NUCLEAR WASTE CLEANUP

DOE Should Use Available Information to Measure the Effectiveness of Its Groundwater Efforts

Report to Congressional Requesters

November 2024
GAO-25-106938
United States Government Accountability Office

Accessible Version

GAO Highlights

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Highlights of GAO-25-106938, a report to congressional requesters
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DOE Should Use Available Information to Measure the Effectiveness of Its Groundwater Efforts

Why GAO Did This Study

EM is responsible for addressing hazardous and radioactive waste from nuclear weapons production and energy research at DOE sites. Contaminated groundwater at these sites poses threats to public health and the environment, making groundwater cleanup critical to EM's mission.

GAO was asked to review EM's groundwater cleanup efforts. This report examines (1) the groundwater cleanup requirements at selected EM sites; (2) the scope, cost, and schedule for groundwater cleanup; and (3) the extent to which EM measures groundwater cleanup progress.

GAO examined four sites selected to represent a variety of facility types at different stages of the cleanup process governed by different regulatory frameworks. GAO examined relevant laws and regulations and reviewed agency documents on groundwater cleanup. GAO interviewed officials from EM, the U.S. Environmental Protection Agency, and state regulators.

What GAO Recommends

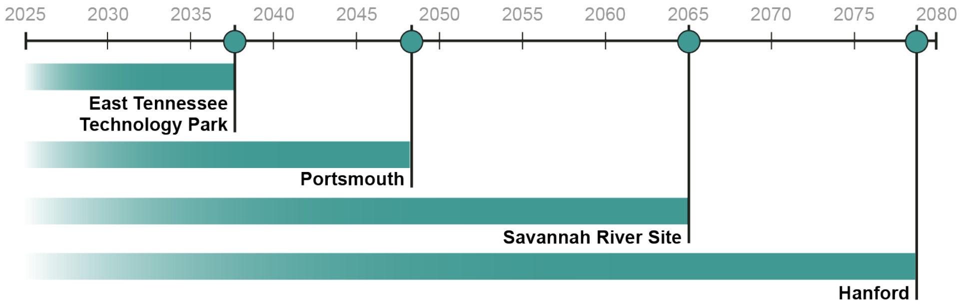
GAO is making three recommendations, including that EM headquarters collect and use comprehensive information on groundwater cleanup scope, cost, and schedule for all EM sites to enhance technical and policy support provided to sites and inform resource allocation decisions; and develop and use **performance** metrics to monitor progress toward cleanup goals**.** DOE concurred with all of GAO's recommendations.

What GAO Found

The U.S. Department of Energy's (DOE) Office of Environmental Management (EM) is responsible for cleaning up groundwater contamination at 13 sites. The four sites GAO examined are cleaning groundwater to meet drinking water standards based on the intersection of several laws that drive cleanup requirements, including the Safe Drinking Water Act, as amended. In cases where it is technically impractical to meet the standards, EM could seek a waiver. Two of GAO's four selected sites are exploring the use of such waivers, but none have been used as of September 2024.

The four sites GAO examined have an estimated groundwater cleanup cost of at least $10 billion over the next 5 decades. However, EM headquarters was unable to identify comprehensive information on the scope, cost, and schedule of groundwater cleanup for all 13 sites because the database combines groundwater and soil cleanup information together. EM protocol states that EM headquarters is responsible for providing technical and policy support for groundwater cleanup. Access to comprehensive scope, cost, and schedule information for groundwater cleanup would enable EM headquarters to better understand the resources needed to meet cleanup requirements.

Estimated Completion Dates for Groundwater Cleanup by Selected Site



Source: GAO analysis of Office of Environmental Management information. | GAO-25-106938

Accessible Data for Estimated Completion Dates for Groundwater Cleanup by Selected Site

- Hanford (2078)
- Savannah River Site (2065)
- Portsmouth (2048)
- East Tennessee Technology Park (2037)

Source: GAO analysis of Environmental Management information. I GAO-25-106938

The four sites assess groundwater progress using metrics that attempt to measure the effectiveness of cleanup. However, EM headquarters' performance metrics do not provide useful information on EM's overall groundwater cleanup progress. For example, EM tracks the number of groundwater wells as a progress metric. However, sites may install new wells for a variety of reasons, such as to replace decommissioned wells. Thus, there is not always a direct relationship between new wells and meeting cleanup requirements.

EM protocol states that results from performance evaluations should inform EM's planning, budgeting, and execution activities, as well as provide lessons learned for improving management processes. EM is developing new qualitative groundwater performance metrics to consistently track progress at all sites. However, until EM aligns performance metrics with groundwater cleanup goals, decision-makers cannot assess whether billions of dollars in cleanup investments are achieving the desired results. Additionally, by leveraging available site-level performance information, decision-makers could draw useful conclusions about cleanup progress and derive valuable lessons learned.

Contents

Abbreviations

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended
DOE	U.S. Department of Energy
EM	Office of Environmental Management
EPA	U.S. Environmental Protection Agency
ETTP	East Tennessee Technology Park
PFAS	per- and polyfluoroalkyl substances
RCRA	Resource Conservation and Recovery Act of 1976, as amended
TRAC	Tracking Restoration and Closure system

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
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November 19, 2024

The Honorable Cathy McMorris Rodgers
Chair
The Honorable Frank Pallone, Jr.
Ranking Member
Committee on Energy and Commerce
House of Representatives

The Honorable Diana DeGette
Ranking Member
Subcommittee on Energy, Climate, and Grid Security
Committee on Energy and Commerce
House of Representatives

The Honorable H. Morgan Griffith
Chairman
Subcommittee on Oversight and Investigations
Committee on Energy and Commerce
House of Representatives

The U.S. Department of Energy's (DOE) Office of Environmental Management (EM) is responsible for addressing hazardous and radioactive waste at 15 sites that have been contaminated from decades of nuclear weapons production and nuclear energy research. Contaminants such as those found in groundwater at 13 of these sites may pose risks to public health and the environment, making groundwater cleanup critical to EM's mission.

According to U.S. Environmental Protection Agency (EPA) documentation, cleaning up groundwater is challenging because information about the contaminated plumes is often unknown or not adequately investigated, and plumes can move through the groundwater in unpredictable ways.[1] EM's 2022 Program Plan shows that cleanup sites are in various stages of the groundwater cleanup process, with many of the most complex contamination plumes still awaiting key cleanup decisions.[2]

We added the U.S. Government's Environmental Liability to our High-Risk List in 2017. As of fiscal year 2023, DOE reported $534 billion in environmental liabilities, related primarily to EM, including through groundwater

[1]Contaminants tend to remain concentrated in the form of a plume.

[2]The EM 2022 Program Plan summarizes accomplishments of the first 30 years and describes the remaining cleanup required to achieve mission completion.

cleanup. In addition, our prior work has found that ongoing groundwater cleanup continues at many sites after the official completion of EM's cleanup scope.[3]

You requested that we review groundwater cleanup at EM sites. This report examines: (1) the groundwater cleanup requirements at selected EM sites; (2) what is known about the scope, cost, and schedule for groundwater cleanup; and (3) the extent to which EM measures groundwater cleanup progress.

To address our three objectives, we interviewed officials and reviewed documentation from a non-generalizable sample of four EM cleanup sites. The four selected sites are East Tennessee Technology Park (ETTP) in Oak Ridge, Tennessee; the Hanford Site in Washington State; the Portsmouth Site in Ohio; and the Savannah River Site in South Carolina. The four selected cleanup sites were chosen from EM's 13 active cleanup sites engaging in groundwater activities.[4] The selected sites were chosen based on the following four factors:

- First, we considered similar groundwater contaminants. Each selected site had at least one overlapping contaminant with another selected site to determine how different site-specific factors might affect the cleanup of that contaminant.
- Second, we considered variation in facility type. We chose to examine two former gaseous diffusion uranium enrichment plant sites and two plutonium production plant sites.
- Third, we considered variation in the stages of cleanup at the site. Having sites with different estimated groundwater cleanup completion dates allows us to see variation in sites' near and long-term cleanup goals and decisions.
- Finally, we considered representation from sites subject to different regulatory frameworks. Specifically, we considered EM sites on the National Priorities List, which are regulated under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended (CERCLA), and sites not on the National Priorities List, which may be regulated under several federal or state laws.[5]

Findings from our nongeneralizable sample cannot be used to make inferences about all 13 EM sites, but the four selected sites are illustrative of groundwater cleanup operations.

To identify the groundwater cleanup requirements at selected EM sites, we reviewed relevant laws, regulations, and agency guidance. We interviewed EM headquarters and site officials to confirm the groundwater cleanup standards established for each site. We reviewed site documentation and agency guidance from EM and EPA to determine what alternatives to cleanup standards exist. We also reviewed documents from other sources, such as EPA comments submitted as part of the regulatory process and

[3]Once EM scope is complete, sites are transferred to DOE's Office of Legacy Management, which continues any needed groundwater cleanup and conducts long-term monitoring. See GAO, *Environmental Liabilities: DOE Needs to Better Plan for Post-Cleanup Challenges Facing Sites*, GAO-20-373 (Washington, D.C.: May 13, 2020).

[4]EM has 15 active sites, but the Waste Isolation Pilot Plant and Environmental Management Consolidated Business Center-New York Project Office sites do not have active groundwater cleanup activities and were excluded from the selection process.

[5]The National Priorities List is the list of sites of national priority among the known releases or threatened releases of hazardous substances, pollutants, or contaminants throughout the United States and its territories. See 42 U.S.C. § 9605(a)(8)(B); 40 C.F.R. pt. 300, app. B. Revised annually, the list is intended primarily to guide EPA in determining which sites warrant further investigation. Cleanup of contaminated sites not on the National Priorities List may be regulated under CERCLA, the Resource Conservation and Recovery Act of 1976, as amended (RCRA), or under state laws, depending on the site's regulatory status.

documentation from the national laboratories. We then interviewed EM headquarters and site officials, EPA officials, and state regulators to determine steps our selected EM sites have taken to pursue cleanup alternatives, if any.

To determine what is known about the scope, cost, and schedule for groundwater cleanup, we reviewed EM headquarters-level and site-specific scope, cost, and schedule information. Headquarters-level information was derived from the Integrated Planning, Accountability, and Budgeting System database. We interviewed EM headquarters officials about their database and their ability to provide groundwater cleanup information for all EM sites. Site-specific information included the site's Federal Site Life-Cycle Estimate.[6] We determined this information to be reliable for our purposes—reporting sites' best estimates of their expected future costs—by interviewing knowledgeable officials to better understand how the site developed the estimates, including the underlying assumptions and how each site accounted for uncertainties when developing scope, cost, and schedule estimates. Because the sites have slightly different methods for creating their estimates, the scope, cost, and schedule information is not directly comparable across sites.

To examine the extent to which EM measures cleanup progress, we reviewed reporting documentation from both EM headquarters and the sites. Headquarters-level documentation included EM's 2022 Program Plan; EM Strategic Vision: 2024–2034; and EM's Calendar Year 2024 Mission & Priorities. Site-level documentation we reviewed included Annual Site Environmental Reports, annual Groundwater Monitoring Reports, regulatory process documentation, and other site-specific documentation. In addition, we interviewed EM headquarters and site officials, as well as EPA officials and the sites' relevant state regulators. To evaluate how EM measures cleanup progress, we compared the practices we identified in these documents and what we learned from our interviews to key practices for evidence-based policymaking outlined in our 2023 report.[7] These key practices were distilled from hundreds of actions identified in our past work as effective for helping federal agencies manage and assess the results of their efforts.

We conducted this performance audit from July 2023 to November 2024 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

EM Cleanup Sites

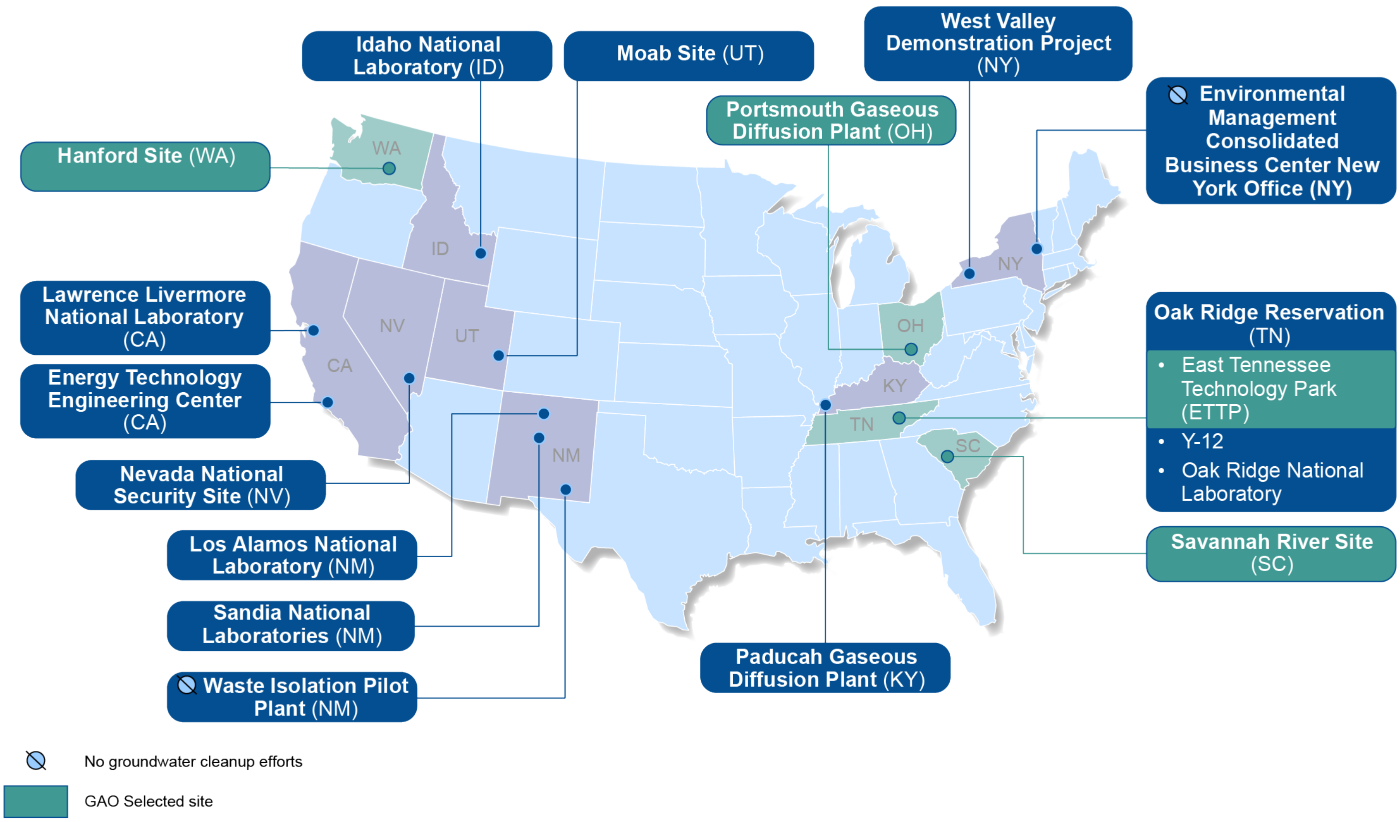
Established in 1989, EM is responsible for the cleanup of legacy waste—hazardous and radioactive materials generated by the development and production of nuclear weapons and government-sponsored nuclear energy

[6]According to EM's Program Management Protocol, the Federal Site Life-Cycle Estimate developed by each site is the scope, cost, and schedule profiles for the work activities required to complete the EM mission at a site. These estimates also include a risk management plan and risk register, which includes both risks and opportunities. Department of Energy, *Environmental Management Program Management Protocol* (Washington, D.C.: Oct. 30, 2020).

[7]GAO, *Evidence-Based Policymaking: Practices to Help Manage and Assess the Results of Federal Efforts*, GAO-23-105460 (Washington, D.C.: July 12, 2023).

research dating back to World War II and the Cold War.[8] EM has completed cleanup at 92 of the 107 sites for which it was responsible, and 15 sites remain (see fig. 1).

Figure 1: Active U.S. Department of Energy Office of Environmental Management Sites



Sources: GAO analysis of Office of Environmental Management documentation and Map Resources (map). | GAO-25-106938

Accessible Data for Figure 1: Active U.S. Department of Energy Office of Environmental Management Sites

GAO selected sites:

- East Tennessee Technology Park (ETTP)
- Hanford Site (WA)
- Portsmouth Gaseous Diffusion Plant (OH)
- Savannah River Site (SC)

Sources: GAO analysis of Office of Environmental Management documentation and Map Resources (map). I GAO-25-106938

Groundwater cleanup has been ongoing at EM sites for more than three decades and is typically one of the last cleanup steps before completing the closure of a site. EM is conducting groundwater cleanup at 13 of its 15 active sites, including sites facing some of the most complex groundwater cleanup challenges.

[8]In the fall of 1989, DOE established the Office of Environmental Restoration and Waste Management, which was later renamed the Office of Environmental Management.

For our report, we examined the groundwater cleanup at four selected sites: ETTP, Hanford, Portsmouth, and Savannah River.

ETTP. ETTP is one of three major cleanup areas at the Oak Ridge Reservation.[9] To support nuclear weapons production, a plant at ETTP used gaseous diffusion to produce weapons-grade enriched uranium from 1945 to 1987. In 2020, EM completed removal of all contaminated facilities at the site. Ongoing cleanup activities on-site include cleanup of remaining soil and groundwater contamination.

Groundwater contaminants at ETTP include chlorinated volatile organic compounds, metals, and radionuclides. Specifically, groundwater cleanup addresses vinyl chloride, nickel, chromium, and trichloroethylene, among other contaminants. Groundwater plumes at ETTP are in varied stages of cleanup. ETTP has one final cleanup decision and six plumes in ETTP's main plant area have interim cleanup decisions in place as of April 2024. Site officials told us that they still need to investigate more than 10 remaining groundwater plumes at the main plant area before they can propose a final cleanup decision, while another area is still being investigated to determine the best cleanup approaches.[10]

Hanford. The 580-square mile Hanford Site was established in eastern Washington State during World War II to produce plutonium for the nation's nuclear weapons, which it did through 1987. These activities caused multiple, large-scale contamination plumes in the groundwater.

Two main areas at Hanford have contaminated groundwater: (1) an area along the Columbia River, called the river corridor; and (2) the center of the site, called the central plateau. Contaminants being addressed at the river corridor include carbon-14, trichloroethylene, hexavalent chromium, nitrate, strontium-90, tritium, and uranium. According to Hanford officials, Hanford has cleaned up most contaminated groundwater from the river corridor. Officials told us they prioritized the river corridor because of its proximity to the Columbia River and public interest in cleaning up this area quickly.

An unspecified number of groundwater plumes for 11 contaminants need cleanup in the central plateau. Sources of contamination are still present at some locations in the central plateau, and contamination continues to migrate into the groundwater. Groundwater beneath the central plateau is contaminated with carbon tetrachloride, trichloroethylene, chromium (total and hexavalent), cyanide, nitrate, iodine-129, strontium-90, technetium-99, tritium, and uranium. EM plans to expand cleanup activities in the central plateau to contain and remove additional contamination from the soil and groundwater.

Portsmouth Gaseous Diffusion Plant. EM's Portsmouth Gaseous Diffusion Plant is located on a 5.8-square-mile site in a rural area of Ohio. Portsmouth produced enriched uranium via the gaseous diffusion process from 1954 to 2001. Gaseous diffusion plant operations generated hazardous and radioactive wastes.

Ongoing groundwater cleanup activities at the site include the cleanup and monitoring of five groundwater plumes. Portsmouth's cleanup mission focuses on cleaning trichloroethylene and other volatile organic compounds. Four of the five plumes at Portsmouth are undergoing active cleanup measures. EM completed

[9]The other two cleanup areas at Oak Ridge Reservation are Oak Ridge National Laboratory and the Y-12 National Security Complex.

[10]When we refer to "site officials" we mean EM officials who work at an EM site rather than EM headquarters.

cleanup activities on the fifth plume in 2021 and is monitoring the area for 10 years to ensure the efficacy of the cleanup treatment.

Savannah River. The Savannah River Site in South Carolina was constructed during the early 1950s to produce materials for nuclear weapons. Most of the contaminated groundwater plumes at Savannah River are in the central area of the site. Groundwater cleanup of the site's 15 plumes addresses a broad range of contaminants, including volatile organic compounds, nitrates, hazardous metals, radionuclides, and other emerging contaminants. Volatile organic compounds in groundwater, mainly trichloroethylene and tetrachloroethylene, originated from their use as degreasing agents in industrial work at the site. Since approximately 2003, EM has completed extensive cleanup and closure work at Savannah River.

Regulatory Framework and Agreements Governing Cleanup at EM Sites

Federal and state laws, agreements, and court orders require federal agencies to clean up contaminated sites under their jurisdiction. Key federal laws that govern EM's cleanup of its sites include the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended (CERCLA), and the Resource Conservation and Recovery Act of 1976, as amended (RCRA).[11]

CERCLA. Commonly known as Superfund, CERCLA authorizes federal agencies to respond to releases or threatened releases of hazardous substances, pollutants, and contaminants that may endanger public health or the environment. Under CERCLA, EPA has certain oversight authorities for cleaning up releases of hazardous substances, pollutants, or contaminants at federal facilities on the National Priorities List. At DOE's National Priorities List sites, DOE must enter into an interagency agreement with EPA and state regulators, known as a federal facility agreement, that governs the investigation and cleanup of any such releases at these facilities.[12] There are several activities in the typical CERCLA process, including the investigation, decision-making, and cleanup stages. Figure 2 outlines the general CERCLA process used by the lead agency for cleanup at National Priorities List sites.

[11]Comprehensive Environmental Response, Compensation, and Liability Act of 1980, Pub. L. No. 96-510, 94 Stat. 2767 (codified as amended at 42 U.S.C. §§ 9601-9675); Resource Conservation and Recovery Act of 1976, Pub. L. No. 94-580, 90 Stat. 2795 (codified as amended at 42 U.S.C. §§ 6901-6987).

[12]*See* 42 U.S.C. § 9620(e)(2).

Figure 2: Typical Stages of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended (CERCLA), Cleanup Process

Investigation	Decision	Cleanup
Preliminary assessment/ Site inspection Complete initial inspection and review information to confirm the release of hazardous substances, pollutants, or contaminants, and decide whether to proceed with further investigation.	**Proposed plan** Propose the preferred remedy to the lead regulator, state agency, and public for comment.[a]	**Remedial design/ remedial action** Design the implementation of the selected remedy including construction and operation of treatment systems, if applicable. Cleanup and monitor the contamination using the selected remedy until cleanup requirements and standards are met.
Remedial investigation Collect data to characterize site conditions, determine the nature and extent of the contamination, and assess risk to human health and the environment.	**Remedy selection** Select remedy after considering comments.[b] The selected remedy may be no further action.	**Site closeout** Document completion of all response actions implementing the remedy and compliance with cleanup requirements and standards. Post-completion operation and maintenance activities are required where waste is left on site.
Feasibility study Develop, screen, and conduct detailed evaluation of potential alternatives for the remedy.	**Record of decision** Document the selected remedy, scope of work, and applicable federal and state cleanup requirements and standards.	

Types of CERCLA cleanup response actions

- Removal actions are used to address releases that pose an immediate threat to human health or the environment. A removal action can occur at any stage of the CERCLA process.
- Remedial actions follow the remedial design stage and involve the actual construction or implementation of the permanent remedy.

Source: GAO analysis of legal requirements and agency guidance documents. | GAO-25-106938

Accessible Data for Figure 2: Typical Stages of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended (CERCLA), Cleanup Process

Category	Category information
Investigation	• Preliminary assessment/Site inspection: Complete initial inspection and review information to confirm the release of hazardous substances, pollutants, or contaminants, and decide whether to proceed with further investigation. • Remedial investigation: Collect data to characterize site conditions, determine the nature and extent of the contamination, and assess risk to human health and the environment. • Feasibility study: Develop, screen, and conduct detailed evaluation of potential alternatives for the remedy.
Decision	• Proposed plan: Propose the preferred remedy to the lead regulator, state agency, and public for comment.[a]: • Remedy selection: Select remedy after considering comments.[b] The selected remedy may be no further action. • Record of decision: Document the selected remedy, scope of work, and applicable federal and state cleanup requirements and standards.

Category	Category information
Cleanup	• Remedial design/remedial action: Design the implementation of the selected remedy including construction and operation of treatment systems, if applicable. Cleanup and monitor the contamination using the selected remedy until cleanup requirements and standards are met. • Site closeout: Document completion of all response actions implementing the remedy and compliance with cleanup requirements and standards. Post-completion operation and maintenance activities are required where waste is left on site.

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- Remedial actions follow the remedial design stage and involve the actual construction or implementation of the permanent remedy.

Source: GAO analysis of legal requirements and agency guidance documents. I GAO-25-106938

Notes: This figure groups the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended (CERCLA), cleanup framework for National Priorities List sites into the high-level stages of investigation, decision, and cleanup, as generally set forth in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) at 40 C.F.R. Part 300. The process for the lead agency may vary depending on site-specific conditions. The U.S. Environmental Protection Agency (EPA) defines the “lead agency” as the agency that plans and implements response actions under the NCP. 40 C.F.R. § 300.5.

[a]EPA defines the “lead regulator” as the primary agency (i.e., EPA or the state) that oversees the cleanup. EPA, *Lead Regulator Policy for Cleanup Activities at Federal Facilities on the National Priorities List* (Nov. 6, 1997).

[b]For a federal facility on the CERCLA National Priorities List, the final remedy must be selected jointly by the lead agency and EPA. If the agencies cannot reach agreement on the remedy, EPA will select the final remedy. 42 U.S.C. § 9620(e)(4); 40 C.F.R. § 300.430(f)(4)(iii).

RCRA. RCRA regulations establish detailed and often waste-specific requirements for the treatment, storage, or disposal of hazardous wastes. Under RCRA, EPA may authorize states to administer their own hazardous waste regulatory program in lieu of the federal program, so long as the state program meets certain requirements and is at least as stringent as the federal program.[13] RCRA 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.[14] 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. Figure 3 outlines the typical RCRA process used for cleanup of hazardous waste releases.

[13]42 U.S.C. § 6926(b). See also 40 C.F.R. pt. 71. RCRA defines a “state” as any of the 50 states, the District Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, Guam, American Samoa, and the Commonwealth of the Northern Mariana Islands. 42 U.S.C. § 6903(31).

[14]42 U.S.C. § 6924(u), (v). See also 40 C.F.R. § 264.100. RCRA-permitted facilities are required to monitor groundwater to detect and correct any releases from regulated hazardous waste units. 40 C.F.R. pt. 264, subpt. F. RCRA defines “mixed waste” as waste containing both hazardous waste and source, special nuclear, or by-product material subject to the Atomic Energy Act of 1954. 42 U.S.C. § 6903(41).

Figure 3: Typical Stages of the Resource Conservation and Recovery Act, as amended (RCRA), Corrective Action Process

Investigation	Decision	Cleanup
RCRA facility assessment Regulator completes initial inspection and reviews information to confirm an actual or potential release of hazardous waste and decide whether to proceed with further investigation.	**Statement of basis** Regulator proposes for public comment the selected remedy, cleanup levels for containing or cleaning up contamination, and RCRA permit modifications.	**Corrective measures implementation** Facility designs, constructs, operates, maintains, and monitors actions taken to implement the remedy.
RCRA facility investigation Facility collects data to characterize the nature and extent of the hazardous waste release, assess risk to human health and the environment, and determine whether corrective action is needed.	**Corrective action remedy selection and response to comments** Regulator selects final remedy, documents its response to public comments, and finalizes any necessary RCRA permit modifications.	**Corrective action completion** Regulator determines that the completed corrective actions meet RCRA's standards for a portion or entire facility or for a specified unit or release and may require post-completion operation, maintenance, and controls to ensure the remedy remains protective may be necessary.
Corrective measures study (if necessary) Facility develops and evaluates corrective action alternative(s) to meet RCRA's standards to protect human health and the environment, achieve cleanup objectives, and remediate the sources of hazardous releases.	**RCRA order/permit modification** Regulator documents the selected remedy, scope of work, and the applicable federal and state cleanup requirements and standards.	

Interim actions are used to control or abate contamination that poses on-going risks or an immediate threat to human health or the environment. Interim actions may occur at any stage in the corrective action process but generally occur prior final remedy selection.

Source: GAO analysis of legal requirements and agency guidance documents. | GAO-25-106938

Accessible Data for Figure 3: Typical Stages of the Resource Conservation and Recovery Act, as amended (RCRA), Corrective Action Process

Category	Category information
Investigation	• RCRA facility assessment: Regulator completes initial inspection and reviews information to confirm an actual or potential release of hazardous waste and decide whether to proceed with further investigation. • RCRA facility investigation: Facility collects data to characterize the nature and extent of the hazardous waste release, assess risk to human health and the environment, and determine whether corrective action is needed. • Corrective measures study (if necessary): Facility develops and evaluates corrective action alternative(s) to meet RCRA's standards to protect human health and the environment, achieve cleanup objectives, and remediate the sources of hazardous releases.
Decision	• Statement of basis: Regulator proposes for public comment the selected remedy, cleanup levels for containing or cleaning up contamination, and RCRA permit modifications. • Corrective action remedy selection and response to comments: Regulator selects final remedy, documents its response to public comments, and finalizes any necessary RCRA permit modifications. • RCRA order/permit modification: Regulator documents the selected remedy, scope of work, and the applicable federal and state cleanup requirements and standards.
Cleanup	• Corrective measures implementation: Facility designs, constructs, operates, maintains, and monitors actions taken to implement the remedy. • Corrective action completion: Regulator determines that the completed corrective actions meet RCRA's standards for a portion or entire facility or for a specified unit or release and may require post-completion operation, maintenance, and controls to ensure the remedy remains protective may be necessary.

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Source: GAO analysis of legal requirements and agency guidance documents. I GAO-25-106938

Note: This figure groups the Resource Conservation and Recovery Act, as amended (RCRA), corrective action cleanup framework into the high-level stages of investigation, decision, and cleanup as generally set forth in U.S. Environmental Protection Agency regulations and guidance documents. The cleanup process may vary depending on site-specific conditions.

For sites on the National Priorities List, DOE enters into federal facility agreements with EPA and the relevant states. These agreements are generally negotiated between DOE, state regulators, and EPA. There may also be compliance orders, consent orders, and consent decrees governing cleanup at the sites. Federal facility agreements, also known as tri-party agreements, integrate DOE's CERCLA response action obligations at the site with its RCRA corrective action obligations. These agreements generally set out a process for deciding cleanup actions and a sequence for accomplishing cleanup work; tend to cover a relatively large number of cleanup activities; and include enforceable milestones that DOE must meet. Federal facility agreements can also be amended if the parties agree and follow the amendment process specified in the agreement.

In addition to these agreements, EM sites may be subject to administrative compliance or consent orders, and judicial consent decrees under RCRA. Compliance and consent orders are issued by regulators and typically require DOE to take site-specific actions to correct violations of laws, regulations, permits, or agreements.

Groundwater Cleanup Technologies Used at Selected Sites

EM sites use several technologies to clean up groundwater. The selection of groundwater cleanup technologies for a specific plume is based on the site investigation and evaluation of cleanup remedy alternatives where specific criteria—including effectiveness, implementability, cost, and time to achieve cleanup goals, among others—are used to determine a preferred remedy, according to DOE and EPA officials. Factors such as plume size, number of contaminants, contaminant types, contaminant concentrations, the nature and mass of the contaminant source, and the hydrogeology of the plume area also affect technologies used.

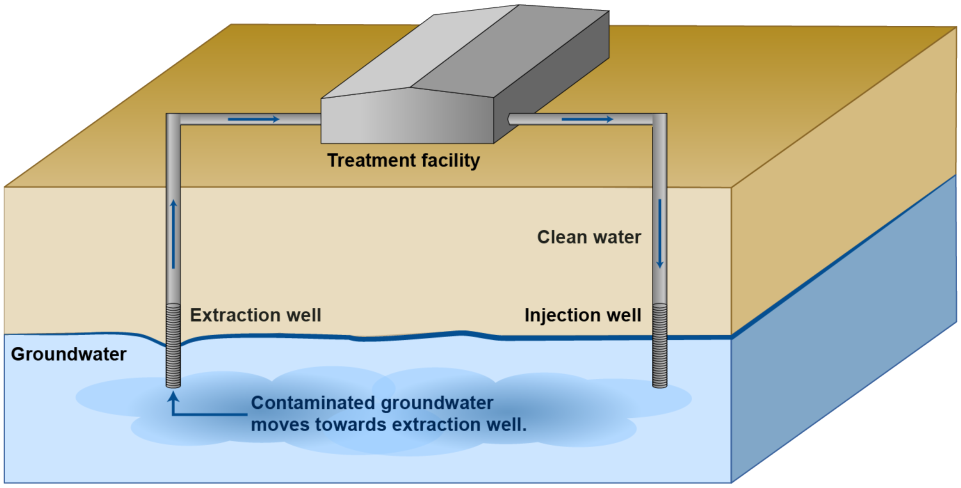
Cleanup technologies can be active or passive. Active groundwater cleanup technologies can remove contaminant sources, prevent contamination from spreading, and lower contaminant concentrations in plumes. In contrast, passive cleanup technologies are low-energy-consumption, low-carbon-emission technologies that treat contaminated groundwater. Contaminated groundwater may require several cleanup methods. For example, sometimes an active method is used to remove the most contaminated portion of a plume before switching to passive technologies at a later stage in the cleanup. Some examples of groundwater cleanup technologies are described in the following sections.

Pump and Treat

Pump and treat is an active groundwater cleanup method that uses extraction wells to pump contaminated groundwater to an above-ground treatment system to remove contaminants. For example, the Hanford Site uses multiple pump and treat systems: five systems along the Columbia River and one at the central plateau.

Pump and treat systems can also be used to contain a contaminant plume. The extraction wells pump contaminated water toward the wells, which helps control the plume and protect drinking water wells, streams, and other natural resources. Treated groundwater can be injected through strategically placed wells, typically at the edges of the plume to move the contaminated groundwater toward the extraction wells (see fig. 4). For example, in 1996 the Savannah River Site installed a pump and treat system to keep a plume of contamination from leaving the property boundary. The pump and treat method may be used from a few years to several decades depending on site complexity and may be modified as contaminant conditions evolve. It is typically followed by a passive remedy to achieve final cleanup goals.

Figure 4: Example of Pump and Treat System with Extraction and Injection Wells

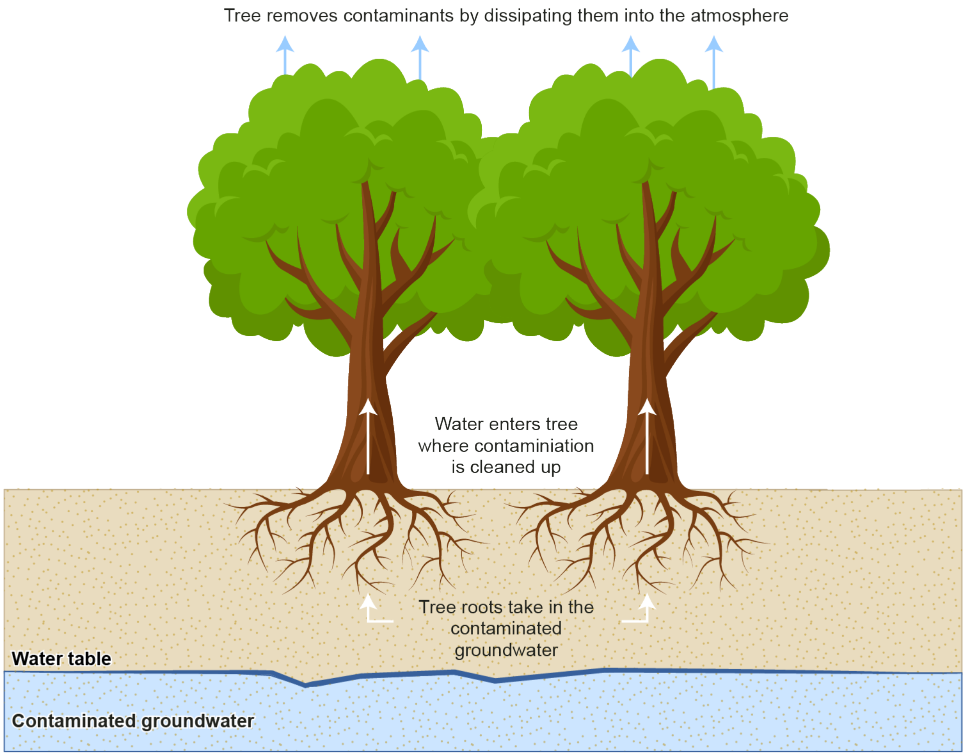


Source: GAO analysis of Office of Environmental Management documentation; GAO (illustration). | GAO-25-106938

Phytoremediation

Phytoremediation is a passive cleanup remedy that uses plants, such as trees, to clean selected contaminants in groundwater. Specifically, phytoremediation can lead to contaminant degradation, removal, or immobilization. Phytoremediation may be used to (1) degrade groundwater contaminants through destroying or transforming organic contaminants in the root system or plant body; (2) remove contaminants from soil and groundwater by dissipating them into the atmosphere or absorbing them into the plant (root system, stem, leaves, etc.); and (3) immobilize contaminated groundwater by using vegetation as a form of hydraulic control. Thus, phytoremediation can influence, and potentially contain, groundwater movement through the plant uptake of groundwater into the root system (see fig. 5). Costs associated with phytoremediation are lower because only a few employees need to maintain the remedy and contaminated groundwater flows naturally to the surface without a need for mechanized pumping.

Figure 5: An Example of the Phytoremediation Process



Sources: GAO analysis of Environmental Protection Agency documentation; Bro Vector/stock.adobe.com (illustration). | GAO-25-106938

For example, according to EM documentation, the Savannah River Site has a 62-acre forest of pine trees and other plant resources that limit radioactively contaminated groundwater from reaching waterways on the site. Specifically, EM waters the trees from a nearby holding pond containing tritium-contaminated water and the trees act like a forest of tall pumps, each drawing up the contaminated water and dissipating it into the atmosphere through photosynthesis. Since 2001, when the treatment began, approximately 190 million gallons of water—including nearly 7,000 curies of tritium that otherwise may have entered the Savannah River—have been sprayed through the forest of pine trees.[15]\

Monitored Natural Attenuation

Some sites also use monitored natural attenuation—which relies on natural processes that can decrease groundwater contaminant amount, movement, or concentrations—to complement active technologies or as an alternative method. For example, the Portsmouth Site plans to use monitored natural attenuation for plumes with low contaminant concentration levels. According to EPA documentation and officials, this method may be appropriate when the contaminant source has been removed and low concentrations of contaminants remain in soil or groundwater. The right conditions must exist underground for these natural processes to clean sites properly and within a reasonable timeframe. The anticipated cleanup time for monitored natural attenuation must be reasonable compared to that of other more active cleanup methods. Monitored natural attenuation requires less equipment and labor than most methods, which decreases cleanup costs. However, regular monitoring must be conducted to ensure that monitored natural attenuation continues to work.

Several Federal Laws Shape Cleanup Requirements at EM Sites

Several Federal Laws Intersect to Require EM to Clean Groundwater to Drinking Water Standards at Selected Sites

The intersection of several laws drives groundwater cleanup requirements. EPA or state designations regarding the expected use of the groundwater are factors in implementing each of these laws. EPA and states established some of these groundwater designations decades ago.[16]

The laws that intersect to determine the groundwater cleanup requirements at EM sites include:

- **The Safe Drinking Water Act.** This act protects the quality of drinking water in the U.S.[17] This law focuses on all waters actually or potentially used for drinking, whether from above ground or underground sources. Under the Safe Drinking Water Act, as amended, EPA establishes national, health-based minimum standards, known as maximum contaminant levels, for public water systems that limit the specific contaminants in drinking water that can adversely affect public health.
- **CERCLA.** At DOE's CERCLA sites, EPA sets the baseline cleanup requirements for groundwater cleanup. Generally, EPA requires sites to clean groundwater to national drinking water standards if there is current or potential future use of the groundwater for drinking water. Specifically, remedial action at CERCLA sites

[15]Curies are a measure of the intensity of the amount of radiation released when an element emits energy as a result of radioactive decay.

[16]Specifically, EPA designation or certain designations by state authorities determine current and future use of groundwater. For example, if a state has an EPA-approved Comprehensive State Groundwater Protection Program, those are the groundwater classifications and standards that will drive the groundwater cleanup.

[17]Safe Drinking Water Act, Pub. L. No. 93-523, 88 Stat. 1660 (1974) (codified as amended 42 U.S.C. §§ 300f–300j-9).

must attain the maximum contaminant level established under the Safe Drinking Water Act, as amended, where such levels or standards are "applicable or relevant and appropriate."[18]

- **RCRA.** States authorized by EPA to implement and enforce the RCRA hazardous waste program primarily determine groundwater cleanup requirements. Under RCRA's corrective action provisions, EM must clean up contamination caused by hazardous waste at its sites by implementing remedial measures that protect human health and the environment. For RCRA sites, EPA guidance recommends that state regulators base groundwater cleanup levels on the maximum beneficial use of the groundwater wherever practicable within a reasonable timeframe given the particular circumstances of the site. Maximum beneficial use is frequently drinking water.

According to site officials, all four of our selected EM sites are required to clean up contaminated groundwater to drinking water standards because the groundwater is classified as an actual or potential source of drinking water. Groundwater cleanup at three of our four selected EM sites is subject to CERCLA and RCRA requirements (ETTP, Hanford, and Savannah River), and one is subject to RCRA requirements only (Portsmouth).[19] Other federal and state laws, administrative orders, and judicial consent decrees also apply to some of these sites.

Because the groundwater is classified as a potential source of drinking water at these sites, EM must clean up the contaminated groundwater to drinking water standards even if certain protections could prevent such drinking water use in the future. At the Portsmouth Site, for example, site officials and state regulators are in the process of creating a site-wide environmental covenant that would ensure the site's water will never be used as drinking water. Even if the environmental covenant is finalized, EM will be required to continue to clean contaminated groundwater to drinking water standards because the state has classified the groundwater's maximum beneficial use as drinking water. In addition, Savannah River Site officials have agreed with regulators and local communities that the site should remain under federal control in perpetuity. The groundwater on the site would be inaccessible for drinking water purposes. Nevertheless, EM must continue to clean contaminated groundwater to drinking water standards.

EM May Seek Waivers from Cleaning Groundwater to Drinking Water Standards in Certain Circumstances

In cases where it is technically impractical to meet cleanup standards, EM sites may seek a waiver from EPA under CERCLA. Technical impracticability waivers are contaminant- or area-specific waivers that would allow sites to implement an alternative clean up strategy when compliance with the requirement, such as the drinking water maximum contaminant level, is technically impracticable from an engineering perspective.[20] EPA has

[18]For contaminated current and potential sources of drinking water, CERCLA requires remedial action to attain maximum contaminant level goals established under the Safe Drinking Water Act. 42 U.S.C. § 9621(d)(2)(A). When the maximum contaminant level goal is set at zero, EPA requires remedial actions to meet the corresponding maximum contaminant level. 40 C.F.R. § 300.430(C)(2)(i)(B)-(C). Remedial action at CERCLA sites must also attain the water quality criteria under the Clean Water Act, under which state authorities have primary responsibility over establishing, reviewing, and revising water quality standards that adopt EPA's water quality criteria.

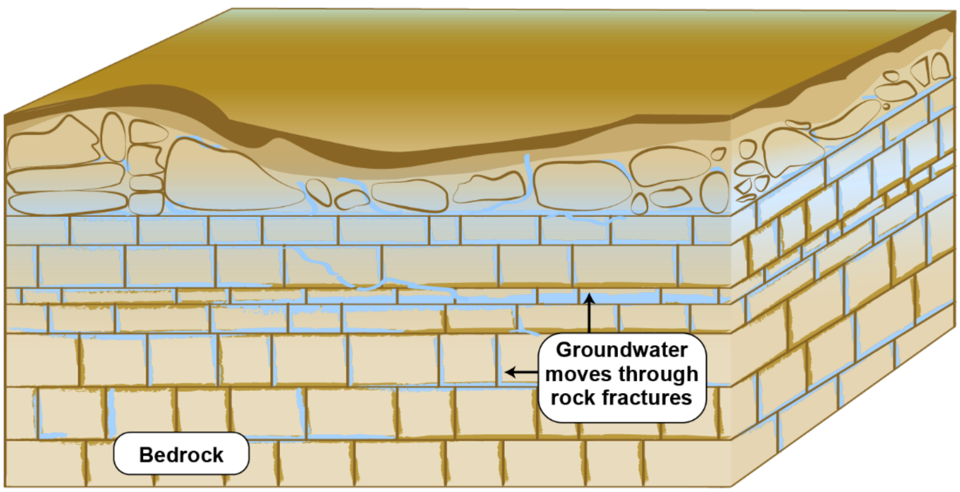
[19]Initial groundwater cleanup at Oak Ridge was conducted under RCRA but now most groundwater plumes are cleaned under CERCLA.

[20]42 U.S.C. § 9621(d)(4)(C); 40 C.F.R. § 300.430(f)(1)(ii)(C)(*3*).

criteria for obtaining technical impracticability waivers.[21] EPA guidance describes hydrogeology and contaminant-related factors at a site that may inhibit groundwater cleanup and support a site seeking a technical impracticability waiver.

The hydrogeology of a site affects how contaminated groundwater flows and contaminants move. When there are complicated hydrogeologic conditions, sites may have difficulty identifying the migration pathways and the nature and extent of contamination, according to documentation on cleanup management from the Interstate Technology and Regulatory Council.[22] For example, ETTP has fractured bedrock, which could make it challenging to map out the fracture occurrence and nature and extent of groundwater contamination at the site (see fig. 6). Complicated hydrogeologic conditions could make it difficult for sites to design effective contaminant monitoring programs and cleanup approaches, which can affect the ability to achieve drinking water standards within a reasonable time frame.

Figure 6: Fractured Bedrock



Source: GAO analysis of information from Eileen Poeter, et al., *Groundwater in Our Water Cycle* (Guelph, Ontario, Canada: The Groundwater Project, 2000); GAO (illustration). | GAO-25-106938

Some contaminants have properties that may limit the effectiveness of cleanup methods. For example, the inherently difficult nature of a contaminant—such as a contaminant that is resistant to removal and persistent by nature—creates complexity. This complexity limits treatment options and increases the time required for removing the contamination. For example, the Savannah River and Hanford Sites are both struggling with iodine-129, a long-lived contaminant that is particularly resistant to removal. At the Savannah River Site, with a shallower water table (as shallow as 30 feet below ground level), EM is trying a new technology to address contamination. However, because of the depth of iodine-129 at the Hanford Site (255 feet below ground level) and other factors, Hanford officials cannot pursue the same technology the Savannah River Site is using and are pursuing other alternatives.

[21]EPA, *Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration* (Washington, D.C.: September 1993).

[22]Interstate Technology and Regulatory Council, *Remediation Management of Complex Sites* (Washington, D.C.: October 2017). The Interstate Technology Regulatory Council is a state-led coalition that produces nationally recognized guidance on cleaning complex nuclear contamination challenges. EM has used this guidance at the headquarters level.

Two of our four selected sites are exploring the use of technical impracticability waivers. Specifically, EM has begun to seek a technical impracticability waiver at the Hanford Site for one of its groundwater plumes and would like to pursue a technical impracticability waiver for groundwater plumes at ETTP's main plant area. However, no EM site has received any technical impracticability waivers as of September 2024.

- **Hanford.** Hanford is in the process of seeking a technical impracticability waiver for iodine-129 in one of its groundwater plumes in the central plateau. Officials stated that it would be technically impracticable to clean groundwater contaminated with iodine-129 within a reasonable timeframe. In the plume, iodine-129 comingles with seven other contaminants. The 2012 interim cleanup remedy for this plume prescribed using pump and treat for 35 years combined with monitored natural attenuation to clean the contaminants in the plume. However, this pump and treat system does not address iodine-129 groundwater contamination, according to Hanford officials. Further, the high concentration portion of the iodine-129 plume is inaccessible because of its location beneath Hanford's Environmental Restoration Disposal Facility.

  In February 2023, Hanford officials presented findings to EPA outlining the technical impracticability of cleaning iodine-129 to drinking water standards. EPA officials told us that they provided draft comments to Hanford officials and that Hanford officials are currently assessing next steps related to pursuing a technical impracticability waiver for iodine-129 contamination in the groundwater plume.

- **ETTP.** ETTP officials told us that they would like to pursue a technical impracticability waiver for groundwater plumes in the main plant area due to hydrogeological and contaminant-specific conditions, though EPA officials stated that EM has not sought a waiver at ETTP yet.[23] Specifically, the main plant area is contaminated with chlorinated volatile organic compounds, such as trichloroethylene, as well as vinyl chloride. ETTP officials plan to use bioremediation over 5 years as an interim cleanup remedy for six contaminated groundwater plumes in the main plant area, costing an estimated $72.3 million. ETTP has fractured bedrock, making it challenging to map out the fracture occurrence and nature and extent of groundwater contamination. Fractured bedrock can make it difficult to design an effective contaminant monitoring program and cleanup approach for contaminants located in fractured bedrock that will reach drinking water standards in a reasonable timeframe.

  The interim remedy may reduce trichloroethylene to lower levels, but the interim remedy is not designed to achieve final cleanup levels.[24] EM officials said the concentrations will likely still be well above the drinking water standards for these contaminants. However, Tennessee state regulatory officials were more optimistic about the effectiveness of the bioremediation and want to see the results of the 5-year bioremediation before making additional cleanup decisions. EPA officials said that they need better site investigation of the main plant area before they would consider issuing a technical impracticability waiver. EPA officials also stated that the waivers address targeted portions of plumes and specific contaminants rather than entire areas.

[23]An EPA analysis of past technical impracticability waivers indicates that two of the most common reasons such waivers were granted are 1) geologic considerations, such as fractured bedrock and 2) the presence of contaminants that are denser than water and dissolve slowly or not at all, allowing them to continue to seep into groundwater over time. EPA, *Summary of Technical Impracticability Waivers at National Priorities List Sites*, OSWER Directive 9230.2-24 (August 2012).

[24]Officials are using the interim remedy to reduce trichloroethylene to below 1,000 micrograms per liter and vinyl chloride to below 400 micrograms per liter, well above the drinking water maximum contaminant level of 5 micrograms per liter for trichloroethylene and the 2 micrograms per liter for vinyl chloride. Micrograms per liter indicate the mass of a chemical in 1 liter of water.

Notably, cost of cleanup is not a main factor when EPA determines whether the use of a technical impracticability waiver at any particular site would be consistent with EPA policy and guidance, unless compliance with applicable standards would be "inordinately" costly.[25] EM officials were unclear on how to provide EPA with appropriate evidence that compliance with standards would be "inordinately" costly. For example, ETTP officials told us that testing technologies to clean up plumes in the main plant area will be costly. According to these officials, there have been no technological advances that have improved EM's ability to clean the groundwater to required levels in a manner that is economically viable. ETTP officials told us that they are unsure of how many costly treatments for the main plant area must fail before EPA can make a technical impracticability waiver determination. However, EPA officials stated that the bioremediation remedy is the first to be tested so far and that EPA would need additional evidence of technical impracticability to determine whether a waiver would be consistent with guidance.

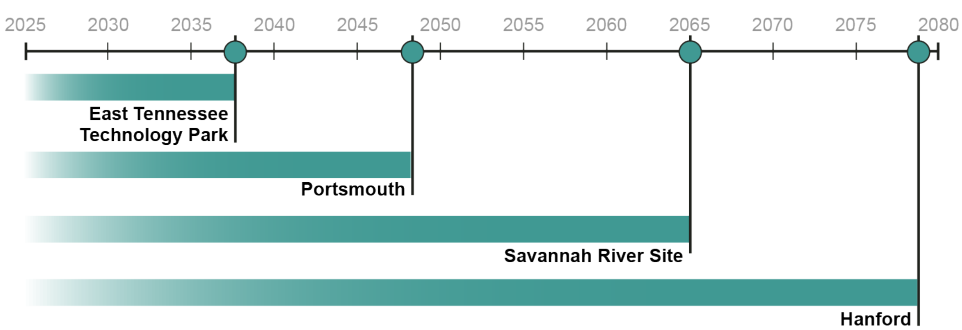
EM Headquarters Cannot Identify Groundwater Cleanup Scope, Cost, and Schedule, Although Selected Sites Report Cleanup Will Take Decades and Cost at Least $10 Billion

The four selected EM sites estimate that cleaning up contaminated groundwater will take more than 5 decades and cost billions of dollars. However, EM headquarters is unable to identify comprehensive groundwater-specific information on the scope, cost, and schedule of cleanup, meaning headquarters may underestimate the scope, cost, and schedule of cleanup work. Specifically, EM headquarters' existing data system is not designed to look at breakouts of scope, cost, and schedule information at the level of groundwater cleanup; instead, soil and groundwater cleanup are often categorized together.

Groundwater Cleanup at Selected Sites Is Estimated to Take More Than 5 Decades and Cost At Least $10 Billion

Across the four selected sites we reviewed, groundwater cleanup is estimated to take another 54 years, as figure 7 shows, and cost at least $10 billion.

Figure 7: Estimated Completion Dates for Groundwater Cleanup by Selected Site



Source: GAO analysis of Environmental Management information. | GAO-25-106938

[25]National Oil and Hazardous Substances Pollution Contingency Plan: Final Rule, 55 Fed. Reg. 8666, 8748 (Mar. 8, 1990). *See also* EPA, *Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration* (Washington, D.C.: September 1993).

Accessible Data for Figure 7: Estimated Completion Dates for Groundwater Cleanup by Selected Site

- Hanford (2078)
- Savannah River Site (2065)
- Portsmouth (2048)
- East Tennessee Technology Park (2037)

Source: GAO analysis of Environmental Management information. I GAO-25-106938

ETTP. Site officials estimate groundwater cleanup projects will cost $203.8 million through 2037. This includes preparation of CERCLA documentation, installation of new groundwater monitoring wells, and combination of monitored natural attenuation and bioremediation, as well as overhead costs for those projects. The final remedy decisions will determine the final recommended alternatives, which could have an impact on future cleanup project costs depending on the alternative selected. The overall program costs and long-term stewardship costs are not included in that estimate.

Hanford. Site officials estimate groundwater cleanup will cost $6.6 billion through 2078. Hanford groundwater projects are estimated to constitute $1.8 billion of that total, with groundwater monitoring and program management accounting for the other $4.8 billion.

Portsmouth. Site officials estimate groundwater cleanup will cost at least $420.9 million through 2048. These costs include excavation of groundwater plumes—EM's primary remedy—as well as monitoring the plumes following excavation and maintenance and operating costs. This does not include anticipated pump and treat for one of the plumes or small remaining costs for some plumes that have already undergone their RCRA corrective actions.

Savannah River. Site officials estimate groundwater cleanup projects will cost $2.2 billion through 2065. Officials estimate an additional $1.4 billion in overall program management costs, which includes both groundwater and soil cleanup.

Across all sites, various factors generate uncertainty around scope, cost, and schedule—specifically, a plume's stage in the cleanup process, hydrogeologic challenges, technical complexity, ongoing negotiations with stakeholders, new regulation of contaminants, and annual funding, as described in the following sections.

Stage in the cleanup process. Plumes that are in early stages of the cleanup process create a lot of uncertainty for cleanup scope, cost, and schedule. For example, ETTP is very early in the groundwater cleanup process. The main plant area at ETTP has an interim remedy decision for six contaminated plumes in the area. But there are more than 10 remaining plumes in the main plant area, which need to be investigated before officials can propose an appropriate remedy. Once the sites and regulators come to an agreement about the remedy for these plumes, cost and schedule estimates will likely become more reliable, according to ETTP officials. EM previously estimated that groundwater cleanup at ETTP would be complete in 2028. However, now that groundwater cleanup at ETTP is farther along in the cleanup decision-making process, ETTP officials told us they are now anticipating cleanup will not be completed until 2037, at the earliest.[26]

[26]According to EM officials, this date is subject to the assumed remedies being approved by the regulators in the areas that do not yet have final decisions in place.

Hanford officials also said that the unknown extent of contamination is a major source of uncertainty in their cost and schedule estimates.

Hydrogeologic challenges. The hydrogeology of a site affects how contaminated groundwater flows and moves contaminants. When there are complicated hydrogeologic conditions, sites have difficulty identifying the migration pathways and the nature and extent of contamination. For example, ETTP's fractured bedrock makes it challenging to map out the fracture occurrence and nature and extent of groundwater contamination, which can result in uncertainty in scope, cost, and schedule estimates. Another example of hydrogeologic challenges is deep groundwater at the Hanford Site, where the groundwater depth averages approximately 250 feet. As a result, (1) conventional, surface-based remedies cannot be implemented at such depths, according to DOE officials; (2) contamination is difficult and expensive to access; and (3) remedy performance is difficult to predict, test, and monitor, according to Hanford documentation. Because it is harder to get information on deep groundwater contamination, there is uncertainty in scope, cost, and schedule estimates.

Technical complexity. Cleanup at sites can be technically complex. For example, the Hanford Site has extensive groundwater contamination, including comingled contaminants and complex contaminant types along with complex site conditions. According to DOE documentation, large-scale, comingled groundwater contaminant plumes at Hanford have less certainty as it relates to the amount and location of contamination, which limits the applicability and effectiveness of conventional technologies and cleanup approaches.

Ongoing negotiations with stakeholders. Sites subject to federal facility agreements must reach agreement about remedy decisions with the EPA regional office in consultation with the state regulators. Relationships among EM sites, relevant stakeholders, the EPA regional office, and the state regulator can also create uncertainty related to scope, cost, and schedule. For example, scope, cost, and schedule estimates for ETTP assume that the primary cleanup technology to be used will be minimal monitoring with natural attenuation with the use of existing monitoring wells. However, disagreements between site officials and its stakeholders could delay the cleanup schedule. ETTP officials we interviewed stated that if regulators pushed for a different remedy, that would likely affect cost and schedule estimates.

New regulation of contaminants. New and emerging contaminants also create uncertainty about the scope, cost, and schedule of groundwater cleanup. For example, revised or new regulations to address emerging contaminants, such as per- and polyfluoroalkyl substances (PFAS), could affect cost and schedule estimates. PFAS were designed to be chemically and thermally stable, meaning they do not easily degrade in the environment, according to EPA documentation. Hanford officials are currently evaluating PFAS in groundwater. To address PFAS, Hanford officials told us that they may need to explore new technologies. Officials we interviewed from ETTP and the Savannah River Site also told us that new contaminants are a source of uncertainty in their estimates.

Annual funding. Officials from the Portsmouth and Savannah River Sites stated that annual funding uncertainty can affect schedule estimates. If the sites receive less funding than they planned, then work must be pushed to future years, which can extend the schedule.

EM Headquarters Cannot Identify Comprehensive Information on the Scope, Cost, and Schedule of Groundwater Cleanup

Our analysis of agency data and interviews with agency officials showed that EM headquarters was not able to identify comprehensive information on groundwater cleanup scope, cost, and schedule for all the sites in its database. Ultimately, one official told us that if we wanted groundwater-specific information, we would need to get it from the sites. Specifically, EM headquarters' existing data system is not designed to break out scope, cost, and schedule information at the level of groundwater cleanup; rather, soil and groundwater cleanup are often categorized together.[27] However, the system is being replaced and EM officials told us that they could add new functionality to the replacement system to address additional needs in the future.

One EM official we spoke with said that the capability to identify information on groundwater-specific scope, cost, and schedule at the headquarters level could be added if it were deemed useful. Other officials maintained that EM headquarters already has the information needed on scope, cost, and schedule based on discussions with sites and emphasized that headquarters gets valuable insight when discussing these issues with sites directly. However, if EM is unable to identify all groundwater cleanup information in its data system, EM headquarters may underestimate scope, cost, and schedule of groundwater cleanup.

EM's 2020 Program Management Protocol states that the headquarters organization responsible for regulatory and environmental compliance provides technical and policy support in the planning and field-execution of EM groundwater cleanup.[28] Collecting and using comprehensive scope, cost, and schedule information on groundwater cleanup would enhance EM's ability to provide technical and policy support to EM sites, particularly when limited resources require trade-offs to be made. Additionally, such information would enable EM headquarters, DOE, regulators, and Congress to better understand the resources needed to meet groundwater cleanup requirements across EM sites.

Sites Use Various Measures of Progress, but EM Headquarters' Metrics Do Not Measure Progress Toward Meeting Cleanup Requirements

EM sites measure groundwater progress in several ways, including using a site's stage in the regulatory process and reporting certain outcome-based performance metrics. However, EM headquarters has not developed strategic objectives or established performance goals to guide groundwater cleanup. Furthermore, EM headquarters' performance metrics do not measure progress toward meeting groundwater cleanup requirements.

EM Sites Measure Groundwater Cleanup Progress in Several Ways

EM headquarters has historically deferred to sites to measure groundwater cleanup progress, and EM's selected sites generally measure cleanup progress on a plume-by-plume basis. Specifically, sites monitor a

[27]EM officials said that, in some circumstances, contamination in groundwater and soil can be comingled and may be addressed under shared remedy decisions.

[28]Department of Energy, Office of Environmental Management, *Program Management Protocol*.

plume's stage in the regulatory process and report certain outcome-based performance metrics to assess groundwater cleanup progress, as described in the following sections.

Stage in the regulatory process. EM officials at our four selected sites said they measure progress using a plume's stage in the regulatory process. Sites can use contracting documents, performance plans, and performance reports to set goals and capture regulatory process information. For example, Savannah River Site officials told us that they set yearly contracting progress goals related to developing cleanup decisions for one of the site's plumes.

Certain outcome-based performance metrics. EM officials at our four selected sites also use outcome metrics to monitor groundwater cleanup progress. Outcome metrics assess the effect of cleanup, such as changes in plume size, changes in concentration of contaminants, or mass of contaminant treated. For example, a Hanford contracting document includes annual contaminant removal rates that its contractors must meet as part of overarching groundwater cleanup objectives. Specifically, in one plume, contractors must achieve a total technetium-99 removal rate of at least half a curie per year. In addition, the Portsmouth 2022 Annual Site Environmental Report reported that most contaminant concentrations detected within Portsmouth groundwater plumes were stable or decreasing in 2022. Outcome metrics, such as changes in contaminant concentration, are important because they can indicate quantifiable progress toward achieving groundwater cleanup goals.

EM Headquarters' Metrics Do Not Reflect Progress toward Meeting Groundwater Cleanup Requirements

EM headquarters has not developed a strategic objective or established performance goals related to groundwater cleanup. In addition, EM headquarters' current performance metrics do not assess progress towards achieving groundwater cleanup goals. EM headquarters is developing new performance metrics and has opportunities to set goals and collect and use performance metrics to inform decision-making.

EM Headquarters Has Not Established Strategic Objectives or Near-term Performance Goals

EM has not established groundwater-specific strategic objectives or performance goals. EM officials told us that their relevant strategic objective is to advance cleanup of radioactive and chemical waste to support environmental cleanup. However, EM officials said they do not have groundwater-specific strategic objectives to guide groundwater cleanup. In addition, EM does not have any supporting performance goals that express a tangible, measurable objective against which EM headquarters could track progress for groundwater cleanup.

Our 2023 report on evidenced-based policymaking outlines several practices relevant to performance assessment, including setting goals.[29] Specifically, agencies should establish near- and long-term goals to communicate what the agency proposes to accomplish. Goals allow agencies to assess or demonstrate the degree to which desired results were achieved. Within the context of groundwater cleanup, strategic objectives would serve as long-term goals that set a general direction for cleanup efforts. Performance goals are generally expressed as tangible, measurable objectives, or as quantitative standards, values, or rates (see table 1).

[29] GAO-23-105460.

Table 1: Key Facets of Strategic Objectives and Performance Goals

Strategic objectives (long-term goals)	Performance goals (near-term goals)
Strategic objectives are the outcome or effect the agency is intending to achieve through its various programs and initiatives. Agencies establish strategic objectives in their strategic plans and may update the objectives during the annual update of performance plans.	Performance goals are the target level of performance expressed as a tangible, measurable objective against which actual achievement is to be compared.
Strategic objectives: • Cover major functions and operations; • Logically relate to mission; • Are results-oriented; • Are expressed in a manner that will allow for assessing whether the objectives are achieved; and • Are complementary, and not duplicative, of goals of other agencies' performance-related activities.	Performance goals: • Are objective, measurable, and quantifiable; • Address important dimensions of program performance and balance competing priorities; • State a particular target level of performance; • Are linked to strategic goals and objectives; • Cover all programs and activities; and • Address mission-critical management problems.

Source: GAO analysis of survey data | GAO-25-106938

These key practices state that performance goals should identify the results that an organization seeks to achieve. They guide the organization's activities, and allow decision makers, staff, and stakeholders to assess performance by comparing planned and actual results. By establishing groundwater cleanup strategic objectives and near-term performance goals that cover all EM sites and more specifically target meeting cleanup requirements, EM would be better positioned to understand progress toward advancing site cleanup.

EM's Two Groundwater Performance Metrics Do Not Effectively Measure Progress toward Meeting Cleanup Requirements

EM headquarters tracks some performance metrics, but these do not provide useful information on EM's overall groundwater cleanup progress. Specifically, two performance metrics included in EM's 2022 Program Plan are (1) the number of groundwater wells installed at all EM groundwater sites and (2) the number of soil and groundwater cleanup completions.[30] While these measures have utility in certain contexts, neither of these two metrics demonstrate progress on meeting groundwater cleanup requirements. Specifically:

- N**umber of groundwater wells.** EM reports on the number of groundwater wells as a progress metric. However, sites may install new wells for a variety of reasons, such as to replace decommissioned wells or to optimize monitoring networks. Thus, there is not always a direct relationship between new wells and progress in reducing contaminant levels to meet cleanup requirements.
- **Number of cleanup completions.** EM reports on the number of cleanup activities completed as a progress metric. However, such reporting does not provide a sense of how long it will take to clean up the remaining complex groundwater plumes, nor does it provide a way to track incremental progress at any given site.

[30]Cleanup completions are areas that are ready to transition to long-term monitoring. This metric also appeared in DOE's Fiscal Year 2018 Annual Performance Report/Fiscal Year 2020 Annual Performance Plan. Department of Energy, *Fiscal Year 2018 Annual Performance Report/ Fiscal Year 2020 Annual Performance Plan* (Jan. 25, 2021).

EM officials told us that these metrics were historically used in contracts and acknowledged that they do not provide useful information on EM's groundwater cleanup progress.

EM Is Developing New Performance Metrics and Could Incorporate Available Information to Improve Them

EM is in the process of developing new performance metrics related to groundwater cleanup. For example, in 2023, EM created four qualitative metrics.[31] EM plans to rank each site on a low to high scale for these four metrics, with a goal of consistently tracking progress at all sites. Of these four metrics, one—groundwater plume status—best attempts to directly address progress towards clean groundwater. However, ranking an entire site with a qualitative metric can cause useful performance information to be mischaracterized or lost.

For example, EM headquarters ranked the groundwater plume status of ETTP's main plant area as "medium-high," meaning the "plume is partially controlled and final remedy is proposed but waiting on regulatory approval, or plume is controlled via active remediation." We found that the groundwater plume status at ETTP is more complicated than this ranking indicates, with an additional 10 groundwater plumes awaiting investigation and remedy decisions. EM officials told us that it is challenging to find the right level of information to track groundwater cleanup progress. However, EM could track plume status in a way that could be aggregated up to the site level by, for example, reporting that six out of at least 16 plumes in ETTP's main plant area have interim remedy decisions in place. EM could also track progress more directly through a metric like amount of contaminant removed.

EM also includes performance information in its Tracking Restoration and Closure system (TRAC), but TRAC does not yet contain information on many of EM's sites. According to agency officials, by the end of calendar year 2024, TRAC is expected to include groundwater cleanup information at most EM sites.[32] The information in TRAC includes, for example, plume maps, plume size, key contaminants, stage of the regulatory process, and the technologies used in the remedies. EM headquarters officials intend for TRAC to: (1) improve transparency by publicly providing information and conveying the status of sites' plumes; (2) share cleanup technology information between sites; and (3) help EM headquarters manage groundwater cleanup by efficiently tracking changes in plumes over time.

Key practices in evidence-based policymaking state that agencies should collect and use performance metrics to assess progress.[33] For each goal, agencies should establish one or more performance metrics for which they should collect relevant information. Performance metrics help agencies collect quantitative or qualitative data to track progress toward achieving agency goals or objectives. Performance metrics are generally collected on a recurring basis (monthly, quarterly, or annually) to allow for consistent assessment toward achieving goals. Metrics can be used to inform management decisions, such as plans to expand effective

[31]The four metrics are end state, groundwater plume status, control of exposure, and stakeholder engagement. New metrics would also have to be put into contracts with companies hired to perform cleanup operations. EM officials told us they sought advice from their Environmental Management Advisory Board on how to leverage contracting metrics to incentivize more progress and received the Board's recommendations in July 2024. EM's 2020 Program Management Protocol emphasizes the importance of defining vision and goals so that related performance incentives can be established in contracts.

[32]Two sites will be added to TRAC after 2024: Oak Ridge Reservation Sites, including ETTP; and the Energy Technology Engineering Center in California.

[33]GAO-23-105460.

approaches or address performance gaps. In addition, EM's 2020 Program Management Protocol states that results from regular performance evaluation should inform EM's planning, budgeting, and execution activities, as well as provide lessons learned for improving management processes.[34]

In June 2024, we analyzed high-level performance metrics across EM's entire program and emphasized the importance of having a clear set of performance metrics consistent across all documents that provide a clearer and more complete picture of program performance.[35] We recommended that EM develop program-wide performance metrics that follow the key components of effective performance metrics. EM agreed with our recommendation but said that their metrics were already aligned with the key attributes of effective performance measures. Groundwater cleanup is just one component—but a critical one—of the EM cleanup program. While high-level, program-wide performance metrics would enhance EM's planning, performance, and oversight across EM sites, for groundwater cleanup, they may obscure progress, particularly at individual sites and for individual plumes. Given the decades-long cleanup times, developing performance metrics specific to tracking groundwater progress is particularly vital.

EM has an opportunity to leverage the information in TRAC to develop performance metrics that provide insight into groundwater cleanup progress across all sites. This could bring the agency's new qualitative performance metrics and the information in TRAC into alignment with key practices and make performance metrics more useful to improving management processes. Without collecting and using performance metrics to regularly monitor progress toward groundwater cleanup goals, decision-makers cannot assess whether site cleanup investments are achieving desired results. In addition, it will be harder for decision-makers to draw useful conclusions about cleanup progress and derive valuable lessons learned to inform decisions.

Conclusions

Contaminants found in groundwater at EM sites pose risks to public health and the environment, making groundwater cleanup critical to EM's mission. With many of the most complex cleanup challenges remaining, groundwater cleanup is expected to continue for decades and cost billions of dollars.

However, EM risks making strategic decisions based on information that is not comprehensive, which may increase the costs and schedule of completing its groundwater cleanup mission. Specifically, because EM headquarters is unable to identify comprehensive groundwater-specific information on the scope, cost, and schedule of cleanup, it risks underestimating the full scope, cost, and schedule of groundwater cleanup and allocating resources among its sites and plumes in a suboptimal manner.

Furthermore, by establishing groundwater cleanup strategic objectives and near-term performance goals for groundwater cleanup, EM would be better positioned to guide progress toward advancing site cleanup. Additionally, as EM headquarters develops new performance metrics for groundwater cleanup, it has opportunities to improve the way it measures groundwater cleanup progress. By using performance metrics, such as plume information included in TRAC, to regularly monitor progress toward groundwater cleanup goals,

[34]Department of Energy, Office of Environmental Management, *Program Management Protocol*.

[35]EM's performance metrics did not fully align with the following key attributes of effective performance metrics—linkage, clarity, balance, and government-wide priorities. See GAO, *Nuclear Waste Cleanup: Closer Alignment with Leading Practices Needed to Improve Department of Energy Program Management*, GAO-24-105975 (Washington, D.C.: June 4, 2024).

EM can show the degree to which its investments achieve its desired results and derive lessons learned to inform decisions.

Recommendations for Executive Action

We are making the following three recommendations to EM:

The Senior Advisor for the Office of Environmental Management should ensure that EM headquarters collects and uses comprehensive information on groundwater cleanup scope, cost, and schedule for all EM sites to enhance technical and policy support provided to sites and inform resource allocation decisions. (Recommendation 1)

The Senior Advisor for the Office of Environmental Management should establish groundwater cleanup strategic objectives and near-term performance goals for groundwater cleanup that cover all sites and more specifically guide sites’ progress in meeting the groundwater cleanup requirements. (Recommendation 2)

The Senior Advisor for the Office of Environmental Management should develop and use performance metrics to regularly inform groundwater cleanup decisions and document progress toward cleanup goals. (Recommendation 3)

Agency Comments

We provided a draft of this report to DOE and EPA for review and comment. In its written comments, reproduced in appendix I, DOE concurred with our recommendations. In its comments, DOE also described actions it is taking or planning to take to address these recommendations. Both DOE and EPA provided technical comments, which we incorporated as appropriate.

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

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

Nathan J. Anderson
Director, Natural Resources and Environment

Appendix I: Comments from the Department of Energy

Department of Energy
Washington, DC 20585
October 28, 2024

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

Dear Mr. Anderson:

The Department of Energy (DOE) Office of Environment Management (EM) appreciates the opportunity to comment on the U.S. Government Accountability Office (GAO) draft report, *NUCLEAR WASTE CLEANUP: DOE Should Use Available Information to Measure the Effectiveness of its Groundwater Efforts (GAO-25-106938)*.

EM is dedicated to continuing its cleanup mission. Interim contaminant control measures have successfully reduced health and safety risks to the public in groundwater and soils. Additionally, EM conducts regular analyses of groundwater cleanup alternatives and science-based approaches that support innovation and reduce cleanup schedules.

The Department appreciates GAO's recognition of EM's progress in developing new qualitative metrics to track progress and planning efforts to incorporate performance information into its Tracking Restoration and Closure system. EM also initiated other groundwater-related programs, including the Advanced Long-Term Environmental Monitoring Systems and a new soil and groundwater remediation strategy.

EM concurs with GAO's recommendations, and EM's responses to the recommendations are enclosed.

If you have any questions, please contact me or Ms. Lois Jessup, Director, Office of Program Planning, at (703) 946-4003.

Sincerely,

Candice Trummell

Candice Trummell
Senior Advisor for Environmental Management

Enclosure

Enclosure

Management Response to GAO Recommendations
GAO-25-106938 Draft Report, *NUCLEAR WASTE CLEANUP: DOE Should Use Available Information to Measure the Effectiveness of its Groundwater Cleanup Efforts*

Recommendation 1: The Senior Advisor for the Office of Environmental Management should ensure that EM headquarters collects and uses comprehensive information on groundwater cleanup cost, scope, and schedule for all EM sites to enhance technical and policy support provided to sites and inform resource allocation decisions.

Management Response: Concur.

The Office of Environmental Management (EM) Headquarters (HQ) will work with EM sites to ensure that comprehensive information on groundwater cost, scope, and schedule is reported to EM HQ, separate from other cleanup activities to the extent feasible. EM HQ will ensure that the level of groundwater information reported to EM HQ will allow EM senior leadership to make resource allocation decisions to support groundwater cleanup goals and objectives.

Estimated Completion Date: September 30, 2025.

Recommendation 2: The Senior Advisor for the Office of Environmental Management should establish groundwater cleanup strategic objectives and near-term performance goals for groundwater cleanup that cover all sites and more specifically guide sites' progress in meeting the groundwater cleanup requirements.

Management Response: Concur.

EM will use the Environmental Management Advisory Board report, *Best Practices for Implementing EM's Groundwater Closure Strategy and Long-Term Monitoring Paradigm*, to prioritize a list of near-term and longer-term actions to improve the cleanup mission. Complex-wide strategic goals and objectives will also be outlined in the 2025 update to the EM Program Plan. These high-level goals and objectives will address the major cleanup areas of the EM Program, including groundwater remediation.

Estimated Completion Date: September 30, 2026.

Recommendation 3: The Senior Advisor for the Office of Environmental Management should develop and use performance metrics to regularly inform groundwater cleanup decisions and document progress toward cleanup goals.

Management Response: Concur.

Activities mentioned in Recommendations 1 and 2 will aid the development of performance metrics to regularly inform groundwater cleanup. EM will use the Tracking Restoration and Closure (TRAC) system as a tool to aid in the documentation of progress towards cleanup goals. This tool is in the final stages of development and data from all sites will be populated in the system by the end of 2024. Each year, sites will update information in TRAC to allow headquarters and other users of this information to assess progress towards cleanup goals and inform decision-making.

Estimated Completion Date: April 30, 2027.

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

Department of Energy
Washington, DC 20585

October 28, 2024

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

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If you have any questions, please contact me or Ms. Lois Jessup, Director, Office of Program Planning, at (703) 946-4003.

Sincerely,

Candice Trummell
Senior Advisor for Environmental Management

Enclosure

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GAO-25-106938 Draft Report, NUCLEAR WASTE CLEANUP: DOE Should Use Available Information to Measure the Effectiveness of its Groundwater Cleanup Efforts

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Estimated Completion Date: September 30, 2025.

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Estimated Completion Date: April 30, 2027.

Appendix II: GAO Contact and Staff Acknowledgments

GAO Contact

Nathan Anderson, (202) 512-3841 or AndersonN@gao.gov

Staff Acknowledgments

In addition to the contact named above, Janice Poling (Assistant Director), Jaci Evans (Analyst in Charge), Rachel Pittenger (Analyst in Charge), John Delicath, Gina Hoover, Madeline Kasik, Sara Sullivan, and Linda Tsang made key contributions to this report.

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