons ranging from vendors going out of business to the pretreatment facility no longer requiring the item

[21]BNI tracks its costs in its EVM system, in which costs are assigned to different accounts depending on the type of activity. According to EM officials, DOE's Office of Project Management is currently reviewing the WTP contractor's EVM system.

[22]ORP and BNI use the terms "shared services" or "project services allocation" for what we refer to as overhead for reporting purposes.

Pretreatment Facility Lifetime Overhead Costs

In fiscal year 2019, Bechtel National, Inc. (BNI), the prime contractor for Hanford's Waste Treatment and Immobilization Plant (WTP)—including the pretreatment facility—allocated $1.5 billion in overhead costs to the pretreatment facility in its Earned Value Management system (for fiscal years 2001 through 2014) that had previously been recorded in non-facility specific accounts. What we refer to as overhead BNI refers to as project services allocation or shared services, which according to officials at the Office of River Protection includes both traditional overhead costs (such as light and power), as well as the cost of common activities for multiple facilities and the management system used for those facilities. Prior to fiscal year 2015, overhead costs for the entire WTP were recorded in non-facility specific accounts. In fiscal year 2015, BNI changed the way that it accounts for these costs by allocating overhead costs to each individual facility; however, at the time, this change was only made for future overhead costs for the entire WTP. In June 2019, BNI also applied this change to pre-2015 costs, which brings BNI's total pretreatment facility costs, from the beginning of the contract in December 2000 through July 2019, to $3.4 billion—$1.5 billion of which are overhead costs. However, this allocation of cost to each facility from the project level shared services accounts did not change the overall cost of the WTP project.

Source: GAO analysis of DOE data. | GAO-20-363

because of design changes.[23] According to ORP officials, EM did not pay a termination fee for procurements that were terminated because of the vendor going out of business; however, for other terminated procurements, EM might have to pay additional costs if the vendor submits a claim for compensation to BNI, for which BNI in turn seeks reimbursement from EM. In either case, there may be additional costs related, for example, to picking up and transporting items.

- **Facility Maintenance.** About $18.8 million—or 2 percent of the total $752 million—went towards the costs of general facility maintenance. According to ORP officials, facility maintenance includes activities such as maintaining building access controls, maintaining installed components, cleaning up waste from birds, removing snow and trash, and conducting periodic walks of the facility to determine the condition of materials in the building, among other things.

In addition to BNI's costs, in fiscal years 2013 through 2018, EM also spent funds on:

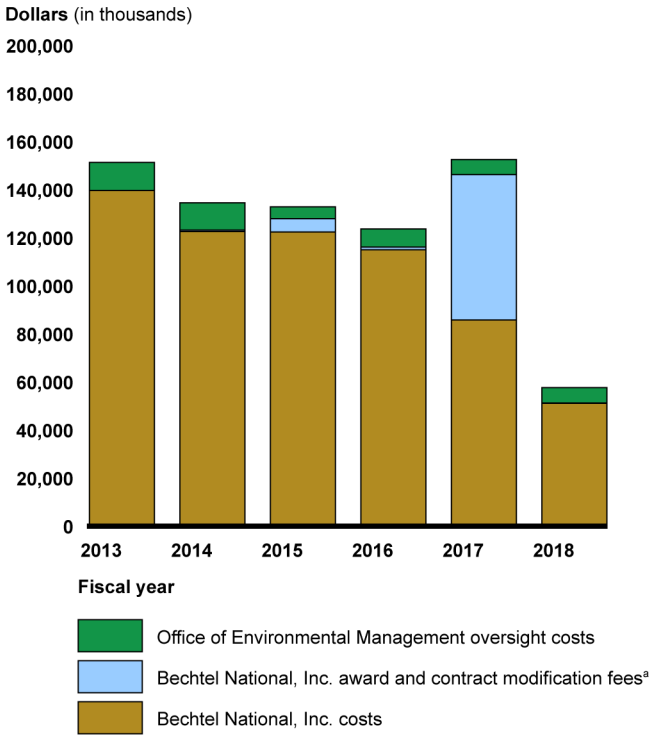
- **EM Oversight.** EM spent about $48.1 million—or 6 percent of the total $752 million—for its oversight of the project. EM officials told us these oversight costs included, for example, technical support from various DOE organizations and national laboratories that perform testing, as well as support from general services support contractors to supplement EM resources.
- **BNI Award and Contract Modification Fees.**[24] EM spent about $67.8 million—or 9 percent of the total $752 million—on BNI's award and contract modification fees. This was primarily a factor in fiscal year 2017, when the pretreatment facility's total costs reached about

[23]In 2017, DOE's Inspector General found that neither DOE nor BNI had fully acted to terminate 28 procurements that BNI had recommended for termination in 2015, and as a result DOE incurred $1.9 million in suspension costs that could have been avoided. The Inspector General recommended that EM ensure that BNI take action to manage the suspended procurements to ensure cost and schedule effectiveness, among other things. See Department of Energy, Office of Inspector General, *Special Report: Management of Suspended Procurements at the Waste Treatment and Immobilization Plant Project,* OIG-SR-17-04 (Washington, D.C.: February 2017).

[24]Award fees are an amount of money added to a contract, which a contractor may earn in whole or in part by meeting or exceeding subjective criteria stated in an award fee plan typically related to areas within quality, technical ingenuity, cost-effective management, program management, and other unquantifiable areas. Award fees in the context of this report refer to money earned by BNI based on its performance in carrying out work on the pretreatment facility. In this report, contract modification fees refer to money negotiated between BNI and EM based on a change in the contract agreed to by both parties.

$153 million—the facility's highest costs from fiscal year 2013 through fiscal year 2018. (See fig. 4.) Contributing to the fiscal year 2017 costs was a one-time $60 million contract modification fee for both the pretreatment facility and the high-level waste facility that was negotiated between BNI and EM.[25] According to EM officials, EM and BNI negotiated this fee for work completed by BNI in previous years for which it had not been paid a fee. This work included developing facility designs, resolving technical issues, and conducting reviews and research studies.

Figure 4: Pretreatment Facility Costs by Fiscal Year, Fiscal Years 2013 through 2018



Source: GAO analysis of Department of Energy data. | GAO-20-363

Note: the Department of Energy's Office of Environmental Management spent a total of about $752 million from early fiscal year 2013—when work involving design and construction of the pretreatment facility was suspended—until the end of fiscal year 2018. Approximately $637 million of the total $752 million were costs incurred by the prime contractor for the pretreatment facility, Bechtel National, Inc. (BNI), for its work on the facility.

[a]Award fees refer to money earned by BNI based on its performance in carrying out work on the pretreatment facility. These fees are awarded by calendar year; however, for our purposes, they are reported here for the fiscal year that corresponds most closely to the calendar year (i.e., calendar

[25]EM officials estimate that about half of the $60 million was specifically for work done on the pretreatment facility.

year 2016 is fiscal year 2016). Of the $7.8 million in total award fees that BNI received in fiscal years 2013 through 2018, $2.8 million were assessed for work done on both the pretreatment facility and the high-level waste facility. Contract modification fees refer to money received by BNI based on a change in the contract. According to DOE officials, BNI received a $60 million contract modification fee in fiscal year 2017 for work done on both the pretreatment facility and the high-level waste facility.

Design and Construction of the Pretreatment Facility Remain On Hold, and EM Does Not Have a Cost Estimate for Completing the Pretreatment Facility

Design and construction of the pretreatment facility have been on hold since 2012. At the time construction was halted, BNI estimated that construction of the facility was about 40 percent complete. In July 2018, the U.S. Army Corps of Engineers reported that construction of the facility was still about 40 percent complete. In a tour of the facility in May 2019, we observed that construction remains on hold and that EM is instead using the space inside the partially constructed building to conduct worker training exercises. Additionally, DOE's budget request for fiscal year 2020 states that EM plans to continue "limited activities"—such as maintaining the existing facility, storing uninstalled equipment, and maintaining records for quality assurance—on the pretreatment facility to keep the facility in a preservation and maintenance mode. ORP officials told us in September 2019 that EM does not plan to restart design and construction activities on the pretreatment facility until alternatives for pretreating HLW have been analyzed.

According to EM officials, EM does not have an updated cost estimate for completing the pretreatment facility, as required under DOE Order 413.3B. This order requires EM to develop, maintain, and document cost estimates in a manner consistent with methods and best practices identified in GAO's *Cost Estimating and Assessment Guide*, as well as other documents, including the Office of Management and Budget's Circular A-11, prior to DOE approving a performance baseline change.[26] EM's last independently verified approved cost estimate for completing the entire WTP was completed in 2006. At that time, EM estimated that completing the pretreatment facility would cost approximately $2.5 billion.[27] However, the pretreatment facility has surpassed that amount. Specifically, through fiscal year 2018, EM spent about $3.8 billion on the facility, including approximately $3 billion spent prior to halting construction in 2012 and $752 million spent in fiscal years 2013 through

[26]GAO-09-3SP; Office of Management and Budget, *Preparation, Submission, and Execution of the Budget,* OMB Circular No. A-11 (revised 2019).

[27]According to EM officials, the original $2.5 billion estimate to complete the pretreatment facility did not include the cost of BNI overhead, BNI fees, or EM oversight.

2018.[28] EM was in the process of updating the cost estimate in 2012 when construction of the pretreatment facility was suspended, and therefore EM's update to the cost estimate was suspended as well.[29]

ORP officials told us that they do not have plans to complete a cost estimate for the pretreatment facility. According to these officials, they cannot complete a cost estimate for the pretreatment facility until EM has made a decision about the future of the facility and, if necessary, BNI develops design changes to address technical challenges. The officials explained that the development of design changes depends on the prioritization of funding. They also explained that ORP's highest funding priority is to begin vitrifying some LAW as soon as possible by bypassing the pretreatment facility using alternative technologies and sending the separated LAW directly to the WTP's LAW vitrification facility—an approach known as Direct-Feed Low-Activity Waste (DFLAW). Officials told us that ORP's second highest funding priority is the completion of the HLW facility and that the pretreatment facility will not be a priority until EM has made a decision on which pretreatment methods to use going forward and updated the design changes for the facility as needed.

EM Reported that Technical Challenges on the Pretreatment Facility Have Been Resolved, but EM Has Not Yet Designed or Engineered the Solutions

After EM halted construction on the pretreatment facility in 2012, EM began working with BNI to address the longstanding technical challenges associated with the design and construction of the pretreatment facility. According to July 2019 correspondence between EM and BNI, both parties consider these technical challenges to be resolved, and according to ORP officials, pretreatment facility engineering and design followed by its construction may now continue. However, based on our interviews with EM and BNI officials, EM has not yet designed or engineered the solutions. In addition, according to DNFSB officials, the DNFSB does not consider the technical challenges to be resolved yet, though it continues to review EM's efforts.

[28]The $3 billion spent through fiscal year 2012 was calculated from data provided in EM's Fiscal Year 2017 Budget Justification. See Department of Energy, *FY 2017 Congressional Budget Request, Environmental Management*, DOE/CF-0123 (Washington, D.C.: February 2016). This document does not include details on what costs (e.g., EM oversight, BNI fees) are or are not included in the data. Of the $3.8 billion spent through fiscal year 2018, BNI directly spent $3.4 billion.

[29]Although EM does not have an official cost estimate, BNI estimated in 2018 that, as originally designed in the early 2000s, it would cost an additional $7.7 billion to complete the pretreatment facility. This would be in addition to the approximately $3.8 billion EM has already spent on the facility.

Since 2012, EM and BNI Have Worked to Resolve Technical Challenges with the Pretreatment Facility, and EM Reported that the Challenges Have Been Resolved

In late 2012, EM halted construction of the pretreatment facility, and EM and BNI began work to resolve technical issues. In November 2012, EM formed a design completion team responsible for resolving the technical challenges. In May 2014, EM asked BNI to submit a plan for resolving the challenges and resuming construction of the pretreatment facility. EM ultimately identified eight key categories of technical challenges to be resolved before resuming construction of the pretreatment facility (see table 1 for a list of the eight categories, and see app. III for a more detailed description of each category of technical challenges). The majority of these categories involved portions of the pretreatment facility intended to manage the HLW. For example, one category EM identified involves preventing hydrogen from building up in the facilities' piping and vessels, which could cause an explosion. Another category involves preventing corrosive waste from eroding treatment equipment, which could cause a leak of radioactive materials.

Table 1: Summary of the Technical Challenges Facing the Hanford Site's Pretreatment Facility as Reported by the Department of Energy (DOE)

Challenge	DOE Description
Hydrogen Gas in Vessels	Inadequate mixing can lead to the accumulation of hydrogen and potentially lead to explosions.
Criticality in Pulse-Jet Mixer Vessels	Large-size plutonium particles could settle onto internal surfaces of the pulse-jet mixer vessels causing an uncontrolled nuclear chain reaction known as a criticality accident.
Hydrogen in Piping and Ancillary Vessels	The accumulation of hydrogen gas in piping and small vessels can occur, potentially leading to explosions.
Pulse-Jet Mixer Vessel Mixing and Control	Accumulating solids in pulse-jet mixing vessels could cause excessive air to be discharged in the vessels causing premature erosion of vessels.
Erosion/Corrosion in Piping and Vessels	Excessive wear could damage plant equipment and result in interruption of operations or leakage of material from vessels and piping.
Standard High Solids Design	The project team has not established an inspection program related to the incorporation of a recent vessel design change.
Black Cell Vessel/ Equipment Structural Integrity	Potential weaknesses in equipment and piping located within black cells (rooms inaccessible to humans once operations begin) must be identified before operations begin.
Facility Ventilation/ Process Offgas Treatment	The structural integrity of some ventilation systems could be compromised if seismic or other events beyond the design basis occur.

Source: GAO summary of DOE data. | GAO-20-363

In June 2014, BNI formed eight teams to address each category of technical challenges. For example, to address the technical challenges associated with mixing the waste in the pretreatment facility using a technology known as pulse-jet mixing, the design completion team developed a plan to standardize and test a new design to address pulse-jet mixing challenges. Similarly, to address concerns about the potential weaknesses in equipment and piping located in rooms inaccessible to

humans once operations begin (known as black cells), EM formed a black cell analysis team. BNI submitted interim updates to EM on the proposed resolution of specific challenges as BNI addressed them. For example, in December 2017, BNI informed EM of its resolution of the challenges related to facility ventilation. Similarly, in September 2018, BNI informed EM of its resolution of the challenges related to the black cells. BNI sent similar correspondence on the other six categories of technical challenges to EM throughout 2019. According to EM officials, EM and its contractors provided DNFSB documentation and briefings on the resolution of the technical challenges.

In June 2019, BNI informed EM that it considered all eight categories of technical challenges to be resolved. In July 2019, EM subsequently informed BNI that it agreed with BNI's conclusions that the technical challenges were resolved. According to ORP officials, "resolved" means that all the required studies, calculations, and testing have been completed and demonstrated to independent experts and EM that (1) the issue is fully understood so that no further research is needed and (2) a solution is ready for detailed design.

EM Has Not Yet Designed or Engineered the Solutions, and the DNFSB Does Not Consider the Technical Challenges to Be Resolved

Although EM and BNI consider the technical challenges associated with the pretreatment facility to be resolved, EM and BNI have not yet designed or engineered the solutions. BNI acknowledged early in the process that resolution of the technical challenges would involve not only a conceptual solution, but also subsequent design, engineering, and, in some cases, testing of the solutions before construction could resume on the pretreatment facility. For example, in its June 2014 plan for addressing the challenges, BNI noted that prior to making a decision to proceed with construction of the facility, it would need to conduct a number of additional steps, including updating the designs of the pretreatment facility and assessing the nuclear safety basis and the contract implications for the updated designs. In addition, ORP officials told us that proposed revisions to the pretreatment facility would require negotiation with Ecology. As of February 2020, EM and BNI had not yet begun developing these required designs and engineering changes and have no plans to do so until a decision is made on the future of the facility. According to EM officials, ORP's current priorities are to begin DFLAW operations and to conduct an analysis of alternatives related to the treatment of the HLW.

These next steps could involve significant work and potential rework to the facility. According to EM officials, resolving the technical challenges likely will require BNI to change its designs for the pretreatment facility

and conduct significant rework in portions of the facility that have been completed. ORP officials said that they expect this design work to be significant and do not expect it to be complete enough to proceed with the construction of the facility until at least 2022, depending on the availability of funding to support the design work. BNI's plan going forward includes a number of steps related to updating the pretreatment facility designs. As a result of this significant engineering work still ahead, as we reported in May 2015, EM likely will have to conduct rework of the existing facility (which is 40 percent built), leading to further cost increases and schedule delays.[30] For example, BNI will need to redesign any existing components and systems that have become obsolete since EM halted construction or that need to be reworked to accommodate the technical solutions.

In addition, DNFSB officials have begun reviewing EM's proposed solutions, but they said that they do not consider the technical challenges to be resolved. Although EM does not require DNFSB approval to restart construction of the pretreatment facility, ORP officials said that they consider the next step in the process to be DNFSB review of their solutions. DNFSB officials, on the other hand, said that the process used to review issues is as follows: (1) DNFSB raises a concern; (2) EM comes up with a conceptual solution, presents it to DNFSB, and receives feedback; and (3) EM then comes up with a design solution, presents it to the DNFSB, and receives feedback. According to DNFSB officials, because they have not been able to review the updated engineering and design plans, they are not in a position to approve the proposed solution. Since 2012, DNFSB has been reviewing EM's proposed technical solutions as part of its role to provide independent advice and recommendations to DOE regarding the protection of public health and safety at DOE facilities.

As of December 2019, DNFSB had officially commented on one of EM's proposed solutions—related to technical challenges surrounding the pulse-jet mixers—and noted simply that EM's and BNI's work "strengthens the technical foundation" for using the mixers and that DNFSB would "continue to follow the design process."[31] With regard to the remaining challenges, DNFSB officials said that for some, additional deficiencies needed to be addressed. For others, DNFSB officials said they were reviewing the details of EM's proposed solution or needed

[30]GAO-15-354.

[31]Defense Nuclear Facilities Safety Board, Letter to the Honorable James Richard Perry, Secretary of Energy (Washington, D.C.: Nov. 18, 2019).

additional information from EM. For two of the categories of technical challenges, DNFSB officials said they considered them to be operational rather than safety issues and therefore DNFSB would not review EM's proposed solutions. (See table 2.)

Table 2: Current Status of the Defense Nuclear Facilities Safety Board's (DNFSB) Assessment of the Technical Challenges Facing the Hanford Pretreatment Facility

Technical Issue	DNFSB Assessment
Hydrogen Gas in Vessels	Additional deficiencies need to be addressed
Criticality in Pulse-Jet Mixer Vessels	Additional deficiencies need to be addressed
Hydrogen in Piping and Ancillary Vessels	Additional deficiencies need to be addressed
Pulse-Jet Mixer Vessel Mixing and Control	Proposed solution strengthens the technical foundation for moving forward
Erosion/Corrosion in Piping and Vessels	Awaiting further information from the Department of Energy's Office of Environmental Management (EM) and Bechtel National, Inc. (BNI)
Standard High Solids Design	Not applicable[a]
Black Cell Vessel/Equipment Structural Integrity	Not applicable[a]
Facility Ventilation/Process Offgas Treatment	Awaiting further information from EM and BNI

Source: DNFSB officials. | GAO-20-363

[a]DNFSB considers these two challenges to be operational issues, rather than safety issues, and does not plan to comment on these challenges identified by EM.

EM Has Not Yet Met Two Best Practices in Its Analysis of Alternatives to the Pretreatment Facility, and Regulators Have Concerns about EM's Engagement

To begin treating LAW by 2023 as required, EM began pursuing pretreatment alternatives in 2013 and has spent about $428 million on developing these alternatives for LAW pretreatment capabilities that were originally planned for the pretreatment facility. We reported in May 2015 that in analyzing alternative LAW pretreatment approaches, EM did not meet two key steps outlined in best practices and DOE internal guidance—define mission need and develop a life-cycle cost estimate for its alternatives. We recommended that EM revise its mission need and its cost estimates for the alternatives being reviewed.[32] In April 2019, EM began analyzing alternatives for treating HLW, and EM officials stated that this analysis of HLW treatment alternatives would follow best practices. However, as of February 2020, EM did not yet have a well-defined mission need statement for its HLW treatment AOA, nor did it have life-cycle cost estimates related to the pretreatment facility, as called for by best practices. In addition, Ecology, a key regulatory stakeholder

[32]GAO-15-354.

for the Hanford cleanup, has raised concerns about the AOA as well as EM's engagement with regulators during this process.

EM Has Been Pursuing LAW Pretreatment Alternatives since 2013 to Begin Treating LAW by 2023

In 2013, to meet its deadline to begin treating LAW by 2023, EM began work on a strategy to bypass the pretreatment facility and instead separate out some of the LAW to remove most of the radioactivity from the tank waste. This approach, called DFLAW, has involved several different activities since 2013 such as constructing separate facilities and infrastructure to accomplish this work, as well as modifying existing facilities:

- **Direct-Feed Low-Activity Waste Modifications and Effluent Management Facility.** EM has spent $272 million on modifications to the WTP to support the DFLAW approach, including designing and constructing the Effluent Management Facility. The Effluent Management Facility is intended to manage the high volume of contaminated liquid generated through the processing of LAW. This capability was originally designed to be located in the pretreatment facility.
- **Low-Activity Waste Pretreatment System.** In fiscal years 2014 through 2018, EM spent approximately $146 million on the Low-Activity Waste Pretreatment System. The Low-Activity Waste Pretreatment System included designing a permanent facility to receive and treat liquid waste, separating out the less radioactive portion from the underground tanks in preparation for direct feed to the WTP's LAW facility. This function was originally intended to be accomplished by the pretreatment facility. In November 2017, ORP ordered work on this permanent facility to be suspended because, according to EM officials, the cost estimates for completing it had become too high and the urgency of meeting the pending treatment deadline too great.

  Tank Side Cesium Removal System (TSCR). EM spent about $6 million for work on a demonstration of the TSCR technology in fiscal year 2018 after suspending the Low-Activity Waste Pretreatment System. TSCR will be built next to an underground double-shelled waste tank and will filter waste directly from the tank to remove solids and cesium. The resulting waste will be pumped to a different underground tank for storage until it can be sent to the LAW facility for vitrification.[33] This would enable the rest of the waste to be fed directly

[33]The cesium would be removed by loading it onto ion exchange columns, which would then be put into interim storage.

to the WTP's LAW facility. ORP plans this demonstration project to be complete as early as 2021 and then, depending on the results, ORP could decide to build additional TSCR units near other tank farms to treat more of the tank waste. [34]

Tank Closure Cesium Removal (TCCR) at Savannah River Site

The Department of Energy's Office of Environmental Management (EM) is currently testing a technology, called Tank Closure Cesium Removal (TCCR). TCCR is designed to accelerate the removal of radioactive waste from tanks at its Savannah River Site in South Carolina. The Savannah River Site was established in the 1950s to produce nuclear materials, resulting in 42 millions of gallons of nuclear waste that was placed in underground tanks. Initiated in January 2019, TCCR removes high-level waste constituents, such as cesium, from the liquid waste so that the low-activity waste—that is, the waste that is less radioactive—can be processed more quickly. The remaining low-activity waste is transferred to the Savannah River Site's Salt Waste Processing Facility where it is immobilized in grout. As of January 2020, the Savannah River Site had processed over 210,000 gallons of waste using TCCR. TCCR is expected to process 600,000 to 750,000 gallons of low-activity waste, after which EM will evaluate the effectiveness of the technology and the feasibility of continued operations.

Source: GAO analysis of DOE data. | GAO-20-363

In addition to DFLAW, EM briefly pursued a smaller-scale pretreatment approach—known as the Test Bed Initiative—in which low-level waste was drawn directly out of the underground tanks (using existing processes and commercial facilities), grouted on site, and shipped to a disposal facility in Texas.[35] EM spent about $4.8 million in fiscal years 2016 through 2018 to design the technology and treat 3 gallons of waste from the underground tanks. EM suspended the Test Bed Initiative in June 2019.[36]

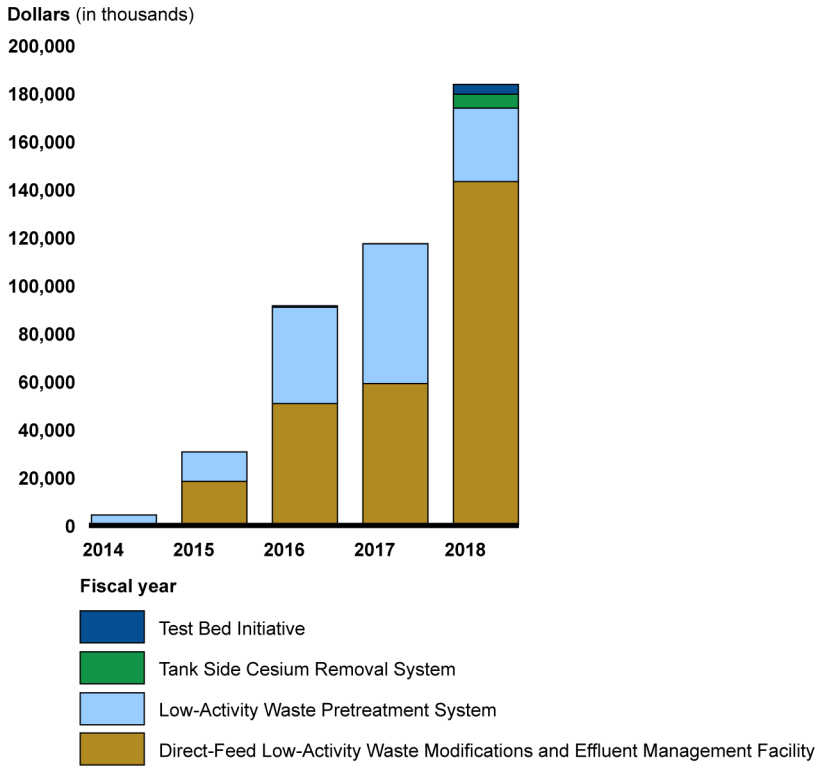
In total, EM has spent about $428 million developing these alternative pretreatment approaches for LAW, in addition to the $752 million spent on the pretreatment facility since 2012. (See fig. 5.)

[34]According to EM officials, after a year of TSCR operations, EM will perform another independent AOA in 2023, to determine the best path for long term LAW treatment.

[35]Grouting is a process in which liquid waste is combined with a concrete-like or grout mixture, which then hardens to immobilize the waste. 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, 2018).

[36]Specifically, EM withdrew the permit for phase 2 of the Test Bed Initiative, citing a May 2019 letter from Ecology as the reason for suspending the project. However, in a response letter, Ecology noted that nothing in the original letter mentioned the initiative, and in fact Ecology had been moving forward to process the Test Bed Initiative permit to meet EM timelines. For fiscal year 2020, Senate and House appropriations committees recommended that DOE spend no more than $10 million on this initiative. S. Rep. No. 116-102 at 132 (2019); H.R. Rep. No. 116-83 at 125 (2019). The House committee report also stated that "the Department is reminded that meeting the Consent Decree milestone for operations of Direct-Feed Low-Activity Waste must remain the Department's top focus within the Office of River Protection." Id.

Figure 5: Low-Activity Waste Pretreatment Alternatives Costs by Fiscal Year, Fiscal Years 2014 through 2018



Source: GAO analysis of Department of Energy data. | GAO-20-363

Note: The costs for all projects except the Test Bed Initiative come from the Department of Energy's Office of Environmental Management's (EM) earned value management (EVM) system for the project. These costs do not include contractor fees or EM oversight costs. For the Test Bed Initiative, we used invoiced costs data because the project did not use an EVM system until fiscal year 2018.

EM Has Not Yet Met Two Best Practices or DOE Guidance in Analyzing HLW Treatment Alternatives

Low-Activity Waste Analysis of Alternatives

EM began exploring alternative LAW pretreatment approaches as early as 2006 in connection with its analysis of options for treating the

supplemental LAW at Hanford.[37] In September 2013, in an effort to make progress while working to resolve technical challenges on the pretreatment facility, EM announced plans to pursue these alternative LAW pretreatment approaches and received funding to do so. However, as we reported in May 2015, EM did not properly define the mission need for the analysis or develop a reliable life-cycle cost estimate for the alternatives it analyzed prior to selecting its preferred alternative:

- First, in May 2015, we found that EM had developed a narrow statement of mission need that effectively excluded other potential alternatives from being considered.[38] This, we noted, was contrary to DOE requirements in DOE Order 413.3B and our best practices for an AOA process, which specify that statements of mission need should not identify a particular solution such as equipment, facility, or technology, to allow the analysis the flexibility to explore a variety of alternatives without limiting potential solutions. We noted that by narrowly defining the mission need in this way, EM effectively narrowed the range of acceptable options and excluded from consideration other alternatives to expediting waste treatment and addressing the potential danger posed by the leakage of waste from the tanks.
- Second, we noted in May 2015 that in choosing its current approach to treating LAW, EM did not develop a life-cycle cost estimate for its Low-Activity Waste Pretreatment System approach and did not develop life-cycle cost estimates for all of the alternatives before choosing its course of action. Our AOA best practices and DOE's AOA Guide call for developing a life-cycle cost estimate for each alternative, including all costs from inception of the project through design, development, deployment, operation, maintenance, and disposal.

We recommended in our May 2015 report that EM revise its mission need statement and life-cycle cost estimate for the Low-Activity Waste Pretreatment System. EM opted to change this alternative pretreatment approach and in 2018 began designing and building TSCR, as noted above. EM did not undertake an AOA process before making that decision; instead, EM chose to pursue TSCR, a technology similar to one being used at the Savannah River Site in South Carolina. EM officials

[37]As previously mentioned, the WTP as currently designed would only have capacity to treat a third to half of the LAW currently in the waste tanks. EM is required by the consent order to begin treating LAW by 2023.

[38]GAO-15-354.

said the decision to move forward on these LAW pretreatment alternatives without an AOA process was based on the urgency of the upcoming requirement to begin treating LAW by 2023. We continue to believe that as EM pursues additional treatment alternatives, EM should properly define the mission need for the analysis and develop a reliable life-cycle cost estimate for the alternatives it is analyzing.

High-Level Waste Analysis of Alternatives

In April 2019, EM initiated an AOA for treating the HLW in the tanks at Hanford and plans to conclude the review and report its findings in September 2020. According to the review team's September 2019 study plan, the review is to analyze 15 alternatives, including completing the pretreatment facility as planned, repurposing the pretreatment facility, and changing the current approach to pursue other pretreatment options. Some of the other options the review team plans to explore include sending HLW directly from the underground tanks to the HLW facility for treatment, building alternate HLW pretreatment facilities, and shipping the HLW to the Savannah River Site in South Carolina for treatment. (See appendix IV for a list of the alternatives being analyzed.)[39]

EM officials said that in undertaking this AOA for HLW treatment alternatives, they plan to meet best practices for an AOA process and those in DOE's AOA Guide. They noted that, consistent with these AOA best practices, EM has developed a time frame to complete the review, established a review team, and defined and weighed selection criteria against which to compare the alternatives. However, based on our review, as of February 2020, EM had not yet met two key steps—defining mission need and developing a life-cycle cost estimate for the baseline alternative—that are among the best practices we identified for an AOA process.

- First, EM has not yet defined the mission need, which is the first element in a successful AOA and is called for in DOE's guidance for conducting an AOA. One ORP official said that a succinct definition of the mission need for the AOA does not exist but is or can be deduced from the documents provided to the contractor conducting the analysis. An official from DOE's Office of Project Management

[39]The Savannah River Site was established in the 1950s to produce nuclear materials, such as tritium and plutonium that were needed to manufacture nuclear weapons. As a result of nuclear materials production at the site from 1954 to the present, about 42 million gallons of waste has been stored in 51 underground tanks at the site. According to EM officials, EM has treated about 10.5 million gallons of LAW (grouted) and about 4.3 million gallons of HLW (vitrified) of the Savannah River Site's tank waste.

confirmed that there is no mission need statement and noted that because the WTP began prior to the DOE Order requiring a mission need statement, there is no such statement for the WTP or for the current AOA. We have previously noted that defining the mission need is the first step in the AOA process in order to ensure that the AOA process does not favor one solution over another.[40] We have also previously noted that when a concise set of objectives is established, it can ensure that the decision-making process stays open to a range of potential options.[41]

- Second, as we noted earlier in this report, EM does not have an updated cost estimate for the baseline (or status quo) alternative of completing the pretreatment facility. As such, it is uncertain if or how EM will have a life-cycle cost estimate to compare the baseline alternative to the other alternatives it is analyzing. One of the best practices for an AOA process calls for the inclusion of the cost to pursue the baseline alternative (in this case, the cost of completing the existing pretreatment facility), to provide a basis of comparison among alternatives. However, EM officials told us that they do not intend to update EM's cost estimate for completing the existing pretreatment facility because it is not a priority for ORP; instead, ORP's priority is beginning DFLAW operations. Without a life-cycle cost estimate for EM's baseline alternative, decision makers will not have a complete picture of the costs and will have difficulty comparing the alternatives because comparisons may not be based on accurate information.

Without a defined mission need and a complete cost estimate for the baseline alternative, EM's AOA for HLW treatment alternatives will be missing key elements that are necessary to provide decision makers with the information needed to make the best decision going forward. EM's analysis and the subsequent decisions that are made based on that analysis could be undermined as a result.

[40]GAO-20-195G.

[41]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).

EM and Ecology Disagree about the Adequacy of Ecology's Engagement in the Process to Analyze Alternatives to the Pretreatment Facility

Officials from Ecology have raised concerns about EM's lack of progress on finishing the original pretreatment facility and EM's shifting focus on the pretreatment mission. In a letter to EM in May 2019, Ecology's director outlined a series of concerns related to the pretreatment mission and stated that Ecology is not "conceding to, accepting, or acquiescing in any alternative path forward that is different than what has been agreed to in the TPA and Amended Consent Decree between our two agencies." In September 2019, ORP informed Ecology that a serious risk had arisen that DOE might be unable to meet certain Amended Consent Decree milestones related to, among other things, the construction of the pretreatment facility. In the same month, ORP agreed to participate in "holistic negotiations" to identify a new path forward for treating and disposing of Hanford's tank waste. As part of this agreement, the parties involved—EM, Ecology, and the Environmental Protection Agency—could use the services of a mediator to assist with negotiations, which may be completed by July 31, 2020.

Ecology officials also said that EM has not adequately consulted with them while making important decisions about the pretreatment mission and facility. In particular, in January 2020, Ecology officials told us that they had not been engaged early, often, or appropriately by EM regarding EM's changing plans to pretreat the tank waste and that they were concerned about the possible negative impacts of EM diverting its resources away from completing the pretreatment facility. According to Ecology officials, they have been invited to key EM meetings but have not been properly engaged in the decision-making process. In an October 2019 presentation to panelists from the National Academies of Sciences, Engineering, and Medicine, Ecology officials noted their frustration with "too many ideas that did not work out, resulting in long delays." In December 2019, because of concerns that EM was not providing access to all of the information needed to make timely regulatory decisions, Ecology issued a determination requiring EM to provide information as required by the TPA within 30 days. In January 2020, after EM failed to provide the information, Ecology fined EM $1 million and reiterated that without access to this crucial data, it was nearly impossible for Ecology to independently verify compliance with cleanup regulations.

According to officials at EM headquarters, engagement with Ecology is a priority, and ORP officials said that since 2018, their engagement with Ecology has improved. In particular, ORP officials noted that Ecology has had representatives on a joint team tasked with exploring the options to be examined under the HLW AOA and has a representative on the AOA review team to observe the deliberations.

In September 2019, we outlined a risk-informed framework for making cleanup decisions and recommended that EM incorporate this framework into its cleanup policy across the entire DOE complex. DOE agreed with this recommendation but has yet to respond with a plan to implement it. In that report, we state that the risk-informed decision-making framework can be applied to a range of cleanup decisions, from selecting a cleanup approach at a single site to prioritizing cleanup activities across sites. The risk-informed decision-making framework consists of several steps, including engaging with stakeholders such as Ecology throughout the decision-making process.[42] In that report, we noted that the goal of engaging stakeholder groups in a risk-informed cleanup decision should be to incorporate their viewpoints and seek their acceptance of the decision-making process as transparent and legitimate, rather than to obtain their concurrence with the final decision. We also found that this can best be accomplished when EM seeks stakeholders' input and buy-in to the process by providing meaningful opportunities for engagement early in the process, communicating throughout the process, and providing transparent, understandable information about the science and rationale behind the final decision. Doing so can help improve the likelihood that stakeholders will view the decision-making process as fair and legitimate. By following the steps outlined in our risk-informed decision-making framework as it makes decisions about the future of the Hanford pretreatment facility, EM and stakeholders would have greater assurance that EM's decision-making process is transparent, participatory, and credible.

Conclusions

After nearly 20 years and with over $11 billion spent since EM awarded the contract to design and build the WTP, the WTP is not complete and has faced numerous technical challenges, cost overruns, and schedule delays. According to a recent study by the U.S. Army Corps of Engineers and EM's *Hanford Lifecycle Report*, the largest and most complex portion of the WTP—the pretreatment facility—is unlikely to be completed as designed and scheduled. Since the early years of the project, we have recommended that EM stop moving ahead on the pretreatment facility until it resolves the numerous technical challenges or conducts a reliable analysis of alternatives and determines a risk-informed, cost-effective path forward. However, EM has yet to fully implement these recommendations. EM officials reported that the technical challenges that have plagued the project for years have been solved, but EM has not developed the design and engineering changes needed to implement the

[42]GAO-19-339.

solutions. Instead, EM is focusing on analyzing alternatives to accomplish the mission of the pretreatment facility and officials have stated that this analysis will follow best practices we have identified and DOE guidance. EM's current AOA of HLW treatment alternatives is still under way, and officials told us that they intend to follow best practices for developing an AOA. However, as of February 2020, the AOA still lacks at least two key elements of the best practices. First, without a clear statement of mission need, it is unclear on what basis decision makers will consider and assess the alternatives being considered. Second, without an updated life-cycle cost estimate to complete the pretreatment facility, it is unclear whether the HLW pretreatment alternatives being analyzed represent a better path forward than completing the partially constructed pretreatment facility as originally planned. Without these key elements of an AOA, EM's ultimate decision may not be the best option or be credible with stakeholders. Throughout this decision-making process, EM's engagement with Ecology has not met the expectations of the regulator, resulting in fines and further delays as all parties participate in an ongoing, mediated negotiation on a path forward. By following the steps outlined in our risk-informed decision-making framework as it makes decisions about the future of the pretreatment facility, EM can ensure that its regulators have greater assurance that EM's decision-making process is transparent, participatory, and credible.

Recommendations for Executive Action

We are making the following two recommendations to DOE:

- The Secretary of Energy should direct the Assistant Secretary of Environmental Management to ensure that EM's final AOA for HLW pretreatment at the Hanford Site includes a definition of mission need and life-cycle cost estimates for the baseline or status quo alternative, as called for in the best practices for an AOA process we have identified and DOE guidance. (Recommendation 1)
- The Secretary of Energy should direct the Assistant Secretary of Environmental Management to follow the steps outlined in GAO's risk-informed decision-making framework as EM makes decisions about the future of the pretreatment mission; in particular, engaging the Washington State Department of Ecology in the AOA process, communicating with them throughout the process, and providing them with transparent information about the rationale behind the final decision. (Recommendation 2)

Agency Comments

We provided a draft of this report to the Secretary of the Department of Energy. In its written comments, reproduced in appendix VI, DOE concurred in principle with our recommendations and outlined a plan to address the recommendations by December 31, 2020. DOE also provided additional technical comments, which we have incorporated into the report as appropriate.

We are sending copies of this report to the appropriate congressional committees, the Secretary of Energy, and other interested parties. In addition, this 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 trimbled@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 VII.

David C. Trimble
Director, Natural Resources and Environment

List of Committees

The Honorable James M. Inhofe
Chairman
The Honorable Jack Reed
Ranking Member
Committee on Armed Services
United States Senate

The Honorable Lamar Alexander
Chairman
The Honorable Dianne Feinstein
Ranking Member
Subcommittee on Energy and Water Development
Committee on Appropriations
United States Senate

The Honorable Adam Smith
Chairman
The Honorable Mac Thornberry
Ranking Member
Committee on Armed Services
House of Representatives

The Honorable Marcia Carolyn Kaptur
Chairman
The Honorable Michael K. Simpson
Ranking Member
Subcommittee on Energy, Water Development,
and Related Agencies
Committee on Appropriations
House of Representatives

Appendix I: Objectives, Scope, and Methodology

Our report examines (1) the cost of pretreatment efforts from fiscal year 2013 through fiscal year 2018 and the status of the pretreatment facility, (2) the status of the technical challenges facing the pretreatment facility, and (3) the steps the U.S. Department of Energy's (DOE) Office of Environmental Management (EM) is taking to begin treating waste by 2023 as required and the extent to which EM has engaged with regulators.

To determine the cost of the pretreatment facility, we reviewed Earned Value Management (EVM) status reports from Bechtel National, Inc. (BNI) and fiscal year totals for EM's oversight costs and BNI's award and contract modification fees for the pretreatment facility for fiscal years 2013 through 2018 provided by officials in EM's Office of River Protection (ORP), which oversees the construction of the Waste Treatment and Immobilization Plant (WTP) at Hanford.[1] BNI's EVM status reports give actual costs for the work performed categorized by a number of different activities, such as engineering to design the pretreatment facility and the acquisition of plant equipment items to be installed in the pretreatment facility. For reporting purposes, we combined BNI accounts with similar activity descriptions and renamed them. To determine the activities included in the accounts, we reviewed both the Work Authorization Document, which describes activities covered by each account used in BNI's EVM status reports, as well as descriptions of major accomplishments achieved each fiscal year included in the summary status report.

To determine the cost of alternative pretreatment efforts, we reviewed EVM status reports for the Direct-Feed Low-Activity Waste project, the Low-Activity Waste Pretreatment System, and the Tank Side Cesium Removal project for fiscal years 2014 through 2018. Because the Test Bed Initiative project did not use an EVM system until fiscal year 2018, we reviewed invoiced costs data for that project for fiscal years 2016 through 2018. To gain context on the planned capabilities of these projects, we reviewed project presentations for pretreatment alternatives and interviewed ORP and BNI officials to learn more about the progress made in developing each project. To assess the reliability of all cost data for both the pretreatment facility and alternative pretreatment efforts, we reviewed documentation and officials' responses related to data-gathering

[1]EVM measures the value of work accomplished in a given period and compares it with the planned value of work scheduled for the period and with the actual cost of the work accomplished. EVM is an industry standard and is considered a best practice for conducting cost and schedule performance analysis for projects.

processes, data storage systems, and data limitations for each of the relevant sources to ORP. Based on this, we found all of the data sources to be sufficiently reliable for our reporting objectives. Finally, to determine the extent to which EM has established a cost estimate to complete the pretreatment facility that is consistent with DOE policy set out in DOE Order 413.3B, we interviewed officials about EM's cost estimate to complete the facility.

To examine the status of technical challenges facing the pretreatment facility and to gather information pertaining to obstacles and risks of project completion, we reviewed the following documents:

- ORP's 2018 briefing to the Washington State Department of Ecology (Ecology) regarding the status of challenges,
- BNI's 2018 briefing about the status of the pretreatment facility,
- The U.S. Army Corps of Engineers' 2018 report on the status of the WTP, and
- The Defense Nuclear Facilities Safety Board's (DNFSB) 2017 technical report on WTP hazards.

We also interviewed officials from EM, regulators at Ecology, officials from the U.S. Environmental Protection Agency, and contractor officials who are working to resolve these challenges to better understand the status of the technical challenges, as well as any concerns they might have. In addition, we interviewed officials from DNFSB—an independent agency that provides analysis, advice, and recommendations to the Secretary of Energy regarding the adequate protection of public health and safety at DOE's defense nuclear facilities—regarding DNFSB's assessment of the technical challenges and what additional steps, if any, DOE needs to take to resolve the challenges.

To examine the steps EM is taking to begin treating waste by 2023 as required, we visited the WTP construction site at Hanford in May 2019 to observe the status of the construction of the pretreatment facility and pretreatment alternatives. We reviewed historical documentation, such as technical reports summarizing testing, and studies conducted by EM and its contractors. These reports included Washington River Protection Solutions' 2014 low-activity waste (LAW) alternatives analyses summary and its 2011 conceptual design report, and CH2M HILL Hanford Group's 2006 LAW First Study. We interviewed DOE officials from headquarters to discuss the status of and future plans for the WTP and DOE officials from ORP at Hanford to gather information about the project. We also

interviewed ORP contractors regarding their ongoing and planned efforts related to pretreatment of the tank waste and regulator officials from Ecology to better understand their concerns and priorities.

To analyze the extent to which EM is following guidance and best practices as it conducts its analysis of alternatives (AOA) of high-level waste (HLW) treatment alternatives, we first interviewed DOE officials and reviewed available documentation associated with DOE's ongoing AOA to determine the status of the draft AOA. We then reviewed the steps EM is taking and compared them against DOE's project management requirements (DOE Order 413.3B) and guidance (DOE Analysis of Alternatives Guide) and the best practices for an AOA process that we identified in our prior work.[2] Because EM was conducting its own AOA concurrent with our review, we selected two key best practices in an AOA process—define mission need and develop a life-cycle cost estimate for the baseline (or status quo) alternative—because these two steps are requisite for completing the remaining steps of an AOA. These steps are also essential to ensuring that the other 20 best practices and the results of the AOA are credible and based on accurate information.[3] We also noted best practices that EM officials noted EM has met thus far. In addition, we compared EM's decision-making process, in particular its stakeholder engagement, against a framework for risk-informed decision-making we developed in our prior work.[4] We developed this framework in 2019 to assist agencies in identifying and implementing the essential elements of risk-informed decision-making. To create the framework, we synthesized key concepts from relevant literature and input from experts who participated in a meeting convened by the National Academies of Sciences, Engineering, and Medicine.

We conducted this performance audit from February 2019 to May 2020 in accordance with generally accepted government auditing standards.

[2]Department of Energy, *Program and Project Management for the Acquisition of Capital Assets*, DOE Order 413.3B (Washington, D.C.: Nov. 29, 2010). Department of Energy, *Analysis of Alternatives Guide*, DOE G 413.3-22 (Washington, D.C., June 6, 2018). GAO, *Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Program Costs*, GAO-20-195G (Washington, D.C.: March 2020). See appendix V for a full list and explanation of these best practices.

[3]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).

[4]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).

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 Bechtel National, Inc. (BNI) Cost Accounts

The Office of Environmental Management's contractor for its pretreatment facility, BNI, tracks its costs in its Earned Value Management system. Costs are tracked through the use of different accounting codes that represent the costs of different types of activities. For reporting purposes, we combined BNI accounts with descriptions of similar activities and renamed them. The table below lists the labels we used, the BNI account codes included in each label, and selected examples of activities described for each accounting code.

Table 3: GAO Analysis of Bechtel National, Inc. (BNI) Cost Accounts

GAO label	BNI account code	Selected examples of activities included in BNI account
Resolution of technical challenges	1.01.ENG	Continued efforts to resolve eight technical challenges.
	1.01.I	Continued efforts to resolve the pulse-jet mixer vessel mixing and control technical challenge.
Overhead and project management	1.01.ZPSA	Shared services cost, including overhead and the cost of common activities for multiple facilities.
	1.01.PM/PC/Q	Monitoring and reporting of project cost and schedule performance and administrative support.
Equipment purchase and management	1.01.EQ	Long-term material storage and periodic inspections.
	1.01.MT	Suspension of pipe spools and structural steel purchase orders.
	1.01.U	Preservation maintenance of permanent equipment.
Facility maintenance	1.01.T	Site preventative maintenance, including weather protection and general cleanup.

Source: GAO analysis of Department of Energy data. | GAO-20-363

Appendix III: Technical Challenges Facing the Department of Energy's Waste Treatment and Immobilization Plant's (WTP) Pretreatment Facility

Table 4: Summary of the Technical Challenges Facing the Hanford Site's Pretreatment Facility

Technical Challenges	Description
Hydrogen Gas in Vessels	Inadequate pulse jet mixing can lead to the accumulation of solids in process vessels, resulting in generation and accumulation of hydrogen and potentially leading to explosions. Settled sludge layers will rise in temperature, increasing the hydrogen generation rate.
Criticality in Pulse-Jet Mixer Vessels	Up to 16 of the 177 underground tanks at Hanford contain large-size plutonium particles that could settle onto internal surfaces of the pulse-jet mixer vessels, which use compressed air to mix the waste.[a] If the pulse-jet mixers could not then resuspend settled particles, an uncontrolled nuclear chain reaction known as a criticality accident could occur.[b]
Hydrogen in Piping and Ancillary Vessels	In the Pretreatment facility and High-Level Waste (HLW) facility, the accumulation of hydrogen gas in piping and small vessels can occur after the loss of off-site power or after an interruption of a transfer of waste due to operator error and during normal operation in isolated pipe sections, potentially causing an explosion.
Pulse-Jet Mixer Vessel Mixing and Control	Accumulating solids in pulse-jet mixing vessels could cause excessive air to be discharged in the vessels. This discharge could cause premature erosion of vessel surface bottoms, all of which are located in nonmaintanable areas called black cells. In addition, pulse-jet mixing vessels may need structural modifications to account for abnormal environmental conditions, such as seismic events.
Erosion/Corrosion in Piping and Vessels	Because of uncertainties in waste feed characteristics, the vessel and piping design in the Pretreatment facility and HLW facility may require revisions to account for the amount of wear the equipment will need to withstand. Excessive wear could damage plant equipment and result in interruption of operations or leakage of material from vessels and piping.
Standard High Solids Design	The potential incorporation of a Standards High Solids Vessel into Pretreatment requires a detailed study to determine the feasibility and optimization of this design change. An additional opportunity is created to revisit the capability to perform In service inspections in order to underpin resolution of erosion/corrosion questions. The Project has not established an in-service inspection program.
Black Cell Vessel/ Equipment Structural Integrity	Once WTP operations begin, equipment in black cells within the Pretreatment facility and HLW facility must last for the WTP's 40-year expected design life without maintenance because significant failures of components installed in the black cells could impact the throughput and mission duration of the WTP. Potential weaknesses in equipment and piping located within black cells must be identified before WTP operations begin to ensure that timely repairs can be conducted, should failure of these components occur.
Facility Ventilation/ Process Offgas Treatment	Ventilation systems in the Pretreatment facility, HLW facility, and Low-Activity Waste facility must be able to contain radioactive material that could be released from primary confinement. The structural integrity of some internal vessel components in these facilities could be compromised if seismic or other events beyond the design basis occur. The ventilation system must survive a release of radioactive material without shutdown, plugging, or blowing out filters to continue to provide confinement.

Source: GAO summary of Department of Energy data. | GAO-20-363

[a]Such devices have been used successfully in other materials mixing applications but required testing and analysis to ensure satisfactory performance for waste conditions like that to be treated at the WTP, according to Office of River Protection officials.

[b]Criticality accidents result from the unintentional assembly of a critical mass of fissile material, such as plutonium or enriched uranium, in a protected or unprotected environment. To shield plant workers from intense radiation that will occur during WTP operations, some processing tanks will be located in sealed compartments called "black cells." These black cells are shielded rooms where inspection, maintenance, repair, or replacement of equipment or components is extremely difficult because high radiation levels prevent access into the rooms. As a result, plant equipment in black cells must last for WTP's 40-year expected design life without maintenance. According to the Department of Energy, black cells are intended to provide for a protected/shielded environment in the event that a criticality occurs.

Appendix IV: High-Level Waste (HLW) Alternatives Being Analyzed by the Office of River Protection

Table 5: High-Level Waste (HLW) Treatment Alternatives Being Analyzed by the Office of River Protection

Alternative	Description
Pretreatment in new HLW Feed Preparation Facility	HLW is received, characterized, and pretreated in HLW Feed Preparation Facility; contaminated liquids produced in the process are concentrated in a new HLW Effluent Management.
Characterization in the tanks and pretreatment in HLW Feed Preparation Facility	HLW is sampled, characterized, and staged in the tanks. HLW is then pretreated in HLW Feed Preparation Facility; contaminated liquids produced in the process are concentrated in HLW Effluent Management Facility.
Pretreatment (at high temperatures) in new HLW Feed Preparation Facility	Same as previous alternative with some processes performed at a higher temperature.
Repurposed pretreatment facility	HLW is transferred to the pretreatment facility for preparation and staging; then leached, washed, and concentrated in the HLW Feed Preparation Facility. Contaminated liquids produced in the process are concentrated in the pretreatment facility.
Alternative technologies	HLW treated using alternative technologies such as grouting or steam reforming. Would require technology development, research and development, lab testing and technology readiness assessment.
Immobilize HLW in the tanks	HLW is immobilized within existing tanks using alternative technologies. Would require technology development, research and development, lab testing and technology readiness assessment.
Construct new treatment facilities on the Hanford Site	HLW in the tanks located furthest away from the Waste Treatment and Immobilization Plant (in the western portion of the site) is pretreated and treated in new west area HLW Feed Preparation Facility, HLW Effluent Management Facility, and HLW vitrification facilities.
Pretreatment in new HLW Feed Preparation Facility, effluent management in repurposed pretreatment facility	HLW is received, characterized, and pretreated in in HLW Feed Preparation Facility; contaminated liquids produced in the process are concentrated in new facilities. Pretreatment facility repurposed to treat low-activity waste.
Treatment and vitrification at the Savannah River Site	HLW is transferred to compliant mediums for transfer to Savannah River Site for treatment and vitrification.
Repurpose the unused Fuels Material Examination Facility	Fuels Material Examination Facility would be retrofitted to provide pretreatment capabilities.
Repurpose pretreatment facility	HLW vitrification facility is abandoned; pretreatment facility is repurposed to pretreat and vitrify HLW.
Bulk vitrification	HLW is pretreated and vitrified at a near-tank mobile facility or in a centrally located facility using bulk vitrification technology. Would require technology development, research and development, lab testing and technology readiness assessment.
HLW Feed Preparation Facility with added filtering capability and HLW Effluent Management Facility	Same as the second alternative above with added filtering capability.
Direct feed HLW with HLW Effluent Management Facility	HLW is sampled, characterized, and staged in the tanks. Contaminated liquids produced in the process are concentrated in HLW Effluent Management Facility.
Direct feed HLW with pretreatment in tanks and HLW Effluent Management Facility	Same as previous alternative with added step of concentrating the HLW in the HLW Effluent Management Facility before sending it to be vitrified.

Source: GAO summary of Department of Energy data. | GAO-20-363

Appendix V: Analysis of Alternatives (AOA) Best Practices

The guidance below is meant as an overview of the key principles that lead to a successful AOA process and not as a "how to" guide with detailed instructions for each best practice identified. Conforming to the 22 best practices helps ensure that the preferred alternative selected is the one that best meets the agency's mission needs. Not conforming to the best practices may lead to an unreliable AOA, and the customer will not have assurance that the preferred alternative best meets the mission needs. Table 6 shows the 22 best practices.

Table 6: Best Practices for the Analysis of Alternatives (AOA) Process

1.	Define mission need	The customer defines the mission needs (i.e., a credible gap between current capabilities and those required to meet the goals articulated in the strategic plan) without a predetermined solution. To ensure that the Analysis of Alternatives (AOA) process does not favor one solution over another, the AOA is conducted before design and development of the required capabilities. The customer decides at which level of design completion an AOA should be performed, with the understanding that the more complete the design, the more information is available to support a robust analysis and to select a preferred alternative that best meets the mission need.
2.	Define functional requirements	The customer defines functional requirements (i.e., the general parameters that the selected alternative must have to address the mission need) based on the mission need without a predetermined solution. The customer defines the capabilities that the AOA process seeks to refine through characterized gaps between capabilities in the current environment and the capabilities required to meet the stated objectives for the future environment. These functional requirements are realistic, organized, clear, prioritized, and traceable. It is advisable that functional requirements be set early in the AOA process and agreed upon by all stakeholders.
3.	Develop AOA time frame	The customer provides the team conducting the analysis enough time to complete the AOA in order to ensure a robust and complete analysis. Since an AOA process requires a large team with many diverse resources and expertise, the process requires sufficient time to be accomplished thoroughly. A detailed schedule is developed prior to starting the AOA process. The duration of the AOA process depends on the number of viable alternatives and availability of the team members. The time frame is tailored for the type of system to be analyzed and ensures that there is adequate time to accomplish all of the AOA process steps robustly.
4.	Establish AOA team	After the customer establishes the need for the AOA in steps 1 through 3, a diverse AOA team is established to develop the AOA. This team consists of members with a variety of necessary skill sets, specific knowledge, and abilities to successfully execute the study. For example, the AOA team includes individuals with skills and experience in the following areas: program management, federal contracting, cost estimating, risk management, sustainability, scheduling, operations, technology, earned value management, budget analysis, and any other necessary areas of expertise.
5.	Define selection criteria	The AOA team or the decision maker defines selection criteria based on the mission need. The defined criteria are based on mission needs and are independent of a particular capital asset or technological solution. The selection criteria are defined based on the mission need prior to starting the analysis.
6.	Weight selection criteria	The AOA team or the decision maker weights the selection criteria to reflect the relative importance of each criterion. While the selection criteria are ranked in importance, the alternatives are based on trade-offs between costs, operational effectiveness, risks, schedules, flexibility, and other factors identified by the team or the decision maker.

7.	Develop AOA process plan	The AOA team creates a plan to include proposed methodologies for identifying, analyzing, and selecting alternatives prior to beginning the AOA process. This plan establishes the critical questions to be explored, the selection criteria, the basis of estimates, and measures that are used to rate, rank, and decide among the alternatives. Additionally, the plan includes the criteria used to determine each alternative's viability. A road map and standard work breakdown structure are used to compare the alternatives with the baseline and with each other.
8.	Develop list of alternatives	The AOA team identifies and considers a diverse range of alternatives to meet the mission need. To fully address the capability gaps between the current environment and the stated objectives for the future environment, market surveillance and market research is performed to develop as many alternative solutions as possible for examination. Alternatives are mutually exclusive, that is, the success of one alternative does not rely upon the success of another.
9.	Describe alternatives	The AOA team describes alternatives in sufficient detail to allow for robust analysis. All alternatives' scope is described in terms of functional requirements. This description is detailed enough to support the viability, cost, and benefit/effectiveness analyses.
10.	Include baseline alternative	The AOA team includes one alternative to represent the status quo to provide a basis of comparison among alternatives. It is critical for the AOA team to first understand the status quo, which represents the existing capability's baseline where no action is taken, before comparing alternatives. The baseline is well documented as an alternative in the study and is used to represent the current capabilities and also for explicit comparison later in the study.
11.	Assess alternatives' viability	The AOA team screens the list of alternatives to eliminate those alternatives that are not viable, and it documents the reasons for eliminating any alternatives. All alternatives are examined using predetermined qualitative technical and operational factors to determine their viability. Only those alternatives found viable are examined fully in the AOA process. However, all assumptions regarding the alternatives' viable and nonviable status are fully documented, including reasons that an alternative is not viable, in order to justify the recommendation. Additionally, viable alternatives that are not affordable within the projected available budget are dropped from final consideration.
12.	Identify significant risks and mitigation strategies	The AOA team identifies and documents the significant risks and mitigation strategies for each alternative. Risks are ranked in terms of significance to mission needs and functional requirements. All risks are documented for each alternative along with any overarching or alternative specific mitigation strategies. Schedule risk, cost risk, technical feasibility, risk of technical obsolescence, dependencies between a new project and other projects or systems, procurement and contract risk, and resources risks are examined.
13.	Determine and quantify benefits/effectiveness	The AOA team uses a standard process to document the benefits and effectiveness of each alternative. The AOA team drafts a metric framework that details the methods used to evaluate and quantify the measures of effectiveness and measures of performance for all mission needs. The AOA team quantifies the benefits and effectiveness of each alternative over the alternative's full life-cycle, if possible. Just as costs cover the entire life-cycle for each alternative, the benefits and effectiveness measures cover each alternative's life-cycle, if possible, in order to determine each alternative's net present value—the discounted value of expected benefits minus the discounted value of expected costs. In cases where the means to monetize a benefit are too vague (for example, intangibles like scientific knowledge), the AOA team treats those benefits as strategic technical benefits and uses scalability assessments to quantify those benefits so that they are compared across all viable alternatives. In situation where benefits cannot be quantified, the AOA team explains why this is the case as part of their analysis.
14.	Tie benefits/effectiveness to mission need	The AOA team explains how each measure of effectiveness supports the mission need. The AOA team shows how the measures of effectiveness describe the way the current environment is expected to evolve to meet the desired environment; the team also shows how the measures are tied to specific mission needs and functional requirements. This is the hierarchy that connects the overarching requirements to the data that are needed.

15. Develop life-cycle cost estimates (LCCEs)	The AOA team develops a LCCE for each alternative, including all costs from inception of the project through design, development, deployment, operation, maintenance, and disposal. The AOA team includes a cost expert who is responsible for development of a comprehensive, well-documented, accurate, and credible cost estimate for each viable alternative in the study. The LCCE for each alternative follows the GAO 12-step guide and uses a common cost element structure for all alternatives and includes all costs for each alternative. Costs that are the same across the alternatives (for example, training costs) are included so that decision makers can compare the total cost rather than just the portion of costs that varies across all viable alternatives. The AOA team expresses the LCCE in present value terms and explains why it chose the specific discount rate used. The AOA team ensures that economic changes, such as inflation and the discount rate are properly applied, realistically reflected, and documented in the LCCE for all alternatives. Furthermore, the present value of the estimate reflects the time value of money—the concept that a dollar today can be invested and earn interest.
16. Include a confidence interval or range for LCCEs	The AOA team presents the LCCE for each alternative with a confidence interval or range, and not solely as a point estimate. To document the level of risk associated with the point estimate for each viable alternative, the confidence interval is included as part of the LCCE for each viable alternative (in accordance with GAO Cost Estimating Best Practice #9, risk and uncertainty analysis).b Decision makers must have access to the confidence interval associated with the point estimates for all viable alternatives in order to make informed decisions. Additionally, the AOA team uses a consistent method of comparing alternatives in order to present a comparable view of the risk associated with each alternative. For example, the comparison can be based on an established dollar value across alternatives (in order to observe the confidence level for each alternative at that dollar value). Alternatively, the comparison can be based on a predetermined confidence level across alternatives (in order to observe the dollar value associated with that confidence level for each alternative).
17. Perform sensitivity analysis	The AOA team tests and documents the sensitivity of the cost and benefit and effectiveness estimates for each alternative to risks and changes in key assumptions. Major outcomes and assumptions are varied in order to determine each alternative's sensitivity to changes in key assumptions. This analysis is performed in order to rank the key drivers that could influence the cost and benefit estimates based on how they affect the final results for each alternative. Each alternative includes both a sensitivity and risk and uncertainty analysis that identifies a range of possible costs based on varying key assumptions, parameters, and data inputs. As explained in best practice #16, life-cycle cost estimates are adjusted to account for risk and sensitivity analyses.
18. Document AOA process in a single document	The AOA team documents all steps taken to identify, analyze, and select alternatives in a single document. This document clearly states the preferred alternative and provides the detailed rationale for the recommendation based on analytic results. The report includes sections detailing the steps taken to initialize the AOA process, and to identify, analyze, and select alternatives. For example, one section lists the overall selection criteria and rationale for nonviable or viable ratings for alternatives, assumptions for each alternative, risk drivers and mitigation techniques, analysis of the costs and benefits associated with each alternative, and the trade-offs between costs, benefits, and risks.
19. Document assumptions and constraints	The AOA team documents and justifies all assumptions and constraints used in the AOA process. Assumptions and constraints help to scope the AOA. Assumptions are explicit statements used to specify precisely the environment to which the analysis applies, while constraints are requirements or other factors that cannot be changed to achieve a more beneficial approach. Both assumptions and constraints are detailed and justified for each alternative in the AOA plan.
20. Ensure AOA process is impartial	The AOA team conducts the analysis without a predetermined solution. The AOA process informs the decision-making process rather than reflecting the validation of a predetermined solution. The AOA process is an unbiased inquiry into the costs, benefits, and capabilities of all alternatives.

21. Perform independent review	An entity independent of the AOA process reviews the extent to which all best practices are followed. The AOA process is completed with enough thoroughness to ensure that an independent organization outside of the project's chain of command can review the AOA documentation and clearly understand the process and rationale that led to the selection of the recommended alternative. Part of the documentation includes approval and review from an office outside of the one that asked for or performed the AOA process. For certain projects, in addition to an independent review at the end of the AOA process, additional independent reviews are necessary at earlier stages of the process, such as reviews of the AOA process plan of the identification of viable alternatives. While early reviews are not a substitute for the independent review conducted at the end of the AOA process, they help ensure that bias is not added throughout the course of the AOA process.
22. Compare alternatives	The AOA team or the decision maker compares the alternatives using net present value, if possible, to select a preferred alternative. Net present value can be negative if discounted costs are greater than discounted benefits. Net present value is the standard criteria used when deciding whether an alternative can be justified based on economic principles. In some cases, net present value cannot be used, such as when quantifying benefits is not possible. In these cases, the AOA team documents why net present value cannot be used. Furthermore, if net present value is not used to differentiate among alternatives, the AOA team should document why net present value is not used, and describe the other method that is used to differentiate, and explain why that method has been applied.

Source: GAO. | GAO-20-363

Appendix VI: Comments from the Department of Energy

Department of Energy
Washington, DC 20585
April 27, 2020

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

Dear Mr. Trimble:

The Department of Energy (DOE) appreciates the opportunity to provide a response to the Government Accountability Office's (GAO) draft report titled, *Hanford Waste Treatment Plant: DOE Is Pursuing Pretreatment Alternatives, but Its Strategy Is Unclear and Costs Are Unknown (GAO-20-363).*

The draft report contains two recommendations for DOE. DOE concurs in principle with each of GAO's recommendations.

DOE is concerned that the draft audit report, in its current form, could lead to misunderstandings with the public and interested stakeholders. In order for the report to more accurately reflect DOE current actions, and the information provided to GAO during the course of its engagement, DOE is providing additional comments on the draft report.

If you have any questions, please contact me or Ms. Candice Robertson, Acting Associate Principal Deputy Assistant Secretary for Field Operations, at (202) 287-5603.

Sincerely,

William I. White
Senior Advisor for Environmental Management
to the Under Secretary for Science

Enclosures

Enclosure 1

Management Response
Hanford Waste Treatment Plant: DOE Is Pursuing Pretreatment Alternatives, but Its Strategy Is Unclear and Costs Are Unknown, GAO-20-363

Recommendation 1: *The Secretary of Energy should direct the Assistant Secretary of Environmental Management to ensure that its AOA for HLW pretreatment at the Hanford Site include a definition of mission need and life-cycle cost estimates for the baseline or status quo alternative, as called for in the best practices for an AOA process we have identified, and DOE guidance.*

Management Response: *Concur in Principle*

The High Level Waste (HLW) Treatment Analysis of Alternatives (AOA) is following the Government Accountability Office (GAO) best practices for an AOA process, and is consistent with the Department of Energy (DOE) Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets*, and DOE Guide 413.3-22, *Analysis of Alternatives Guide*. Accordingly, the evaluation is based on a mission need statement and will include life-cycle costs and capital costs, for the baseline and each alternative.

The AOA is based on a well-defined mission need and the report includes life cycle cost estimates consistent for each alternatives.

Estimated completion date: September 30, 2020

Recommendation 2: *The Secretary of Energy should direct the Assistant Secretary of Environmental Management to follow the steps outlined in GAO's risk-informed decision-making framework as it makes decisions about the future of the pretreatment mission; in particular, engaging the Washington State Department of Ecology in the AOA process, communicating with them throughout the process, and providing them with transparent information about the rationale behind the final decision.*

Management Response: *Concur in Principle*

The Office of Environmental Management (EM) has established a cross-cutting team of experts to support the HLW Treatment AOA that is comprised of experienced independent contractors, subject matter experts, and DOE staff members. They are responsible for approving the evaluation factors and screening criteria, providing scoring and risk rating input to ensure independence and compliance with all applicable directives, best practices and guidance documents. Also, Washington State Department of Ecology (Ecology) has been an active participant in the AOA in an observer role.

Since October 2018, DOE and Ecology have worked collaboratively in regular leadership forum meetings to discuss the HLW treatment mission and to set the stage for the AOA process. Ecology has also been an active participant throughout the entire AOA process and evaluation to date. An Ecology representative has participated in on-site working sessions, including weekly conference calls addressing the progress and planning of the evaluation. Ecology has provided

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Management Response
Hanford Waste Treatment Plant: DOE Is Pursuing Pretreatment Alternatives, but Its Strategy is Unclear and Costs are Unknown, GAO-20-363

meaningful input on the development of the alternatives, potential state permitting requirements, screening criteria, system descriptions, and in the development of risk profiles and ratings. Also, Ecology has reviewed and provided comments on the draft AOA study plan and will have an opportunity to review and provide comments on the draft AOA final report prior to approval.

EM will continue to include Ecology in the AOA process as an active participant, which provides transparent and open communications through the process, inclusive of any rationale behind and final EM decision.

Estimated completion date: December 31, 2020

Appendix VII: GAO Contact and Staff Acknowledgments

GAO Contact

David C. Trimble, (202) 512-3841 or trimbled@gao.gov

Staff Acknowledgments:

In addition to the contact named above, Amanda K. Kolling (Assistant Director), Jeffrey T. Larson (Analyst in Charge), Mark Braza, Kelly Friedman, Richard P. Johnson, Gwen Kirby, and Alan K. Smith made key contributions to this report.