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May 2025

NUCLEAR WASTE

An Integrated Disposal Plan Could Help DOE Complete Its Cleanup Mission and Save Billions

GAO-25-107109

GAO Highlights

Highlights of GAO-25-107109, a report to congressional committees

May 2025

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An Integrated Disposal Plan Could Help DOE Complete Its Cleanup Mission and Save Billions

Why GAO Did This Study

To complete its cleanup mission, EM must dispose of over 11 million cubic meters of nuclear waste that pose a range of risks to human health and the environment. In addressing its nuclear waste disposal needs, EM chooses among disposal options with different costs and risks. Final approval of a disposal pathway can take years of careful planning and communication with regulators and a variety of federal, state, and other stakeholders.

Senate Report 117-130 includes a provision for GAO to report on EM's nuclear waste disposal planning efforts. This report addresses (1) available information about nuclear waste requiring disposal to complete EM's mission, (2) disposal options available to EM, and (3) how EM and cleanup sites plan for nuclear waste disposal.

GAO analyzed EM waste data, interviewed or requested information from all 15 EM sites, visited commercial nuclear waste disposal facilities, and developed a hypothetical model for optimizing transuranic waste disposal using EM data.

What GAO Recommends

GAO is making five recommendations to EM, including that EM develop complex-wide analyses—such as optimization models—to identify optimal disposal pathways; develop a complex-wide disposal plan; and create a forum for EM and cleanup site and disposal facility regulators to address regulatory constraints to optimal disposal approaches. EM did not agree or disagree with the five recommendations and deferred its response for whether it will implement them to a later date.

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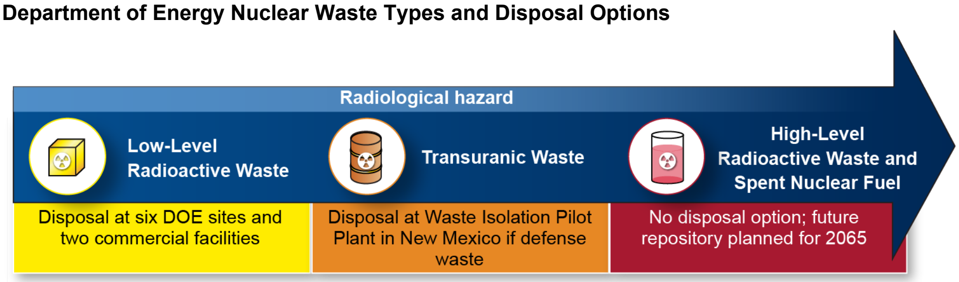
What GAO Found

The Department of Energy's (DOE) Office of Environmental Management (EM) is responsible for cleaning up and disposing of nuclear waste from 15 federal sites, known as the EM complex. EM primarily manages four types of nuclear waste: low-level radioactive waste (LLW), transuranic waste, high-level radioactive waste, and spent nuclear fuel. EM develops estimates of the amount of each type of waste that it expects to dispose of to complete its cleanup work. However, EM's estimates include significant uncertainties. For example, waste amounts could vary depending on the future cleanup approaches selected.

Department of Energy Nuclear Waste Types and Disposal Options



Source: DOE documentation and interviews. | GAO-25-107109

EM has multiple disposal options for LLW, including six DOE facilities and two commercial facilities. GAO's analysis found that EM's disposal needs exceed these facilities' current capacity and future expansion will be required. Further, transuranic waste currently has only one disposal option—the Waste Isolation Pilot Plant in New Mexico—and additional future transuranic waste could nearly exceed the facility's capacity. High-level radioactive waste and spent nuclear fuel have no existing disposal option and will require the siting of a new deep geologic repository.

EM headquarters delegates disposal decisions to individual cleanup site officials and supports them as needed. However, EM has not assessed opportunities to optimize complex-wide disposal decisions—GAO has previously found that EM could save billions of dollars by considering alternate disposal plans for certain waste. EM has also not developed an integrated waste disposal plan to address factors affecting EM's ability to complete its cleanup mission.

EM officials told GAO they have not assessed complex-wide strategic alternatives to current disposal plans because regulatory constraints limit alternatives. However, the use of models, such as optimization models, could reduce the costs of EM's cleanup mission by billions of dollars. By developing a complex-wide plan, EM will be better able to address interrelated issues across its 15 sites and identify opportunities to address regulatory constraints. Moreover, implementing its disposal plan will likely require EM to negotiate with multiple regulators to revise agreements at different sites. By leveraging modeling and integrated planning, EM would be better positioned to engage with regulators in a complex-wide forum to ensure that each waste stream is disposed of in a cost-effective manner that protects human health and the environment.

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Abbreviations

ATWIR	Annual Transuranic Waste Inventory Report
BLDD	Baseline Low-Level Waste & Material Disposition Data
DOE	Department of Energy
EM	Office of Environmental Management
EPA	U.S. Environmental Protection Agency
GTCC	Greater-Than-Class C
HLW	High-level radioactive waste
LLW	Low-level radioactive waste
m^3	cubic meters
NNSS	Nevada National Security Site
RCRA	Resource Conservation and Recovery Act of 1976, as amended
SNF	Spent nuclear fuel
TRU	Transuranic
WCS	Waste Control Specialists
WIPP	Waste Isolation Pilot Plant

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May 29, 2025

Congressional Committees

The Department of Energy's (DOE) Office of Environmental Management (EM) is responsible for cleaning up the 15 remaining DOE sites contaminated by radioactive and hazardous materials resulting from decades of nuclear weapons production and nuclear energy research. EM estimates that its remaining cleanup mission will take decades to complete at a cost of over $400 billion.[1] This cleanup work, generally performed by contractors working for EM, is expected to generate over 11 million cubic meters of radioactive waste, according to EM estimates. This waste is expected to pose a range of risks to human health and the environment and will require disposal.

EM makes choices among options for disposing of this waste that have different costs, limitations, and risks. The disposal options available to EM are often dictated by legal and regulatory requirements (e.g., permissible disposal approaches for different waste types), the technical specification of disposal facilities (e.g., capacity and types of waste they can accommodate), and government and stakeholder considerations (e.g., approval from regulators). In addition, it can take EM years to get needed approvals for a disposal option, and doing so requires careful planning and communication with stakeholders. The use of different disposal options can increase or decrease costs by billions of dollars. In many cases, EM has committed to the methods and schedule for waste disposal in a series of agreements with state and federal regulators that were negotiated at each site.

Disposal options for EM's radioactive waste depend on the categorization of the waste, which is based on the waste's physical and chemical characteristics and, in some cases, the waste's origin. Federal statutes,

[1]EM's estimate of the probable costs for the future cleanup of this waste is known as its environmental and disposal liability (or environmental liability). EM's environmental liability is a major driver of overall federal environmental liability. In February 2017, we added the U.S. government's environmental liability to our list of agencies and program areas that are at high risk for fraud, waste, abuse, and mismanagement or that are most in need of transformation. See GAO, *High-Risk Series: Progress on Many High-Risk Areas, While Substantial Efforts Needed on Others,* GAO-17-317 (Washington, D.C.: Feb. 15, 2017). In 2019, we reported that EM's environmental liability continues to grow, and that EM needed a program-wide strategy to effectively set priorities. See GAO, *Department of Energy: Program-Wide Strategy and Better Reporting Needed to Address Growing Environmental Cleanup Liability*, GAO-19-28 (Washington, D.C.: Jan. 29, 2019).

regulations, and DOE orders define different types of radioactive waste, three of which are of particular relevance to EM's mission: low-level radioactive waste (LLW), transuranic (TRU) waste, and high-level radioactive waste (HLW). In general, LLW is categorized based on what it is not—namely, radioactive waste that is not HLW—or certain other specific wastes and materials. TRU waste is defined by its radiological characteristics—that is, waste containing certain concentrations of radionuclides whose atomic number is greater than uranium on the periodic table. Excepted from that definition is HLW and certain other specific wastes. HLW is generally defined as highly radioactive material resulting from the reprocessing of spent nuclear fuel. EM is also responsible for managing spent nuclear fuel (SNF)—used fuel from nuclear reactors—generated at DOE and other sites as a result of atomic energy defense activities and research and development.[2] EM is not responsible for disposition of SNF generated by commercial nuclear power plants, with the exception of limited quantities of commercial SNF stored at EM sites for various reasons (e.g., fuel from the Three Mile Island incident).[3] Disposal options and requirements can differ between commercial and defense radioactive waste. Currently, based on a number of factors, EM expects to continue to dispose of its LLW in available near-surface disposal facilities and to dispose of its defense TRU waste in the Waste Isolation Pilot Plant (WIPP) deep geologic repository in New Mexico. EM is also planning to dispose of its HLW and SNF in a deep geological repository, pending selection and availability of a future site that can accept these waste types.

Senate Report 117-130 includes a provision for GAO to evaluate the radioactive waste streams EM is currently managing or plans to generate that do not yet have a disposal option and the extent to which EM has an integrated strategic plan for waste disposal across the EM complex of 15 sites. Specifically, this report (1) examines what available information shows about radioactive waste streams that require disposal before EM can complete its cleanup mission, (2) describes what disposal options are available to meet EM's radioactive waste disposal needs, and (3) examines how EM and its sites plan for radioactive waste disposal.

[2]LLW, TRU waste, HLW, and SNF are all defined in various federal laws, regulations, and DOE orders. We include the full relevant definitions below and rely on those definitions throughout this report.

[3]Another entity within DOE, the Office of Nuclear Energy, is responsible for accepting SNF generated and stored at commercial nuclear power plants for permanent disposal.

To address our first objective, we analyzed data from EM and DOE databases on radioactive waste types managed by EM. For each database, we took several steps—including requesting information on how the data was updated and checking for errors and interviewing officials managing the data—to assess the reliability of the data. We determined that these databases contained sufficiently reliable information to present what information EM has on how much waste will require disposal to complete its mission. We then interviewed or received written responses from each of EM's 15 sites to understand how they develop their radioactive waste estimates and what gaps or uncertainties might exist in those estimates. We also reviewed relevant laws, regulations, and DOE documents on how radioactive waste is defined.

To address our second objective, we reviewed documents on the capabilities and regulatory structure for disposal at EM sites and commercial facilities. To understand whether the capacity of the disposal facilities we identified was sufficient to meet EM's needs, we compared the data we gathered on EM radioactive waste to the current and planned capacities of these facilities.

To address our third objective, we interviewed EM headquarters and site officials regarding the process they follow to determine the disposal options for their waste, plans for addressing waste expected to be generated in the future, and waste that had barriers to disposal. To further understand barriers for EM waste disposal, we interviewed officials and reviewed documents from the Energy Facility Contractors Group, the Energy Communities Alliance, and the Nuclear Regulatory Commission. We chose these groups because they had previously published material related to EM waste with disposal barriers. We conducted site visits to WIPP in New Mexico and commercial disposal facilities in Texas and Utah to gain perspective on their capabilities and discuss facility plans with officials. We selected these sites as they represent three of the four sites that accept off-site waste from EM cleanup sites.[4] We also met with state regulators in New Mexico, Utah, Texas, and Nevada to hear their perspectives on the current and future operations of disposal facilities operating in their states. We selected these regulators as they oversee the operations of disposal sites that accept off-site waste from EM cleanup sites.

[4]The fourth site is located at the Nevada National Security Site, and we remotely interviewed officials from this site.

We also interviewed EM headquarters officials regarding their planning for radioactive waste disposal. We then reviewed the documents they identified to understand the extent to which these documents address complex-wide disposal provisions outlined in relevant DOE orders. We also interviewed EM site officials to identify what disposal plans they have developed and how they interact with EM headquarters in the development and execution of these plans. In addition, we reviewed information obtained for the prior objectives to identify waste streams with barriers to disposal and understand what these barriers are, and the steps EM is taking to address them. As part of our work on the third objective, we obtained data on the locations, amounts, and costs for managing and shipping DOE's TRU waste to develop a hypothetical model. See appendix III for more information on the assumptions and limitations associated with this hypothetical model. Using this hypothetical model, we analyzed alternatives to current plans for shipping TRU waste from generator sites to WIPP to examine how this data could be used to model approaches that potentially reduce costs. See appendix I for more information on the sources and methods for this report.

We conducted this performance audit from October 2023 through May 2025 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

Types of Radioactive Waste Managed by EM

EM is responsible for the disposal of different types of radioactive waste during cleanup activities across its 15 sites. Waste that contains both radioactive and hazardous components is called mixed waste. This report focuses on the following types of radioactive waste:

- **LLW.** Most remaining EM sites have LLW requiring disposal, and the amount of LLW is typically much larger than the other types of waste at a site. LLW results from soil and debris excavation and treatment, and from decontamination and decommissioning of facilities no longer in use. According to EM officials, disposal of LLW is typically one of the last remaining cleanup activities to be completed at sites. Since fiscal year 2006, EM headquarters has annually collected estimates of all remaining LLW, mixed LLW, and byproduct material across DOE sites.[5] Generally collected by contractors at the site level, this information is compiled in the Baseline Low-Level Waste & Material Disposition Data (BLDD).

EM headquarters provided guidance in fiscal year 2024 for how sites should collect this information. Estimates should identify each LLW and mixed LLW waste stream at a site that requires disposal, including information about the remaining volume, planned disposal location, and if there are barriers to disposal. According to BLDD guidance, these data play an increasingly critical role in identifying future department-wide waste disposition needs, planning future capabilities, and communicating with internal and external interested parties.

- **TRU.** TRU waste generally consists of contaminated materials, such as solid sludge or clothing, tools, rags, residues, and debris resulting from the production of plutonium. Much of this waste was historically packaged in boxes and temporarily buried in dirt trenches on sites and will need retrieval and packaging for disposal. EM cleanup sites estimate the volume of TRU waste that will require disposal to complete their cleanup mission.[6] A group working for EM's Carlsbad Field Office collects these estimates annually to create the Annual TRU Waste Inventory Report (ATWIR).
- **HLW.** EM's HLW takes several forms, the majority of which is waste in underground tanks in a solid, semi-solid, or liquid form.[7] EM also has other waste managed as HLW, such as sodium-bearing liquid waste in tanks at the Idaho National Laboratory and ion exchange columns containing cesium extracted from tank waste at the Savannah River and Hanford sites.[8] According to EM headquarters officials, each site tracks HLW inventories. Because EM is not actively

[5]Among other things, byproduct material can be produced by extraction or concentration of uranium or thorium from processed ore. See 42 U.S.C. § 2014(e).

[6]Programs in other DOE offices, including the National Nuclear Security Administration and the Office of Nuclear Energy, also develop estimates of the volume of defense TRU waste that will require disposal to complete their respective missions.

[7]As discussed further below, "high-level radioactive waste" is defined by federal law and subject to specific requirements. DOE is currently, as a matter of policy, managing all tank waste as if it is "high-level radioactive waste" unless the waste has been formally classified as another waste type. According to DOE Manual 435.1-1, DOE should assume that all HLW is mixed waste. According to DOE officials, DOE generally does not formally classify its waste until it is retrieved from the tanks and pretreated, to inform treatment and disposition decisions.

[8]In this report, when discussing cleanup work at the Idaho National Laboratory site, we are referring to work performed by EM and managed by the Idaho Clean-up Project.

generating significant amounts of new HLW, the officials said the expected volumes requiring disposal should remain relatively constant.[9]

- **SNF**. EM's SNF is composed of nuclear fuel elements that have been irradiated in a nuclear reactor to create a fission reaction. The spent fuel was generally placed in pools of water to promote cooling and then packaged in dry canisters for temporary storage at EM sites. DOE's Idaho National Laboratory maintains a database of SNF across all EM sites.

See table 1 for the legal definitions and disposal expectations of each waste type.

[9]According to EM officials, EM expects to process SNF at the Savannah River Site through 2032, which will produce minimal additional volumes of new HLW.

Table 1: Legal Definitions for Select Types of Radioactive Waste at Department of Energy's (DOE) Office of Environmental Management's (EM) Sites and Disposal Expectations for that Waste

Waste Type	Legal Definition	Disposal Expectations
Low-level radioactive waste (LLW)	LLW is defined in the Nuclear Waste Policy Act of 1982 as radioactive material that "(A) is not high-level radioactive waste, spent nuclear fuel, transuranic waste, or by-product material as defined in [42 U.S.C. § 2014(e)(2)]; and (B) the [Nuclear Regulatory] Commission, consistent with existing law, classifies as low-level radioactive waste."[a]	EM expects to dispose of LLW in certain near-surface facilities. There are several DOE LLW disposal facilities and two commercial LLW facilities available to EM.
Transuranic (TRU) waste	TRU waste is defined in the Waste Isolation Pilot Plant Land Withdrawal Act as "waste containing more than 100 nanocuries of alpha-emitting transuranic isotopes per gram of waste, with half-lives greater than 20 years, except for – (A) high-level radioactive waste; (B) waste that the Secretary [of Energy] has determined, with the concurrence of the Administrator [of the Environmental Protection Agency], does not need the degree of isolation required by the disposal regulations; or (C) waste that the Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with [10 C.F.R. Part 61]."[b]	EM expects to dispose of defense-related TRU waste at the Waste Isolation Pilot Plant (WIPP) in New Mexico. WIPP is currently the only disposal option for TRU waste, and this waste can only be disposed of at WIPP if it was generated by atomic energy defense activities.
High-level radioactive waste (HLW)	HLW is defined in the Nuclear Waste Policy Act of 1982 as "(A) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in the reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations; and (B) other highly radioactive material that the [Nuclear Regulatory] Commission, consistent with existing law, determines by rule requires permanent isolation."[c]	EM expects to dispose of HLW in a permanent deep geological repository. However, there is no current repository for HLW.
Spent nuclear fuel (SNF)	SNF is defined in the Nuclear Waste Policy Act of 1982 as "fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing."[d]	EM expects to dispose of SNF in a permanent deep geological repository. However, there is no current repository for SNF.

Source: GAO analysis of DOE documents and the Nuclear Waste Policy Act. | GAO-25-107109

[a]Pub. L. No. 97-425, § 2(16), 96 Stat 2201 (1983) (codified at 42 U.S.C. § 10101(16)). LLW is also defined by the Low-Level Radioactive Waste Policy Amendments Act of 1985 as "radioactive material that (A) is not high-level radioactive waste, spent nuclear fuel, or byproduct material as defined in [42 U.S.C. § 2014(e)(2)]; and (B) the Nuclear Regulatory Commission, consistent with existing law and in accordance with paragraph (A), classifies as low-level radioactive waste." The term does not include byproduct material as defined in 42 U.S.C. § 2014(e)(3) and (4). Pub. L. No. 99-240, § 102, 99 Stat 1842 (1986) (codified as amended at 42 U.S.C. § 2021b(9)). Commercial LLW disposal facilities that accept EM waste are subject to Nuclear Regulatory Commission regulations, which classify LLW as Class A, B, C, or Greater-Than-Class C based on radioactivity. DOE does not use the Nuclear Regulatory Commission's classification system for LLW disposed of at DOE facilities.

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

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

[d]Pub. L. No. 97-425, § 2(12), 96 Stat. 2201 (1983) (codified at 42 U.S.C. § 10101(23)). This definition is also cross-referenced in the Atomic Energy Act of 1954, as amended, 42 U.S.C. § 2014(ee), and the Waste Isolation Pilot Plant Land Withdrawal Act, Pub. L. No. 102–579, § 2(10), 106 Stat. 4777 (1992).

Relevant Legal Background

Much of EM's waste is mixed waste that contains both radioactive and hazardous components.[10] In part because of this, the management, treatment, and disposal of EM's waste is governed by many federal and state laws and regulations, DOE Orders, and cleanup agreements. Below, we highlight some of the laws, regulations, orders, agreements, and legal history of particular relevance to EM's waste disposal approaches and decisions.

- **The Atomic Energy Act of 1954** established a comprehensive regulatory scheme for military and domestic nuclear energy. It authorized the Atomic Energy Commission—now DOE and the Nuclear Regulatory Commission—to regulate possession and use of nuclear material, including radioactive waste. In 1974, the Atomic Energy Commission was abolished, and, through several subsequent laws, its functions were transferred to the Nuclear Regulatory Commission and DOE. Under the act, as amended, the Nuclear Regulatory Commission has regulatory authority over commercial uses of radioactive materials and licenses commercial facilities that dispose of LLW. With limited exceptions, the Nuclear Regulatory Commission is not authorized to regulate defense nuclear facilities and wastes, which, pursuant to the act, are generally managed and regulated by DOE.

  The act, as amended, also authorizes the Nuclear Regulatory Commission to enter into agreements with states (called agreement states) so they assume—and the Commission relinquishes during the duration of the agreement—regulatory authority over specified radioactive materials. There are currently 39 agreement states, including, as relevant to this report, Texas and Utah. These agreement states act as regulators of commercial facilities that handle radioactive materials and wastes.

- **The Resource Conservation and Recovery Act of 1976, as amended (RCRA)** is administered by the U.S. Environmental Protection Agency (EPA) and governs hazardous waste from

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

generation to disposal. Under RCRA, EPA can authorize states to administer their own hazardous-waste regulatory programs to operate in lieu of the federal program. RCRA generally requires facilities that treat, store, or dispose of hazardous waste to have a permit from EPA or an authorized state to operate, and RCRA regulations establish detailed and often waste-specific requirements for the handling, storage, treatment, and disposal of hazardous wastes by permitted facilities. Nuclear materials covered by the Atomic Energy Act of 1954 are expressly excluded from RCRA's hazardous waste regulatory regime, meaning that EM's waste that is solely radioactive in nature is not subject to regulation or permitting under RCRA. But, subject to certain exclusions, RCRA gives EPA and authorized states regulatory and permitting authority over the hazardous components of the mixed waste managed by EM and commercial entities.[11] Many EM facilities, including certain facilities at Hanford and the WIPP repository, as well as commercial disposal facilities for mixed waste operate under permits issued by states under their authorized RCRA authority.

- **The Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended**, commonly known as Superfund and administered by the EPA, authorizes the President to respond to releases or threatened releases of hazardous substances to the environment. In the late 1980s, the President delegated the act's response authorities to EPA and other federal agencies. If there is a release from a federal facility, the agency that administers the facility—such as DOE—has the responsibility and authority to take response actions under the act, subject to oversight by EPA and the states in which those facilities are located.[12] At DOE's National Priorities List sites, the act requires DOE to enter into an interagency agreement with EPA, known as a federal facility agreement, that governs the investigation and cleanup of any such releases at these

[11]RCRA also requires corrective action for all releases of hazardous waste and mixed waste from any solid waste management unit at a treatment, storage, or disposal facility. Under the RCRA corrective action process, EPA and authorized states impose remedial measures to clean up releases at individual sites through permits or compliance orders.

[12]While the agency that administers the facility where there has been a release of hazardous substances will typically be the lead agency to undertake cleanup activities at federal facilities, EPA oversees Comprehensive Environmental Response, Compensation, and Liability Act cleanup activities at federal facilities on its National Priorities List, which includes some of the most seriously contaminated federal and non-federal sites around the country. For federal facilities that are not on the National Priorities List, most cleanups are overseen by state agencies rather than EPA, as allowed by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended, which provides that state cleanup and enforcement laws apply to federal facilities not included on the National Priorities list.

facilities. Often, state regulators are also parties to federal facility agreements under the act, which can include sections designed to integrate cleanup and other requirements under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended, and RCRA.

- **The Nuclear Waste Policy Act of 1982, as amended**, establishes procedures for the evaluation, selection, and approval of sites for deep geologic repositories for the permanent disposal of SNF and HLW. The act required the President to determine whether the development of a separate repository—separate from a repository for commercial SNF—was required for the disposal of HLW resulting from atomic energy defense activities. In 1985, President Reagan determined that defense HLW should not be disposed of separately from commercial SNF. In 1987, Congress amended the act to specify that the only site that could be considered for the permanent disposal of commercial SNF is a geologic repository at Yucca Mountain, Nevada. However, after several decades of attempting to develop Yucca Mountain for SNF and HLW disposal, in 2010 DOE terminated its efforts to license the Yucca Mountain repository, and Congress stopped funding activities related to the site. Attempts to develop a repository for commercial SNF have been at an impasse since. However, in March 2015, President Obama reversed President Reagan's 1985 finding under the act, and instead found that a separate repository for defense HLW was required. In 2016, DOE drafted a plan describing a path for development of a Defense Waste Repository to permanently dispose of all or a portion of defense-managed HLW, but the plan was never finalized.
- **The Waste Isolation Pilot Plant Land Withdrawal Act** was enacted in 1992 to authorize operation of the WIPP repository and establish a regulatory framework for it. The act, as amended, establishes limits on the volume of waste and amount of radioactivity in the waste disposed of at the facility, and restricts disposal at WIPP to TRU waste generated by atomic energy defense activities. The act also required EPA to (1) develop final disposal regulations that DOE is required to comply with at WIPP, (2) issue criteria for certifying DOE's compliance with the final disposal regulations, and (3) certify that WIPP would comply with the disposal regulations. As required by the act, EPA issued final regulations regarding the disposal of TRU waste and certified WIPP's compliance with the regulations in 1998. The act also

requires EPA to recertify WIPP's compliance with the disposal regulations every 5 years.[13]

- **DOE Order 435.1 and Manual 435.1-1** set forth procedures for the management and disposal of DOE's radioactive and hazardous wastes in a manner that is protective of worker and public health and safety, and the environment. Under the manual, DOE has two processes for determining that waste resulting from the reprocessing of SNF can be managed as something other than HLW, which can be the most expensive form of waste to treat and dispose.[14] The manual also requires EM to establish and maintain a data system to compile projections of how much waste requires disposal across the complex.
- **Cleanup agreements** that DOE has negotiated with various regulatory entities establish hundreds of milestones that specify actions EM must take and deadlines it must meet as it carries out its cleanup work across the complex.[15]

[13]Pursuant to the Waste Isolation Pilot Plant Land Withdrawal Act, EPA regulates the radiological safety of WIPP. In addition, the state of New Mexico issues a hazardous waste storage and disposal permit for WIPP under its authorized RCRA program and state regulations. DOE must obtain approval from the New Mexico Environment Department for any modifications to the WIPP Hazardous Waste Facility Permit.

[14]Beyond the two processes in Manual 435.1-1, there is a third process that DOE can use to classify certain reprocessing waste as a waste type other than HLW that is found in section 3116 of the Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005.

[15]These agreements include Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended, federal facility agreements generally negotiated among DOE, state regulators, and EPA, as well as additional compliance agreements, compliance orders, consent orders, and consent decrees. Federal facility agreements, also known as tri-party agreements, generally set out a sequence for accomplishing cleanup work, tend to cover a relatively large number of cleanup activities, and can include milestones that DOE must meet. Compliance agreements, consent orders, and consent decrees can vary significantly but include agreements negotiated at a site subsequent to the initial federal facility agreement or other agreements with the state. These agreements may impose penalties for missing milestones and may amend or modify earlier agreements, including extending or eliminating milestone dates. Compliance orders are issued by regulators and require DOE to take specific actions to correct violations of laws, regulations, permits, or agreements. See GAO, Nuclear Waste: DOE Should Take Actions to Improve Oversight of Cleanup Milestones, GAO-19-207 (Washington, D.C.: Feb. 14, 2019).

EM's Estimates of Radioactive Waste Amounts Include Uncertainties, and LLW Estimates Are Incomplete

EM's estimates for the amounts of each of the waste types that it is responsible for disposing of include uncertainties and its estimates for LLW requiring disposal are incomplete. Developing waste estimates involves uncertainties that prevent EM from having complete information about waste amounts, such as when a site has not reached agreement with its regulators about how to address cleanup. EM's estimates also include unique uncertainties by waste type that reflect the different data collection processes and disposal decisions yet to be made. Specifically, we found several other reasons why EM's estimates of LLW are incomplete and uncertain, including that they focus on near-term disposal amounts. Further, EM may underestimate the volume of TRU waste that EM will need to dispose of. Lastly, EM's estimates of HLW and SNF waste volumes may change depending on future decisions by EM on whether to treat and dispose of waste currently managed as HLW or SNF as other waste types.

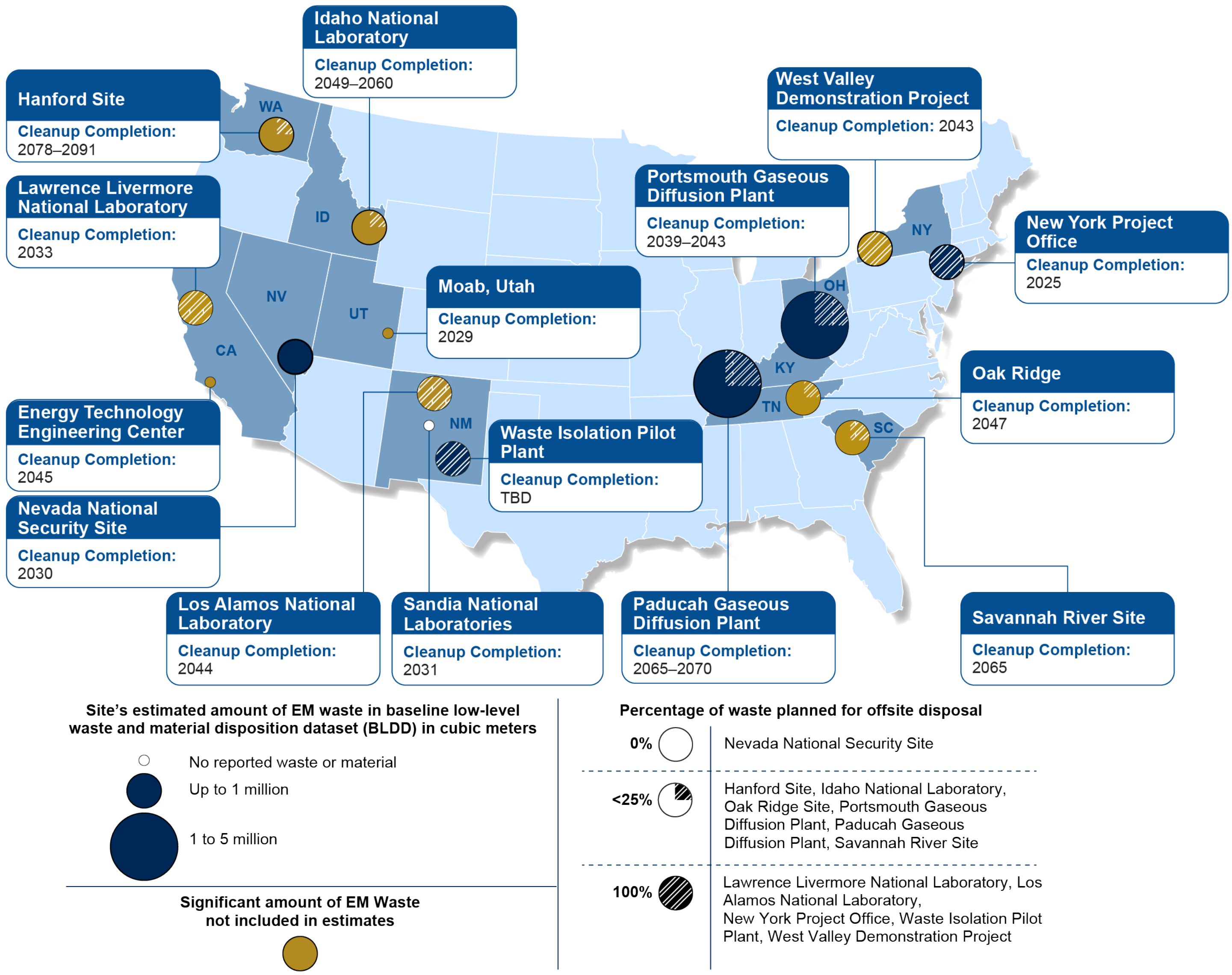
Estimates of LLW Are Incomplete and Uncertain

EM's complex-wide estimates of remaining LLW in the BLDD are incomplete and do not include significant volumes of waste that is EM's responsibility for disposal. Specifically, we found EM did not include significant amounts of waste in LLW estimates for nine of EM's 15 sites. EM headquarters officials we interviewed told us that they use these estimates for a long-term view on disposal and trends across the EM complex.

According to LLW estimates from the BLDD in fiscal year 2024, there are almost 11 million cubic meters of remaining LLW across the complex that EM is responsible for disposing of, 8 million of which is at the Portsmouth and Paducah gaseous diffusion plants.[16] Figure 1 shows EM's estimates of remaining LLW that it is responsible for across 15 sites. The figure also indicates the exclusion of significant amounts of waste we identified at nine of the 15 sites.

[16]Most of the 8.5 million cubic meters of LLW at Portsmouth and Paducah will be generated by deactivation and decommissioning of large gaseous diffusion plants.

Figure 1: Office of Environmental Management (EM) Site Estimates in the Baseline Low-Level Waste and Material Disposition Data (BLDD) for the Amount of Low-Level Radioactive Waste Requiring Disposal, cubic meters (m^3)



Sources: DOE's BLDD data and GAO analysis and Map Resources (map). | GAO-25-107109

Note: BLDD guidance indicates that sites' estimates should reflect all remaining waste at a site that requires disposal. To identify missing waste, we reviewed sites' estimates against DOE documentation describing remaining cleanup efforts at each site and asked site officials about the extent their estimates include all remaining waste.

We found several reasons why estimates of LLW amounts in the BLDD are incomplete and do not include significant volumes of waste. First, EM relies on site contractors to develop estimates of remaining LLW, which has resulted in data focused on the near-term that often excludes estimates of waste to be disposed of beyond the current cleanup contract. Second, LLW estimates do not include readily available data about waste streams for which EM has not reached agreement with regulators on a final disposal approach or a final decision on disposal has not been made. Third, EM bases LLW estimates on incomplete information about whether it is responsible for certain waste streams generated by other DOE offices and does not include adequate data on the potential barriers to waste disposal. Finally, EM does not assess the quality of LLW estimates, raising questions about the usefulness of the data for long-term planning and department-wide decisions.

EM relies on contractors to develop estimates. The process EM uses to develop LLW estimates in the BLDD relies on site contractors, who use different methods to estimate the amount of LLW that will be generated as part of cleanup efforts. Specifically, contractors use their own methods to make single-point "best" estimates about how much waste will require disposal each fiscal year through 2054.[17] Generally, given inherent uncertainties in estimating radioactive waste amounts, contractors at multiple sites told us they try to make their single-point estimates conservative, such as by adding an additional percentage to the volume they expect. However, contractors at other sites told us they do not make their estimates conservative, or they use a different method to do so. For example, contractors at the Hanford Site look to capture uncertainty by using a range for some of its LLW volume estimates. According to EM headquarters officials, the BLDD as currently designed does not allow for sites to input a range to account for uncertainties. Officials said adding ranges to the process would create an additional burden on sites that do not already use them, and the use of ranges may be confusing to stakeholders.

Additionally, contractors at multiple sites do not include estimates for waste disposal beyond their current cleanup contract. Guidance indicates that estimates should reflect all remaining waste at a site that requires disposal and include the best estimate available, whenever possible. However, according to EM headquarters and site officials, contractors

[17]According to guidance, any LLW estimated to be disposed of after fiscal year 2054 should also be included within a single estimate for total projected quantity past 2054.

may not have developed estimates for cleanup efforts beyond their contract and therefore often do not provide estimates for waste that will need to be disposed of after the current contract. Officials in site offices, which oversee contractors and are in place for the duration of a site's cleanup mission, do not have a specific requirement to supplement contractor estimates so that estimates are comprehensive and reflect all remaining cleanup. EM officials we interviewed told us they would prefer to have at least general estimates beyond the current contract. However, they think it would be too burdensome to enforce the BLDD guidance provision that contractors or site officials provide such estimates if they have not already developed them.

EM has not reached an agreement or decision regarding disposal for certain waste streams. LLW estimates in the BLDD also do not include waste streams for which EM and regulators have either not reached agreement or not made final decisions regarding the method or extent of cleanup—even if ranges of LLW estimates likely to be generated are available. These cleanup projects can represent a significant amount of waste. According to EM headquarters officials, sites should not include such estimates because doing so raises challenges in EM's interactions with regulators and stakeholders. Specifically, their concerns were that these estimates could be seen as a commitment to a certain level of cleanup, could confuse stakeholders or strain relationships with regulators, and may introduce litigation risk. Some examples of waste streams missing from the estimates that we confirmed in interviews with site officials include:

- **West Valley Phase 1B & 2:** According to EM site officials from the West Valley Demonstration Project in New York State, EM's estimates in the BLDD only include Phase 1A of their site's cleanup, which is expected to be completed in 2025. Phase 1B and Phase 2 are not included, and EM officials said Phase 1B is expected to generate a larger volume of waste than Phase 1A. Additionally, while DOE is still conducting an environmental review of cleanup options for Phase 2, it is possible that the cleanup of contaminated facilities and soil during this phase could generate almost 700,000 cubic meters of LLW that would require off-site disposal.
- **Los Alamos National Laboratory Material Disposal Area C:** The BLDD does not include waste from buried pits and shafts in the Material Disposal Area C at Los Alamos National Laboratory in New Mexico. The New Mexico Environment Department has proposed selecting full excavation of the waste as the remedy for this disposal area under the authorized RCRA program and a 2016 Compliance

Order on Consent, as amended, that governs cleanup at the site. According to EM officials at Los Alamos, the site's budget planning estimate assumes the area will be capped. According to DOE officials, the site has provided feedback to the state and requested a hearing regarding the state's basis for proposing excavation as the remedy. If the waste were exhumed, DOE estimated 315,000 cubic meters of mixed LLW would need off-site disposal. New Mexico officials told us that additional material disposal areas at Los Alamos will likely need to be exhumed in the future, and, according to EM officials, this waste is also not included in their estimates.

- **Hanford low-activity tank waste:** A January 2025 agreement among EM, EPA, and Washington State includes a milestone for EM to grout (immobilize in concrete) certain Hanford low-activity tank waste and dispose of the treated waste at off-site LLW disposal facilities.[18] EM Hanford Site plans estimate this volume of grouted waste could be up to approximately 266,000 cubic meters after treatment. Hanford tank waste that may be disposed of off-site is not currently captured in BLDD estimates.[19]
- **Energy Technology Engineering Center cleanup:** A 2018 DOE environmental analysis estimated up to 84,000 cubic meters of LLW could be generated from contaminated soil and other contamination at the Energy Technology Engineering Center in California and require off-site disposal. However, the site has not yet reported any volume for how much remaining LLW may require disposal in the BLDD. EM site officials told us they are engaging in discussions with California regulators as part of the cleanup process and have not reached agreement on the cleanup method for its contaminated soil.

Further, we found that some waste being actively disposed of as part of EM cleanup work is also not included in the BLDD, such as byproduct material from the Moab Site in Utah and LLW disposed of in Saltstone Disposal Units at the Savannah River Site in South Carolina. EM headquarters officials said they plan to address these missing waste streams in fiscal year 2025 data by removing the requirement that

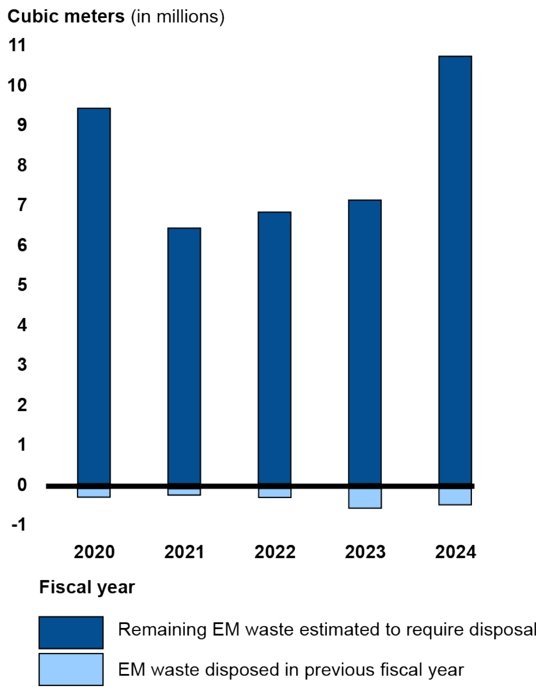
[18]DOE uses the term "low-activity waste" to mean the waste that remains after as much radioactivity as technically and economically practical has been separated from tank waste that, when solidified, may be disposed of as LLW in a near-surface facility.

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

byproduct material be included in the BLDD and ensuring that Savannah River Site reports this waste.

Despite ongoing disposal of LLW, the total remaining LLW in EM's estimates has increased instead of decreasing in the last 3 years as previously unaccounted for waste is added—see figure 2 below. EM headquarters officials attributed the decrease of nearly 4 million cubic meters from fiscal years 2020 through 2021 to site reevaluations of previously reported volumes and the removal of duplicate waste.

Figure 2: Office of Environmental Management (EM) Estimates of Remaining Low-Level Radioactive Waste Have Increased Despite Ongoing Disposal (2020-2024), cubic meters (m^3)



Source: GAO analysis of BLDD. | GAO-25-107109

EM has collected incomplete LLW data. Estimates of LLW are also incomplete because, while they include waste estimates from all of DOE, they do not include relevant data about how much of DOE's total waste EM will ultimately be responsible for disposing of. In some cases, EM conducts cleanup for other DOE offices, like the National Nuclear Security Administration and the Office of Science, and some of their generated waste will become EM's responsibility, although EM officials said they do not know how much. The BLDD allows sites to identify the DOE office “responsible for managing” a waste stream, and EM headquarters officials said it is not clear in some cases how sites should fill out this field. For example, EM may perform cleanup work for another DOE office but not take ownership of the waste. In addition, it is not clear to what extent or how National Nuclear Security Administration facilities that will be decontaminated and decommissioned by EM in the future are captured in the BLDD.

LLW estimates also include inconsistent and likely incomplete data about the extent to which waste streams face barriers to disposal. LLW estimates include a data field that allows sites to identify if a waste stream has barriers to disposal. However, EM headquarters officials we interviewed said sites do not always provide data about barriers and, when they do, the data are not consistent across sites. EM headquarters officials said they do not review or otherwise use the data to understand barriers to LLW disposal.

EM does not assess the quality of LLW estimates. Finally, estimates of LLW in the BLDD are uncertain because EM’s data quality procedures do not include assessing the quality of estimates. EM headquarters officials told us that they believe the quality of the estimates to be sufficient to inform their high-level management of sites. However, other sources of existing information suggest possible issues with the accuracy of waste estimates generated by sites. For example, we identified discrepancies of 100 percent or more between the LLW estimates included in the BLDD and comparable estimates submitted by two sites to the Nevada National Security Site (NNSS) for waste estimates covering the next 5 fiscal years.[20] EM officials from one of the sites with such discrepancies told us they included only currently contracted efforts for the LLW estimates submitted to headquarters in the BLDD, but included additional waste in their estimates for NNSS data. EM headquarters officials said discrepancies could be due to the different timing of submissions or because a different person at the site submitted the estimates.

EM does not know the quality of estimates because it does not formally or routinely assess them. EM officials said that they have previously

[20]NNSS conducts its own data call twice a year to DOE sites for estimates of how much waste sites expect to dispose of at NNSS. Representatives from EnergySolutions, which operates a commercial LLW disposal site, told us they conduct similar data calls with DOE sites for operational planning purposes.

compared estimates to actual disposal amounts but no longer regularly do so.[21] While EM headquarters' data quality procedures do not include an assessment of the quality of estimates, they do include a series of checks for potential errors and a comparison of waste streams estimates to those from the previous year. In our analysis of the BLDD we identified non-radioactive waste incorrectly included in LLW estimates, including over 300,000 cubic meters of industrial waste from Paducah.

DOE Manual 435.1-1 requires EM to maintain data on waste estimates across the DOE complex. In addition, federal internal control standards state that management should use quality information to achieve its objectives.[22] Without improving the quality of LLW estimates, EM cannot have confidence in complex-wide decisions that the estimates inform. Such improvements in the estimates could involve (1) adding headquarters oversight procedures to ensure the reported streams are comprehensive in representing the remaining cleanup at DOE sites; and (2) assessing the quality of BLDD estimates using other available information, such as the previous years' actual disposal data. Furthermore, until EM headquarters updates its guidance to clarify how sites should be capturing waste estimates beyond current contracts and waste with significant uncertainty about the scope of cleanup, the data reported by sites may be limited in its usefulness for long-term planning and complex-wide decisions.

EM's TRU Waste Inventory May Underestimate the Amount of Waste That Will Require Disposal

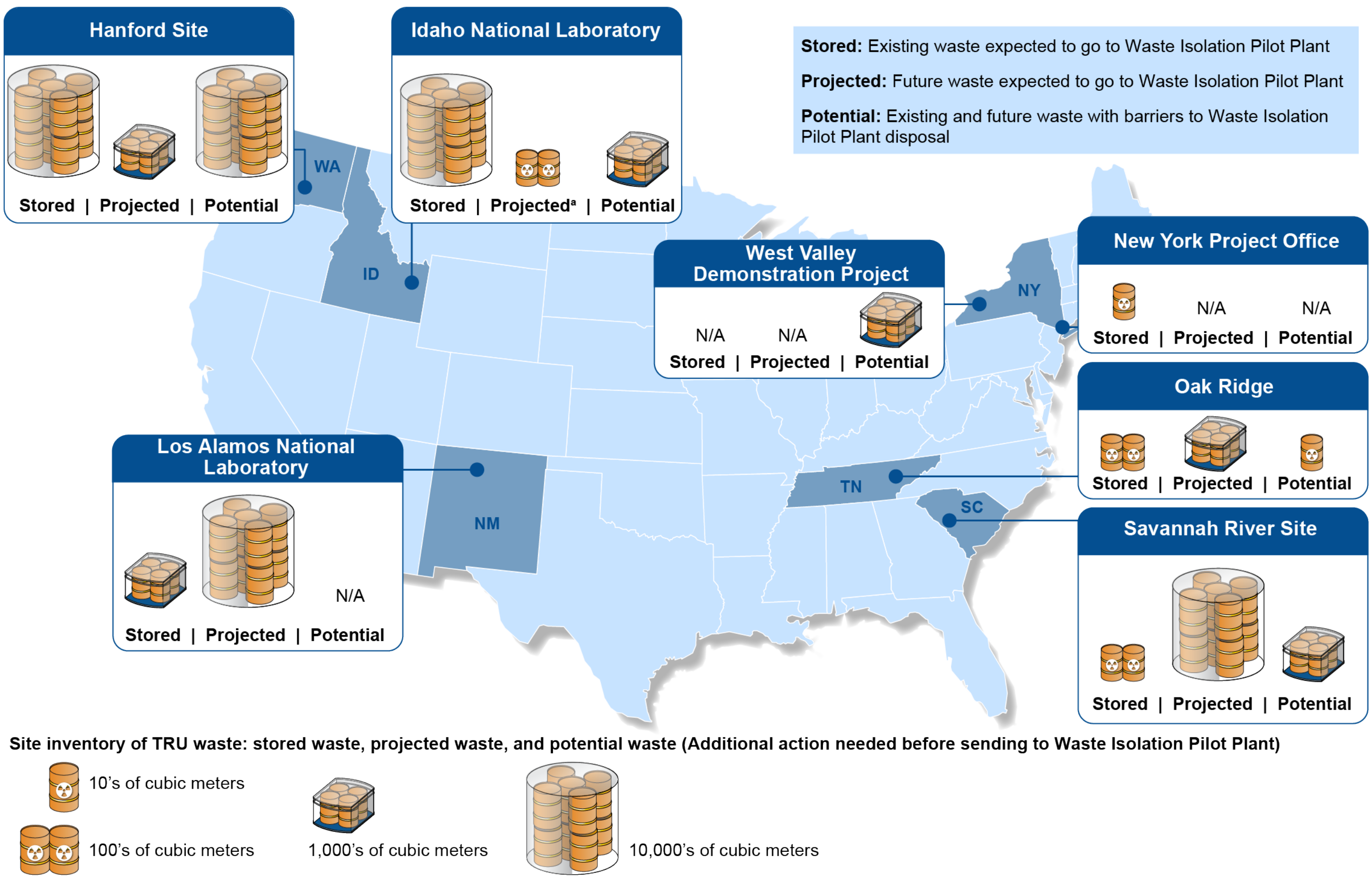
EM's inventory report of TRU waste, the ATWIR, may underestimate the amount of TRU waste that will require disposal because this report does not capture some uncertainties regarding EM's TRU waste. Specifically, the report does not include information about TRU waste that could be generated by future cleanup activities not yet planned. Additionally, the waste inventory does not capture the uncertainties in the waste volume estimates that are included.

See figure 3 for a map of seven sites where EM is conducting cleanup of TRU waste that requires disposal.

[21]According to EM officials, in past assessments of the quality of estimates against actual disposal data, they observed that estimates overstated the annual amount of waste requiring disposal due to the scope of cleanup changing as the year progressed.

[22]Principle 13. *Standards for Internal Control in the Federal Government*, GAO-14-704G (Washington, D.C.: Sept. 10, 2014).

Figure 3: Department of Energy (DOE) Office of Environmental Management Site Estimates of Transuranic (TRU) Waste in the 2023 Annual Transuranic Waste Inventory Report



Sources: GAO analysis of DOE's Annual Transuranic Waste Inventory Report; GAO (icons), and Map Resources (map). | GAO-25-107109

Note: The figure does not include some DOE sites which reported small quantities of TRU waste in the 2023 Annual TRU Waste Inventory Report.

[a]Projected waste at Idaho National Laboratory is from Office of Nuclear Energy programs which are reported separately in the Annual TRU Waste Inventory Report.

EM has captured some uncertainty by identifying multiple substantial waste streams in the ATWIR—called “potential waste”—that the sites believe may be appropriate for disposal at WIPP. However, technical, legal, or regulatory considerations would first have to be addressed. Examples of EM site waste categorized as potential waste in the ATWIR include:

- **The Hanford Site’s waste from future deactivation and decommissioning of facilities, including the PUREX facility and tunnels.** According to Hanford officials, this waste was reported as potential waste because they have not developed specific cleanup plans and therefore sufficient information on the waste characteristics are not yet known.
- **Waste from 11 tanks storing liquid radioactive waste at the Hanford Site that officials are considering disposing of as TRU waste if legal and regulatory issues can be resolved**.[23] For example, WIPP’s permit with the State of New Mexico prohibits disposal at WIPP of waste that has ever been managed as HLW—which includes Hanford’s tank waste. This prohibition also applies to waste from certain specified tanks at Hanford, even if the waste meets WIPP’s waste acceptance criteria based on its characteristics, unless the waste is specifically approved through a permit modification.
- **Waste treated in the Integrated Waste Treatment Unit facility at Idaho National Laboratory called sodium-bearing waste.** Idaho officials we interviewed told us that, similar to the Hanford tank waste, there are legal and regulatory issues that would need to be resolved before the waste could be categorized as TRU waste or disposed of at WIPP.

While EM officials request that sites provide them with estimates for all the TRU waste they expect to generate, the ATWIR does not always include information on TRU waste that could be generated by unplanned future cleanup activities. For example, in 2020 we found that EM had not developed estimates for TRU waste volumes from unplanned future deactivation and decommissioning projects at sites such as Los Alamos and Savannah River.[24] We interviewed officials at these, and other EM

[23]In 2024, we reported that, in addition to these 11 tanks, a portion of waste that EM had planned to vitrify in the High-Level Waste Facility could also potentially be managed as TRU waste if legal and regulatory issues can be resolved. GAO-24-106989.

[24]GAO, *Nuclear Waste Disposal: Better Planning Needed to Avoid Potential Disruptions at Waste Isolation Pilot Plant,* GAO-21-48 (Washington, D.C.: Nov. 19, 2020).

sites, who confirmed that future cleanup projects may produce TRU waste for which there are no volume estimates in the ATWIR. Cleanup at Material Disposal Area C at Los Alamos National Laboratory could produce hundreds of thousands of cubic meters of waste. An EM document addressing cleanup options at Los Alamos stated that at least a portion of the waste generated could be TRU waste, and EM site officials told us that this waste is not included in the ATWIR because of uncertainty in how this cleanup will be conducted.[25]

Additionally, the ATWIR does not capture uncertainty in the estimated volume of each waste stream included in the inventory. We reported in 2020 that, according to EM officials, the actual volume of waste that is disposed of at WIPP in the future may be higher than their current estimates. For example, EM may need to repackage certain stored wastes into multiple containers, which would thereby increase the total volume of waste. In other cases, the actual volume of waste disposed of at WIPP could be lower than what EM currently estimates because, for example, cleanup sites are working to develop more efficient waste packaging processes. According to EM officials, TRU waste estimates have historically been higher than the actual volume of waste disposed of at WIPP. According to EM officials, EM does not use range estimates to reflect these uncertainties in the ATWIR because they consider doing so to be speculative.

EM's Estimates of HLW and SNF May Be Uncertain, as Some Waste Could Be Treated and Disposed of as Other Types of Waste

According to EM officials, because EM is not actively generating new HLW or SNF, the volume of waste that requires some form of treatment and disposal is unlikely to change.[26] However, estimates of HLW and SNF volumes may be uncertain, as some of the waste could be treated and disposed of as other waste types.

Four EM sites manage HLW—the Savannah River Site, the Hanford Site, Idaho National Laboratory, and the West Valley Demonstration Project

[25]Los Alamos National Laboratory, *Corrective Measures Evaluation Report for Material Disposal Area C, Solid Waste Management Unit 50-009, at Technical Area 50, Revision 1*, Los Alamos National Laboratory Document EM2021-0177 (Los Alamos, NM: June 2021).

[26]According to EM officials, EM expects to process SNF at the Savannah River Site through 2032. The inventory of newly generated SNF and HLW from continued processing of SNF at the Savannah River Site and from newly discharged SNF from certain domestic and foreign research reactors will not have a significant impact on the volume of waste that requires some form of treatment and disposal.

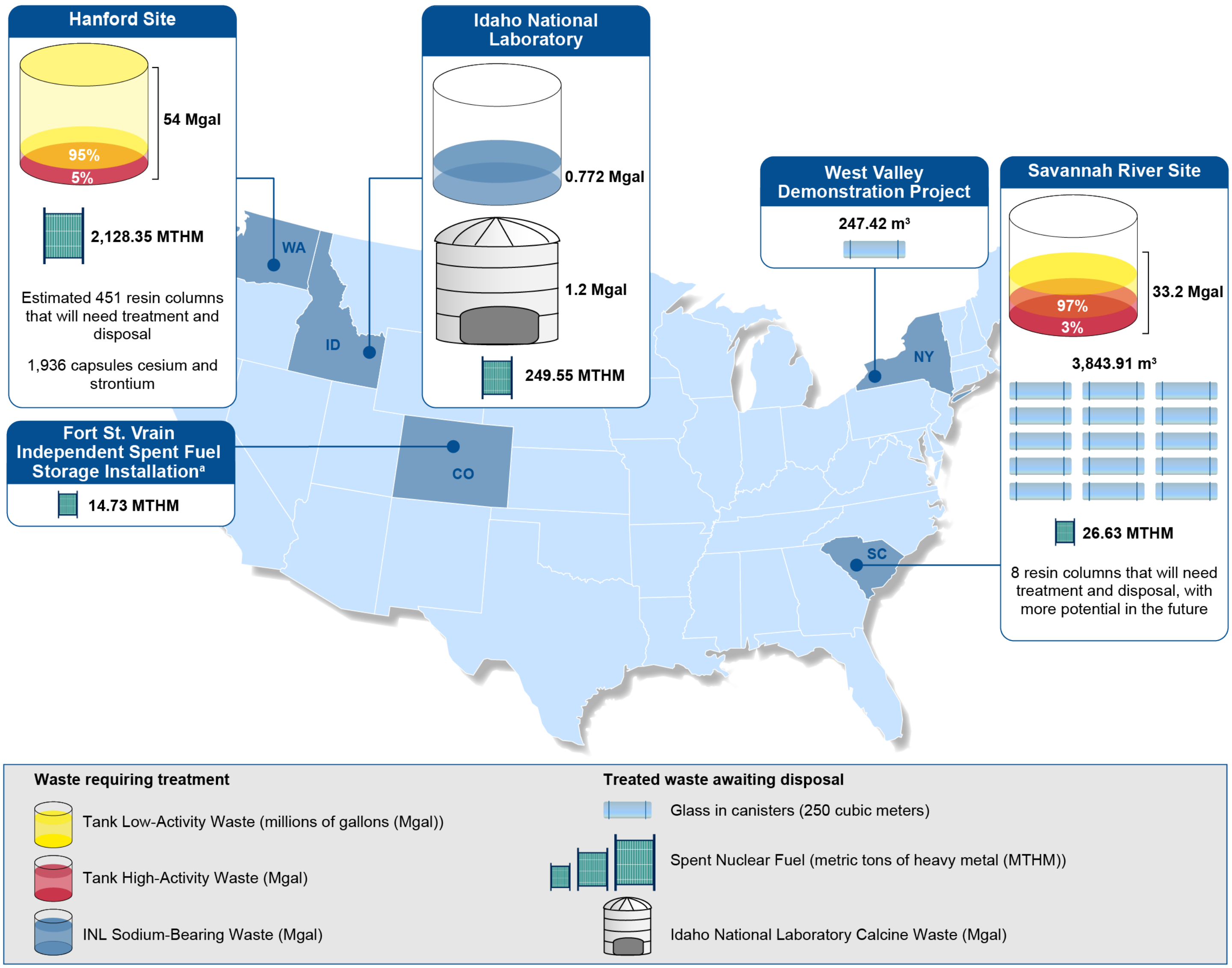
(see fig. 4).[27] The majority of HLW is in the form of untreated waste located in tanks or bin sets at the Hanford and Savannah River Sites, according to EM officials. Three of the sites—Savannah River, Hanford, and Idaho[28]—also manage SNF, some of which has been packaged and temporarily stored in on-site facilities for future shipment to an off-site repository when it becomes available.[29]

[27]The West Valley Demonstration Project is a cleanup effort that DOE has been carrying out since the 1980s at the Western New York Nuclear Service Center, which was the nation's only commercial facility for reprocessing spent nuclear fuel. The HLW stored on-site there includes commercial HLW. DOE maintains a federal site office near the center that is co-located with the site office for the New York State Energy and Research Development Authority, which holds title to the area encompassing the Western New York Nuclear Service Center.

[28]Idaho National Laboratory manages SNF on-site and at the Fort St. Vrain Independent Spent Fuel Installation in Colorado.

[29]According to EM officials, although some of EM's SNF has been packaged in a road-ready condition (i.e., in a form that can be shipped off-site for disposal when an off-site repository becomes available), most of EM's SNF still needs to be packaged into a road-ready configuration. At the Savannah River Site, EM's SNF is stored in a wet basin (L-Basin) pending processing, or long-term storage. The inventory not processed would need to be packaged in a road-ready configuration awaiting final disposition. EM's remaining SNF inventory at other sites is in dry storage. This inventory also needs to be packaged in road-ready configuration pending a future repository.

Figure 4: Department of Energy (DOE) Estimates of Waste Managed by the Office of Environmental Management as High-Level Radioactive Waste and Spent Nuclear Fuel (SNF)



Sources: DOE documents, GAO (icons), and Map Resources (map). | GAO-25-107109

[a]SNF located at Fort St. Vrain is managed by Idaho National Laboratory and is of commercial origin.

Waste Managed as High-Level Radioactive Waste

The vast majority of untreated HLW that EM is managing is tank waste.[30] As a matter of policy, EM manages certain tank waste at its Hanford, Idaho, and Savannah River sites as if it is "high-level radioactive waste" as defined by federal law unless the waste has been formally classified as another waste type. EM manages this waste as HLW because much of it originated from the reprocessing of SNF. The Hanford and Savannah River sites consider over 90 percent of their tank waste currently managed as HLW to be what DOE calls "low-activity waste." DOE has three processes it can use to determine that certain waste from reprocessing, such as low-activity waste, is not high-level radioactive waste and can instead be managed as either LLW or TRU waste.[31] Each of these processes has specific requirements and certain limitations. Regarding tank waste at the Hanford, Savannah River, and Idaho sites:

- **Hanford Site.** Of the 54 million gallons of tank waste at the Hanford Site, a large portion—95 percent of the waste when retrieved and certain radionuclides are removed—is considered to be what the site refers to as "low-activity waste".[32] The Hanford Site plans to treat about half of that low-activity waste by vitrifying it (mixing with molten glass), classifying it as LLW, and disposing of it on-site. In April 2024, EM, EPA, and the State of Washington proposed an agreement under which EM would likewise classify another portion of this low-activity waste as LLW, grout it, and dispose of it at facilities outside the state of Washington.[33] They finalized this agreement in January 2025. If EM is able to carry out these plans, the volume of waste at the Hanford

[30]The HLW at the West Valley Demonstration Project has been vitrified and packaged in storage casks.

[31]These three processes include: (1) the Waste Incidental to Reprocessing determination as outlined in DOE Manual 435.1-1, (2) Section 3116 of the Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005, and (3) DOE's HLW interpretation, as incorporated in DOE Manual 435.1-1. For details on each of these processes, see GAO-24-106989.

[32]The 54 million gallons of untreated waste represents the waste volume in the Hanford tanks as of September 2024. The volume of waste to be treated and eventually disposed of is much greater than the volume of waste currently in the tanks because liquid is added during retrieval, staging, and pretreatment processes.

[33]The agreement contemplates that EM will grout low-activity waste from 22 tanks assuming EM has a regulatory pathway to grout the waste and dispose of it off-site.

Site that needs to be treated and disposed of as HLW could be significantly reduced.[34]

Similarly, in September 2024 we found that portions of the remaining 5 percent of the tank waste that the Hanford Site plans to treat and dispose of as HLW may also be able to be disposed of as LLW or TRU waste, further reducing the overall amount of HLW inventory.[35] Because cleanup decisions about these wastes are in flux or have not been made, uncertainty exists about the amount of waste that will actually need to be treated as HLW and disposed of in a permanent geologic repository.

- **Idaho National Laboratory.** Similarly, as of July 2024, Idaho National Laboratory managed about 772,000 gallons of untreated sodium-bearing waste as HLW. This could be disposed of as TRU waste at WIPP if EM is able to overcome regulatory and legal barriers. The Waste Isolation Pilot Plant Land Withdrawal Act prohibits disposal of HLW at WIPP.[36] Therefore, for EM to dispose of the sodium-bearing waste at WIPP, the waste would need to be classified as TRU waste. Further, WIPP's permit with the state of New Mexico generally prohibits disposal of any waste that has ever been managed as HLW, which may pose an additional regulatory barrier to the disposal of Idaho's sodium-bearing waste at WIPP. No disposal decisions have been made yet; however, the waste is currently being treated and packaged as if the waste were TRU waste, even while it is reflected in EM's HLW estimates.[37]
- **Savannah River Site.** The Savannah River Site has also determined that a large portion of its tank waste can be disposed of as LLW. The site has already implemented a process which separates the low-

[34]We reported in May 2017 and December 2021 that DOE could save billions of dollars by grouting this portion of the low-activity waste stream and disposing of it in off-site LLW disposal facilities. GAO, *Nuclear Waste: Opportunities Exist to Reduce Risks and Costs by Evaluating Different Waste Treatment Approaches at Hanford*, GAO-17-306 (Washington, D.C.: May 3, 2017); and GAO, *Nuclear Waste Disposal: Actions Needed to Enable DOE Decision That Could Save Tens of Billions of Dollars*, GAO-22-104365 (Washington, D.C.: Dec. 9, 2021).

[35]GAO, *Hanford Cleanup: Alternatives for Treating and Disposing of High-Level Waste Could Save Billions of Dollars and Reduce Certain Risks*, GAO-24-106989 (Washington, D.C.: Sept. 26, 2024).

[36]Pub. L. No. 102-579, § 12, 106 Stat. 4777, 4791 (1992).

[37]In total, Idaho is treating 900,000 gallons of sodium-bearing waste in its Integrated Waste Treatment Unit using a process called steam reforming. The process converts the liquid sodium-bearing waste to a solid granular material, after which the treated waste is packed into stainless steel canisters and stored on-site.

activity portion of its tank waste, treats the waste to reduce the concentration of certain key radionuclides, and stabilizes the treated liquid using grout. The site then disposes of the grouted waste as LLW on-site in large containers referred to as Saltstone Disposal Units. The remaining tank waste—considered HLW—is vitrified and put into stainless steel canisters. These canisters are temporarily stored on-site in one of two waste storage buildings.

Spent Nuclear Fuel

Information about the amount of SNF for which EM is responsible is in the Spent Fuel Database maintained by Idaho National Laboratory. Officials at Idaho National Laboratory collect estimates of SNF waste amounts from EM sites and maintain these data. The inventory of SNF is fairly stable and does not change, with waste stored in stainless steel canisters on-site until a permanent off-site repository is built. However, according to Idaho officials, 54.9 metric tons of Idaho National Laboratory's SNF inventory consists of sodium-bonded blanket material—spent fuel that contains metallic sodium used for a thermal bond between the cladding and the fuel, which generally comes from DOE nuclear reactors. This fuel may eventually be able to be disposed of as LLW or TRU waste. However, these site officials said that disposing of the Idaho site's SNF as LLW or TRU waste would require an update to DOE Order 435.1-1 to allow EM to determine this waste can be managed as LLW or TRU waste.

Meeting EM's Disposal Needs Will Require Additional Capacity Beyond What Is Currently Available

Our analysis shows that estimated volumes of EM's remaining LLW that will require off-site disposal exceed the current available capacity of off-site disposal facilities. Officials from these facilities state that additional capacity can be made available, and they typically expand as needed. But, additional regulatory approvals for expansions may be needed in the future. For TRU waste, DOE's estimates show that WIPP could have capacity for all the waste under consideration for disposal, but unplanned waste could come close to exceeding WIPP's capacity. In addition, EM sites are estimating future storage costs for HLW and SNF based on assumptions that waste shipments will begin earlier than assumed by the DOE office responsible for planning for the repository.

EM Has Both On-site and Off-site Disposal Options, But Off-site Options Will Require Additional Capacity

EM has several disposal options available for LLW disposal, including on-site facilities at EM sites and three facilities that accept off-site waste. EM headquarters officials we interviewed told us they believe there is sufficient LLW disposal capacity, but our analysis shows that off-site capacity will need to be expanded to meet EM's estimated disposal needs.

EM Disposes of LLW Either On-site or Off-site; Off-site Facilities Rely on Regulators to Approve Future Operations and Expansion

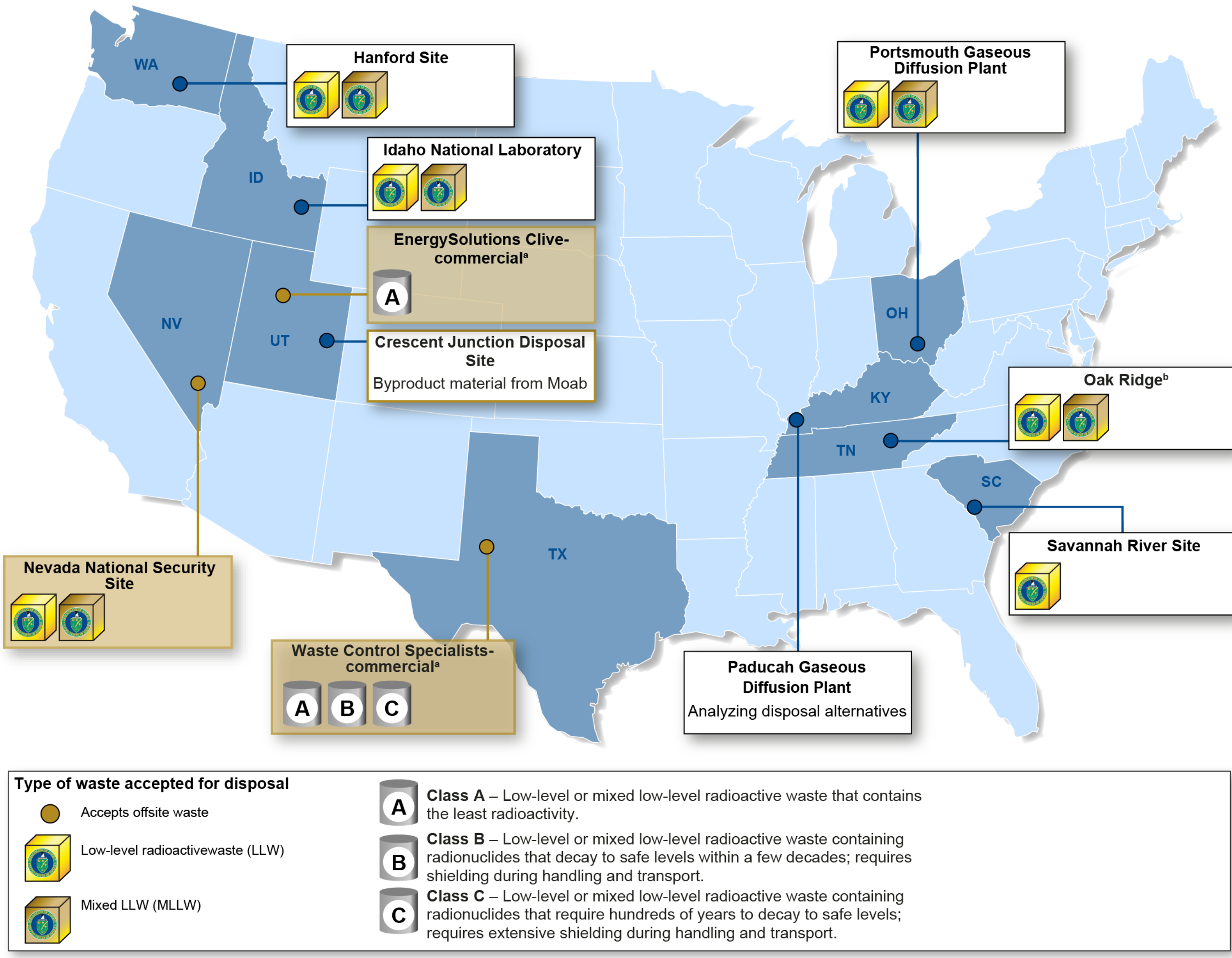
LLW disposal options include EM on-site facilities and three facilities that accept off-site waste. According to LLW estimates in the BLDD, six of EM's 15 cleanup sites will use on-site LLW disposal facilities to dispose of an estimated 92 percent of the remaining volume of EM's LLW.[38] EM also plans to use three off-site facilities—a federal disposal facility which also disposes of waste generated on-site at NNSS, commercial disposal facilities at Waste Control Specialists in Texas, and EnergySolutions in Utah—to dispose of approximately 1.48 million cubic meters of waste from EM and other DOE offices. See figure 5 for the locations of all LLW disposal facilities available to EM.

EM sites are responsible for selecting a disposal option for their waste streams.[39] Specifically, DOE Manual 435.1-1 includes a tiered approach to selecting a disposal option with a preference for, in order, DOE on-site disposal, DOE off-site disposal, and then non-DOE (commercial) off-site disposal. Site managers are responsible for approving exemptions to use off-site disposal. According to EM headquarters officials, EM sites prioritize the disposal option that has the best value to the government. Officials said this allows sites to consider multiple factors other than the cost of disposal, including supporting the long-term viability of commercial disposal facilities and addressing regulator and stakeholder sensitivities. EM headquarters officials said they receive copies of exemption forms but do not formally review or otherwise oversee these disposal decisions.

[38]In addition to the six sites that dispose of EM cleanup waste on-site, the Paducah Gaseous Diffusion Plant site is analyzing disposal alternatives for its LLW, and the Crescent Junction site in Utah is primarily for disposing of uranium mill tailings, which are a separate type of waste.

[39]EM headquarters officials we interviewed told us they maintain awareness of sites' waste generation and disposal plans, consult with sites regarding any issues that arise, and help facilitate discussions between sites, if needed. In general, however, EM headquarters officials told us that they take a lead role in complex-wide issues, and it is the responsibility of the sites to identify other issues where headquarters assistance is needed.

Figure 5: Locations of Low-Level Radioactive Waste and Byproduct Material Disposal Facilities Available to the Department of Energy's (DOE) Office of Environmental Management



Source: GAO analysis of DOE information and Map Resources (map). | GAO-25-107109

[a]Nuclear Regulatory Commission regulations specify how LLW should be classified according to its radiological hazard for disposal in licensed commercial facilities. Specifically, 10 C.F.R. § 61.55 specifies certain radionuclide concentration limits for Class A, B, and C LLW for near surface disposal. Commercial facilities may be licensed to accept only some classifications of LLW. DOE does not use the Nuclear Regulatory Commission classification system for LLW disposed of at DOE facilities, but it instead relies on site-specific performance assessments and waste acceptance criteria. Nonetheless, DOE also disposes of LLW at commercial waste facilities, and those facilities are subject to the Nuclear Regulatory Commission's classification system.

[b]As of December 2024, DOE is constructing a second on-site disposal facility at Oak Ridge.

Officials at sites with existing on-site disposal facilities told us that they expect the capacity of their facilities will be sufficient to complete LLW cleanup at their sites, with the exception of Oak Ridge, which is constructing a second on-site disposal facility to meet its disposal needs.[40] Officials at the Paducah Site are conducting an analysis of alternatives for addressing its LLW disposal needs, which includes pursuing an on-site disposal facility.

In addition, there are three off-site disposal facilities that can accept LLW and mixed LLW for disposal. For the two commercial disposal facilities that accept off-site waste, the state regulators must generally approve the facilities' applications to remain licensed and operational over time or to expand the facilities beyond already approved capacity limits to accommodate additional waste.

- **EnergySolutions at Clive, Utah.** EnergySolutions is a commercial facility licensed and permitted by the state of Utah to dispose of Class A LLW and mixed LLW, and certain byproduct material. EnergySolutions staff we interviewed said they are seeking approval from Utah to supplement their existing LLW disposal facilities, such as their Class A waste facility, which is at about 70 percent capacity. However, EnergySolutions' application for renewal of its Class A LLW facility license has been under review by Utah since 2012.[41] Utah regulators told us that they are currently working on EnergySolutions' Class A LLW license renewal and delays have been partially caused by administrative processes, such as mergers of certain Utah state offices, along with competing site priorities from EnergySolutions. EnergySolutions staff told us they have asked Utah regulators to prioritize review of a new federal disposal facility.

  Utah regulators stated that EnergySolutions began seeking a license for a new federal disposal facility over a decade ago and formally filed

[40]Oak Ridge's active on-site disposal facility is more than 85 percent full. The new disposal facility is scheduled to be completed in 2030. A significant amount of the remaining LLW at Oak Ridge has some level of mercury contamination, and Oak Ridge is still working with regulators to determine the waste acceptance criteria of the new disposal facility and the extent to which it can accept mercury-contaminated waste.

[41]According to Utah regulators, EnergySolutions' Class A LLW facility license is under "timely renewal," meaning that while the license is technically expired, EnergySolutions submitted a renewal application on time and continue to operate in compliance with state requirements while the state reviews the application.

an application in 2021.[42] According to EnergySolutions staff and Utah regulators, if licensed as planned, the new federal disposal facility could allow for the disposal of depleted uranium from the Savannah River Site, which has been stored on-site at EnergySolutions since around 2010 with storage paid for by DOE.[43] The facility could also allow for disposal of large quantities of depleted uranium from Portsmouth and Paducah.

[42]Discussions between EnergySolutions and Utah regulators are ongoing and have focused primarily on assessing the long-term performance of the proposed facility. As proposed in the application under review, this facility would be licensed to dispose of concentrated depleted uranium oxides. The peak radiological dose for depleted uranium occurs after 1 million years, and Utah regulators said the ability of the modeling being used to demonstrate compliance that far out is a significant challenge. While the Nuclear Regulatory Commission considers depleted uranium to be a Class A LLW, both EnergySolutions and Utah regulators indicated that there are challenges to the licensing process because, in their development, the current Nuclear Regulatory Commission land disposal regulations for LLW did not explicitly consider the impacts resulting from the disposal of certain unique waste streams such as large quantities of depleted uranium.

[43]EnergySolutions originally accepted depleted uranium from the Savannah River Site. Upon arriving at the site, Utah regulators told us they objected to disposal of such a significant quantity of this waste, leading to the indefinite on-site storage of 5,408 drums of depleted uranium.

Nuclear Regulatory Commission Rulemaking Could Facilitate Disposal of Greater-Than-Class C and Similar Wastes

An ongoing Nuclear Regulatory Commission rulemaking regarding its licensing requirements for land disposal of radioactive waste—found in 10 C.F.R. Part 61—could facilitate disposal of Greater-Than-Class C (GTCC) waste and similar waste at commercial near-surface disposal facilities. Nuclear Regulatory Commission staff told us the main purpose of the rulemaking is to increase the flexibility of licensees to use generic or site-specific criteria for disposal. Under the rulemaking, determining whether waste could be disposed of at a facility would be based primarily on waste characteristics and disposal facilities' capabilities.

DOE is responsible for disposal of GTCC, which is waste that contains radionuclides that exceed Class C limits and is often generated upon closure of commercial nuclear power plants. GTCC has no disposal options and is stored at sites across the country. In addition, DOE is responsible for disposal of waste types that are radiologically similar to GTCC but not of commercial origin, including defense transuranic waste and GTCC-Like waste (DOE-owned or generated waste that is not of defense origin).

According to Nuclear Regulatory Commission staff, the draft proposal submitted to the Commission includes proposed rule language on whether GTCC and GTCC-Like waste can be safely disposed of at near-surface facilities no matter the origin. Therefore, if a near-surface disposal facility receives regulatory approval to dispose of GTCC waste, DOE may have an opportunity to dispose of appropriate streams of GTCC, GTCC-Like, and transuranic waste at that facility.

Nuclear Regulatory Commission staff submitted the draft proposed rule to the Commission in 2024 and, if approved, they will publish a notice in the Federal Register requesting public comments. Staff estimate that a final rule could be in place in the next few years.

Source: Nuclear Regulatory Commission information. | GAO-25-107109

- **Radioactive Waste Management Complex at Nevada National Security Site (NNSS).** The Radioactive Waste Management Complex at NNSS is a federal facility operated by EM for disposal of LLW and mixed LLW. DOE regulates LLW disposal at NNSS under its Atomic Energy Act authorities and does not need state approval to expand its LLW capacity.[44] In addition to DOE, the state of Nevada regulates mixed LLW disposal at NNSS under its RCRA authority and state hazardous waste laws. Expansion of mixed LLW capacity at NNSS would require state approval. Nevada regulators said that they understand the important role of NNSS waste disposal within the DOE complex. However, Nevada regulators told us they are also focused on protecting human health and the environment and want to ensure NNSS is not DOE's default option for LLW disposal.

  DOE has not determined what organization will operate disposal facilities at NNSS in the future. Currently, National Nuclear Security Administration's site contractor operates the disposal facilities while EM funds those operations and ensures compliance with the waste acceptance criteria, among other things. However, EM estimates it will complete other cleanup activities at the site by 2030, and DOE has yet to decide whether the site owner, the National Nuclear Security Administration, will take over disposal operations at NNSS after 2035. The Nevada regulators preference is to retain the current operating structure rather than the National Nuclear Security Administration taking over disposal responsibilities, given that its mission focus is on national security, not radioactive waste disposal. NNSS site officials from EM said that they and site officials from the National Nuclear Security Administration submitted a decision paper to EM headquarters recommending that EM continue overseeing disposal past 2035. According to EM headquarters officials, they plan to wait and have discussions about the future of NNSS disposal operations closer to 2030.

- **Waste Control Specialists at Andrews, Texas.** Waste Control Specialists is a commercial facility licensed and permitted by the state of Texas to dispose of Class A, B, and C LLW and mixed LLW, as well as certain byproduct material. While it can expand its disposal facilities as needed to its approved capacity, Waste Control Specialists needs approval from Texas if additional expansions are

[44]According to Nevada officials, the State of Nevada and DOE also jointly oversee disposal of LLW under an Agreement in Principle and a Memorandum of Understanding between DOE and the State. In addition, Nevada officials said that waste disposed of at the Area 5 Radioactive Waste Management must meet the NNSS Waste Acceptance Criteria, and the waste must be verified upon arrival at the site.

necessary and to continue to renew its license with the state every 10 years.[45] Waste Control Specialists includes two LLW disposal facilities that are available to EM: a federal waste facility that accepts up to Class C LLW and mixed LLW from the federal government and a hazardous/exempt waste facility that accepts some Class A LLW and mixed LLW.[46] Texas regulators did not provide comment on future expansions at Waste Control Specialists beyond the currently approved capacity because they said the facilities have not yet been fully built out to the approved capacity.

Additional Off-site Capacity for LLW Will Be Required to Meet EM Needs

While EM headquarters officials we interviewed told us they believe there is sufficient LLW disposal capacity overall, our analysis shows that off-site capacity will need to be expanded to meet EM's estimated disposal needs. Specifically, off-site disposal capacity is limited to three disposal facility options and represents a complex-wide issue since multiple sites rely on these facilities. EM officials told us the LLW estimates they collect—the BLDD—are not appropriate to use to determine EM's needs for future capacity, and there is no other tool available for them to do so. Since the BLDD is the best data available, we used it as a proxy for the amount of off-site capacity DOE will need in the future and added additional waste we identified as missing from the BLDD.[47] Based on our analysis, we found that DOE disposal needs exceed the current capacity of off-site disposal facilities. EM officials told us off-site commercial facilities use a "build-as-needed" approach and have the ability to expand their capacity. When considering the amount of expansion capacity that is available at off-site facilities that has already received regulatory approval, if needed, we found that there is sufficient capacity to meet current estimates of DOE's off-site disposal needs.

In October 2024, we requested information from the three locations with off-site disposal facilities—EnergySolutions, NNSS, and Waste Control

[45]Representatives from Waste Control Specialists said their license includes two 10-year renewal options, which would extend the facility to 2044. State officials said Texas law allows for additional renewal options past 2044, and the facility would need to remain operational past 2044 to support the state's commercial waste disposal needs.

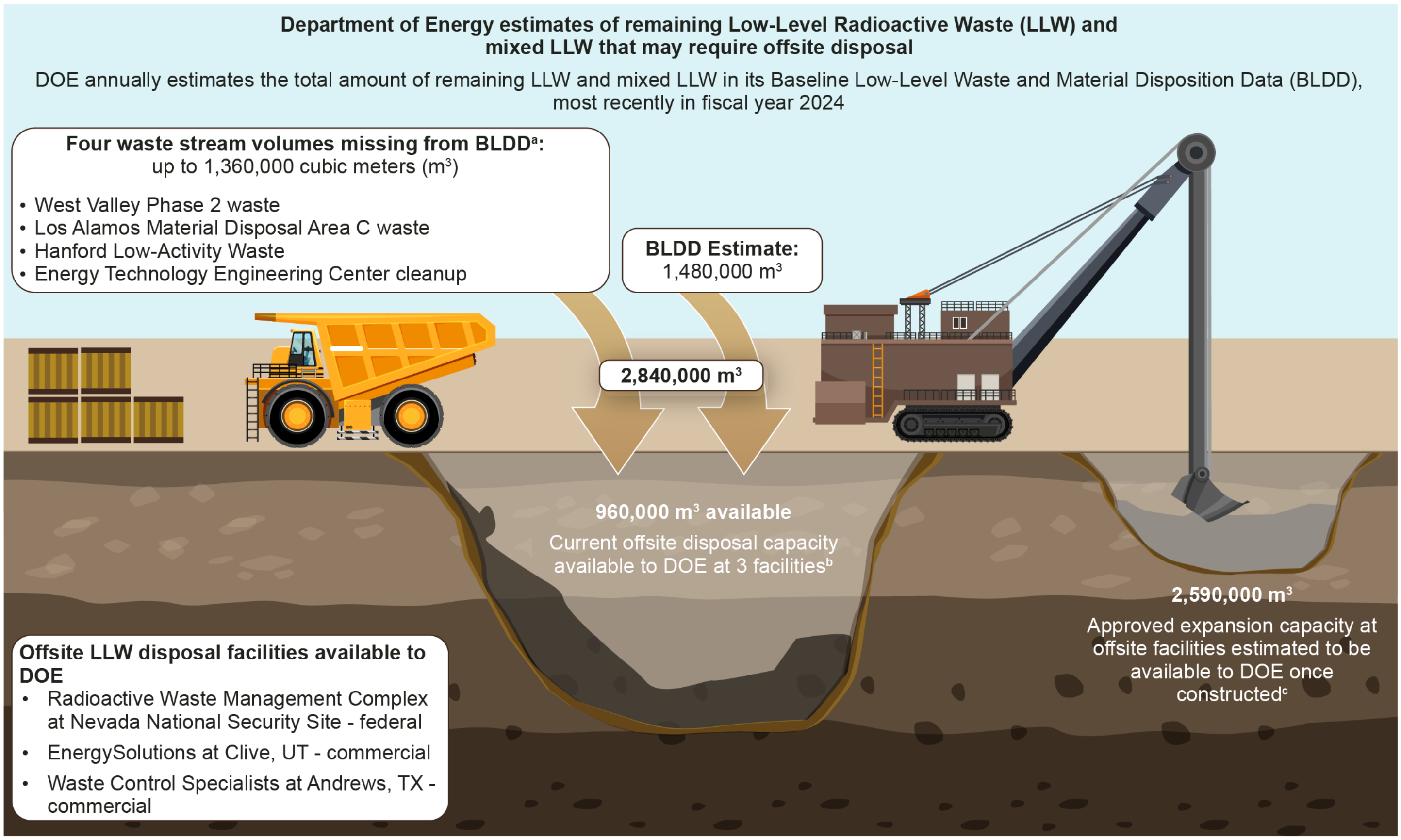
[46]Representatives from Waste Control Specialists said about 80 percent of waste they receive from EM and other DOE offices is disposed of at the hazardous/exempt waste landfill, which is cheaper to operate but only accepts waste that is up to around 10 percent of Class A radioactivity limits.

[47]We used estimates of all DOE LLW that is planned for off-site disposal from the BLDD, not only EM waste, because off-site disposal capacity is shared by EM and other DOE offices.

Specialists—regarding their current and approved LLW disposal capacity estimated to be available to DOE. We then used this information to analyze the extent to which off-site capacity for LLW can address BLDD estimates of remaining LLW requiring off-site disposal. We added additional waste volume to account for waste streams we noted above that are missing from EM's BLDD to show the impact of the missing data when evaluating complex-wide capacity. Specifically, we selected four waste streams—Los Alamos National Laboratory Material Disposal Area C waste, Hanford low-activity tank waste, Energy Technology Engineering Center contaminated soil, and West Valley Phase 2 waste—for which an agreement or final decisions regarding the extent or method of cleanup has not been made. Altogether, these waste streams could add up to 1.36 million cubic meters of additional waste that may require off-site disposal.

Based on our analysis, the estimated volumes of LLW that DOE plans to send to off-site disposal exceeds the current available capacity of off-site disposal facilities—see figure 6. As mentioned above, EM officials told us off-site commercial facilities use a "build-as-needed" approach and can expand their capacity. When considering the amount of expansion capacity that is available at off-site facilities that has already received regulatory approval, if needed, we found that there is sufficient capacity to meet current estimates of DOE's off-site disposal needs.

Figure 6: GAO Analysis Comparing Department of Energy (DOE) Estimates of Low-Level Radioactive Waste that May Require Off-Site Disposal to Available and Approved Disposal Capacity



Sources: GAO analysis of BLDD, disposal facility data, and DOE documents and interviews; blueringmedia/stock.adobe.com (illustration). | GAO-25-107109

[a]As discussed in this report, these waste streams were not included in the BLDD due to an agreement or final decision regarding the method or extent of cleanup having not been made. We selected the maximum volume of the potential range of waste found in DOE reports to illustrate the potential impact of not accounting for such streams in long-term disposal plans.

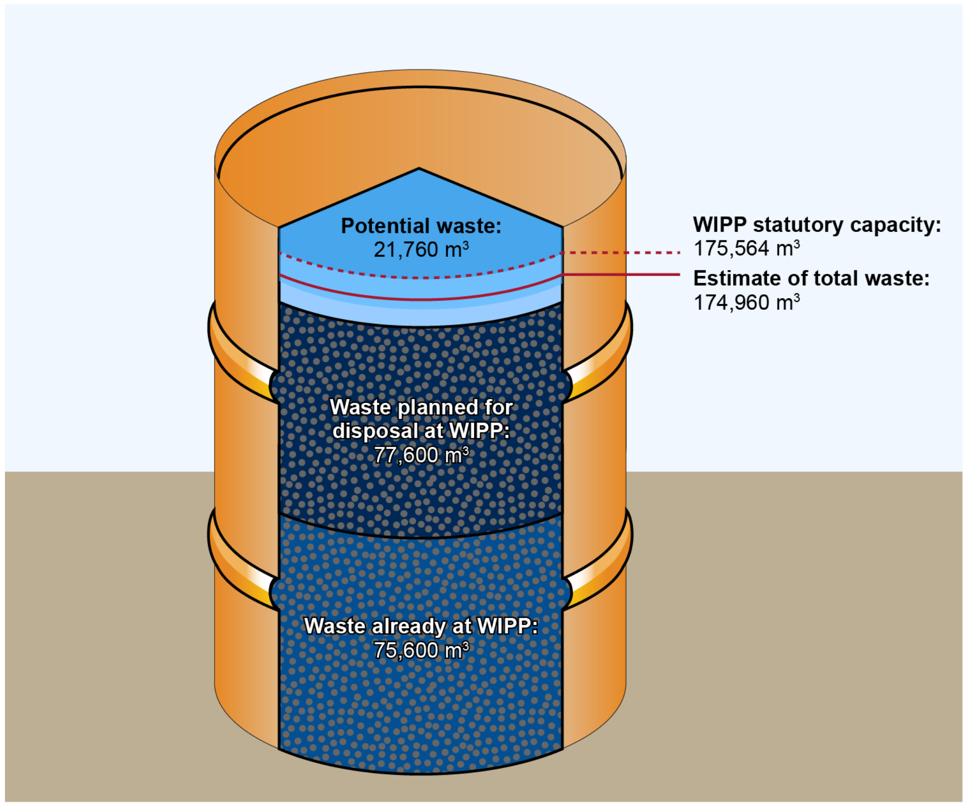
[b]We received capacity data from the three off-site disposal facilities between October 2024 and February 2025. The total current capacity available is larger than 960,000 m^3 because there is capacity that these facilities estimate will be used by non-DOE customers.

[c]According to EnergySolutions staff, it has over 10 million cubic meters of additional expansion capacity that could be available in the future if approved by its Utah regulator. According to Waste Control Specialists staff, about 10 percent of its total acreage has been approved for disposal facilities, which means 90 percent is potentially available for future expansion if approved by its Texas regulator.

EM Has Sufficient Capacity for Disposing of TRU Waste at WIPP, but Additional Waste Could Exceed WIPP's Disposal Limits

WIPP, a deep geologic repository in southeastern New Mexico, is currently the only disposal option for TRU waste generated by atomic energy defense activities. WIPP began accepting TRU waste for disposal in 1999 and had accepted 75,600 cubic meters as of December 2023. The Waste Isolation Pilot Plant Land Withdrawal Act limits the volume of TRU waste that can be disposed of at WIPP to 6.2 million cubic feet, or roughly 175,564 cubic meters. According to the 2024 ATWIR, an estimated 77,600 cubic meters of TRU waste is planned to be disposed of in the future, leaving 22,364 cubic meters (about 13 percent) of disposal capacity remaining at WIPP before reaching its statutory capacity. However, as noted above, there is additional waste in the form of potential waste identified in the ATWIR and waste generated by future unplanned cleanup work, which could come close to reaching WIPP's capacity. For instance, if all potential waste identified in the 2024 ATWIR (21,760 cubic meters) were to be disposed of at WIPP it would leave 604 cubic meters of WIPP's statutory capacity remaining—see figure 7.

Figure 7: Volume of Transuranic Waste Disposed of in the Waste Isolation Pilot Plant (WIPP), New Mexico, and Estimated Future Volumes in cubic meters (m^3)



Source: GAO analysis of Office of Environmental Management information. | GAO-25-107109

Note: The waste volumes in the figure are rounded.

To reach its statutory capacity, EM will need to expand the physical disposal space (called "panels") at WIPP. In 2020, we reported that EM estimated that it would need to construct approximately nine additional panels to reach WIPP's statutory capacity.[48] To construct additional panels, EM needs approval from the New Mexico Environment Department and EPA. New Mexico approved the construction of two panels in October 2023. As of November 2024, EPA was considering public comments on an administrative action approving these two panels. EM officials we interviewed said they were developing a plan for

[48] GAO-21-48.

requesting additional disposal space beyond the two panels already requested.

WIPP's Hazardous Waste Facility Permit states that additional disposal capacity (i.e., additional panels) at WIPP must be requested by submitting a permit renewal application that describes the final facility footprint. According to New Mexico Environment Department officials, this requirement is meant to ensure that the next request for additional panels includes information on all additional disposal space needs for WIPP through the rest of its operational phase. The permit further states that DOE must provide an inventory of TRU waste from the DOE complex to support a renewal application, and that the inventory must provide the basis for estimated quantities. According to New Mexico Environment Department officials we interviewed, the inventory of waste submitted along with the request for additional panels should include any waste that DOE intends to send to WIPP even if DOE has not finalized a decision to do so because of technical uncertainty or the need for regulatory approvals. These officials also indicated that, in its next renewal application, EM would need to decide whether to pursue WIPP disposal for wastes, which, as indicated above, would require a change to the WIPP permit, such as sodium-bearing waste at Idaho, where EM had not yet determined a disposal path.

The WIPP Hazardous Waste Facility Permit also includes language requiring EM to submit an annual report to the state summarizing DOE's progress toward siting another repository for TRU waste outside of New Mexico. The first of these reports was issued in December 2024.[49] In the report, EM describes that it is working with DOE's Office of Nuclear Energy (Nuclear Energy) officials to benefit from lessons learned from the consent-based siting process Nuclear Energy is conducting to site a repository for HLW and SNF. According to officials from both EM and Nuclear Energy, they are unsure whether efforts to identify an additional TRU waste repository will be combined with efforts for siting a HLW repository or remain separate.

[49]DOE's Carlsbad Field Office, *Repository Siting Annual Report* (Carlsbad, NM: Dec. 23, 2024).

A Permanent Repository for HLW and SNF May Not Be Available Until Years Later Than EM Sites Are Planning

There is currently no geologic repository for the permanent disposal of HLW and SNF in the United States. In the interim, according to DOE officials, HLW and SNF are stored on-site at both DOE and commercial nuclear power plant sites until a permanent repository is identified and developed.

The Nuclear Waste Policy Act of 1982, as amended, specifies that the only site that can be considered for the permanent disposal of commercially generated SNF is a geologic repository at Yucca Mountain, Nevada.[50] Congress approved the siting and building of the Yucca Mountain repository in Nevada in 2002, and DOE long planned to dispose of defense HLW and SNF along with commercial SNF at a single repository at the site. However, the project encountered many difficulties and was highly contested by the public and others.[51] In March 2010, DOE terminated its efforts to license a repository at Yucca Mountain, and Congress stopped funding activities related to the site.

Since terminating the Yucca Mountain proposal in 2010, DOE headquarters has not completed a detailed proposal for a new repository.[52] In 2016, DOE drafted a plan describing a path for development of a Defense Waste Repository to permanently dispose of all or a portion of defense-related HLW and SNF.[53] According to DOE officials, the plan was never completed, and as of January 2025, they were not considering moving forward with a defense-only repository. These officials told us that this was because, for the time being, they

[50]The Yucca site is on federal land adjacent to the Nevada National Security Site in Nye County, Nevada, about 80 miles northwest of the Las Vegas Valley.

[51]See GAO, *Commercial Nuclear Waste: Effects of a Termination of the Yucca Mountain Repository Program and Lessons Learned*, GAO-11-229 (Washington, D.C.: Apr. 8, 2011).

[52]In 2013, DOE issued *The Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste*, which indicated that the Administration at that time, with the appropriate authorizations from Congress, planned to make demonstrable progress on the siting and characterization of repository sites to facilitate the availability of a geologic repository by 2048.

[53]In 2015, DOE provided information to the President supporting separate repositories for commercial and defense waste and cited several benefits, including cost efficiencies. On the basis of this information, the President in 2015 reversed a 1985 presidential finding and determined that a separate repository for defense waste was required, setting DOE down the path of considering separate repositories.

consider a repository for both defense and commercial waste to be more likely to garner public support.[54]

Until DOE constructs a repository, EM sites will need to store HLW and SNF on-site, absent DOE providing a consolidated storage option for this material, which the agency currently has no plans to pursue. Nuclear Energy officials, who are responsible for developing a plan for a permanent repository for HLW and SNF, said they have primarily been working on developing options for an interim storage facility for commercial SNF. These officials said they expect to complete a proposal that includes estimated time frames and costs for a permanent repository for both commercial and defense HLW and SNF by 2025.[55] Nuclear Energy officials told us that their current estimate for when a repository might be available is 2065. They noted that until Congress passes legislation designating a location other than Yucca Mountain for a repository, any proposal could not move forward.

Nuclear Energy officials we interviewed stated that historical planning documents—documents pertaining to the potential Yucca Mountain repository—assumed commercial and defense HLW and SNF will be disposed of in a geologic repository concurrently.[56] Officials said it could take up to 50 years once a repository opens to dispose of the approximately 140,000 tons of estimated commercial SNF and no decision has been made about the sequencing of disposal of commercial

[54]DOE officials further clarified that congressional direction and appropriations would be needed to pursue a defense-only repository.

[55]Nuclear Energy officials noted that its plan for a federal Consolidated Interim Storage Facility assumes the facility begins operations to receive commercial SNF as early as fiscal year 2038 subject to congressional authorization and funding.

[56]In 2021, we reported that as of September 2020, the federal government had paid the owners of commercial nuclear power reactors almost $9 billion in damages for the costs those owners had incurred to store SNF at reactor sites after the point at which DOE had agreed to take that SNF pursuant to the Nuclear Waste Policy Act of 1982, as amended. We reported that costs will continue to grow until the federal government develops and approves a consolidated interim storage facility or permanent disposal repository and takes custody of the fuel. See GAO, *Commercial Spent Nuclear Fuel: Congressional Action Needed to Break Impasse and Develop a Permanent Disposal Solution*, GAO-21-603 (Washington, D.C.: Sept. 23, 2021). In its Fiscal Year 2024 Agency Financial Report, DOE estimated the total liability estimate for failure to take ownership of commercial SNF as of September 30, 2024, ranged between $48.7 billion and $55.6 billion. After deducting the cumulative amount paid of $11.1 billion as of September 30, 2024, the remaining liability is estimated to range between $37.6 billion and $44.5 billion. A key input to the estimate is the duration that each operating reactor will continue to operate. Given that a longer operating duration results in an increased amount of SNF generated, a longer operating duration also increases liability.

SNF as compared to defense HLW and SNF. Officials added that SNF is generally more radioactive than HLW because EM often removes certain radionuclides when it treats its HLW. Furthermore, officials noted that the requirements for HLW disposal are currently tailored to disposal at Yucca Mountain and, therefore, once a repository is selected these requirements could change in a manner that affects HLW treatment and disposal.

We found EM sites' planning assumptions for the disposal of HLW and SNF do not match the DOE's potential dates for opening a SNF and HLW repository. In the absence of a permanent repository to accept their waste and a potential repository not available for decades, the four EM-managed sites may have challenges meeting regulatory deadlines and incur costs to store SNF and HLW on site. Specifically:

- **Idaho National Laboratory.** A legally binding agreement—the 1995 Settlement Agreement—among Idaho DOE, and the U.S. Navy requires DOE to remove all SNF from Idaho by January 1, 2035, and to treat all HLW at the Idaho National Laboratory so that it is ready to be moved out of Idaho for disposal by a target date of 2035. The 1995 Settlement Agreement also carries a fine of $60,000 for each day the milestone for removal of SNF is not met and provides that shipments of DOE SNF to the site shall be suspended if DOE fails to meet its obligations or deadlines under the agreement. Site officials told us that they received guidance from EM headquarters directing them to assume a repository for their HLW and SNF will be available in the 2050s and shipping will start in the late 2050s and possibly in the 2060s. The site does have some temporary storage for its treated sodium-bearing waste, currently packaged as TRU waste; but the site would need to expand storage facilities to store all treated sodium-bearing waste. In addition, if EM is unable to dispose of the sodium-bearing waste at WIPP as TRU waste, EM may need to conduct additional treatment of the sodium-bearing waste to dispose of it at a HLW repository. In fiscal year 2024, DOE spent about $20 million for storage of treated sodium-bearing waste. In addition, the estimated costs of managing SNF—including some of Idaho's waste stored in Colorado—in fiscal year 2023 was $13.5 million. Idaho National Laboratory will also need to continue to incur storage costs at the site and at the facilities storing commercial-origin SNF at the Ft. St. Vrain site until a repository is available.
- **Hanford Site.** Certain cleanup activities at the Hanford Site are governed by a legally binding agreement—the Tri-Party Agreement—among EM, EPA, and the State of Washington. The Tri-Party Agreement sets 2047 as the date for completing treatment of all of

Hanford's HLW waste.[57] The agreement does not include a milestone for the removal of SNF or HLW from the site. However, Hanford officials anticipate building a storage facility to store treated HLW until a permanent off-site repository is available. Hanford's System Plan 10, which it uses for planning purposes, indicates that the Interim Hanford Storage facility would be available in 2038 and would operate from 2038 through 2072. Hanford officials estimate that it will cost $30 million to $35 million annually to store the HLW. Hanford currently stores its SNF in the Canister Storage Building, an on-site facility designed to hold this waste, and the 200 Area Interim Storage Area. According to officials, the SNF at the 200 Area Interim Storage Area will be packaged into road-ready canisters to be later transferred to the Canister Storage Building.

- **Savannah River Site.** The Savannah River Site plans to complete treatment of its HLW by 2037. Savannah River Site officials assume that vitrified canisters could start shipping to a repository by 2058—about 7 years before the Office of Nuclear Energy anticipates opening a repository. EM built a storage facility to temporarily store its HLW on-site. According to EM officials, there is sufficient storage space to accommodate all remaining tank waste once treated. Savannah River Site officials estimate the costs of operating and maintaining these existing storage facilities is $750,000 per year.
- **West Valley Demonstration Project.** Around 2002, the West Valley Demonstration Project site completed vitrification of HLW, with the waste now stored in 56 casks at the site, according to site officials. These officials track waste storage costs for both these casks and the site's Greater-Than-Class C waste and report that these costs have totaled $7.3 million as of fiscal year 2023. The site will continue to accrue additional storage costs until these wastes are disposed of.

[57]In the agreement among EM, EPA, and the State of Washington finalized in January 2025, there is an acknowledgement that the 2047 milestone must be revised in the future.

EM Has Not Analyzed Complex-wide Alternatives or Developed an Integrated Plan to Optimize Waste Disposal

EM headquarters is responsible for overseeing disposal across the EM complex and has taken some actions to oversee and participate in complex-wide disposal planning decisions. However, we identified nine waste streams with barriers to disposal and other complex-wide issues that EM headquarters' actions have not fully addressed. Further, EM headquarters has not assessed opportunities to optimize complex-wide disposal decisions or developed an integrated waste disposal plan.

EM's Current Planning Does Not Address Waste Streams with Disposal Barriers and Issues That Require Coordination Across Sites

EM headquarters officials take some steps to oversee and participate in disposal decisions across the EM complex. For example, officials told us they maintain awareness of sites' waste generation and disposal plans, consult with sites regarding issues that arise, and help facilitate discussions between sites, if needed. In addition, some EM headquarters officials told us that they and site officials meet annually with state and federal regulators and participate in national conferences. EM headquarters officials also participate in certain national groups, such as one that oversees the operations of LLW disposal sites and the National TRU waste program, which oversees DOE's process for shipping and disposing waste at WIPP. However, these efforts do not address waste streams with disposal barriers nor address issues that require coordination across sites.

At least nine waste streams across the EM complex face barriers to disposal, and EM has not undertaken centralized planning to fully address these barriers.[58] See appendix II for overviews of each waste stream. Later in the report, we discuss the importance of taking a complex-wide approach to analyzing potential alternatives that could help optimize disposal efforts, including these nine waste streams with barriers to disposal. The barriers are mostly tied to legal and regulatory constraints that span multiple sites and states. For example:

[58]We identified waste streams and barriers based on interviews with EM site and headquarters officials, representatives from disposal facilities, and state regulators, as well as through our review of relevant documentation, including prior GAO reports. The nine waste streams are: (1) depleted uranium oxide at Portsmouth and Paducah, (2) Greater-Than-Class C (GTCC) and GTCC-Like waste, (3) Hanford high-activity tank waste, (4) Hanford low-activity tank waste, (5) Hanford TRU tank waste, (6) Idaho calcine waste, (7) Idaho sodium-bearing waste, (8) Oak Ridge mercury-contaminated LLW, and (9) Oak Ridge sludge waste.

- **Idaho sodium-bearing waste** is managed as HLW but being treated and packaged by Idaho National Laboratory as if it will eventually be disposed of as TRU waste at WIPP. Under the 1995 Settlement Agreement, this waste must be treated so that it is ready to be moved out of the state for disposal by a target date of 2035. However, the waste faces legal and regulatory barriers to being able to be disposed of as TRU waste at WIPP. For example, WIPP's Hazardous Waste Facility Permit does not allow waste that has ever been managed as HLW or waste from certain specified tanks at Idaho—which includes Idaho's sodium-bearing waste—to be disposed of at WIPP unless the waste is specifically approved through a permit modification. According to Idaho site officials, EM headquarters has told them to wait to initiate the process to have this waste classified as TRU waste. A senior official from the New Mexico Environment Department told us that the state's regulators have been frustrated with the lack of communication from EM about potential new waste streams planned for disposal at WIPP, including hearing about potential TRU waste in Idaho from a news article and not EM.
- **Hanford low-activity tank waste** is managed, as a matter of policy, as HLW unless and until it is classified as another waste type, such as LLW. EM is planning for the second phase of a demonstration project to treat 2,000 gallons of this tank waste with grout and dispose of it as LLW at both Waste Control Specialists in Texas and EnergySolutions in Utah. According to Texas regulators, EM has communicated with them regularly regarding this demonstration project. As of November 2024, Utah regulators stated that EnergySolutions' interpretation of the demonstration project waste complies with requirements for the waste to be disposed of at the company's disposal site. In addition, a January 2025 agreement among DOE, EPA, and the Washington State Department of Ecology includes a plan for DOE to grout the low-activity waste from 22 tanks at Hanford and dispose of the waste off-site as LLW. However, this agreed upon plan is expressly contingent on DOE having a regulatory pathway to grout and dispose of this waste off-site. Regulators in Texas and Utah were not included in the negotiations that led to this agreement, which according to regulators, could have provided an opportunity to discuss potential disposal issues.

In addition, in our review of EM's disposal efforts, we identified several complex-wide issues that have not been fully addressed by current EM actions. These issues include:

- **Communication with states that host disposal sites**. According to state regulators we interviewed in Texas, Utah, and New Mexico, EM does not communicate long-term and complex-wide disposal plans, nor consistently discuss key waste streams that face barriers to disposal, to ensure states have clarity about their roles in working with EM to complete its cleanup mission.[59] These regulators indicated that such communication is critical to facilitating the disposal of EM's radioactive waste and reaching agreement on how to address waste with barriers to disposal.
- **Long-term availability of LLW off-site disposal.** EM has not assessed the long-term availability of off-site LLW disposal facilities, both in terms of ensuring sufficient capacity and the financial stability of the commercial disposal facilities. As discussed above, we compared EM's estimates of remaining LLW against the current available capacity of off-site disposal facilities and found these facilities are not sufficient for DOE's disposal needs without expansion. According to EM officials, they do not monitor the amount of off-site LLW disposal capacity available or the need for future potential capacity. With the significant amount of waste missing from EM's LLW estimates it is unclear when and how much additional capacity will be needed. EM may therefore face a disposal capacity disruption if it does not actively monitor and communicate its LLW plans to disposal facilities. Representatives from both commercial disposal facilities we interviewed said better planning and communication from DOE would be helpful. For example, planning long-term LLW disposal needs with more complete estimates, as discussed earlier, and communicating that information to off-site disposal facilities would help better inform the facilities about the need and timing of future expansions, which can take time, money, and planning to execute. Moreover, if off-site disposal options become temporarily unavailable, cleanup progress may be disrupted, potentially resulting in missed regulatory milestones and higher waste storage costs.

  According to EM officials, they cannot conduct oversight of the financial stability of commercial disposal facilities, and it is unclear if sites consider this when selecting a disposal option. EM officials told us that sites select the disposal option that provides the best value to the government and can include consideration of the viability of disposal options. However, this process is not overseen by EM

[59]Nevada officials also stated that they requested complex-wide disposal inventories and plans from EM. These officials also noted that they meet annually with EM to discuss potential waste streams that could be disposed of at NNSS.

headquarters and does not represent a complex-wide analysis of the long-term viability of disposal options. EnergySolutions and Waste Control Specialists are owned by private equity firms. These ownership models rely on the generation of revenue to continue operating. EM has no assurance that these facilities will continue to operate through the 2070s, which is the time frame that EM estimates needing off-site disposal.[60]

- **Reducing reliance on WIPP.** EM has not evaluated whether some TRU waste could be disposed of at commercial facilities under an ongoing Nuclear Regulatory Commission rulemaking effort discussed above.[61] The rulemaking, if approved by the Commission and finalized as proposed, would allow for the disposal of certain GTCC waste at near-surface commercial facilities and provide specific regulatory requirements for this disposal. It also would amend the definition of "waste" in certain Nuclear Regulatory Commission regulations such that LLW that is acceptable for disposal no longer excludes "transuranic waste." According to Nuclear Regulatory Commission staff, certain TRU waste is likely to be similar in terms of characteristics to GTCC, and the rulemaking could allow for some TRU waste to be acceptable for disposal in commercial near-surface facilities. EM officials said that it is not practical to conduct an evaluation of additional options for TRU waste disposal until the Nuclear Regulatory Commission publishes a final rule, which these staff estimate could occur in in the next few years. Additionally, officials from one EM site told us they are implementing new technology that can identify radiological contamination with greater precision and therefore could result in reductions in the volume of waste classified as TRU.[62] However, EM has not documented any integrated, complex-wide approach for implementing this or similar approaches. As a result, DOE may be missing opportunities to reduce

[60]DOE has previously encountered challenges with relying on a private company for uranium enrichment, which is used for nuclear power and to meet certain national security needs. In 1992, United States Enrichment Corporation was established as a government corporation to, among other things, provide uranium enrichment services. In 1998, the corporation was privatized under the USEC Privatization Act, but the company ceased enrichment operations in 2013 and filed for Chapter 11 bankruptcy protection in 2014, leaving the United States without a source of uranium needed for national security purposes.

[61]Nuclear Regulatory Commission, *Proposed Rule - Integrated Low-Level Radioactive Waste Disposal*, SECY-24-0045 (May 29, 2024).

[62]This technology allows EM sites to separate more highly contaminated portions of waste from portions with less contamination resulting in a larger percentage of the waste being categorized as LLW.

the volume of waste that, currently, can only be disposed of at WIPP and better ensure that it does not exceed WIPP's TRU waste capacity limits.

- **Remote-handled TRU waste.** EM has not fully evaluated the extent to which WIPP will have sufficient disposal space for the remaining remote-handled TRU waste at EM sites.[63] Disposal of remote-handled waste at WIPP requires the use of either horizontal boreholes in panel walls or shielded container assemblies that allows remote-handled waste to be disposed of like contact-handled waste on the panel floor. It is unclear if sites' plans for disposal of their remote-handled TRU waste will be able to be fulfilled by WIPP given inefficient disposal of such waste in the past and uncertainty about the future availability of horizontal borehole disposal. We reported in 2020 that EM has struggled to dispose of remote-handled waste in WIPP, having filled only 35 percent or less of the amount permitted in existing panels.[64] The use of horizontal boreholes has also been on hold since a 2014 incident at WIPP that resulted in the contamination of the machinery needed to execute remote-handled waste disposal and the machinery left in the panel where the incident occurred. EM officials said that while the abandoned equipment has been replaced, resuming horizontal borehole disposal has not been a high priority. According to EM's Carlsbad Field Office officials, horizontal borehole disposal may resume in the early 2030s but could be delayed. Shielded container assemblies are increasingly being considered by sites as another option to dispose of their remote-handled TRU waste, but the National TRU Program has not directed sites whether to proceed with packaging the waste for borehole disposal or in shielded container assemblies. EM officials told us that, as of May 2024, Argonne National Laboratory and Sandia National Laboratories are the only

[63]How TRU waste is disposed of at WIPP depends on the amount of radiation dose measured at the surface of the waste container. There are two types of TRU waste at WIPP, "contact-handled" and "remote- handled." Contact-handled waste has a lower radioactivity and comprises the vast majority of the TRU waste already disposed of at WIPP. The Waste Isolation Pilot Plant Land Withdrawal Act defines remote-handled TRU waste as "transuranic waste with a surface dose rate of 200 millirem per hour or greater." Pub. L. No. 102–579, § 2(12), 106 Stat. 4777 (1992). Remote-handled TRU waste emits relatively high levels of gamma radiation, which is the primary radiological health hazard for workers handling such waste. These waste containers should not be handled directly by workers. According to EM headquarters officials, they previously conducted an analysis on the extent WIPP can accommodate remaining remote-handled TRU waste. However, officials were unable to provide this analysis for our review.

[64]GAO-21-48.

DOE sites that have disposed of remote-handled TRU waste using shielded container assemblies.

EM Has Not Assessed Complex-wide Approaches for Optimal Disposal Decisions or Developed an Integrated Waste Disposal Plan

EM headquarters has not assessed opportunities to optimize complex-wide disposal decisions or developed an integrated waste disposal plan. Doing so could allow EM to identify opportunities for more efficient disposal alternatives. Effectively implementing such opportunities would likely require EM to engage with regulators across its sites in a holistic fashion to obtain any needed regulatory actions and approvals for opportunities identified in the planning process.

Assessing Optimal Complex-wide Disposal Approaches

EM's 2020 Program Management Protocol states that EM headquarters should coordinate with sites to periodically identify and conduct analysis of strategic alternatives to its plans. These analyses may include assessing potential alternatives as a result of regulatory changes and identifying opportunities to lower overall life-cycle costs. Additionally, the DOE Office of Inspector General reported in 2024 that the department needed to take steps to assess risks using a complex-wide data informed approach.[65] EM officials we interviewed said the optimal outcome for EM radioactive waste cleanup would be to have disposal pathways for all its waste, and each waste stream would be sent to the most cost-effective disposal facility that ensures the protection of human health and environment. However, EM headquarters officials told us that they have not developed complex-wide analyses for assessing alternative approaches for optimizing its radioactive waste disposal. Further, they stated that analysis of disposal options is generally conducted at the site level.[66]

According to EM officials, they have not assessed different complex-wide scenarios for achieving its waste disposal mission, in part, because EM faces constraints from legal and regulatory agreements and other commitments with parties at its cleanup and waste disposal sites. These officials added that it would be challenging to implement more optimal approaches to their current waste disposal pathways because of existing legal and regulatory constraints. However, EM has successfully worked with regulators to revise existing agreements to implement alternative approaches that are assessed to be more optimal. For example, in 2025,

[65]DOE Office of Inspector General, *Special Project Report: The Department of Energy Should Invest in and Implement Enterprise-Wide Data Analytics to Identify and Mitigate Risk*, DOE-OIG-25-06 (Washington, D.C.: Dec. 4, 2024).

[66]EM officials noted that they have performed a broader analysis for Greater-Than-Class-C waste, which considered multiple locations.

EM reached an agreement with the State of Washington and EPA that put forward sweeping changes to DOE's approach for cleaning up the Hanford Site. This agreement includes a new cleanup milestone under which EM would complete retrieval of waste from 22 tanks and grout the low-activity portion of the waste for off-site disposal.

To demonstrate the value of assessing complex-wide strategic alternatives, we developed a hypothetical optimization model as an example of how TRU waste disposal decisions could potentially be optimized to reduce the costs.[67] Findings from the hypothetical model suggest that by considering only the costs of TRU waste storage, transportation, disposal, and not taking existing regulatory constraints into account, EM could reduce the costs associated with TRU waste disposal.[68] Notably, the analysis identified that annual storage costs at certain sites were greater than others and overall costs could be reduced by reprioritizing the order EM plans to ship its waste to WIPP.[69] See appendix III for additional details about the hypothetical model.

In addition to the potential opportunities identified by the hypothetical model, we have previously found that EM could save tens of billions of dollars by considering alternative plans for classifying, treating, and disposing of tank waste at the Hanford Site in Washington State. For example, in 2017 and 2021 we found that treating and disposing of a portion of Hanford's low-activity tank waste using grout instead of

[67]An optimization model is a mathematical method used to find the best possible outcome-such as the lowest cost or highest profit-while following specific rules and limitations.

[68]For example, one requirement driving the current sequencing for TRU waste disposal is the Idaho Settlement Agreement, which requires EM to allocate 55 percent of all annual shipments to WIPP to TRU waste from Idaho National Laboratory.

[69]We developed this model by identifying categories of funding in EM budget estimates related to TRU waste management and disposal across the EM complex. We requested data from EM on the specific costs or funding amounts for TRU waste management and disposal, and they were unable to provide us with a complete set of data. For the locations and volumes of DOE's TRU waste, we used data from DOE's *2023 Annual TRU Waste Inventory Report*.

vitrification could result in billions of dollars in savings.[70] In September 2024, we found that according to experts, the costs for treating the high-activity portion of Hanford tank waste could be reduced by billions of dollars by classifying portions of the HLW as either LLW or TRU based on their characteristics and level of risk.[71] We recognize that EM faces legal and regulatory uncertainties in pursuing such alternatives. Given its existing agreements, permits, and commitments, EM would face challenges in achieving the results identified by our model or implementing alternatives identified in our prior reports. However, such agreements, permits, and commitments are subject to renegotiation and changes.

By developing complex-wide analyses, including optimization models, that identify optimal disposal pathways and schedules for its radioactive waste, EM would be able to compare strategic alternatives to its current disposal plans. Evaluation of complex-wide strategic alternatives for waste disposal could also help EM better understand where engaging with regulators to renegotiate and potentially revise existing agreements, permits, and commitments may allow EM to achieve its disposal mission more efficiently and effectively.

Developing and Implementing an Integrated Complex-wide Waste Disposal Plan

While sites are primarily responsible for overseeing disposal of their radioactive waste, EM headquarters has responsibilities for overseeing waste disposal across the complex of sites. Specifically, the DOE Manual 435.1-1 states that EM headquarters should develop a complex-wide radioactive waste management program plan that addresses the storage,

[70]GAO-17-306 and GAO-22-104365. In our 2017 report, we recommended that EM should develop updated information on alternative treatment and disposal methods for Hanford's low-activity waste and have an independent entity assess the costs for these alternatives. EM implemented these recommendations. In our 2021 report, we recommended that EM should expand future analyses of disposal options for grouted low-activity tank waste at Hanford to include all facilities that could receive it. EM implemented this recommendation. In both reports, we made matters to Congress suggesting that it clarify DOE's authority to manage tank waste as a waste type other than high-level radioactive waste. As of February 2025, Congress has not passed legislation that would implement these matters.

[71]GAO, *Hanford Cleanup: Alternatives for Treating and Disposing of High-Level Waste Could Save Billions of Dollars and Reduce Certain Risks*, GAO-24-106989 (Washington, D.C.: Sept. 26, 2024). In this report, we made three recommendations including that EM should target research and development for Hanford's high-level radioactive waste toward reducing risk, schedule, and cost, and that EM pause engineering, design, and construction activities on its facility for treating high-level radioactive waste until EM defines a mission need for the project independent of the facility as well as other steps. EM has not yet implemented these recommendations.

treatment, and disposal of LLW, TRU waste, and HLW. The Manual states this plan should include a waste management strategy that integrates waste projections and life-cycle waste management planning into complex-wide facility configuration decisions. EM headquarters officials told us that they fulfill these complex-wide planning responsibilities with several documents, including the EM Strategic Vision, EM Program Plan, and standard operating policies and procedures. These documents, however, focus on each site individually and do not integrate site-level information into a complex-wide plan. EM officials we interviewed said that they have not developed a complex-wide disposal plan because they rely on sites to conduct such planning and certain legal and regulatory constraints limit their ability to consider more optimal disposal alternatives.

In our work identifying complex-wide disposal issues and in modeling TRU waste disposal options, we found improvements to current approaches would require changes at multiple waste generator and disposal sites and agreement from their respective regulators. In addition, we reported in 2024 on steps EM should take to improve its engagement with stakeholders and governments.[72] Specifically, we identified leading practices for engagement, including (1) systematically and iteratively identifying and including relevant stakeholders and governments, and (2) considering whether the parties included are consistent with the goals of engagement. This report made three recommendations, including that EM develop a national framework that defines EM's strategy for engagement with stakeholders and governments complex-wide that incorporates the elements of leading practices for engagement we identified. EM has not yet implemented our recommendations.

As a part of pursuing an integrated approach to radioactive waste disposal, EM has an opportunity to engage regulators across its sites to address regulatory constraints and pursue a more optimized approach to waste disposal that could accelerate EM's cleanup mission and save taxpayer dollars. To implement an optimized, integrated disposal plan, EM would need to negotiate with multiple state and federal regulators to revise existing agreements and permits that pertain to EM's disposal activities at different sites. Further, these negotiations would likely need to

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

involve both regulators overseeing waste cleanup and regulators overseeing waste disposal sites.

For example, EM is considering disposing of waste from 11 tanks at the Hanford Site as TRU waste instead of vitrifying it for disposal as HLW. However, Washington State asserted that the state's authorized RCRA program required Hanford tank waste to be vitrified unless DOE obtains a variance from RCRA's treatment standards. WIPP's current permit from New Mexico also does not allow for waste that has ever been managed as HLW—which includes Hanford's tank waste—to be disposed of at WIPP absent a permit modification. To dispose of this waste at WIPP, EM would need to (1) address disagreements with Washington State and EPA to allow for alternate treatment of this waste so that it can go to WIPP; and (2) reach agreement with the state of New Mexico, to include a public participation process, on allowing this waste to be disposed of at WIPP.[73] Without addressing regulatory issues at both sites, EM would be unable to achieve this disposal outcome and may face delays to completing its cleanup mission, which in turn increases costs and risks to human health and the environment.

By developing a nationwide, integrated radioactive waste disposal plan informed by assessments of strategic alternatives and modeling, EM will be better able to address complex-wide disposal issues and implement potential alternatives. Such a plan would better position EM to pursue potential disposal approaches that may require negotiation or other changes at all relevant sites. In addition, by sharing this plan with key stakeholders—such as state and federal regulators at cleanup sites and disposal facilities—and incorporating their feedback as appropriate, EM can better ensure the plan addresses the perspectives of parties EM may need agreement from to implement the plan.

Furthermore, by leveraging the results of optimization analysis and integrated planning to identify specific opportunities to optimize radioactive waste disposal by addressing regulatory constraints, EM will have the information it needs to engage with regulators to try to ensure

[73]In May 2024, EPA granted DOE a treatment variance under RCRA that authorized DOE to grout—rather than vitrify—2,000 gallons of low-activity tank waste from Hanford for off-site disposal as a part of the second phase of DOE's demonstration project to treat a specific volume of tank waste with grout and dispose of it off-site. *Department of Energy Hanford Mixed Radioactive Waste Land Disposal Restrictions Variance*, 89 Fed. Reg. 35008 (May 1, 2024). However, questions remain about how RCRA's treatment requirements will apply to other portions of Hanford's tank waste—such as the waste in the 11 tanks noted above—that DOE has historically managed as HLW.

that each waste stream is disposed of at a cost-effective location, and in a cost-effective order, that is protective of human health and environment. By creating a forum for regulators from cleanup sites and disposal facilities to holistically negotiate implementing these opportunities, EM will ensure that all parties involved in achieving a more optimal outcome for waste disposal across the nation are included in the decision-making process.

Conclusions

EM estimates that its remaining cleanup mission will take decades to complete at a cost of over $400 billion. The cleanup and disposal decisions that lead to these substantial costs and lengthy schedules are complicated by the need to consider both the origin and the risk posed by radioactive waste when categorizing it, having no available disposal pathway for some wastes, and constraints on the disposal of certain wases that are rooted in laws, regulations, and permits and agreements that do not account for commitments made at other EM sites. These same factors also make it difficult to develop effective estimates of the amount of waste to be disposed and the time frames for disposal.

Opportunities exist to address these factors. Several immediate measures could improve the quality of the data EM uses to develop waste estimates, particularly for LLW, and enhance its ability to accurately plan for future disposal needs. Additionally, EM could develop complex-wide analyses, including optimization models that identify optimal disposal pathways for its radioactive waste. As we demonstrated with our hypothetical optimization model, such analyses would likely identify opportunities to lower costs and optimize schedules for waste disposal. Such analyses, when combined with a nationwide, integrated radioactive waste disposal plan, could also yield opportunities to work holistically with regulators and stakeholders to address site-specific requirements that constrain optimal radioactive waste disposal across the complex. Taking such actions could help EM address risks to human health and the environment in a timely manner while also saving billions of dollars.

Recommendations for Executive Action

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

The Senior Advisor for EM should improve the quality of its LLW estimates by (1) adding headquarters oversight procedures that ensure reported waste streams are comprehensive in representing remaining cleanup at DOE sites; and (2) assessing the quality of waste estimates in the BLDD using available information, such as the previous years' actual disposal data, and using the results of this assessment to inform additional improvements. (Recommendation 1)

The Senior Advisor for EM should update guidance for the BLDD to clarify site reporting responsibilities. Such clarifications include that LLW estimates should encompass waste beyond the current cleanup contract and how sites should report waste streams facing significant uncertainty about the scope of cleanup (e.g., related to final disposal decisions, barriers to disposal). (Recommendation 2)

The Senior Advisor for EM should develop complex-wide analyses, including optimization models, that identify optimal disposal pathways and schedules for its radioactive waste and analyze strategic alternatives to current disposal plans. (Recommendation 3)

The Senior Advisor for EM should develop a nationwide, integrated radioactive waste disposal plan that includes an assessment of strategic alternatives and modeling, and addresses complex-wide disposal issues, such as waste with no disposal pathway. EM should share this integrated plan with key stakeholders—such as state and federal regulators at cleanup sites and disposal facilities—and incorporate their feedback as appropriate. (Recommendation 4)

The Senior Advisor for EM should leverage the results of radioactive waste disposal optimization analyses and integrated planning to identify specific opportunities to optimize radioactive waste disposal by addressing regulatory constraints and create a forum for regulators from cleanup sites and disposal facilities to holistically negotiate implementing these opportunities. (Recommendation 5)

Agency Comments and Our Evaluation

We provided a draft of this report to DOE and the Nuclear Regulatory Commission for review and comment.

In its comments, reproduced in appendix IV, DOE neither agreed nor disagreed with our recommendations and stated that it would provide management decisions for our recommendations in a later response to this report. Disposal is essential for the completion of EM's cleanup mission, yet EM faces multiple, significant challenges to dispose of its radiological waste. In our report, we call attention to these challenges, including uncertainty surrounding the amount of waste EM needs to dispose of, the limited capacity of commercial and federal waste disposal facilities, and regulators' concerns about EM's transparency of its disposal decisions. Moreover, we present opportunities for EM to address these challenges and save billions of dollars by taking steps to optimize waste disposal, undertake integrated planning across its 15 sites, and engage with stakeholders more holistically. Overall, we offer EM a roadmap of five recommendations to help overcome these challenges and achieve completion of EM's cleanup mission while saving taxpayers billions of dollars. However, DOE officials did not commit to implementing these recommendations. We encourage DOE to take advantage of the opportunities identified in this report to better ensure the success of its cleanup mission.

In its comments, reproduced in appendix V, the Nuclear Regulatory Commission stated that it appreciated the constructive interactions between GAO and their office on this topic.

We also received technical comments from DOE and the Nuclear Regulatory Commission, which we incorporated as appropriate.

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

If you or your staff have any questions about this report, please contact me at AndersonN@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made significant contributions to this report are listed in Appendix VI.

//SIGNED//

Nathan J. Anderson
Director, Natural Resources and Environment

List of Committees

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

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

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

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

Appendix I: Objectives, Scope, and Methodology

Our report (1) examines what available information shows about radioactive waste streams that require disposal before the Office of Environmental Management (EM) can complete its cleanup mission, (2) describes what disposal options are available to meet EM's radioactive waste disposal needs, and (3) examines how EM and its sites plan for radioactive waste disposal.

To address our first objective, we analyzed data from EM and Department of Energy (DOE) databases on radioactive waste types managed by EM.

- **Low-level radioactive waste (LLW).** For LLW, we reviewed data from fiscal years 2020 through 2024 from EM's Baseline Low-Level Waste and Material Disposition Data (BLDD) on individual waste streams of LLW and mixed LLW. This database annually collects and updates information on these waste streams from all DOE sites. We assessed the reliability of these data by conducting checks for errors and inconsistencies, including comparing these data to BLDD guidance. We also interviewed EM headquarters officials responsible for maintaining the data about the data's limitations and their quality control efforts. We identified additional limitations, including waste missing from these data, by reviewing DOE documents and asking EM site officials about the extent that their data submission reflected all remaining cleanup work at their site. We also compared data in the BLDD for fiscal year 2024 to similar data submitted by some sites to the Nevada National Security Site and identified further discrepancies. We discussed our findings about limitations and the data's reliability in our report. To address these limitations, we grouped the waste estimates into large summary categories that represented the magnitude of the estimated volume (no reported waste, up to 1 million cubic meters, and 1 to 5 million cubic meters). We determined the data were sufficiently reliable for the purpose of summarizing the magnitude of LLW and mixed LLW reported by each EM site in fiscal year 2024 in a figure.
- **Transuranic (TRU) waste.** For TRU waste, we reviewed data from EM's 2023 Annual TRU Waste Inventory Report on the amount of TRU waste already disposed of at the Waste Isolation Pilot Plant (WIPP) and estimates of TRU waste at sites that may require disposal in the future.[1] In interviews with EM officials at sites that generate and store TRU waste, we identified uncertainty in these TRU waste estimates and that the database does not use ranges or other steps to

[1]EM published the 2024 Annual TRU Waste Inventory Report in December 2024. We used the volumes from this report in our analysis of WIPP's disposal capacity.

represent this uncertainty. Further, we assessed the reliability of these data by reviewing prior assessments of this database, interviewing site officials responsible for submitting annual data updates, and interviewing officials responsible for maintaining the data. We determined that these data are sufficiently reliable for the purpose of representing EM's best estimates for the amount of TRU waste that has been disposed of in WIPP and needs to be disposed of in the future while noting the limitations in the estimates resulting from uncertainty.

- **High-level radioactive waste (HLW).** For HLW, EM headquarters officials told us this information was managed by sites with this waste. We gathered data and documents on HLW and waste managed as HLW from the four sites with this waste: the Hanford Site, Idaho National Laboratory, the Savannah River Site, and the West Valley Demonstration Project. We then we compared this information with data reported on HLW from EM's 2022 Program Plan. We also interviewed officials from these sites to discuss the characteristics, reliability, and limitations of their databases. Based on these steps, we identified these data are reliable for the purpose of presenting EM's estimates for the HLW it is responsible for.
- **Spent nuclear fuel (SNF).** For SNF, we obtained data from the Spent Fuel Database managed by the National Spent Nuclear Fuel Program at the Idaho National Laboratory. We received written responses and documents from officials responsible for this database regarding the data reliability of these data. We also interviewed officials from the three sites that manage this waste to confirm the accuracy of the data. Based on these steps, we identified that these data are reliable for the purpose of reporting on the quantity of SNF that EM is responsible for.

To understand whether any gaps or uncertainties might exist in the radioactive waste estimates developed at EM's 15 sites, we interviewed or received written responses from each site and reviewed documentation they provided to support their statements. We also reviewed relevant laws, regulations, and DOE documents on defining radioactive waste, requirements for collecting and maintaining data on waste, and the processes for categorizing waste or making changes to how certain wastes are categorized.

To address our second objective, we reviewed the data on radioactive waste referenced above and DOE documents to identify on-site and off-site waste disposal options that were available for meeting EM's disposal requirements. We then reviewed documents on the capabilities and regulatory structure for waste disposal at DOE sites and off-site commercial facilities.

- **LLW.** To understand whether the capacity of off-site LLW disposal facilities we identified was sufficient to meet EM's needs, we compared the data we gathered on DOE's LLW and mixed LLW from the BLDD that was expected to be disposed of off-site to the current and planned capacities of these facilities.[2] We also included in our analysis four waste streams we identified as missing from the BLDD in our first objective that could require a significant amount of additional waste to be disposed of off-site. To determine the capacity of the three disposal facilities that accept off-site waste, we requested information on their available capacity and approved capacity as of October 2024, which includes both capacity that is currently available to DOE and capacity that has been approved by regulators, but not yet constructed, and expected to be available to DOE in the future.
- **TRU.** For understanding TRU waste disposal capacity, we used information from the 2024 Annual TRU Waste Inventory Report regarding the capacity of WIPP and compared it to volume of waste already disposed of at WIPP, the estimated volume of waste expected to come to WIPP in the future, and the volume of potential waste that could come to WIPP in the future.
- **HLW and SNF.** To understand the status of efforts to develop a disposal option for HLW and SNF we reviewed available documentation on planning for a new geologic repository. We also interviewed officials from DOE's Office of Nuclear Energy who are responsible for developing a disposal option for these wastes.

To address our third objective, we interviewed EM headquarters and site officials regarding the process they follow to determine the disposal options for their waste and plans for addressing waste expected to be generated in the future. To identify waste streams with disposal barriers we conducted interviews with EM site and headquarters officials, representatives from disposal facilities, state regulators, and by reviewing relevant documentation, including prior GAO reports. To further understand barriers for EM waste disposal, we interviewed officials and reviewed documents from the Energy Facility Contractors Group, the Energy Communities Alliance, and the Nuclear Regulatory Commission.

[2]The disposal facilities that accept waste from off-site that we identified were EnergySolutions in Clive, Utah, the Nevada National Security Site, and Waste Control Specialists in Andrews, Texas.

We chose these groups because they had previously published material that related to EM waste with disposal barriers.

We conducted site visits to WIPP in New Mexico and commercial disposal facilities in Texas and Utah to gain perspective on their capabilities and discuss facility plans with officials. We selected these sites as they represent three of the four sites that accept off-site waste from EM cleanup sites.[3] We also met with state regulators in New Mexico, Utah, Texas, and Nevada to hear their perspectives on the current and future operations of disposal facilities operating in their states. We selected these regulators as they play a regulatory role over disposal sites that accept off-site waste from EM cleanup sites.

We also interviewed EM headquarters officials regarding their planning for radioactive waste disposal. We then reviewed the documents they identified to understand the extent to which these documents address complex-wide disposal provisions outlined in relevant DOE orders. These documents include EM's 2022 Program Plan, and EM's Strategic Vision 2024–2034. We also interviewed EM site officials to identify what disposal plans they had developed and how they interacted with EM headquarters in the development and execution of these plans. As part of our work on the third objective, we obtained data on the locations, amounts, and costs for managing and shipping DOE's TRU waste to develop a hypothetical model. Using this hypothetical model, we analyzed alternatives to current plans for shipping TRU waste from generator sites to WIPP to identify potentially more efficient approaches. See appendix III for more information on the development and limitations of this model.

We conducted this performance audit from October 2023 through May 2025, in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

[3]The fourth site is located at the Nevada National Security Site, and we remotely interviewed officials from this site.

Appendix II: Radioactive Waste Streams with Disposal Barriers

At least nine waste streams across the Department of Energy's (DOE) Office of Environmental Management's (EM) complex face barriers to disposal. In this appendix, we include information on the source, location, amount of the waste, potential disposal locations, and a description of the disposal barriers. We identified these waste streams, potential disposal locations, and barriers based on our review of relevant documentation, including EM documents and prior GAO reports and interviews with EM site and headquarters officials, representatives from disposal facilities, and state regulators. The barriers are mostly tied to legal and regulatory constraints that span multiple sites and states.

Depleted Uranium Oxide

Waste Stream Overview

- **Why We Included It:** EM has demonstrated the capability to convert depleted uranium hexafluoride into depleted uranium oxide and dispose of it as low-level radioactive waste (LLW). However, a large quantity of depleted uranium hexafluoride is still awaiting conversion and disposal. According to EM planning documents, it will likely take decades to complete disposal.

- **Source of Waste:** Depleted uranium hexafluoride is a highly corrosive byproduct of the uranium enrichment process. It is stored in large cylinders and can be converted into depleted uranium oxide, which is a more stable chemical form that can be disposed of or reused.

- **Locations:** Portsmouth and Paducah Gaseous Diffusion Plants in Ohio and Kentucky, respectively. EnergySolutions in Clive, Utah, is also storing depleted uranium originally from the Savannah River Site.

- **Amount of Waste:** Approximately 60,000 cylinders at Portsmouth and Paducah. 5,408 drums at EnergySolutions in Clive, Utah, from Savannah River Site.

- **Potential Disposal Locations:** Waste Control Specialists (WCS) in Andrews, Texas; EnergySolutions in Clive, Utah; and Nevada National Security Site (NNSS).

- **Related GAO Reports:** GAO-22-105471.

Summary of Disposal Barriers

Although EM has determined that all three LLW disposal facilities that accept off-site waste may be technically suitable for disposal of depleted uranium oxide, only WCS is currently able to accept it. To date, EM has shipped 366 cylinders to WCS for disposal across three shipments in 2023 and 2024. EM officials attribute the lack of disposal progress to limited funding. Officials told us disposal at another facility would promote price competition and likely reduce costs.

State regulators of two potential off-site disposal facilities have expressed concerns about this waste. EnergySolutions and Utah regulators continue to work on licensing a new federal facility specifically for disposal of depleted uranium. According to Utah regulators, EnergySolutions first started seeking a license for this facility over a decade ago. Utah regulators told us one of the significant challenges was related to the models used to demonstrate environmental impact over the million-year timeline in which the radionuclides will decay. Utah regulators also cited regulatory uncertainty as a barrier, given the Nuclear Regulatory Commission is considering updates to its LLW disposal regulations in a manner that is expected to address disposal requirements for large quantities of depleted uranium oxide.

In March 2019, the State of Nevada submitted comments to EM stating that they do not support transporting the depleted uranium for off-site disposal at NNSS because there was far less environmental impact from the no action alternative. EM officials said NNSS is an option for disposal; however, they have not started the waste approval process with NNSS.

EM has an agreement to sell 24,300 cylinders of depleted uranium hexafluoride to a private company. This agreement is contingent on the company constructing and operating a laser enrichment facility at the Paducah site. We reported in 2022 that DOE's legal authority to sell its depleted uranium is unclear and recommended that Congress consider clarifying DOE's authority to sell depleted uranium. We found that if EM could sell its depleted uranium hexafluoride, it would have to convert and dispose of less of it, saving over $2 billion in costs.

EM also has efforts to transfer some of its depleted uranium hexafluoride to the National Nuclear Security Administration (NNSA). First, EM has an agreement to reserve and transfer ownership of a portion the depleted uranium hexafluoride inventory at Portsmouth to NNSA's Tritium and Domestic Uranium Enrichment Program. In the agreement, EM identified approximately 4,200 cylinders that meet the needs of the program. NNSA officials told us these transfers have been paused to allow use of facilities for other work, and they anticipate transfers to resume in fiscal year 2025. Second, EM has an agreement with NNSA to convert approximately 1,200 cylinders into depleted uranium tetrafluoride for NNSA's Depleted Uranium Modernization Program. Officials said this program is currently conducting an analysis of alternatives to optimize the material flow and supply chain.

Figure 8: Depleted Uranium Hexafluoride Canisters at Portsmouth

Source: Department of Energy (DOE). | GAO-25-107109

Greater-Than-Class C (GTCC) and GTCC-Like Waste

Waste Stream Overview

- **Why We Included It:** EM is responsible for the disposal of GTCC and GTCC-like waste. GTCC is LLW generated by commercial and other activities licensed by Agreement States that has radionuclide concentrations exceeding the Nuclear Regulatory Commission's Class C LLW limits; GTCC-like waste is DOE owned or generated waste with similar characteristics to GTCC. Both GTCC and GTCC-like waste may contain transuranic radionuclides, and both are generally non-defense related. Currently, no commercial facility can dispose of this waste, and it cannot be disposed of at the Waste Isolation Pilot Plant (WIPP) since it is not from atomic energy defense activities.

- **Source of Waste:** Contaminated metals from nuclear facilities; material sealed in industrial and medical equipment; or other forms like contaminated debris and gear.

- **Locations:** About 150 commercial nuclear reactor sites, hundreds of medical and industrial facilities across the country, and EM's West Valley Demonstration Project Site in New York.

- **Amount of Waste:** 12,000 cubic meters (m^3) has been or will be generated by 2083, according to DOE estimates from 2010.

- **Potential Disposal Locations:** LLW commercial disposal facilities and/or WIPP near Carlsbad, New Mexico.

- **Related GAO Reports:** GAO-22-105636.

Summary of Disposal Barriers

EM legally cannot decide on a disposal location for GTCC and GTCC-like waste until it receives direction from Congress.

In addition, there are currently no legally viable disposal options for GTCC and GTCC-like waste. In 2016, DOE selected disposal at WIPP or a commercial facility as its preferred alternative for disposal of this waste. However, both options face barriers such as:

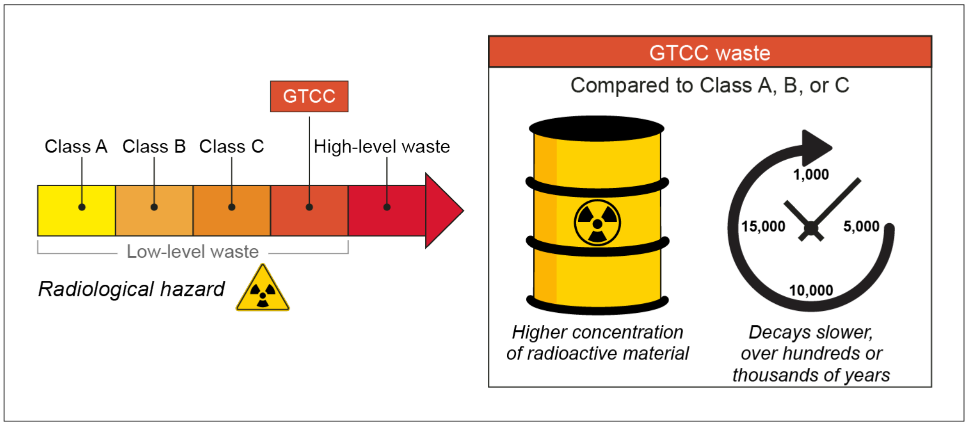
- Disposal at WIPP would require legal and regulatory changes at the federal and state level to address several issues, including that this waste does not generally meet the defense-generated requirement for WIPP disposal and that WIPP's permit does not allow disposal of this waste.

- Disposal at commercial LLW disposal facilities in Texas and Utah would also require regulatory changes at the federal and state level to address several issues, including that the Nuclear Regulatory Commission's regulations generally prohibit near surface disposal of GTCC, the Texas administrative code prohibits disposal of GTCC, and the commercial disposal facility in Utah only accepts Class A waste.

Current Nuclear Regulatory Commission regulations allow disposal of GTCC on a case-by-case basis at licensed LLW commercial disposal facilities but provide no specific regulatory requirements for such disposal. In 2015, the Nuclear Regulatory Commission started the rulemaking process to update its relevant regulations (10 C.F.R. Part 61) to allow for the disposal of certain GTCC at near-surface LLW commercial disposal facilities and to provide specific requirements for this disposal. In 2024, Nuclear Regulatory Commission staff sent the proposed rule to the Commission for review. According to these staff, if the Commission approves the proposed rule, the current timeline for the final rule to be published is in May 2026.

In September 2022, we suggested two matters for congressional consideration, including that Congress clarify regulatory roles and provide direction to DOE so it can proceed with a disposal decision on GTCC and GTCC-like waste.

Figure 9: Comparative Radiological Hazard of Greater-Than-Class-C waste



Source: GAO analysis of Nuclear Regulatory Commission documents. | GAO-25-107109

Note: Nuclear Regulatory Commission regulations classify low-level radioactive waste as Class A, B, C, or Greater-Than-Class C based on radioactivity. DOE does not use the Nuclear Regulatory Commission's classification system for low-level radioactive waste disposed of at DOE facilities.

Hanford High-Level Tank Waste and Cesium Columns

Waste Stream Overview

- **Why We Included It:** EM intends to dispose of any waste classified as high-level radioactive waste in a geological repository for this waste type. Currently no such repository exists. DOE officials said such a repository could be available by 2065. Other disposal pathways may be available if some portion of this tank waste can be classified as other waste types, such as LLW.
- **Source of Waste:** We refer to two sources of waste at Hanford: (1) about 3 million gallons of solid waste in underground tanks that resulted from reprocessing spent nuclear fuel, and (2) ion exchange columns holding cesium removed from some of the tank waste prior to final treatment.
- **Location:** The Hanford Site, Washington State.
- **Amount of Waste:** About 3 million gallons of Hanford's approximately 54 million gallons of tank waste that, after retrieval and separation, EM expects to treat and dispose of as high-level radioactive waste; and 451 ion exchange columns EM expects to generate.
- **Potential Disposal Locations:** No permanent disposal location exists for high-level radioactive waste. However, potential disposal pathways may be available if a portion of this tank waste is classified as LLW or transuranic (TRU) waste.
- **Related GAO Reports:** GAO-24-106989

Summary of Disposal Barriers

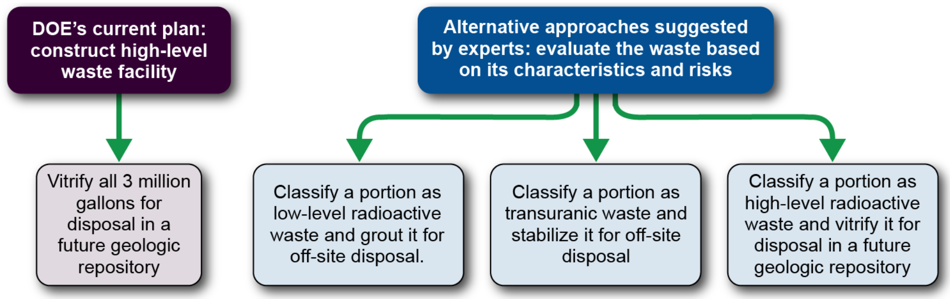
As a matter of policy, EM manages Hanford's 54 million gallons of tank waste as if it is "high-level radioactive waste," as defined by federal law, unless it has been formally classified as another waste type. High-level radioactive waste is subject to specific treatment and disposal requirements. However, much of Hanford's tank waste—about 51 million gallons—is "low-activity" waste that EM expects to ultimately pre-treat, classify, and manage as LLW. The remainder of the tank waste—about 3 million gallons that EM calls "high-level waste" or HLW—EM expects to continue to manage as high-level radioactive waste and dispose of in a future geologic repository. EM also currently manages Hanford's ion exchange columns as high-level radioactive waste.

We reported in 2024 that alternative treatment and disposal paths may be available for the portion of Hanford's tank waste EM considers HLW. According to experts at meetings convened by GAO and the National Academies, portions of Hanford's HLW stream could potentially be classified as LLW or TRU waste based on the waste's physical characteristics. According to experts, if portions of the waste were classified as LLW or TRU waste, EM could use cheaper treatment approaches and dispose of the waste in existing facilities. For example, experts noted that waste classified as LLW could potentially be sent to off-site LLW disposal sites, and waste classified as TRU waste could potentially be disposed of at WIPP. Experts noted that some portion of the HLW may still need to be managed as high-level radioactive waste; however, they also said that managing a portion of the HLW stream as LLW or TRU waste could save billions of dollars.

Regarding the ion exchange columns, EM has not yet conducted an analysis of alternatives to inform a final treatment or disposition path. However, a 2023 Hanford system plan notes that the most viable option is to vitrify the spent resin and dispose of it in a future geological repository. As an alternative, experts noted that the columns, which are currently stored on-site at Hanford, could continue to be stored and monitored until the radioactivity decays to a point where they could be disposed of as LLW according to its characteristics.

Classifying and disposing of Hanford's HLW as LLW or TRU waste faces barriers. For example, EM faces legal uncertainty and is vulnerable to legal challenges regarding its authority to classify portions of Hanford's HLW as a waste type other than high-level radioactive waste. Further, waste would need to meet the waste acceptance criteria of off-site disposal facilities, and the states hosting these facilities would need to agree to accept the waste. In September 2024, we recommended DOE evaluate alternatives for addressing the 3 million gallons of HLW and the ion exchange columns, including treating it and disposing of it according to its characteristics.

Figure 10: The Office of Environmental Management's Current Plan for Addressing Hanford High-level Waste and Potential Alternatives



Source: GAO analysis of Department of Energy (DOE) plans and experts' recommendations. | GAO-25-107109

Hanford Low-Activity Tank Waste (LAW)

Waste Stream Overview

- **Why We Included It:** EM plans to retrieve and separate Hanford's tank waste into two waste streams: LAW and high-activity waste. Hanford plans to vitrify and dispose of some of the LAW on-site. Another portion of the LAW is subject to a 2025 agreement that calls for grouting and disposing of this portion off-site. The remaining LAW could potentially be treated and disposed of off-site as LLW; however, no agreement about treatment and disposal of this waste has been reached between EM and its regulators, or with off-site disposal sites.
- **Source of Waste:** Much of the LAW was generated from reprocessing spent nuclear fuel.
- **Location:** The Hanford Site, Washington State.
- **Amount of Waste:** EM estimates that about 95 percent of Hanford's approximately 54 million gallons of tank waste, after retrieval and separation, will be LAW. According to Hanford officials, up to 60 percent of the LAW stream may be able to be grouted and disposed of at off-site disposal facilities.
- **Potential Disposal Locations:** WCS in Andrews, Texas; EnergySolutions in Clive, Utah; NNSS; or Hanford on-site disposal facility.
- **Related GAO Reports:** GAO-23-106880; GAO-22-104365; and GAO-17-306.

Summary of Disposal Barriers

Under a legal agreement with Washington State, EM is required to begin treating Hanford's LAW with a process called vitrification—which immobilizes the waste in glass in stainless steel containers—in the LAW Facility by August 1, 2025. The canisters will then be disposed of at a facility on the Hanford Site. However, the LAW Facility is designed to treat only about 60 percent of Hanford's LAW.

In May 2017 and December 2021, GAO found that grouting, rather than vitrifying, portions of Hanford's LAW could save tens of billions of dollars and reduce certain risks compared to vitrification.

To address the remaining volume of LAW, EM has initiated a project to demonstrate that LAW can be grouted and disposed of at commercial low-level waste facilities. To date, this project has disposed of approximately 3 gallons of grouted Hanford tank waste at WCS. EM plans to dispose of an additional approximately 2,000 gallons of the waste in 2025—1,000 gallons at WCS and 1,000 gallons at EnergySolutions.

An April 2024 agreement among DOE, the U.S. Environmental Protection Agency, and the Washington State Department of Ecology proposed sweeping changes to DOE's approach for cleaning up the Hanford Site. This agreement was finalized in January 2025. Under the agreement, EM plans to grout LAW from 22 tanks and dispose of it off-site. However, regulators we interviewed in Texas and Utah told us that they had not discussed disposal of waste from the 22 tanks in their states.

EM has not determined an approach for treatment and disposal for the remaining LAW that will not be vitrified or that is not part of existing agreements for grouting the waste. In December 2021, we found that DOE may face legal challenges if it grouts LAW. For example, before DOE can consider alternatives to vitrification, it must show it can manage Hanford's tank waste as a waste type other than high-level radioactive waste. We suggested that Congress consider clarifying DOE's authority to determine whether portions of Hanford's tank waste can be managed as a waste type other than high-level radioactive waste and can be disposed of outside the state of Washington. If EM intends to send the waste to one or more off-site disposal facilities, it could require additional agreements or approvals from state regulators where those facilities are located.

Figure 11: 2021 Analysis of Estimated Total Costs for Treatment and Disposal of Vitrified and Grouted Low-Activity Waste

	Department of Energy's (DOE) current baseline approach	Alternative approach
		
Waste form	Glass	Grout
Disposal site	Hanford Integrated Disposal Facility, Washington	Several options, including two federal facilities in Washington or Nevada and two commercial facilities in Texas and Utah
Total cost	$21–$37 billion	$11–$13 billion

Sources: GAO analysis of DOE and disposal site documents, photos: DOE, mdbildes/stock.adobe.com. | GAO-25-107109

Hanford Transuranic (TRU) Tank Waste

Waste Stream Overview

- **Why We Included It:** EM has identified waste in 11 tanks at Hanford as potential TRU waste, although the waste is currently managed as high-level radioactive waste. However, there are barriers to disposing of this waste as TRU waste at WIPP. EM is also not currently pursuing agreement on disposal of this waste with New Mexico regulators. EM withdrew a Class 3 permit modification request on this issue as part of the settlement agreement on the recent WIPP renewal permit.

- **Source of Waste:** The 11 tanks have been identified by EM as containing waste that did not result from reprocessing of spent nuclear fuel at Hanford.

- **Location:** The Hanford Site, Washington State.

- **Amount of Waste:** According to Hanford's Best Basis Inventory—a database of tank volumes and constituents—in May 2024, the 11 tanks contained approximately 1.3 million gallons of waste that could be classified as TRU waste.

- **Potential Disposal Locations:** WIPP near Carlsbad, NM, or a future high-level radioactive waste repository.

- **Related GAO Reports:** GAO-24-106989 and GAO-21-48.

Summary of Disposal Barriers

Although the waste from the 11 tanks have been identified as potential TRU waste, Hanford Site officials currently manage the waste as if it is high-level radioactive waste. As such, EM would need to undergo an administrative process to evaluate meeting certain criteria to potentially classify and manage this waste as TRU waste. Hanford Site officials told us they have not initiated any such evaluation process for this waste nor made any decision about where it will be disposed.

WIPP's permit with the state of New Mexico generally prohibits disposal of waste that has ever been managed as high-level radioactive waste, which includes waste from tanks at Hanford. To address this disposal barrier, EM would need a WIPP permit modification, which must be agreed to by New Mexico regulators. New Mexico regulators told us they have not discussed disposal of Hanford tank waste at WIPP with EM in over 10 years and that more information about EM's plans for such waste would be helpful. These officials also said New Mexico's priority is for cleanup of legacy TRU waste at Los Alamos National Laboratory.

Figure 12: Underground Area at the Waste Isolation Pilot Plant

Source: GAO File Photo. | GAO-25-107109

Idaho National Laboratory Calcine Waste

Waste Stream Overview

- **Why We Included It:** Calcine waste from the Idaho National Laboratory Site is managed as high-level radioactive waste; however, EM site officials stated that this waste will likely require further treatment to be disposed of in a future high-level radioactive waste repository. Under a settlement agreement with Idaho, treatment of this waste is to be completed by a target date of December 31, 2035.
- **Source of Waste:** This waste resulted from reprocessing of spent nuclear fuel. The liquid reprocessing waste was converted into a solid, granular form and stored in stainless steel bins.
- **Location:** Idaho National Laboratory Site, Idaho.
- **Amount of Waste:** Idaho National Laboratory stores approximately 4,400 m^3 of dried granular calcine waste, stored in 6 stainless steel bin sets.
- **Potential Disposal Locations:** No high-level radioactive waste repository exists to dispose of this waste.
- **Related GAO Reports:** GAO-19-494.

Summary of Disposal Barriers

EM does not currently have a strategy for determining how it will treat or dispose of the calcine waste. In April 2024, EM Idaho site officials told us that the agency is making progress toward its milestones for calcine waste treatment. For example, officials said they are considering alternatives for processing the waste for disposal and conducting a pilot project to remove it from the oldest storage silo. EM had previously planned to treat calcine waste in the Integrated Waste Treatment Unit, a treatment facility that is currently being used to treat the site's sodium-bearing tank waste. EM has faced issues with this approach, including challenges in determining how to retrofit the Integrated Waste Treatment Unit to treat the calcine waste. In 2016, EM suspended work on this treatment path.

In addition to treatment challenges, EM faces challenges to disposing of the waste. Specifically, there is no existing repository in the United States which could accept calcine in either its present or any treated form. These challenges make determining a treatment method and a disposition pathway for calcine uncertain and problematic. In 2019, we recommended that EM develop a treatment approach and disposal strategy for addressing the calcine waste to ensure that EM meets the 2035 target date for treatment of this waste. EM has partially addressed this recommendation by conducting an analysis of alternatives and supplemental environmental analysis for addressing calcine waste.

Figure 13: The Integrated Waste Treatment Unit That Was Considered for Treating the Calcine Waste and Currently Treats Sodium-bearing Waste

Source: Fluor-Idaho, LLC. | GAO-25-107109

Idaho National Laboratory Sodium-bearing Waste

Waste Stream Overview

- **Why We Included It:** EM is treating and packaging this waste to meet requirements for disposal at WIPP in New Mexico as transuranic waste. However, this waste is currently being managed as high-level radioactive waste, and EM has not started the process to categorize it as TRU waste or addressed legal and regulatory barriers to disposing of this waste at WIPP.
- **Source of Waste:** Sodium-bearing waste primarily resulted from activities after the initial reprocessing of spent fuel and contains other wastes, such as decontamination solutions.
- **Location:** Idaho National Laboratory Site, Idaho.
- **Amount of Waste:** As of July 2024, the site estimated that 772,000 gallons of the original 900,000 gallons of sodium-bearing waste remain in 3 tanks.
- **Potential Disposal Locations:** WIPP near Carlsbad, New Mexico, or a future high-level radioactive waste repository.
- **Related GAO Reports:** GAO-19-494.

Summary of Disposal Barriers

In 2005, EM selected disposal at WIPP as its preferred disposal path for treated sodium-bearing waste. The Idaho Cleanup Project at the Idaho National Laboratory Site is currently treating the waste as if it were TRU waste using steam-reforming technology to convert the liquid to a solid, granular material and packaging it in canisters that are stored on site. However, because it contains small amounts of waste that could meet the definition of high-level radioactive waste, EM manages all of the waste as this waste type. If the treated sodium-bearing waste were not accepted for disposal at WIPP, the site may need to re-treat the waste for disposal as high-level radioactive waste, for which the treatment standard is generally vitrification. As we reported in 2019, EM still faces three barriers to disposing of sodium-bearing waste at WIPP:

- **Federal law prohibits disposing of high-level radioactive waste at WIPP.** The WIPP Land Withdrawal Act prohibits disposal of high-level radioactive waste at WIPP. Therefore, to enable EM to dispose of the sodium-bearing waste at WIPP, the waste would need to be classified as TRU waste generated by atomic energy defense activities for WIPP disposal. EM has processes allowing for certain waste resulting from reprocessing to be classified as TRU waste. In 2001, EM started its process to classify the waste as TRU waste but has not yet completed documentation or approvals needed to finalize the determination. EM headquarters officials stated that the focus is on treating the waste and that there are no current efforts to move forward with classifying this waste as TRU waste.
- **WIPP's permit prohibits disposal of certain tank waste.** New Mexico amended its permit for WIPP in 2004 to generally prohibit disposal of waste that has ever been managed as high-level radioactive waste, including the sodium-bearing waste. According to New Mexico officials, they have not been approached recently by EM officials to discuss a permit modification to allow for disposal.
- **WIPP has limited disposal space**. As mentioned earlier in this report, WIPP would nearly reach its disposal capacity limit when accounting for all potential waste currently noted in EM's annual inventory report, which includes sodium-bearing waste. In addition, WIPP has not disposed of remote-handled waste using horizontal boreholes since a 2014 incident, which is how sodium-bearing waste would likely be disposed of as currently packaged. WIPP is in the process of resuming this capability, but officials estimate it may not restart until the early 2030s.

In 2019, we recommended that EM develop a strategy and timeline for achieving its preferred disposal pathway for sodium-bearing waste.

Figure 14: Idaho National Laboratory's Integrated Waste Treatment Unit Which Treats Sodium Bearing Waste

Source: Fluor-Idaho, LLC. | GAO-25-107109

Oak Ridge Mercury-Contaminated LLW

Waste Stream Overview

- **Why We Included It:** Oak Ridge will be decontaminating and decommissioning four large buildings known to be contaminated with mercury. Mercury contamination from the site has reached nearby waterways. Despite ongoing construction of a second on-site disposal facility, the site has not reached agreement with regulators about the extent that mercury-contaminated waste will be able to be disposed of on-site. As a result, a significant amount of this waste may need to be disposed of off-site.

- **Source of Waste:** Mercury contamination stems from processes used in nuclear weapons production and can be found in liquid and vapor forms and in porous solid materials making it challenging to detect, contain, and remove.

- **Locations:** Oak Ridge Reservation, Tennessee.

- **Amount of Waste:** Site officials estimate between 100,000 and 200,000 cubic yards (as of 2015) of debris and soil across the four processing buildings—Alpha-2, Alpha-4, Alpha-5, and Beta-4. According to officials, soil and slabs beneath these buildings may contain mercury, but these levels will not be known until after decontaminating and decommissioning activities.

- **Potential Disposal Locations:** NNSS, off-site LLW disposal facilities, and/or new on-site disposal facility.

- **Related GAO Reports:** GAO-24-107096.

Summary of Disposal Barriers

EM continues to seek agreement with regulators over the waste acceptance criteria for the new on-site disposal facility at Oak Ridge. EM officials from Oak Ridge are working with regulators to determine what waste can be disposed of at the on-site disposal facility under construction, which EM site officials state they are planning to use to dispose of LLW with non-hazardous amounts of mercury. Specifically, Oak Ridge is undergoing a groundwater field demonstration to assess the groundwater elevation impacts of its new disposal facility. According to EM officials, the goal is to have this facility ready to accept waste by 2029.

If the final waste acceptance criteria for the new on-site disposal facility does not allow for disposal of waste that is contaminated by non-hazardous amounts of mercury, it could limit EM's ability to dispose of decontaminating and decommissioning debris on-site. Instead, EM may have to dispose of a significant amount of this waste off-site at a higher cost than currently planned.

According to EM site officials, some mercury contaminated LLW waste that is hazardous and unsuitable for on-site disposal can be disposed of at NNSS or EnergySolutions using encapsulation (fully enclosing the hazardous waste in another material, such as a high-density plastic container).

In 2024, we recommended that Oak Ridge elevate its risk management for mercury cleanup activities to a programmatic level and that it assess the mercury technology development program's progress toward cleanup goals. As of February 2025, EM has not addressed these recommendations.

Figure 15: Mercury-Contaminated Buildings at Oak Ridge

Source: U.S. Department of Energy (DOE) Office of Environmental Management – Oak Ridge. | GAO-25-107109

Oak Ridge Sludge Waste

Waste Stream Overview

- **Why We Included It:** As of November 2023, EM's Oak Ridge Reservation did not have an approved treatment approach for addressing stored sludge waste so that it can be disposed of.
- **Source of Waste:** This waste was generated from defense-related research activities and is in the form of sludge (solids) and supernate (liquids). The waste contains elements heavier than uranium, so it is considered TRU waste until treated. It is expected to be considered LLW after treatment.
- **Location:** Oak Ridge Reservation, Tennessee.
- **Amount of Waste:** 800,000 to 1,000,000 gallons —or approximately 2,000 m^3—of sludge waste.
- **Potential Disposal Locations:** NNSS, EnergySolutions in Clive, Utah or WCS in Andrews, Texas, or WIPP near Carlsbad, New Mexico.
- **Related GAO Reports:** GAO-22-104622 and GAO-24-106716.

Summary of Disposal Barriers

Design work for the effort to treat this waste for disposal—referred to as the Sludge Processing Facility Buildouts project—began in 2014. The project aimed to construct a facility at Oak Ridge that would solidify approximately 2,000 m^3 of transuranic waste. This process was expected to produce a LLW form suitable for disposal at a LLW disposal facility.

As we reported in 2022, the project encountered problems during the design process when EM officials determined that additional technology development was necessary before any further design or construction could proceed. According to EM officials, in 2017, EM halted design work after DOE's Project Management Risk Committee recommended that the project focus on technology maturation and testing efforts.

In November 2023, EM officials stated that the project was canceled as they had completed the technology maturation process, and no funding was available to continue beyond that point. These officials noted that Oak Ridge is in the process of evaluating existing technologies to determine if there is a more efficient and cost-effective way to process the sludge in order to dispose of it as LLW.

EM project officials told us that, once funding is available, the project would be able to quickly restart, as the scope of work needed to be completed would remain the same. However, project officials also told us, despite having already expended resources to evaluate technologies for treating this waste, they would need to conduct another analysis of alternatives and assess potential alternatives to the previous treatment approach. Currently, there is no timeline for restarting the project.

Figure 16: Sludge Processing Facility Buildouts Project at Oak Ridge

Source: Department of Energy. | GAO-25-107109

Appendix III: Transuranic (TRU) Waste Optimization Model Findings

Model Purpose and Overview

This appendix provides an illustrative example of a limited, hypothetical optimization model to support data-driven decision-making related to the storage, transportation, and disposal of transuranic (TRU) waste. Specifically, this limited model considers only contact handled TRU waste located at several sites nationwide that will be transported to and disposed of at the Waste Isolation Pilot Plant (WIPP) in New Mexico—the nation's only repository for TRU waste generated by atomic energy defense activities.

The model has three main components:

- Hoteling (storage) cost estimates to capture site-level storage costs that drop in "steps" once enough waste is removed.
- Transportation cost estimates to approximate a per-mile cost of moving TRU waste from Department of Energy (DOE) sites to WIPP.
- An optimization approach to minimize cost under different shipping scenarios (for example, requiring a certain fraction of shipments from a specific site).

These three components are described in more detail below. However, this is a limited model and is not intended to serve as a federal cost estimate nor to suggest how DOE's Office of Environmental Management (EM) could or should operationalize its program.[1] We made extensive assumptions, such as assuming fixed and known hoteling and transportation costs and excluding WIPP operating costs. We also used proxy data sources, such as budget and hypothetical future data for hoteling costs. See the section on Model Limitations below for more details.

This model is not intended for agencies' direct use; rather, it is an illustrative example of how a model framework and data could allow for comparisons between different scenarios and requirements.

Hoteling (Storage) Costs

We estimated each site's hoteling costs for TRU waste as a stepwise function. Under this approach, costs remain at one level until a threshold amount of waste is shipped off-site. Once that threshold is reached, the costs "step down" to a lower level, reflecting reduced operational and

[1]GAO has established well-documented best practices in its Cost Estimating and Assessment Guide. This limited model serves as an initial exploration, and other approaches could follow these guidelines. See GAO, Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Program Costs, GAO-20-195G (Washington, D.C.: Mar. 12, 2020).

maintenance needs. We assumed that these steps correspond to events like facilities closing or campaigns concluding, and that the overall hoteling cost are unchanging with respect to small changes to remaining TRU waste.

To estimate each site's hoteling costs, we applied a univariate clustering approach to DOE budget data for six sites related to TRU waste and assumed that the budget approximated the hoteling cost.[2] Because DOE was unable to provide us with accurate and comprehensive cost and inventory data for TRU waste at the sites, we used FY 2022 data from DOE's Environmental Management's Financial Integration System (EMFIS).[3] GAO subject matter experts reviewed this data and identified which budget items corresponded to TRU waste storage, transportation, packaging, and shipping. We totaled those budgets by year for each site and adjusted for inflation to normalize costs to 2025 dollars. We then scaled the values to convert them into percentages between 100 percent and 0 percent. We limited our analysis for each site to years between when the maximum value occurred to when the budget value fell to zero for 5 years.[4] Ultimately, we used DOE's actual and future projected budget data from years 2018 through 2080.

Next, we applied the clustering approach to the budget percentage values for each site.[5] Our method automatically selected an appropriate number of clusters between 1–9 based on the Bayesian Information Criterion

[2]We modeled TRU waste disposal from six DOE sites: Hanford, Idaho National Laboratory, Lawrence Livermore, Los Alamos, Oak Ridge, and Savannah River. These sites account for over 99 percent of the stored contact-handled waste in DOE's 2023 Annual Transuranic Waste Inventory Report and represented sites where budget data necessary to estimate hoteling costs was available.

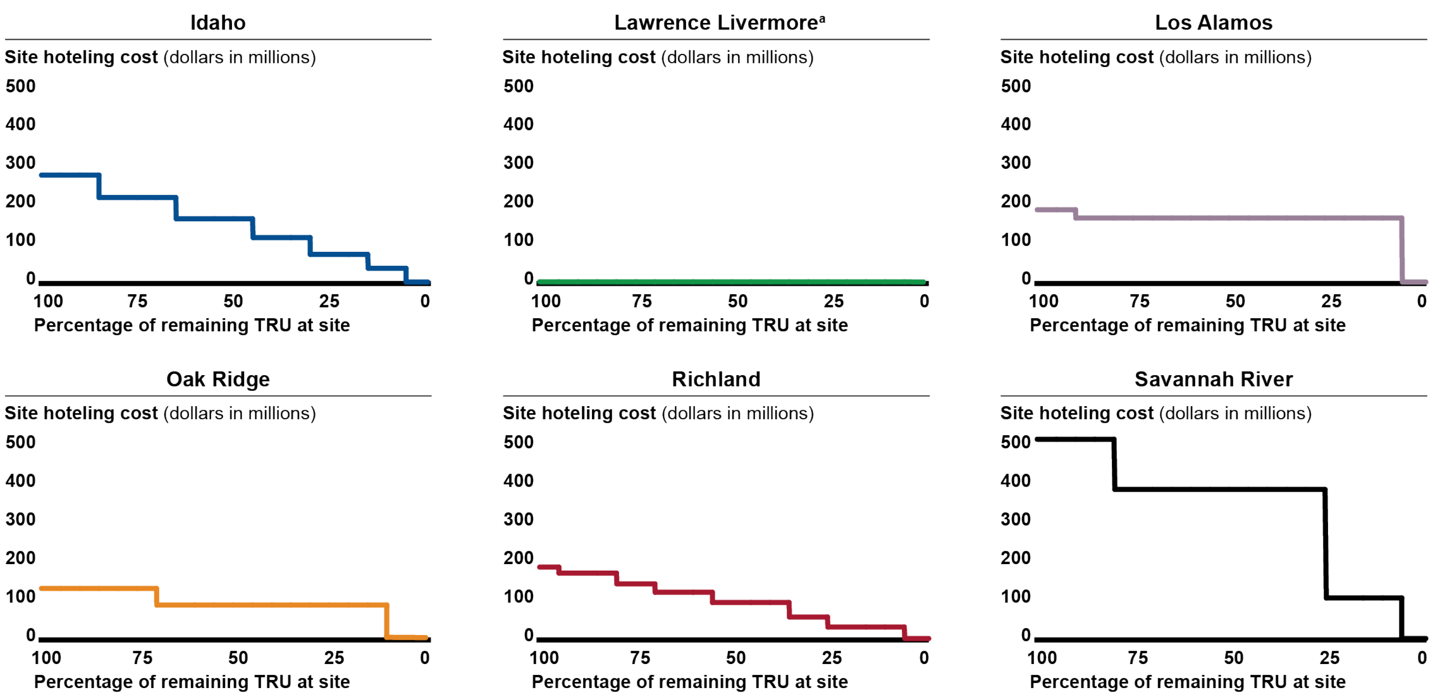
[3]There are limitations to the EMFIS data, such as including some costs related to the management of low-level waste, but it was the best available data and sufficiently reliable for describing each site's estimated base operations and progress costs.

[4]We removed additional zeroes to make the graphs more readable. This had a minimal impact on our model results because leaving in the whole series of zeroes in a site's budget data just strengthened or encouraged a cluster centered at zero. Most of the sites already had a cluster with a center at or near zero and we manually added one to every site for completeness.

[5]Clustering is a method for identifying similar data points from a set of data, making it applicable for identifying steps in a step function as different clusters could signify a change in the overall budget. We only need univariate clustering as we do not take into consideration the year or timeline of the step. Our selected algorithm minimizes the weighted within cluster sum of squared distances (SSQ), a widely used objective function for cluster analysis. For our application, we set the weight of all points to be equal to 1.

value.[6] We converted budget percentages back into dollars by multiplying by the site's maximum budget value. We assumed that the relative decreases in the budget amount reflected a 1-to-1 (1-1) decrease in the TRU waste inventory at a site.[7] For example, if we see a 35 percent reduction in the overall budget, we assumed that 35 percent of the initial TRU waste has been shipped. Thus, the steps are the estimated proportions that a site's budget, and our estimated hoteling cost, can be reduced by with an equivalent reduction in their held TRU waste inventory. The following shows each site's hypothetical stepwise cost profile in millions of dollars as the percentage of TRU waste being stored decreases.

Figure 17: Site-by-Site Stepwise TRU Waste Hoteling Costs



Source: GAO analysis of Department of Energy data. | GAO-25-107109

[a]The site hoteling cost for Lawrence Livermore never exceeded $1M dollars.

[6]The Bayesian Information Criterion is used to balance model fit versus complexity when determining the number of clusters (steps). The Bayesian Information Criterion promotes likelihood based on a Gaussian mixture model and penalizes the number of components in the model.

[7]DOE did not provide reliable projected TRU waste that would remain at each site by year to better model the relationship between budget and remaining inventory.

Transportation Costs

To estimate transportation costs, we developed a transportation-cost-per-mile factor, based on dividing the total transportation cost paid to the WIPP transportation contractor in years 2022 and 2023 by the total shipment miles from active transuranic waste sites to the WIPP site between the calendar year 2022–2023.[8]

Transportation costs were based on the total cost of the delivery orders to track the actual spending of TRU waste shipments. We obtained the TRU waste shipment numbers for the calendar year 2022–2023 by querying WIPP Waste Data System website. An estimate of the typical mileage of a shipment for each site was found from WIPP shared shipment and disposal information which contained a total number of shipments and the total loaded miles from various sites. The ratio of those two values estimated a typical mileage from a site. The total shipment miles is the sum of each site's typical mileage multiplied by the number of shipments from that site in 2022–2023.

Note that in the total cost, we assume that transportation costs are a constant over the course of the optimization since all shipments are transported only once in each scenario, and we assume that the site transportation costs do not change year over year. Hence, we primarily concentrate on how to estimate the cost to transport a shipment of waste from a site to the WIPP.

Table 2: Approximate Transportation Cost Per Mile

Transportation Cost in 2025 dollars	Total Shipment Miles	Transportation Cost Per Mile
$19.37 million	0.923 million miles	$20.99 per mile

Source: GAO analysis of Department of Energy and SAM.gov data. | GAO-25-107109.

[8]We normalized transportation costs to 2025 dollars.

Model Optimization Approach

At a high level, we represent the overall model cost of moving TRU to the WIPP in the formula below.

Figure 18: Overall Model Cost

$$\text{Overall model cost} = \sum_{\text{(All Years)}} \sum_{\text{(Shipments in a year)}} \text{Transportation costs for shipments} + \sum_{\text{(All Years)}} \text{Average hoteling cost across sites over all shipments in a year}$$

Source: GAO analysis of Department of Energy data. | GAO-25-107109

We assumed that the WIPP operating costs are the same across any shipping sequence, and we therefore excluded it from our overall model cost. We also assumed the transportation costs are fixed quantities that are not dependent on the order of TRU waste shipped from sites. We also assumed that environmental risks are inherently addressed in DOE's cost associated with the storage and transportation of the waste.

We developed a heuristic approach to order shipments from sites because we modeled hoteling costs as a step function.[9] We based our approach on the potential hoteling cost savings of each shipment. The potential hoteling cost savings is the eventual amount that each shipment would reduce the hoteling cost at a site.

We assumed that DOE would make 400 TRU waste shipments to WIPP each year. We then compared the following scenarios:

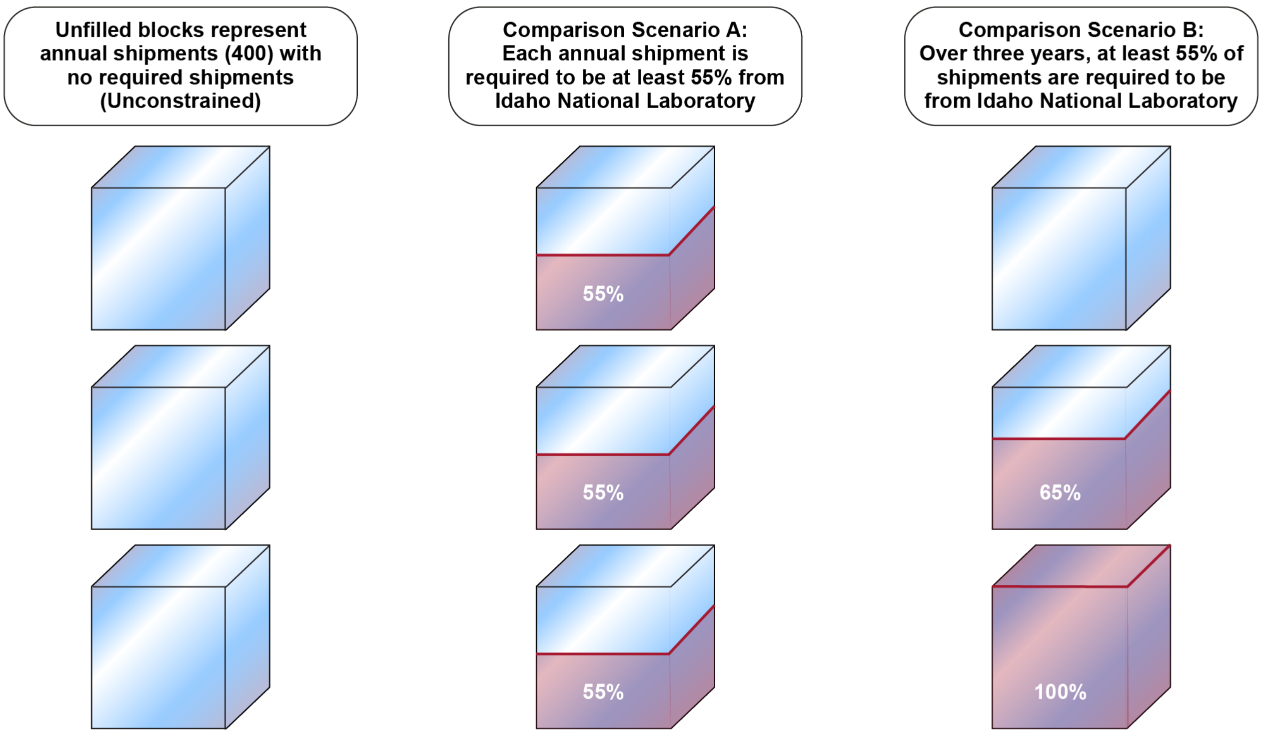
1. (Unconstrained) A scenario with no required shipments.
2. (Comparison A) A scenario where at least 55 percent of every year's shipments must come from Idaho National Laboratory, until no more TRU waste remains at that site.

[9]We did not identify a straightforward way to directly solve how to order shipments to minimize the overall model cost given the discontinuities between steps, the intervals of constant hoteling cost, and the recursive relationship of prior shipments on hoteling cost.

3. (Comparison B) A scenario where at least 55 percent of shipments over every 3-year period must come from Idaho National Laboratory, until no more TRU waste remains at that site. [10]

The figure below shows hypothetical annual shipments under each scenario.

Figure 19: Hypothetical Annual Shipments for each Scenario



Source: GAO analysis of Department of Energy data. | GAO-25-107109

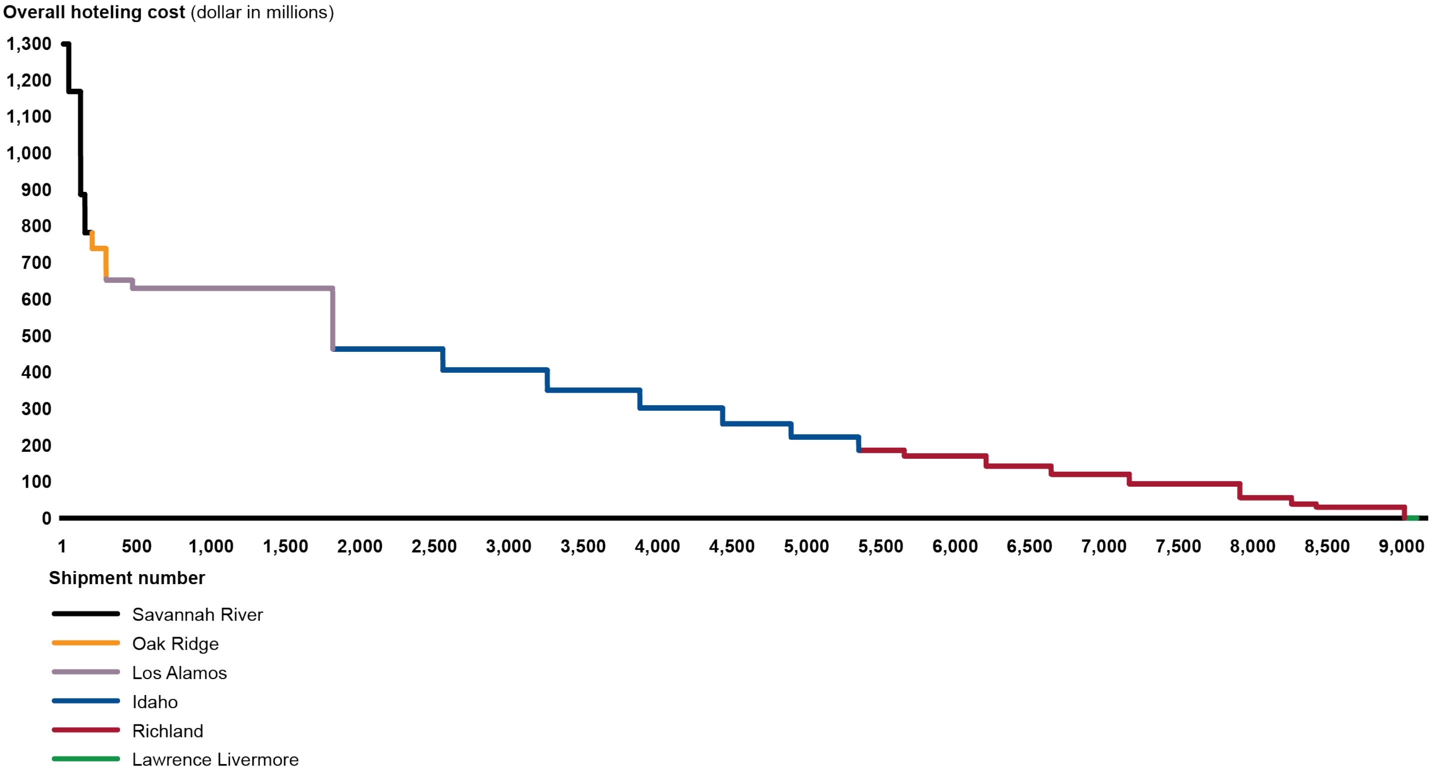
[10] DOE's 1995 Settlement Agreement with the State of Idaho, as amended, regarding cleanup efforts at Idaho National Laboratory requires that "DOE will allocate to and make from the State of Idaho at least 55 percent of all transuranic waste shipments received at WIPP for [Idaho National Laboratory] transuranic waste, including retrieved buried waste, each year until shipments from [Idaho National Laboratory] are complete. This percentage will be calculated on a 3-year running average, beginning with Calendar Year 2019 (total number of shipments over any period of 3 years, divided by three)."

For each site, we calculated the potential hoteling cost savings for each shipment by dividing the site's maximum hoteling cost by the number of shipments at the site.[11] Then, we created an initial shipping order for our three scenarios based on any required shipments and then selecting and ordering shipments with the highest remaining potential hoteling cost savings. We iteratively calculated the hoteling and transportation costs after every shipment. We evaluated whether re-ordering based on actual hoteling cost savings would further minimize the cost, and if so, recalculated the order and costs for the scenario. The hoteling and overall costs were summarized into years based on the assumed fixed annual number of shipments.

Based on our model estimates and assumptions, the following line plots display the hoteling cost after each shipment for each of the three scenarios. The line is colored according to the shipment site, and these plots visualize the order and hoteling cost in millions for each scenario.

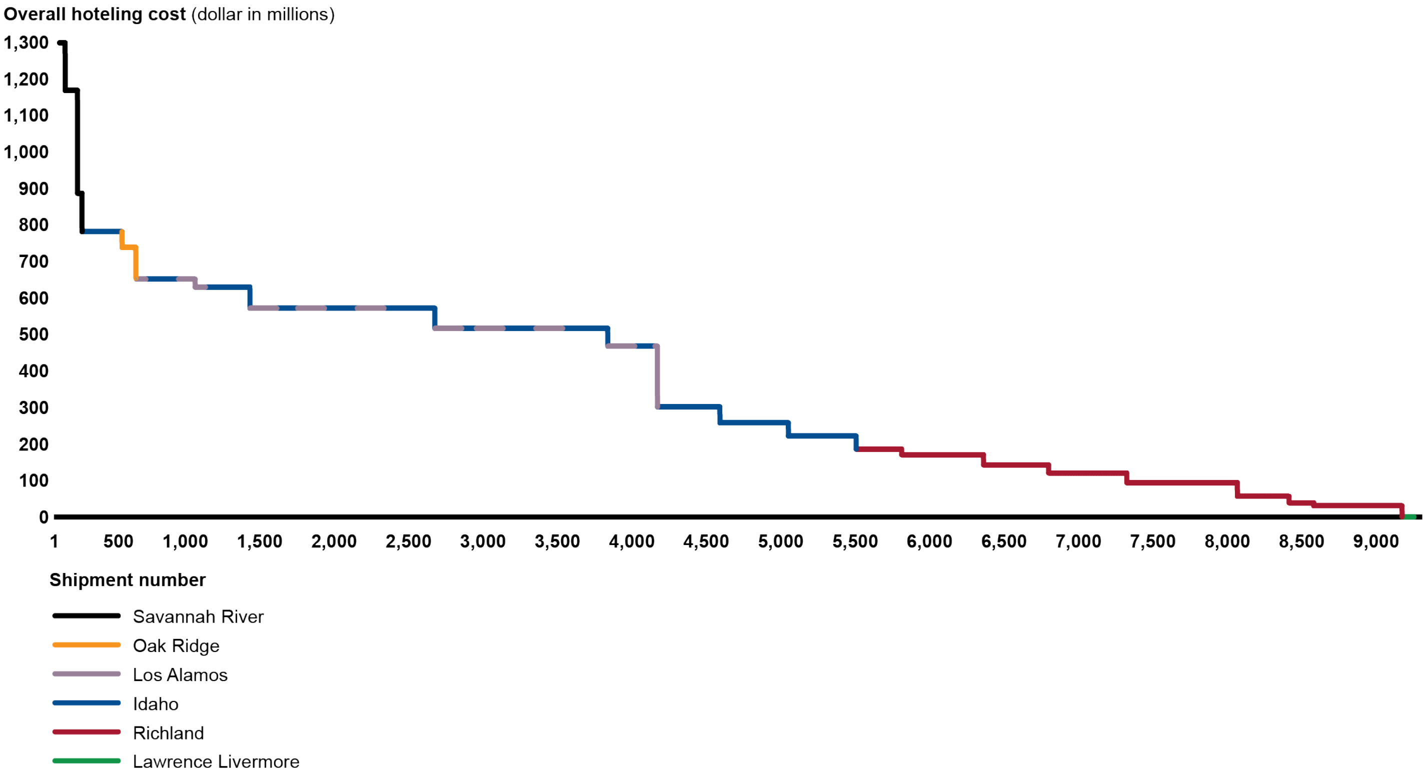
[11]We assumed shipments from each site will all have the same site-specific potential hoteling cost saving because of the one-to-one relationship between budget and remaining inventory.

Figure 20: Overall Hoteling Costs in the Unconstrained Scenario



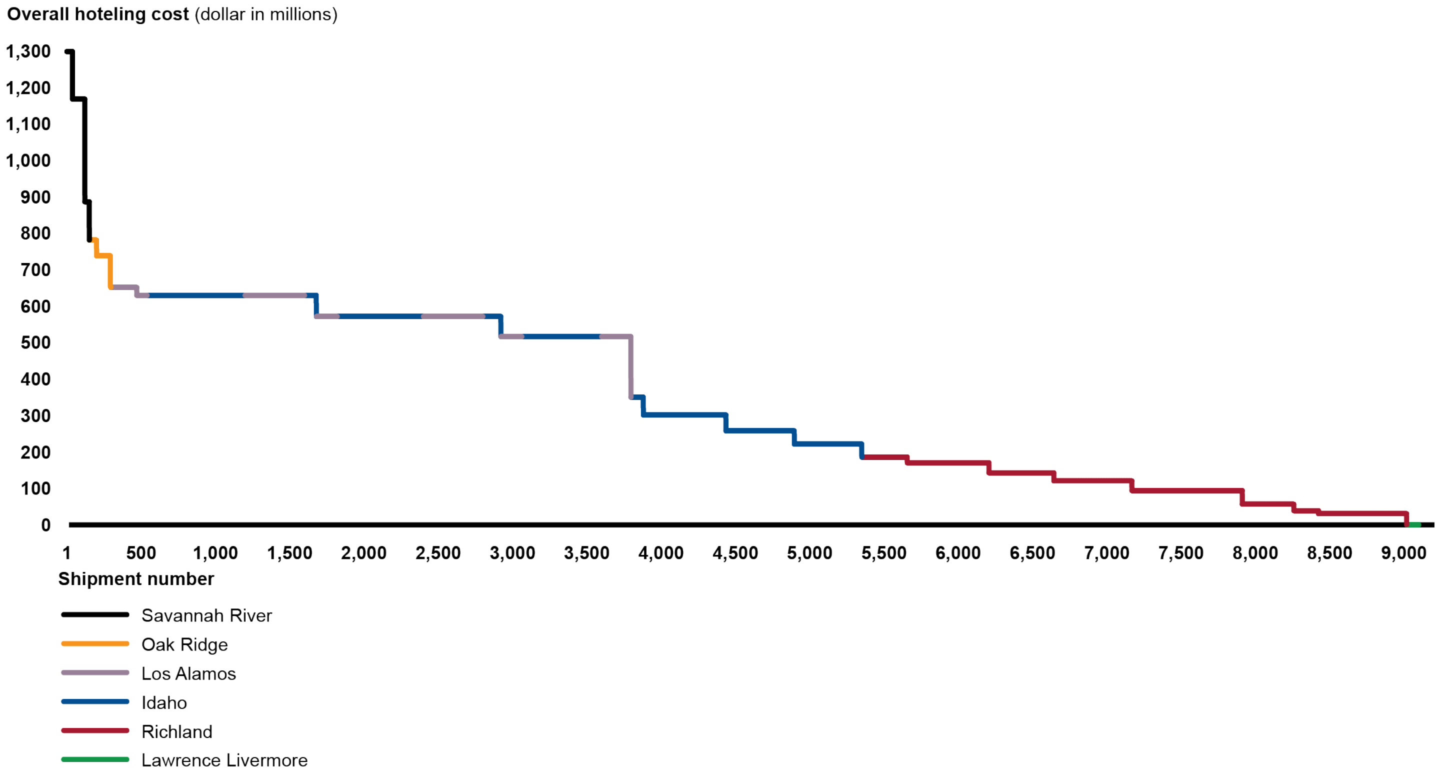
Source: GAO analysis of Department of Energy data. | GAO-25-107109

Figure 21: Overall Hoteling Costs in Comparison Scenario A: At least 55% from Idaho National Laboratory every year



Source: GAO analysis of Department of Energy data. | GAO-25-107109

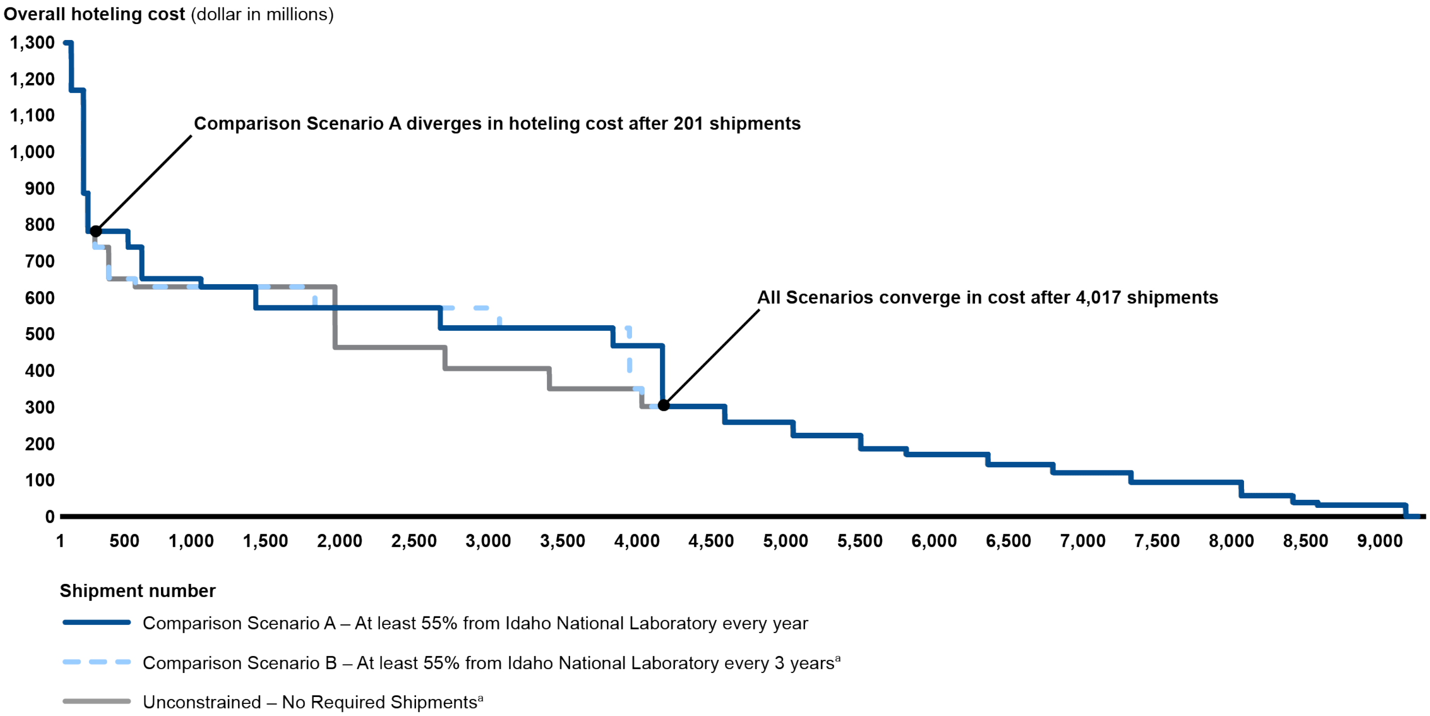
Figure 22: Overall Hoteling Cost in Comparison Scenario B: At least 55% from Idaho National Laboratory every 3 years



Source: GAO analysis of Department of Energy data. | GAO-25-107109

The following line chart shows hoteling costs for Scenario A. Scenario B and the Unconstrained Scenario are plotted when they differ from Scenario A, and the color indicates which scenario is plotted. The chart shows that Scenario A stays at a higher hoteling cost after 201 shipments until the three scenarios converge in cost after 4,017 shipments.

Figure 23: Hoteling Costs for Scenario A Compared to Scenario B and Unconstrained Scenario



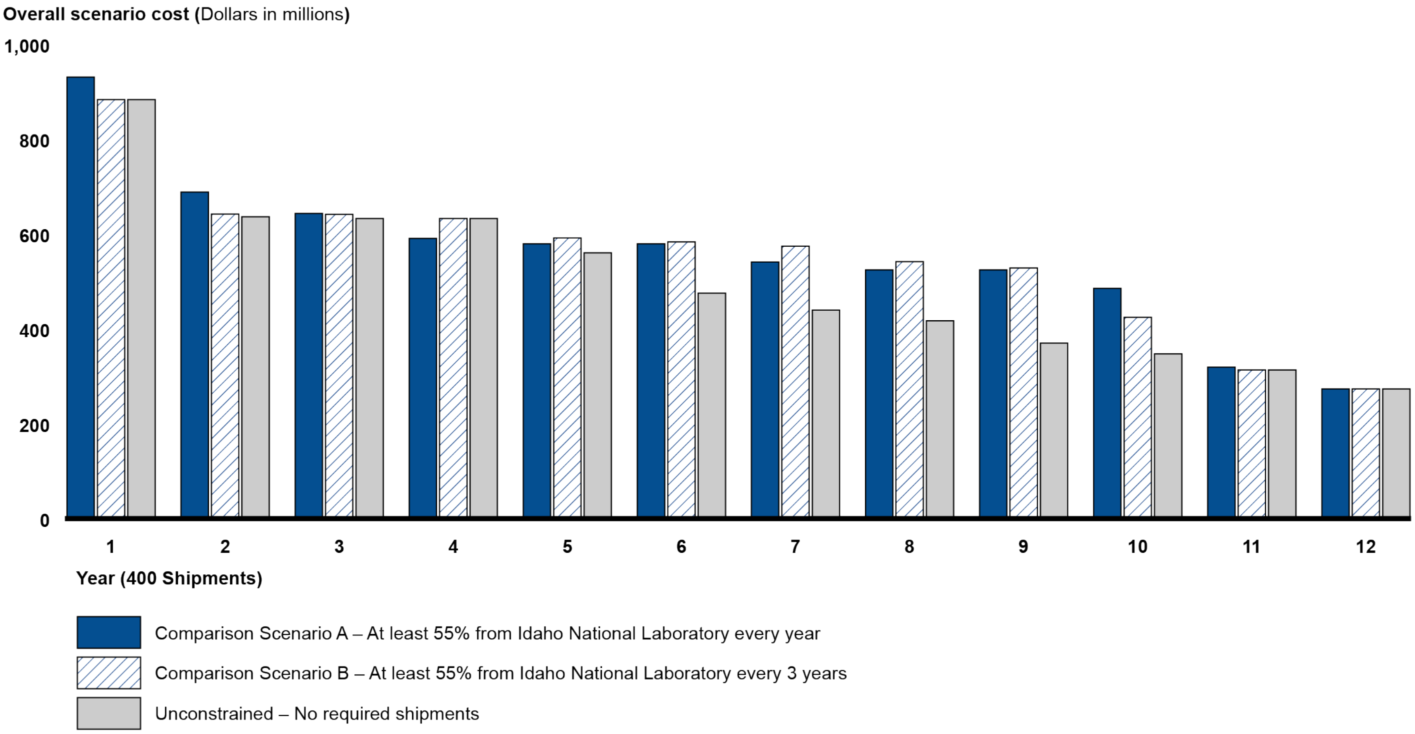
Source: GAO analysis of Department of Energy data. | GAO-25-107109

[a]Comparison Scenario B and Unconstrained are only plotted when different from Comparison Scenario A.

Comparing the hoteling cost progression lines, we observed that the hoteling costs would be reduced stepwise, identical to the way we estimated the hoteling cost at each site. Comparison scenarios where we were required to ship from Idaho National Laboratory, which was the fourth site in our unconstrained shipping order, delayed shipping from other sites with high potential hoteling cost savings. As such, their hoteling cost was typically higher for longer periods of time.

Figure 24 below shows the overall cost by year, combining the hoteling and transportation costs of our shipments for the first 12 years of each scenario since the overall cost between scenarios differed only to year 11.

Figure 24: Yearly Costs by Scenario, First 12 Years



Source: GAO analysis of Department of Energy data. | GAO-25-107109

Figure 24 shows that the Unconstrained scenario typically has lower yearly costs than the Comparison Scenarios A and B, with large differences occurring between years 6 and 11. We note that in year 4, Comparison Scenario A has the lowest annual cost, due to the ability to realize a lower hoteling cost at Idaho National Laboratory. However, those savings are quickly outweighed by the delay in moving TRU waste from sites with larger potential hoteling cost savings.

The following table shows each scenario's overall model cost and the savings to be realized with changes to the required shipments in each scenario. The cost values for the scenarios are limited by the data to which we had access and the assumptions that were made to complete the limited optimization model. These costs are not intended to serve as a federal cost estimate.

Table 3: Overall Model Cost by Scenario

Dollars in millions

Scenario	Overall Model Cost	Savings compared to Comparison Scenario A
Comparison Scenario A (at least 55% every year)	$8,126.91	$0
Comparison Scenario B (at least 55% every 3 years)	$8,077.56	$49.36
Unconstrained	$7,428.77	$698.14

Source: GAO analysis of Department of Energy data. | GAO-25-107109.

The unconstrained scenario has the lowest overall cost, with nearly $700 million in savings over the first 11 years of our example model results compared to Comparison Scenario A.

Model Limitations

As previously stated, this model is not intended to serve as a federal cost estimate nor is it meant to suggest how EM could or should operationalize its program. This model is not intended for agencies' direct use; rather, it is an illustrative example of how a model framework and data could allow for comparisons between different scenarios and requirements. The availability of additional data for inventory and hoteling costs may have resulted in different approaches to optimization. Errors in estimation, especially in the hoteling cost function, may result in model shipping orders that are not feasible or do not minimize the true cost of waste disposal.

We made extensive assumptions and used proxy data sources. Some of our assumptions include that the model would only consider existing contact-handled TRU waste at the starting point of the scenario, that the hoteling and transportation costs functions would be known and fixed, excluding WIPP costs, and that a one-to-one relationship exists between the overall hoteling cost and the remaining TRU inventory. We also assumed that all TRU waste costs the same to store in a site and that all TRU waste shipments would be ready to ship from any site so that we can order shipments only considering the potential hoteling cost savings. DOE was unable to provide us with accurate and comprehensive cost and inventory data for TRU waste sites which would allow for a more direct estimation of these features. Other models could be created with more comprehensive and specific data on TRU waste inventory and hoteling costs and greater contextual sophistication to directly address assumptions we made in our hypothetical approach.

Appendix IV: Comments from the Department of Energy

Department of Energy
Washington, DC 20585

May 14, 2025

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

Dear Mr. Anderson:

The Department of Energy (DOE) appreciates the opportunity to comment on the Government Accountability Office's (GAO) draft report titled, *Nuclear Waste: DOE Needs an Integrated Plan to Complete Its Cleanup Mission, Which Could Save Billions (GAO-25-107109)*.

For over 35 years, the Office of Environmental Management (EM) has been working to dispose waste from decades of nuclear weapons development and research. The volumes and types of radioactive and mixed radioactive wastes vary in magnitude at each of the fifteen remaining cleanup sites. While each waste type has its own management, disposition, and regulatory challenges, EM continues to make great strides in progressing the cleanup mission while protecting human health and the environment.

The draft report contains five recommendations for DOE pertaining to EM's current and future waste disposal strategy. EM continues to revisit waste disposal strategies across the complex. For example, the 2026 EM Program Plan update will provide detailed complex-wide strategic objectives for waste management and disposition mission areas and expand on current plans and opportunities.

DOE will provide management decisions for the GAO recommendations when responding to GAO's final report, as required by 31 U.S.C. 720. Technical comments on the draft report have been provided separately.

If you have any questions, please contact me or Ms. Kristen G. Ellis, Associate Principal Deputy Assistant Secretary for Regulatory and Policy Affairs, at (202) 586-5810.

Sincerely,

Roger A. Jarrell II

Roger A. Jarrell II
Principal Deputy Assistant Secretary for
Environmental Management

Appendix V: Comments from the Nuclear Regulatory Commission

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

March 31, 2025

Amanda Kolling, Assistant Director
Natural Resources and Environment
U.S. Government Accountability Office
441 G Street, NW
Washington, DC 20226

Dear Amanda Kolling:

On behalf of the U.S. Nuclear Regulatory Commission (NRC), I am responding to your e-mail dated February 24, 2025, which provided the NRC an opportunity to review and comment on the U.S. Government Accountability Office (GAO) draft report GAO-25-107109, "Nuclear Waste: DOE Needs an Integrated Plan to Complete Its Cleanup Mission, Which Could Save Billions."

The NRC staff appreciates the opportunity to review the draft report, and we appreciate the GAO staff's professionalism and many constructive interactions during this GAO engagement. In the enclosure to this letter, we have provided some comments and clarifications for your consideration.

Please feel free to contact Mr. John Jolicoeur at 301-415-1642 or John.Jolicoeur@nrc.gov if you have questions or need additional information.

Sincerely,

Signed by Gavrilas, Mirela on 03/31/25

Mirela Gavrilas, PhD
Executive Director
for Operations

Enclosure:
NRC Comments on Draft Report
GAO-25-107109

Appendix VI: GAO Contact and Staff Acknowledgments

GAO Contact

Nathan J. Anderson, andersonn@gao.gov.

Staff Acknowledgments

In addition to the contact named above, Amanda K. Kolling (Assistant Director), Eli Lewine (Analyst in Charge), Claudia Hadjigeorgiou, Nancy Kintner-Meyer, Isabel Rosa, and Cory Ryncarz made key contributions to this report. Also contributing to this report were John Delicath, Charlotte E. Hinkle, Cindy Gilbert, and Sara Sullivan. Contributors to the optimization model include Ramgopal V. Gollakota, Minsoo Kim, Abinash Mohanty, and Shu Wang.

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