United States General Accounting Office

GAO

Report to Congressional Requesters

April 2000

NUCLEAR WASTE CLEANUP

DOE's Paducah Plan Faces Uncertainties and Excludes Costly Cleanup Activities

GAO/RCED-00-96

Contents

Abbreviations

DMSA	DOE material storage area
DOE	Department of Energy
EPA	Environmental Protection Agency
NRC	Nuclear Regulatory Commission
PCBs	polychlorinated biphenyls
TCE	tricholorethene
USEC	United States Enrichment Corporation

United States General Accounting Office
Washington, D.C. 20548

Resources, Community, and
Economic Development Division

B-284388

April 28, 2000

The Honorable Frank H. Murkowski
Chairman, Committee on Energy
and Natural Resources
United States Senate

The Honorable Jim Bunning
The Honorable Mitch McConnell
United States Senate

In 1988, radioactive contamination was found in the drinking water wells of residences near the federal government's uranium enrichment plant in Paducah, Kentucky.[1] In response, the Department of Energy (DOE) connected local residences to municipal water supplies and began a cleanup program to identify and remove contamination in the groundwater, surface water, and soils located within and outside the plant's boundaries. Sources of the hazardous chemical and radioactive contamination included spills, leaks from contaminated buildings, buried waste, scrap yards, and waste lagoons. From 1988 through 1999, DOE spent about $388 million on these cleanup efforts.

In August 1999, in response to a number of allegations that past activities at the Paducah plant had endangered the health of employees, the Secretary of Energy, among other things, directed the Office of Oversight within DOE's Office of Environment, Safety, and Health to conduct an independent investigation at Paducah.[2] This investigation addressed issues such as improperly disposing of hazardous and radioactive materials on-site and off-site, releasing contamination into streams and drainage ditches, inadequately posting and controlling contaminated areas, exposing workers to radioactive material, and ineffectively communicating hazards to workers. The resulting October 1999 report stated that limited progress

[1]The uranium enrichment process prepares uranium for use as a nuclear reactor fuel by converting natural uranium into a mixture richer in the fissionable isotope uranium-235.

[2]The Office of Oversight conducts integrated safety management evaluations, special reviews and studies, and follow-up reviews. Phase I: Independent Investigation of the Paducah Gaseous Diffusion Plant (Office of Oversight; Office of Environment, Safety and Health; Department of Energy; Oct. 1999).

had been made in cleaning up source areas of contamination, such as landfills, burial grounds, and waste and scrap piles. The report also noted that large quantities of waste were stored in conditions that increased the risk of spreading contamination. In addition, the report noted that the funding available for cleanup had been much less than requested. Most of the site's cleanup funding had been devoted to characterizing contamination (that is, identifying its nature and extent); operating and maintaining the site infrastructure; meeting regulatory requirements; and implementing measures in reaction to immediate threats. According to DOE officials, cleanup at the site, including the removal of contaminated scrap metal and low-level waste disposal, was delayed because of funding limitations.

The plant, which operates today under a lease to a private company, the United States Enrichment Corporation, enriches uranium for nuclear power plants. DOE's Office of Environmental Management has overall responsibility for the site cleanup being performed by its contractor, Bechtel Jacobs, while the Office of Nuclear Energy, Science, and Technology (Office of Nuclear Energy) is generally responsible for maintaining the site's infrastructure. DOE's cleanup plan for the Paducah site seeks to assess the extent of radioactive and chemical contamination from past uranium enrichment activities at the site and to treat and dispose of this contamination. Overseeing the cleanup in a regulatory role are the Environmental Protection Agency (EPA) and the Commonwealth of Kentucky.

Concerned about the reportedly slow progress that has occurred to date in the plant's cleanup, you asked us to (1) describe the planned activities, cost, and schedule DOE has for cleaning up the Paducah site; (2) identify the challenges that exist in accomplishing the current cleanup plan; and (3) determine whether the cleanup plan includes all areas at the site requiring cleanup.

In conducting our work, we met with DOE and contractor officials, reviewed agency documents, and visited the Paducah site on three separate occasions. We focused primarily on examining the January 26, 2000, Lifecycle Baseline, which provides details on the planned cleanup approach, schedule, and estimated costs. We also met with federal and state regulators as well as the site advisory board to obtain views from local citizens.

Results in Brief

The Department's plan for addressing the contamination at the Paducah site focuses on six major cleanup categories. Four of these address the physical contamination on the site: groundwater; surface water (for example, in ditches and creeks); soils; and buried waste. Two other major categories of cleanup work include treating and disposing of the equivalent of about 52,000 barrels of waste currently stored on site and decontaminating and removing two unused, contaminated uranium process buildings. The cleanup plan includes cost and schedule estimates for characterizing the contamination in each cleanup category and for using technologies to treat, remove, and dispose of the contamination. The current plan estimates the cost of completing the cleanup at $1.3 billion from fiscal year 2000 through fiscal year 2010.

DOE faces many challenges to completing its cleanup as planned. Uncertainties about the extent, source, and nature of contamination yet to be cleaned up could affect the cleanup plan; the outcome of such uncertainties could increase cleanup costs. DOE also faces several technical risks, including the planned use of technologies that are unproven or perhaps not well suited to the site's conditions. Also underpinning the plan are assumptions that annual federal funding will increase to an average of $124 million through 2010. This assumed average annual funding level is considerably higher than the $43 million average annual funding DOE has received over the last 7 years—since the Congress established a fund for cleaning up contamination at DOE's three uranium enrichment sites. If the planned increase in funding does not occur, the project could take longer to complete. In addition, the plan contains optimistic assumptions about reaching timely agreement with EPA and state regulators on issues such as cleanup levels, strategies, and priorities. Collectively, these issues make it uncertain that the Department will be able to accomplish the cleanup within its estimated time frame and cost.

Even when the planned cleanup has been carried out, billions of dollars and many years will be needed to address areas at the Paducah site that are not in the cleanup plan. More specifically, four areas at the site, currently under the responsibility of the Office of Nuclear Energy, will need to be cleaned up. These areas are (1) large amounts of waste and scrap materials, (2) various unused buildings and structures, (3) thousands of tons of depleted uranium, and (4) the buildings and equipment that are now being used in the enrichment process but that will have to be cleaned up when the plant closes. The materials and structures include nearly a million cubic feet of waste and scrap in areas known as DOE Material Storage Areas and

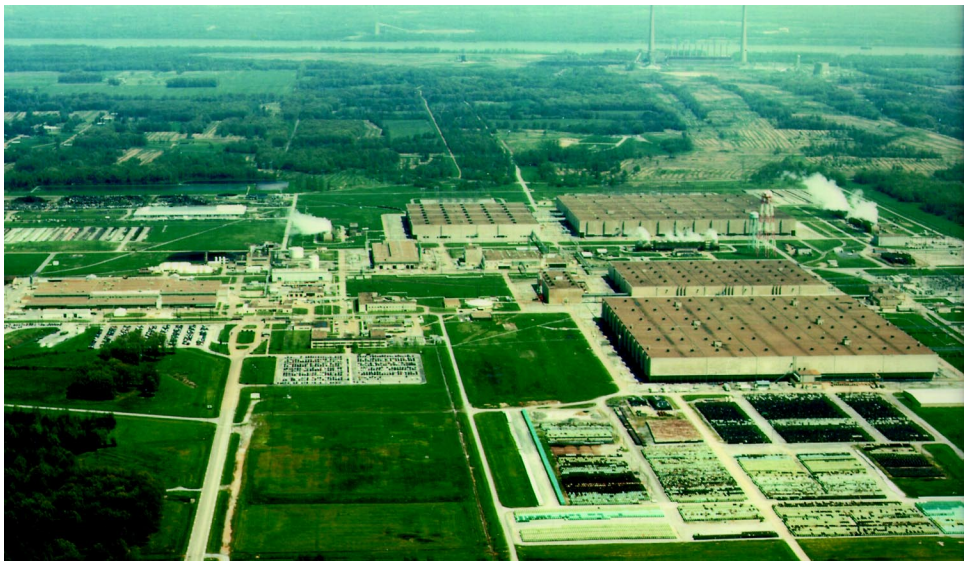
16 unused and inactive buildings and structures. Some of this waste and scrap material poses a risk of an uncontrolled nuclear reaction that could threaten worker safety. Such a reaction produces a burst of radiation that generally lasts several hours; it is, however, a localized event that would not result in an explosion or release of radioactivity to the atmosphere. The additional materials, buildings, and structures are excluded from the cleanup plan not because they require no action, but because they fall under the purview of a different departmental program. According to the DOE official responsible for these areas, they are not in the cleanup plan because DOE is hesitant to transfer any more areas to the Office of Environmental Management, which already has a large workload and limited funding for cleanup. The programmatic distinction between the Department's Office of Environmental Management and its Office of Nuclear Energy prevents the Paducah cleanup managers from assessing risk or planning cleanup on a comprehensive, sitewide basis and distorts the picture of the cleanup task at hand.

Regarding the depleted uranium, DOE recently announced plans to build and operate a facility at Paducah to convert the 496,000 tons of this material on site to a more stable form and remove it from the site. DOE officials estimated that it may cost between $1.8 billion and $2.4 billion to operate the conversion facility at Paducah for nearly 25 years and to store and dispose of the unused converted material. Finally, according to DOE's January 1998 estimate, another $1 billion would be needed for final decontamination and decommissioning activities, when the plant ceases operations and is returned to DOE's ownership. The current plant operator can terminate its lease if it gives 2 years' notice under certain circumstances or if it is unable to maintain certain financial conditions. To ensure that cleanup priorities are established on a comprehensive, sitewide basis, we are making recommendations to the Secretary of Energy to include in the cleanup plan all materials that are potential health hazards to workers and the public.

Background

The Paducah uranium enrichment plant, shown in figure 1, is located on about 3,400 acres in western Kentucky, just south of the Ohio River and about 10 miles west of the city of Paducah. The plant enriches uranium for commercial power reactors. Over its 50-year operating lifetime, the Paducah plant has processed, or enriched, more than a million tons of uranium.

Figure 1: Aerial View of the Paducah, Kentucky, Uranium Enrichment Plant



Source: DOE.

Plant operations have introduced to the site radioactive and hazardous chemical wastes, including technetium-99, polychlorinated biphenyls (PCBs), uranium, and volatile organic compounds such as trichloroethene. In past years, a cleaning solvent containing trichloroethene—much like that used by drycleaners—was used to degrease parts and equipment. In the plant's half century of operations, these various waste materials have contaminated the area's groundwater, surface water, soils, and air.

The Paducah site cleanup is funded through the Uranium Enrichment Decontamination and Decommissioning Fund, which was established by the Energy Policy Act of 1992. Money comes into the fund from both annual federal appropriations and assessments on commercial utilities. Through 1998, the federal government had contributed a total of about $1.5 billion to the fund, and commercial utilities had contributed a total of about $954 million. Through fiscal year 2000 (as of mid-April 2000), the Paducah site has received from the fund annual cleanup amounts ranging from $35.9 million to $52.3 million.

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980, commonly known as Superfund, governs the cleanup of sites placed on the National Priorities List—EPA's list of contaminated sites designated as highest priority for cleanup. Paducah was placed on the list

in 1994. Superfund provides broad federal authority to respond directly to releases or threatened releases of hazardous substances that may endanger public health or the environment. It stresses the importance of permanent cleanup remedies and innovative treatment technologies, and it encourages citizen participation in deciding on how sites should be cleaned up.

The Resource Conservation and Recovery Act of 1976 also comes into play in governing the Paducah cleanup. While Superfund deals with cleaning up inactive and abandoned hazardous waste sites, this act governs the safe management and disposal of the huge amounts of hazardous or other solid wastes that are generated nationwide and are currently destined for disposal or recycling. The act permits states, rather than EPA, to assume primary responsibility for implementing its requirements.

At Paducah, the key documents governing the cleanup are a federal facility agreement, the site management plan, and the lifecycle baseline. The federal facility agreement—between DOE, EPA, and the Commonwealth of Kentucky—coordinates the requirements of both Superfund and the Resource Conservation and Recovery Act for cleanup activities at Paducah. This agreement includes a site management plan, which includes timetables, deadlines and projected activities. Bechtel Jacobs, the cleanup contractor for Paducah since April 1998, prepares a lifecycle baseline, which includes specific cleanup strategies, their cost estimates, and time frames for completion over the life of the cleanup.

The lifecycle baseline, according to DOE and contractor officials, is a "living document;" it is updated frequently to reflect the evolving nature of the cleanup process. Revisions to the lifecycle baseline are made to incorporate such things as changes in funding; updated cost estimates for specific studies, tests, and cleanup tasks; and changes in project approach or scope necessitated by study results. Such revisions affect estimates of the total cleanup cost and schedule. For this report, we examined activities, costs, and schedules contained in the January 26, 2000, version of the lifecycle baseline.

Since 1996, the plant has been operated under lease from DOE by the United States Enrichment Corporation (USEC), which was created by the Energy Policy Act of 1992 and was a first step in the process of privatizing the government's uranium enrichment enterprises. The Nuclear Regulatory Commission (NRC) granted USEC a certificate to operate the plant in November 1996 and received responsibility for the regulatory oversight of enrichment operations from DOE in March 1997. As a result of an initial

public offering, USEC was privatized as an investor-owned corporation in July 1998. USEC recently announced a workforce reduction to offset low market prices for uranium.

DOE's management of the Paducah site is divided between two offices. The Office of Environmental Management is responsible for the site cleanup plan, including characterizing, treating, and disposing of waste and contamination identified during site cleanup. The Office of Nuclear Energy acts as the "landlord," with responsibilities for maintaining roads, grounds, and facilities not leased to USEC, and managing material storage areas and the cylinders of depleted uranium stored on site.

Paducah has a Site Specific Advisory Board, which provides DOE with recommendations and advice on major policy issues regarding environmental restoration, waste management, and related activities at the site. Sixteen members of the local community are on the board. Representatives of DOE, EPA, and the Commonwealth of Kentucky serve as ex-officio representatives on the board.

DOE's Paducah Plan Focuses on Cleaning Up Six Major Categories by 2010 at a Cost of About $1.3 Billion

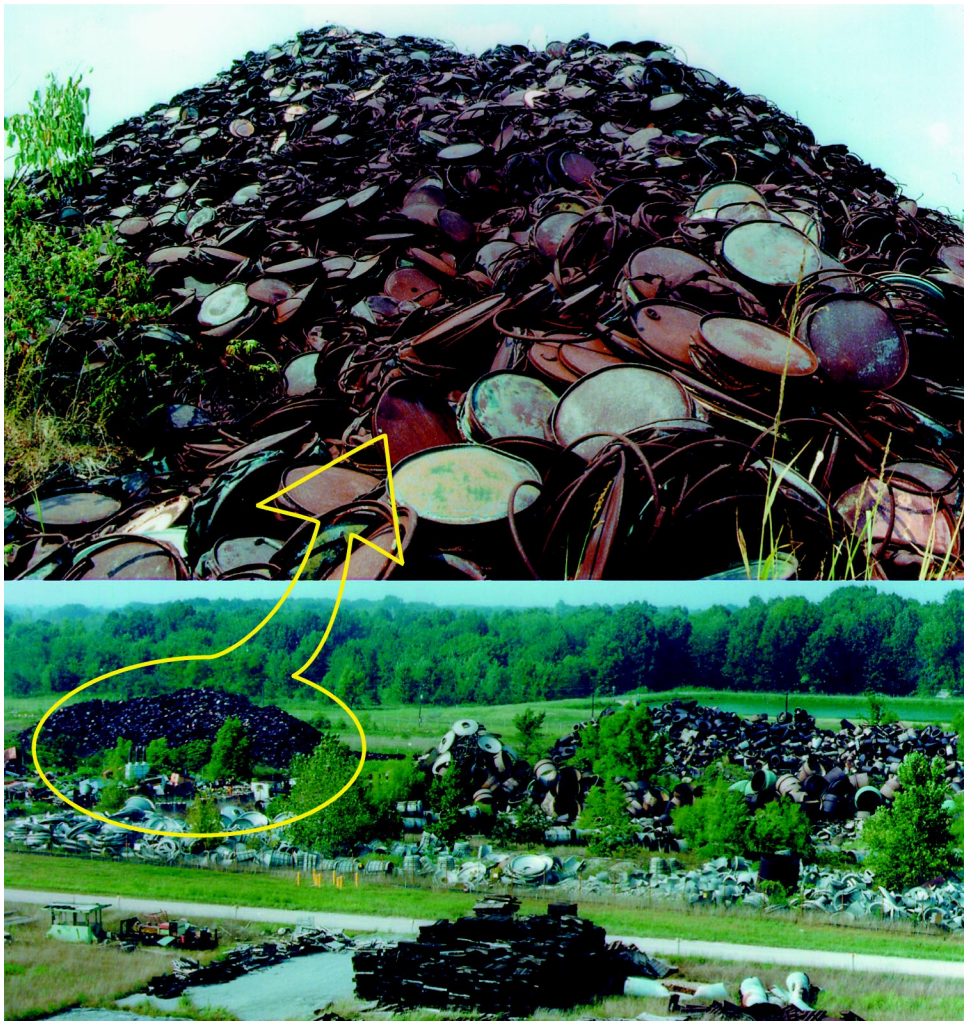
DOE's January 2000 plan for addressing the variety of radioactive and hazardous chemical wastes that have contaminated the Paducah site and surrounding area divides the cleanup work into six major categories. Four of the cleanup categories are concerned directly with the physical contamination—the groundwater aquifer, ditches and water release areas that contribute to surface water pollution running off-site, surface soils, and waste burial grounds. Two other categories address the treatment and disposal of approximately 52,000 barrels of accumulated wastes from past plant operations and the decontamination and removal of two unused, contaminated uranium process buildings. The plan includes estimates of the costs and time frames for characterizing and assessing the severity of the contamination and the costs of selected technologies and strategies to treat or remove it. DOE estimates that it will accomplish the planned cleanup by 2010, at a cost of approximately $1.3 billion.

DOE's Plan Addresses Six Cleanup Categories

The following describes the six cleanup categories included in DOE's plan for the Paducah site. See appendix I for details on the cleanup tasks accomplished and planned in each of the categories and the estimated costs and time frames for each.

- **Groundwater** in an aquifer below the plant is contaminated with radioactive and hazardous chemicals. About 10 billion gallons of contaminated water are spreading off the site in three different plumes, at least one of which may have reached the Ohio River, about 3 miles north of the plant. The interim measures DOE has taken to address this contamination include connecting nearby residences to municipal drinking water supplies and constructing two groundwater pump-and-treat systems to reduce the concentration of contaminants in the two major plumes. Additional assessments are being conducted to identify other contamination sources or plumes, and several cleanup technologies are being considered for treating the groundwater. Pilot studies of these technologies are planned to determine their ability to (1) remove the source of groundwater contamination and (2) clean the groundwater plumes as they leave the site. DOE estimates that the planned groundwater cleanup activities will be completed in 2006.
- **Surface water** contamination has been discovered in surrounding creeks and ditches and in sludge lagoons. One of the main sources of this contamination is the thousands of tons of contaminated scrap metal that DOE has stored on site. During storms, contamination washes from the scrap metal, and the runoff carries contaminated soils and sediments into the ditches and creeks. Another source of contamination is the discharge of wastewater from plant operations. Some interim measures have been taken to address the wastewater contamination, including treating some of the wastewater and installing pipes that route some of the wastewater discharges around areas in the ditches that are highly contaminated. DOE is finishing its characterization of the contamination found both on and off-site. By the end of 2000, DOE also plans to have removed that portion of the contaminated scrap metal called “Drum Mountain,” which is made up of about 8,000 tons of crushed drums that contained depleted uranium (see fig. 2). The remaining planned cleanup tasks include removing the remaining 57,000 tons of scrap metal that contribute to the contamination, dredging ditches and creeks both on and off-site, and installing four basins to catch and treat contaminated water. DOE estimates that the planned surface water cleanup activities will be completed in 2007.

Figure 2: Scrap Metal Stored on Site, With a Close-up View of "Drum Mountain" (30 to 40 feet in height)



Source: DOE.

- **Surface soils** on and off-site have been contaminated by water runoff, spills, and buried waste. DOE has identified 72 areas with contaminated soils and has taken interim measures, such as installing erosion control fences, to prevent further migration of the contamination. DOE is finishing its characterization of the contamination on and off-site. The planned cleanup tasks include removing contaminated soil and, in one highly contaminated area, continuing the use of an innovative

technology to clean the soil. DOE estimates completing the planned work on contaminated soils in 2007.

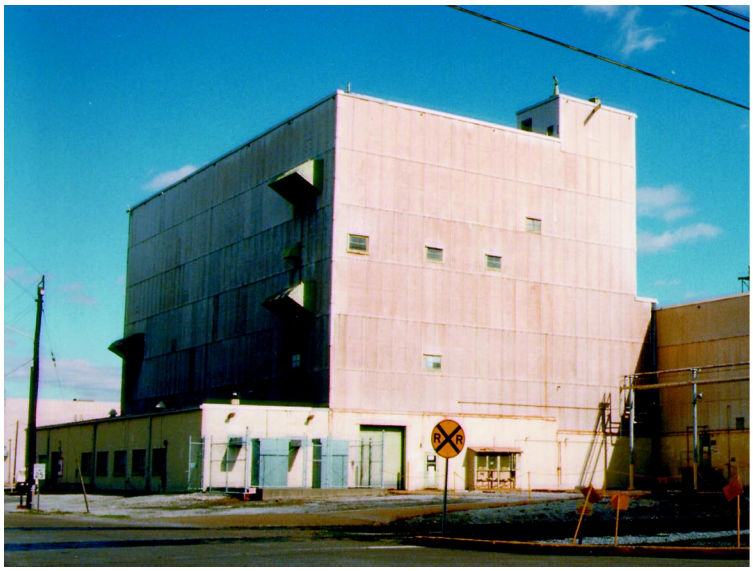
- **Burial grounds**, of which there are 12, contain a variety of waste, including buried barrels of materials with low levels of radioactivity and/or hazardous chemicals, and pyrophoric uranium.[3] DOE is in the process of analyzing sampling data to determine the extent to which these burial grounds are contributing to groundwater contamination. The planned cleanup strategy is to excavate four or five of the burial grounds and to install a protective cover, or cap, over the remaining ones to prevent water from seeping in. DOE estimates completing the planned cleanup of the burial grounds by 2010.
- **Fifty-two thousand barrels of waste**, the majority of which contain materials that have low levels of radioactivity and/or hazardous chemicals, are stored in various locations at Paducah.[4] More than 12,400 barrels of this waste are stored outdoors; many have severely degraded, and some have leaked.[5] DOE has disposed of approximately 750 barrels of waste since 1990. In addition to requiring storage and monitoring, nearly all of the remaining barrels will require additional characterization to determine their suitability for off-site disposal. Owing to a number of factors, including the aged condition of some barrels, transportation requirements, and treatment requirements for waste disposal, the cleanup plan assumes that 80 percent of the 52,000 barrels will need to be "overpacked" (placed inside another barrel) to make them suitable for disposal. DOE's plan calls for removing the barrels by 2010.
- **Two contaminated process buildings** that have not been used as part of the uranium enrichment process since 1977 will be decontaminated and removed. These two buildings are heavily contaminated from earlier operations. DOE recently decided to plan for the removal of the buildings by 2008. Figure 3 shows the two buildings.

[3]Pyrophoric uranium has a tendency to spontaneously combust in the presence of oxygen.

[4]This waste is stored in a variety of containers, such as 55-, 85-, and 110-gallon barrels. The total volume of waste stored at Paducah is equivalent to the volume of about 52,000 55-gallon barrels.

[5]DOE's October 1999 report identified about 8,500 barrel equivalents of this waste. During our review, DOE identified another approximately 3,900 barrel equivalents of waste stored outdoors.

Figure 3: Two Unused, Contaminated Buildings to Be Demolished During Cleanup



Source: DOE.

DOE Estimates a Cost of Approximately $1.3 Billion to Complete the Cleanup by 2010

DOE's January 2000 plan estimated that it would take approximately $1.3 billion through 2010 to complete cleanup activities in the six categories. Table 1 shows the estimated cost of cleanup in each of the six categories. In addition to the direct cleanup activities, about $91 million of this amount will be used to conduct monitoring and maintenance activities (such as repairing fences, replacing warning signs, and conducting required inspections). The $1.3 billion cost represents an 85-percent increase from DOE's October 1999 estimate of $700 million, which had a completion date of 2012.[6] Revisions to the plan since October, decided upon in conjunction with federal and state regulators, have increased costs partly because of the need to (1) dispose of contaminated scrap metal that DOE had previously assumed could be recycled, (2) decontaminate and remove two unused process buildings, and (3) expand the scope of a number of cleanup actions. Although DOE plans to complete the cleanup by 2010, a few

[6]The DOE Assistant Secretary for Environmental Management provided this estimate in an Oct. 26, 1999, hearing before the Subcommittee on Energy and Water Development, Senate Committee on Appropriations.

activities (such as preparing post-cleanup reports) will continue through 2011, at a cost of about $13 million.

Table 1: DOE's Estimated Cost and Schedule for Six Cleanup Categories at the Paducah Site, as of January 2000

Dollars in thousands		
Cleanup area	**Cleanup cost**	**Completion date**
Groundwater	$ 162,100	2006
Surface water	162,300	2007
Surface soils	19,000	2007
Burial grounds	535,400	2010
Waste barrels (52,000)	228,100	2010
Unused process buildings	92,100	2008
Other[a]	104,200	2011
Total	$1,303,200	

[a]Includes approximately $91 million for monitoring and maintaining the site and about $13 million for other activities in 2011, such as preparing post-cleanup reports.

Note: DOE's estimated costs have been adjusted for inflation.

Source: DOE.

DOE Faces Challenges in Achieving Its Cleanup Plan

A number of technical, financial, and regulatory factors associated with the implementation of the cleanup plan make it uncertain whether DOE can complete the cleanup in accordance with its plan. Uncertainties exist about the nature and extent of contamination and the feasibility of available cleanup technologies. In addition, assumptions about the availability of federal funding and the timeliness of stakeholders' agreement with cleanup levels and strategies may affect DOE's ability to meet the plan's milestones. Collectively, the number and nature of the uncertainties and assumptions make it doubtful that Paducah's cleanup will be completed by 2010, as scheduled, within the $1.3 billion cost projection.

Uncertainties About the Nature, Extent, and Sources of Contamination May Increase Costs

Uncertainties about the nature, extent, and sources of contamination yet to be cleaned up could affect the cleanup plan; the outcome of such uncertainties could increase cleanup costs. For example, the extent of contamination in the surface water and soils within and outside the plant

boundaries remains to be determined and could affect cleanup strategies, including the number of sedimentation basins that will need to be installed. The basins would be installed at various points to collect and hold storm water runoff, thus allowing treatment of the contaminants the runoff may contain. The state has expressed its preference for installing eight or nine sedimentation basins, so as to prevent the further spread of soil contamination off-site. DOE has agreed to consider installing basins as needed but is deferring any specific installation plans until it has finished investigating the nature and extent of contamination. DOE officials told us they are concerned that the money needed for installing sedimentation basins could be better used to accelerate the cleanup of the contaminated soil. Nevertheless, for budgeting purposes, the DOE plan assumes that four basins will be installed, at a cost of about $14 million. DOE plans to conduct an engineering evaluation and cost analysis in 2000, with the installation of any needed basins to be completed in fiscal year 2003. EPA officials find DOE's approach unacceptable; they want the installment of the sedimentation basins to coincide with the removal of the scrap metal, which is scheduled to begin in 2000. Removal of the scrap metal, according to EPA officials, will release contaminated sediments that will migrate off-site, via surface water runoff, into adjoining creeks, thus harming the ecosystem. As a result, the ultimate cleanup costs could vary considerably from the current estimate, depending in part on the number of sedimentation basins installed. At an installation cost averaging $4 million per basin, the addition or deletion of basins from the current plan would change the cost estimates.

Furthermore, the identification and mitigation of all the groundwater contamination sources are uncertain and are likely to have the greatest implications for cleanup efforts. One of the principal groundwater contaminants—trichloroethene—migrates down through the soil and aquifer, as is its nature, until it reaches an impermeable layer, where it lays in a mass and slowly contaminates the water. DOE officials suspect that leaks and spills from the building formerly used for degreasing machinery (the C-400 building) caused pockets of this contaminant, which constitutes a major source of groundwater contamination. The highest concentrations of trichloroethene at the site have been found near building C-400: 700,000 parts per billion in the groundwater and 11 million parts per billion in the soils. The drinking water standard for trichloroethene, in contrast, is 5 parts per billion. Other spills and dumping are known to have occurred in other areas across the site and may also have formed pockets contributing to the groundwater contamination.

The difficult task of locating and eliminating these pockets of contamination, perhaps 100 feet underground, could affect DOE's ability to complete its planned groundwater activities within the estimated cost and schedule. For several reasons, according to an August 1996 DOE technology summary, the problem posed by pockets of highly contaminated substances such as trichloroethene is one of the most difficult environmental challenges facing the nation.[7] First, because of the toxicity of most chlorinated solvents, their unique physical properties, and their poorly understood movement underground, it is very difficult to determine the location and distribution of these source areas with any degree of certainty at most sites. In addition, owing to their limited solubility in water, these source pockets are capable of contaminating large quantities of groundwater and can continue to be a source of contamination for many decades. Furthermore, currently available treatment and remediation technologies are generally incapable of completely removing contamination from the source area. Incomplete removal means that the residual contamination will continue to be a long-term source of groundwater contamination.

Technical Uncertainties May Also Increase Costs

Project success also depends upon successfully using technologies not previously used extensively at sites like Paducah. Many of the technologies included in the plan or contemplated for the cleanup are emerging technologies, and others, while not new, remain untested for the specific environment in which they are to be applied. For example, it is uncertain whether the primary treatment strategy planned for addressing the contaminated groundwater plumes will be successful. The strategy is to place thousands of feet of permeable treatment barriers across the paths of the contaminated groundwater plumes. No treatment is contemplated for the portions of the plumes that will extend beyond the treatment barriers. The placement of a barrier involves injecting into the aquifer—at depths up to 120 feet—a gelatinous, gummy substance called guar gel. The guar gel contains iron filings for treating the contamination. This technology is quite new; it is being used at only a few sites across the nation, and the potential for its success at the Paducah site is uncertain. It was selected for the Paducah site because it is one of a very few available technologies that might be able to treat both of the principal contaminants—trichloroethene (TCE) and technetium-99. Yet the barrier's success depends on numerous

[7]Technology Summary: Subsurface Contaminants Focus Area; Department of Energy; Aug. 1996.

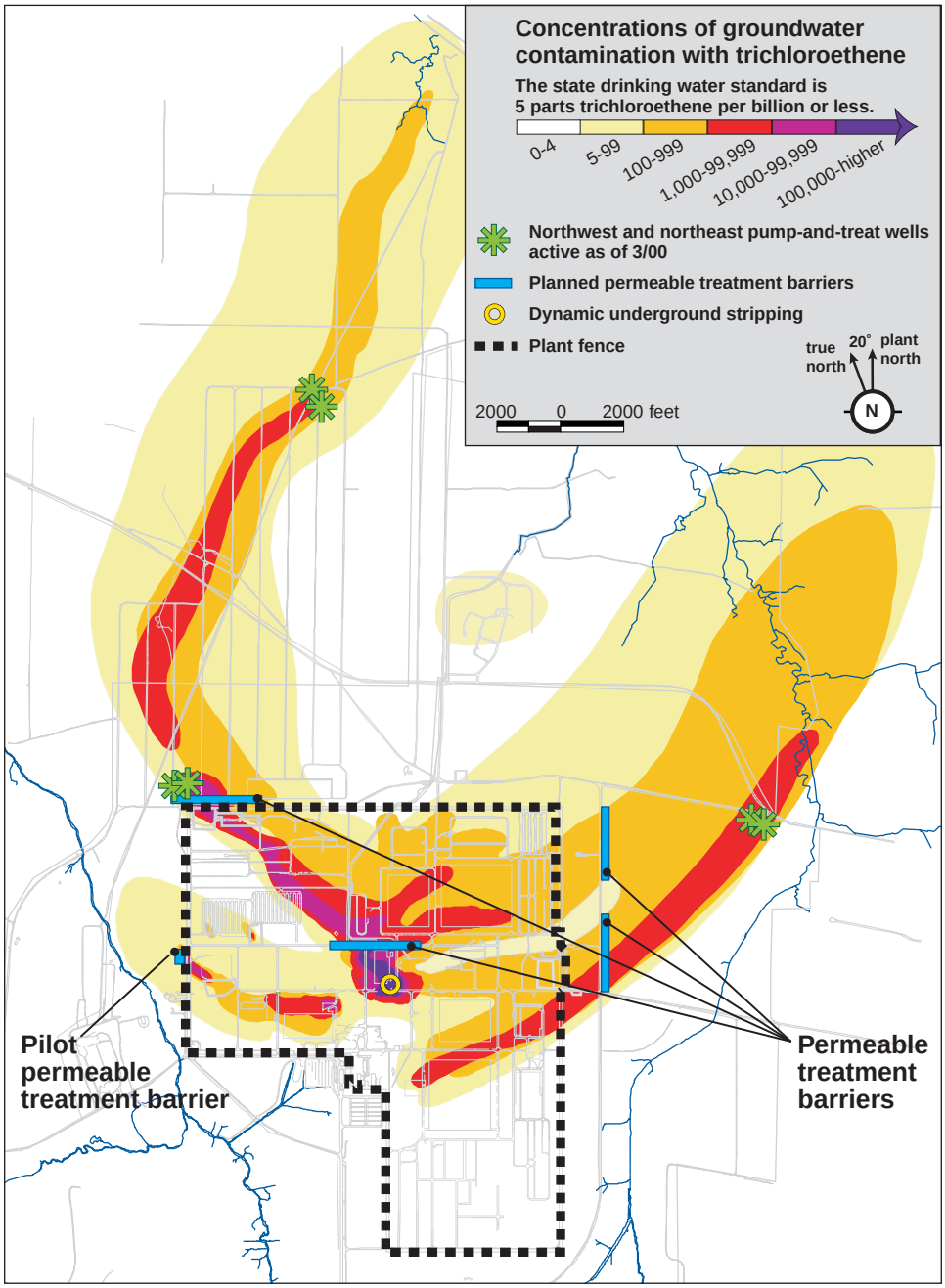
factors, including the rate of groundwater flow, the length of time the water resides in the treatment zone, the level of contamination, and the permeability of the treatment barrier compared to that of the geologic structure into which it is placed. If the groundwater flows too quickly through the barrier and thus spends too little time in the treatment zone, the iron filings might not have time to fully treat the TCE. In that case, the actions of the barrier's treatment zone might only change the contaminant to vinyl chloride, which is more toxic than TCE. Furthermore, it is uncertain how long the other principal contaminant, technetium-99, will adhere (through adsorption) to the iron filings in the barrier. DOE and its contractors are aware of these uncertainties and plan to test the technology to help determine its suitability for the Paducah site.

Technical uncertainties exist as well with the strategies currently contemplated to address the sources of groundwater contamination. DOE believes that the previously mentioned pockets of concentrated TCE cause much of the groundwater contamination. If these sources cannot be removed or isolated, they will continue to contaminate the groundwater, hindering cleanup efforts. However, eliminating the sources of the contamination will be difficult. Some technologies for doing so are relatively new, and some may not be appropriate for use at the Paducah site. Accordingly, DOE is considering and testing several innovative technologies for treatment. One such technology is referred to as dynamic underground stripping with dual-phase extraction. This process involves injecting steam into the aquifer to volatilize the TCE and cause it to rise to the surface, where it is extracted. According to EPA officials, however, difficulties with steam injection were encountered with this technology at another site, and there are considerable questions about whether the technology will work at Paducah because of the complexities of the geologic formation underlying the site.

These various technical uncertainties may increase the costs of cleaning up the site. First, should the technologies now planned for use prove infeasible, additional costs will be incurred to test and implement alternative technologies. And second, until the technologies for treating both the plumes and the sources have been tested, put into place, and proven effective, DOE will continue to incur the costs of operating the two systems—at about $2.1 million annually—that pump water out of the aquifer and then treat it (commonly called pump-and-treat systems) and of providing municipal water to nearby residents and businesses. The cleanup plan assumes that DOE will discontinue operation of the two pump-and-treat systems in fiscal year 2005 (after a year or so of operating the

permeable barriers), but the plan presumes that the barriers will have been successful in treating the contaminated groundwater plumes. The barriers' success depends in part on the success of other strategies, such as the steam injection method, in treating the contamination sources. Figure 4 shows the contaminated groundwater plumes, the pump-and-treat wells in place, the planned placement of the permeable treatment barriers, and the planned pilot test of the dynamic underground stripping technology.

Figure 4: Contaminated Groundwater Plumes at the Paducah Site



Source: DOE, from May 1998 data.

As shown in figure 4, the permeable treatment barriers are not planned to intersect the entire breadth of the groundwater plumes. Rather, the plan is to place them in the path of the highest concentrations of contamination within the plumes. As planned, the parts of the plumes that contain TCE concentrations greater than 99 parts per billion will pass through a permeable treatment barrier for remediation. In theory, as the groundwater moves through the iron filings that constitute the barrier's treatment zone, the TCE will be rendered harmless. Lesser concentrations of TCE—in areas of the plume not intersected by a permeable barrier—will be left untreated to make their way toward the river. Similarly, the portions of the plumes that are located between the barriers and the river (referred to as the off-site plumes) will be left untreated. For the parts of the plumes with lesser concentrations and off-site plumes, the theory is that the TCE will attenuate over time, and will become diluted as it mixes with the sand and gravel near the river.

Not shown in figure 4 is the technetium-99 contamination in the groundwater. This contamination occurs only within the northwest plume. The planned permeable treatment barrier for the northwest plume is intended to intercept the highest concentrations of technetium-99, which generally range from 900 to 3,789 picocuries per liter. (The drinking water standard for technetium-99 is 900 picocuries per liter.) In theory, as the groundwater moves through the barrier's treatment zone, the iron filings will adsorb (i.e., attract and hold) the technetium-99 so that none of it can exit the barrier. As with the TCE, though, the large areas of lesser concentrations of technetium-99 contamination, ranging mainly from 25 to 899 picocuries per liter, will be left untreated; they too are expected to attenuate over time.

While DOE's cleanup plan calls for the groundwater cleanup to be completed by 2006, the costs of providing municipal water to nearby residences and businesses could continue for years beyond that date, depending on the effectiveness of the cleanup strategies. Currently, DOE pays about $78,000 a year for the municipal water provided to approximately 100 residences and businesses near enough to the plant to potentially be affected by the contaminated groundwater. As the northeast groundwater plume approaches more residences and businesses, DOE may have to connect additional homes and businesses to municipal water supplies. DOE plans to continue providing water to the affected residences and businesses indefinitely—until the groundwater is safe to drink.

Finally, the permeable treatment barriers will likely require maintenance in the future, but DOE has not included any maintenance cost in its cleanup plan. Although the technology is too new for the length of the barriers' efficacy to have been definitively determined, their useful life is estimated to be between 10 and 20 years. According to a July 1999 study of a pilot-scale permeable treatment barrier's performance over a 16-month period,[8] scientists theorize that after some period of time, the iron filings intended to adsorb and treat the two major contaminants will lose their effectiveness and will need to be replaced or regenerated. Consequently, the study recommends that entities plan to replace the iron every 10 years; the study also estimates that the replacement cost would be about one-fourth of the original purchase cost of the iron.[9] Additionally, according to the December 1999 draft report of the technical advisory group that has worked with the Paducah site on technology issues, the useful life of a permeable treatment barrier is between 10 and 20 years.[10] Yet in its cleanup plan, DOE has not included any long-term operation and maintenance costs for the treatment barriers, even though they are intended to remain in place for 70 years. According to site officials at Paducah, because they had no reasonable basis for estimating what such costs would be, they included none.

Funding Assumptions Drive the Cleanup Plan

Funding constraints have always been an issue, according to DOE, contractor, and regulatory officials, and their recurrence could delay the project and add to its ultimate costs. DOE has been criticized in the past for not requesting the funding it needs for cleanup. Accordingly, beginning in fiscal year 2001, site officials said their budget requests will more closely resemble the amounts actually needed to accomplish the planned cleanup. For fiscal years 2001 through 2010, DOE's estimates for cleaning up the site range from a low of $78 million in 2001 to a high of $307 million in 2008, or an average of $124 million a year. In contrast, in the 7 fiscal years since

[8]ESTCP Cost and Performance Report: Permeable Reactive Wall Remediation of Chlorinated Hydrocarbons in Groundwater, Environmental Security Technology Certification Program; Department of Defense; July 1999.

[9]For the study report's subject barrier, the purchase cost of the iron was $450 per ton, and 75 tons were required for the barrier's treatment section, which was 10 feet long, 6 feet thick, and 22 feet deep. In contrast, the treatment barriers planned for the Paducah site will be at least 4,300 feet long.

[10]Draft Report, Paducah Project Innovative Technology Review, Technical Advisory Group, Paducah Project, Innovative Treatment Remediation Demonstration Program; Sandia National Laboratories; Albuquerque, New Mexico; Dec. 1999.

appropriations were made from the Decontamination and Decommissioning Fund, the site has received funding levels ranging from about $36 million to about $52 million, an average of $43 million each year.

For fiscal year 2000, the site has received supplemental funding to accelerate the cleanup. The amount originally appropriated for the site's cleanup was about $37.5 million; subsequent congressional and departmental funding actions (as of April 2000) raised that amount to about $50 million—about $14 million more than the previous year's funding.[11] For fiscal year 2001, the budget request includes about $78 million for the site's cleanup activities. If the planned increase in funding does not occur, the project could be delayed and its costs increased.

Assumptions About Regulatory and Stakeholder Agreement Are Optimistic

The plan's assumptions about the timely achievement of regulatory and stakeholder agreement on cleanup levels, strategies, and priorities are optimistic. If the assumptions are not achieved, the completion date and costs of cleaning up the site could be affected.

During the decision-making process in cleaning up the site, regulators have disagreed with DOE's proposed approaches. For example, an earlier version of the cleanup plan called for constructing impermeable barriers, called caps, over the 12 burial grounds to prevent water from entering them. However, Kentucky disagreed with that strategy, and, as a result, DOE's current plan is to excavate four burial grounds and possibly a fifth. In another case, DOE cleaned up an area with PCBs in the soils to EPA's standard of 25 parts per million for open or unoccupied space. Kentucky objected, however, saying that it wanted the PCBs in the soils cleaned up to 1 part per million, EPA's standard for industrial or residential use. That dispute remains unresolved, but the parties agreed to defer its resolution until DOE has submitted its plans for cleaning up the surface water. Kentucky has put DOE on notice, however, that it wants a stringent cleanup level for the surface water in order to protect the ecosystem. If DOE adopts a more stringent cleanup level than currently planned, its costs to complete the effort will grow.

In addition, DOE has not reached agreement with regulators and stakeholders on some issues that may prove to be contentious. For

[11]As of April 19, 2000, an additional supplemental request for $8 million had not been approved, according to DOE officials.

example, while DOE's plan assumes that the site will be used for a mix of industrial and recreational purposes after the plant has ended operations and the site has been cleaned up, DOE has not reached consensus with the regulators and the public on the future use of the site. According to the plan, this step would not be taken until near the end of the planned cleanup and would become part of the final regulatory action at the site. Yet many of the cleanup decisions hinge on what future use is assumed. For example, a decision about whether to cover a waste burial ground with a cap or to excavate it depends, in part, on how that portion of the site is to be used in the future. Assumptions about regulators' agreement with the planned disposition of all buried waste could also affect cleanup costs. For example, although the current cleanup plan assumes the excavation of 4 of the 12 burial grounds, the regulators are still contemplating excavation of a fifth burial ground, which would increase costs.

Without firm regulator and stakeholder agreement on future land use, cleanup levels may continue to be a contentious issue and could result in additional work, at additional cost. DOE's plan presumes that future use will be the same as current use—predominantly industrial. However, the plan's map of the current use includes many acres of agricultural and rural residential land that are located directly over one of the contaminated groundwater plumes. Residential and agricultural land must be cleaned up to more stringent levels than industrial land. For these acres in particular, then, the regulators may require more stringent cleanup levels for contaminated soils and surface water. And, until the vexing problem of groundwater contamination has been resolved, DOE will have to continue to provide municipal water to residences and businesses located on these acres.

Adherence to DOE's cleanup schedule will also be a challenge because the plan assumes that the regulators will comment on only one draft of regulatory documents (such as remedial investigation reports and feasibility study reports) and that the revised draft, with comments addressed, will be satisfactory to all parties. In the past, however, as many as four drafts have been required to address regulators' comments. Unless this "comment and revise, comment and revise" cycle is broken, according to EPA officials, scheduled milestones might be missed. These officials have suggested that DOE bring in a technical facilitator to work with the three parties (DOE, EPA, and Kentucky) to ensure that discussions are held and consensus reached before the regulatory drafts are prepared. According to an EPA official, this process was used at the Savannah River Site and was quite successful in streamlining the site's cleanup efforts.

Public participation is also important to the success of DOE's cleanup plan, but the public's involvement can hinder DOE's ability to meet its completion targets. Citizens can challenge DOE plans and decisions in the courts or through the regulatory process, and have done so. For example, DOE's plan to demonstrate a technology, called VORTEC, to treat some types of hazardous and radioactive wastes was challenged in the courts by a citizen who was concerned that DOE had not adequately assessed the environmental effects of the technology's operation. As a result of this action, DOE halted the demonstration project until an environmental assessment could be completed. The environmental assessment was completed in December 1999 and approved by the Oak Ridge Operations Office in March 2000. The cleanup plan calls for the demonstration project to treat about 865 cubic meters of waste.

Cleanup Plan Does Not Address All Areas That Require Cleanup

Even when the planned cleanup has been carried out, billions of dollars and many years will be needed to address areas at the Paducah site that are not in the cleanup plan. More specifically, four areas at the site, which are currently the responsibility of the Office of Nuclear Energy, will need to be cleaned up. These four areas are (1) large amounts of waste and scrap materials, (2) various unused building and structures, (3) thousands of tons of depleted uranium, and (4) the buildings and equipment currently being used in the enrichment process that will require cleanup when the plant closes. The materials and structures include nearly a million cubic feet of waste and scrap contained in DOE material storage areas (some of which pose a risk of an uncontrolled nuclear reaction) and 16 unused and inactive buildings and structures.[12] The materials and structures are excluded from the cleanup plan not because they require no action, but because they fall under the purview of a different departmental program. According to the DOE official responsible for these areas, a transfer of this area to the Office of Environmental Management has not occurred because DOE is hesitant to transfer any more areas to this office, which already has a large workload and limited funding for cleanup. This programmatic distinction between the Department's Office of Environmental Management and its Office of Nuclear Energy prevents the Paducah cleanup managers from

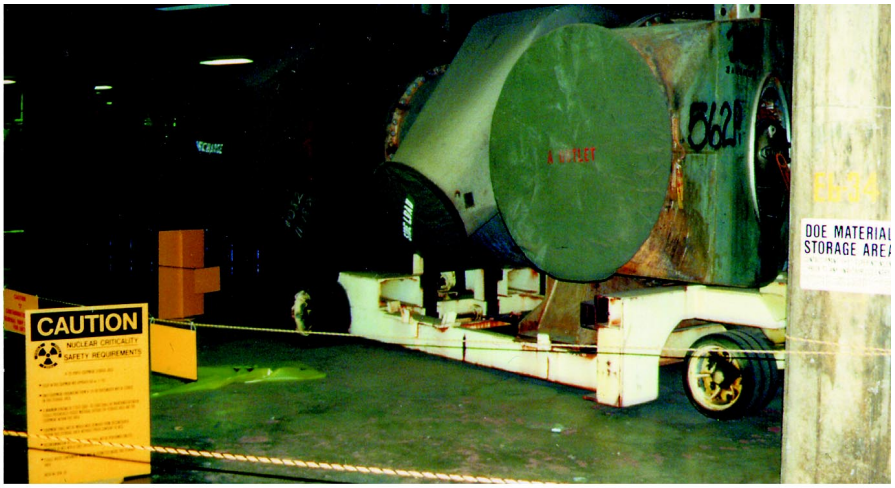
[12]According to DOE, this type of an event, referred to as an inadvertent criticality, includes a burst of radiation and generally lasts several hours. DOE describes this event as a worker safety issue rather than a public health or safety issue. It is a localized event that would not result in an explosion, release of radioactivity to the atmosphere, or—in the case of Paducah—damage to the uranium enrichment process.

assessing risk or planning cleanup on a comprehensive, sitewide basis and distorts the picture of the cleanup task at hand. As a result, the cost and time needed to clean up this additional material has not been estimated or included in the $1.3 billion cleanup plan. In addition, the cleanup schedule could be impeded because some of this material is located in areas that could interfere with the planned cleanup. Regarding the depleted uranium, DOE recently announced plans to build and operate a facility at Paducah to convert the 496,000 tons of this material to a more stable form—at an estimated cost of $1.8 billion to $2.4 billion. Finally, when USEC ceases plant operations, DOE will become responsible for decontaminating and decommissioning the plant's numerous remaining facilities—a process that could cost about another $1 billion.

Exclusion of DOE Material Storage Areas From Plan Could Impede Cleanup Schedule

Nearly 1 million cubic feet of uncharacterized waste and scrap materials not included in DOE's cleanup plan are located on the Paducah site in what are referred to as DOE material storage areas (DMSA). These areas, managed by the Office of Nuclear Energy, were created in 1996 when DOE accepted responsibility for large amounts of material stored in USEC-leased buildings and outdoor areas. DOE accepted responsibility for these material areas to expedite the process USEC used to obtain an operating certificate. The 148 DMSAs are in a variety of locations across the site—133 are inside eight USEC-leased buildings; the other 15 are outdoors. The materials in these areas include thousands of barrels of low-level radioactive waste and PCB wastes, barrels labeled as asbestos waste, contaminated process equipment, various items and containers whose contents are unknown, and scrap metal. DOE has not yet determined the exact nature and extent of contamination in these areas. Figure 5 illustrates the waste and scrap materials contained in DMSAs across the site.

Figure 5: DMSAs Contain a Variety of Contaminated Equipment, Scrap, and Waste Materials, Including Some Posted as Posing Nuclear Criticality Safety Concerns




DOE MATERIAL STORAGE AREA
EMPTY
DOE MATERIAL STORAGE AREA


DOE MATERIAL STORAGE AREA
BB-32

Source: DOE.

One of DOE's primary concerns with the DMSAs is that some of them might contain radioactive material, which, in the right quantity and configuration, could cause an uncontrolled nuclear reaction—a localized event referred to as an inadvertent criticality. Of the 148 DMSAs, DOE has designated 73 as having inadvertent criticality concerns. DOE's October 1999 report noted that uncharacterized radioactive and chemical equipment, materials, and waste in DMSAs continue to present unnecessary and avoidable risk to workers and the environment. DOE officials explained that they have a verbal agreement to pay USEC about $4.8 million to conduct a nuclear criticality safety review on the 10 DMSAs that have the highest risk for an inadvertent criticality. The estimated completion date for this work is July 2000. However, this agreement does not address the need for a review of the other 63 DMSAs that DOE has identified as having nuclear criticality safety concerns. The schedule also does not address the characterization needed for all 148 DMSAs to determine whether they contain material regulated under federal environmental statutes.

According to the DOE official responsible for these areas, the DMSAs have not been transferred to the Office of Environmental Management because DOE is hesitant to transfer any more areas to it. The Office of Environmental Management already has a large workload, and funding for cleanup is limited. Because the materials in the DMSAs have not been transferred to the Office of Environmental Management, these materials could impede the progress of the cleanup schedule. For example, approximately 9,700 barrels of waste that are already part of the cleanup plan are stored with uncharacterized waste material in many of the DMSAs. At least 1,300 of these barrels are stored in DMSAs that pose an inadvertent criticality safety concern.[13] DOE procedures prevent access to these areas without first resolving the nuclear criticality concerns. As a result, these waste barrels cannot be retrieved until these concerns are resolved, and the cleanup plan does not include cost or schedule estimates for resolving the nuclear criticality issues in these DMSAs. In addition, the location of some DMSAs could impede the cleanup schedule. For example, three DMSAs are located outside in the same location as much of the site's scrap yards and burial grounds, which are expected to be cleaned up by 2010. One of these DMSAs is located on top of a burial ground included in the cleanup plan, but, again, the cleanup plan does not include cost or schedule

[13]These 9,700 barrels (approximately 4,500 barrels of low level waste and 5,200 barrels of radioactive PCB waste) represent approximately 7 percent of the 1 million cubic feet of material in the DMSAs.

estimates for removing the DMSA material. Furthermore, DOE and contractor officials could not provide any assurances that the material in the DMSAs, if not characterized and removed prior to the completion of the site cleanup, would not recontaminate any cleaned up areas.

The exclusion of DMSAs from the Office of Environmental Management's cleanup plan has also precluded the assessment of risks on a comprehensive, sitewide basis. From the onset of efforts to assess the site in the late 1980s, DOE's cleanup plan and activities have been predicated on risk. The risks posed—to area residents, to workers, and to the environment—by the various types and sources of contamination have been assessed and addressed in order of priority. Yet throughout the last decade, because the materials in the DMSAs have not been characterized, the risks they pose have been excluded from such assessments. Accordingly, DOE cannot demonstrate that it has taken into account the comparative risks posed by all contaminated materials on site.

Numerous Unused Buildings and Structures Are Not Included in the Cleanup Plan

Although DOE's cleanup plan includes the decontamination and decommissioning of two unused contaminated buildings, it does not include 16 other unused buildings and structures. These other buildings and structures are currently monitored and maintained by DOE's Office of Nuclear Energy. These buildings and structures, which were originally used as part of the enrichment process, include a 120,000-gallon sludge lagoon, two 250,000-gallon water storage tanks, a nitrogen generation plant, and an incinerator previously used for disposing of contaminated items. DOE and contractor officials explained that several of these buildings and structures probably contain some contamination. According to DOE and contractor officials, lack of funding and higher priorities have prevented these 16 buildings and structures from being transferred to the Office of Environmental Management's cleanup plan. These officials explained that the two buildings to be decontaminated and removed were probably transferred to the cleanup plan several years ago because they are the largest and most contaminated of the unused buildings and thus presented the highest risk to worker safety and the environment. As with the DMSAs, because they have not been transferred to the cleanup program, the remaining 16 buildings and structures have not been included in a comprehensive, sitewide risk assessment.

About 496,000 Tons of Depleted Uranium Will Also Need to Be Addressed

Approximately 496,000 tons of depleted uranium hexafluoride, the majority of which is currently stored on site in 14-ton capacity cylinders, are not included in the cleanup plan. This material resulted from many years of uranium enrichment operations and is managed by the Office of Nuclear Energy. In addition to being radioactive, uranium is a heavy metal that can have toxic chemical effects. This material also poses risks if released to the atmosphere because the compounds that are formed in the air are chemically toxic. The advanced age of some of the steel cylinders and the way in which they were originally arranged—sometimes too close together to permit inspection; sometimes in direct contact with the ground, leading to enhanced cylinder corrosion—have created a potential environmental and safety hazard. The October 1999 DOE report noted that these cylinders constitute a radiological exposure hazard and a potential threat to worker and public health in the event of fire and rupture. The Defense Nuclear Facilities Safety Board recommended in 1995 that DOE improve the storage and maintenance of the cylinders.[14]

DOE issued a plan in July 1999 to convert depleted uranium hexafluoride stored at Paducah, Portsmouth, and Oak Ridge.[15] The plan is consistent with the preferred cleanup strategy selected in the environmental impact statement prepared for the conversion plan.[16] The strategy specified that the conversion of the depleted uranium hexafluoride inventory to uranium oxide, to uranium metal, or a combination of both, should begin as soon as possible.[17] It includes the construction and operation of conversion facilities at the Paducah and Portsmouth sites. DOE expects to issue a request for proposals to construct the conversion facilities in October 2000. DOE has estimated a lifecycle cost of its conversion plan—including operating the facilities for nearly 25 years, storage, and disposing of the

[14] The Defense Nuclear Facilities Safety Board is an independent agency created by the Congress in 1988 to oversee DOE's defense nuclear facilities and to ensure that public health and safety are protected.

[15]Final Plan for the Conversion of Depleted Uranium Hexafluoride, Office of Nuclear Energy, Science and Technology; Department of Energy; July 1999.

[16]Final Programmatic Environmental Impact Statement for Alternative Strategies for the Long-Term Management and Use of Depleted Uranium Hexafluoride, DOE/EIS-0269; Office of Nuclear Energy, Science and Technology; Department of Energy; Ap. 1999.

[17]In addition to the depleted uranium hexafluoride stored on-site at Paducah, approximately 218,000 tons are stored at the Portsmouth plant and another approximately 62,000 tons are stored at the Oak Ridge plant.

unused converted material—at between $3 billion and $4 billion. Paducah's share of this cost is between $1.8 billion and $2.4 billion. DOE has not identified any significant uses for this material once it has been converted. DOE recognizes that this plan represents a major new undertaking and involves a significant investment of resources beyond amounts available in the current budget.

Another Billion Dollars Needed for Final Site Decontamination and Decommissioning

DOE's cleanup plan does not reflect the costs of decontamination and decommissioning that will be required after USEC ceases plant operations and terminates its lease with DOE. The lease includes process buildings and areas outside these buildings. In a January 1998 report, DOE estimated a cost of approximately $1 billion to decontaminate and decommission the buildings and associated equipment and materials.[18] This estimate, however, did not include costs for removing any of the site's four large process buildings. Rather, it assumed that these facilities would be decontaminated and reused for industrial purposes. The estimate also did not include the $1.8 billion to $2.4 billion associated with Paducah's share of the disposition of the depleted uranium, which is addressed in DOE's uranium conversion plan discussed above. DOE is currently revising the decontamination and decommissioning cost estimate to more accurately assess numerous assumptions, including the extent to which materials from the site could be recycled and the extent to which site facilities could be reused.

Conclusions

DOE faces significant challenges in cleaning up the Paducah site. First, given the many uncertainties and optimistic assumptions inherent in the cleanup plan, there is reason to doubt that the Department will complete its planned cleanup actions by 2010 within the estimated $1.3 billion cost. Furthermore, if the cleanup plan is carried out as currently envisioned, billions of dollars and many years will be required to address areas not included in the current cleanup plan. For example, additional costs and time will be required to address about 1 million cubic feet of waste and contaminated scrap that is contained in DOE's material storage areas, 16 unused buildings, and other structures that will remain on site. Since these areas are not in the cleanup plan, no estimates of the cost or time to clean

[18]D&D Estimate of Gaseous Diffusion Facilities Incorporating Site Reindustrialization, prepared for DOE by Lockheed Martin Energy Systems, Inc.; Jan. 1998.

up these areas have been included in the plan. The additional materials, buildings and structures are excluded from the cleanup plan not because they require no action, but because they fall under the purview of a different departmental program. According to the DOE official responsible for these areas, these areas have not been included in the cleanup plan because DOE is hesitant to transfer any more areas to the Office of Environmental Management, which already has a large workload and limited funding for cleanup. This programmatic distinction between the Department's Office of Environmental Management and its Office of Nuclear Energy prevents the Paducah cleanup managers from assessing risk or planning cleanup on a comprehensive, sitewide basis and distorts the picture of the cleanup task at hand. In addition, DOE officials estimated that it might cost between $1.8 billion and $2.4 billion to operate the conversion facility at Paducah for nearly 25 years and to store and dispose of the unused converted material. Finally, according to DOE's January 1998 estimate, another $1 billion would be needed for final decontamination and decommissioning activities when the plant ceases operations and is returned to DOE.

Recommendations

To ensure that priorities are established on a comprehensive, sitewide basis to clean up and dispose of materials that are potential health hazards and that a more comprehensive picture of cleanup is presented to the Congress, we recommend that the Secretary of Energy transfer the responsibility for the material storage areas and the unused structures from its Office of Nuclear Energy to its Office of Environmental Management. In addition, we recommend that the Secretary direct the Office of Environmental Management to address in the cleanup plan, regardless of the current organizational responsibility, any and all materials at the site that are potential health hazards and to reexamine the sitewide contamination risks and cleanup priorities, costs, and schedules.

Agency Comments

We provided a draft of this report to DOE for its review and comment. DOE raised two general issues about our draft report. First, DOE believes that while the draft report provides a detailed description of waste and materials that need to be cleaned up at the Paducah site, it did not account for ongoing work and improvements at the site. Second, DOE stated that the draft report describes many of the uncertainties that DOE recognizes will affect cleanup progress, but notes that the report did not offer specific alternatives or recommendations regarding planning assumptions and

targets for completing work. The full text of DOE's comments are in appendix II.

We disagree with DOE's characterization that our draft report does not account for progress made in cleaning up the site. We believe that the report clearly describes the actions taken by DOE to date and discusses the status of each of the areas for early action that DOE identified. We pointed out in our draft report that the cleanup actions on each of these areas are in the early stages, will not be completed for years, and will face challenges as they proceed. In addition, the draft report stated that DOE and the regulators have been discussing planned cleanup activities and approaches. However, it should be noted that there are still areas of disagreement between DOE and the regulators, and that cleanup of many of these areas is just beginning or has not yet begun.

We agree that our draft report did not offer planning assumptions or targets for DOE to complete its cleanup work. This was not an objective of our work nor is it our role. Our objective was to provide the Congress with an understanding of the scope and cost of the cleanup and the challenges and uncertainties that will affect DOE's ability to accomplish it. We have included a number of examples of where DOE's plans will face challenges or uncertainties and point out that delays and additional costs could occur depending on the decisions made. For example, the draft report noted that there is disagreement with regulators regarding the cleanup levels for PCBs, the timing and number of sedimentation basins to be built, the number of waste burial grounds to excavate, and the future land use at the site. The cost and timing of the site cleanup will not be known until the areas of disagreement are resolved.

DOE also provided technical clarifications to the draft report. In these clarifications, DOE stated that the draft report's recommendation to transfer management responsibility for the DOE material storage areas and unused buildings should be revised to recognize the need for advance planning to ensure safety risks are identified and addressed prior to any transfer. DOE also believed that the draft report's recommendation for a sitewide review of cleanup priorities should be revised to acknowledge the role of regulators and the review currently being conducted by DOE, EPA, and the Commonwealth of Kentucky. We recognize that, as with most significant changes to programs, that prior planning will need to be conducted and that participation by various parties may be required. We would expect DOE to use good management practices in implementing

such changes. As a result, we made no changes to the recommendations. DOE's other technical clarifications were incorporated, as appropriate.

Scope and Methodology

To determine the cleanup plan's cost, schedule, and activities, we interviewed officials from DOE's offices of Environmental Management; Nuclear Energy; and Environment, Safety, and Health. In addition, during three visits, we interviewed officials from DOE's Oak Ridge Operations Office, which is responsible for managing the Paducah site, reviewed documents related to the cleanup, and toured the Oak Ridge uranium enrichment cleanup site. During three visits to the Paducah site, we interviewed managers responsible for Environmental Management and Nuclear Energy and toured the site on two separate occasions to examine specific areas of cleanup. We also toured the USEC facility to increase our understanding of the uranium enrichment process. Also at the site, we interviewed representatives from Bechtel Jacobs responsible for the six categories of cleanup, finance, and planning, and reviewed site-specific documents, including the fiscal year 2000 and the January 26, 2000, Lifecycle Baselines; the Federal Facility Agreement, including the Site Management Plan; the Site Treatment Plan for Low-level Mixed Waste; the Oak Ridge Operations Office Integrated Priorities List; and DOE's draft report entitled 1999 Paths To Closure.

To identify the challenges facing DOE in accomplishing its cleanup plan and to determine whether the plan includes all areas at the site that require cleanup, we interviewed officials from DOE's offices of Environmental Management; Nuclear Energy; and Environment, Safety, and Health. In addition, during three visits, we interviewed officials from DOE's Oak Ridge Operations Office, which is responsible for managing the Paducah site, and toured the Oak Ridge uranium enrichment cleanup site. During three visits to the Paducah site, we interviewed managers of DOE's offices of Environmental Management and Nuclear Energy and toured the site on two separate occasions. We also interviewed representatives from Bechtel Jacobs responsible for the six categories of cleanup, finance, and planning. In addition, we interviewed officials from EPA Region IV, the Commonwealth of Kentucky's Department for Environmental Protection, and an official from the Office of the Governor of Kentucky. We also interviewed the chairman of the Paducah Site Specific Advisory Board and attended one of the board's monthly meetings. We reviewed studies of various cleanup technologies, site-specific progress reports and plans for each category, and testimony from congressional hearings.

We conducted our review from October 1999 through April 2000 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 interested congressional committees; the Honorable Bill Richardson, Secretary of Energy; the Honorable Carol M. Browner, Administrator, Environmental Protection Agency; the Honorable Jacob J. Lew, Director, Office of Management and Budget; the Honorable Paul Patton, Governor of the Commonwealth of Kentucky; Mr. James E. Bickford, Secretary, Kentucky Natural Resources and Environmental Protection Cabinet; and other interested parties. We will also make copies available to others on request.

If you have any questions about this report, please call me at (202) 512-3841. Key contributors to this report were Erin Barlow, Daniel Feehan, Glen Trochelman, and Pam Tumler.

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

Cleanup Plan Focuses on Six Major Categories of Effort

The Department of Energy's (DOE) cleanup plan for the Paducah site addresses the cleanup of four contaminated media: groundwater, surface water, soils, and burial grounds. It also includes two other categories of effort: the site's treatment and disposition of about 52,000 barrels of waste that are stored on-site, and the removal of two contaminated, unused buildings. As of January 2000, DOE estimates that the cleanup will be finished by 2010, at a total cost of $1.3 billion.

Groundwater Cleanup to Address More Than 10 Billion Gallons of Contaminated Water

Through investigations beginning in 1988, when hazardous and radioactive contamination was found in the drinking water wells of residences near the Paducah plant, DOE discovered that plumes of contaminated groundwater were heading north of the plant toward the Ohio River. A major source of the contamination was later found to be the C-400 building, where a toxic solvent called trichloroethene, or TCE, had been used for years to degrease parts and equipment. Upon discovering the contamination, DOE took a number of steps to minimize the danger to human health and the environment. For example, it provided safe drinking water to neighboring homes and businesses, undertook efforts to determine the extent of the contamination, and began a program to pump out some of the water and treat it (commonly called a pump-and-treat system). DOE's long-range cleanup plan calls for two cleanup strategies—one to reduce the sources of the contamination and the other to trap and neutralize the highest concentrations of contaminants in the plumes.

DOE estimates that about 10 billion gallons of groundwater has been tainted with TCE, and 250 million gallons with radioactive technetium-99, a fission product. The levels of concentration have been found in places to far exceed the Environmental Protection Agency's (EPA) drinking water standards. The TCE contamination in groundwater has been identified in two major plumes covering more than 3.75 square miles, one heading northwest of the plant and the other heading northeast. Another smaller plume, discovered in about January 1999, heads southwest and then turns toward the north. According to DOE officials, the contaminated groundwater plumes are estimated to be moving at about a foot per day toward the Ohio River (3 miles north of the plant). DOE cannot say with certainty whether the leading edges of the plumes have reached the river; however, officials believe that the technetium-99 plume (heading northwest from the plant) has possibly reached the river. Results from recent samples did not show significant amounts of either contaminant in the river.

DOE has taken a number of actions since the discovery of the groundwater contamination. Citizens affected by the contaminated groundwater were provided with safe drinking water and were connected, at DOE's expense, to the municipal water system. As of January 2000, DOE had connected over 100 residences and businesses to the municipal water supply, at a capital cost of about $1 million and continuing monthly water costs of about $6,500.

In addition, since the discovery of the contamination, a number of studies have been done to determine the extent and nature of the contamination in the groundwater. For example, DOE has identified a degreasing and equipment cleaning building (the C-400 building) as a primary source of TCE contamination. DOE is currently evaluating the data available from groundwater sampling.

As an interim measure, DOE installed two pump-and-treat systems to remove some of the contaminated groundwater, which is then treated. The pump-and-treat system on the northwest plume began operating in August 1995. By June 1999, it had processed about 385 million gallons of water. The pump-and-treat system on the northeast plume began operating in January 1997 and by June 1999 had processed about 213 million gallons of water. The estimated capital cost (that is, design and construction) for the two systems was about $20 million. For fiscal year 1999, the estimated operations and maintenance cost for both systems was $2.1 million. Once a final cleanup strategy has been selected and proven effective, DOE's plan calls for removing the pump-and-treat systems.

DOE's planned cleanup strategy involves the use of two technologies. These technologies are designed to (1) remove the sources of contamination and (2) treat the contaminated groundwater plumes as they move off-site. To remove the source of the contamination, DOE's plan calls for the use of a process called dynamic underground stripping, with dual-phase extraction. In essence, this process injects steam into the ground so the contaminants rise, then extracts and treats the contaminants. Other processes for removing the contamination sources will be considered and pilot-tested as well. To clean the water in the plumes, the planned strategy is to use permeable treatment barriers. This technology involves installing about 4,300 feet of barriers (or possibly as many as 6,000 feet) by injecting into the aquifer—at a depth between 60 and 120 feet—a gummy substance, called guar gel, containing iron filings. These permeable barriers, which will be placed across the paths of the highest concentrations of contamination in the plumes, will allow the groundwater to pass through,

but the iron filings in the barriers will adsorb the technetium-99 and treat the TCE. DOE plans to conduct a pilot test of the permeable treatment technology in 2000 and, if the pilot test proves successful, to then begin constructing the full-scale barriers. Construction is planned for completion in 2003. The total cost of cleaning up the groundwater is estimated at $162 million and is expected to be completed by 2006.

Surface Water Cleanup Includes Removing 65,000 Tons of Scrap Metal

DOE has discovered surface water contamination in creeks, ditches and sludge lagoons. Two streams flank the plant: Bayou Creek to the west and Little Bayou Creek to the east. Stormwater runoff and wastewater from plant operations discharge to these streams through a series of ditches. Each discharge point is monitored to ensure that the effluent entering the stream is within the parameters of the discharge permit issued by the Commonwealth of Kentucky. Contaminants of concern are technetium-99, solid uranium tetrafluoride ("green salt"), uranium-contaminated silts and sediments, radionuclides, metals, and polychlorinated biphenyls (PCBs).

One of the principal sources of this contamination is the approximately 65,000 tons of scrap metal stored in the northwest portion of the site. Much of the scrap metal was placed there over the years. Part of this scrap includes a pile of about 8,000 tons of crushed drums—commonly called Drum Mountain—that were once used to store depleted uranium. Although the drums were emptied before being crushed, residual uranium (known as green salt) remains on or in them.

DOE has conducted a number of assessments and taken some interim measures to minimize surface water contamination. The assessments have included taking radiation readings in the creeks and ditches inside and outside the plant and monitoring the water being released off-site. As an interim measure, DOE has taken steps to reduce the amount of contamination leaving the site. For example, it installed a gabion (a cage filled with rocks) to reduce the migration of contaminated sediments when it rains. Also, some wastewater from the United States Enrichment Corporation's (USEC) operations is now diverted away from the most contaminated portion of a main ditch, the north-south diversion ditch. In another action, DOE constructed two settling lagoons that collect contaminants from wastewater before releasing it off-site. Still another interim action involved installing a system, within an active USEC process building, to treat technetium-99. Process water tainted with high levels of technetium-99 is routed through the treatment system, over and over again, until the system can reduce the contaminant level no further. DOE officials

say this action has accomplished its objective, as have the other actions, because the process water is not only treated but also no longer discharged into the north-south diversion ditch. Instead, it is discharged into a USEC-controlled ditch on DOE property. Nevertheless, the treatment system has been unable to treat the technetium-99 to drinking water standards since October 1998, when USEC restarted its cylinder washing program in the building that houses the treatment system. Since October 1998, the levels of technetium-99 in the wastewater being discharged onto DOE property have at times been quite high. In one instance, the levels exceeded 17,000 picocuries per liter, nearly 20 times the drinking water standard of 900.

DOE's plan for addressing the surface water contamination includes removing the scrap metal (including Drum Mountain), conducting additional assessments, and taking steps to clean up the existing contamination in the ditches and other locations. DOE's plan for the scrap metal is to have a contractor remove and dispose of Drum Mountain by December 2000 at a cost of about $7.1 million. The remainder of the scrap metal is to be removed by 2003, according to the federal facility agreement. But the DOE plan contemplates completing removal of the remaining scrap metal in fiscal year 2004, at a cost of about $74 million. Planned cleanup activities include excavating at least four contaminated ditches and various other areas, installing up to four sedimentation basins to catch contaminated surface water runoff from the plant, and installing a new storm sewer segment. The total cost for cleaning up the surface water has been estimated at more than $162 million, with a completion date of 2007.

Surface Soil Cleanup to Address 72 Contaminated Areas

DOE has identified 72 areas on the site that contain contaminated soil. The primary contaminants are PCBs and radionuclides. To date, DOE has focused primarily on assessing the extent of the problem and using an innovative technology to clean one area of heavily contaminated soil. DOE's plan for cleaning up the surface soil includes conducting additional assessments and excavating contaminated soils. However, some of the cleanup work will have to be deferred until the plant has closed because some of the contaminated areas, such as the electrical switchyards, are in use by USEC. The deferred work will be addressed during the final decontamination and decommissioning of the plant after its closure.

DOE has employed an innovative technology to remediate some of the most heavily contaminated soil. As a result of past cylinder drop-testing operations at one area on the site, about 1.7 acres in size, an estimated 430 gallons of TCE leaked into the site's shallow soil and groundwater. At this area, to reduce the potential for contaminant migration, DOE conducted demonstrations from 1995 through 1997 of an innovative technology called LASAGNA.[1] This technology uses electroosmosis to move shallow groundwater and contaminants through in-ground treatment zones. (The technology is named for its layered structure of electrodes and treatment zones.) In demonstrations, the LASAGNA technology reduced TCE concentration levels from hundreds of parts per million to less than 2 parts per million. DOE selected LASAGNA for full-scale remediation of the area, and the LASAGNA cleanup is expected to be completed by 2003.

DOE's other planned activities include conducting additional assessments and excavating and disposing of contaminated soils. The additional assessments are to be completed by 2005 at a cost of about $8.7 million. DOE plans to excavate about 35,000 cubic yards of soil, at average depths of 1 to 3 feet, but as deep as 16 feet when necessary. The total surface soil cleanup is expected to be completed by 2007 at a cost of about $19 million.

Several Burial Grounds Are Planned to Be Excavated

DOE's cleanup plan includes estimates for excavating the material from 4 of its 12 burial grounds, and DOE is contemplating the excavation of a fifth burial ground. DOE considers the other burial grounds to pose less of a risk—these other burial grounds include closed landfills that are included in DOE's long-term monitoring program. Previous investigations of two burial grounds identified a variety of contaminants, including uranium, PCBs, arsenic, benzene, beryllium, cadmium, copper, nickel, tricholoroethene, toluene, and zinc. DOE's cleanup plan estimates approximately $535 million for the cleanup of these areas with a completion date of 2010. The majority of these costs stem from the cost of disposing of the excavated material.

[1]The term LASAGNA has been trademarked by Monsanto.

DOE made a preliminary assessment of the risk posed to worker safety and the environment for each of 12 burial grounds at the Paducah site and divided them into three risk categories—principal threat, moderate threat, and low threat. This assessment was the result of discussions between DOE, EPA, and Kentucky officials that began in November 1999. DOE designated four of the burial grounds, and a portion of another, as posing a principal threat to worker safety and the environment—the current cleanup plan includes estimates for excavating these areas. The estimated contents of one of the principal-threat burial grounds include 270 tons of uranium (most of it pyrophoric), 59,000 gallons of oils, and 450 gallons of trichloroethene.[2] DOE has designated three other burial grounds as posing a moderate threat, including one that DOE is still considering excavating. [3] The cleanup plan includes placing a protective cap over these areas to mitigate the spread of contamination. DOE designated the remaining five burial grounds as low threat—three of these burial grounds are closed landfills that have a protective cap and are under DOE's long-term monitoring program; a protective cap is planned for the fourth burial ground, and the fifth burial ground is the site's operating landfill.

About 52,000 Barrels of Waste Require Treatment and Disposal

Paducah has the equivalent of 52,000 55-gallon barrels of waste stored in various locations on the site. Most of the barrels contain materials that have a low level of radioactivity. To date, DOE has been assessing the contents of the barrels and containers. Since 1990, DOE has shipped from the site the equivalent of 754 barrels of low-level waste. DOE's plan calls for disposing of the waste off-site after it has been characterized and treated or repacked if necessary.

[2]This pyrophoric uranium, which has a tendency to spontaneously combust in the presence of oxygen, was usually placed in drums with petroleum-based or synthetic oils used to stabilize the waste.

[3]DOE also designated the 65,000 tons of scrap metal being addressed under the surface water portion of the cleanup plan as a moderate threat. The cleanup plan includes estimates for placing a protective cap over these areas.

The majority of the 52,000 barrels of waste were generated before the production facilities were leased to USEC, but some waste continues to be generated by DOE's cleanup activities. The 52,000 barrels are located throughout the site and contain a variety of waste (radioactive and hazardous). More than 12,400 barrels of low-level waste are stored outside and are in deteriorating condition.[4] There are about 20,300 barrels of mixed low-level waste, consisting mainly of PCB waste, and 31,200 barrels of low-level waste, which is mainly soil and debris.[5] In addition, Paducah has 21 barrels with higher levels of radioactivity (called transuranic waste). The site also has about 142 metric tons of hazardous waste, some of which must be incinerated and cleaned of radioactive contamination before it can be shipped off-site.

Federal law and regulations require that the barrel contents be identified for proper storage and disposal. The characterization of waste in barrels has been completed for on-site storage and for the waste barrels that have been shipped to off-site facilities for disposal. But 1,760 barrels require additional characterization to meet a recent EPA storage requirement.

DOE currently plans to ship off-site all waste that cannot be put in the on-site landfill. Additional characterization is needed for over 42,000 barrels of mixed and low-level waste before they can be treated and shipped off-site. DOE has estimated that about 80 percent of its waste will meet the waste acceptance criteria of a private waste disposal contractor (Envirocare, in Utah) and that only the remaining wastes that exceed these criteria will likely be sent to DOE's Hanford facility in Washington State.

DOE revised the cleanup plan to accelerate the removal of certain wastes by fiscal year 2006. As a part of this action, it gave priority removal of low-level waste stored outdoors. Because of the deteriorated condition of some of these barrels, DOE has determined that it will be necessary to repack some of them before they can be shipped off-site. The disposal of the 52,000 barrels is expected to be completed in 2010 at a cost of $228 million. DOE's

[4]DOE's October 1999 report identified the equivalent of approximately 8,500 55-gallon barrels of waste stored outdoors. During our review, DOE identified another approximately 3,900 barrels of waste stored outdoors.

[5]A Becthel Jacobs official responsible for waste management explained that these figures might be underestimated because the waste is stored in a variety of containers, and he had to calculate the barrel equivalents. He recommended that we use 52,000 barrels for the total stored on site.

lifecycle baseline also includes a demonstration project to treat, before disposal, some of the waste that contains both hazardous materials and low levels of radioactive materials. This assumption is predicated on the successful use of the technology, permitting of the project, and an assessment of its environmental impact. The project is currently on hold; however, by the end of fiscal year 2002, the cleanup plan calls for the demonstration project to treat about 865 cubic meters of waste.

Plan Includes Monitoring and Maintaining the Site and Removing Two Contaminated Buildings

DOE's cleanup plan includes monitoring and maintaining the site area and facilities before, during, and after remedial activities and continuing to monitor as necessary to support future cleanup actions. As part of the monitoring and maintenance activities, the plan calls for demolishing two contaminated, unused buildings on the site.

The two contaminated buildings were originally used to produce the uranium materials and to fabricate metal. The buildings were transferred from DOE's Office of Nuclear Energy to its Office of Environmental Management several years ago. General maintenance has been done on the buildings; however, a recent DOE investigation found that large volumes of low-level waste are stored inside the buildings and that contamination within the buildings is spreading.

In December 1999, DOE decided to include in the cleanup plan the decontamination and demolition of the two buildings. DOE estimates that $92 million will be needed to remove these buildings by 2008.

As part of DOE's long-term stewardship responsibilities, monitoring and maintenance activities will continue long past the 2010 cleanup completion target. The costs for this long-term stewardship are not included in the $1.3 billion cleanup estimate. Planned long-term activities include routine maintenance activities, such as mowing grass, replacing signposts, maintaining groundwater monitoring wells, repairing fences, and conducting and reporting on periodic inspections. DOE officials said that long-term stewardship could continue through 2070.

Comments From the Department of Energy

Department of Energy
Washington, DC 20585

April 19, 2000

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

Dear Ms. Jones:

The Office of Environmental Management has completed its review of your draft report, Nuclear Waste Cleanup: DOE: Paducah Plan Faces Uncertainties and Excludes Costly Cleanup Activities (GAO/RCED-00-96, code: 141396).

While the draft report provides a detailed description of waste and materials that need to be cleaned up at Paducah, it fails to account for ongoing work and improvements at the site. The report also fails to adequately address the regulatory controls and oversight of cleanup and the progress made in defining options for accelerating the site's highest priorities. The Department of Energy (DOE) has negotiated a Federal Facilities Agreement with its regulators which provides the framework and schedule for cleanup under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). In accordance with this agreement, the Department has been conducting cleanup under the full CERCLA process including assessments prior to implementing actual cleanup. Since last October, we have been working with our regulators in reevaluating site cleanup strategies to ensure maximum possible use of removal actions. The Life Cycle Baseline was revised in January 2000 to document the results. Our current approach to accelerate cleanup is consistent with recommendations made in Nuclear Waste, Greater Use of Removal Actions Could Cut Time and Cost for Cleanups, (GAO/RCED-96-124, May 1996).

Early actions have been identified for implementation that will result in physical cleanup of source term areas prior to extensive investigation. These early actions include scrap metal removal, excavation of specific burial grounds, decontamination and decommissioning of two large surplus facilities, installation of sedimentation control basins at specific surface water drainage outfalls, and accelerated disposition of thousands of drums of legacy low-level radioactive waste stored outdoors. Conducting early actions and working with the regulators in streamlining the regulatory review process are clear indicators that DOE is making progress in accelerating site cleanup. This progress should be highlighted in the GAO Report.

The site and regulators also are discussing alternatives to waste disposition that will further accelerate cleanup and help DOE meet the cleanup completion milestone date of 2010. This clearly demonstrates the willingness of the Department to work with its regulators and stakeholders to accomplish as much cleanup as possible as soon as possible.

Finally, the report describes many of the uncertainties that the Department recognizes will affect cleanup progress, but fails to offer specific alternatives or recommendations regarding DOE's planning assumptions and targets for completing work. Furthermore, the report fails to put uncertainties in context or explain their significance in relationship to current decisions being made by DOE and its regulators as they map out cleanup plans. The recommendations do not address the uncertainties, nor does the report discuss how the DOE or any entity conducting a complex cleanup should address uncertainties. Clearly, some planning assumptions and schedule goals are essential if any cleanup progress is to be made.

The Offices of Environmental Management and Nuclear Energy, Science and Technology have been working closely to improve and integrate program activities at the Paducah and Portsmouth Gaseous Diffusion Plants. We will formalize this relationship by establishing a Working Group to ensure that an integrated Site Cleanup Plan is prepared for both Paducah and Portsmouth.

The enclosures contain our detailed comments in addition to comments received from other offices within the Department. If you would like to further discuss these comments, please call James J. Fiore at (202) 586-6331 or Richard L. Nace at (301) 903-7219.

Sincerely,

Carolyn L. Huntoon

Carolyn L. Huntoon
Assistant Secretary for
Environmental Management

2 Enclosures

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