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NUCLEAR WASTE

Understanding of Waste Migration at Hanford is Inadequate for Key Decisions



**Resources, Community, and
Economic Development Division**

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The Honorable John Glenn
Ranking Minority Member
Committee on Governmental Affairs United States Senate

The Honorable Ron Wyden
United States Senate

In December 1997, the Department of Energy (DOE) announced that highly radioactive wastes at the Hanford Site in southeastern Washington State from previously leaking underground storage tanks had migrated through the soil and rocks to the underlying groundwater. DOE had previously believed that the area above the water table—called the vadose zone—was an effective barrier between the tank wastes and the groundwater.

Concerned about the potential risk of both radioactive and hazardous chemical wastes at the Hanford Site to populations downstream from the nearby Columbia River, you asked us to review DOE's efforts to develop an understanding of conditions in the vadose zone. As agreed with your offices, we focused our review on the following questions:

- How adequate is DOE's current understanding of the extent to which waste materials are moving through the vadose zone?
- How adequate is DOE's current strategy for investigating vadose zone conditions?

We directed much of our review on wastes that have leaked from storage tanks and, to a lesser extent, on the effects that other programs and activities at the site have had on the vadose zone.

Results in Brief

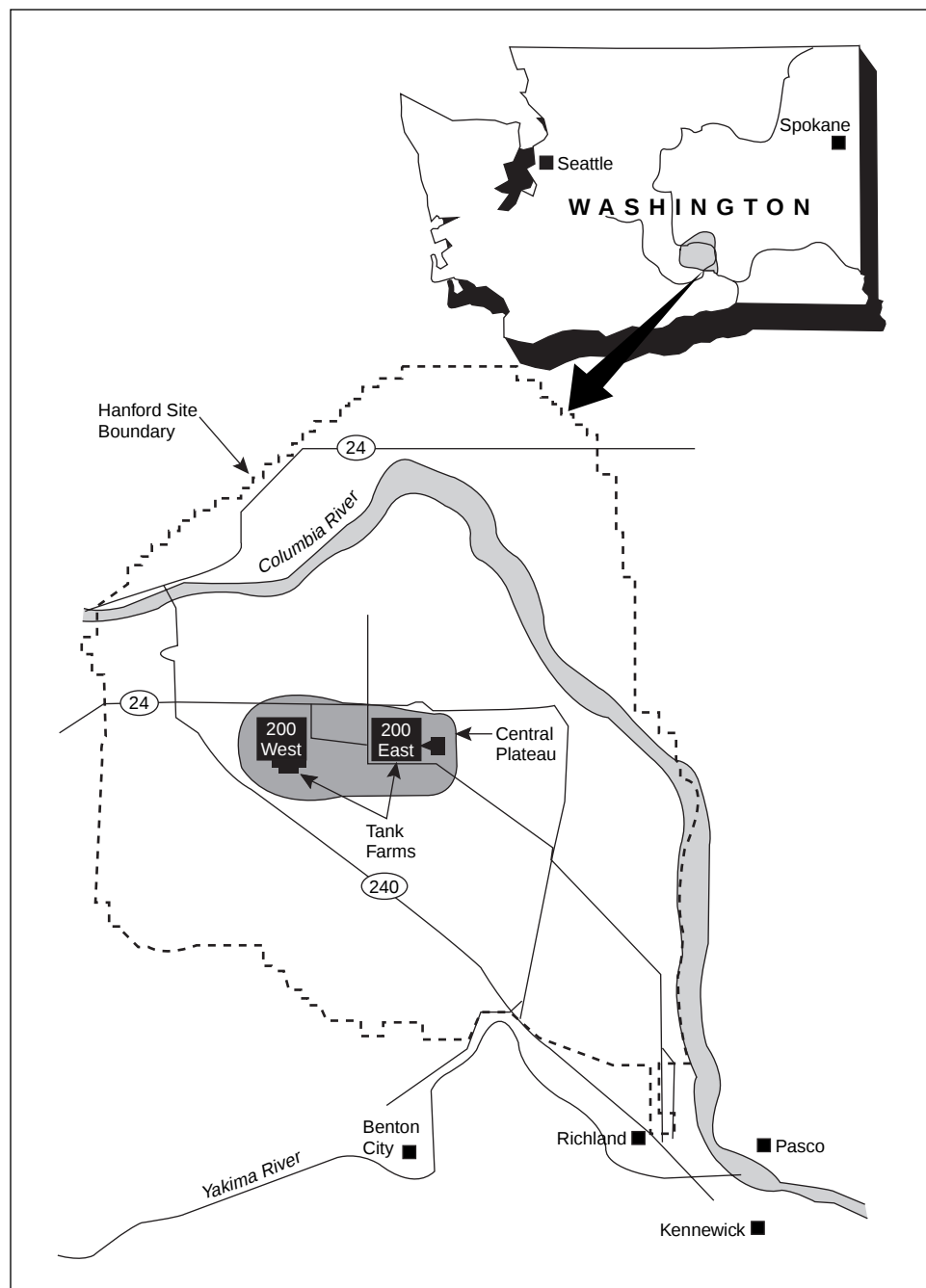
DOE's own reviews conclude what outside experts have been saying for some time: The Department's understanding of how wastes move through the vadose zone to the groundwater is inadequate to make key technical decisions on how to clean up the wastes at the Hanford Site in an environmentally sound and cost-effective manner. For many years, DOE assumed that wastes would move slowly, if at all, through the vadose zone. Therefore, DOE never issued a comprehensive plan to assess vadose zone conditions and funded few studies of the vadose zone. Outside experts have pointed out, however, that DOE cannot credibly estimate the site's long-term risk to the public or select the most efficient cleanup strategies

unless it understands conditions in the vadose zone. For example, the lack of knowledge about the vadose zone has major implications for how to go about retrieving the remaining wastes from tanks that have leaked or are leaking because at least one retrieval option would cause more liquid wastes to leak into the ground.

DOE has no strategy in place for investigating the vadose zone. DOE assigned low funding priority to most proposed studies of it, responded slowly to experts' recommendations for improving ongoing studies, did not integrate the information needs of the three organizational units responsible for cleanup activities, and does not know what information is needed to make key cleanup decisions. With the emerging evidence of waste migration from leaking tanks to the groundwater, DOE has begun to develop a strategy to investigate the vadose zone.

Background

DOE's Hanford Site is located in southeastern Washington State. The Columbia River flows in a southeastern direction through the northern part of the site and forms much of its eastern boundary. (See fig. 1.) As of 1995, about 175,000 people lived immediately downstream in and near the cities of Kennewick, Pasco, and Richland.

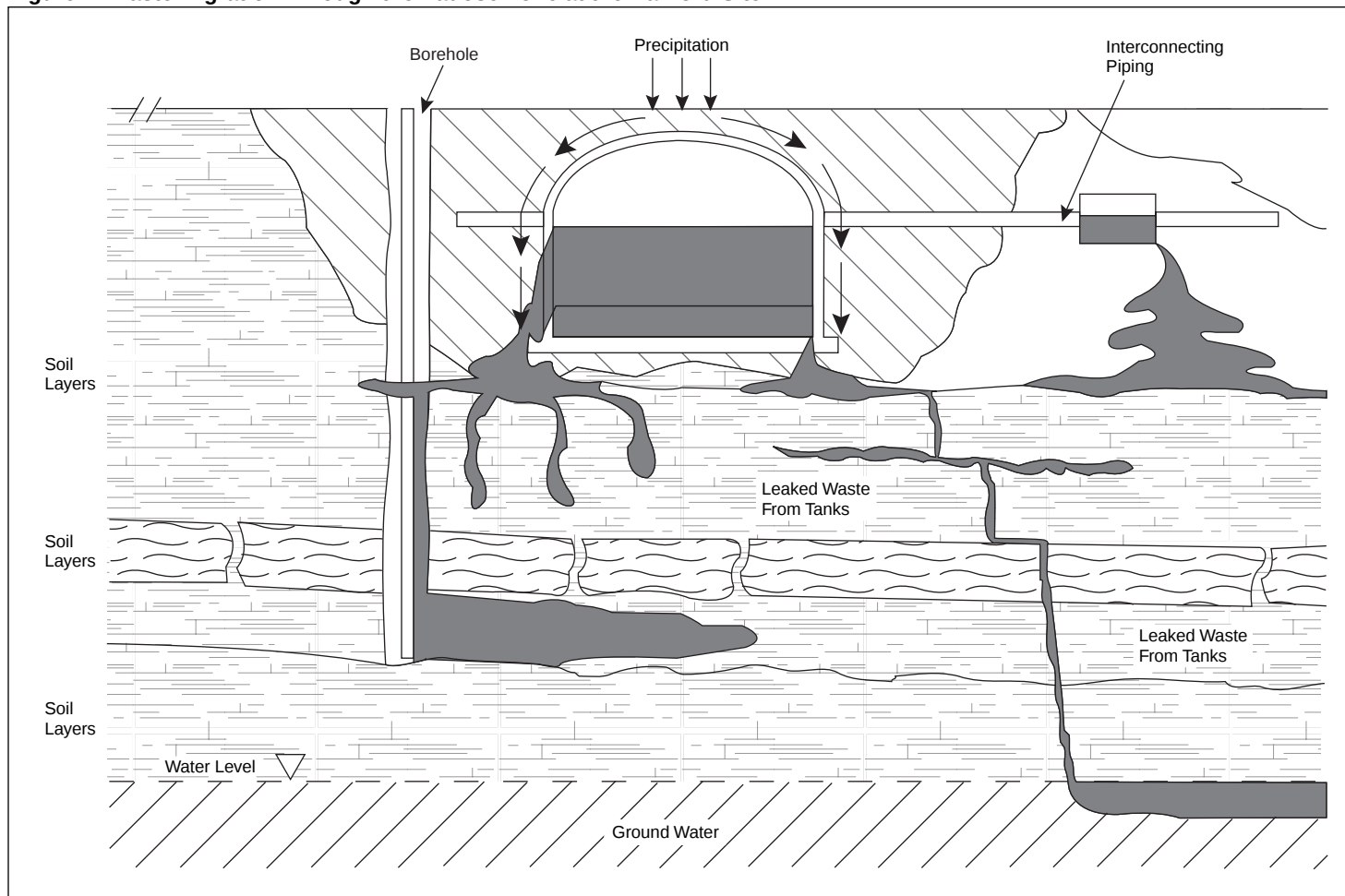
Figure 1: Location of the Hanford Site

Source: Based on a map provided by DOE.

At the Hanford Site, DOE and its predecessor agencies produced materials for nuclear weapons from the 1940s until mid-1989. DOE estimates that these production activities resulted in about 450 billion gallons of liquid waste. DOE released most of this waste directly into the ground through about 300 cribs,¹ ponds, and trenches that are now awaiting final cleanup. The groundwater under more than 85 square miles of the site is contaminated above current standards.

DOE is storing about 54 million gallons of the most radioactive and hazardous wastes in 177 underground tanks pending permanent disposal. Of the 177 tanks, 149, called single-shell tanks, have a single layer of carbon steel encased inside a concrete outer wall, while 28 double-shell tanks have two layers of carbon steel inside the concrete casing. The tanks, arranged in groups or “farms” of several tanks, and most of the cribs, ponds, and trenches are located in the “200 East” and “200 West” areas at the center of the Hanford Site. (See fig. 1.) Beneath the 200 areas, the vadose zone is between 200 and 300 feet thick and is made up of sand, silt, and gravel above a layer of volcanic rock. (See fig. 2.)

¹A crib is an underground structure designed to allow liquid wastes to percolate to the soil.

Figure 2: Waste Migration Through the Vadose Zone at the Hanford Site

Source: Based on an illustration from DOE.

Over time, many of the single-shell tanks developed leaks—DOE currently assumes that 67 tanks have leaked between 600,000 and 900,000 gallons of wastes.² Radioactive materials that have leaked include cesium, strontium, tritium, technetium, iodine, plutonium, and uranium. Some of these materials remain radioactive for hundreds of thousands of years. Nonradioactive but hazardous materials that have leaked include nitrates and metals such as chromium.

²These amounts do not include recent estimates using a new approach that found that leaks could be much higher on some tanks, nor does it include the wastes lost due to surface spills and leaks in pipelines.

The Hanford Site's approximately 14,000 employees are now primarily monitoring and cleaning up the radioactive and hazardous wastes generated by the previous production of nuclear weapons materials. Cleaning up the wastes stored in the single- and double-shell tanks, a project that DOE calls the Tank Waste Remediation System (TWRS), is the largest and most technically complex environmental project DOE has attempted. DOE's most recent estimate, made in 1998, is that it will cost about \$50 billion (in current dollars) to retrieve the wastes from the tanks, separate the wastes into low-level and high-level portions, and prepare the low-level wastes for disposal at the site and the high-level wastes for disposal in a geologic repository.³ In fiscal year 1997, the TWRS program cost about \$314 million.⁴ In fiscal year 1998, DOE expects to spend about \$332 million on the program.

Cleanup of the Hanford Site is being conducted under the Hanford Federal Facility Agreement and Consent Order signed by DOE, the Environmental Protection Agency (EPA), and the Washington State Department of Ecology. This document, commonly called the Tri-Party Agreement, established cleanup requirements for Hanford. For example, in amendments agreed to in 1994, the three parties set a goal of retrieving 99 percent of the wastes from single-shell tanks, which are more susceptible to leakage. Under the agreement, DOE was required to begin retrieving wastes from the first tank by October 31, 1997, and complete the retrieval of wastes from all single-shell tanks by 2018.⁵

Primary responsibility for cleaning up the Hanford Site, including the vadose zone, is divided among three organizations within DOE's Richland Operations Office. First, the TWRS project office is responsible for managing and cleaning up the single- and double-shell tanks, the related facilities such as piping systems, and the vadose zone surrounding the tanks. Second, the Environmental Restoration unit is responsible for

³Under the Nuclear Waste Policy Act of 1982, as amended, DOE is investigating a site at Yucca Mountain, Nevada, for possible use as a repository for permanent disposal of spent (used) fuel from civilian nuclear power plants and the Department's high-level radioactive wastes now stored at the Hanford Site and at sites in Idaho, New York, and South Carolina.

⁴In total, DOE received about \$1.1 billion for cleanup programs at Hanford in fiscal year 1998. In addition to the TWRS program, funds were allocated to the cleanup and monitoring of other waste sites and removal of old facilities (\$135 million), management of spent fuel (\$152 million), facility deactivation (\$129 million), and other programs (\$369 million). DOE also received an additional \$115 million for its TWRS privatization program.

⁵DOE did not begin retrieving wastes from the first tank by the required date. The Department requested an extension to November 30, 1998, from the Washington State Department of Ecology, which is the lead regulator for the cleanup of the Hanford Site. The Department of Ecology denied this request on February 12, 1998.

cleaning up closed facilities and for the vadose zone under the hundreds of inactive liquid waste disposal facilities such as ponds, trenches, and cribs. Finally, the Waste Management unit is responsible for stored and newly generated wastes and related operational facilities, including the vadose zone under these wastes and facilities. DOE's Assistant Secretary for Environmental Management provides policy direction to each of these three organizations.

Although cleanup of the site is not expected to be completed until 2048, many key cleanup milestones specified in the Tri-Party Agreement occur much sooner. Some of these milestones include starting retrieval by 1997 (a milestone that DOE did not meet), permanently closing one single-shell tank by 2003, and closing the remaining single-shell tanks by 2024. DOE must also finish the investigation of all of the other waste sites (such as the cribs, ponds, and trenches) by 2008 and any resulting remediation by 2018.

DOE's Understanding of the Vadose Zone Is Inadequate for Making Key Technical Decisions

The field investigations of the vadose zone that DOE has recently performed led to the Department's December 1997 announcement that some wastes had migrated from leaking storage tanks to the groundwater. This finding invalidated the Department's long-held position that the vadose zone would protect the groundwater. The finding also prompted DOE to agree with independent experts that the Department needs to improve its understanding of vadose zone conditions to help it select safe, cost-effective cleanup strategies.

The Importance of the Vadose Zone

The vadose zone is an important component of a complex environment at the Hanford Site. To clean up the site, DOE will have to make a number of key technical decisions related to emptying and permanently closing the tank farms and remediating the many cribs, ponds, and trenches. Making these decisions will require DOE to demonstrate that the residual contamination at the site does not present unacceptable risks of increased pollution to the Columbia River or harm to nearby residents. When existing containers, such as single-shell tanks, fail, the vadose zone is the only remaining barrier to groundwater contamination.

One illustration of the importance of understanding the vadose zone can be seen in DOE's current plans for retrieving wastes from single-shell tanks. DOE has transferred most of the pumpable wastes from 119 of the 149 single-shell tanks into double-shell tanks, but left behind are wastes that

have solidified to the point that they could not be pumped. As part of its effort to remove and treat 99 percent of the wastes in the single-shell tanks, DOE currently proposes to use large volumes of water injected under pressure to dissolve much of the remaining wastes so that they can be pumped from the tanks. DOE estimates that this approach, called sluicing, could allow as much as another 596,000 gallons of wastes to leak from the tanks into the vadose zone.

DOE has assumed that leaks from sluicing operations averaging 4,000 gallons will occur. However, in commenting on DOE's waste retrieval plans, the National Research Council (the principal operating agency of the National Academies of Sciences and Engineering) noted that the risks from additional leakage must be analyzed. Also, the Council contends that an inadequate understanding of how wastes behave in the vadose zone precludes rationally selecting a tank waste retrieval and treatment alternative. DOE is planning to try approaches other than sluicing that may have lower potential for creating additional leaks.

Proper understanding of the vadose zone is critical in moving ahead on this issue. If the vadose zone allows very little of the radioactive or hazardous wastes to reach the groundwater, cleanup strategies that add to the amount of wastes in the ground, such as sluicing leaking waste tanks, may not eventually lead to excessive contamination of groundwater. However, if such materials can pass through the vadose zone and into the groundwater with relative ease, such strategies may be inappropriate.

Acquiring a better understanding of what is occurring in the vadose zone would also help resolve questions about the appropriateness of two ongoing activities at Hanford that might be contributing to contamination of the vadose zone. First, DOE is covering underground storage tanks with more gravel. According to studies funded by DOE, the use of gravel allows rain and snow to drive leaked wastes toward the water table. Second, DOE has proposed to slow down its program to transfer liquid wastes from single-shell tanks into double-shell tanks. DOE had expected to complete this program in 2000 but does not now expect to complete the program until 2003. Washington State regulators are concerned that additional wastes could leak into the vadose zone before they can be pumped. (See app. II for details on these ongoing activities.)

DOE Has Focused Limited Attention on Monitoring Vadose Zone Issues

DOE's efforts to date to develop an understanding of conditions in the vadose zone have been limited. First, according to the TWRS vadose zone program manager, over the past several decades, DOE built its waste

Assumption That Vadose Zone Acts as a Barrier

disposal strategy on the assumption that the vadose zone would prevent most wastes from migrating down to the groundwater without setting up a program for determining whether its assumption was correct. Second, according to officials of DOE and Washington's Department of Ecology, there is no requirement in law—similar to that for groundwater—for monitoring contamination of the vadose zone.

Early operations at the Hanford Site had assumed that wastes could be disposed of in the soil and that most of the contaminants would remain there. DOE estimates that it had disposed of over 350 billion gallons of wastes directly into the cribs, ponds, and trenches in the vadose zone beneath the 200 East and 200 West areas by the time it stopped this practice. As late as 1996, DOE was developing tank farm cleanup plans that were still based on the assumption that the vadose zone would act as a barrier. For example, DOE stated in a 1996 draft environmental impact statement for TWRS that certain contaminants, such as cesium, were assumed to be largely immobile in the vadose zone. In part on the basis of this assumption, DOE estimated that, even if it did not remove any wastes from the underground tanks, some of the wastes would still not reach the groundwater for more than 10,000 years after all of the tanks had eventually begun to leak.

Cautions and concerns raised by us and others about the possible movement of materials through the vadose zone were largely set aside. For example, in 1989, we reported that DOE faced a mounting body of evidence indicating that its assumption about the immobility of wastes in the vadose zone was incorrect and recommended that DOE gather sufficient data to assess the risks from tank leaks.⁶ The next year, a review team, called the "Tiger Team" and composed of technical specialists from DOE's headquarters and other locations within its complex of nuclear sites, said that DOE's understanding of the site's hydrology was too poor to guide remedial actions. According to DOE's groundwater program manager, however, neither of these reviews led DOE to assign proposed studies of the vadose zone high enough priority to be funded.

Since the 1960s, DOE has monitored the vadose zone near the single-shell tanks for the limited purpose of detecting and estimating the size (in gallons) of leaks from the tanks. DOE used probes to measure one type of radiation in the nearly 800 "boreholes" that it drilled over the years through the sand and gravel in the vadose zone in and around the tank

⁶Nuclear Waste: DOE's Management of Single-Shell Tanks at Hanford, Washington (GAO/RCED-89-157, July 18, 1989).

farms. (Hundreds of other boreholes are also located in and near many of the ponds, cribs, and other waste sites.) The scope of this monitoring program, however, did not include measuring how much of the wastes is moving in the vadose zone, how fast the wastes are moving, and the identity of specific radionuclides.

DOE also has a limited understanding of the behavior of contaminants placed in hundreds of cribs, trenches, and other waste sites above the groundwater. For example, DOE has not routinely monitored waste sites other than the tank farms since 1988, and earlier monitoring of these sites was limited and sporadic. In fiscal year 1996, DOE analyzed some wells located near about 20 waste facilities and found that wastes can continue to migrate long after facilities are no longer used. In commenting on a draft of this report, DOE said that, at the request of stakeholders, it has concentrated vadose zone activities on liquid disposal sites along the Columbia River because these sites pose the most immediate threat to the river. DOE also said that most liquids discharged into cribs, ponds, and trenches were in relatively dilute form and that less mobile contaminants are retained in the soil.

Although DOE's monitoring of these other waste sites has been limited, most of the contamination in the 200 areas comes from the cribs, ponds, and trenches. According to DOE's project manager, the Department has proposed some analysis of these waste sites with about \$800,000 allocated for fiscal year 1998. DOE's Grand Junction (Colorado) Office has informally proposed extending its recent study of the vadose zone under the single-shell tank farms to include many of these other waste sites, but DOE has not funded this proposal.⁷

No Vadose Zone Regulatory Requirements

DOE's lack of emphasis on developing an understanding of the vadose zone conditions is also due to the absence of an explicit requirement in law, regulation, or in the Tri-Party Agreement to investigate or monitor the vadose zone. An official of Washington State's Department of Ecology told us that it did not impose such a requirement in the agreement because he believed no clear authority exists for the agency to do so. In contrast, under the Resource Conservation and Recovery Act (RCRA) of 1976, as amended, and the Tri-Party Agreement, DOE is required to monitor groundwater in waste site areas. Also, under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of

⁷The team is using data from the approximately 800 existing boreholes in the tank farms to establish a baseline of information about contamination distributed in the vadose zone near the single-shell tanks.

1980, as amended, where relevant and appropriate, the groundwater must be cleaned up to meet safe drinking water standards.

This situation may now be changing. Under the groundwater monitoring requirements of RCRA, DOE has been assessing the quality of the groundwater under three groups of single-shell tank farms (a total of eight tank farms) to determine whether or not the tanks in these farms are the sources of contamination detected in the groundwater. The results of these assessments led DOE to conclude that wastes from tanks that have previously leaked have migrated to the groundwater. Therefore, in accordance with EPA's groundwater monitoring regulations, DOE is beginning more detailed assessments of the extent of contamination and potential treatment options. For these assessments, the regulatory agency under RCRA—in this case Washington's Department of Ecology—has the authority to require DOE to, among other things, investigate conditions in the vadose zone and develop a specific plan for a groundwater quality assessment program at the site.

DOE's Recent Findings About the Vadose Zone Contradict the Department's Long-Standing Assumption That It Acts as a Barrier

Beginning in 1994, DOE's Grand Junction Office, using technology developed to detect uranium ore deposits, performed tests in about 800 existing boreholes in the single-shell tank farms. These tests were primarily intended to provide baseline information about the distribution of certain radioactive wastes around the tanks.⁸ However, the tests also enabled the Grand Junction team to identify radioactive substances at considerable depths in the vadose zone. DOE program managers said that this work has greatly enhanced DOE's understanding of vadose zone conditions to a depth of 75 to 150 feet and provided some information about conditions down to the groundwater more than 200 feet beneath the land surface. In tank farms where the Grand Junction team has completed its work, the team has been able to develop visual representations of how contaminants are distributed around the waste storage tanks. In addition, the team found indications of possible new leaks in some tank farms and deep contamination by some radionuclides in several farms.

The Grand Junction team's findings led Washington's Department of Ecology to request DOE to assess whether contaminants had migrated from a specific tank farm to the groundwater. In addition, since 1993 DOE had been conducting a similar assessment at three other tank farms. At a

⁸Radioactive wastes contain three types of radiation. One of these types—gamma—is, like radio waves, electromagnetic radiation. The equipment used by the Grand Junction team detects radioactive isotopes, such as cesium, that emit gamma radiation. The equipment does not detect other types of radiation.

November 1997 news conference, DOE released draft reports confirming that groundwater testing at two groups of tank farms had found that wastes from the tanks and/or related equipment, such as pipes connecting the tanks, had migrated to the groundwater. DOE has acknowledged that there are significant uncertainties and data gaps in the understanding of the inventory, distribution, and movement of contaminants in the vadose zone. This information is essential, DOE has added, in evaluating the effects of releases of radioactive or hazardous wastes to the environment.

Other recent findings about tank leaks and migration of wastes in the vadose zone include:

- DOE announced in February 1996 and September 1997, respectively, that its Grand Junction team had found cesium 125 feet below one single-shell tank farm and just above the water table under another tank farm. After deepening the well near the first tank farm, DOE found cesium at a depth of 142 feet and technetium at 177 feet, according to the lead scientist on the project.
- An October 1996 draft report prepared for DOE by its Los Alamos National Laboratory analyzed the history of leaks at one tank farm and concluded that the leaks from four tanks may have been 3 to 6 times greater than previously reported.
- In January 1998, DOE released a draft groundwater quality assessment report by its Pacific Northwest National Laboratory for a group of three single-shell tank farms, stating that wastes from one farm has reached the groundwater.

Reviewers Criticized DOE's Understanding of Vadose Zone Conditions

Several times from 1994 through 1997, outside reviewers, such as the National Research Council, questioned DOE's understanding of contamination conditions in the vadose zone and the potential effects of the contamination on the groundwater. In March 1996, for example, DOE asked the Council to review its draft environmental impact statement for the TWRS program. In a September 1996 report, the Council concluded the following:

- An important component of a long-term commitment to remediating the single-shell tanks is an adequate understanding of the extent to which the soil and groundwater beneath the tanks have been contaminated. Characterization (scientific investigation) should continue until such an understanding has been obtained.

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- It is not evident how a tank waste retrieval and treatment method can be rationally selected without also considering what is to be done with the contamination left behind.
 - Adequate characterization of the tank wastes and surrounding contaminated environment (in the vadose zone) will be required for processing of wastes that are removed for treatment and for the disposition of wastes not removed from the tanks either by choice or necessity. To assess risks associated with wastes removal, processing, and in-place disposition, DOE needs a better understanding of what wastes have already leaked and how rapidly the wastes are moving. Leakage from the tanks caused by sluicing, as well as the risk associated with waste left in the tanks, must be analyzed in the context of overall risks posed by the Hanford Site. Finally, DOE needs to be concerned about wastes at other nearby waste sites.

In response, DOE acknowledged that there was a high degree of uncertainty about the level of contaminants in the vadose zone and revised the final environmental impact statement accordingly.

The Council's conclusions about obtaining a better understanding of the vadose zone to help in analyzing risks were similar to earlier findings of the Defense Nuclear Facilities Safety Board.⁹ In 1994, the Board found that DOE needed to estimate the overall risk posed by each of its nuclear sites (such as the Hanford Site) and not just the risks from each individual activity or facility at each site. In a recommendation covering all of DOE's nuclear sites, the Board said that DOE should quantify the cumulative risk of harm from all of its facilities at each nuclear site. According to the Board's staff, implementing this recommendation at Hanford would require an understanding of conditions in the vadose zone.

The most detailed outside review, in terms of the amount of feedback provided to DOE, was conducted by a panel of four vadose zone experts from 1996 and 1997. DOE convened the panel in 1996 to resolve the issue of whether the cesium that the Grand Junction team had found 125 feet below one tank farm indicated migration through the vadose zone or movement of the material down the borehole. The panel concluded that it is likely that large quantities of cesium (and other contaminants) are reaching the depths to which it has been detected along narrow pathways in the formation. Similar to the National Research Council, the panel concluded that

⁹The Board was created by the Congress to make recommendations to the Secretary of Energy, related to DOE's nuclear operations and wastes, to ensure the protection of public health and safety.

“Characterization of the vadose zone is an essential step toward understanding contamination of the groundwater, assessing the resulting health risks, and defining the concomitant groundwater monitoring program necessary to verify the risk assessments.”

The panel added that reliable computer models of groundwater contamination cannot be developed without reliable data on the transport of contaminants within the vadose zone. That subject, according to the panel, is poorly understood and, as a result, previous and ongoing computer modeling efforts are inadequate and based on unrealistic and sometimes optimistic assumptions. The panel characterized the output of such models as “entirely unreliable.”

The panel made about 20 recommendations to DOE, including a recommendation that the Department comprehensively study the vadose zone. DOE generally agreed with the panel’s conclusions and is implementing many of the recommendations. The lack of funds is one reason DOE gives for not implementing the remaining recommendations.

DOE’s most recent response to this growing body of research and evaluation came in a January 1998 report to the Secretary of Energy by an internal management team. The team’s report, which dealt with management of the TWRS (tank farm) program, found that many key questions remained unresolved about contamination in the vadose zone. The team concluded that the program lacked credibility in part because the program had not timely acknowledged the information it possessed about the extent of contamination in the vadose zone. The team concluded that

“Without significant and diligent management attention, these credibility issues and the lack of adequate characterization of vadose zone contamination could affect implementation of future regulatory milestones for waste retrieval and tank closure.”

DOE Recognizes That It Needs a Strategy for Investigating the Vadose Zone

Because DOE believed that most wastes from leaking tanks would not migrate to the groundwater, it did not see the need for a comprehensive program for investigating the vadose zone. Therefore, studies of the vadose zone were assigned relatively low priority for funding, and the limited funds used for vadose zone activities were not always spent efficiently. The division of responsibilities for assessing conditions in the vadose zone among three organizational units also contributed to the low priority assigned to this subject because each unit typically viewed the subject only from the narrow perspective of its own cleanup operations.

With the emerging evidence of waste migration to the groundwater, however, DOE now recognizes that it needs a better understanding of vadose zone conditions and, therefore, has begun to develop a strategy for investigating the vadose zone.

DOE Has Not Had a Comprehensive Program for Investigating the Vadose Zone

DOE has based past efforts on what, given the many competing demands for funds, it believed it could afford rather than on a clear sense of what was needed to understand vadose zone issues. For example, in our 1989 report, we recommended that the Department investigate leakage of wastes from tanks into the vadose zone. Although DOE agreed with our recommendation, its subsequent drilling of one new borehole used up all of the money the Department was willing to spend on this investigation. In this borehole, located near the tank with the largest confirmed leak volume, DOE found mobile contaminants 121 feet below ground level. Scientists working on this project recommended that DOE conduct additional studies, but the Department, citing a lack of funds, declined.

This same pattern has continued as concerns about the vadose zone mounted. For example, the Grand Junction team investigating old boreholes proposed improvements costing about \$600,000 that would better define the contamination, enhance measurement in highly contaminated areas, and allow moisture and temperature monitoring. Several of these improvements had been recommended by DOE's expert panel on the vadose zone. DOE has implemented one proposal costing about \$100,000; however, citing budgetary concerns, the Department has not yet implemented the other recommendations.

Because DOE has never developed a comprehensive plan for investigating the vadose zone, it also has not determined the funding level required to obtain the understanding of vadose zone conditions needed for future cleanup decisions and activities. Nevertheless, some managers involved with the limited ongoing vadose zone activities believe that they have already identified more essential investigations than can be completed with the current level of funding. Yet, in recent years DOE reduced funding levels for vadose zone work in favor of what it decided was higher-priority work. For the TWRS vadose zone program, for example, the funding level of \$5.5 million in fiscal year 1994 declined to about \$3.3 million in fiscal year 1997.¹⁰ For fiscal year 1998, DOE has budgeted \$4 million and has requested \$4 million in 1999 for the TWRS vadose zone program.

¹⁰In fiscal year 1997, some amounts were spent on vadose zone activities other than those for this specific program, but DOE budget documents did not clearly identify the amounts.

The manager for the TWRS vadose zone program developed two alternative plans for fiscal year 1998. According to this manager, either of the two alternative plans, which he estimated would cost \$8 million and \$12 million, respectively, would have enabled the program to make significant progress in implementing the recommendations of the expert panel on the vadose zone. However, even these more ambitious plans were less than what one member of the expert panel suggested that DOE needs for an adequate understanding of conditions in the vadose zone. In that member's view, the Department needs to drill one well a year in each of the tank farms for several years—at a cost he estimated at about \$18 million a year.

With the limited amount of funds available for vadose zone work, it is important for DOE to spend these dollars as effectively as possible. Our review of recent TWRS vadose zone expenditures showed this has not necessarily occurred. We reviewed two major drilling projects in which work was marked by false starts, frequent interruptions, and poor coordination. These projects are described in appendix III.

DOE's Richland Office also spends a large portion of vadose zone expenditures for functions other than field work. While drilling boreholes and supporting Grand Junction's baseline characterization effort are the two largest expenditures of the office's \$4 million budget for vadose zone activities in fiscal years 1998, DOE is devoting about 25 percent of the budget to oversight, management, and other administrative activities. (This amount is separate from, and in addition to, normal administrative costs that are factored into all field projects.) As a result, the amount of characterization work that can be done is limited.

DOE's approach of dividing vadose zone responsibilities across operating units has been a contributing factor to the low priority the vadose zone has received. Under this approach, three different organizational units have been responsible for understanding those aspects of the vadose zone that related to their programs—TWRS for the tank farms, Environmental Restoration for closed waste disposal sites and other facilities, and Waste Management for stored and newly generated wastes. One way in which this divided responsibility contributed to lowering the priority for vadose zone issues can be seen from DOE's initial attempt to develop a comprehensive plan for investigating the vadose zone. In a 1992 report, we recommended that DOE develop such a plan.¹¹ DOE concurred and began

¹¹Nuclear Waste: Improvements Needed in Monitoring Contaminants in Hanford Soils (GAO/RCED-92-149, July 6, 1992).

planning efforts. However, in October 1994 DOE reassigned vadose zone responsibilities from one group to the three programs and never issued the plan.

DOE's three primary organizational units at Hanford have also typically viewed the issue of vadose zone contamination from the narrow perspectives of their respective cleanup responsibilities. For example, the recent studies of the migration of wastes through the vadose zone have focused on wastes that have leaked from the tank farms. The tank farms, however, are just one source of groundwater contamination. In fact, when measured by volume, DOE has pumped the largest quantity of liquid wastes directly into the ground. Yet, for a number of years the Department has not conducted any systematic monitoring of the migration of wastes from other waste sites.

DOE has drilled thousands of wells, conducted numerous other investigations of soil conditions and contamination, and has compiled historic information on the Hanford vadose zone, including the 200 area, in what it calls aggregate area management system reports. However, the Department has never synthesized this information to determine what useful information it has already collected and what gaps exist in this information. As a result, DOE does not know what additional information is needed, and at what cost, to enable the Department to achieve its cleanup objectives and milestones. For example, in the Tri-Party Agreement, DOE has committed to close its single-shell tanks and hundreds of other waste sites outside the tank farms by 2024. A sufficient understanding of conditions in the vadose zone beneath and around these waste sites is necessary to ensure that this milestone can be met. Such an understanding, for example, could help DOE determine whether expensive covers need to be placed over the various waste sites or if lesser measures are sufficient. According to experts among DOE's contractors, developing adequate information on waste migration may require several years of monitoring data.

Key Considerations in Developing a Workable Strategy

DOE has begun to develop a strategy for investigating vadose zone conditions. As of February 1998, DOE had taken steps to provide greater attention from management, develop an investigation plan, seek the views of outside experts and stakeholders, and improve internal coordination. (Table 1 summarizes these actions as described by DOE.) These steps appear to be in the right direction. Whether the steps will ultimately be successful depends, in our view, on how well DOE addresses the issues of

(1) the relative funding priority of vadose zone studies among competing demands for funding site cleanup activities, (2) leadership and accountability for developing and implementing the vadose zone plan, and (3) building technical credibility into the vadose zone plan.

Table 1: Summary of Recent Vadose Zone Actions Announced by DOE

Action	Status as of February 1998
Development of an overall plan	Bechtel Hanford, the Environmental Restoration program's main contractor, has been directed to take the lead in developing a plan. The framework for the plan is to be completed in February 1998.
Greater management attention	DOE's vadose zone and groundwater management strategies are being reviewed by the Office of the Under Secretary of Energy to assess issues surrounding groundwater contamination and the vadose zone.
Improved coordination among responsible organizations	Environmental Restoration, TWRS, and Waste Management have signed a memorandum clarifying how the three organizations will coordinate vadose zone responsibilities. Environmental Restoration has been directed to lead the Hanford-wide integration effort.
Review by outside experts	DOE is reviving its use of the independent panel of vadose zone experts.
Stakeholder involvement	A Hanford-wide team of stakeholders for vadose zone issues has been identified but has not met. TWRS program management established its own team of stakeholders to coordinate and plan vadose zone activities. The team is made up of representatives of site contractors, Washington State, the state of Oregon, regulators, and affected Indian tribes. This team has held several meetings.
Geophysical characterization ^a	DOE will continue the characterization projects of the team from its Grand Junction Office until the projects have been completed (expected in Apr. 1999).
Drilling	DOE plans to drill another borehole to sample the soil in the vadose zone. Additional wells may be needed in the future.

^aLowering radiation-measuring instruments into wells permits the identification of gamma-emitting radioactive elements and the measurement of their concentrations.

Although DOE now recognizes that it needs a better understanding of vadose zone conditions, it has not yet determined if it will make more funds available for vadose zone studies and, if so, where the funds will come from. As discussed earlier, the vadose zone is an important component of a complex environmental system. Overall clean up at Hanford will require DOE to make a number of key technical decisions related to emptying and permanently closing the tank farms; remediating the many cribs, ponds, trenches, and other waste sites; and assessing the effects of these decisions on the vadose zone. Making these decisions will require DOE to demonstrate that the residual contamination of the vadose zone from all sources on the site does not present unacceptable risks. Only when the significance of vadose zone studies to the overall cleanup of the site has been made clear will DOE be in a good position to fund—or not fund—these studies.

DOE has also begun to address the leadership of, and accountability for, the new vadose zone strategy. First, the Secretary of Energy has tasked the Under Secretary of Energy with reviewing Hanford's programs for vadose zone and groundwater management. Also, in August 1997, the Environmental Restoration, TWRS, and Waste Management programs agreed to coordinate their activities. Subsequent refinements have led to the Environmental Restoration unit's taking the overall lead in coordinating vadose zone efforts. In conjunction, the integrating contractor for this program is developing an approach to an overall plan. Although these steps are promising, much hard work remains. In its January 1998 report to the Secretary, the management review team captured the amount of organizational shifting that will have to take place:

“Even with the reorganization, the task of coordination and integration will be significant and require considerable attention by [DOE-Richland] senior managers. The new MOA [memorandum of agreement] still faces a myriad of implementation and coordination issues because of the many organizations that still have key responsibilities for issues that cross over both the vadose zone and groundwater programs. Additionally, the site is still operating under different program management plans for [the Hanford tank waste initiatives], vadose zone, and groundwater. The actual staff work is being done by two major integrating contractors—Bechtel Hanford and Fluor Daniel—and Lockheed Martin Hanford Company, a subcontractor to [Fluor Daniel], where much of the actual vadose zone work is being conducted. All of these factors suggest that a high degree of coordination will ultimately be required if the site is to build credibility with external parties.”

There also are signs that DOE's efforts still do not reflect an integrated approach among organizational units at the Hanford Site. For example, DOE's management review team was critical of recently released draft reports confirming that tank wastes were contributing to the contamination of groundwater. The team noted that the reports contain little discussion of or data from previous attempts to characterize the vadose zone. The team concluded that "The clear lack of substantive discussion of the links between available vadose zone and groundwater data suggest the degree to which the two [vadose zone and groundwater] programs have yet to be integrated."

Finally, to help ensure that the new strategy will be credible, DOE intends to seek the participation of its panel of independent vadose zone experts and Hanford stakeholders in developing and implementing the strategy. A 1993 report by the Secretary of Energy Advisory Board's Task Force on Radioactive Waste Management found a widespread lack of public trust in DOE activities. The task force attributed this problem to the public's experiences with the Department. This problem also affects the vadose zone program today, as DOE's management review team found that external credibility issues continue with the program. Examples cited in the review team's January 1998 report include tardiness by DOE in acknowledging the extent of contamination of the vadose zone, unresponsiveness to recommendations by independent experts, and difficulties in moving towards a new organizational structure for managing vadose zone issues.

One option potentially available to DOE in improving its credibility is greater reliance on independent technical staff and review by outside experts. The use of independent technical staff has already been important in the recent progress DOE has made in understanding the vadose zone under the tank farms. DOE used the team from its Grand Junction Office to analyze the extent of potential contamination and, when controversy developed over the team's findings at one location, DOE brought in the expert panel to provide further guidance. Using staff who have established credibility on the issues and who are independent could greatly enhance stakeholders' confidence.

DOE's responses to the efforts of independent technical staff and outside technical experts, however, have not always been effective. Three examples illustrate this point. First, the original Grand Junction baseline characterization project was scheduled to last 3 years, be completed in 1997, and cost about \$8.6 million. However, DOE has not funded several

proposed program improvements in the last 3 years and diverted some of its resources to support other efforts, such as the new boreholes. As a result, completion of the original project will now cost about \$10 million and require almost 5 years, ending in 1999.

Second, DOE committed to further use of the expert panel on the vadose zone but did not use the panel again for almost a year after the panel had issued its report. Although DOE has developed a schedule for implementing the panel's recommendations, some efforts have been delayed due to a lack of funds. According to DOE's manager for the TWRS vadose zone program, DOE disagrees with some of the panel's recommendations, such as the need for having an independent group perform computer modeling of how waste contaminants may be transported through the vadose zone.

Third, DOE has been slow to address recommendations by independent technical experts for improving ongoing projects such as the computer modeling that DOE uses to simulate the movement of waste contaminants through the vadose zone. As discussed earlier, reviews by the National Research Council and the panel of vadose zone experts in 1996 and 1997 had both been critical of the modeling methods DOE was using. Subsequently, DOE's management review team reported in January 1998 that DOE's Richland Office did not appear to be actively addressing the experts' recommended changes to the models. The team concluded that "Prompt implementation of the experts' recommendations, or explanations why recommendations are not being pursued, would greatly enhance the program's credibility."

DOE has other nuclear waste management programs that it could draw on to help enhance, through systematic external review, the credibility of future efforts to characterize the Hanford Site vadose zone. At Hanford, for example, the Department could adapt procedures for obtaining external reviews that it follows in its projects to investigate Yucca Mountain, Nevada, and the Waste Isolation Pilot Plant near Carlsbad, New Mexico, as potential sites for the permanent disposal of certain nuclear wastes. On both of these projects, organizational and procedural requirements for periodic independent reviews have contributed to better science and, therefore, increased the credibility of scientific methods and results. In this regard, the TWRS management team cited the need for greater ongoing use of expert panels and for greater diligence in responding to and implementing expert panels' recommendations.

Conclusions

DOE's past efforts have left the agency unable to answer basic questions about what radioactive and hazardous wastes are in the vadose zone at the Hanford Site, how quickly these wastes are migrating, the degree to which they might contaminate the underlying groundwater, and the risks of such contamination to current and future residents of the surrounding area. Answering these questions is critical to proceeding with the overall cleanup of the Hanford Site because the answers will affect the selection of cleanup strategies and DOE's ability to comply with agreed-upon cleanup schedules.

DOE's proposal to inject water under pressure into waste storage tanks to dissolve hardened wastes illustrates the weakness in the Department's current understanding of conditions in the vadose zone. DOE acknowledges that this approach could allow additional wastes to leak into the vadose zone from tanks that have already leaked. Independent experts, however, have pointed out that the risks from additional leakage must be analyzed to determine if they are acceptable.

Although DOE's management recently made a strong commitment to dealing with vadose zone issues, past actions have not been encouraging. Ways to help ensure that the new strategy is successful include (1) identifying the information needed for future cleanup decisions and specifying how this information is to be obtained on time, (2) addressing leadership and accountability issues; and (3) adopting methods for ensuring that DOE's approach to the vadose zone—and the information that is collected—forms a technically credible basis for making cleanup decisions.

Recommendations

We recommend that the Secretary of Energy develop a comprehensive vadose zone strategy for the Hanford Site that addresses cleaning up the high-level waste tank farms and the cribs, ponds, trenches, and other waste sites. The strategy should do the following:

- Address the importance of understanding conditions in the vadose zone to ongoing cleanup activities and future decisions on cleaning up the Hanford Site. Examples of such activities and future decisions include, but are not limited to, (1) covering tank farms with gravel; (2) slowing the removal of wastes from single-shell tanks; and (3) deciding whether to retrieve wastes from leaking single-shell tanks and if so, how.
- Define leadership roles within DOE and its contractors. The overall leadership for this program should be clearly defined, with measurable

performance goals and accountability for meeting the goals established at the outset.

- Identify steps to ensure the credibility of the process and the information that is collected, such as review by stakeholders and subject matter experts.

We also recommend that the Secretary of Energy reevaluate, as soon as better information is available on the behavior of wastes in the vadose zone, the Department's proposed strategy of removing additional wastes from single-shell tanks by injecting pressurized water into the tanks.

Agency Comments and Our Evaluation

We provided a draft of this report to DOE for its review and comment. The Department's comments appear in appendix I.

DOE agrees with our recommendations and our assessment that significant uncertainties and data gaps exist in its understanding of the inventory, distribution, and movement of contaminants in the vadose zone at the Hanford Site. DOE said that addressing these uncertainties and data gaps is essential in evaluating the effects of radioactive or hazardous wastes on the environment. DOE also said that it will develop, by October 1998, a Hanford-wide plan for assessing waste contaminants in the vadose zone and groundwater that

- establishes a project office, staffed by representatives of the affected organizations, that will be responsible for developing a comprehensive vadose zone investigation program;
- includes scientific research and development of technology as major components of the plan so that DOE can develop and use optimal technologies for remediation of the vadose zone;
- identifies steps to contain contaminants; and
- provides for independent technical review and meaningful involvement by stakeholders.

From this description of DOE's proposed plan, it appears that DOE is responding to our recommendations.

DOE also said that it is taking steps to reduce the risk of contaminants' entering the vadose zone. These steps include requesting from the Congress a supplemental appropriation and approval to reprogram existing funds. If approved, the request would provide \$15 million for accelerated removal of pumpable liquids from waste storage tanks that are

suspected of leaking. Finally, DOE provided technical comments (1) updating the status of its ongoing vadose zone, waste retrieval, and technology development activities and (2) clarifying what it viewed as omissions or factually imprecise statements in our draft report. We have incorporated these technical comments, as appropriate, in our report.

We directed much of our review on wastes that have leaked from storage tanks and, to a lesser extent, on the effects that other programs and activities at the site have had on the vadose zone. To assess the adequacy of DOE's current understanding of the extent to which waste materials are moving through the vadose zone, we interviewed DOE officials at Hanford, Grand Junction, Colorado, and Washington, D.C. We also obtained and reviewed reports from these officials and officials of other DOE contractors at Hanford. We reviewed environmental impact statements and related documents; observed meetings of the Hanford Advisory Board; and discussed vadose zone issues with representatives of stakeholder groups, state and federal regulators, and outside experts, such as expert panel members and staff of the National Academy of Sciences.

To evaluate DOE's current strategy for investigating vadose zone conditions, we interviewed officials of DOE and its contractors who are responsible for the vadose zone and groundwater programs; observed various initiatives, such as meetings of the TWRS Vadose Zone Team; and reviewed information on DOE's program to extend the borehole in one tank farm. We also reviewed the report of DOE's TWRS management review team and interviewed the team's director. We performed our work from May 1997 through February 1998 in accordance with generally accepted government auditing standards.

As arranged with your offices, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days after the date of this letter. At that time, we will send copies to the Secretary of Energy and other interested parties. We will also make copies available to others upon request.

Please call me at (202) 512-3991 if you or your staff have any questions.
The major contributors to this report are listed in appendix IV.

A handwritten signature in black ink that reads "Gary L. Jones". The signature is written in a cursive style with a large, stylized "G" and "J".

Gary L. Jones
Associate Director, Energy,
Resources, and Science Issues

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Abbreviations

CERLCA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
DOE	Department of Energy
EPA	Environmental Protection Agency
GAO	General Accounting Office
RCRA	Resource Conservation and Recovery Act of 1976
TWRS	Tank Waste Remediation System

Comments From the Department of Energy



Department of Energy

Washington, DC 20585

March 5, 1998

Mr. Gary L. Jones
Associate Director
Energy, Resources, and
Science Issues
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Jones:

Thank you for providing the Department of Energy (DOE) with the opportunity to comment on the draft report, entitled "Nuclear Waste: Waste Migration at the Department of Energy's Hanford Site is Poorly Understood" (GAO/RCED-98-80), sent with your letter dated February 20, 1998. Our comments on the report are enclosed.

I appreciate the importance of understanding the science of how contaminants behave in the vadose zone for the protection of the groundwater and Columbia River. The understanding of this scientific question is of considerable importance to DOE in making key decisions in our waste management and environmental restoration programs at Hanford. Because of the scientific uncertainties, the Secretary asked the Under Secretary of Energy, Ernest Moniz, to give this matter his personal attention. The Environmental Management program is working with the Under Secretary to develop a Hanford site-wide plan for assessing contaminants in the vadose zone and groundwater by October 1998. Elements of the plan, as announced by the Under Secretary during his January 1998, visit to Hanford, include:

- Address organizational and technical fragmentation: Bechtel Hanford, Inc. has been assigned this project and will integrate these activities with other Hanford contractors, including the Pacific Northwest National Laboratory. Bechtel delivered a draft integrated management strategy on February 13, 1998, for the DOE's review and approval which will be made available for stakeholder input. As part of this strategy, the Richland Operations Office environmental restoration program is establishing an integrated project office to include the Hanford tank, waste management, and science and technology programs.
- Integrate science research and technology development as major components of the plan.

Appendix I
Comments From the Department of Energy

- Identify steps needed to contain contamination.
- Independent Technical Review by:
 - * Expanded Hanford site vadose zone expert panel,
 - * DOE laboratories, and
 - * National Academy of Sciences to examine generic vadose zone issue at DOE, including Hanford, and other sites in the West.
- Meaningful stakeholder involvement.

There are significant uncertainties and data gaps in our understanding of the inventory, distribution, and movement of contaminants in the vadose zone. This information is essential in evaluating the impact of radioactive or otherwise hazardous releases to the environment. In particular, the potential impact of these contaminants to the groundwater must be clearly understood.

I would like to elaborate further on our current efforts to develop a comprehensive strategy for investigating the vadose zone which includes the following three phases:

Phase I: Pre-Planning - Develop the planning approach for management and integration of the Hanford vadose zone and groundwater programs.

Phase II: Integration and Formulation - Organize and establish an integrated project management function to evaluate existing programs and determine the needs for a comprehensive program and what gaps in data exist. Establish a Richland Operations Office team to manage the effort.

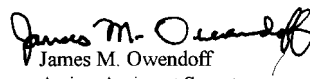
Phase III: Implementation - Carry out detailed work plans for priority activities in Fiscal Year 1999.

We expect to issue the draft integrated management strategy covering Phase I for comment later this month. The final plan will be available by October 1998. We would appreciate your input during our planning process, as appropriate.

Appendix I
Comments From the Department of Energy

I sincerely appreciate the effort that went into this report and the cooperation of the GAO audit staff in working with the Richland Operations staff in attempting to resolve their respective issues.

Sincerely,


James M. Owendoff
Acting Assistant Secretary
for Environmental Management

Enclosure

DEPARTMENT OF ENERGY COMMENTS

The DOE largely agrees with the recommendation of the General Accounting Office and acknowledges that there is a need to develop a site-wide strategy to assess the impacts of Hanford contaminants in the vadose zone and groundwater. The DOE also recognizes that protection of the groundwater beneath the Hanford site and of the Columbia River from contaminants generated at Hanford should be a high priority for the Department. As part of this effort, we are taking steps to reduce the risk of contaminants entering the vadose zone. In this regard, the Administration recently submitted a Supplemental Appropriations Request and reprogramming which includes \$15 million in funding for accelerated removal of pumpable liquids from high-level waste tanks that are suspected of leaking.

The DOE also recognizes that in order to have a full and comprehensive understanding of the potential impacts on the vadose zone and groundwater, not only must the discharges and leaks from the Hanford high-level waste tanks be considered, but all other relevant contaminant discharges to the vadose zone as well. The Department has gathered a substantial amount of data on groundwater contaminations which is of significant value; but, much more needs to be done to establish a better quantitative understanding of the vadose zone and the numerous source terms that have contributed to the existing groundwater and vadose zone contamination.

To meet these goals, the Department is developing an integrated plan by October 1998, to characterize the Hanford site vadose zone and groundwater--with the primary objective of protecting the Columbia River. The DOE, in partnership with the scientific community and the private sector, will develop a comprehensive site-wide vadose zone and groundwater characterization program. Operational safety will continue to be given the highest priority.

In developing this plan we are committed to several objectives:

1. **Establish a single integrated groundwater/vadose zone management process for the Hanford site.**

This effort involves integrating the planning and execution processes for Hanford project potentially affecting groundwater resources and the Columbia River. It will also require a clear identification and clarification of project decisions affecting vadose zone characterization and groundwater protection.

2. **Develop a focused research and development program for vadose zone remediation.**

A multi-disciplinary research and development program will be evaluated that taps into the assets of the Department, the private sector, and academia to develop and use optimal remediation technologies that may already be available for the vadose zone.

3. **Identify steps needed to contain contamination:**

- * To establish requirements for all Hanford activities to assure protection of the vadose zone and groundwater resources.

Areas to be examined include the establishment of: (a) leak-loss limits for the vadose zone from tank waste retrieval; (b) groundwater/vadose zone protection requirements for spent nuclear fuel sludge treatment and retrieval, including characterization of the K-Basin groundwater plume; (c) groundwater/vadose zone sanitary water and sewer system protection requirements; and (d) active management of surface recharge to groundwater.

- * Establish a comprehensive approach to understand transport mechanisms and pathways to the Columbia River.

Other sources of contamination to be included, in addition to high-level waste tanks, are trenches and other sources where transuranic waste were disposed; cribs, soil columns, burial grounds, and transfer lines where high-level wastes were discharges or leaked; solid waste burial grounds; and spent fuel storage facilities. The DOE also recognizes that this provides an important opportunity to utilize the resources and expertise of other DOE programs and the DOE national laboratory system.

4. **Establish a strong and effective independent technical review process, involving a three-tiered effort that includes:**

- * Expanded site vadose zone expert panel at the Hanford site;
- * Multi-laboratory involvement and review of the plan; and
- * Involvement by the National Academy of Sciences to review the Hanford vadose zone/groundwater plan in the context of understanding generic examination of contaminants behavior in unsaturated or vadose zones.

5. **Meaningful stakeholder involvement**

The active involvement by states, Indian tribes, and citizen groups in the development of this plan is essential to its success. The DOE is establishing a process for stakeholder involvement that will solicit input on goals, expectations, and values. It is also DOE's intention to maintain open communication channels during the development and implementation of the plan.

Recognizing the lack of a comprehensive, integrated Hanford site-wide vadose zone and groundwater plan, we believe it is important to note our progress to date on our ongoing vadose zone, waste retrieval, and technology development and deployment activities. Descriptions of these activities are provided below in comments 1 and 2. With regard to both the Tank Waste Remediation Systems (TWRS) program and the Environmental Restoration (ER) program, there are omissions and some statements that are not factually precise in the GAO report. These are discussed in comments 3 through 6.

1. In developing its environmental remediation strategy, TWRS is working closely with the State of Washington Department of Ecology (Ecology), the Oregon Department of Energy, and affected Tribal Nation governments. TWRS decisions for which vadose zone data are needed or which potentially impact the vadose zone decision-making and analysis include: (a) sequencing of tanks for waste retrieval; (b) leak detection, monitoring, and mitigation for single-shell tank (SST) waste retrieval; (c) proceeding with a National Environmental Policy Act (NEPA) process for tank farm closure as discussed in the TWRS Environmental Impact Statement (EIS); (d) waste retrieval system performance requirements, (e) disposal of immobilized low activity waste from waste treatment; and (f) tank farm infiltration controls (e.g., leaking water lines, alternatives to gravel covers) to minimize further spread of contaminants prior to tank farm closure.

DOE's decision to adopt a phased approach for remediation of tank waste in the 1997 Record of Decision (ROD) for the 1996 TWRS EIS acknowledged the inextricable linkage of tank waste retrieval and tank farm closure decisions, but also recognized that insufficient information was available to proceed with closure decisions at the time the EIS was prepared because of uncertainties regarding vadose zone conditions and processes, as well as tank waste retrieval system performance. DOE's decision to proceed with a phased approach to waste retrieval was based on the recognition that risks associated with initiating waste retrieval in the absence of final decisions on tank farm closure were outweighed by risks associated with delaying waste retrieval until sufficient information was available to make those decisions. SST waste retrieval and vadose zone planning and characterization are based on this overall strategy, as reflected both in the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement or TPA) milestones, and the ROD for the TWRS EIS.

2. DOE also agrees with the GAO recommendation concerning SST waste retrieval and believes that certain ongoing activities will address a number of concerns about potential leakage and impact on the vadose zone. The SST retrieval strategy takes into account uncertainty with waste behavior in the vadose zone in selection of applicable retrieval approaches. DOE has established hydraulic sluicing, similar to past-practice, as the baseline SST retrieval technology (i.e., sluicing was used as cost/schedule estimating basis for TPA milestones). Sluicing is planned for retrieval of waste from tank C-106 to resolve the high-heat waste safety issue and eliminate the need to continue adding cooling water to the tank. However, DOE recognizes that sluicing may present

unacceptable risk for SST retrieval in tanks other than C-106, in particular for tanks with a high probability for leaking during retrieval (i.e., the 67 tanks known to have leaked in the past). To address this, the Hanford Tank Initiative (HTI) is completing demonstration of alternative technologies to sluicing. These technologies are planned to be applicable to SSTs other than C-106 and provide greatly reduced leakage potential. HTI is also completing initial analysis of risks from retrieval leakage in accordance with TPA commitments for leak detection, monitoring, and mitigation. Based on building additional experience with sluicing operations, alternative technology demonstrations, and additional insight into waste leakage behavior in the vadose zone, decisions will be made for SST retrieval to allow for tank closure.

3. Because much of the present strategy for tank waste retrieval and treatment, and vadose zone characterization needed to support it, grew out of analyses in and decisions from the 1996 TWRS EIS, DOE is concerned that the GAO report does not accurately reflect the EIS or the decisions in the ROD. The GAO report implies that DOE completed the EIS without acknowledging the limits on its understanding of the vadose zone. On the contrary, in the January 1994 Notification of Intent to prepare the TWRS EIS, DOE informed the public that DOE also needed to eventually address closure of tanks (including disposal of tanks, piping, ancillary facilities, and contaminated soil), but would not in this EIS because sufficient data, including data on the vadose zone, were not available. DOE committed then to conduct an appropriate NEPA review, such as preparing a tank closure EIS, in the future when data became available. This position was reiterated in the April 1996 Draft TWRS EIS, and the August 1996 Final EIS. This strategy was agreed to by Ecology which co-prepared the TWRS EIS with DOE.

However, in the EIS, DOE did address uncertainties relative to vadose zone and groundwater transport of contaminants and how those uncertainties may affect future tank waste remediation decisions. As more data, including data on the vadose zone, become available and Hanford contaminant transport models are revised, DOE will, as it committed in the ROD, assess potential implications of the assessment of long-term risks and evaluate if changes to the TWRS remediation approach are required. Further, in the TWRS EIS and ROD, DOE committed to evaluation of waste retrieval options under the HTI and other programs to determine if retrieval technologies could be implemented that would mitigate the potential impacts of losses to the environment that may be associated with retrieval using hydraulic sluicing. The National Research Council, which reviewed the Draft EIS at DOE's request, also endorsed DOE's effort to evaluate alternative retrieval technologies under HTI.

DOE's efforts to address contaminant transport using modeling for the TWRS EIS was conducted independently and was subject to external review including that of the National Research Council, the Oregon Department of Energy, and Ecology. Peer review will continue to be an important element of vadose zone and groundwater work at the Hanford Site.

4. DOE agrees with the GAO that the spectral gamma-logging program has played an important role in the characterization of the vadose zone of the SST farms, and it will continue to do so, especially as enhancements, such as shape factor analysis and more thorough analysis of historic gamma logs (both recommendations of the vadose zone expert panel implemented this Fiscal Year), are added. However, DOE is concerned that the GAO draft report does not acknowledge that spectral gamma logging, like any other technology, has limitations.

Spectral gamma logging is an effective means, using the already existing drywells, of assessing where contaminant migration from tank leaks and other releases has occurred and supports the development of a baseline to assess whether gamma emitting contaminants in the upper vadose zone are migrating. It also is being used as a tool for selecting sites for more detailed vadose zone characterization in the tank farms. In addition, because drywells were put in all the SST farms, the spectral gamma logs provide a common set of vadose zone data by which to compare all tank farms. However, the effective use of spectral gamma logging at Hanford is limited by several factors including: 1) the types of contaminants in groundwater today from tank leaks and releases, 2) the types of contaminants believed to account for the majority of potential risk to groundwater in the future if tank waste was to go untreated, and 3) the limited vertical extent of most of the drywell in the SST farms. Based on the Resource Conservation and Recovery Act (RCRA) Phase I Groundwater Quality Assessments of Waste Management Areas containing the SST farms, major contaminants from tank leaks and other releases include technetium, tritium, nitrates, iodine, chromium, and sodium, none of which can be detected by spectral gamma logging. Furthermore, from a list of those contaminants thought to contribute the greatest risk to groundwater from tank waste if it remains untreated--namely technetium, iodine, uranium, carbon-14, selenium, and nitrates--only uranium can be detected by spectral gamma logging. Consequently, for DOE to collect vadose zone data needed to make key decisions on tank retrieval and closure will require other types of analyses and efforts to complement the information gained from the spectral gamma logging. One such effort was the borehole extension to groundwater discussed in the GAO report, providing important information on the distribution of mobile, risk-driving contaminants such as technetium in the lower 100 feet of the vadose zone. Work on other such data collection efforts in the tank farms is underway.

5. A valuable compilation of historic information on the Hanford vadose zone, including that of the 200 area, is contained in the Aggregate Area Management System Reports. DOE completed these reports, which includes spectral gamma logging data, in fulfillment of a Tri-Party Agreement milestone. This information is being reviewed, and gaps will be identified, during the implementation of the integrated plan for vadose zone and groundwater activities.
6. In its report, GAO states that "DOE also has a limited understanding of the behavior of contaminants placed in hundreds of cribs, trenches, and other waste sites above the

groundwater. For example, DOE has not routinely monitored waste sites other than the tank farms since 1988, and earlier monitoring of these sites was limited and sporadic.” It should be noted that at the request of stakeholders and in an effort to address immediate risks, the Hanford site’s Office of Environmental Restoration has concentrated much of its vadose zone monitoring, characterization, and remediation efforts in recent years on liquid disposal sites along the Columbia River because they pose the most immediate threat to this important resource. Thus, it should also be noted that a program is not currently in place to monitor all wells and boreholes associated with liquid waste disposal sites in the 200 Area. Besides the need to emphasize work along the Columbia River, there are other bases for this:

- * The TPA requires characterization of the 200 Area past liquid disposal sites to be complete by 2008. There should be minimal transport of gamma-emitting contaminants between now and when characterization is complete. In general, the gamma-emitting radionuclides are not very mobile in cribs; characterization of two of the largest have already demonstrated this. Applying limited resources to gamma logging of these sites now would detract resources from characterization and remediation of higher priority sites.
- * Except for wastes discharged from cascading tanks to cribs, a small number of reverse wells, and specific retention trenches where wastes are similar to tank leaks, contaminants disposed in cribs, ponds, and ditches were in a relatively dilute form with large amounts of water. Most of the mobile contaminants disposed of at these sites have already reached groundwater. The less mobile species such as plutonium, americium, cesium, and strontium have generally been removed from the liquid phase as wastewater percolated through the soil column.
- * The Aggregate Area Management Studies included a baseline vadose zone spectral gamma logging program of the 200 Area liquid waste disposal sites. The logs developed from this work suggest that the less mobile contaminants are retained in the soil.

Other DOE Actions That Could Exacerbate Vadose Zone Contamination at the Hanford Site

One pending Department of Energy (DOE) project involves injecting water into single-shell tanks to dissolve solid wastes into a slurry for retrieval. This step would cause additional leaks from some tanks and, therefore, could increase the potential for wastes to migrate through the vadose zone to the groundwater. Two actions that DOE is currently taking, presented in this appendix, also could increase the amount of waste contaminating the vadose zone.

Covering Tank Farms With Gravel

DOE is proceeding with a program that calls for using uncontaminated gravel to replace or add to the existing gravel surface of tank farms. Gravel above the tanks allows rain and snow to drive leaked or spilled wastes through the vadose zone toward the water table. A 1989 modeling study by DOE's experts estimated that about three-fourths of annual precipitation migrates through this coarse backfill and increases the rate of movement of some contaminants and recommended a different type of cover.¹

DOE selected its approach of adding more gravel because the clean gravel helps shield workers from exposure to radiation. DOE also evaluated other approaches for reducing risks to workers while minimizing infiltration that did not involve putting gravel over the tanks, but it selected the gravel approach because it was relatively inexpensive. DOE has completed this effort in three tank farms at a cost of about \$1 million, but no funding is currently available to continue.

Slowing the Pumping of Wastes From Single-Shell Tanks

DOE has slowed its efforts to pump liquid wastes from single-shelled tanks into double-shell tanks, leaving the wastes susceptible to additional leakage. In 1980, DOE began a program to remove all pumpable liquid from single-shell tanks by 1996 or earlier. At the time, the single-shell tanks contained an estimated 8.5 million gallons of pumpable liquid. The pumping program has encountered numerous delays. As of November 1997, about 5.7 million gallons of pumpable liquid remains in 30 tanks. Current milestones call for pumping to be completed by 2000, but DOE has requested a 3-year extension.

Additional leakage has resulted from not completing the pumping on the originally scheduled date. DOE estimates that one unpumped tank leaked an estimated 7,500 gallons of high-level mixed waste to the vadose zone before it could be pumped. Currently, three tanks assumed to have leaked

¹According to the one of the authors of the study, contractor scientists and others recommended several times that DOE measure the infiltration of precipitation in the tank farms but DOE never funded the studies.

Appendix II
Other DOE Actions That Could Exacerbate
Vadose Zone Contamination at the Hanford
Site

in the past have not yet been pumped. These tanks hold an estimated 574,000 gallons of pumpable liquid waste. The Director of Washington State's Department of Ecology, in rejecting DOE's request to delay one of the program milestones, said that the wastes present a very real and increased threat to health and the environment.

Delays in pumping the tanks have been caused by budget fluctuations, technical issues, and safety issues. DOE, citing overall budget constraints, had cut its proposed spending in fiscal year 1998 to about one-half the 1997 level of about \$9 million. According to the manager of the TWRS project, DOE plans, during fiscal year 1998, to start pumping three of the four tanks that had leaked and to try to reduce program costs. DOE recently submitted a request to Congress for \$15 million in funds for accelerated removal of pumpable liquids.

Examples of Inefficient Use of Vadose Zone Investigation Funds

With the limited amount of funds available for vadose zone work, it is important for DOE to spend these dollars as effectively as possible. Our review of recent expenditures on investigations of vadose zone conditions around tank farms showed this has not necessarily occurred. We identified a number of cases in which work on individual drilling projects was marked by false starts, frequent interruptions, and poor coordination.

Well Drilling Activities

At Hanford, one of the key steps in gathering extensive information about vadose zone conditions is to drill wells and sample the soil to learn about soil conditions and the distribution of radioactive and hazardous materials. Drilling wells is one of the major expenditures of the vadose zone programs, and DOE expects that a number of additional wells will be needed. We reported in early 1993 that high well drilling costs could be reduced¹ and, on the basis of our current review of the recent drilling of two tank farm wells, our conclusion has not changed.

The first well, drilled about 180 feet deep in 1993, was located near the largest confirmed tank leak (tank T-106) at the Hanford Site. Several officials involved with the drilling of this well cited problems with poor management of the borehole project. Staff assigned to the project said that it was poorly organized and far more costly than it should have been. Instead of beginning the project in the spring, DOE began drilling in November and encountered severe winter weather, which hindered or prevented drilling on 6 days. Overall weather, staffing, equipment, site, lunch breaks, and other problems resulted in only two-thirds of the time during the 82 working days being spent in drilling and sampling or on related activities. In total, the borehole cost at least \$3.2 million for activities such as installation, laboratory analyses, and report preparation.² The borehole, planned to take 2-1/2 months, instead required 5 months.

The second well that we looked at was a project, recommended by DOE's expert panel on the vadose zone, to deepen to groundwater (about 210 feet) the earlier well that had found the cesium at 130 feet beneath the surface. According to DOE's drilling expert, this project had challenges to overcome from the beginning. The first 130 feet consisted of a 6-inch steel pipe with a pointed tip that had been driven into the ground. Because the tip was welded on instead of removable, the DOE crew spent 14 days trying to remove it. The crew had to add water to the hole during the removal,

¹Nuclear Waste: Hanford's Well-Drilling Costs Can Be Reduced (GAO/RCED-93-71, Mar. 1993).

²DOE's financial records were incomplete. A DOE contractor manager on the project told us that another \$882,000 was spent on project planning and documentation.

which altered the consistency of the first samples taken. DOE's drilling expert had told staff of the vadose zone program to think about the eventual uses of the borehole before initiating the original drilling. The drilling expert believed that DOE should have considered the possibility that they would be deepening the hole, which would have lead DOE to design the original hole differently using a larger pipe and a removable tip. However, DOE did not plan for this possibility.

Instead of just deepening the existing well, the DOE drilling experts recommended that DOE first investigate the most effective ways to drill in the tank farm environment so that cost-effective drilling can be done for the many wells that they believe will be needed to fully characterize the vadose zone.³ DOE's TWRS vadose zone program manager said they went ahead because DOE believed that the data would provide needed information about conditions in the lower vadose zone. Using a method that drills only a few feet a day in Hanford conditions, the drilling and sampling, scheduled to take 24 days instead took 62 days and the entire project cost over \$600,000 (including analysis of samples). Aside from the slow drilling method, other problems included limited advanced planning which caused DOE to stop work and revise the work package two times. In addition, failure of DOE's tank farms contractor to manage the work so that adequate support was available led to missing 16 days of work and starting late on many days. Despite overtime, the drilling crew averaged only about 5 hours work a day. The poor support by the tank farms contractor caused one of the Indian tribes in December 1997 to call for immediate transfer of vadose zone responsibilities to the Environmental Restoration program.

Monitoring Equipment

In the 1990 study by the Secretary of Energy's "Tiger Team" review of the Hanford Site and in our 1992 report, a number of recommendations for technical improvements in the vadose zone monitoring techniques were recommended. While DOE concurred with the findings, the engineer responsible for the program said no changes were made to the equipment or procedures because the equipment was old and had little ability to be adjusted. This equipment is still used at some tanks even though much more capable equipment is on site.

³The experts noted that DOE did not design the original hole to allow for readily extending the well.

Modeling Studies of Vadose Zone and Groundwater

Work continues on numerous modeling studies. In addition, to the money being spent directly on vadose zone characterization activities, DOE is spending about \$1.5 million on several different groundwater and vadose zone modeling projects to support other programs during fiscal years 1996 to 1998. DOE's expert panel concluded that reliable modeling could not be done without reliable data on contaminant transport. In addition to developing more data, the panel recommended that DOE's modelers assess the various models to determine which best fits the Hanford site. The panel also suggested that DOE's modeling efforts should be reviewed by others. The management review team cited this as an area where TWRS is not actively addressing the recommendations. According to the manager of DOE's groundwater program, the Under Secretary of Energy has also called for the modeling to be reviewed by outside experts.

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Related GAO Products

Nuclear Waste: Further Improvements Needed in the Hanford Tank Farm Maintenance Program ([GAO/RCED-95-29](#), Nov. 8, 1994).

Nuclear Waste: Hanford Tank Waste Program Needs Cost, Schedule, and Management Changes ([GAO/RCED-93-99](#), Mar. 8, 1993).

Nuclear Waste: Improvements Needed in Monitoring Contaminants in Hanford Soils ([GAO/RCED-92-149](#), July 6, 1992).

Nuclear Waste: Problems and Delays With Characterizing Hanford's Single-Shell Tank Waste ([GAO/RCED-91-118](#), Apr. 23, 1991).

Nuclear Waste: DOE's Management of Single-Shell Tanks at Hanford, Washington ([GAO/RCED-89-157](#), July 18, 1989).

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